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CONCEPT
OF DEVELOPMENT OF UP-TO-DATE
JET REGIONAL PASSENGER AIRCRAFT

Monograph

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С74

Подано концепцію та наукові основи створення сучасних реактивних регіональних пасажирських літаків, включаючи концепцію, принципи та методи інтегрованого проектування регіональних пасажирських літаків; концепцію створення силової установки; концепцію створення системи керування польотом регіональних пасажирських літаків.

Наведено кілька розроблених нових конструктивно-технологічних рішень, які застосовано при створенні планера модифікацій літаків Ан-148-100/Ан-158, особливості забезпечення аеродинамічних характеристик регіонального пасажирського літака, результати виконаного комплексу робіт із забезпечення льотної придатності літаків модифікацій Ан-148-100/Ан-158, результати сертифікаційних робіт.

Для інженерів і науково-технічних працівників підприємств авіаційної промисловості, магістрів, аспірантів вищих навчальних закладів, які навчаються за спеціальностями «Авіаційна та ракетно-космічна техніка», «Авіаційний транспорт».

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This work covers philosophy and scientific background in developing modern regional jet passenger aircraft including concept, principles and procedures of integrated designing in developing regional passenger aircraft as well as philosophy for development of power plants, control and fuel systems intended for regional passenger aircraft.

This work involves a number of design and technical concepts having been used in airframes development of the An-148-100 / An-158 aircraft family. This publication also covers peculiar features or regional passenger aircraft aerodynamical properties and the results of the performed scope of operations to provide airworthiness of the An-148-100 / An-158 aircraft as well as the results of Certification operations.

This work can be useful for engineers, scientists and technicians of aviation industry companies post-graduate students and masters of higher educational establishments trained with reference to specialities of "Aviation and Rocket Engineering", "Aviation Transport".

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CONTENTS

INTRODUCTION

Ukraine is among the countries that have full and complete cycle of aircraft development. Resources of aviation industry companies in Ukraine demonstrate capabilities to develop and modify modern regional passenger aircraft having efficiency reliability and flight safety characteristics to be at the highest world level.

Development of new compatitive regional passenger aircraft according to airworthiness requirement requires creation of scientifically grounded design techniques with their production and testing to be much more advanced in compare with the competitions. Provision of desired performance data, lift to drag ratio (K = 16), aircraft lifetime (80000 – 90000 flight hours) under minimum aircraft weight, in this case, is one among the main characteristics proving their perfection while the solution of these problems is associated with the use of integrated designing, engineering and manufacturing with the use of CAD\CAM\CAE systems as well its development to be a current scientific field of activity.

A lot of national and foreign scientific schools under the leadership of O.K. Antonov, C.B. Ilushin, A.M. Tupolev, P.V. Balabuev, C.M. Eger, G.V. Novojilov and many others took part in development of scientifically grounded methods in designing passenger aircraft. Activity of all experts and specialists of aviation industry was based on scientifically grounded design concepts and usage of optimal, systematic design techniques involving a unified criteria if efficiency and selection of different versions among different concepts. Each new aircraft has been designed and developed with an account made for revealed and predicted demand of national economy and defence ability and for scientific analys's result of aviation engineering condition and capabilities.

At the stage of aircraft appearance, arrangement and special characteristics defining and development of general design concept, the designers did their best to achieve high level of its aerodynamical properties stability and controllability, strength, lifetime and production characteristics, manufacturing process ability and operation.

High property characteristics used in designing aircraft under development are implemented id general when aircraft structure, its units and components are under development with common activity of the designers, aerodynamical and strength experts, process engineers, scientific and research bureaus and universities.

Design techniques and development of efficient aircraft prototypes are in progress and modification in association with the development of science and technology as well as integration of CAD\CAM\CAE\PLM computer aided systems.

Accumulation of experience in achieving desired operability characteristics of passenger aircraft due to the use of CAD\CAM\CAE\PLM computer aided systems provides integration of empiric and experimental design methods with the procedure of aircraft 3D modelling as well as their upgraded versions within their lifetime.

Thus, determination of philosophy and scientific grounds for development of today's jet regional passenger aircraft is an actual problem while development of techniques in achieving desired aircraft performance under minimum aircraft weight is high practically important in solving the problems of efficient and safety flights under passenger aircraft operation condition.

The goal of this publication is the determination of the philosophy and scientific grounds for the development of jet regional passenger aircraft meeting to day's and advance airworthiness norms and regulations.

To achieve this goal it is necessary to solve the following problems:

1. Making analysis of peculiar features in development of regional passenger aircraft.

2. Defining concepts and scientific grounds for methods and techniques in integrated designing of and production of regional passenger aircraft family.

3. Defining new variants to provide desired performance of regional passenger aircraft.

4. Implementing defined methods and techniques under development of regional passenger aircraft.

Mathematical models to obtain design solutions, analytical design techniques and 3D computer-aided simulation of aircraft and their structural components with the help of today's CAD\CAM\CAE\PLM computer-aided systems, strength analytical estimated and experimental methods for attaining aerodynamical properties, methods providing static strength and lifetime, aircraft flying tests procedures have been used to obtain specified target and to get significant results in work.

The most significant elements of the work results are as following:

1. A great scope of scientific technical estimation and design works have been

firstly performed under development and putting the An-148-100/An-158 aircraft family into production by using 3D computer-aided design and manufacturing analytical integrated systems as well as execution of required researches under conduction of ground and flight tests.

2. Regional passenger aircraft design methods have been improved by means of selecting optimal aerodynamical, structural-strength volume and mass properties, wing airfoil data, fuselage cross-section parameters, flight performance characteristics (FPC), take-off and landing data (TLD), engines, equipment and systems.

3. Strength-strain state properties estimation procedure, aircraft strength state and lifetime have been upgraded by using finite element of CAD\CAE systems, MSC.Software, NASTRAN, Front.

The following main results are practically significant:

– A number of competitive high efficient jet regional passenger modified version of the An-148-100/An-158 aircraft been developed which as for their technical and operative properties meet the level of the best foreign prototypes to be as comfortable for the passengers as passenger airliners of similar types up to 270 km/h (M=0.8);

– Aerodynamical configuration has been developed that has any comparable prototypes in world practice of aircraft production. This made it possible to develop high-wing regional passenger aircraft with a flight speed of up to 870 km/h (M=0.8);

– A unique world jet passenger regional aircraft has been developed capable to be operated from ground air fields;

– A power of two central AC electrical systems are used at the An-148-100/An-158 aircraft for main airfoil control instead of additional hydraulic systems for operation of actuators (booster) (power set diagram "2H/2E");

– Development, serial production and operation of the An-148-100/An-158 aircraft family enabled to provide new working vacancies in Ukraine in the amount of more than 14000 employees;

– Implementation of the work results enabled to develop a new generation of regional passenger aircraft family at the ANTONOV Company.

The authors experts great thanks to the specialists of the ANTONOV Company and MOTOR SICH JSC for their help and assistance in performing and preparing this work for publication.

Chapter 1
PASSENGER AIRCRAFT DEVELOPMENT SPECIFIC FEATURES EVALUATION

Passenger aircraft development involves designing, manufacturing, certification and putting into operation.

1.1 PASSENGER AIRCRAFT GENERAL DESIGNING ANALYSIS OF METHODOLOGICAL GROUNDS

According to aircraft classification the regional aircraft belong as for their purpose to passenger aircraft of civil aviation. They are designed for transportation of passengers, baggage, post luggage and cargo at a range of 1800…5500 km.

The main requirement for passenger aircraft to provide as follow:

- Reliability and passengers safety;
- High level of comfort;
- Flight economical efficiency;
- Ecological characteristics under operation (standard noise level in environment as well as harmful exhausts to atmosphere) that produce minimal effect on the environment [74].

Passenger transportation cost values a and fuel efficiency ratio $k_{f.e}$ are used to determine perfection of regional passenger aircraft [67, 97]

$$a = \frac{A}{k_{p.l} \cdot m_{p.l} \cdot V_f}, \tag{1.1}$$

where a – passenger transportation cost values, grv/t km; A – significant expendures for aircraft operation; $k_{p.l}$ – payload factor; $m_{p.l.}$ – payload mass, t; V_f – flight speed, km/h.

$$k_{f.e} = \frac{m_f}{m_{p.l} \cdot L_{ef}}, \tag{1.2}$$

where $k_{f.e}$ – fuel efficiency factor; m_f – fuel weight; L_{ef} – effective flight range; $m_{p.l}$ – payload mass.

It is obvious that passenger seating capacity increase and higher flight speed take priority in development of passenger aircraft at flight speed.

A value A associated with the reduction of operating cost can be specified by the cost of aircraft and for its operational infrastructure, its maintenance system, fuel cost and materials used during maintenance personnel cost.

Cargo factor increase is determined by comfort level and passengers servicing in flight, air ticket price, flight schedule stability under variable meteorological condition, perfection of infrastructure managerial level under passenger aircraft operation. $m_{p.l}$ is replaced for passenger aircraft and in this case, the $k_{f.e}$ value is specified in g/pass·km. Under fuel price rising condition, fuel efficiency factor has become an integral value demonstrating highly advance level of passenger aircraft [74].

Economical grounds, requirement for higher safety flight level, provision of ecological and environment friendly requirements are specified as the main aspects in designing and development of passenger aircraft that need to provide a great scope of scientific, research and design work as well as great investments [33, 34, 35]. Modification of available aircraft passenger aircraft and the development of the new ones are the main trends in the development of today's passenger aircraft that meet advance engineering requirements and do not need significant financial expenditures.

Today's passenger aircraft is developed as a basic one of a great aircraft family including implementation of the new advanced scientific and technical research results.

Two-engine layout of passenger aircraft with long aspect ratio of the wing is selected to provide required level of regional aircraft fuel efficiency, Also, it should have moderate swept like wing made by the use of supercritical airfoils to obtain maximum lift-to-drag ratio $K_{max} = 18$ under cruising flight condition. In doing so, reduction of weight-to-drag ratio losses for balancing and mass of airframe and flight under cruising condition are performed at low stability values while desired centering s ensured by fuel transfer system.

Passenger aircraft wing is provided with slats along the total wing span and two-slotted flaps t ensure aircraft operation at an airfield with a runway length of about 2500 m. An aircraft is provided with fly-by-wire control system having three-channel analogue redundancy resulting in reduction of psycho-physiological loads on two-member crew.

Flight hour cost decreasing and passenger aircraft economical efficiency increasing are ensured, also, by built-in automated monitoring of all aircraft systems and by implementing a strategy of on condition technical maintenance [74].

The main demands for the above-mentioned passenger aircraft are the requirements associated with the significant reduction of fuel consumption and an effect produced on the environment (reduction of noise and emission level of carbon dioxide and nitrogen oxides) that can result n development of aircraft of the "flying wing" and the consumption of alternative types of fuel based on liquefied hydrogen and natural gas.

The target of new aircraft designing is the development of new scientific and technical concepts on the grounds of technical assignment its design, technical and operation documentation to provide efficient fulfillment of traditional and new function [6, 43, 74, 75].

Design target lies in development of the project which implementation is provided by the most efficient achievement of design target values. Aircraft is a part of aviation complex system (Fig. 1.1) that, in its turn, needs a systematic approach as for aircraft development on the basic of scientific, technical and manufacturing integrated complex.

Designing of new aircraft is a multi stage iteration process involving "appearance design", development of technical proposal, draft sketch designing, working drawings (Fig. 1.2) fabrication of aircraft prototypes, its ground and flight tests which determine aircraft real characteristics and the way it meets airworthiness and technical assignment level [80, 81].

Probability of series production can be specified as a result of aircraft flight tests.

Initial data for passenger aircraft designing involve as following:

– Technical assignment for designing;
– Statistical data representing achieved world level in a field of passenger aircraft designing;
– Recommended scientific and technical concepts for aircraft designing.

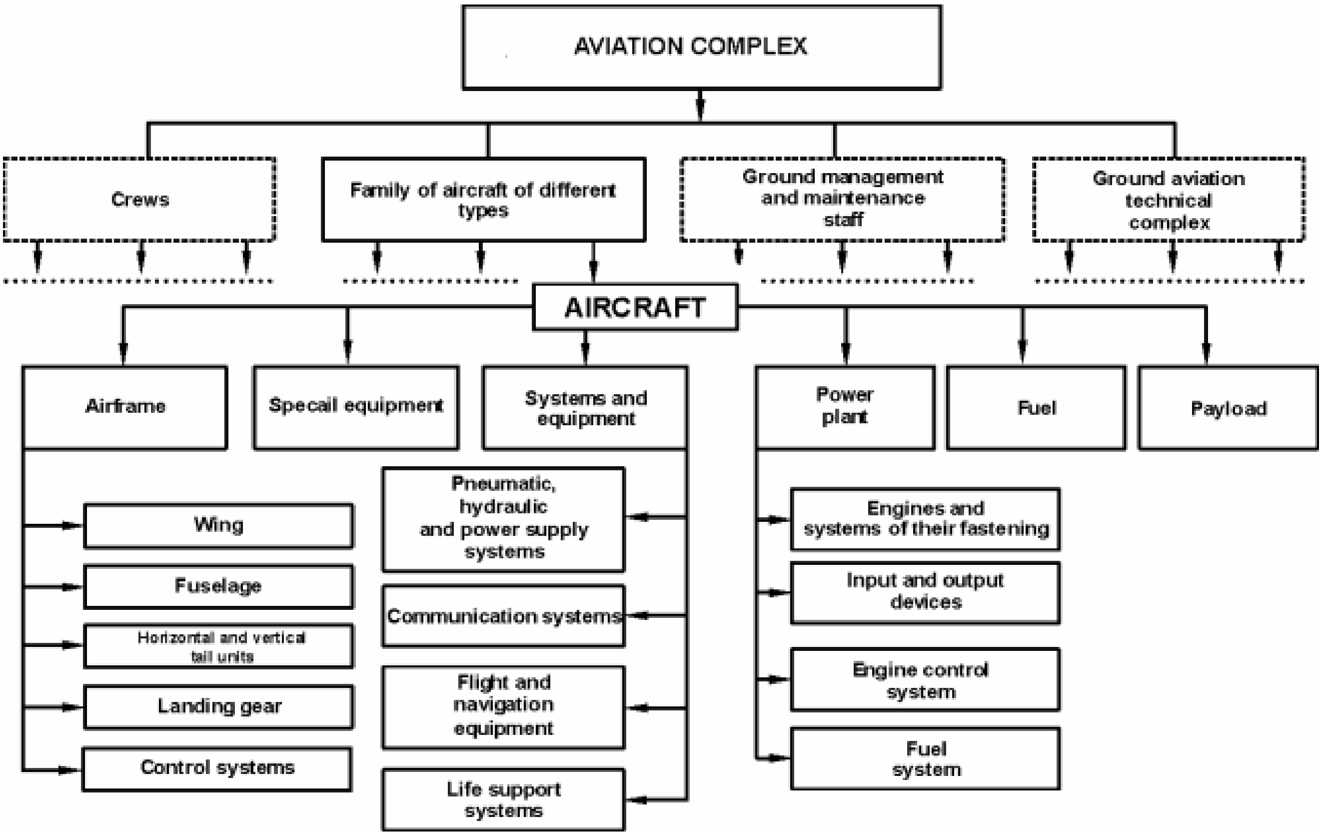


Fig. 1.1. Aviation Complex Functional Block Diagram

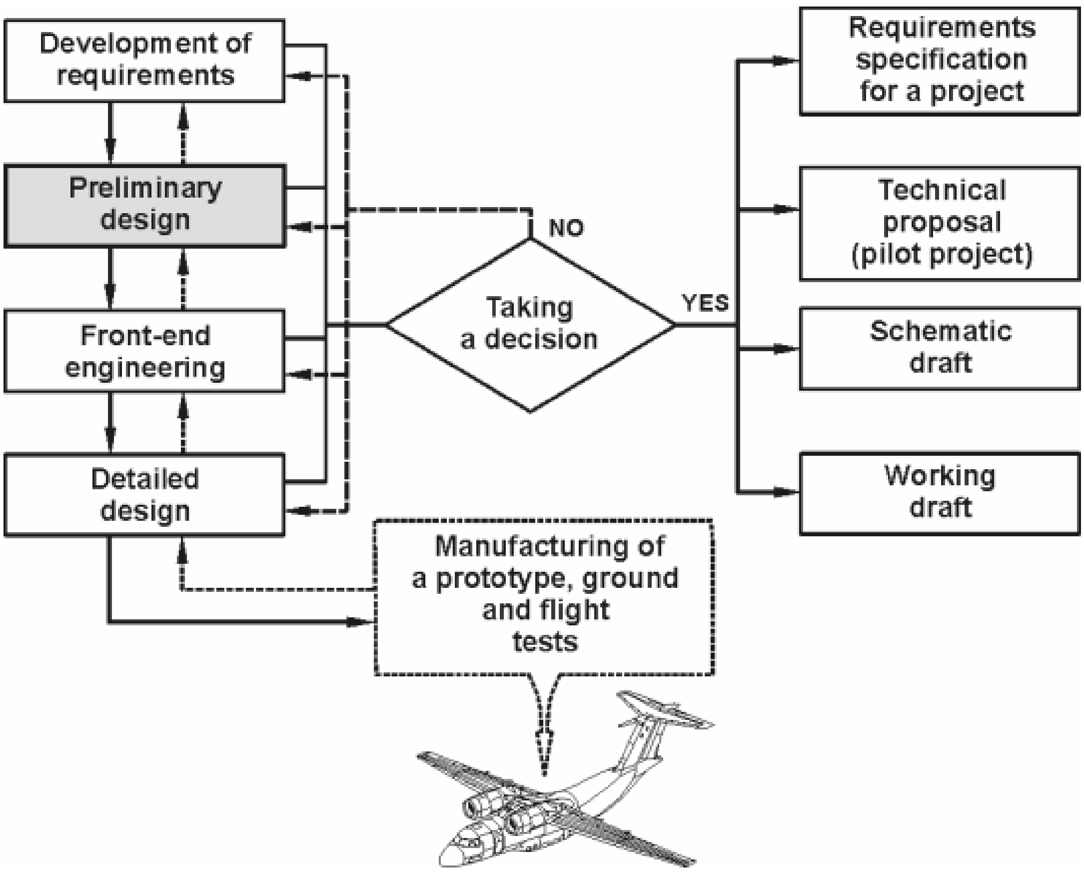


Fig. 1.2. New Aircraft Main Development Stages

The technical assignment incorporates as following:

- Purpose of passenger aircraft under design;
- List of standard specification and technical publications to be used under aircraft development (Aviation Regulation AR-25 requirements and norms for aviation noise and environment pollution, general technical requirements for passenger compartment layout and for equipment set);
- Flight and technical data characteristics;
- Aircraft technical level and economical characteristics;
- Predicted progress in aircraft development, probable modified versions;
- Requirements for airframe lifetime, for vendor items and equipment set;
- Main characteristics of passenger aircraft engine (lifetime, noise level, emission);
- The list of special equipment and its assignment;
- Requirement for reliability, maintenance systems, and overhaul;
- Standardization and unification level.

For the development of compatible passenger aircraft it is necessary to implement about 100 new patented technical concepts proved to be true at a moment of design start up being scientific and technical experience data.

Passenger aircraft design process analysis demonstrates that it is a sequential, parallel and iteration process for concepts preparation and acception [56] both between the stages of designing and when every stage is in progress. It should be noted that the development of pilot project and draft project is the most critical stages in development of aircraft covering up to 90 % of technical and management problems solutions, provision of processability level and reduction material cost closely associated with automation and information support within the total aircraft lifetime cycle and usage of CAD\CAM\CAE integrated computer-aided systems.

Realization of design process by the use of computer-aided systems requires development of integrated designing methodology based on principles and methods incorporating a systematic approach under designing, mathematical and physical modelling, achievement of integrated technologies advanced level, intellectual skills and scientific-technical practical experience, accumulated by the designers of passenger aircraft.

A systematic approach requires deep knowledge on transport systems and aviation complex involving a family of single type passenger aircraft, flight and ground personnel (Fig. 1.1) as a united complex with the possibility of its decomposition into independent subsystems.

Development of methods in decomposition of systems into subsystems and determination of interconnection between system elements are the main target of the new methodology.

An important problem under implementation of new methodology is the development of principles and techniques for determination of aircraft optimal (feasible parameters and its components basing on the combination of efficiency criteria).

The first results in development and practical implementation of transport category aircraft integrated design methodology will be obtained in Ukraine under solution of design and technical problems during development of the An-74TK-300, An-140, An-3, An-148.

But practical methods in aircraft internal design principles realization have been developed not in full scope under the stage of these aircraft pilot and draft projects. In the connection that a significant part of design procedures can not be subjected to formal characterization under development of new aircraft

The integrated design of these aircraft is performed by a great number of specialists and for successful completion of this work an account should be made for technical, managerial and psychological aspects of these problems.

An aircraft as a design object is represented in the form of structural-functional diagram (Fig. 1.3) of hierarchical structure. Different models are associated with the principle of systematic approach and different design level.

Association links between performance and characteristics are in the grounds of aircraft model: flight and technical, productive, operational, processability and flight safety characteristics. These links under design development are united into separate units. Different methods of weight and aerodynamical calculations for strength, calculation of stability and controllability properties, power plant characteristics are taken as a basis for the mathematical description of submodels.

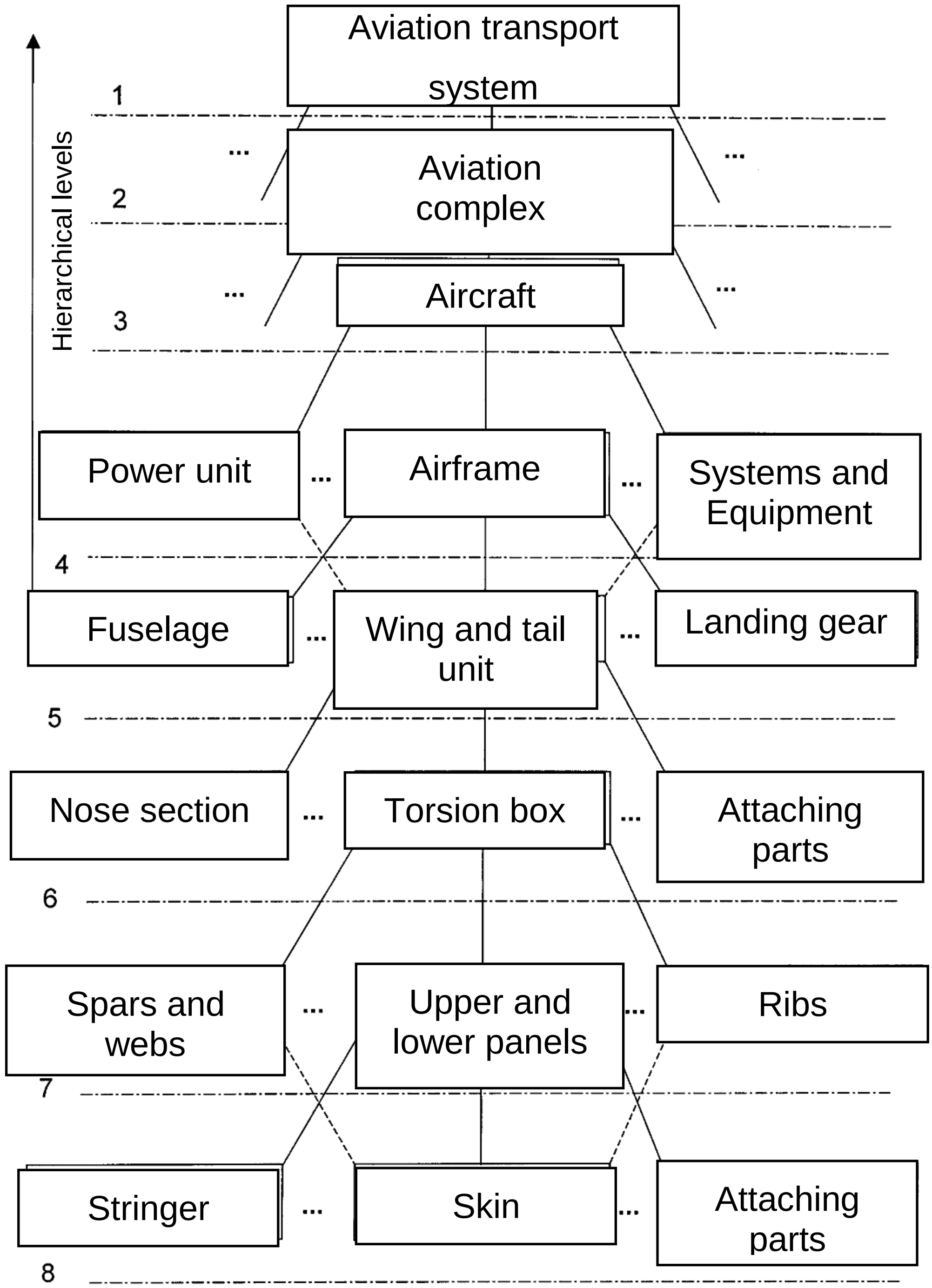


Fig. 1.3. Graphical Model of Hierarchical Aircraft Structure (Fragment)

Relation between parameters and characteristics allows to solve the problem of parametric synthesis and aircraft optimization. Development of alternative aircraft lay-outs is performed by an empiric method with the analysis of its peculiar features taken into account.

The main problems to be solved under passenger aircraft designing are as follows:

1. Selection of aircraft layout and its scaling (determination of the main design

parameters, arrangement and centering to meet technical assignment requirements).

2. Specifying effect produced by different design concept versions (eccentric, parametric) on the level of compliance with technical assignment and technical economical characteristics.
3. Optimization of design parameters due to combination of selected parameters and requirement of standard materials and procedure specifications.
4. Estimation of flight performance and technical-economical characteristics with selected parameters.
5. Development of aircraft modified versions.

On the grounds of technical assignment the designer selects aircraft layout among available alternative versions to provide its continuation of balancing (standard, "conard", "flying wing" tailless or their combination). Power plant in many cases also, effects on aircraft appearance. Bypass turbofan engines become widely used at passenger aircraft.

Relations between parameters and characteristics serve as a basis for aircraft models aiding to solve the problems of parametric analysis, parametric synthesis and optimization. To solve these problems it is necessary to use optimality criteria expressions or specified functionality depending on aircraft parameters and characteristics as well as information on exterium of this function in the aspect of tolerable values of design parameters x_{perm}:

$$extr\ F(x, y(x)),\ x \in x_{perm}.$$

Development of aircraft alternative layouts is performed with estimation of different parameters peculiar features taken into account.

Techniques and algorythm in determination of design parameters realizing described methodology are defined in works [56, 67]. They cover:

– Selection of aircraft layout and its power plant;
– Definition of aircraft design parameters and their optimization;
– Automated modelling of aircraft appearance;
– Determination of aircraft weight and inertia characteristics;
– Arrangement and definition of CG position of passenger aircraft (including aerodynamic configuration volume-weight and structural-power plant arrangement);
– Selection of methods for final definition of aircraft configuration and determina-

tion of aircraft zone outlines making drawing of aircraft appearance as well as arrangement drawing.

The application of CAD\CAM\CAE systems for upgrading design quality the necessity arises to create parametric model on the basis of obtained results, aircraft master-geometry, space distribution model and analytical systems of aircraft components and units [67].

Aircraft designing as a science is a system of true knowledge about properties of object under design, directions and really acting trends of their development, knowing principles and methods in selection of parameters and definition of characteristics. Science on aircraft experience in development of aircraft projects and practically developed available aircraft.

The targets of aircraft general designing allow to specify its several types of aerodynamic, weight, arrangement-layout, structural and power plant requirements. There are direct and back feed relations between them specified in general system of aircraft automatic designing. Alongside with differentiation of aircraft designing, there is its integration on the basis of general tendencies, mathematization and automation of all procedures for aircraft development.

The sense of weight designing process lies in optimization of aircraft take off weigh and its structural components at the phase of appearance characteristics determination, minimization of aircraft parts and units weight under development of load carrying patterns and structures, equipment systems and power plants as well as their modifications.

At the stage of specifying future aircraft appearance, its arrangement and main data for development of general aircraft concept, the designers want to achieve perfect level of aerodynamical strength and weight characteristics.

The designers pay special attention to aircraft safety under turbulence conditions in atmosphere, critical and supercritical angles of attack. In this case, availability of perfect aerodynamical parameters is not singly sufficient enough being one of the property in the chain "dimension-weight-strength" that specify quality of passenger aircraft design project [96].

The problems of designing and weight, strength and passenger aircraft production processability to ensure high safety and reliability of the structure are thoroughly and aimed investigated in research design bureau (RDB).

Practical procedure in development of high-wing prototypes of passenger aircraft is grounded on advanced designing methods and high perfection level of calculations, developing and changing alongside with the development of science, engineering and technology going to the use of new techniques based on the results of theoretical researches, advanced scientific and investigation works, implementation of computer-aided integrated systems into aircraft development practice.

1.2 PASSENGER AIRCRAFT DESIGNING ESTIMATION METHODS

No single aircraft manufacturing company in the modern world can be compatible if it is uncapable to provide high quality in manufacture of aviation engineering objects, their quick modification or change of aircraft version. But it is quite normal on today's market to have a great number of modified versions of basic prototype (An-74, An-74TK-100, An-74TK-200, An-74TK-300, ATR.42 and ATR.72, A310, A319, A320, A321 etc.). Provision of high development rate followed by keeping high quality of final product and its variety is highly complicated without the use of the CAD/CAM/CAE computer-aided integrated systems enabling to integrated designing process, engineering analysis and preparation for aircraft production.

Designing of passenger aircraft involves the following phases [67, 74]:

1. Aircraft pleminary design estimation:
   - Development of initial data for designing;
   - Estimation of predeveloped aircraft statistical characteristic data;
   - Development of technical assignment for designing;
   - Estimation of performance requirements for passenger aircraft;
   - Specifying requirements for aircraft with respect to Airworthiness Rules and Regulations AP-25, FAR-25, CS-25.
2. Passenger aircraft parametric analysis:
   - Main absolute and relative parameters of aircraft and its characteristics;
   - Aircraft parametric model as an objects of investigation;
   - Estimation of the effect produced by aircraft parameters on flight speed value;

– Effect of produced by aircraft parameters on flight range;
– Effect of produced by aircraft parameters on flight height;
– Effect of produced by aircraft parameters on the rate of climb;
– Effect of produced by aircraft parameters on its maneuverability;
– Effect of produced by aircraft parameters on standard overload value under the flight in turbulent atmosphere;
– Effect of produced by aircraft parameters on take off and landing characteristics;
– Measures leading to reduction of drag ratio.

3. Aircraft layout and power plant selection:
   – Estimation and selection of aircraft general layout and its length wise balancing;
   – Estimation and selection of power plant and its characteristics.
4. Determination of aircraft design parameters.
5. Specifying mass-inertia characteristics.
6. Development of aerodynamic, 3D-weight and load carrying structural arrangement, inter arrangement of structural components and development of aircraft outlines. Calculation of aircraft centre of gravity.
7. Issuance of arrangement results and making drawing of aircraft appearance.

The process in development of passenger aircraft and their modified versions is followed by the development of their designing methods. The phases of statistical, analytical, optimal, automated and systematic methods of designing have been already done. Optimal designing method based on integral criteria of modern aircraft quality lies in grounds of designing methodology to be selected on the condition that Customer (Buyer) requirement to aircraft and Aviation Regulations are met [56, 67].

At present, transportation cost and flight safety are widely considered as a quantative criteria of civil passenger aircraft quality estimation. Aircraft and airframe designers conceptually achieve desired quantitative values of quality criteria by the following way [88, 101]:

– Structure mass reduction as the main property to reduce direct operation cost due to capability of increasing payload;
– Structure lifetime and service life increase under provision of reliability and flight safety as a thing reducing depreciation, maintenance and overhaul cost.

The main criteria in the basic of the modern methods in designing aviation engineering structures is the development and operation of reliable structure with a minimum weight to be fail safe in compliance with the specified lifetime. In this case, the possibility of revealing damage until it reaches tolerable critical sizes and keeping sufficiently enough residual strength of the structural must be ensured.

It is obvious, that the development of the structure to be fail safe [17, 18, 20, 24, 25, 46, 50], is envisaged by the Strength Standards and Aviation Regulations while designing for the specified safe life under minimum weight is related with economical problems.

Development program of new regional passenger and transport aircraft with a wide range of operational probabilities is envisaged by the Development Program of aviation industry in Ukraine. They can be characterized by:

– Modern technical and operational development level to be higher than in XX-century and to be reached on the grounds of new technologies, scientific and technical concepts and inventories in the field of aerodynamics, designing, strength, weight perfection, power plant, aircraft systems, equipment, materials, manufacturing procedures, its preproduction, operability and reliability and safety;
– Compliance with modern Airworthiness Norms and Aviation Regulations harmonized as for content structure and requirements with FAR (JAR) quality standards and advanced ecological standards;
– High level of structural-technical and operational unification and in heritage with up-to-date aircraft;
– Economical efficiency followed by less cost in compare with competitors as for the similar aircraft under respective operation data according to assigned design lifetime 80 000-flying hours (40 000 flight), design service time (30 years) and total assigned lifetime of the engine 30 000 hours (15 000 cycles);
– Strategy application of on-condition technical maintenance;
– Implementation of integral design technologies, preproduction, engineering analysis, test procedures, certification, information support of aviation complex lifetime cycle using CAD\CAM\CAE\PLM and ERP systems.

Development of integrated systems to provide high quality, long lifetime, reliability and safe life, certification of aviation engineering objects and its production as well as scientific-technical experience obtained initiate proconditions for modifying aviation engineering objects of next generations with application of integrated computer-aided systems under designing, modeling, preproduction procedures, serial production flight tests on the grounds of continuous information support of the object life cycle (CALS-technologies) being an important assignment of aviation object production under today's market conditions [6, 22, 28, 38, 44, 51, 53, 54, 58, 67].

Information technologies together with the advanced aviation design technologies and production procedures on availability of unified information field that make it possible to increase sufficiently labour productivity, quality of aviation engineering objects being produced under significant reduction of time required for implementation into manufacturing and production of new more advanced aircraft that meet Buyer's requirements.

Integration of design, production and operation database into unified database is required for organization area.

An idea of common information media development and its integration into all spheres of product support during life cycle also helps to solve the main problem of aviation in Ukraine – that is to provide safety of transportation under minimum cost for transportation of ton/kilometer load or one passenger-kilometer as well as cost reduction of aircraft life cycle.

With reference to product support as for as life cycle is concerned, the common database must contain data on already developed aviation engineering products of manufacturing companies and service centres involving description of organizational, design and production procedure processing that are in progress. At present, the methods and ideas in supporting aviation engineering product with reference to life cycle and integrated on this basis information technologies find different application in all aviation companies world wide.

Development of information technologies allows to intensify progress of technical documentation development, providing design and preproduction procedures production control and product support, mainly implementation of product life cycle information support which diagram is presented in Fig. 1.4.

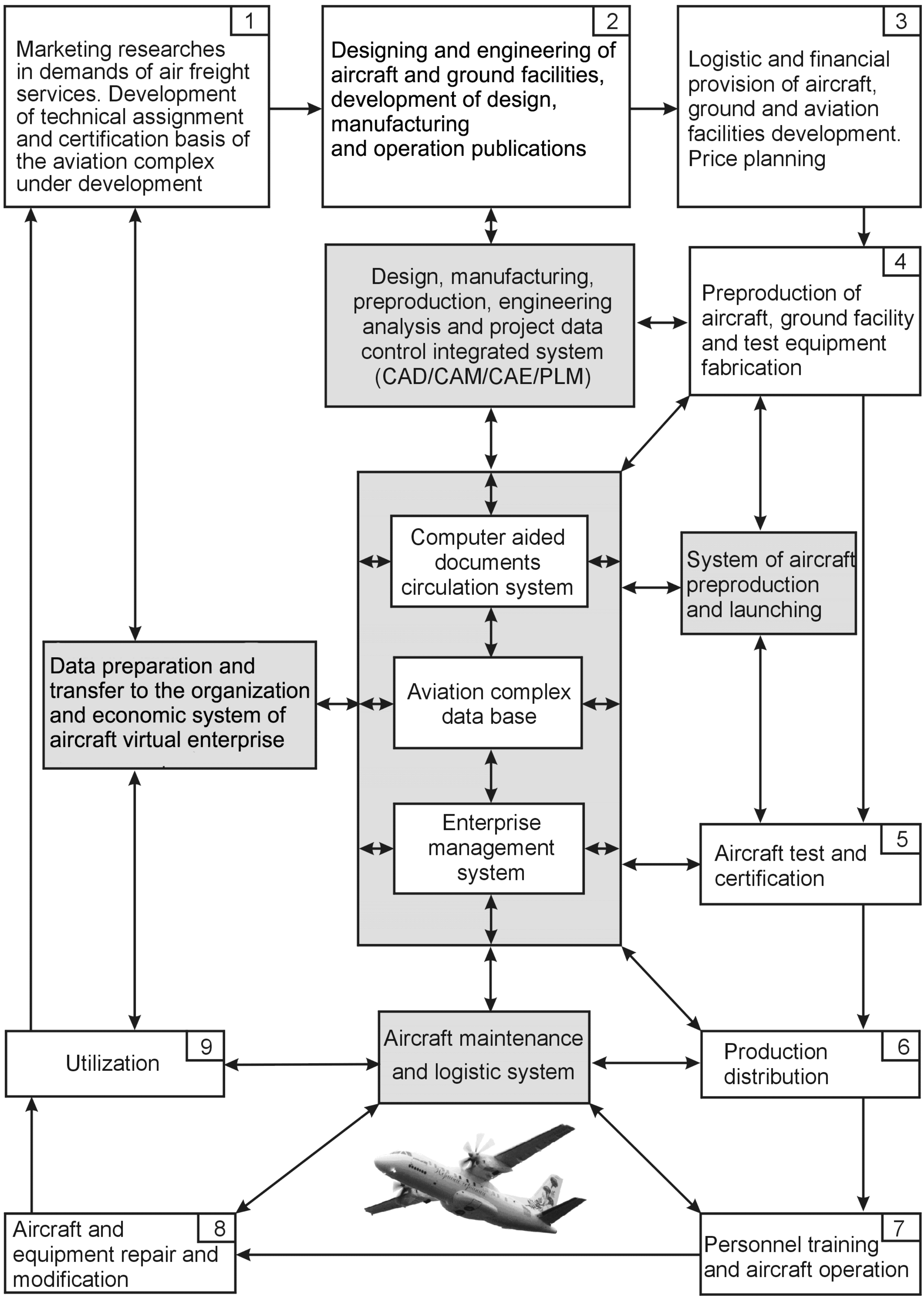


Fig. 1.4. Aircraft Life Cycle and Information Support Components

Data for information support are collected and put in order in organizationally distributed unified database with a free access of all members involved in life cycle support.

Under development of the new product: preparation of design and preproduction procedures using the CAD\CAM\CAE\PLM integrated systems in integrated information system the product structure is subjected to description as well as its composition and all components involved, parts, units, assemblies, vendor items, materials.

The application of information integrated technologies with the reference to aircraft designing process allows to reduce cost for the production development and aircraft life cycle support at 30 % to increase labour intensity and labour ergonomity that finally upgrade quality and product compatibility, production quality and investors activity [68, 73, 94].

Information technology of aircraft integrated designing envisages usage of parametric analytical structural model created in the CAD\CAM\CAE system under the calculation of the following aerodynamic, strength and survivability; lifetime and its integration; dynamics of structure and its operational safety as well as under preparation of production procedures and quality control, operation and overhaul.

For realization of methodological grounds in designing modern regional aircraft it is necessary to develop scientifically proved methods of integrated designing.

Chapter 2
PHILOSOPHY AND SCIENTIFIC BACKGROUNDS OF METHODOLOGY OF REGIONAL PASSENGER AIRCRAFT FAMILY INTEGRATED DESIGNING

2.1 CONCEPT, PRINCIPLES AND METHODS OF INTEGRATED DESIGN OF REGIONAL PASSENGER AIRCRAFT

Published results of studies of trends and prospects for the development of the world civil aviation industry predict a further increase in the volume of air transportation and the needs of the world market in new passenger airliners [47]. The domestic market for passenger air transportation requires about 50 aircraft per year [93] to replace obsolete aircraft. The new aircraft should be designed to carry 75 to 85 passengers, luggage, mail and cargo with a range of 2500 to 5000 km. In this case, the aircraft must be capable of modification and increase of passenger capacity. According to Bombardier [56], the need for new regional aircraft in 2007 through 2027 will be 11 000 units, about 53 % of which are aircraft for 100 – 149 seats and 37 % – for 60 to 99 seats, with airline companies primarily interested in reducing operating costs.

In order to create a competitive regional passenger jet, the methodology of integrated design, features of the concept (Fig. 2.1), principles and methods aimed at performing the mission requirements, compliance with the requirements of standard regulations (AP-25 [79]), CS-25, FAR-25 and ensuring maximum technical efficiency has been developed. Provision should be made for the airplane design considering comfort and economical efficiency.

The integrated design method covers the design and computer-aided parametric three-dimensional modeling of the plane design as a whole and its individual parts. An airplane is a set of parts, units, assemblies and aggregates interconnected by different types of detachable and non-detachable joints. The mass, resource, aerodynamic and aesthetic characteristics of the aircraft depend on the quality of designing and execution [56, 67].

Integrated design contains:

– Formation of integrated infomedia, a complex of technical and software means for creation of the aircraft, production and research base, a team of specialists;
– Developing the concept of creating a new aircraft or modification of an existing aircraft using computer integrated design systems;

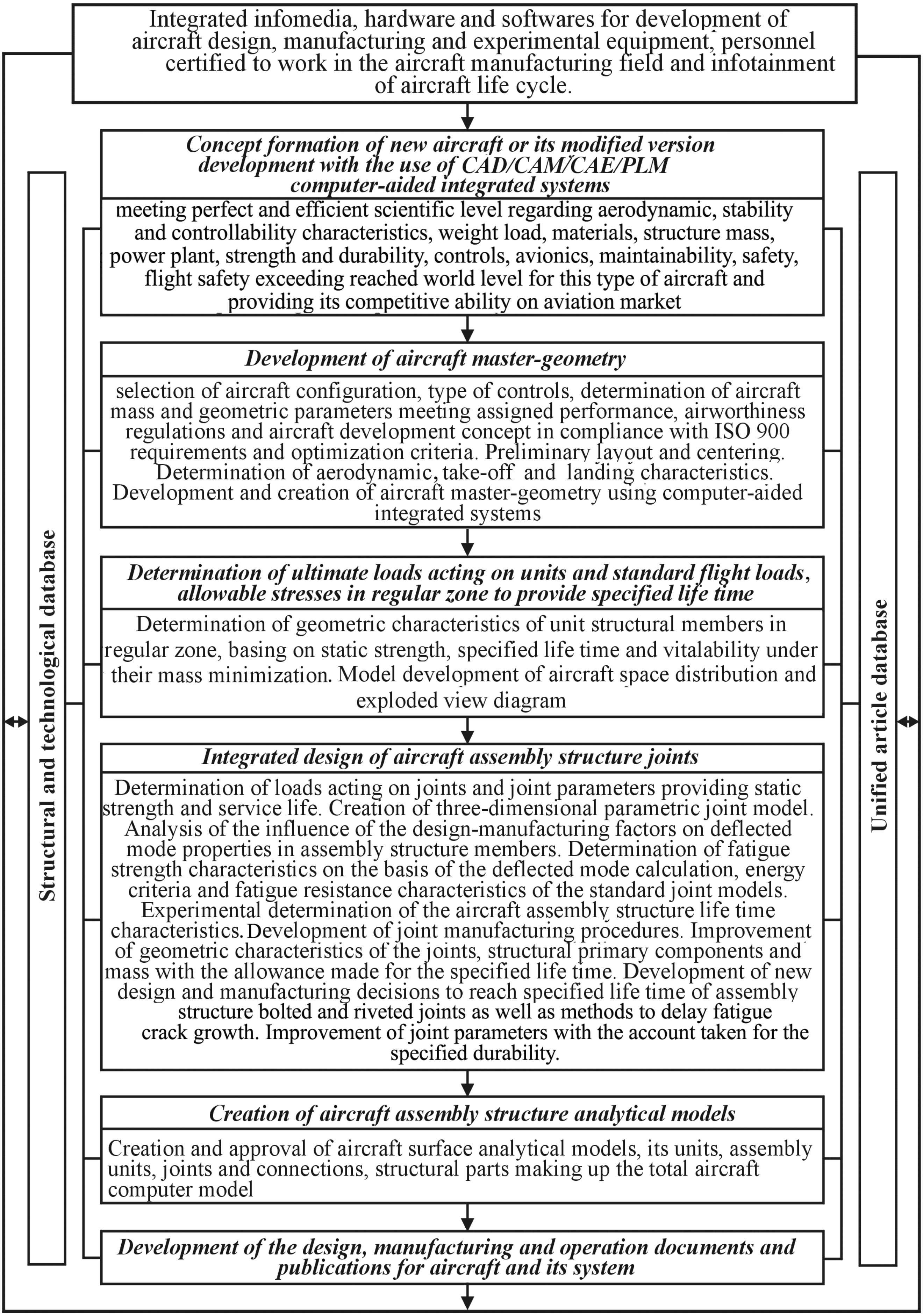


Fig. 2.1. Basic Regional Passenger Jet. Features of Integrated Design Concept

– General designing of individual parts, joints, systems, etc.;
– Computer simulation of the aircraft using the CAD\CAM\CAE\PLM systems, which contains both the development of master geometry and analytical standards of structures and elements;
– Creation of design, technological and operation documentation.

Based on the proposed concept [56, 67] the following principles of integrated design of passenger jet have been developed:

The Principle of Creating Analytical Standards of the Passenger Aircraft

Three-dimensional computer models of master geometry, space distribution, analytical standards of components of aircraft assembled structures are created using analytical geometry methods using the integrated CAD\CAM\CAE\PLM systems in a single information environment for aircraft life cycle support.

The Principle of Creating a Master Geometry of the Airplane Appearance

The parameters of the appearance of a new aircraft having minimum mass and the scheduled durability should satisfy the given prospective mission requirements (MR), the Aviation Rules, the concept of creating a new aircraft and be determined from the relationships:

$$MR, AR \rightarrow \text{aircraft configuration} \rightarrow$$

$$\rightarrow m_0 = \frac{m_{s.l} + m_{eq\&cntrl} + m_{pl}}{1 - \left[\overline{m}_s(p, n_d, N_{sch}, \lambda, RGP) + \overline{m}_{pp}(p, t_0, \gamma_e, R, n_e) + \overline{m}_F(p, C_f, k, L)\right]} \rightarrow$$

$$\rightarrow m_{0\,min} \rightarrow p_{opt} \rightarrow t_{opt} \rightarrow P_0 \rightarrow S_i \rightarrow airfoils_i \rightarrow (l_i, \lambda_i, \chi_i, \bar{c}_i, \eta_i, D_f, L_{VT}, L_{HT}) \rightarrow$$

$$\rightarrow (\bar{x}_G - \bar{x}_F) \rightarrow \text{analytical standard of aircraft surface.}$$

The Principle of Designing Aircraft Units and Systems

The design parameters and technology for producing the regular zones (r.z.) of aircraft units should provide the specified aerodynamic quality, the perception of the calculated destructive loads, the sheduled durability when loaded equivalent to the loads in typical flight in the operational environment, given coefficient of fatigue quality (K_f), degree of tightness, and satisfy such inequalities:

$$P_{destr} \geq P_{calc}\left(DP_{r.z}, \sigma_{\partial\, r.z}\ \left(N_{sch.r.z}\right)\right);$$

$$N_{sch} \leq N_{est.r.z}\ \left(SP_{r.z}, \sigma_{0\, eq}, \sigma_{s}, TS\right);$$

$$\Delta_s < 0\ \ at\ \ P = P_{oper};\ \Delta h \leq\ 0.05\text{ mm};\ K_f \leq 3$$

The Principle of Designing Irregular Zones of Aircraft Assembled Structures

The design parameters and technology for the implementation of irregular zones (ir.z.) should provide for carrying the design ultimate loads in the irregular zone under static loading, the scheduled durability, the quality of the external surface, the air-tightness degree, which equal to parameters of a regular zone or exceed them, and satisfy the following inequalities:

$$P_{br} \geq P_{est}\left(DP_{ir.z}, \sigma_{\partial\, ir.z}\ \left(N_{sch.\, ir.z}\right)\right);\ \Delta h_{ir.z} \leq \Delta h_{r.z};\ \Delta_{s.ir.z} < \Delta_{sir.z};$$
$$N_{sch} \leq min\ \left(N_{d.ir.z}\left(DP_{ir.z}, \left(\sigma_{0\, eq} \cdot \varepsilon_{0\, eq}\right), \sigma_d,\ TR\right)\right);\ N_{oper}\left(DP_{ir.z},\ \sigma_0,\ \sigma_d,\ TR\right).$$

The Principle of Supporting and Achieving Survivability of Airframe Load-Bearing Structures with Fatigue Cracks

The design parameters of safely destructible assembled aircraft structures should provide the ability to control critical locations, detect fatigue cracks and apply progressive ways to delay their growth, restore the bearing capacity and leak tightness of the damaged structure, and satisfy the following inequalities:

$$\left(N_{CGDT}/N_{d.\, s}\right)\ > 1;\ \Delta_{D,CGDT} < 0.$$

Features of the use of the concept of designing regional passenger aircraft is to provide a level of excellence that exceeds existing analogues in terms of flight, life cycle, operational and economic characteristics [56] and requires the choice of aircraft scheme and the method of analysis of the impact of the aircraft parameters, designed for such characteristics. In doing so, it is necessary to solve the problems regarding the performance criterion and the list of relevant parameters.

Mission requirements are developed to design a regional passenger aircraft. According to it, the aircraft is created as the base of a series of passenger aircraft with a passenger capacity of up to 100 people with two bypass jet engines with a high degree of structural and technological and operational continuity and unification with the aircraft produced at domestic aircraft-building enterprises. Airplanes of this range should provide:

- Compliance with airworthiness requirements of АП-25 (AP-25), FAR-25, CS-25;
- Reliability and safety of flights;
- Environmental characteristics (standardized noise levels in passenger compartments and terrain, the level of harmful emissions) affecting the environment;
- High level of comfort;
- Efficiency in operation.

The mission requirements contain specific requirements for its characteristics and operating conditions for a competitive aircraft.

Main Performance of Basic Airplane

Number of passengers, prs.	73 – 99
Maximum payload, t	~ 7…7.5
Engine:	
– Type	Bypass turbojet
– Quantity	2
Speed, km/h:	
– Maximum	~ 870
– Maximum range	~ 820
Cruising level, km:	11…12
Operational range, km:	
– With maximum payload	~ 2500
– With passengers	~ 4500
– Without cargo and passengers	~ 5500
RWY (dry concrete, H=0, SA), m	1500…1800
Crew members, pers.:	
– Captain	1
– Co-pilot	1
– 2 cabin attendants	if necessary

Durability and Endurance

Design durability	80000 h
Design endurance	30 years

Technical level

Fuel efficiency	24.9 + 2% g per 1 pass·km
Weight efficiency	284+2% kg of empty equipped aircraft per 1 passenger
Specific labor intensity of maintenance	2.5 mh per 1 h of flying hours
Annual flying rate	2 800…3 500 h

Expected operating conditions and operational factors

Barometric pressure within the flight altitude range	acc. to GOST 4401-81
Outdoor air temperature $t_{a.a}$	acc. to GOST 4401-81
Deviation $t_{a.a}$ from the mean value for different heights along the lines	"Max – tropical" "Min – arctic"
Mass density, barometric pressure, air viscosity	acc. to ГОСТ 4401-81
Outdoor air temperature near the ground	minus 55 … + 45 °C
Relative humidity of outdoor air near the ground at $t_{a.a}$ = 35 °C	≤ 98 %
The direction and speed of the wind near the ground:	
– Headwind component	≤ 25 m/s
– Tailwind component	≤ 5 m/s
– Crosswind component at an angle up to 90° to RWY:	
$f \geq 0.5$	≤ 15 m/s
$f \geq 0.3$	≤ 6 m/s

The aircraft must be operated at aerodromes with concrete and flexible reinforced pavement (asphalt concrete, pebbles or gravel in a bound state, hardened soil), prepared in accordance with Instructions on Airfield Service of Civil Aviation (НАС ГА-86 (NAS GA-86)).

The Height of Aerodrome Location

Above sealevel	up to 3 000 m

Below sea level up to 300 m

Permissible state of the runway (in compliance with НАС ГА-86 (NAS GA-86)):

- ♦ Dry; wet;
- ♦ Wet with the areas of water;
- ♦ Filled with water up to 10 mm;
- ♦ Covered with a layer of slush up to 15 mm; covered with snow with $f \geq 0{,}3$.

The aircraft must provide flights:

- ♦ According to the rules of visual flight and instrument flight;
- ♦ During day and night;
- ♦ In simple and complex weather conditions;
- ♦ In icing conditions (at t_{RWY} not below minus 30 °C);
- ♦ On domestic and international air routes and lines;
- ♦ Over the plains, hills and mountains;
- ♦ Over water, landless terrain and in the range of latitudes up to 73°, north, and 55°, south.

Operational weather minimums:

- ♦ For take-off – range of visibility on the runway not less than 200 m;
- ♦ For landing – the ICAO category II with the possibility of bringing to category III A of ICAO, provided the composition and characteristics of ground means of flight support in accordance with the AS of CA, taking into account the existing and future means of navigation and communication.

During the aircraft development concept, the analysis of statistical data on similar aircraft has been performed. Aircraft of such types have been considered as the closest analogues: Tu-134, ERJ 170LR, ERJ 175LR, CRJ 700LR, CRJ 705ER (Fig. 2.2, Table 2.1).

As a result of the analysis of statistical data of similar aircraft, the concept of providing a level of perfection that exceeds existing analogues in terms of flight-technical, resource, operational and economic characteristics is proposed:

– **The aerodynamic layout** of the aircraft should provide cruising aerodynamic quality at the level of 15 to 17 units, which is 5 to 7 % higher than analogs;

– **Take-off and landing characteristics** must ensure safe operation of the aircraft being developed from unpaved airfields with a runway length of 800 m, which corresponds to class D according to СНИП (SNIP) 2.05.08-85, СНИП (SNIP) 32-03-96, or class 1B according to the ICAO classification, as well as operation from non-equipped airfields;

– **Fuel efficiency** should be achieved by reducing fuel consumption in cruising mode by 10 to 15 % compared to analogs up to 24.9 g per 1 pass·km;
– High mass efficiency must be achieved by increasing the level of mass perfection of the design and systems, the relative weight of the airframe-no more than 27 % (by 7 through 15 % lower than analogs);

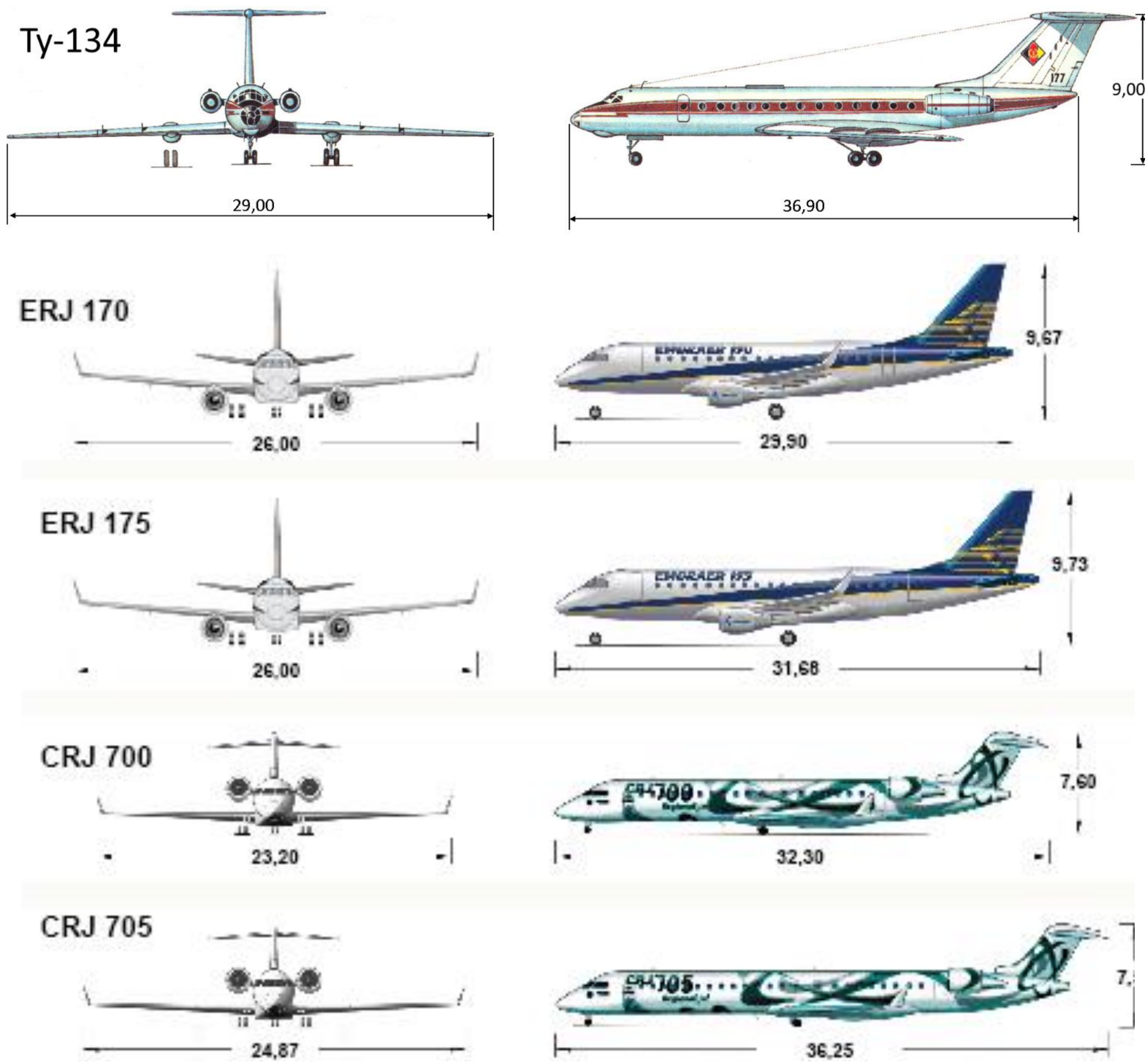


Fig. 2.2. Configurations of Prototype Airplanes

Table 2.1

Statistic Data of Prototypes

Airplane	Tu-134	ERJ170	ERJ175	CRJ700	CRJ705	Project
Maximum take-off weight, t	47.6	37.2	38.79	34.93	37.42	
Passenger capacity, prs.	76	70	78	70	74	73 – 99
Engine type	Д-30	CF34-8E5	CF34-8E5	CF34-8C5	CF34-8C5	TFE
Maximum thrust, tf	6.8	6.44	6.44	6.26	6.58	
Maximum cruising speed, km/h	870	870	870	876	880	~ 870
Maximum cruising height, km	12.0	12.5	12.5	12.5	12.5	~ 12.0
Flight range, km: with passengers maximum	 2400 3800	 3411 4480	 3175 4300	 3408 4900	 3770 4450	 ~ 2500 ~ 5400
RWY length for take-off, m	2500	1689	1910	1851	1969	1800
Dimensions of airplane, m: length height wing span	 36.90 9.00 29.00	 29.90 9.67 26.00	 31.68 9.73 26.00	 32.30 7.60 23.20	 36.25 7.50 24.87	
Price, US dollars mln		34	38	41	42	30

– The power plant must provide the necessary level of load-carrying capacity, with low noise, vibration and low fuel consumption in cruising mode-no more than 0.55 to 0.60 kg/kgf per hour. Regarding ground noise, the aircraft must meet the requirements of Chapter 4 of the International standards "Environmental Protection", Annex 16 to the Convention on international civil aviation (volume I "Aircraft Noise", 2001);

– The control system and the flight and navigation system must be performed using modern equipment. The accuracy characteristics of the flight navigation system must meet international requirements (RNP, RVSM, BRNAV and PRNAV). The pilot's cabin is designed to meet modern ergonomics requirements. The main devices that display flight and navigation information, as well as data about the main aircraft systems and power plants, are color liquid crystal displays with an active matrix;

– The design life of the glider must be at least 80 000 flight hours, the service life – at least 30 years;

– The cost should not exceed 28 to 30 million dollars, which is 10 to 20 % less than the average cost of modern aircraft of this class;

– Operational manufacturability should ensure the specific labor intensity of maintenance no more than 2.5 manhour for 1 hour flight, as well as the possibility of offline routine maintenance of the aircraft by the crew;

– To ensure the competitiveness of the aircraft, the requirements of modern airworthiness standards (AP-25, FAR-25) must be met, as well as unique requirements for operation in tropical and mountainous airfields;
– The layout of the cabin should provide comfort at the level of modern world standards for economy class salons with a seat pitch of 812 mm, with the possibility of re-equipment and production of aircraft with business class and luxury class salons;
– To ensure the effectiveness of aircraft design, modern computer-aided design (CAD) systems should be widely used to optimize the design parameters of the aircraft, as well as integrated design systems CAD\CAM\CAE\PLM.

Based on the results of the analysis of existing competitive aircraft, taking into account the requirements of the technical task and ensuring the continuity of the design, a decision is made on the layout of the aircraft that is being designed. For example, for an aircraft designed using a normal aerodynamic scheme with a high-placed wing of moderate sweep with advanced high-lift system. Two turbofan engines are located on pylons under the wing. Tail unit of the T-shaped scheme. The fuselage of the aircraft is an independent module with attachment points for landing gear, wing, vertical and horizontal tail. The fuselage has a sealed cabin crew and passenger compartment, radar compartment, avionics compartment and other equipment. Landing gear is of a tricycle type with a nose wheel (Fig. 2.3).

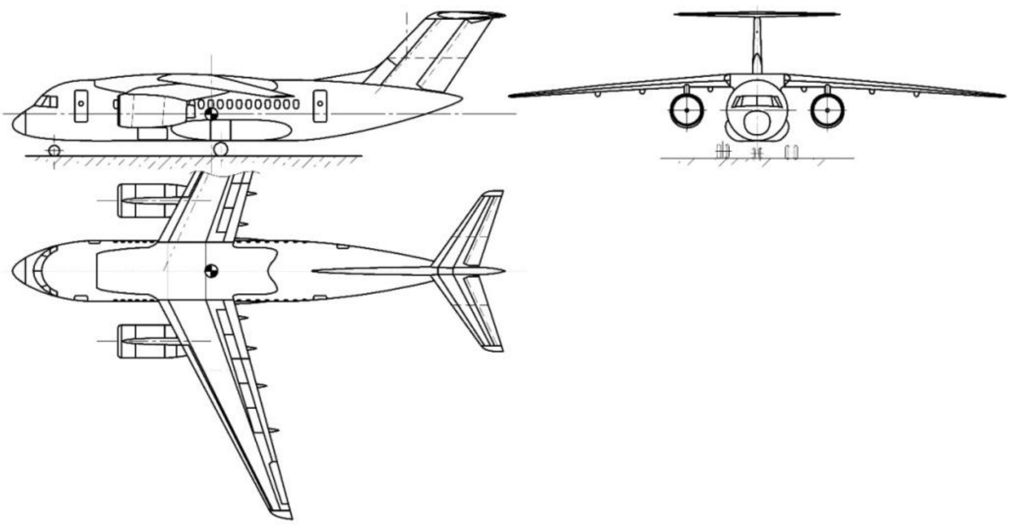


Fig. 2.3. Configuration of Aircraft

The method of general design of regional passenger aircraft is implemented in accordance with the methodology of integrated aircraft design [67, 97] in the form of a block diagram shown in Fig. 2.4.

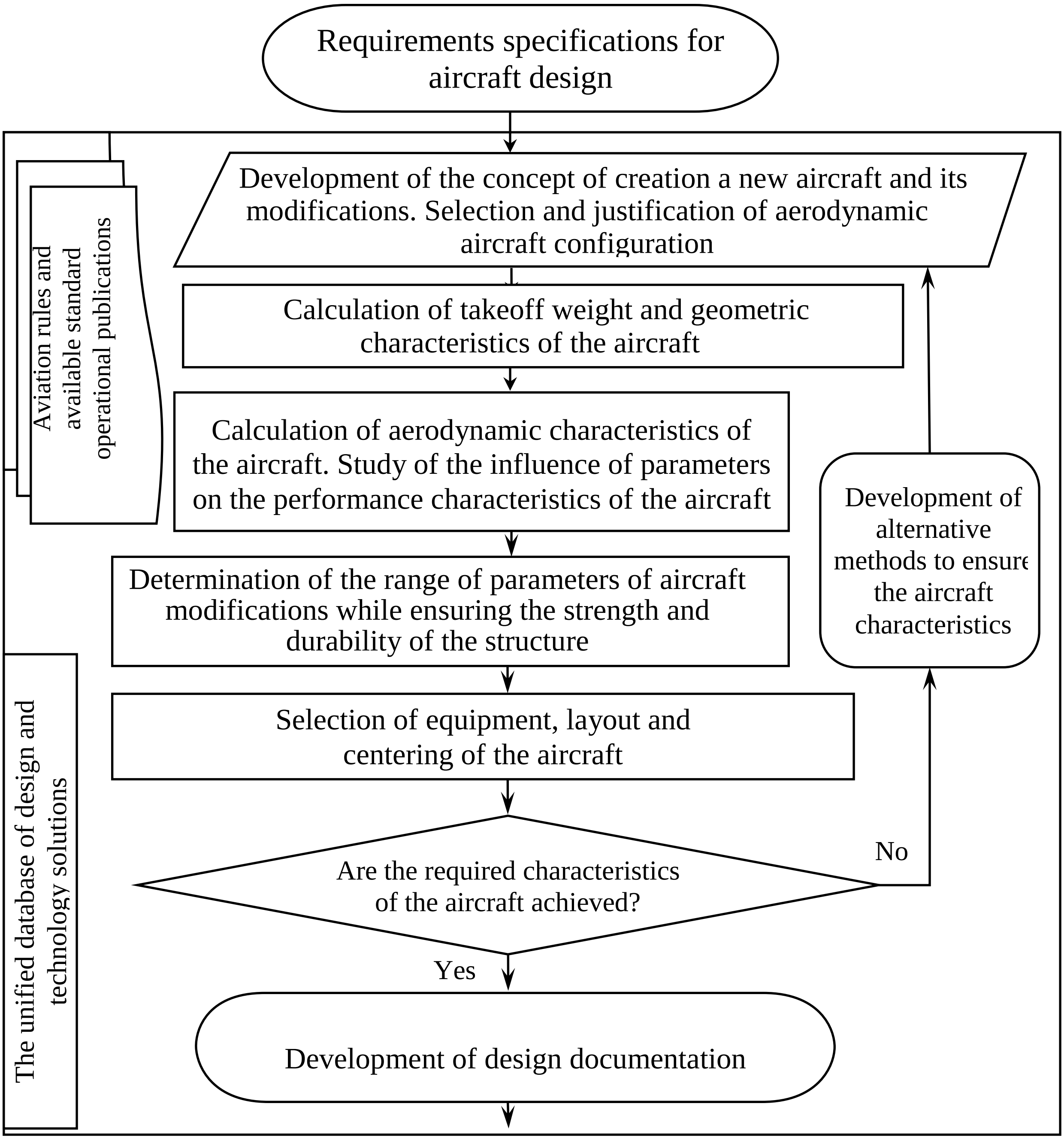


Fig. 2.4. Flow Diagram of General Design Method of Regional Passenger Aircraft

To determine priority directions of development of regional passenger planes perform specific indicators of excellence in manufacturing and operation such as the technical effectiveness of the aircraft or the cost of 1 ton·km of transportation, the ratio of fuel efficiency etc [29, 31, 32, 36, 37, 39, 67, 87, 97].

But at the stage of selection of parameters of a general view of a passenger plane (see Fig. 2.4) it is advisable to use a take-off weight of the aircraft as a criterion of effectiveness.

The mathematical dependence for determining the take-off weight of an aircraft in the zero approximation can be written as follows [65, 89, 90, 97, 100]:

$$m_0^0 = \frac{m_{s.l} + m_{pl}}{1 - \left(\overline{m}_s + \overline{m}_{pp} + \overline{m}_{eq.c} + \overline{m}_f\right)},$$

where $m_{s.l}$ – weight of a service load, kg;

m_{pl} – mass of payload of the aircraft, kg;

$\overline{m}_s$ – relative weight of the structure;

$\overline{m}_{pp}$ – the relative mass of the power plant;

$\overline{m}_{eq.c}$ – the relative weight of equipment considering equipment and control;

$\overline{m}_f$ – the relative mass of the fuel.

In the zero approximation, the relative mass of the structure, power plant, equipment, and fuel is determined based on statistical data. The required number of crew members is determined taking into account the requirements of aviation regulations regarding the number of flight attendants.

For various modifications of the An-148 aircraft accepted $m_{s.l}$ = 720 kg; $\overline{m}_s = 0.28$; $\overline{m}_{pp} = 0.1$; $m_{eq.c} = 0.1$ and received $m_0^0 = 37700$ kg ($n_p = 80$, $L = 2100$ km, $\overline{m}_f$ = 0.22) and m_0^0 = 42240 kg (n_p = 80, L = 4200 km, $\overline{m}_f$ = 0.36).

In the first approximation, the formula for determining the take-off weight of an aircraft has the form [56, 67, 80, 100]:

$$m_0' = \frac{m_{s.l.} + m_{pl} + m_{eq.c}}{1 - \left[\overline{m}_s\left(m_0^0, p, n_d, N_{sch}, \lambda, RGP, \ldots\right) + \overline{m}_{pp}\left(p, t_0, \gamma_e, R, N_e, \ldots\right) + \overline{m}_f\left(p, C_T, k, L, \ldots\right)\right]}.$$

The relative masses of the structure, power plant and fuel in the first approximation are determined depending on the parameters of the aircraft. The weight of equipment and controls $m_{eq.c}$ is calculated in accordance with the list of equipment compiled from the data of aircraft analogues and taking into account the requirements of the mission requirements.

The mass of the service load for a passenger aircraft is determined by the formula

$$m_{s.l} = m_{cr} \cdot n_{cr} + \Delta m_{s.l},$$

where m_{cr} = 80 kg – the weight of one crew member n_{cr} – the number of crew members, psns, $\Delta m_{s.l}$ – the weight of the aircraft's service equipment, kg.

The analysis of literature sources [65, 89, 97, 100] and statistical data on existing aircraft allows us to propose calculating the service load mass, kg, for passenger aircraft of short and medium airlines using the formula:

$$\Delta m_s = 8.617 n_p + 3.53 \left(n_p \overline{m}_f / K_r\right)^{2/3},$$

where n_p – the number of passengers, people; $\overline{m}_f$ – the statistical value of the relative mass of fuel; $K_r = m_{pl} / m_0$ – the statistical value of the coefficient of return.

To calculate the mass of the service load, kg, of a long-distance passenger aircraft, the formula is proposed

$$\Delta m_{s.l} = 14.97 n_p + 4.121 \left(n_p \overline{m}_f / K_r\right)^{2/3}.$$

In the first approximation, the relative mass of the structure, power plant and fuel is determined depending on the parameters of the aircraft based on analytical dependencies, taking into account correction coefficients. These analytical dependencies allow us to perform a parametric analysis of the influence of aircraft parameters on its take-off weight, followed by finding the values of the minimum mass and optimal parameters of the aircraft.

The relative mass of the power plant $\overline{m}_{pp}$ is determined by the formula:

$$\overline{m}_{pp} = R \gamma_e t_{0\,max},$$

where R – coefficient that takes into account the increase in the weight of the power plant compared to the weight of the engines:

$$R = k_1\left(1 + 0.1\frac{n_{e.th}}{n_e}\right)\left[1 + \frac{0.0236}{\gamma_e}\left(1.5 + 0.275y^{0.75}\right)^2\right],$$

where k_1 – coefficient taking into account the number and location of engines on the airplane;

n_e – the number of engines on the aircraft;

$n_{e.th}$ – the number of engines equipped with thrust reverser;

γ_e – specific weight of the engine, daN/daN;

y – the degree of engine bypass.

The starting load t_0 to perform calculations according to the above formula is found as the maximum due to such requirements for cruising flight with a given speed and height, the length of the take-off run before take-off, and continued take-off when one engine fails.

The starting tractive power required to ensure the maximum number M at height H is determined by the formula:

$$t_{0cr} = \frac{0.7 p_H M_{cr}^2 C_{xcr}}{\xi_V \xi_H \xi_{th} \xi_{ai} p}.$$

Indeed, that on cruising flight modes

$$C_{xcr} \approx \frac{4}{3} C_{x0} = \frac{4}{3}\left(F_1 + F_2 p\right);$$

$$\text{then } t_{0cr} = \frac{0.933 p_H M_{cr}^2}{\xi_V \xi_H \xi_{th} \xi_{ai}}\left(\frac{F_1}{p} + F_2\right),$$

where $F_1 = k_{tu} C_{xw}$ – drag coefficient of the wing and tail;

$F_2 = \dfrac{C_{xf}}{k_{mid}}$ (where C_{xf} – drag coefficient of the fuselage, engine nacelles, engine fairings and landing gear, and the like; k_{mid} – specific load on the midle section, daN/m^2);

p_H – atmospheric pressure at cruising altitude, daN/m^2;

ξ_V, ξ_H, ξ_{th} – coefficients that take into account the change in engine thrust depending on the speed and altitude of flight and engine operation (M_{cr}, H_{cr}

are determined from the passport data of similar engines for; ξ_{ai}– coefficient that takes into account the loss of thrust associated with the loss of high-speed head in the air intakes. Cruising numbers M_{cr} and H_{cr} are determined by the data from statistics or from the experience of operating such aircraft.

When the wing specific load and wing aspect ratio values vary, and when other parameters are unchanged, the dependence $t_{0\,cr} = f_1$ (p, λ, const) has the form shown in Fig. 2.5, curves 1 and 2.

The starting thrust-to-weight ratio required to ensure a given take-off length before take-off is determined by the formula:

$$t_{0lr} = \frac{1}{\xi_{to}} \left[\frac{0.832\,p}{L_r C_{y\,to}} + \frac{1}{3}\left(\frac{1}{K_{to}} + 2f \right) \right],$$

where $\xi_{to} = \xi_V \xi_H \xi_{ai} \xi_{th}$ – coefficients determined for take-off modes $M = M_{lo}$ and $H = 0$;

L_r – take-off length before take-off, set in MR, m;

f – coefficient of friction of wheels on the runway surface during take-off.

The dependency $t_{0lr} = f_2$(p, L_{lr} , const) is shown in Fig. 2.5, curves 3 and 4.

The starting thrust-to-weight ratio required to ensure an extended take-off in the event of a single engine failure during the run-up before take-off is determined by the formula:

$$t_{0\theta} = \frac{n_e}{\xi_{to}(n_e - 1)} \left(\frac{1}{K_{to}} + tg\theta_g \right),$$

where n_e – the number of engines installed on the aircraft;

$tg\theta_g$ – the gradient of climb at the third stage of take-off when one engine fails, set in the airworthiness Standards of the aircraft.

The dependency $t_{0lr} = f_3$ (p, θ, const) has the form shown in Fig. 2.5, curves 5 and 6.

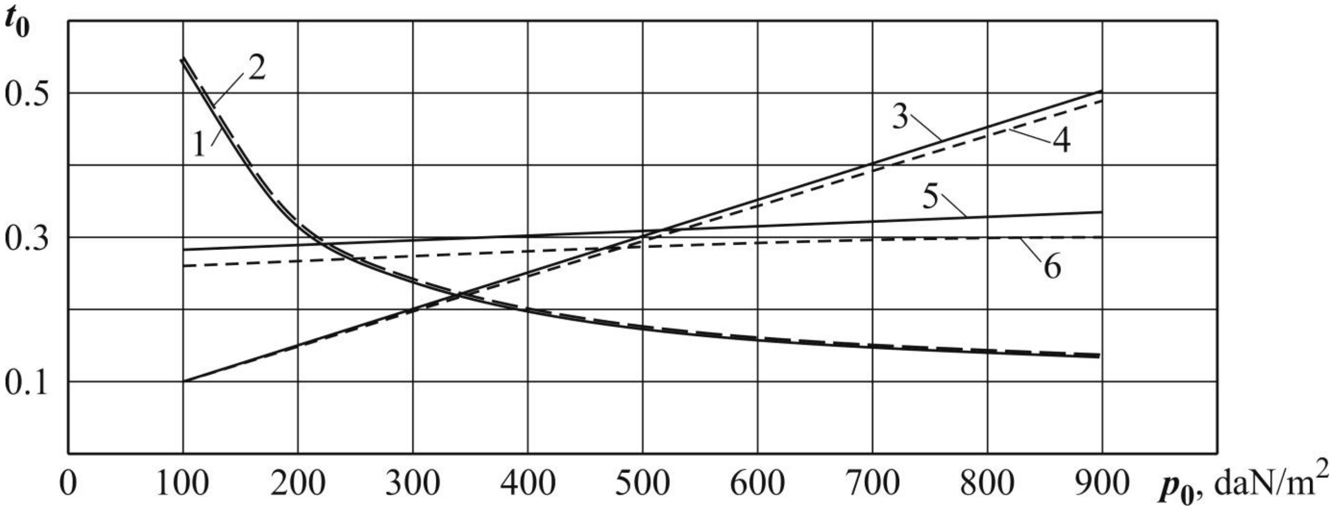


Fig. 2.5. Influence of Aircraft Parameters on the Starting Thrust-to-Weight Ratio of the Aircraft: curves 1 and 2 – starting load capacity, required for maximum speed M_{max} at altitude H ($1 - \lambda = 8$; $2 - \lambda = 10$); curves 3 and 4 – the starting load required to ensure the specified take-off length before take-off ($3 - \lambda = 8$; $4 - \lambda = 10$); curves 5 and 6 – the starting load capacity required to provide an extended take-off in the event of a single engine failure during the take-off ($5 - \lambda = 8$; $6 - \lambda = 10$)

The effect of the specific load and wing extension on the relative weight of the powerplant according to the above requirements is shown in Fig. 2.6.

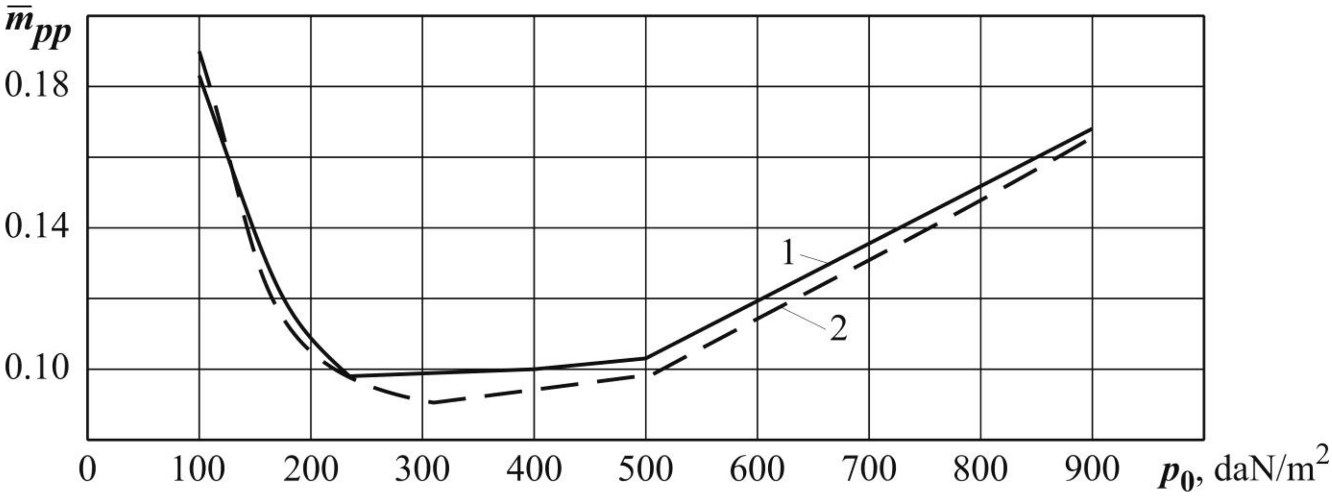


Fig. 2.6. Effect of specific load and wing extension on the relative weight of the aircraft's powerplant: $1 - \lambda = 8$; $2 - \lambda = 10$
($\lambda = 4$, $\chi_{fs} = 26$, $\lambda = 2500$ km)

The relative mass of fuel $\overline{m}_f$ is defined as the sum of the masses [80, 81, 100]:

$$\overline{m}_f = \overline{m}_{f.cl} + \overline{m}_{f.cr} + \overline{m}_{f.r} + \overline{m}_{f.d.l} + \overline{m}_{f.r},$$

where $\overline{m}_{f.cl}$ – the relative mass of fuel used for take-off and climb; $\overline{m}_{f.cr}$ – the relative mass of fuel used for cruising with M_{cr} and H_{cr}; $\overline{m}_{f.r}$ – the relative mass of the navigation fuel reserve; $\overline{m}_{f.d.l}$ – the relative mass of fuel used for descent and landing; $\overline{m}_{f.r}$ – the relative mass of fuel that can not be used;

$$\overline{m}_{f.c} = \frac{0.0035H_i(1-0.03y)}{1-0.004H_i} \quad \overline{m}_{f.d.l} = 0.002H_f(1-0.03y)(1-0.023H_f),$$

where H_i, H_f – the value of the initial and final height of cruising flight, km;

y – the engine bypass ratio.

The relative mass of the fuel used for cruising and the relative mass of the navigational fuel reserve:

$$\overline{m}_{f.cr} + \overline{m}_{f.r} = 0.052 + \left[\frac{0.2(L-40H_m)}{a_H M_{ct} - 0.28W_h} + 1\right] C_{c.cr} \sqrt{\frac{k_2(1+\overline{S}_f)}{k_1\lambda}} (F_1 + F_2 p),$$

where L – range of flight, km – $H_m = (H_i + H_f)/2$ – average altitude of cruising flight, km; a_H – speed of sound at the average altitude of cruising flight, m/s; M_{cr} – Mach number, which corresponds to the cruising speed of flight; W_h – headwind speed, km/h; $C_{c.cr}$ – specific fuel consumption at cruising flight mode, kg/daN·h.

The effect of specific load and wing extension on the relative mass of fuel is shown in Fig. 2.7.

The relative mass of the structure consists of the relative mass of the wing, fuselage, tail and landing gear:

$$\overline{m}_s = \overline{m}_w + \overline{m}_f + \overline{m}_t + \overline{m}_{\text{lg}}.$$

To calculate the relative mass of the wing, we use the formula [80, 89, 100]

$$\overline{m}_w = \frac{7.2k_1 n_A^p \left(m_0^0\right)^{0.5} \varphi\lambda}{10^4 p \overline{c}_0^{\,0.75} cos^{1.5} \chi_{0.25}} \cdot \frac{\eta+4}{\eta+1} + \frac{4.5k_2 k_3}{p} + 0.015,$$

where p – the specific load on the wing, daN/m^2; k_1 – coefficient taking into account the type of panels; k_2 – coefficient taking into account the presence of nodules, interceptors, remaking and type of flaps; k_3 – coefficient taking into account the type of fuel tanks and type of closure; n_A^p – the estimated coefficient of overload of aircraft for simulation case A; $\varphi = b - 0.83\overline{m}_f$ – coefficient of relief of the wing with fuel and engines; λ, $\bar{c}$, $\chi_{0.25}$, η – the value of aspect ratio, the relative profile thickness, 0.25 chord sweep and taper ratio of the wing, taken for calculations.

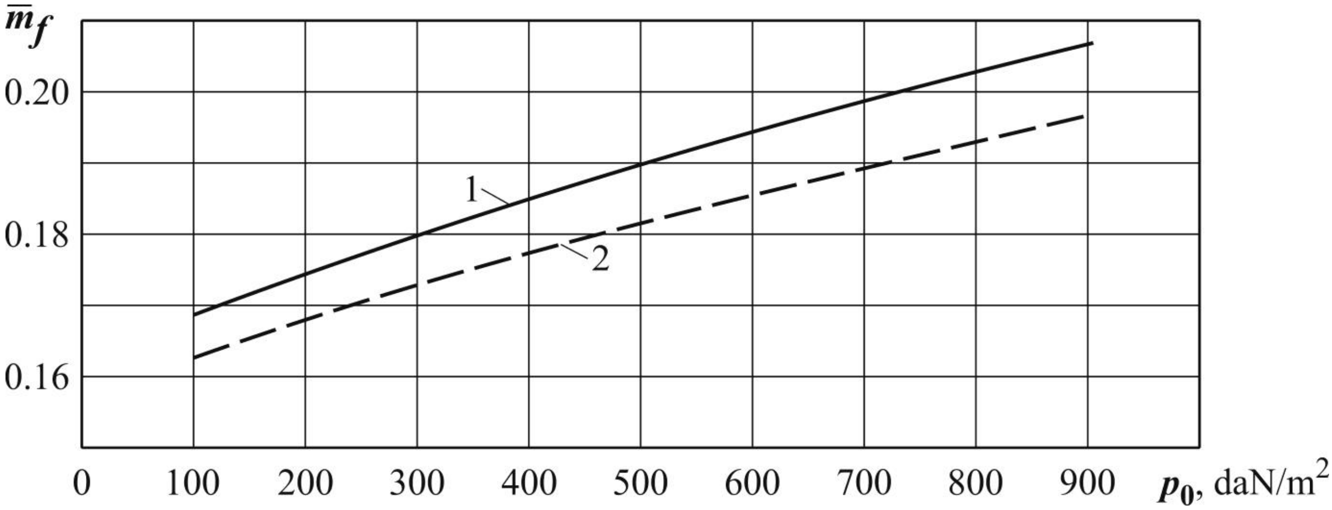


Fig. 2.7. Influence of Specific Load and Wing Aspect Ratio on Relative Fuel Mass: 1 – λ = 8; 2 – λ = 10 (η = 4, χ_f = 26°, L = 2500 km)

The relative weight of the fuselage is determined by the Scheinin formula [96, 100]:

$$\overline{m}_f = k_1 \lambda_f d_f^2 \left(m_0^0\right)^i + k_2 + k_3 + k_4,$$

where k_1 = 4.56 – 0.441 d_f for schemes with engines located on the fuselage; k_1 = 3.4 – 0.26 d_f for schemes with engines located on the wing, or with a mixed engine layout (DC-10, L-1011); i = – (0.77 – 0.01d_f); k_2 – coefficient that takes into account the place of attachment of the main landing gear struts; k_3 – coefficient that takes into account the place of main landing gear struts retraction; k_4 – coefficient that takes into account the method of loading luggage.

To determine the relative weight of the plumage, we use the statistical formula from [80, 89, 97]:

$$\overline{m}_t = 0.85 k_f k_t^{cx} p^{-0.56} \overline{S}_t^{1.16} \left(m_0^0\right)^{0.16},$$

where $k_n = 1$ at $p \le 450$ daN / m^2;

$k_n = 0.84$ at $p > 450$ daN / m^2;

$\overline{S}_t = \overline{S}_{ht} + \overline{S}_{vt}$; $k_t^{cx} = \dfrac{1.564 - 0.0011 S_t}{3.1 + 0.0038 p}$ for a low horizontal tail;

$k_t^{cx} = \dfrac{1.33 - 0.0032 S_t}{1.295 + 0.0028 p}$ for T-tail; $S_t = \overline{S}_t \cdot \left(m_0^0 / p\right)$.

To calculate the relative weight of the landing gear, we use the Fadeev formula [80, 89]

$$\overline{m}_{lg} = k_{lg}\ k_{df}\ \frac{m_0^0 + 204000}{m_0^0 + 79000},$$

where k_{lg} – coefficient that takes into account the number of main landing gear struts;

k_{df} – coefficient that takes into account the impact of the size of the fuselage and the type of engines on the weight of the landing gear.

The results of calculations of the relative weight of the aircraft structure are shown in Fig. 2.8.

The results of calculations of the take-off weight of the aircraft for various combinations of parameters are shown in Figs 2.9 – 2.11.

To determine the range of parameters of possible modifications, the mass calculation was performed for different values of the design parameters. Figs 2.12 through 2.14 show the dependence of the take-off weight on the take-off length at different values of the general view parameters, and Figs 2.15 through 2.17 – on the flight range, taking into account the layout of the cabin for 75 passengers.

The take-off weight calculations take into account the limitations of the specific load on the wing for landing speed and normal overload when flying in a turbulent atmosphere. The minimum weight is determined for modifications with a cabin layout for 82 passengers with a flight range of 2100, 3500 and 4240 km. The results are shown in Fig. 2.18.

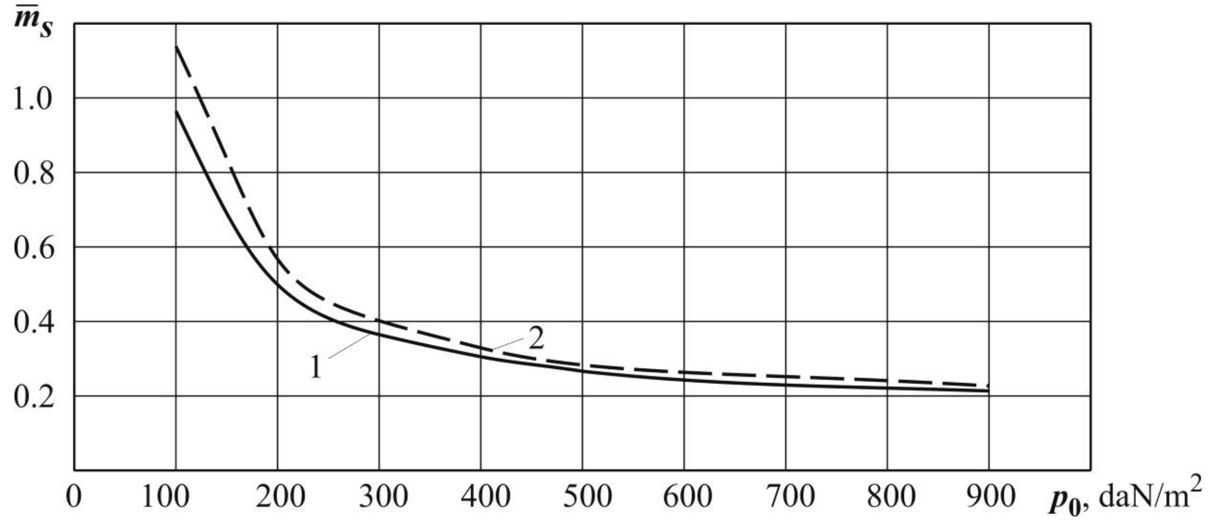


Fig. 2.8. Influence of Specific Load and Wing Aspect Ratio on the Relative Weight of the Aircraft Structure: 1 – λ = 8; 2 – λ = 10 (η = 4, χ_{le} = 26°, L = 2500 km)

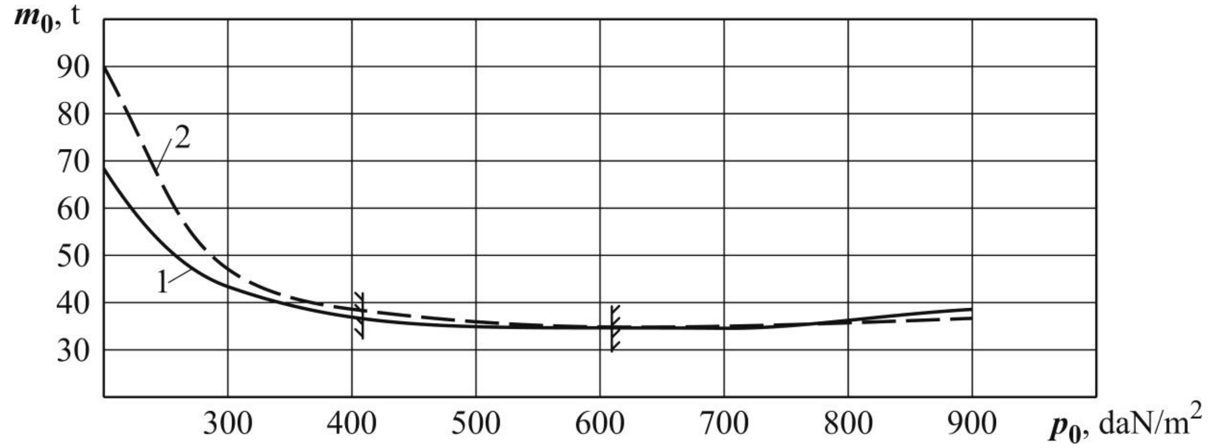


Fig. 2.9. Influence of Specific Load and Wing Aspect Ratio on the Take-off Weight of the Aircraft: 1 – λ = 8; 2 – λ = 10 (η = 4, χ_{le} = 26°, L = 2500 km)

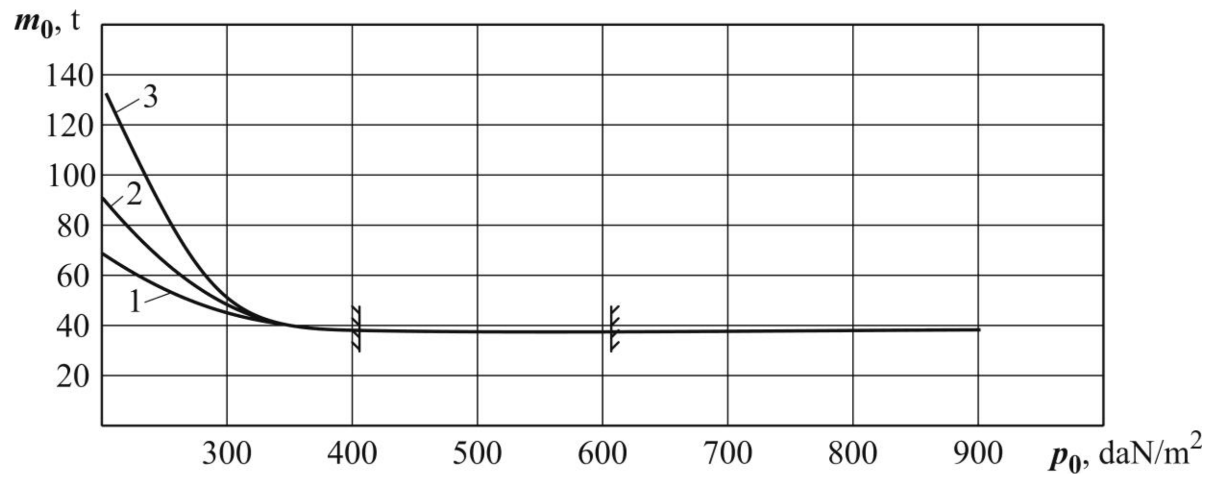


Fig. 2.10. Influence of Specific Load and Wing Taper Ratio on the Take-off Weight of the Aircraft: 1 – η = 3; 2 – η = 4; 3 – η = 5 (λ= 9.6, χ_{le} = 26°, L= 2500 km)

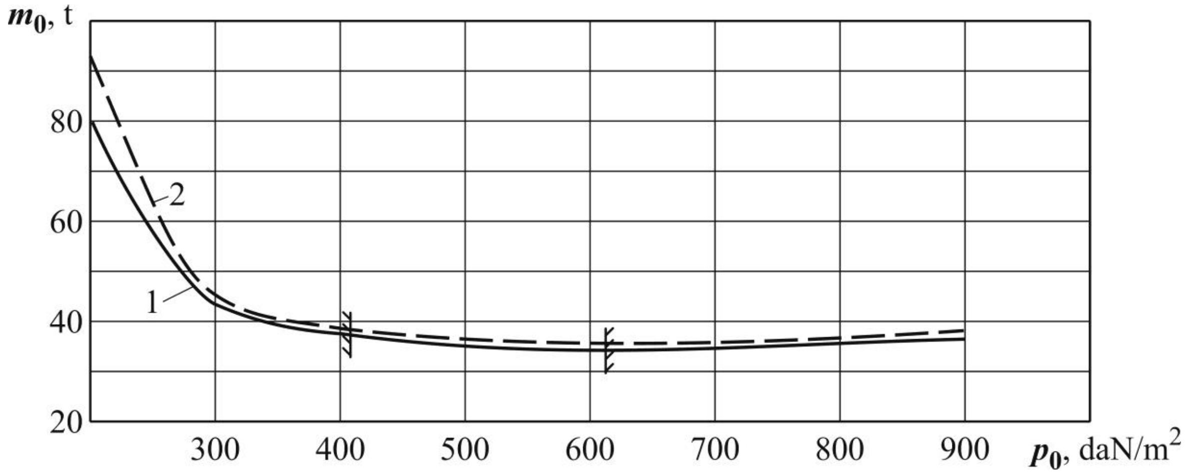


Fig 2.11. Influence of Specific Load and Wing Sweep on Take-off Weight: 1 – $\chi_{le} = 24°$; 2 – $\chi_{le} = 32°$ (λ = 9.6, η = 4, L = 2500 km)

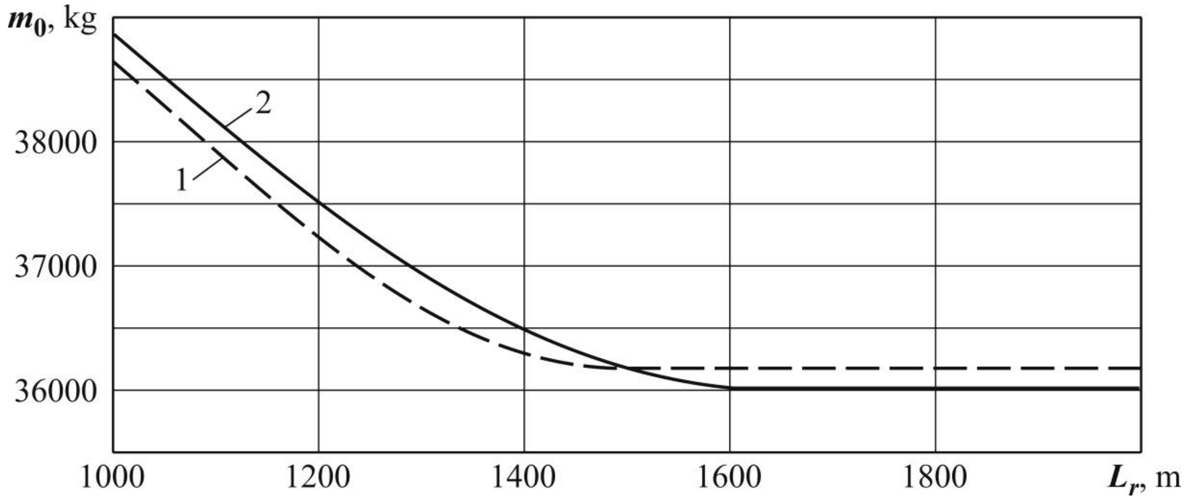


Fig. 2.12. Influence of Landing Run and Wing Aspect Ratio on Take-off Weight of the Aircraft: 1 – λ = 8; 2 – λ = 10 (λ = 4, χ_{le} = 26°, λ = 2500 km)

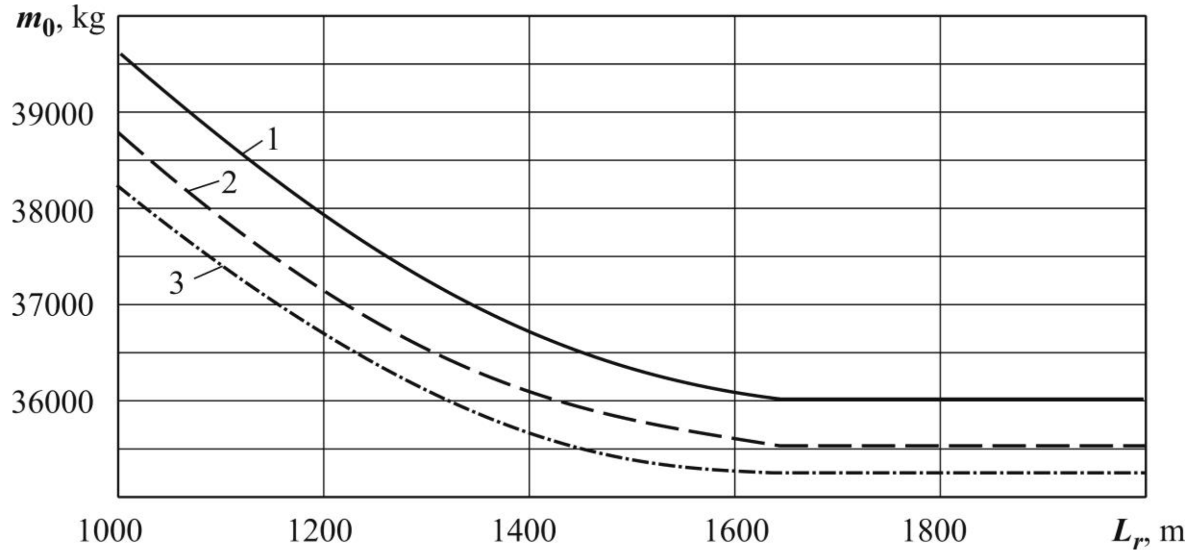


Fig. 2.13. Influence of Landing Run and Wing Taper on Airplane Take-off Weight: 1 – η = 3; 2 – η = 4; 3 – η = 5 (λ = 9.6, χ_{le} = 26°, L = 2500 km)

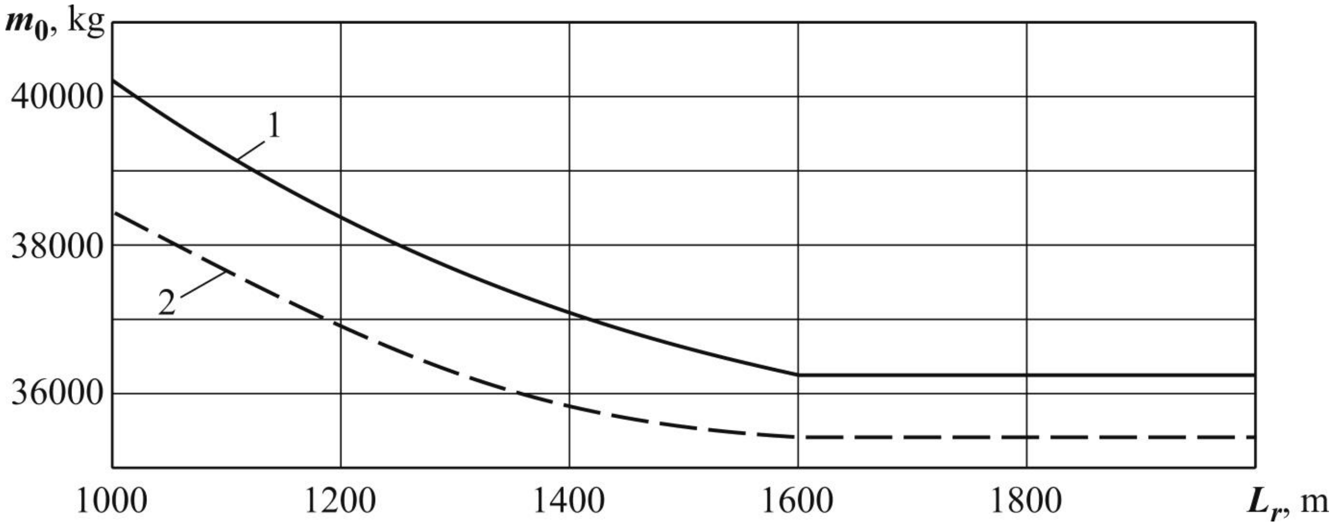


Fig. 2.14. Influence of Landing Run and Wing Sweep on Take-off Weight of the Aircraft: 1 – χ_{le} = 24°; 2 – χ_{le} = 32° (λ = 9.6, η = 4, L = 2500 km)

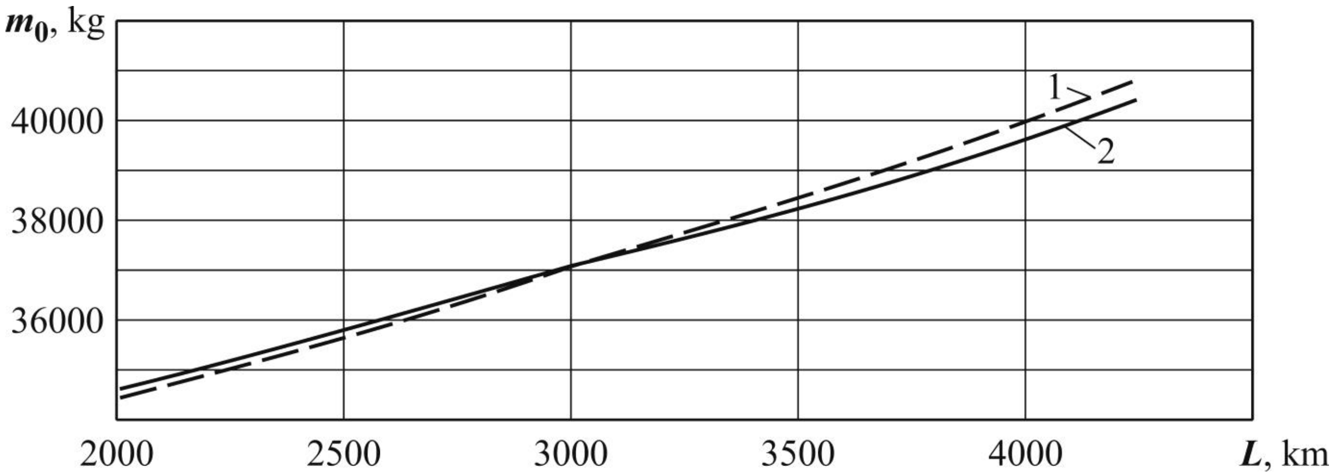


Fig. 2.15. Influence of Flight Range and Wing Aspect Ratio on Take-off Weight of the Aircraft: 1 – λ = 8; 2 – λ = 10 (η = 4, χ_{le} = 26°, L = 2500 km)

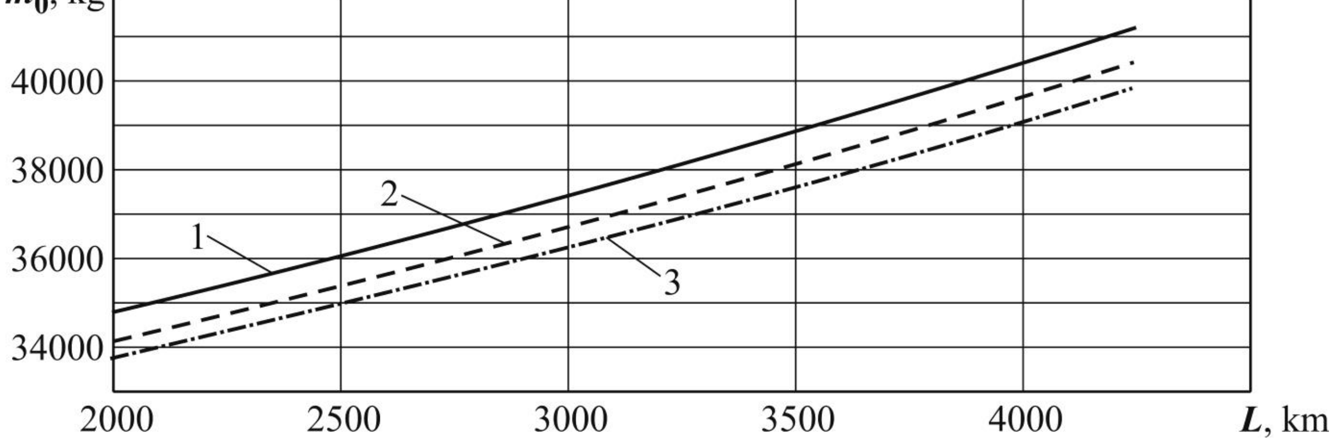


Fig. 2.16. Influence of Flight Range and Wing Taper on Airplane Take-off Weight: 1 – η = 3; 2 – η = 4; 3 – η = 5 (λ = 9.6, χ_{le} = 26°, η = 2500 km)

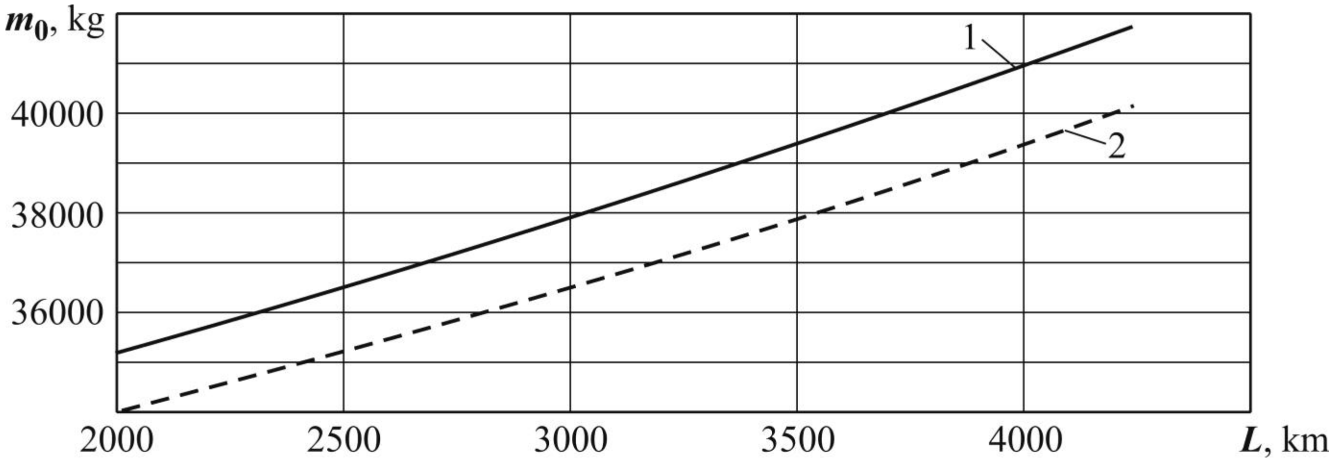


Fig. 2.17. Influence of Flight Range and Wing Sweep on Take-off Weight of the Aircraft: 1 – χ_{le} = 32; 2 – χ_{le} = 24° (λ = 9.6, η = 4, L = 2500 km)

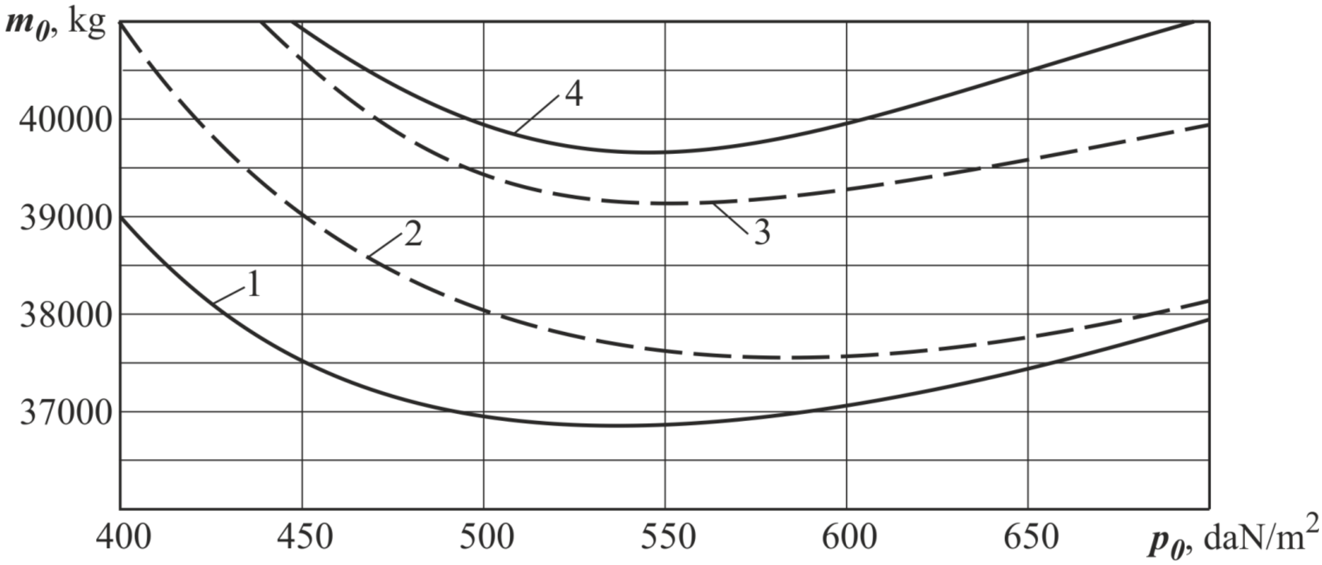


Fig. 2.18. Influence of Specific Load and Wing Aspect Ratio on Take-off Weight of the Airplane:
1 – λ = 8, L = 2100 km; 2 – λ = 10, L = 2100 km;
3 – λ = 10, L = 4240 km; 4 – λ = 8, L = 4240 km

Comparison of the proposed calculation results with the characteristics of existing An-148 aircraft modifications is given in Table 2.2. The errors of take-off mass calculations do not exceed 3.5 %, which indicates that the results obtained are correct.

The desired level of mass perfection of the design is envisaged to be achieved through the widespread use of composite materials (CM). The vertical and horizontal tail unit should be completely made of CM, as well as the LE, the ends and all the high-lift devices of the wing (slats, flaps, ailerons, trim tabs and servo tabs). The fuselage, wing box and wing center section are intended to be made of aluminum alloys to maintain technological continuity and to simplify preparation for production of the aircraft at domestic aviation enterprises. Due to the significant use of CM and the increased use of integrated design methods with fatigue, the estimated relative mass of the structure is 15 to 20 % less than existing counterparts, provided that a given design service life of the airframe is 80 000 years. This should ensure the design life of the aircraft 30 years with an annual flying time of 2800 to 3500 h.

Table 2.2

Comparison of the Results of Determining the Take-off Weight in the First Approximation with the Masses of Modifications of the An-148 Aircraft

Aircraft characteristics	Aircraft modifications		
	An-148-100A	An-148-100B	An-148-100E
	L = 2100 km, n_{pass} = 80	L = 3500 km, n_{pass} = 80	L = 4200 km, n_{pass} = 80
Estimated take-off weight m_0', kg	38 090	41 530	42 150
Take-off weight of available modifications, kg	38 950	41 950	43 700
Error, %	2.2	1	3.5

Based on the results of the analysis of the engine performances and aerodynamic characteristics of the aircraft, it is concluded that to ensure a given level of fuel efficiency (24.5 g/pass.·km) in cruising flight mode, it is necessary to ensure the cruising lift-to-drag ratio of the aircraft of at least 18 to 19. Taking into account the mission requirements for the operation of the aircraft on unpaved and unequipped airfields, it was decided to locate the wing according to the "high-wing" scheme and to place the engines under the wing. According to preliminary calculations, to ensure the specified take-off distance, it is necessary to achieve the take-off and landing lift-to-drag ratio of 10 to 12 when C_y = 2.4. Based on preliminary calculations and optimization of the geometric parameters of the wing using CAE, a decision was made to use the swept wing of great aspect ratio with an automatic multi-section slat and a multi-slotted two-section flap with a load on the wing up to 550 daN / m^2. Optimization was carried out by aerodynamic parameters in cruising mode, provided that the specified take-off and landing characteristics were provided, taking into account the use of high lift devices. The variation parameters were the relative thickness of the wing profile, the peak load on the wing, the wing aspect ratio, and the type of wing tip. The pedicted value of the aerodynamic quality for the cruising mode is 19.4. Further works to improve the aerodynamic perfection of the aircraft will be carried out with a more thorough study of the aerodynamic layout by selecting the optimal aerodynamic and geometric wing twist, as well as in the process of clarifying the mutual influence of different units of the aircraft design.

On the basis of the obtained values of the specific load on the wing and take-off weight, the geometric parameters of the aircraft are determined.

Wing area $S = \dfrac{m_{0\min} g}{10 \cdot p_{opt}}$ = 87.3 m^2.

Wing span $l = \sqrt{\lambda_{opt} S}$ = 28.9 m.

Root chord is $b_0 = \dfrac{2S}{l} \dfrac{\eta}{\eta + 1}$ = 4.83 m (for this type of aircraft η = 4).

Tip section $b_k = \dfrac{b_0}{\eta} = 1.2$ m.

Coordinate of the leading edge of the wing tip chord relative to the leading edge of the root chord $x_{rcle} = \dfrac{l}{2} tg\chi_{le}$ = 13.5 m, where $\chi_{le} \approx 25°$ – wing sweep along the leading edge.

The mean aerodynamic chord of the wing is $b_a = \dfrac{2 \cdot \left(1 + \eta + \eta^2\right) b_0}{3\eta(1 + \eta)}$ = 3.4 m.

Horizontal stabilizer area is $S_{HT} = \bar{S}_{HT} S = 17.95$ m^2, where $\bar{S}_{HT} \approx 0.21$.

Horizontal tail span $l_{HT} = \sqrt{\lambda_{HT} S_{HT}}$ = 9.346 m, where $\lambda_{HT} \approx 5$.

Vertical tail area $S_{VT} = \bar{S}_{VT} S = 19.91$ m^2, where $\bar{S}_{HT} \approx 0.2$.

Fuselage length $l_f = \lambda_f d_f =$ 26.2 m, where $\lambda_f \approx 7{,}8$, $d_f \approx 3.35$ m.

The location of the wing and tail along the length of the fuselage is determined by the horizontal and vertical tail length which in the first approximation are selected based on the value of the static moment coefficient of the horizontal tail area: $L_{HT} = \frac{A_{HT} b_a}{\bar{S}_{HT}} = 20.3$ m. For this class of aircraft $A_{HT} \approx 1$.

For a high-wing aircraft, the landing gear height is determined by the minimum distance from the lower point of the fuselage to the surface of the runway. At the same time, the height H must provide a tail clearance $\varphi \approx 10°$ and a main strut tip-back angle $\gamma = \varphi + 3°$.

The obtained geometric and mass characteristics of the aircraft coincide with the characteristics of the ANTONOV Company An-148 series aircraft.

According to the obtained geometric parameters, a general view drawing has been developed (Fig. 2.19).

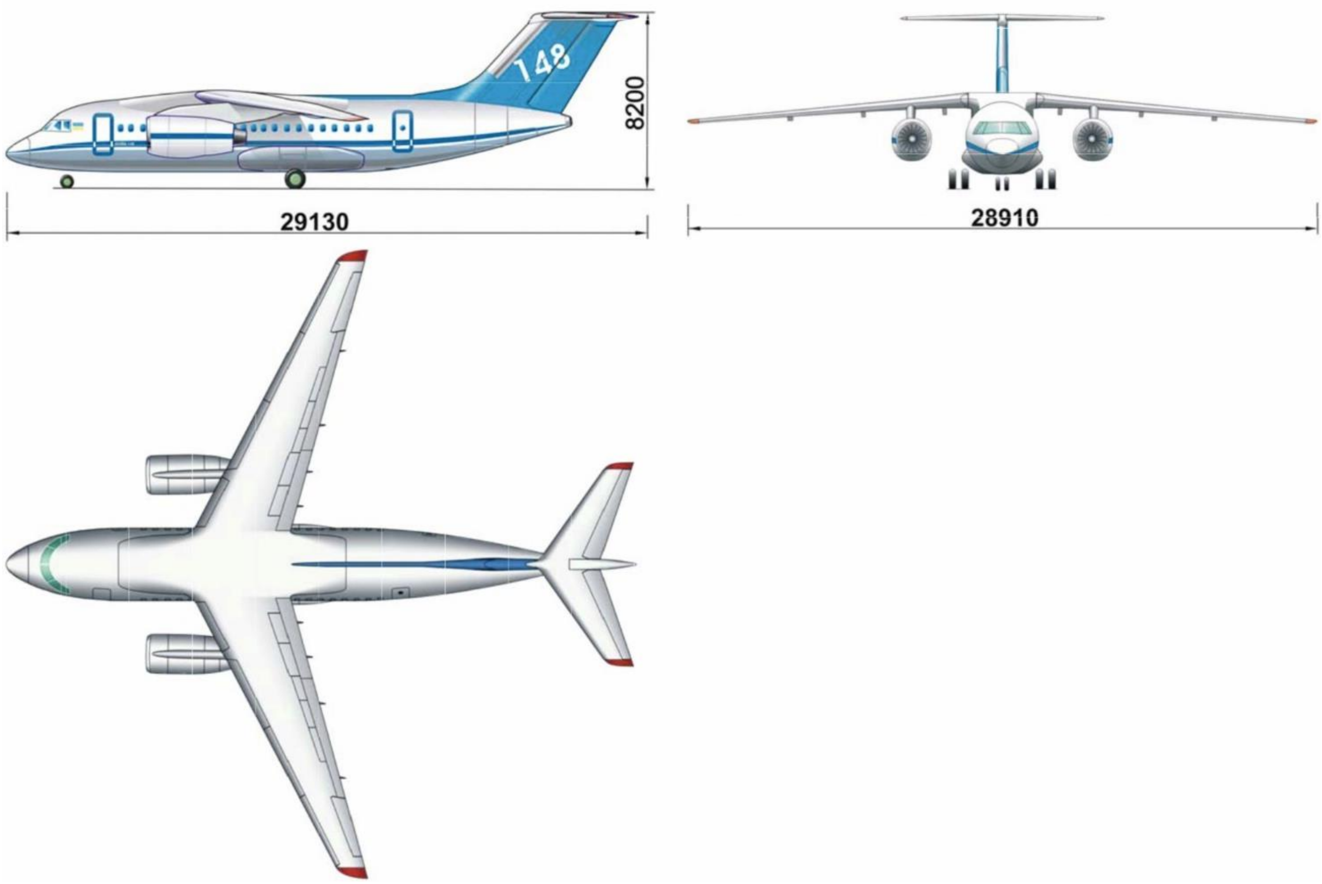


Fig. 2.19. Aircraft General View

Parametric modeling of the aircraft was performed using the Siemens NX system. Models of individual components and assemblies of the aircraft were created, after which they were mutually linked. As a result, the parametric master geometry of the designed aircraft is obtained (Fig. 2.20), with which all the structural elements inside the aircraft are associated, resulting in the creation of a model for the distribution of the aircraft's space.

Since this aircraft, similar to the ANTONOV Company An-148 and An-74 series, is designed according to the "high-wing" scheme, in which the engines are located much higher above the runway surface than the engines of analogues (for example, those made according to the "low-wing" scheme: ERJ 170/175), this means that the engines are much better protected from foreign objects, dirt and dust from the runway surface (Fig. 2.21).

Thus, the probability of early removal of the engine for repair is much lower than that of the ERJ 170/175. Therefore, unlike competitors, the aircraft can operate on dirt and weed runways and is the only one of the short-haul analogues that is certified for take-off and landing from unpaved runways.

Thus, the high-wing scheme of the aircraft, in which the engine is lifted from the runway by 1.65 m, ensures safe operation of the aircraft on a wide network of poorly prepared airfields in the CIS countries, as well as in any other regions of the world.

Fig. 2.20. Parametric Model of Aircraft Master Geometry

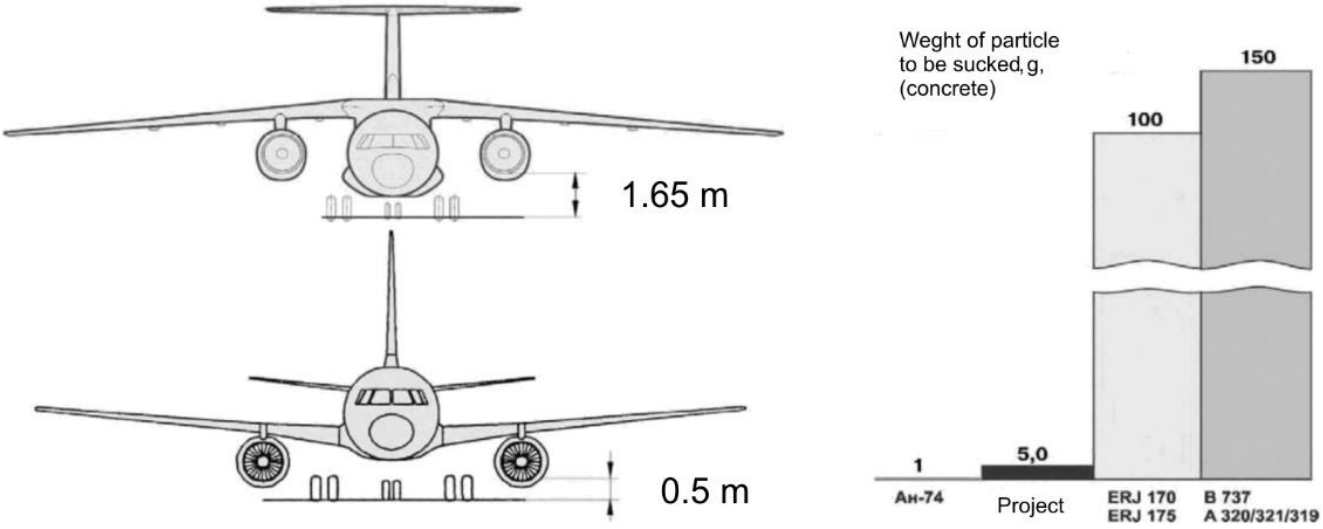


Fig. 2.21. Advantages of the "High-Wing" Scheme

In addition, the "high-wing" scheme made it possible to reduce the height of the passenger cabin floor above the ground and use the entrance door, which is always available on the plane, and in the open position turn into convenient stairs for passengers. This technical solution significantly increased the autonomy of the aircraft, accelerated and reduced the cost of its operation (after all, at airports, bringing up the stairs to the aircraft is a separately paid service).

When developing the cabin layout, comfort is provided at the level of modern world standards for economy class cabins with the maximum possible control over the comfort of business class and the possibility of re-equipment and production of aircraft with business class and luxury class cabins. The standard layout of the passenger cabin is designed for 75 passengers with the placement of passenger seats according to the "3+2" scheme. Chairs are placed with a pitch of 790 mm, chair width – 418 mm, width of armrests is 53 mm, the minimum aisle width – 384 mm, the maximum is 508 mm, the average height – 1820 mm.

The layout of the aircraft seats is similar to the ANTONOV aircraft of the An-148 series according to the scheme "3+2" in a row (competitors have "2 + 2" in a row), which allowed to reduce the lengthening of its passenger cabin. Taking into account the comfort of passengers, the "3+2" seat layout is better than the "2+2" Seat layout used on regional Embraer and Bombardier aircraft. Due to the greater width and shorter length of the cabin, the An-148-100 passenger cabin has a more voluminous appearance, which brings it closer to the cabins of medium-haul aircraft. More elongation of the passenger cabins of competitors ERJ 170/175 and CRJ 700/705 creates the effect of a "pipe" or "tunnel", which negatively affects the subconscious assessment and feeling of the comfort of the cabin as a whole. For a number of CRJ 700/705 aircraft, this effect is particularly pronounced due to the strong embossing of the fuselage cross-section, the lower aisle height (1.890 mm vs. 2.000 mm) and the width of the aisle (406 mm vs. 480 mm). The length of the passenger cabin, which is smaller than that of competitors, makes it possible to solve the problem of emergency evacuation of passengers only with the help of front and rear doors and hatches – without organizing special emergency hatches in the middle of the fuselage. This reduced the weight and simplified the design of the aircraft. The entrance door of 1800 and 1070 mm is located on the left side in front of the cabin, on the right side – the service door of 1651 and 533 mm, which is used in emergency as a type II emergency exit.

The layout of the cabin is shown in Fig. 2.22.

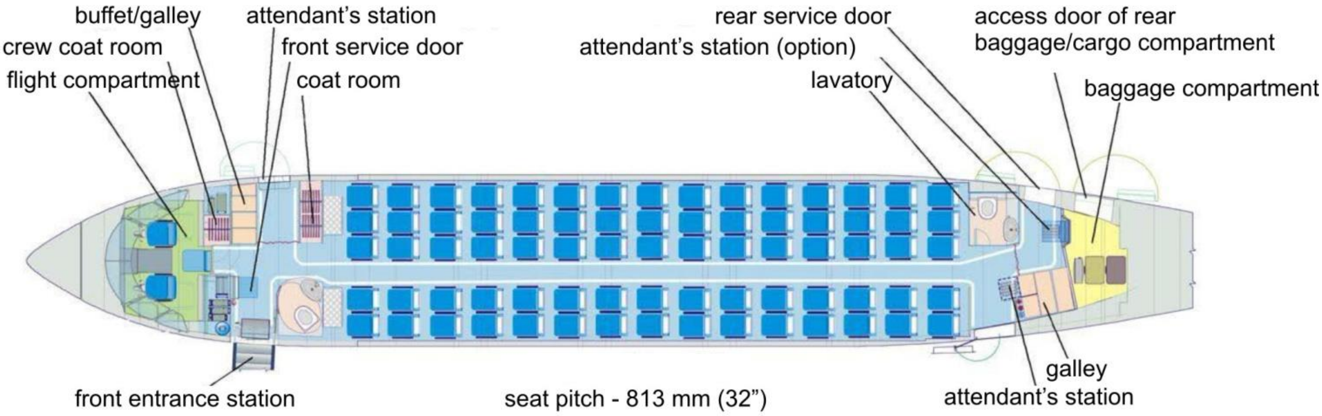


Fig. 2.22. Layout of the Aircraft Cabin for 75 Passengers

In addition, the large width of the passenger compartment allows you to organize the most voluminous luggage shelves in this class of aircraft. The transverse dimensions of the shelves are 250×665 mm / 250×560 mm, while the CRJ 700/705 aircraft have 200×380 mm, and the ERJ 170/175 aircraft have 250×400 mm.

A comparison of the side-by-side sections of the fuselages of the An-148-100 and its analogues is shown in Fig. 2.23.

The actual flight time of the aircraft is 300 flight hours per month (3600 flight hours per year), which is 44 % higher than the average global flight time of regional aircraft, which is 3 000 flight hours per year. The high level of aircraft flight provides a reduction in direct operational costs (DOC) by 1 seat-kilometer, along with an increase in operating income from passenger transportation.

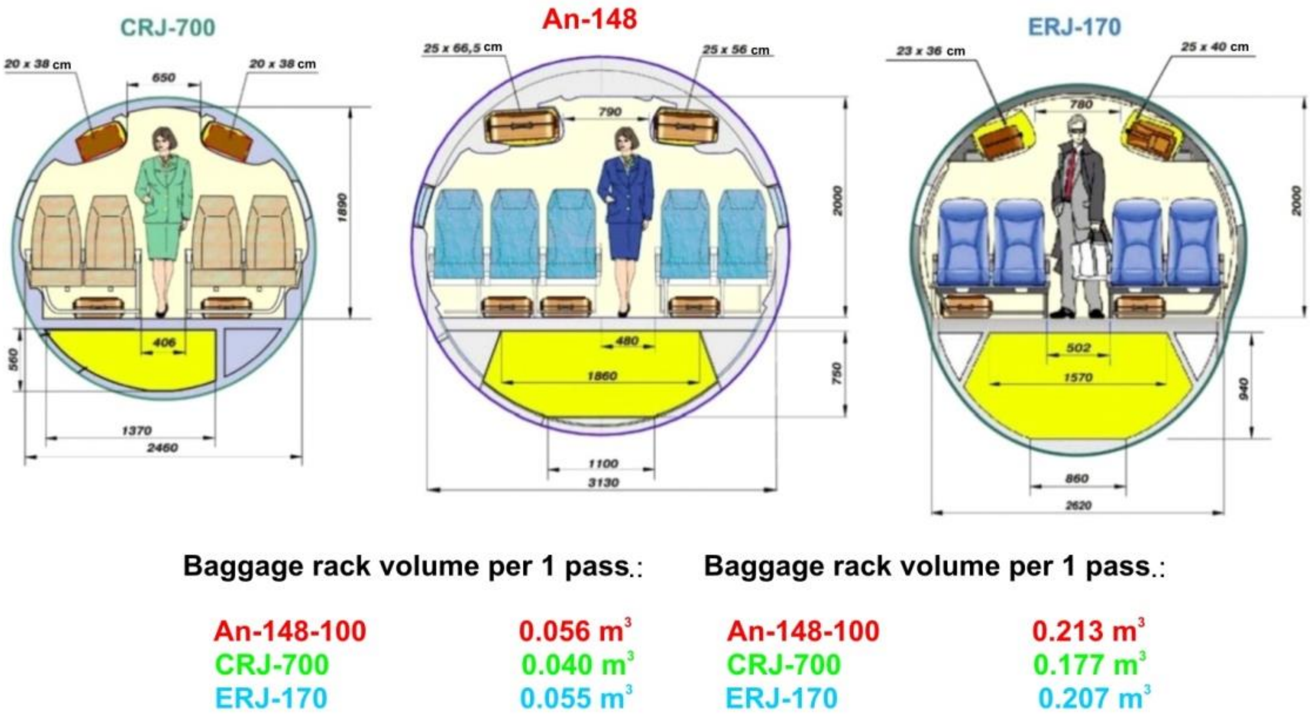


Fig. 2.23. Comparison of Side-by-Side Sections of the Fuselage of An-148-100 and its Analogues

The cockpit (Fig. 2.24) is designed to meet modern ergonomics requirements for crew placement. The on-board equipment is a digital flight and navigation system with information and analytical support for the introduction of geo-information and GPS / GLONASS technologies.

The aircraft's on-board electronic equipment complex consists of a short-range and long-range navigation system, onboard avionics that integrates the main aircraft systems, radio communication systems, radar for detecting thunderstorms, atmospheric turbulence and performing survey functions, and a passenger entertainment system.

The precision characteristics of the flight and navigation system meet international requirements (RNP, RVSM, BRNAV and PRNAV).

The onboard equipment includes equipment that provides such operating conditions:

– Performance of flight visually and by instruments;

– Ensuring flight day and night, in simple and difficult weather conditions, at any

time of the year;
– Provision of flights in the area of the airfield, on routes within the state and in international air routes and lines at a 5-minute interval and with a vertical distance of 300 m, over a non-stationary and low-speed water-supplied ground surface and over the water area when flying on tracks.

Fig. 2.24. Cockpit of the Aircraft

The landing of the aircraft must be provided according to the ICAO category III, the height of the decision – making is 30 m.

According to physical and geographical conditions, the flight must be performed over flat, hilly and mountainous terrain in the range of geodetic latitudes from 70° North to 55° South, 180° longitude.

On-board equipment must consist of the following basic elements:
– LCR-93-system for determining the course and position of the aircraft (course-vertical);
– КИ-13 (KI-13) – combined compass;

– АГБ-96 (AGB-96) – attitude indicator;
– ИК ВСП (FEDS) – information complex of altitude and speed parameters;
– РСБН-85 (SHORAN-85) – short-range navigation radio system;
– DME/p-85 – aircraft rangefinder (2 sets);
– КУРС 93М (COURSE 93M) – VOR/ILS navigation system;
– ВСС-100 (NCS-100) – aircraft navigation computer system;
– САУ (AFCS) – automatic flight control system;
– БВУ (CDB) – block of the AFCS computing device;
– ТСАС-2000 (TCAS-2000) – air collision avoidance system;
– АРК-25 (ARK-25) – automatic radio compass;
– СО-96 (AT-96) – range aircraft transponder;
– Р-855А (R-855A) – communication radio station.

The main devices that display flight and navigation information, as well as data on the main aircraft systems and power plants, are the AMLCD (active matrix liquid crystal display) – the main flight display (indicator) (PFD) and the multifunction display (MFD). If any indicator fails, it is possible to redistribute the displayed information between the other indicators.

The complex is provided with multi-functional control panels for effective interaction between pilots and the aircraft in order to ensure all flight modes and uninterrupted control of equipment in flight.

It is advisable to consider the issue of aircraft CG position.

The calculation of the aircraft's CG position was carried out in a certain sequence.

The position of the centers of mass of all parts of the aircraft, units and cargo is determined by the layout drawing. When filling out the weight report (Table 2.3), the weights and positions of all units, equipment, and commercial and service loads are taken into account.

Information on CG position is compiled for the following cases:

1) Empty aircraft, m_e = 21 t;

2) Take-off, landing gear extended, maximum commercial load, m_0 = 40 t;

3) Climb, landing gear retracted, flight to the maximum range, m_0 = 40 t;

4) Landing, landing gear extended, passengers in the cabin front section,

m_0 = 33 t;

5) Descending, landing gear retracted, passengers in the cabin rear section, m_0 = 33 t.

Coordinates of the center of mass of the aircraft are defined as $x_{cm} = \frac{\sum m_i \cdot x_i}{\sum m_i}$.

Aircraft CG position is calculated using the formula $x = \frac{x_{cm} - x'_a}{b_a}$,

where x'_a = 10 585 mm – coordinate of the MAC nose relative to the fuselage nose; b_a = 3 401 mm – the mean aerodynamic chord. Vertical position of the center of mass y_{cm} is determined in the same way.

We compile weight report for all units. Table 2.3 shows the mass values and coordinates for the take-off configuration. In other configurations, the position of the center of mass of the landing gear and the fuel mass change accordingly in compliance with the layout. Let's consider the most typical cases of loading an aircraft. The results of the calculations are shown in Table 2.4.

The results of the CG position calculations are shown in Fig. 2.25 as an operational CG diagram.

Based on the data obtained, we will make a preliminary conclusion about the static stability and controllability of the aircraft. The stability condition of the aircraft is as follows:

$$\bar{x}_F - \bar{x}_{a.CG.l} = 0.04 – 0.06,$$

where $\bar{x}_{a.CG.l}$ – the maximum aft CG limit.

For the designed aircraft, the stability parameters are:

– AC position – 0.4625;

– Aft CG limit – 0.41.

The aircraft is statically stable and such that it is guided in the considered range aircraft loading cases. The difference in the relative coordinates of the aerodynamic centre and aft CG limit is 0.0525.

Table 2.3

Weight report

Name	m_i, kg	x_i, m	$m_i \cdot x_i$, kg·m	y_i, m	$m_i y_i$, kg·m
Airframe design					
Wing structure	3942	11.986	47248.81	4.031	15890
Fuselage	4106.25	12.5	51328.13	2.333	9580
Horizontal tail	592.32	14.683	8697.035	8.079	4785
Vertical tail	623.13	11.817	7363.527	5.618	3501
Empennage	1215.45		16060.56		8286
Landing gear	1543.95		15744.28		446
Nose strut	308.79	2.435	751.9037	0.395	122
Main struts	1235.16	12.138	14992.37	0.262	324
Powerplant	3849.14	8.062	31031.77	2.533	9750
Auxiliary power plant	80	25.897	2071.76	3.12	250
Airframe	14736.79		163485.3		34202
Equipment					
Radar facilities	500	1,4	700	1.862	931
Radio facilities	300.44	3.78	1135.663	1.872	562
Electrical equipment	553	3.9	2156.7	1.493	826
Electronic devices	296	3.2	947.2	1.603	474
Navigation equipment	356	3.2	1139.2	2.235	796
Crew cabin	334	2.1	701.4	3.03	1012
General equipment	550	15.6	8580	2.364	1300
Passenger cabin equipment	2340	13.6	31824	2.35	5499
Total equipment mass	5229.44		47184.16		11400
An empty plane without crew, fuel, payload, sum	19966.23		210669.5		55602
				1.862	931
				1.872	562
				1.493	826
Fuel					
Left panel	2461.63	12.195	30019.58	4.12	10142
Right panel	2461.63	12.195	30019.58	4.12	10142
Centre wing section	955.43	10.156	9703.347	4.35	4156
Fuel mass	6188.094		73515.68	4.1	25371

Table 2.3 (End)

Name	m_i, kg	x_i, m	$m_i \cdot x_i$, kg·m	y_i, m	$m_i y_i$, kg·m
Payload and crew	8900	13.434	119562.6	2.35	20915
Take-off mass, landing gear extended	35054		403747.7		122172
Coordinate of CM	x_{cm}, m	11.518	y_{cm}, m	3.485	
CG location	$\bar{x}_{cm}$	0.274	$\bar{y}_{cm}$	–0.181	

Table 2.4

Typical Airplane Loading Cases

No.	Payload, pass.	Landing gear	Fuel	$x_{c.m}$, mm	$\bar{x}_{c.m}$	$y_{c.m}$, mm	$\bar{y}_{c.m}$
1	No passengers	down	Not available	10 551	0,31	3.485	–0.2058
2	73	down	100 %	11 517	0.41	3.435	–0.1925
3	99	up	100 %	11 511	0.25	3.455	–0.1476
4	85	up	10 %	11 440	0.22	3.65	–0.1471
5	90	down	10 %	11 448	0.4	3.59	–0.15

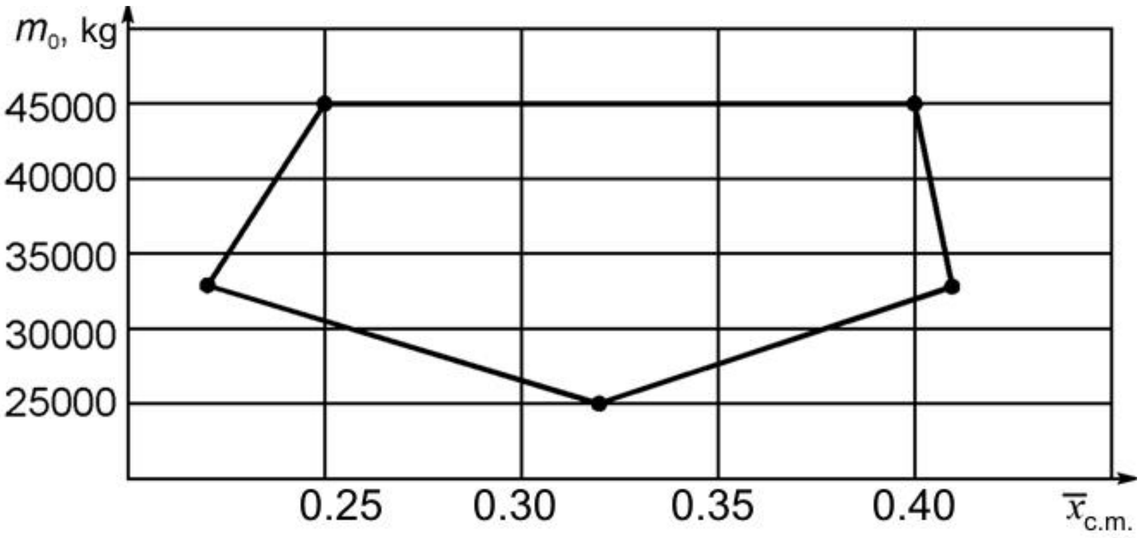


Fig. 2.25. CG Range

Parametric modeling of the aircraft has been performed using the Siemens NX system. Mathematical models and airplane master-geometries units are developed and created and their mutual location has been carried out. As a result, we obtained the parametric master-geometry of the designed aircraft (see Fig. 2.20), with which all structural elements are associated.

A model for the space distribution of the aircraft and its units has been developed. Fig. 2.26 shows a fragment of the model of the space distribution of an airplane wing.

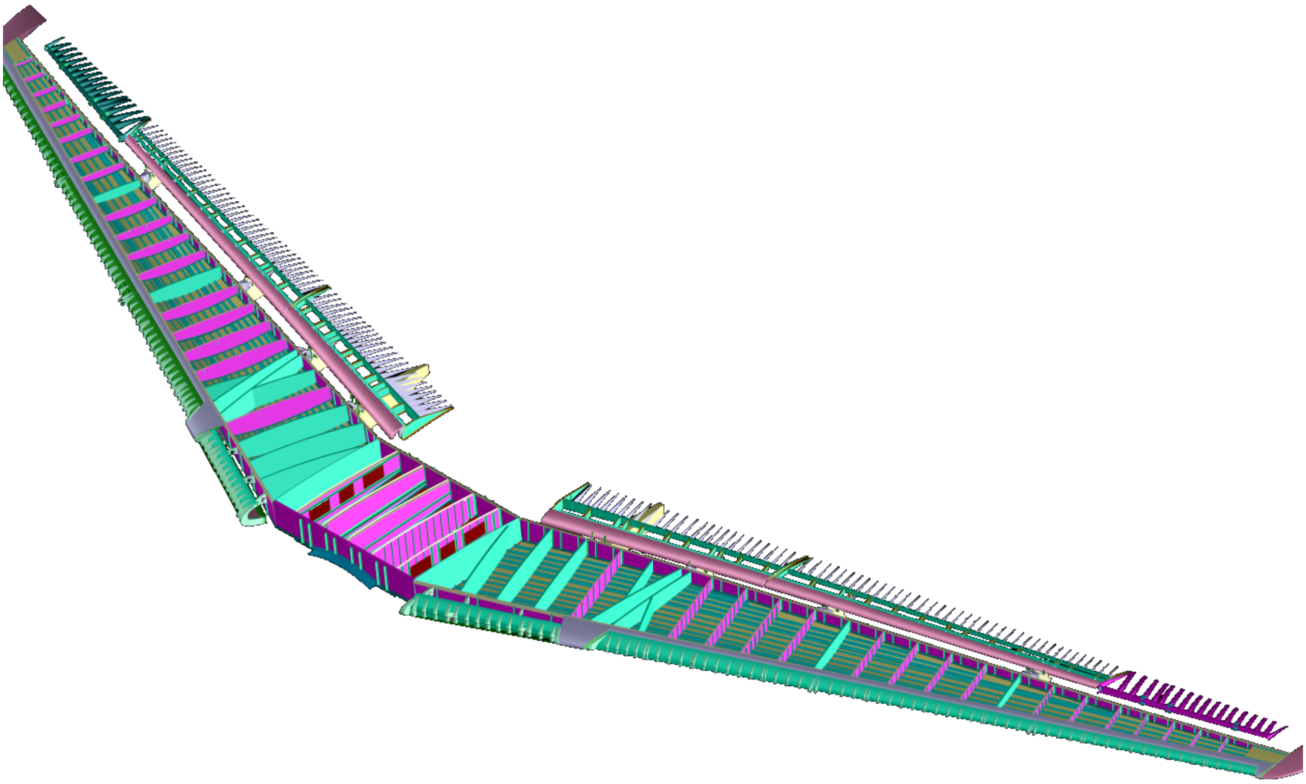


Fig. 2.26. Model Fragment of the Aircraft Wing Space Distribution

Thus, the implementation of the principle of creating the aircraft appearance master-geometry has been demonstrated.

The implementation of the proposed principle of aircraft units design allows, in addition to a three-dimensional computer model of the aircraft master-geometry being designed, to develop models for the space distribution. To create an aircraft space distribution model, it is necessary to solve the following tasks: to develop design and technology structuring; paneling; determine the number and location of the elements of the structural load-bearing set; to solve the issue of the list and placement of equipment, facilities; system layouts; crew cabin and passenger compartment layout for a different passengers number and the cabin comfort. In addition, the layout and range calculations of aircraft central mass position as a whole are performed [76].

The next step is the creation of analytical standards for the primary structural member based on a number of design and verification calculations of regular zones and structural irregularities zones. They are created by methods of analytical geometry using integrated CAD\CAM\CAE\PLM systems in a single information environment for supporting the aircraft life cycle. Figs 2.27 and 2.28 show the analytical standards of the wing center section upper hatch panel and the ribs of the outboard wing.

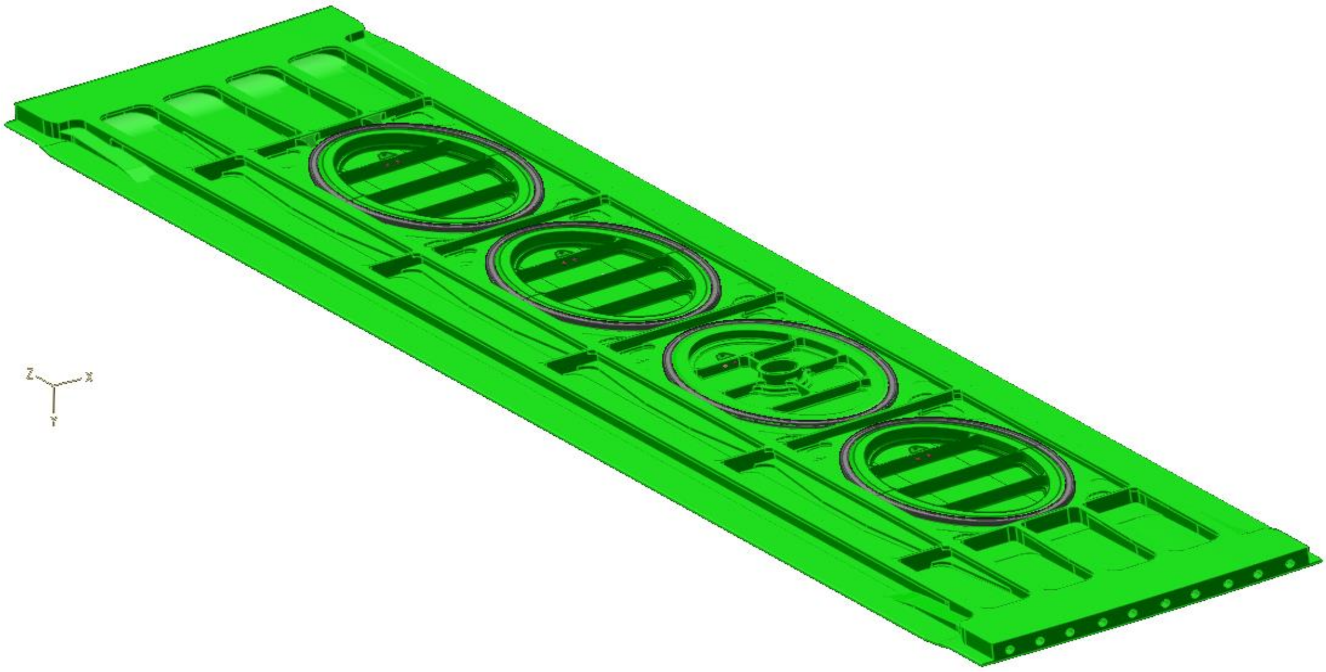


Fig. 2.27. Analytical Standard of the Upper Hatch Panel
of the Wing Center Section

After determining the connection parameter in the regular and irregular zones of the structure based on the parametric models of the space distribution and analytical standards of parts and composite aircraft assemblies, parametric models of the complete definition of units and the aircraft as a whole have been created. Fig. 2.29 shows a complete definition of a tail unit model and Fig. 2.30 shows a model fragment for the complete definition of a regional passenger aircraft.

Thus, the application of the proposed concepts and principles of design and use of CAD\CAM\CAE\PLM systems in a single information space can significantly increase the efficiency of designing the aircraft as a whole and its units.

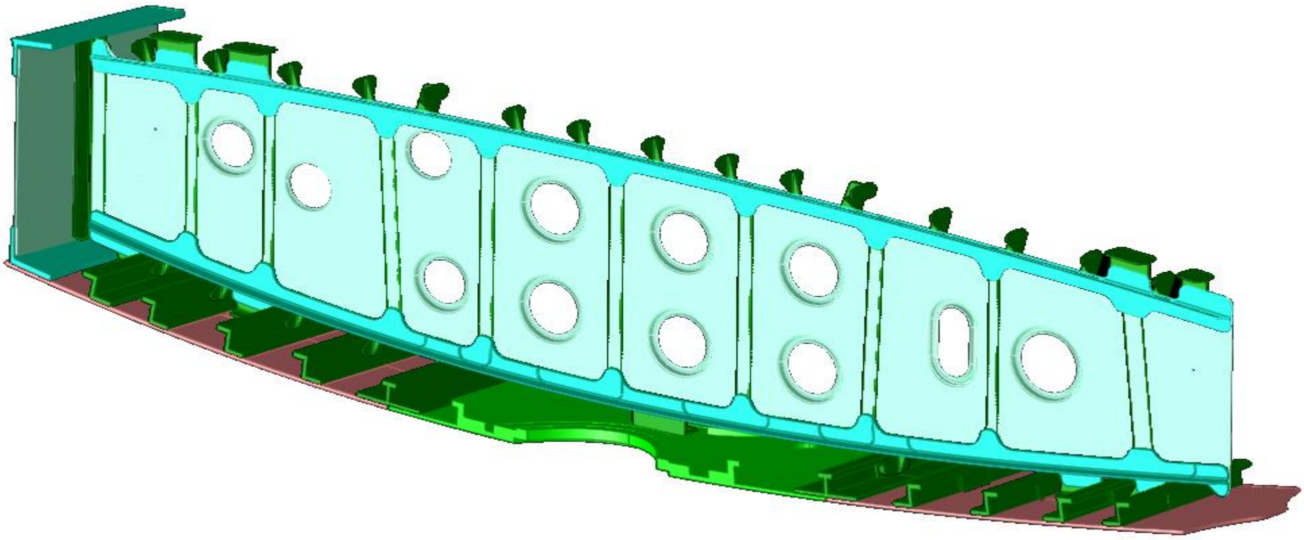


Fig. 2.28. Analytical Sample of a Standard Rib of Outboard Wing

Fig. 2.29. Model of Complete Definition of Airplane Tail Unit

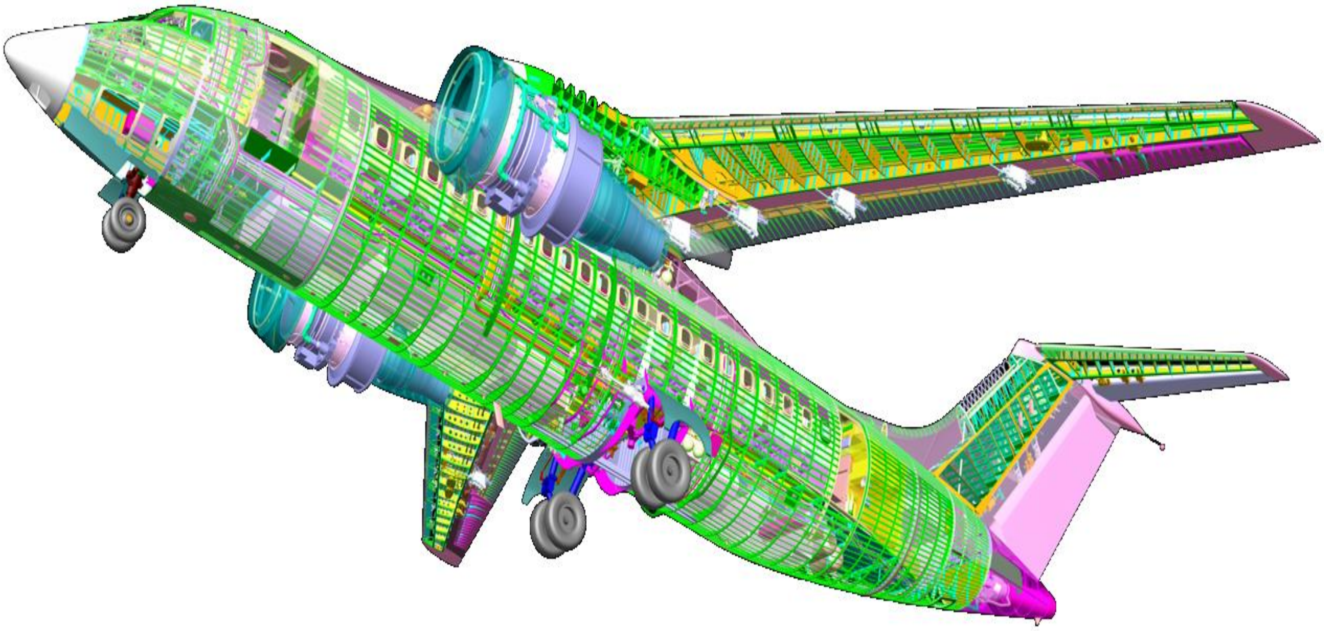


Fig. 2.30. Fragment of the Model of the Aircraft Complete Definition

Summary

The concept and principles of integrated design of competitive regional passenger airplanes intended for the transportation of passengers, baggage, mail and cargo on domestic and international airlines with the possibility of operation at artificial aerodromes and prepared unpaved runways have been proposed. It is planned that the aircraft will be able to replace the previous generation aircraft in the fleet of regional passenger aircraft of the airlines in different countries. The relevance of work on this topic is confirmed by the needs of the modern air transportation market and the need to create competitive equipment.

Integrated aircraft design is based on the use of analytical techniques in calculations with the capabilities of integrated computer systems CAD\CAM\CAE. Their mutual relationship and interdependence is shown. The contributions of creating the master geometry of the aircraft, a model for the distribution of its space, and analytical standards are presented.

Features of the concept and design principles of regional passenger airplanes have been tested using the parameters of the ANTONOV Company aircraft of the An-148 series.

When performing the above calculations, the influence of appearance parameters on the performances of the designed aircraft has been demonstrated.

The design method was tested using the parameters of the ANTONOV Company aircraft of the the An-148 series. It is proposed a comparison of the calculation results by the method with the parameters of existing aircraft of the An-148 series that indicates the correctness of the developed method and calculation results.

The aircraft is characterized by a modern aerodynamic configuration, using economical engines. Modern flight and navigation equipment and radio communication equipment, the use of multi-functional indicators, an electro-remote flight control system allow it to be used on any airways, in simple and difficult weather conditions, day and night, as well as on routes with a high flight intensity with a high level of crew comfort.

Passenger comfort is ensured at the level of average comfort on long-range aircraft and is achieved by rational layout and composition of service rooms, deep ergonomic optimization of the overall and individual space of the passenger cabin. The aircraft fully complies with the airworthiness standards of the AP-25.

Compared with the Tu-134, the aircraft has:

– A higher level of passenger comfort (75 seats are located with a row spacing of 812 mm versus 76 seats with a row spacing of 750 mm);
– Almost 1.8 times longer maximum flight range (4240 km versus 2400 km) with almost the same passenger capacity;
– Significantly shorter runway length required (1950 m versus 2500 m);
– 1.55 times lower fuel consumption for 1 h (1650 kg/h against 2550 kg/h).

The high technical level inherent in the design of the aircraft, in particular its aerodynamic and mass perfection, made it possible to design the wing, area which is 1.46 times smaller than the wing area of the Tu-134. This, as well as the layout with engines placed on pylons under the wing, and not in the rear of the fuselage, allows to minimize the overall dimensions of the aircraft, reduced by 27% the required parking area compared to the Tu-134. The maximum take-off weight of the aircraft was reduced by 8 % in comparison with the Tu-134.

The main advantages of the aircraft in comparison with analogues that are currently operating on the world market (ERJ 170LR, ERJ 175LR, CRJ 700LR, CRJ 705ER):

– The possibility of operation at aerodromes from austere site;

– Autonomy of operation (the presence of entrance stairs);
– High engine protection from damage by foreign objects;
– High level of comfort for passengers (at the level of long-haul aircraft);
– Large luggage racks (at the level of long-haul aircraft);
– Low price compared to ERJ170/175 and CRJ700/705;
– Low direct operating costs compared to ERJ170/175 and CRJ700/705;
– High operational efficiency in comparison with ERJ170/175 and CRJ700/705.

The results of the calculations indicate that all the main specifications of the aircraft are better than those of the aircraft-analogues of the Embraer and Bombardier firms. In addition, the aircraft has many advantages, such as the ability to operate on austere site and unpaved runways, the presence of entrance stairs, high engine protection against damage from foreign objects, a high level of passenger comfort and large luggage racks, and high operational efficiency.

These advantages provide a high level of competitiveness of the aircraft in the global market.

2.2 CONCEPT FOR CREATING POWER PLANT SERIES OF REGIONAL PASSENGER AIRCRAFT

The development and creation of a series of regional jet passenger airplanes with specified tactical and technical requirements that ensure the technical level of their excellence, which exceeds the level of domestic and foreign class analogue aircraft, is provided on the basis of the development of new concepts, which include the concept of creating a power plant [62]. It consists of the development and creation of a power plant with bypass engines with a high bypass ratio in accordance with the requirements of section E of the Airworthiness Standards of Transport Category Aircraft (AP-25 [79]), which provide specific fuel consumption at maximum cruising mode of up to 61.61 kg/kN·h.

2.2.1 Description of Power Plant Systems

The power plant (PP) of the An-148-100/An-158 aircraft (Fig. 2.31) consists of two cruising gas turbine engines Д-436-148 (D-436-148) (Fig. 2.32) of the high bypass level developed by the Ivchenko-Progress State Enterprise and manufactured by the

Joint Stock Company Motor Sich, an auxiliary power unit (APU) with an АИ-450-МС (AI-450-MS) engine (Fig. 2.33), as well as systems that ensure the operation of these engines (control and monitor systems, fuel supply systems, lubrication and venting systems, starting systems).

Fig. 2.31. Modern Regional Passenger Aircraft An-148 and An-158

The three-shaft turbojet Д-436-148 (D-436-148) bypass engine (see Fig. 2.32) consists of a fifteen-stage compressor, an intermediate casing, an annular combustion chamber, a five-stage turbine, a reversing device in an external (fan) casing, and dividing unregulated output nozzles of the external and internal ducts.

The engine compressor is axial, three-stage. It consists of a fan, a subsonic booster assembly of a fan, a low-pressure transonic compressor (LPC) and a high-pressure subsonic compressor (HPC). LPC and HPC have air bleed valves.

The combustion chamber is equipped with an annular type flame tube, with eighteen single-channel fuel nozzles (four of them are air nozzles). Two flare-type lighters with spark plugs are installed on the body of the combustion chamber.

Fig. 2.32. High Bypass Ratio Д-436-148 (D-436-148) Engine

Fig. 2.33. Gas Turbine Engine АИ-450-МС (AI-450-MS)

The turbine is jet, three-stage, it consists of a single-stage high-pressure turbine (HPT), a single-stage low-pressure turbine (LPT) and a three-stage fan turbine (FT). Each of the turbines rotates the corresponding compressor rotor.

The rotors of the fan, LPC and HPC are interconnected only gas-dynamically and have different optimum speeds.

Reversing device (RP) is of a lattice type, annular, with a fixed lattice and twelve shutters, which block the external duct of the engine during the reversal of the channel.

Sensors and indicators are installed on the engine to measure the current values of the operating parameters of the engines and their systems, as well as to give signals about the normal operation of the engines and their systems or about deviations that have occurred in the operation.

On each engine, a hydraulic pump НП-148 (NP-148) (the main source of pressure of the hydraulic complex), a drive-generator ГП-21 (GP-21) (the main power source of 200/115 V) are installed. For the needs of aircraft systems, constant air bleed from the engine is provided in all operating conditions.

Starting system is air, automatic; it consists of electronic, air and fuel systems.

Automatic switching on and off according to the set cyclogram of all units involved in the start-up process is carried out according to the commands of the СУ-148 (SU-148) automatic flight control system (AFCS) of propulsion system control.

Engine start air is bled from the onboard auxiliary power unit (APU), airfield source or from a previously started engine. The air starter СВ-36-1 (SV-36-1) rotates the high-pressure rotor.

Engine management and control are provided by the СУ-148 (SU-148) AFCS in manual and automatic modes.

Information on the control of each engine is transmitted by the electronic control and monitor unit БУК-148 (BUK-148) via regional communication lines to the aircraft systems.

The ИПСУ-148 (IPSU-148) engine parameter control indicator is installed on board, which displays information about the main engine parameters.

The engine, assemblies and units are accessed via hinged bonnet covers and operating hatches of the nacelle and the pylon. Maintenance of units and assemblies located in the upper compartments of the nacelle and in the pylon is carried out from the stairs. The units and assemblies located below the engine are serviced from the ground.

The engine is attached to the load-carrying frame of the pylon by the front and rear suspension assemblies mounted on the engine (Fig. 2.34).

The design of the engine suspension provides duplication elements of the front and rear of the engine mount.

When replacing the engine, the engine is removed from the pylon together with the removable part of the nacelle and assemblies mounted on it.

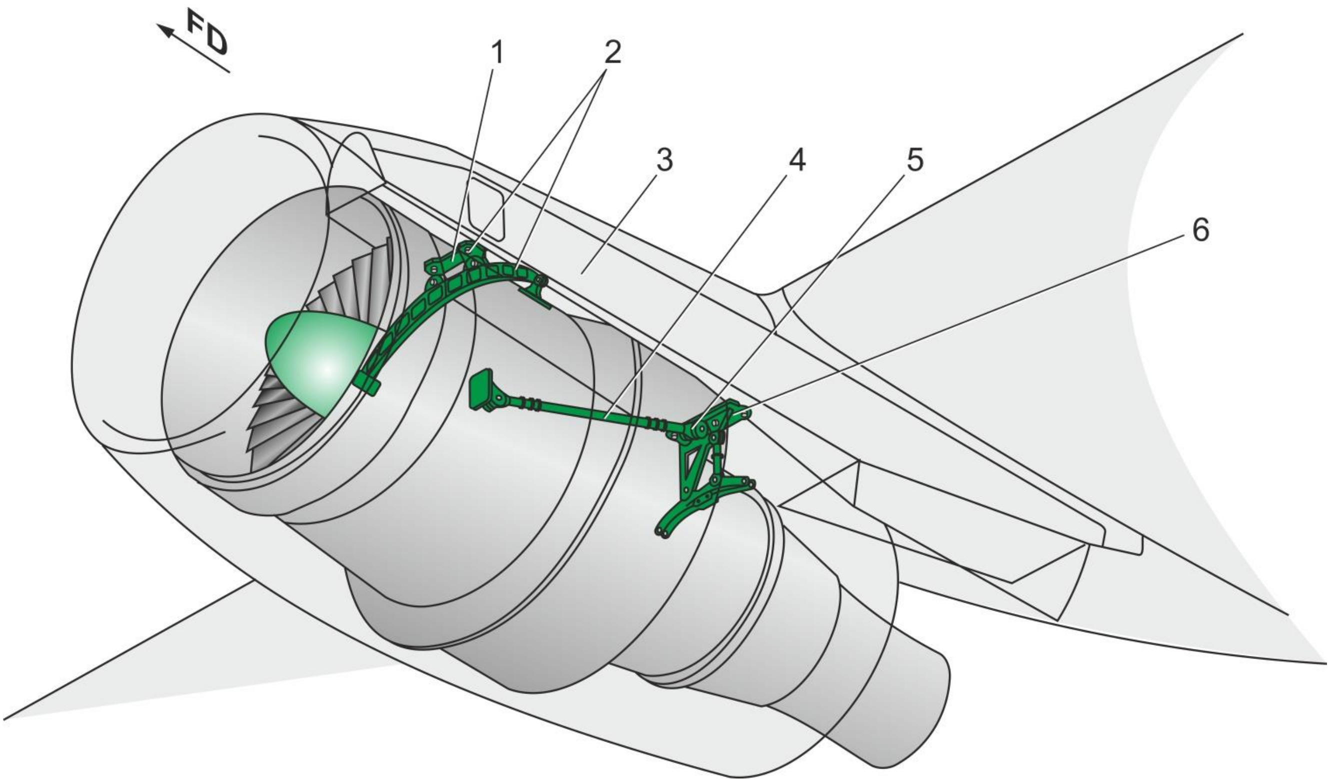


Fig. 2.34. Engine Mount Diagram: 1 – the front suspension (part of the aircraft structure); 2 – bracket; 3 – engine motor pylon; 4 – a rod of engine thrust reduction; 5 – rear suspension (part of the engine structure); 6 – bracket

The main advantages of the engine:

– Low specific fuel consumption and low specific gravity;
– High reliability due to years of the Д-36 (D-36) engine operation experience of the same class;
– Low noise and emission levels;
– Simplicity of service and high efficiency of the control and diagnostics;

– The presence of universal suspension, which allows unchanged engine design application of it on different planes, placing the engine under or over the wing, in the aircraft fuselage or on both sides;
– Low operating costs during long service life.

The experience gained during the development of An-140 and An-70 aircraft, the analysis of foreign aircraft (Airbus, Boeing, Gulfstream, etc.) power plants, as well as the close cooperation with the National Aerospace University "Kharkiv Aviation Institute", National Aviation University and Ufa State Aviation Technical University allowed to create a power plant that has a number of advantages and allows efficient operation of An-148-100/An-158 aircraft.

The power plant allows the operation of An-148-100/An-158 aircraft at high altitude aerodromes – up to a base altitude of 4 100 m.

2.2.2 An-148/An-158 Aircraft Engine Nacelle

The Engine Propulsion System (EPS) is designed to form the gas-air path, protect the engine and the systems installed on it from atmospheric precipitation, aerodynamically flowing about the EPS, and to provide noise reduction on the ground and fire resistance of the engine installation.

The An-148-100 / An-158 aircraft engine nacelle with the Д-436-148 (D-436-148) engine consists (see Fig. 2.35) of the air intake, fan cowling, reverse fairing, fan nozzle and gas generator hood.

During the design of the engine nacelle, a number of scientific and technical works were carried out to reduce the noise level on the ground according to the standards of Section 4 of the ICAO standard. In the course of these works, two-layer (air intake) and single-layer (fan nozzle, gas generator hood) sound-absorbing structures (SAS) of acoustic filler were considered. The evaluation of the acoustic efficiency of the SAS confirmed compliance with the standards of Section 4 of the ICAO standard, and the greatest reduction of aircraft noise was detected during the take-off mode of the engine.

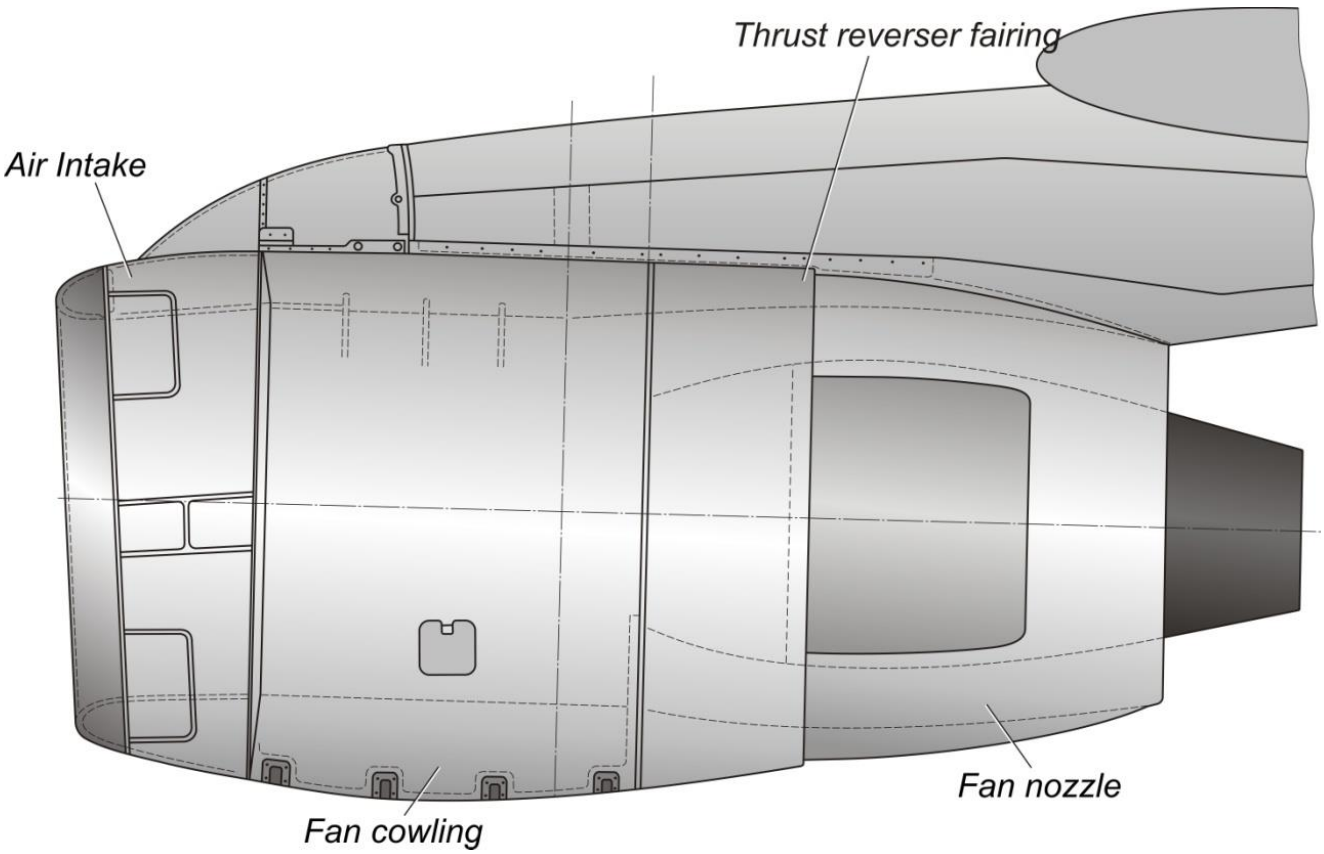


Fig. 2.35. Diagram of Engine Nacelle

The results of the work carried out are reflected in the scientific and technical report of ФГУП ЦАГИ (FGUP TSaGI) "Development of systems of noise suppression for power plants of the An-74TK-300 aircraft with engines Д-36 (D-36) of series 4A and An-148 with engines Д-436-148 (D-436-148), providing noise reduction on terrain up to the norms of Chapter 4 of the ICAO Standard".

Composite materials (CM), reinforced with a metal mesh, were used in the design of the fan hood, the reverse cowl and the gas generator hood to ensure the fire resistance of the motor gondola.

In order to confirm the conformity of the standard design of the nacelle units of the propulsion system with the requirements of item 25.1193 (e) of the CB-148, fire tests of various samples of engine nacelle fragments were carried out on the issue of fire resistance. During the tests, the ability of the engine nacelle units of CM, reinforced with a metal mesh, to obstruct the permeation of the flame with temperature $T = (1100 \pm 50)$ °C and heat flux density $P = (10.5 \pm 0.315)$ W/cm^2 was verified for 15 minutes with simultaneous vibration with a frequency of 25 Hz and an oscillation amplitude of 0.8 mm and an overload of 2 g, which meets the requirements of item 25.1193 (e) of the CB-148. Test materials are reflected in Act No. 148.98.0989.001D3 "The An-148-100A aircraft (models An-148-100A, An-148-100B, An-148-100E). Certification fire tests of typical elements of EPS hoods".

For the first time in the design of engine nacelle assembly units from CM, a copper, "lightning-protective" grid was used to protect systems and units mounted on the engine from lightning and HIRF. The test results confirmed the conformity of the engine nacelle with the requirements of item 25.581, item 25.1316 of the CB-148 and are reflected in the report on the research work "Determination of the lightning induced voltage in the electrical circuits of the systems and equipment of the An-148 aircraft".

The engine air intake housing of the engine is designed in such a way as to be a fully enclosed sheath of CM of a two-layer acoustic aggregate structure. The fabricated technology of such construction made it possible to increase the gas-dynamic characteristics of the air intake device, to increase the area of the RWY, to reduce the weight and to increase the operational technology.

The engine design of the Д-436-148 (D-436-148) engine of the An-148-100/An-158 aircraft was performed using advanced 3D design and EPD Connect project management systems, which made it possible to link systems and units in the design phase. The use of three-dimensional design made it possible to shorten the design documentation and to improve its quality.

2.2.3 Engine Control System

A fully automatic FADEC-type automatic flight control system (AFCS) has been implemented, allowing the implementation of high-precision control laws that ensure engine performance with maximum efficiency.

On the An-148-100/An-158, unlike the considered foreign planes, in case of failure of the main engine ACS, the engine is not disengaged, and it is change over to the hydromechanical control system, which ensures the engine operation in two fixed modes, selected from the conditions of providing take-off safety, continued cruise flight and landing.

The main engine ACS has a built-in control system that allows continuous monitoring of engine sensors and assemblies. In order to improve the performance of the aircraft, the information display on the current failures of the engine's ACS was implemented in accordance with their influence on the safety of flight performance and the maintenance schedule of the aircraft.

In order to implement automatic airplane modes, including approach by the ICAO category IIIA, the An-148-100 / An-158 aircraft has direct automatic control of the propulsion thrust of the aircraft's AFCS signals similar to Airbus airplanes. The throttle control lever (TCL) in tracking mode is used to control the mode of operation of the engine, which is set by the aircraft AFCS.

Each of the propulsion engines is equipped with a reversing device with electronic-hydraulic control to ensure the braking of the airplanes at the landing run and during the interrupted take-off.

To monitor the technical condition of each engine, including the state of its vibration, an electronic engine control unit is used with a built-in vibration control module. A separate electronic converter is installed on the engine to convert the signals transmitted from the vibration sensors to the vibration control module.

A separate electronic control and monitor unit is installed to integrate the automatic control and monitor systems for each main engine with the airplane systems, and the component interaction is performed using a numeric sequence code to reduce the number of connections.

To control the performance of the power plant in the event of failure of the main means of indication in the cockpit, a standby indicator is installed, which displays a minimum set of operating parameters of each main engine.

2.2.4 Auxiliary Power Unit

The An-148-100 / An-158 aircraft uses the auxiliary gas turbine engine АИ-450-МС (AI-450-MS) (see Fig. 2.33) as an auxiliary power unit (APU) with a free-turbine driven compressor drive that eliminates the effects of variable power take-offs and air to the engine, which minimizes fuel consumption.

The auxiliary power plant consists of engine АИ-450-МС (AI-450-MS), engine mounting elements, inlet, air intake, fire screen, air-cooling system and exhaust system. The scheme of APU is shown in Fig. 2.36.

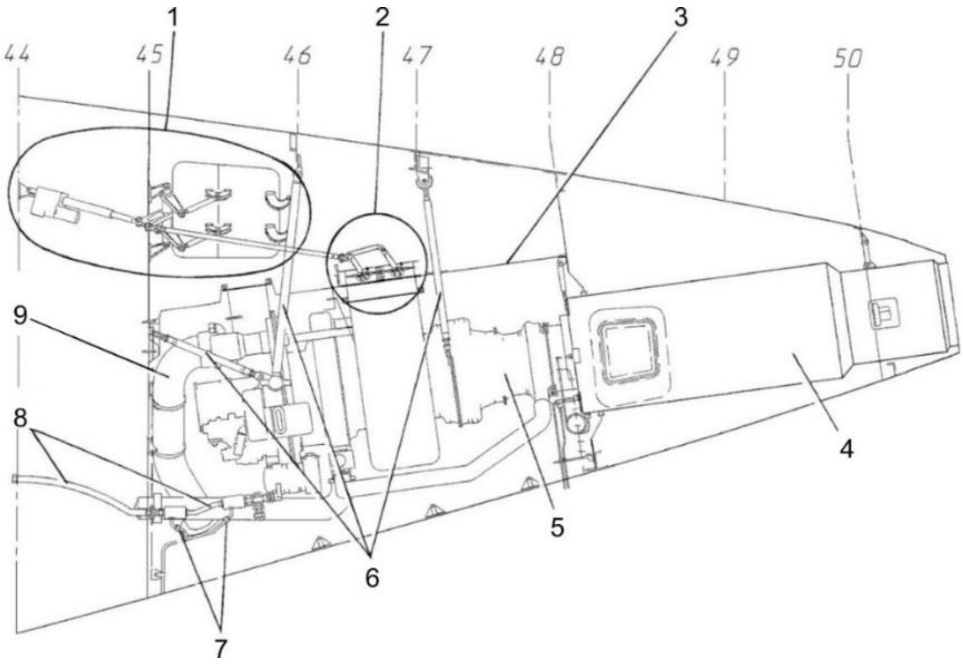


Fig. 2.36. Auxiliary Power Plant Installation Scheme:
1 – air inlet section; 2 – air intake of APU; 3 – fire shield; 4 – exhaust unit;
5 – АИ-450-МС (AI-450-MS) engine; 6 – APU mounting system;
7 – drain pipelines; 8 – fuel pipelines; 9 – air outlet tube from the APU fan

The AU is an auxiliary power unit of the aircraft that provides:

– Air launch of the Д-436-148 (D-436-148) engines in the range of ambient temperatures from minus 60 °C to plus 50 °C at aerodromes located up to an altitude of 4 500 m above sea level and in flight in an emergency situation up to altitude 8 000 m;
– Compressed air supply to the aircraft's air conditioning system and de-icing system on the ground up to 4 500 m and in flight up to 12 000 m in an emergency situation;
– Supply of the aircraft electrical system with AC power on the ground up to 4 500 m above sea level and in flight up to 12 000 m in case of emergency.

The APU is functional in the temperature range from minus 60 C to plus 50 C on the ground and in flight from the minimum arctic to maximum tropical at all altitudes of the aircraft flight.

The APU compartment is located in the fuselage tail section between ribs No. 45 and No. 48. The engine access for a quick engine change is provided through the orifice closed by two gill covers for the auxiliary power unit compartment ventilation to ensure serviceability and controllability.

During the flight when the APU engine is not operating, the compartment is heated by air, bled from the air-conditioning system.

The АИ-450-МС (AI-450-MS) engine is a twin-shaft gas turbine engine with a service compressor, with an air bleed system and a mechanical power to the AC generator drive.

The engine consists of a compressor, combustion chamber, turbine, service compressor with a turbine, input device, gearboxes, units and engine systems. The engine is equipped with a 40 kV A alternator.

Starting the engine is automatic on commands from the engine start control panel.

The APU has an autonomous fuel system. Fuel is supplied to the engine from the aircraft fuel system.

The lubrication system is also autonomous, made according to the normal closed circuit with oil circulation through the oil tank and provides lubrication and cooling of rotor supports, engine parts and assemblies, which rotate and rub.

The engine is equipped with an automatic control system depending on the operating mode. The control system of the APU includes the БУК МС-2 (CMU MS-2) control and monitor unit.

The APU control is fly-by-wire, with a control panel, installed in the cockpit. Operation parameters, APU monitoring signals are displayed on the multi-function display system (MFDS) and MMD system. The control system provides for automatic shutdown of the APU on limiting parameters both at startup and during operation.

The engine is started from aircraft storage batteries or from a 27 DC V external source by pressing the "START" button with the subsequent control of start of the control and monitor unit БУК МС-2 (CMU MS-2).

To reduce the noise and bleeding the exhaust gases, the APU is equipped with an exhaust pipe with a noise muffler to remove exhaust and air gases.

2.2.5 Auxiliary Power Plant Control System

An electronic control system with full reliability of FADEC type and integrated control system is used to control the APU, allowing the realization of control laws with high accuracy, providing the engine operation with maximum efficiency.

2.2.6 Fuel Measuring System

A fuel measuring digital system of a domestic production ТИС-158 (TIS-158) developed by ПАО НТК "Электронприбор" (PJSC STE "Electronpribor") is installed on An-148-100 /An-158 aircrafts (Fig. 2.37).

The ТИС-158 (TIS-158) system is developed on the modern element base with the use of new linear electric fuel flow transmitter and LED fuel level switch. In terms of service characteristics and measurement accuracy the system complies with the latest world developments.

Unlike previous analogues, the ТИС-158 (TIS-158) system provides:

- Control of the fuel system units, measuring channels, sensors and indicators of the fuel measuring unit without using auxiliary equipment by means of built-in test. In comparison with the analogues, the ТИС-158 (TIS-158) system provides increased serviceability by means of built-in test equipment with the depth to the structurally detachable element and measurement accuracy;

- Output of information on fuel quantity, condition of fuel system units and indication system is realized by means of on-screen display installed in the cockpit (the "glass cabin" concept). Fuel system units are controlled from the ПКУ-158 (PKU-158) control panel, designed on a "dark cabin" principle, which greatly simplifies the system operation;

- Convenient, prompt and clear information of the crew on the screens of the MMD and MFDS in case of necessity to interfere with the fuel system operation at possible operational failures of fuel units. The ТИС-158 (TIS-158) system provides for the possibility to control in flight the fuel units of the refueling system in case it is necessary to use the entire fuel reserve or equalize the fuel unbalance in the tanks when the engine and cross-feed valve fail, what significantly increases flight safety;

- Achieving the required accuracy of fuel measurement with the help of software, which takes into account not only the geometry of the integral tanks and their inner structure, the wing deflection and twisting under the influence of aerodynamic forces, but also the angle of pitch and roll during the flight. The fuel parameters can be set before refueling. The measurement error and information on the fuel quantity in each tank and the total fuel quantity in the cruising mode with the ±3 roll and ±3 pitch angle is not more than ±2.5% of the maximum measured fuel quantity in the tank;

- Automatic warning of the crew when the fuel temperature in the tank reaches the temperature of the beginning of crystallization, fuel unbalance and its elimination, reserve fuel;

- Automatic warning of the crew and control system on the beginning of fuel use from the fuel reservoir to reduce the aircraft speed for the safe completion of the flight;

- The ТИС-158 (TIS-158) system corresponds to the requirements of the qualification base and made in accordance with AP-21, AP-25, KT-178B, KT-160D.

2.2.7 Fire Protection System

When developing the fire protection system (FPS) of An-148/An-158 aircraft (Fig. 2.38), the systems of domestic and foreign regional aircraft have been analyzed. As a result of the analysis, the most optimal schematic diagram that meets modern requirements has been selected.

In order to ensure constant automatic control of fire/heat indicator in flight and on the ground, as well as to increase the system resource the decision has ben taken to use linear pneumatic indicators of "MEGGITT" company.

To control and monitor the fire protection system of the An-148 / An-158 family aircraft, a fire protection system block БКУ-СПЗ (MCU-FPS) was designed.

The unit БКУ-СПЗ (MCU-FPS) at all operational and control modes provides continuous automatic control of all FPS units functionality and processing of signals coming from smoke detectors, pyrocartridges and minimum pressure switches of fire extinguishers.

Block БКУ-СПЗ (MCU-FPS) meets the requirements of DO-160D, KT-178B, approved by Ukraviatrans and AR IAC according to APU-21 and AP-21 taking into account Letters of instructions AR IAC No. 1-96, No. 3-97 and has Certificates of Airworthiness of Ukraviatrans and AR IAC.

When designing the system, the necessary amount of the substance for fire extinguishing was calculated and ground and flight tests were carried out to measure the concentration of this substance in fire hazardous areas of the aircraft.

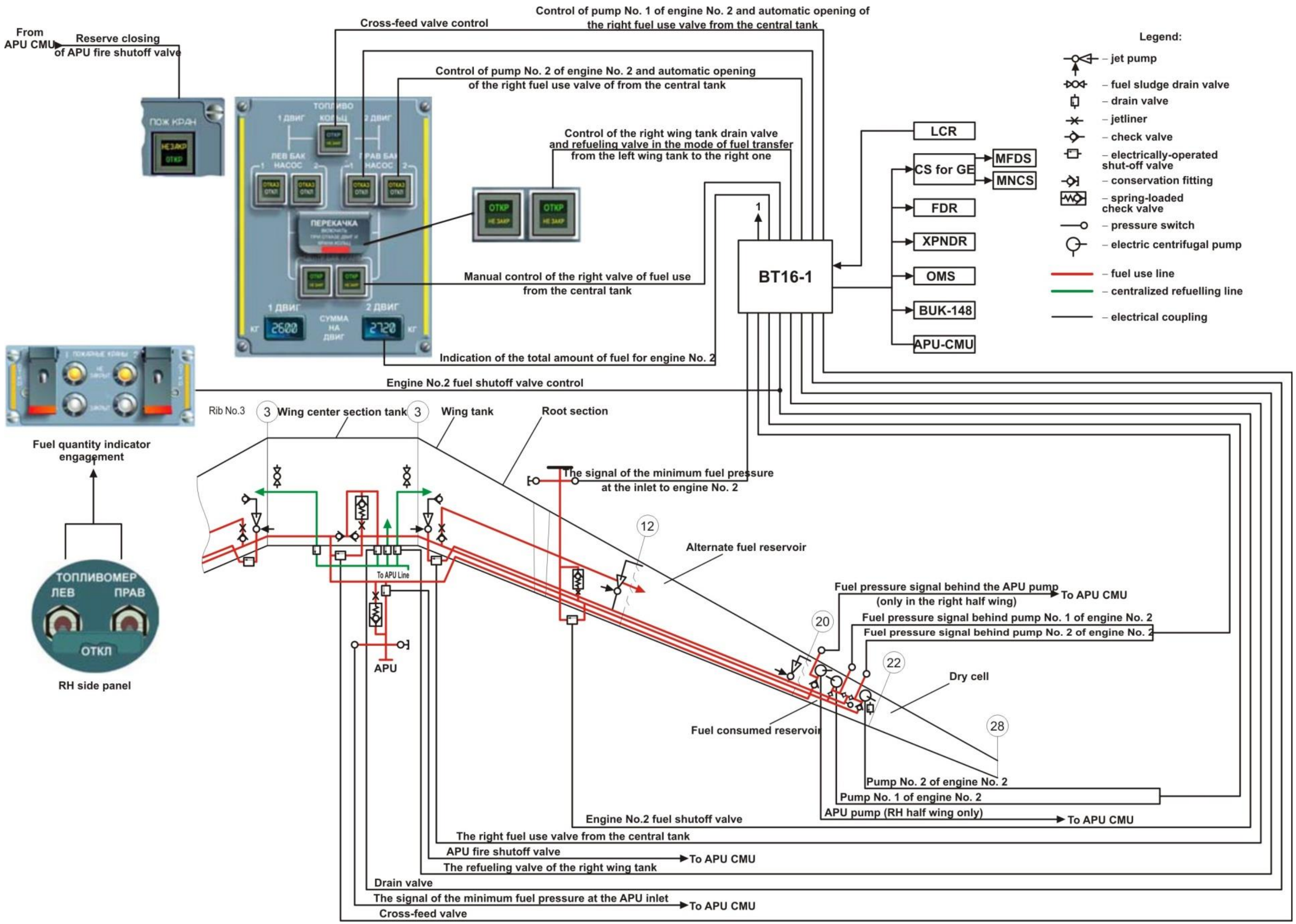


Fig. 2.37. Functional Diagram of the Fuel System

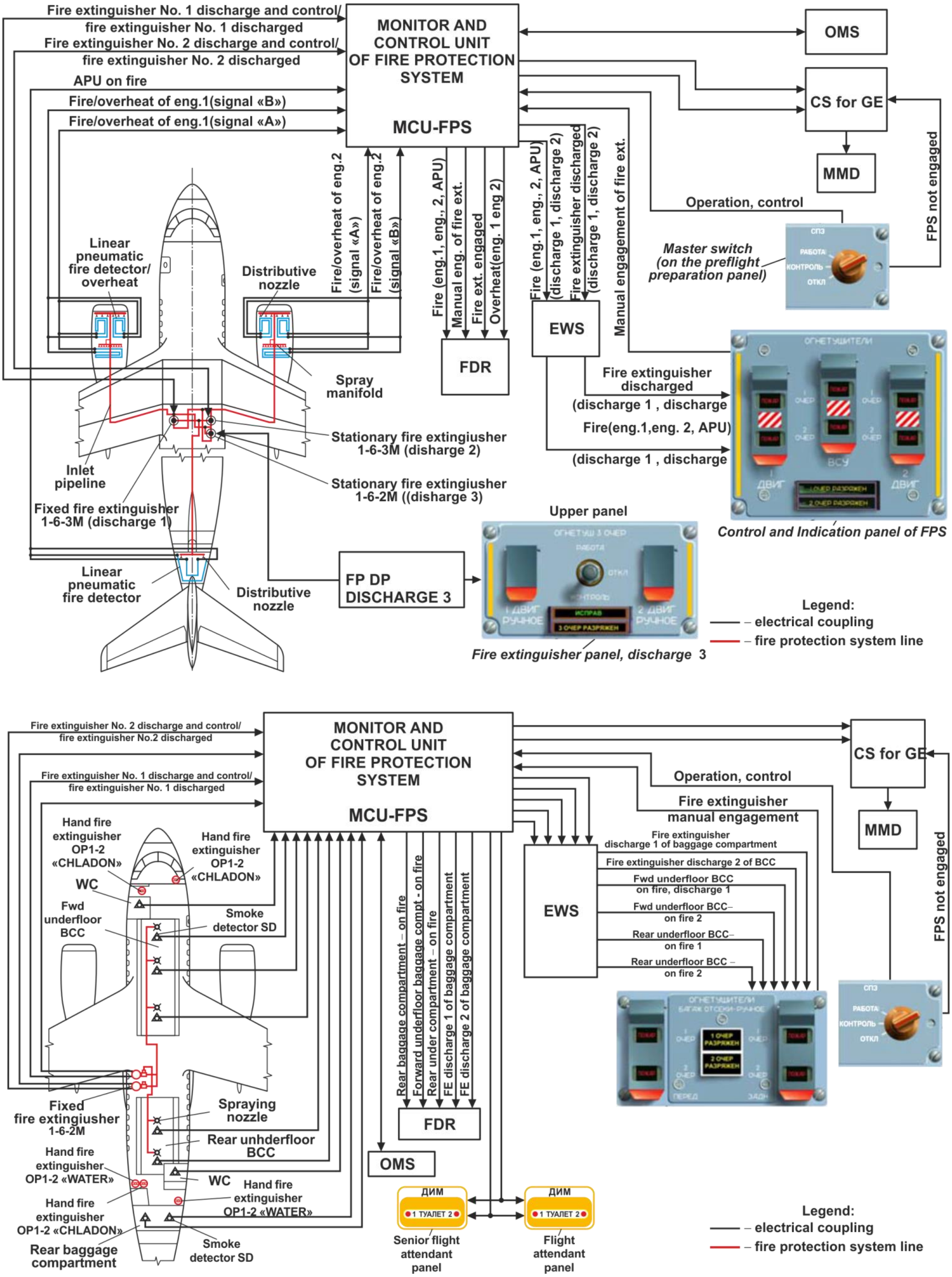


Fig. 2.38. Firefighting Equipment Diagram

The evidential documents for the power plant and its systems of the An-148-100/An-158 aircraft family are listed below:

- ♦ The An-148-100 aircraft (models An-148-100A, An-148-100B, An-148100E). Certification fire tests of typical cowl elements of EPS.
- ♦ Scientific and technical report. Development of noise reduction systems for power plants of the An-74TK-300 aircraft with engines Д-36 (D-36), series 4A, and the An-148 aircraft with engines Д-436-148 (D-436-148), which reduces the noise level on the ground to standard of ICAO Chapter 4.
- ♦ Research report. Determination of voltages, given by lightning in the electrical circuits of systems and equipment of the An-148 aircraft.
- ♦ Fuel system. Control and fuel measurement. Schematic diagram.
- ♦ Fuel measuring system ТИС-158 (TIS-158) (a). Verification and control on the airplane. Instructions.
- ♦ Act of interdepartmental testing of ТИС-158 (TIS-158) system.
- ♦ Fuel-measuring system ТИС-158 (TIS-158). Maintenance Manual.
- ♦ The An-158 aircraft. Additional certification ground and flight tests of the fuel system with the ТИС-158 (TIS-158) fuel measuring system.
- ♦ The An-148-100 aircraft. Conformity assessment of fuel measurement system ТИС-158 (TIS-158) aircraft to the requirements of paragraph 25.1309(a) of the CB-148 Certification Basis.
- ♦ Fire protection system of BCC (baggage and cargo compartment) and cabins. The scheme is functional.
- ♦ Fire protection system of engines and APU. The functional diagram.
- ♦ Certified ground and flight tests of fire protection means of the power plant and auxiliary power unit.

2.2.8 Main Conclusions about the Power Plant and its Systems

1. The use of single- and double-layer sound-absorbing structures of acoustic filler in the engine nacelle design reduces the aircraft noise level from the engine on the ground in accordance with the standards of Section 4 of the ICAO standard. The largest aircraft noise reduction was found during take-off operation mode of the engine.

2. Nacelle components reinforced with a metal grid prevent the flame through penetration Within 15 minutes with a temperature of T = (1100 ± 50) °C and a heat transfer

rate of P = (10.5 ± 0.315) W/cm^2 under the simultaneous influence of vibration with a frequency of 25 Hz, an oscillation amplitude of 0.8 mm and an overload of 2g, which meets the requirements of item 25.1193 (e) of the CB-148.

3. The design of the engine nacelle components with composite materials and a copper grid used, protects the systems and units mounted on the engine from lightning and HIRF and confirms the compliance of the engine nacelle design with the requirements of item 25.581, item 25.1316 of the CB-148.

4. The mastered manufacturing technology of a completely closed shell with composite materials of a two-layer design of an acoustic filler made it possible to increase the gasdynamic characteristics of an air intake device, increase the area of a sound-absorbing materials, reduce weight and increase operational manufacturability.

5. The use of FADEC-type electronic automatic control systems for controlling main engines and APU ensured the operation of the aircraft power plant with high specific fuel consumption rates and made it technically possible to operate the aircraft power plant.

6. The use of two fixed modes of engine operation in the event of a failure of the engine automatic control system made it possible to simplify the design of the fuel regulator, reduce its weight and size characteristics and increase the resistance to engine failures and the reliability of the aircraft power plant as a whole.

7. Direct control of the operation modes of the main engines by signals from the aircraft's automatic control system with the thrust levers moving to the tracking mode made it possible to exclude the influence of the electromechanical thrust levers drives and ensured automatic aircraft navigation, including in the approach to the ICAO IIIA category, with the necessary accuracy.

8. The use of the electronic-hydraulic thrust reversal control system for each main engine ensured the minimum time for the power plant to reach the maximum thrust reversal mode, and increased take-off and landing characteristics of the aircraft.

9. The use of an electronic converter of signals from vibration sensors on the engine minimized the length of low-current circuits, which, in turn, increased the reliability of the system as a whole, as well as increased the reliability of information about the state of vibration of the engine.

10. The use of an electronic control and monitor unit, as well as a digital serial code for the exchange of information between the components of the power plant and

aircraft systems, reduced the number of links, which led to an increase in the reliability of the power plant and the aircraft with a decrease in its weight characteristics.

11. The installation in the cockpit of a parameter backup indicator of the power plant makes it possible to complete the flight safety in the absence of the main means of indication while maintaining constant control of the basic operating parameters of each main engine.

12. The use of АИ-450-МС (AI-450-MS) engine with a service compressor drive from a free turbine as APU eliminated the influence of variable power and air take-offs on the engine operating mode, which ensured minimization of fuel consumption.

13. The integration of the APU monitoring system into the automatic control system allowed to minimize the weight and size characteristics of the APU automatic control system components and reduced the length of the communication lines.

14. The ТИС-158 (TIS-158) fuel measuring system, which is implemented on a modern elemental base, provides convenient, timely and clear information to the crew on the screens of the MFDS (multi-function display system) and a multi-function indicator, automatic warning of the crew and aircraft control systems, and meets the specified measurement accuracy requirements.

15. The use of the ТИС-158 (TIS-158) fuel measuring system made it possible to ensure the monitoring of the state of the fuel system units and fuel gauge without the use of auxiliary equipment by integrated control means.

16. The installation of the ПКУ-158 (PKU-158) control panel in the cockpit made it possible to maintain constant monitoring of the state of the fuel system units and the amount of fuel in the aircraft tanks in case of failure of the main indicating devices in the cockpit.

17. The use of the БКУ-СПЗ (MCU-FPS) unit made it possible to provide constant automatic monitoring of the serviceability of all elements in the fire protection system in flight and on the ground.

18. The installation of an electronic control and monitor unit, as well as the use of a digital serial code for the exchange of information between elements of a fire protection system and aircraft systems, made it possible to reduce the number of links, which led to an increase in reliability and a decrease in its weight characteristics.

19. The design of the power plant (main and auxiliary engines and their control systems) allows the operation of the An-148-100/An-158 aircraft at aerodromes with a

base height of 4 100 m.

20. In order to preserve the engine resource and fuel economy when taking off the aircraft from long RWYs, take-off at the maximum long-term mode has been introduced. To reduce the loading on crew members, the engagement of this mode is automated.

21. To ensure the use of thrust reverse mode at speeds below 110 km/h (on runways with insufficient traction), a minimum reverse mode has been introduced. In order to improve the conditions for applying this mode, an intermediate stop on the engine control panel is installed.

2.3 Concept of Creating a Flight Control System for Regional Passenger Aircraft

The creation of a flight control system for regional passenger aircraft was based on a new control concept developed, the main idea of which is the development and creation of a control system that is supplied from two hydraulic systems and two centralized electrical systems.

The An-148-100/An-158 aircraft family uses an innovative flight control system. At the time of the first take-off on December 27, 2004, the An-148 aircraft became the first aircraft in the world in the transport category, which irreversible booster control system receives power from only two hydraulic systems. Previously, to ensure compliance with the requirements of Airworthiness Standards for the reliability and safety of power supply of booster irreversible aircraft control systems, at least three hydraulic systems were implemented.

On the An-148/An-158 aircraft, instead of additional hydraulic systems, the energy of two centralized AC electric systems to power the power drives ("boosters") of the main control surfaces is used.

Adopted solutions on the system allowed to provide:

a) Reduction in the weight of the equipment installed;
b) Optimizing the power consumption of the flight control system;
c) Improving environmental safety by significantly reducing the volume of toxic hydraulic fluid;
d) Increasing the survivability of the aircraft due to the heterogeneous reservation of power of the control system surfaces drives.

Such an approach to the design of the flight control system and the energy complex of the aircraft has become generally accepted and has been used in the latest developments of leading aircraft manufacturers: Airbus (A380, A400M, A350), Dassault (Falcon 7X), Gulfstream (G650), etc.

2.3.1 General Description

The flight control system of the An-148/An-158 aircraft consists of two systems:

- ♦ Wheel control system СШК (WCS), designed to control the spatial position and air braking of the aircraft;
- ♦ High-lift devices control system СКМК (HLDCS), designed to increase the wing lift during take-off and landing.

Aerodynamic control surfaces of the aircraft are shown in Fig. 2.39.

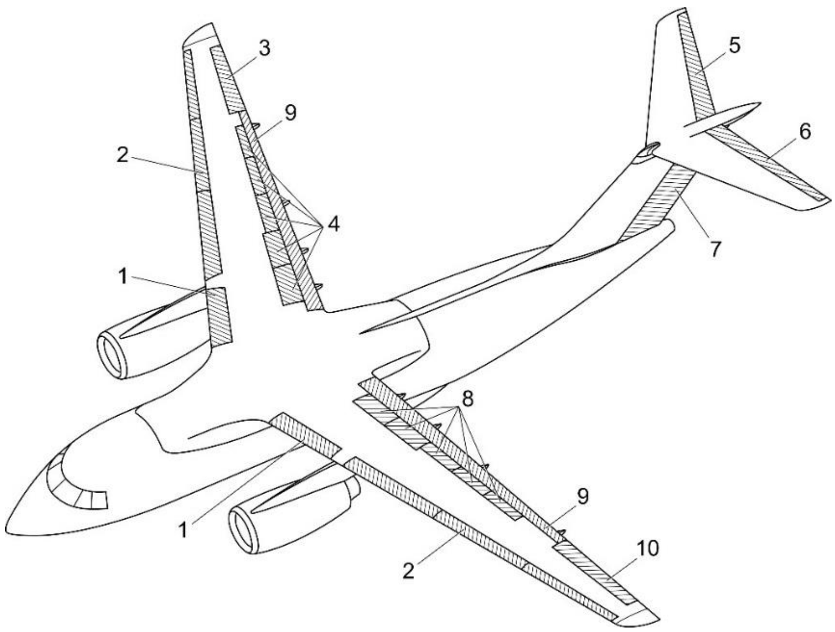


Fig. 2.39. Arrangement of Airplane Aerodynamic Control Surfaces:
1 – the drooping wing leading edge; 2 – slats; 3 – right aileron; 4 – right spoilers;
5 – right section of the elevator; 6 – left section of the elevator; 7 – rudder;
8 – left spoilers; 9 – flaps; 10 – left aileron

2.3.2 Flight Control Indication

The position of the control surfaces, as well as the visual indication on the functioning of the flight control system, are displayed in the multifunction indicator (MFI) and the multi-function display system (MFDS) of the master monitor display system (MMD) (Fig. 2.40).

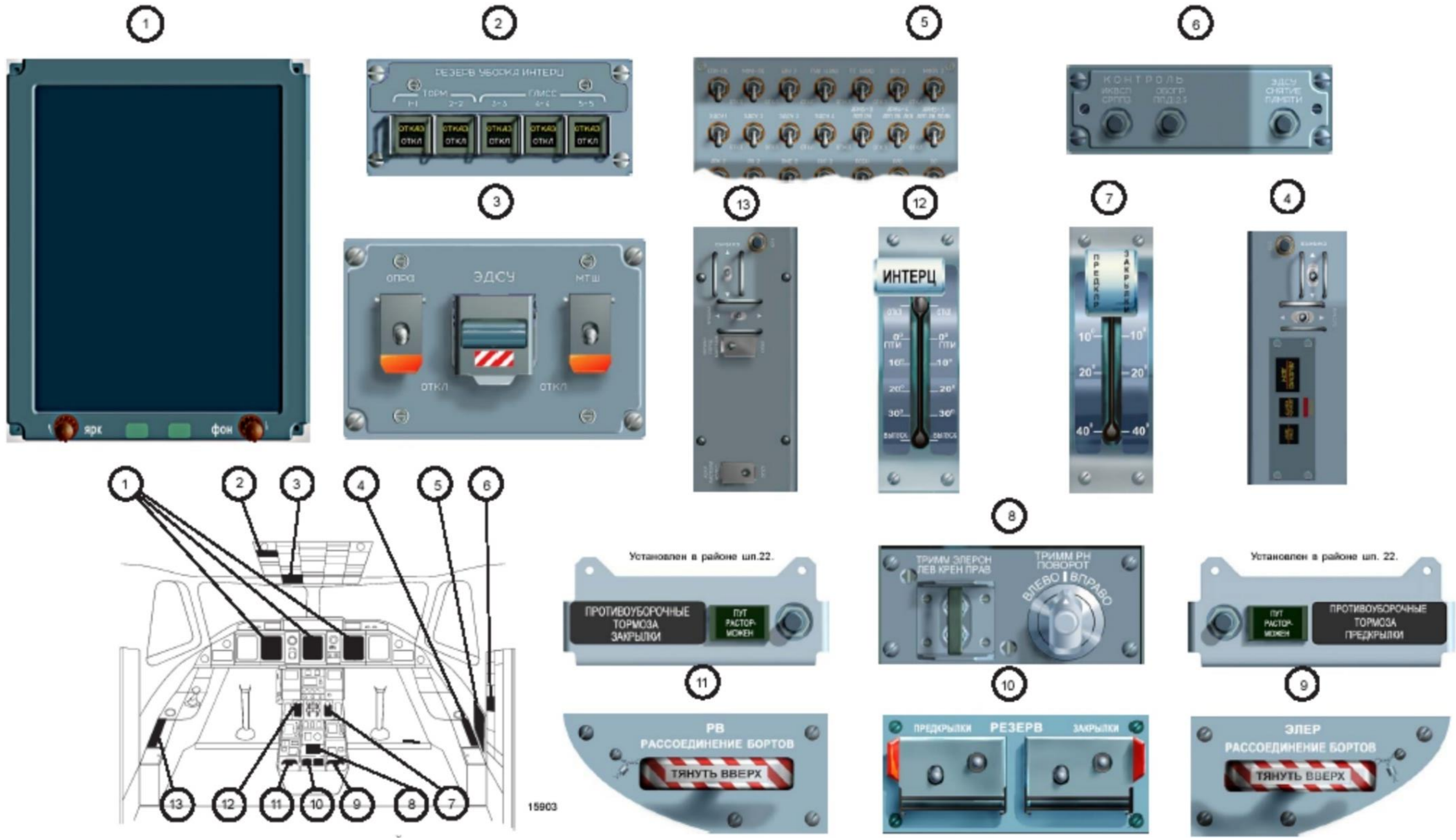


Fig. 2.40. Arrangement of the Controls of the Aircraft Control System in the Cockpit

2.3.3 *Wheel Control System*

The wheel control system (WCS) provides control of the aircraft by pitch, roll and yaw.

The WCS receives control signals from pilots or an automatic flight control system.

The control of the aircraft by pitch is provided by the use of two sections of the rudder mounted on a fixed horizontal stabilizer.

The control of the aircraft by roll is provided by two ailerons (one surface on each half-wing) and three pairs of multifunctional spoilers (pairs No. 3, No. 4 and No. 5, pairs are numbered from the root of the half-wing).

A single-section rudder mounted on a vertical tail unit provides the control of the aircraft by yaw.

WCS also provides air braking control:

- In flight: using multifunctional spoilers;
- On the ground: using multifunctional and brake spoilers (pairs No. 1 and No. 2).

WCS consists of two subsystems: the main one, which ensures functioning in the main mode, and the backup one, which ensures functioning in the reserve mode.

The main subsystem of the WCS is based on the main fly-by-wire control system ЭДСК (FWCS) of the "ЭДСУ-148 (FWCS-148)" type.

The main fly-by-wire control system is a four-channel system. The electronic equipment of the main fly-by-wire control system is located in two containers ("A" and "B"), which, in turn, contain two independent channels.

Each of the channels (No. 1, No. 2, No. 3 and No. 4) of the electronic equipment of the main fly-by-wire control system is functionally divided into a computing device and a set of drive control devices. Computing devices are made according to a two-channel scheme: a monitoring channel and a control channel.

The electronic equipment of the main fly-by-wire control system is powered by direct current with a voltage of 27 (28) V. The cooling fans are connected to a single-phase alternating current network with a voltage of 115 V and a frequency of 400 Hz.

WCS provides an unstressed change of operating modes. The transition from the main control mode to the backup one is carried out either automatically for the entire system as a whole, or individually for individual control surfaces. It depends on the state of the power supply systems and electronic equipment of the main fly-by-wire control system, or manually using the "FWCS – OFF" switch for the entire HCS as a whole.

The actuators of the WCS control surfaces are powered by two centralized hydraulic systems (HS1 and HS2) and centralized three-phase AC power system with a voltage of 115 V and 400 Hz frequency.

The HCS uses combined actuators, which are powered from both one of the two centralized hydraulic systems and the centralized electrical supply system with three-phase AC 115 V / 400 Hz. Combination actuators are used to deflect multifunctional spoilers as well as backup actuators for elevation and yaw rudders.

The modules of the actuator power supply control system of the БРУИ-148-01 (BRUI-148-01) units control the power supply modes of the combined actuators (hydraulic or electric). The HCS includes three БРУИ-148-01 (BRUI-148-01) units, each of them controls the power supply modes of three combined actuators: one of three pairs of multifunctional spoilers and, respectively, elevators and rudders.

It is possible to forcefully switch all combined HCS actuators to power mode using the "AA" button.

2.3.4 Control of Ailerons and Multi-Function Spoilers

The roll controls are the first and second pilots' steering wheels. The steering wheels are mechanically linked. The force on the steering wheels is simulated by spring loaders (loading devices). It is possible to disconnect the mechanical connection between the steering wheels using handle "AILER SIDE UNCOUPLING".

In accordance with the roll control signals, the ailerons and pairs of multi-functional spoilers No. 3, No. 4 and No. 5 are deflected.

Multi-functional spoilers also function as air brakes. The air brake control is the "SPLR" handle.

To deflect each of the ailerons, two electro-hydraulic servo units (SU) of the PA110-01 (RA110-01) type are used. In this case, one of the SU on each aileron operates in the control mode, the second – in the damping mode.

The surface of the ailerons is provided with the mass balance. Mass-balance weight is provided on the ailerons.

One АРМ-19Н (ARM-19N) combined drive is connected to each of the surfaces of the multi-functional spoilers (pairs No. 3, No. 4, and No. 5).

There are two roll control modes:

- ♦ The main mode – when the main FWCS is functioning normally;
- ♦ Backup mode – using the backup spoiler control system (BSCS) (built on the BSCS modules of the "БРУИ-148-01 (BRUI-148-01)" units).
- ♦ In the main roll control mode, the following functions are provided:
- ♦ The deflection of ailerons and multi-function spoilers is proportional to the steering angle;
- ♦ Changing the balancing position of the control surfaces (without changing the neutral position of the steering wheels) using the balancing control switches;
- ♦ Roll damper;
- ♦ Changing the transmission coefficient in the aileron and multi-function spoilers control paths depending on the indicated speed (V_{IAS}) or the position of the flaps.

To implement air braking in flight or when taxying, a symmetrical deflection of pairs of multi-functional spoilers is carried out in proportion to the position of the "SPLR" handle in addition to the roll control signals of the multi-functional spoilers. During taxying when you install the handle "SPLR" to "0° / PTI" or the control levers of the engines "TCL" to "REVERSE" multi-function spoilers fully deflected after the appearance of strong compression signal of both main landing gear struts.

In backup mode, roll control is performed by turning the multifunction spoilers (pairs No. 3, No. 4 and No. 5) proportionally to the steering angle of the steering wheels with the provision of transmission ratio changes in the control paths of the multi-function control spoilers depending on the position of the flaps. The ailerons are in the feathered position. There is no roll balancing control.

2.3.5 Rudder Control

The direction controls are the pedals of the left and right pilots' foot controls (Fig. 2.41).

The pedals of the left and right pilots are mechanically linked. Pedals are loaded by spring loaders (loading devices). Adjustment of pedals for the height of pilots is provided by electromechanical drives.

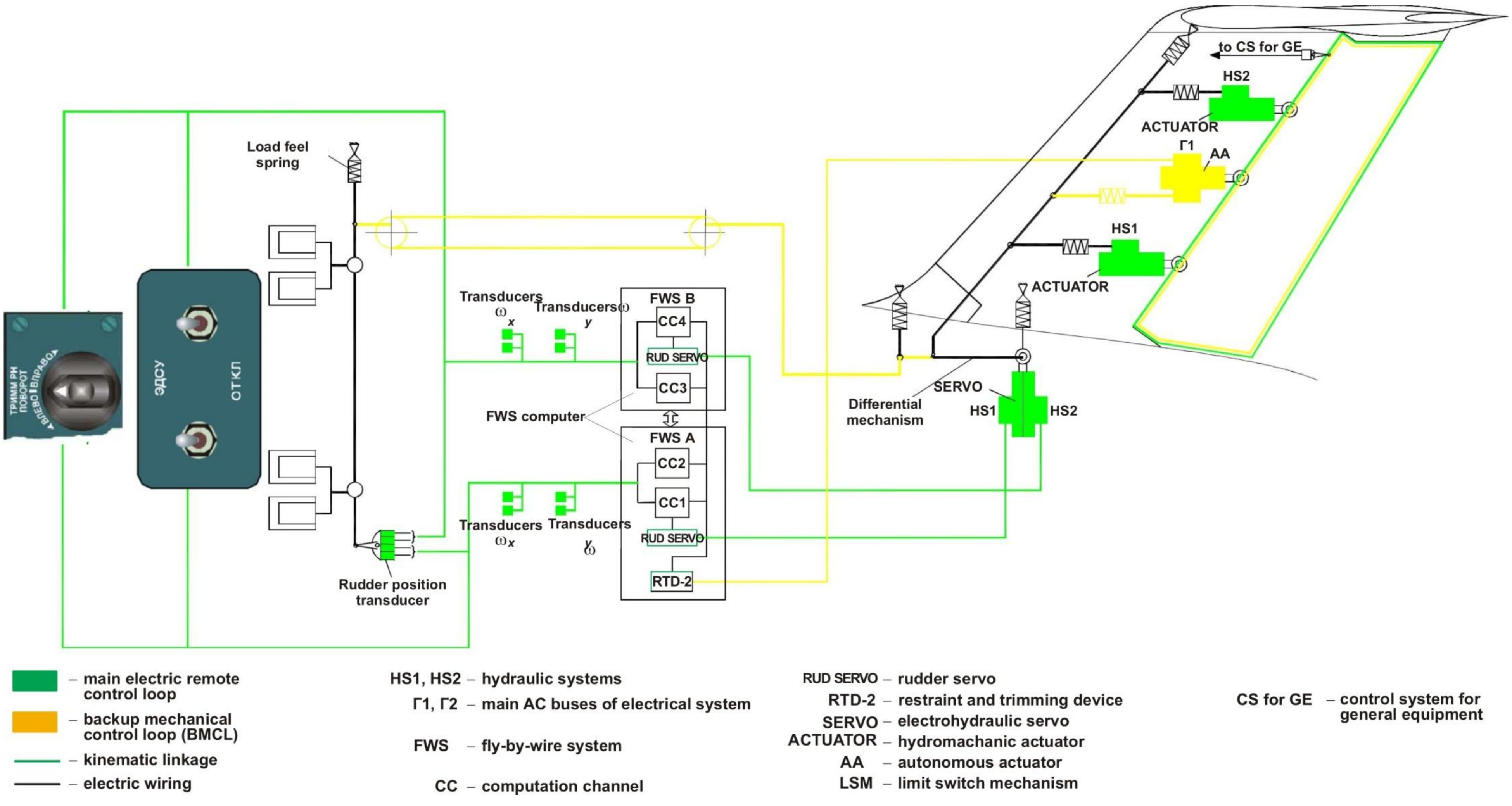


Fig. 2.41. Rudder ControlSystem. Schematic Diagram

Deflection of the rudder is performed by two hydro-mechanical drives (type РП67А (RP67A)), the input links of which are moved by a two-channel electro-hydraulic servo unit (type РА81Н (RA81N)) of the main FWCS, or a combined drive (type АРП-21Н (ARP-21N)), which is controlled by mechanical wiring.

Two rudder control modes are provided by:

- The main – if the main FWCS and at least one of the two hydraulic systems (HS1 or HS2) are functioning properly;
- The backup – with the help of mechanical control wiring and actuator, in case of failure of the corresponding two channels of the main FWCS, or autonomous actuator, in case of failure of both hydraulic systems HS1 and HS2.

In the main rudder control mode, the following functions are provided:

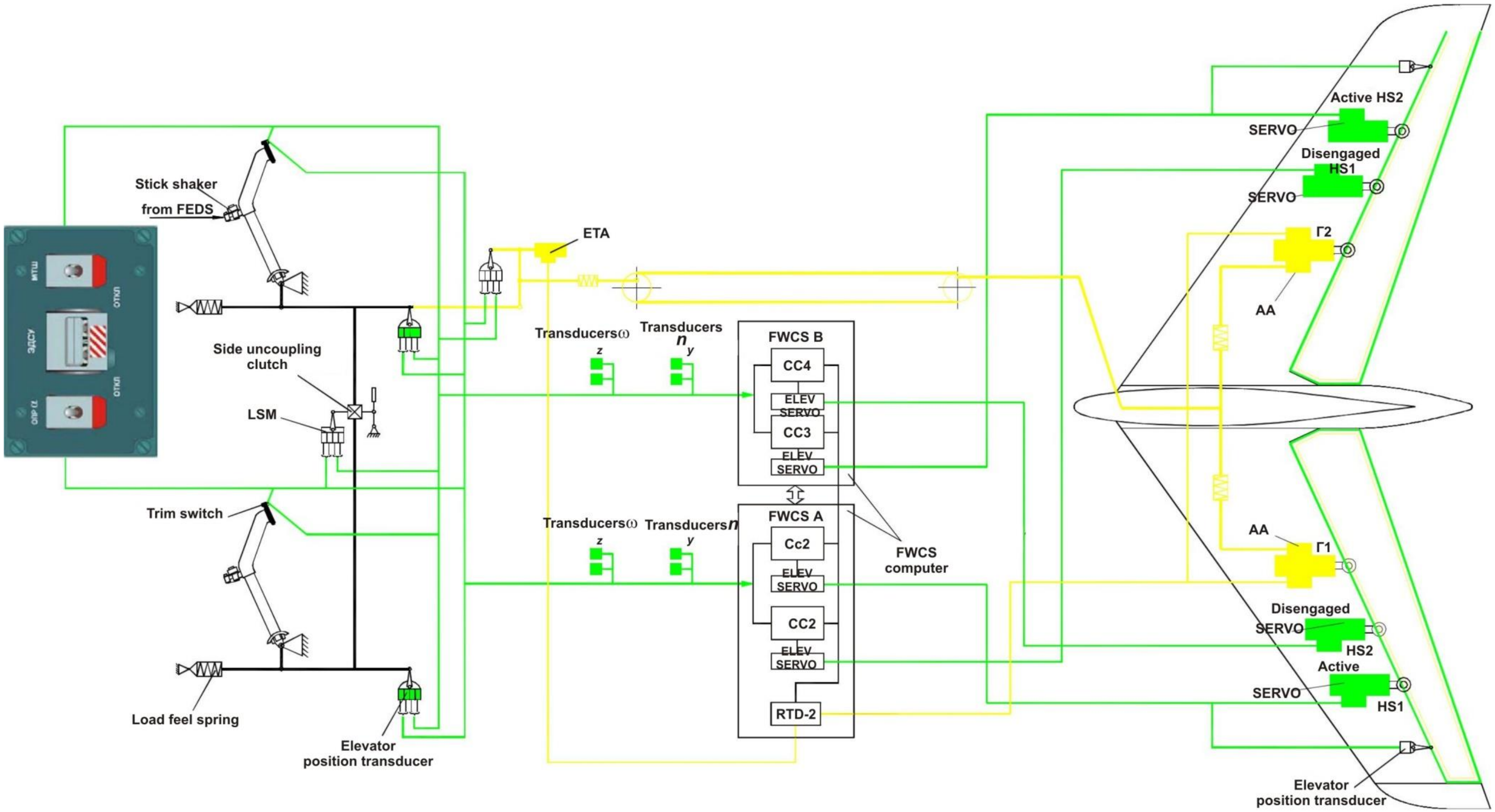
- The deflection of the rudder is proportional to the movement of the pilots' pedals;
- Changing the balancing position of the rudder (without changing the neutral position of the pedals) using the balancing control switch;
- Yaw damper;
- Bank-to-turn maneuver;
- Changes in the transmission coefficient depending on the VIAS or the position of the flaps.

In the main wheel control mode, the channels of the РА81Н (RA81N) servo unit are controlled by channels No. 1 and No. 4 of the main FWCS. The servo unit moves the mechanical wiring directly connected to the input links of the РП67А (RP67A) steering drives. The АРП-21Н (ARP-21N) combined drive operates in back-to-back mode.

In the backup mode, the rudder deflection is proportional to the movement of the pedals, but the maximum deflection of the rudder is less than in the main mode. There is no control of balancing and the transmission coefficient changing.

2.3.6 Elevator Control

The pitch control is perfoprmed by the steering column of the first and second pilots, mechanically linked (Fig. 2.42). Simulation of forces on the steering columns is carried out by spring loaders. Manual disconnection of the steering columns is provided using the handle "ELEV SIDE UNCOUPLING".



– main fly-by-wire control loop
– backup mechanical control loop
– mechanical linkage
– electrical wiring

HS1, HS2 – hydraulic systems
Г1, Г2 – main AC buses of electrical system
FWCS – fly-by-wire control system
CC – computation channel

ELEV SERVO – elevator servo
RTD-2 – restraint and trimming device
SERVO – electrohydraulic servo
A – hydromechanic actuator
AA – autonomous actuator
LMS – limit switch mechanism

ETA – electric trimming actuator
SSh – stick shaker
FEDS – flight environment data system

Fig. 2.42. Elevator Control Scheme

On the levers of the steering columns under the floor of the crew cabin, there are stick shakers (SS), which provide tactile indication of approaching the limit value of the attack angle.

Two electro-hydraulic units are drives of each section of the elevator (type PA100-01 (RA100-01) of the main FWCS and the combined drive (type АРП-20Н (ARP-20N)).

Two elevator control modes are provided by:

- ♦ The main mode – if the main FWCS and at least one of the hydraulic systems (HS1 or HS2) are functioning properly;
- ♦ The backup mode is provided by mechanical control wiring and combined drives in case of failure of the main FWCS or two hydraulic systems (HS1 and HS2).

The main mode of elevator control provides:

- ♦ The deflection of the elevators is proportional to the deflection of the steering columns;
- ♦ Changing the balancing position of the elevator (without changing the neutral position of the steering columns) using the balancing control switches;
- ♦ Performing the pitch damper function;
- ♦ Border mode limits by angle of attack;
- ♦ Changing the transmission coefficient in the elevator control paths based on the VIAS signals and the position of the flaps.
- ♦ In the main control mode, only one of the two steering units PA100-01 (RA100-01) on each section of the elevator operates in the control mode, the second one – in the damping mode. However, combined drive АРП-20Н (ARP-20N) operates in the back-to-back mode.

In the backup mode, both servos of the same section of the elevator function in the damping mode, while the AA – in the control mode. This ensures that:

- ♦ The deflection of the elevators is proportional to the deflection of the steering columns (the maximum deflection of the elevator is less than in the main mode);
- ♦ Changing the balancing position of the elevator segments (without changing the neutral position of the steering columns) using the balancing control switches.

2.3.7 Control Linkage

Control linkage is used in elevator and rudder sections' backup control subsystems.

Control linkage runs in the upper right part of the fuselage (in the direction of flight) above the ceiling panels of the passenger compartment. For pumping units, rods, cables, sections and other elements of the linkage, the access through the access hatches and panels is provided. A cable of the КСАН (KSAN) type with a diameter of 2.5 mm is used in the control linkage.

Cables are laid between the guides, and the gap between the branches of the cable wiring along the entire length is provided by rollers and textolite guides. The guides are attached to the airframe structure and are equipped with limiters that prevent the cables from slipping off. The rollers are equipped with closed-type ball bearings that do not require lubrication during the service life.

For ease of installation and adjustment, the cable wire is equipped with turnbuckle joints.

Cables have an identifying marking. The marking is applied to the corresponding parts of the turnbuckles and consists of color coding and two symbols.

2.3.8 Control of Brake Spoilers (Air Brakes when Taxying)

To slow down taxying, the brake spoilers (pairs No. 1 and No. 2) are deflected at full speed.

Signals for preparing the system for the release of brake spoilers are as follows:

- ♦ Setting the "SPLR" handle to the "0º/PTI" or "RELEASE" position;
- ♦ Setting the throttle control levers of the engines "TCL" to the "REVERSE" position.

The brake spoilers are released with the appearance of compression signals for both main landing gear struts.

When the taxying speed is reduced to less than 30 km/h, the brake spoilers are retracted.

Each brake spoiler is deflected by a single hydraulic cylinder.

The release of brake spoilers is controlled by channels No. 2 and No. 4 of the main FWCS.

2.3.9 The Wing High-Lift Devices Control System

The wing high-lift devices control system (WHLDCS) is designed to move the high-lift devices surfaces of the front and rear edges of the wing.

The WHLDCS receives control signals from pilots.

The aerodynamic surfaces of the WHLDCS on each half-wing are the inner and outer flap sections, the deflected wing LE section, and three slat sections.

WHLDCS structurally consists of two subsystems: the flap control system (FCS) and the deflected wing LE and slats control system (WLESCS).

Both systems are built (based) on identical FWCS systems with the main tracking control mode and backup positional control.

2.3.10 Flap Control System

The flap control system (FCS) is designed to control the movement of flap surfaces (Fig. 2.43). Mechanisms for moving the flaps linked with a mechanical transmission consisting of ball-and-screw actuators, reducers and rigid shafts, which are driven by the output shaft of the high-lift devices combined drive (HLDCD of type "КПМ-148Н (KPM-148N)").

The HLDCD is equipped with a hydraulic motor and an electric motor.

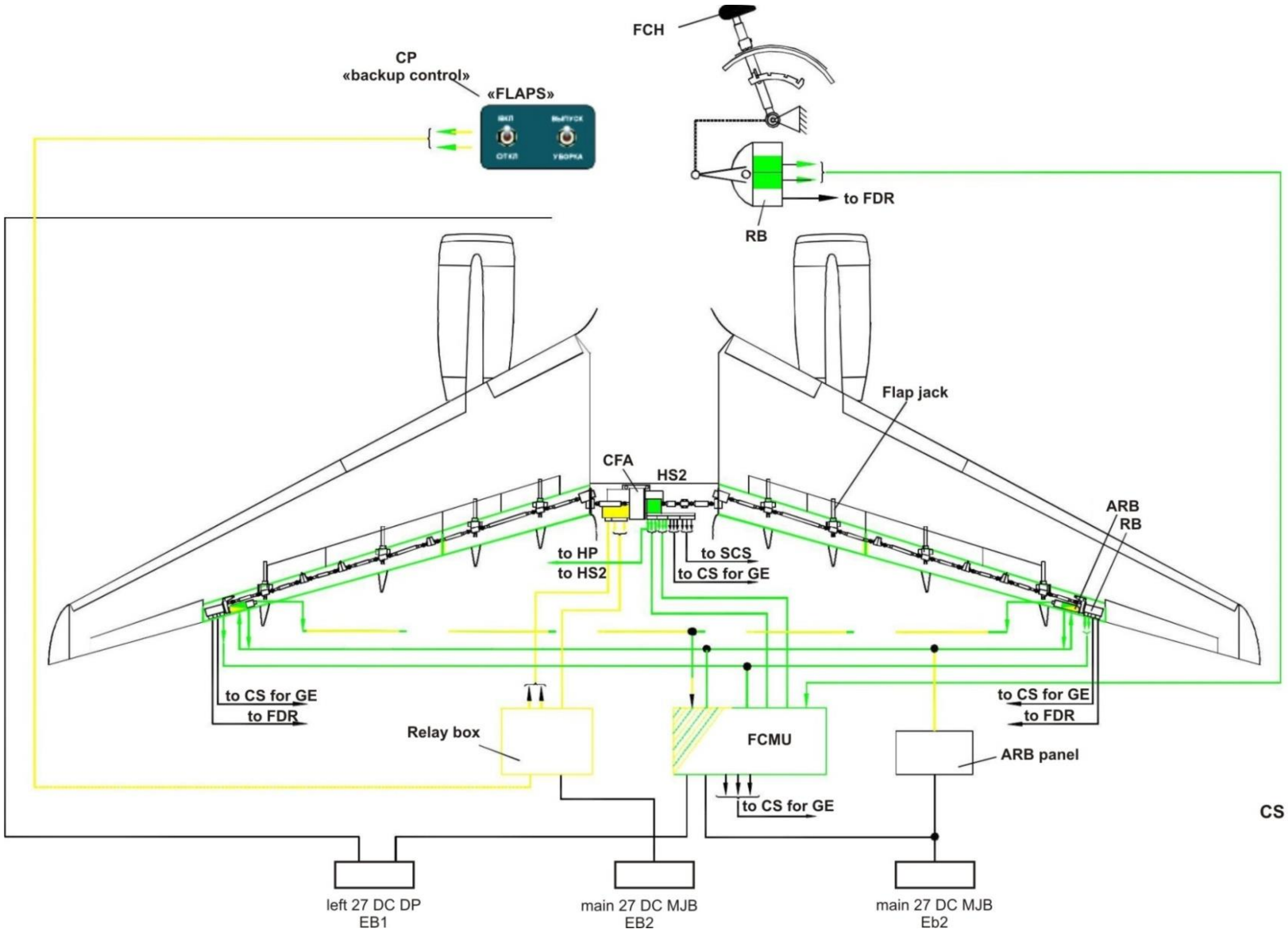
Anti-retracting brakes are fixed at the outer ends of the transmission links, that prevent retracting of the flaps, and flaps position sensors that transmit feedback signals to the control unit (such as "БУКЗ-140-01 (BUKZ-140-01)").

FCS can operate in two modes: main and backup. Switching between control modes is performed by the "FLAPS ON – OFF" switch.

In the main mode, the FCS provides tracking control in accordance with the position of the control handle for flaps and slats using the control unit "БУКЗ-140-01 (BUKZ-140-01)" and the MCD hydraulic motor.

The flap and slat control handle (FCH) has the following fixed positions: 0º, 10º, and 40º; a two-way stop is installed in the 20º position.

In the backup mode, the release and retracting of the flaps is performed using the signals of the "RETRACT – RELEASE FLAPS" switches using the HLDCD electric motor.



main fly-by-wire control loop (follow-up operation mode)

backup fly-by-wire control loop (relay mode)

FCH – flap control handle

CA – combined flap actuator

TLC – torque limiting clutch

FCMU – flap control and monitor unit

ARB – anti-retraction box

RB – resistor box

SCS – slat control system

HS2 – hydraulic system

EB1, EB2 – emergency DC buses

CS for GE – control system for ground equipment

Fig. 2.43. Flap Control System. Schematic Diagram

In the main and backup control modes, the HLDCD is switched off and the transmission is locked under these conditions:

- ♦ The asymmetry of the flaps;
- ♦ Offset of flaps from the desired position;
- ♦ Movement of the flaps in the opposite direction to the desired one.

When you enable anti-retracting brakes the main and backup control subsystems are turned off.

In case of jamming, the flaps and transmission surfaces are protected from increased load from the output shaft of the HLDCD by means of torque-limiting clutches.

The "БУКЗ-140-01 (BUKZ-140-01)" control unit transmits signals about the status of the WLESCS for displaying messages on the MFI and MFDS of the MMD system.

WLESCS is powered from a DC system with a voltage of 27 (28) V and hydraulic power from HS2.

2.3.11 The Deflected Wing LE and Slats Control System (WLESCS)

The WLESCS is designed to control the movement of the surfaces of the retracted LE of the wing and slats. Mechanisms of movement of surfaces are linked with the mechanical transmission consisting of ball-and-screw actuators, gear-rack mechanisms, reducers and rigid shafts driven by the output shaft of the high-lift devices combined drive (HLDCD of type "КПМ-148Н (KPM-148N)").

The combined drive is identical to that used in the flap control systems.

On the outer ends of the transmission links are installed anti-brakes that prevent the deflection of retracted LE of wing and slats, and position sensors that transmit feedback signals to the control unit (type "БУКЗ-140-01 (BUKZ-140-01)").

The deflected wing LE and slats control system can operate in two modes: main and standby. Switching between control modes is made by means of the "SLATS ON / OFF" switch.

In basic mode, the deflected wing LE and slats control system provides monitoring control in accordance with the regulation on the FCH with the help of the control unit "FCMU" and hydraulic motor of the combined drive.

There are two fixed positions of the surfaces: retracted and released.

In the backup mode, the releasing and retracting leading edges and slats is carried out on the signals of the switches "RETRACT – RELEASE LDG EDGE" with the help of a combined drive electric motor.

In the main and backup control modes, it is possible to switch off the combined driver and block the transmission under the following conditions:

- Asymmetry of surfaces;
- Shift of surfaces from a given setting;
- Movement of surfaces in the opposite direction.

The main and standby control subsystems are switched off when the anti-brakes are turned off.

In case of seizure, the surfaces and transmissions are protected from increased load by the output shaft of the combined driver by means of torque-limiting clutch.

The FCMU control unit transmits the status of the WLESCS for displaying messages on the multifunction indicator and MFDS of the MMD system.

The WLESCS is powered from a DC system with a voltage of 27 (28) V and hydraulic power from the HS2.

The following is a list of evidentiary documents for the An-148-100/An-158 family of aircraft control systems:

- Engineering analysis of the documentation which regulate the flight and technical operation of the An-148-100 to meet the requirements of the CB-148 Certification Basis.
- The An-148-100 aircraft. Certificated tests for the determination of flight performance, manoeuvrability, stability and controllability. Control system evaluation. Technical Report.
- The An-148-100 aircraft. Special certificated flight tests in conditions of natural icing. Technical Report.
- The An-148-100 aircraft. Special certificated ground and flight tests in conditions of high temperatures and high altitude. Technical Report.
- The An-148-100 aircraft. Special certificated ground and flight tests to determine whether the characteristics of the aircraft meet the general requirements of

Airworthiness Standards when simulating failures of functional systems. Technical Report.

- The An-148-100 aircraft. Layout of the crew cabin. Engineering Analysis.
- The An-148-100 aircraft. In-cab display system. Engineering Analysis.
- The An-148-100 aircraft. Certificated tests for evaluating the crew cabin layout. Technical Report.
- The An-148-100 aircraft. Research on the ИПС-148 (IPS-148) characteristics of the An-148-100 to assess the implementation of the General requirements for airworthiness of the CB-148 in the event of failures of the control system and hydraulic system. Technical Report.
- The An-148-100 aircraft. Characteristics of stability and controllability capabilities in case of functional system failures. Technical Report.
- The An-148-100 aircraft. Certificated ground and flight tests to determine vibration and shock loads acting on the onboard equipment and airframe structure. Technical Report.
- The An-148-100 aircraft. Certificated ground and flight tests to determine the levels of acoustic noise that affects on-board equipment. Technical Report.
- The An-148-100 aircraft. Certificated ground and flight tests to determine the influence of external factors on equipment. Technical Report.
- The An-148-100 aircraft. Certificated ground tests to determine the specifications. Technical Report.
- The An-148-100 aircraft. Conclusion of the compliance of the standard design of the aircraft with the requirements of CB-148 under the conditions of static integrity. Engineering Analysis.
- Conclusion of establishing the initial assigned resources and service life of the airframe, landing gear, engines and mechanical elements of control systems and changing the configuration of the aircraft of the standard design. The An-148-100 – 10 000 flights and 20 000 flight hours, 10 years under the conditions of structural integrity during long-term operation.
- Conclusion of Certification Centre "Material" on the compliance of materials used in the standard design of the An-148-100 with the requirements of 25.603, 25.609 and 25.613 of CB-148.

- The An-148-100 aircraft. Validation of the aircraft's compliance with the requirements of 25.581 (a*) (2), 25.672 (a*), 25.1316 and 25.1431 (a*) of the CB-148 in part of system 027 "Flight Control System". Engineering Analysis.
- The An-148-100 aircraft. Summary report on the analysis and calculation of the probability of occurrence of failure types of modules.
- The An-148-100 aircraft. Fire safety considerations of a standard design aircraft in areas with flammable liquids.
- The An-148-100 aircraft. Analysis of the consequences of unlocalized engine disintegration and APU, calculation of the level of risk of catastrophic damage to the aircraft structure and its systems.
- Approval of components of category "B" for the use on the An-148-100 aircraft.
- The An-148-100 aircraft. Certificated ground and flight tests of aircraft electrical system and lighting facilities. Technical Report.
- The An-148-100 aircraft. Certificated bench running of wheel control system WCS-148. Technical Report.
- The An-148-100 aircraft. Certificated bench running of the FCS-148 flap control system. Technical Report.
- The An-148-100 aircraft. Certificated bench running of the deflected leading edges and slat control system SCS-148. Technical Report.
- The An-148-100 aircraft. Validation of the An-148-100 compliance with the requirements of 25.677 (a), (c), Standard Specifications / 148-25.677 (b), 25.685 (a*, b*), (c*), 25.689, 25.697 (a), (b), (c) of the CB-148. Engineering Analysis.
- The An-148-100 aircraft. Validation of compliance of the An-148-100 with the requirements of 25.607 (b), 25.609 of the CB-148 Certification Basis for ensuring the protection of structural elements from environmental impact and abrasion in the control system. Engineering Analysis.
- The An-148-100 aircraft. Validation of compliance of the An-148-100 with the requirements of 25.685 (a), (b), (c) of the CB-148 Certification Basis for ensuring space between the airframe structure and parts, assemblies and units of the control system. Engineering Analysis.
- The An-148-100 aircraft. Validation of compliance of the An-148-100 with the

requirements of 25.671 (b) of the CB-148 Certification Basis with marking the parts, assemblies and units of the control system. Engineering Analysis.

- The An-148-100 aircraft. Validation of compliance of the An-148-100 with the requirements of the CB-148 Certification Basis for ensuring retracting of the wing high-lift devices surfaces from the fully released position during stable flight and maximum sustained engine power at a speed of VF + 16.5 km/h. Engineering Analysis.
- The An-148-100 aircraft. Engineering analysis of control systems for compliance with the requirements of 25.671 (c) of the CB-148 Certification Basis.
- The An-148-100 aircraft. Validation of compliance of the An-148-100 with the requirements of 25.671 (c) (3) of the CB-148 Certification Basis when one of the control panels in the control system is seized in critical flight conditions. Engineering Analysis.
- The An-148-100 aircraft. Validation of compliance of the An-148-100 with the requirements of 25.671 (c) (3) of the CB-148 Certification Basis when the control slider of one of the two rudder drives is seized in the control system. Engineering Analysis.
- The An-148-100 aircraft. Validation of compliance of the An-148-100 with the requirements of 25.607 of the CB-148 Certification Basis in a part of the control system (introduction of double locking). Engineering Analysis.
- The An-148-100 aircraft. Validation of compliance of the An-148-100 with the requirements of 25.671 (d) of the CB-148 Certification Basis in a part of the control system (flight in case of all engines failure). Engineering Analysis.
- The An-148-100 aircraft. Validation of the An-148-100 aircraft type compliance (An-148-100A, An-148-100B, An-148-100E models) with the requirements of 25.1301 (c) and 25.1301 (a*) of the CB-148 Certification Basis in a part of control system (027) for operating conditions on prepared runways. Engineering Analysis.
- Approval of imported components of category "B" for the use on the An-148-100 aircraft. Technical Report.

2.3.12 Main Conclusions on the Flight Control System

1. In the aircraft family An-148-100 / An-158 an innovative flight control system is

applied, which is characterized by:

- ♦ The power-boost irreversible control system is powered only by two hydraulic systems. Instead of additional hydraulic systems to power the control surfaces drivers the energy of two centralized AC electrical systems are used;
- ♦ The system uses combined drives that are powered from both one of the two centralized hydraulic systems, and from a centralized electrical system with three-phase alternating current of 115 V / 400 Hz. Combined drives are used for deflecting multi-functional spoilers, flaps, slats, as well as backup drives for elevators and rudders.

2. The validated system technical solutions allowed to provide:

a) Decrease of the installation weight of the equipment;

b) Optimization of power consumption of the flight control system;

c) Improving environmental safety by significantly reducing the volume of toxic hydraulic fluid;

d) Increasing the survivability of the aircraft due to the heterogeneous reservation of power energy of the control surfaces drives.

2.4 CONCLUSIONS

1. The concept, principles and methods of integrated designing of regional passenger aircraft have been developed.

2. The design method is tested with using the parameters of aircraft An-148. Comparison of the calculation results using the proposed method with the parameters of existing aircraft of the An-148 series indicates the correctness of the developed method and the calculation results.

3. The results of calculations indicate that all the main specifications of the aircraft are better than the characteristics of aircraft analogues of the Embraer and Bombardier companies. In addition, the aircraft has many advantages, such as the ability to operate on airfields with insufficiently prepared and unpaved runways, the presence of a ramp door, high protection of engines from damage by foreign objects, a high level of passenger comfort and large overhead lockers, high operational efficiency. These advantages ensure a high level of competitiveness of the aircraft in the world market.

4. The concept of creating a power plant has been developed. The design of the power plant (main and auxiliary engines and their control systems) allows the operation of the An-148-100/An-158 at airfields with height of up to 4 100 m. In order to save engine lifetime and save fuel when taking off from long-length runways, take-off at the maximum speed is imposed. To reduce the load on crew members, this mode is automatized.

5. In the An-148-100/An-158 aircraft family is used an innovative flight control system, which differs in this way: the power-boost irreversible control system is powered only by two hydraulic systems. Instead of additional hydraulic systems to power the actuator drives of the control surfaces, power is used from two centralized AC electrical systems; the system uses combined drives that are powered from both one of the two centralized hydraulic systems, and from a centralized electrical supply system with three-phase alternating current of 115 V / 400 Hz. Combined actuators are used to deflect multi-functional spoilers, flaps, slats, as well as backup drives to drive elevators and a rudder.

Chapter 3
NEW DECISIONS TO PROVIDE CHARACTERISTICS OF REGIONAL PASSENGER AIRPLANES

3.1 FEATURES OF PROVIDING AERODYNAMIC CHARACTERISTICS OF A REGIONAL PASSENGER PLANE

The creation of a new regional jet aircraft for 75 – 85 passengers was conditioned by the need of the passenger air transport market, in first of all in the CIS countries, caused by the suspension of fleet flights of morally and physically outdated Tu-134 aircraft due to their unprofitable operation, as well as by the aviation noise and emission rules inconsistency of their characteristics.

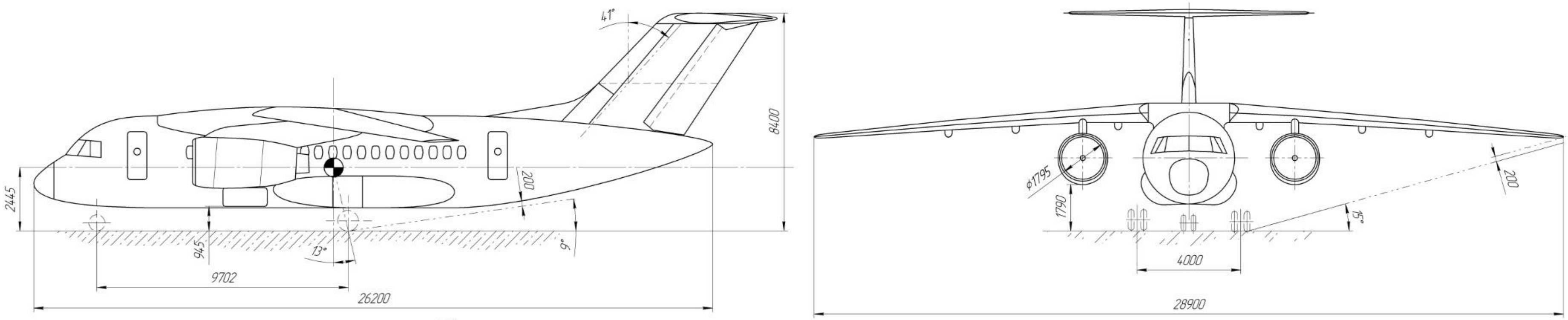
The relevance of creation a new regional jet aircraft for our state is confirmed by the fact that such topic was included in the activities of the "State Comprehensive Program for the Development of the Aviation Industry of Ukraine until 2010", approved by the Cabinet of Ministers from 12.12.2001 No. 1665-25, and partially funded in the development of the An-148-100, as well as capital costs for the organization of aircraft production.

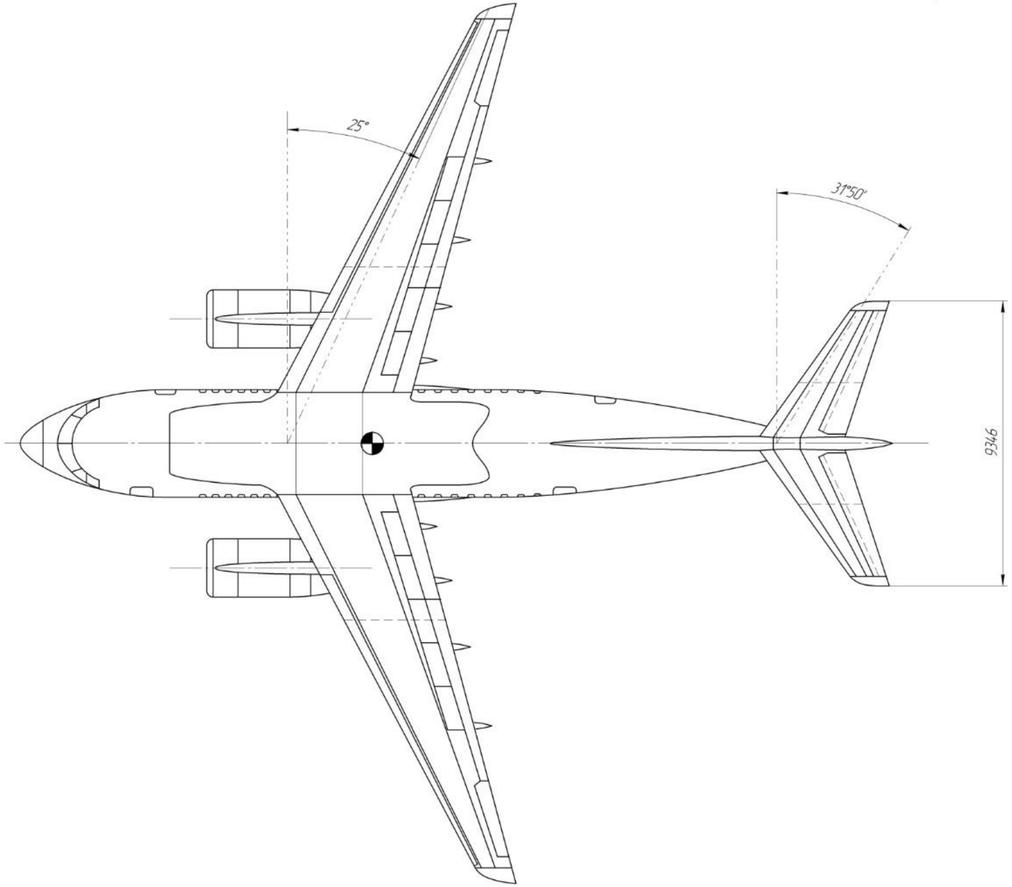
Creating a modern regional jet passenger aircraft ensuring its aerodynamic characteristics is an important task [36, 42].

This section presents the main results of the computational and experimental studies on the aerodynamic characteristics of the regional passenger aircraft, which were conducted at the ANTONOV Company when creating the An-148-100/An-158 types of aircraft.

3.1.1 Computational Research on the Selection of Aerodynamic Layout of Aircraft

Main requirements for flight enroute characteristics and the location of the An-148-100/An-158 types of regional aircraft (Fig. 3.1, 3.2) (An-148-100A, An-148-100B, An-148-100E and An-158) were initially determined by the Chief Designer approved mission requirements, which set control values for such parameters as cruise altitude and flight speed, practical flight distances with different payload, maximum operational speed V_{MO}, as well as conditions of landing - the required runway lengths for take-off and landing.





Льотні дані	1	$M_{крейс}$		0,725
	2	$H_{крейс}$	км	12,5
	3	$V_{пос}$	км/год	240
	4	$L_{роз.}$	м	600
	5	$L_{дmax}$	км	3900
Масові дані	6	$m_{порожн}$	кг	26154
	7	$m_{злітна}$	кг	35054
	8	$m_{комерц}$	кг	8500
	9	$n_{ек.}$	чол	5
	10	$n_{пас}$	чол	80
Дані СУ	11	P_0	даН	12760
	12	t_0		0,37
	13	Кількість і тип двигунів		2ХТРДД
Геометричні дані	14	$S_{крила}$	$м^2$	87,32
	15	$S_{го}$	$м^2$	18,95
	16	$S_{во}$	$м^2$	19,91
	17	$\eta_{крила}$		4,045
	18	$\chi_{крила}$		$27{,}9^0$
	19	$\lambda_{крила}$		9,495
	20	$D_{фюзеляжу}$	м	3,35
	21	$\lambda_{фюзеляжу}$		7,82

Fig. 3.1. Appearance of Modern Regional Passenger Aircraft

Fig. 3.2. The An-148-100B Modern Regional Passenger Plane

The safe operating conditions of the aircraft were to be ensured by the performance of the CB-148 Certification Basis, which contains the AP-25 requirements of the CIS (Commonwealth of Independent States) and the European CS-25 Aviation Rules.

Achievements of the necessary flight performance, stability and controllability were provided, first of all, by the reliably developed aerodynamic layout of the aircraft and its main unit – wings.

A large part of the aerodynamic configuration relates to the stage of synthesis of an airplane configuration (since it determines its appearance) and has its goals [74]:

– Achieving the maximum value of aerodynamic quality in cruise flight or in the main operational mode of the aircraft;
– Providing the necessary take-off and landing characteristics;
– Ensuring standardized reserves of stability and controllability in all flight modes;
– Guaranteed provision of safe and efficient operation of the aircraft power plant;
– Ensuring security at the entrance (random) to the limiting flight modes.

The following goals are achieved [74] by:

– Optimal aerodynamic layout of individual aircraft units, such as a wing or a engine nacelle, which is an independent complex task;
– Reduction of aerodynamic quality losses on balancing by selecting a rational aircraft balancing scheme;
– The selecion of relative positioning of the aircraft units, that provides their favorable interference (aerodynamic interaction);
– Using the carrying capacity of the units projecting into the stream, by selecting

their optimal angle of attack (incidence);

– The choice of rational parameters and the location of the horizontal and vertical tail unit, taking into account their "non-shadowing" on critical flight modes;

– The location of the air intakes in the areas with a stable air flow without major vortices and pressure losses;

– The location of the turbojet engine nozzles in the areas providing favorable interference of the jet with the aircraft units on the main (cruising) flight modes;

– Elimination of the harmful effect of the downwash from the flaps on other units of the aircraft (for example, on engine nacelles located on the tail part of the fuselage).

Aerodynamic Layout of the Wing Development. Planes of the An-148-100/ An-158 types are made according to the high-wing scheme with a T-shaped tail and with two D-436-148 turbojet bypass engines mounted on pylons under the wing.

Due to a comprehensive analysis of aerodynamic, structural, technological and other requirements, the following (compromise) wing geometric characteristics were selected:

– Wing area S = 87 m^2;

– Trapezoidal shape in planview of the wing without front and rear extensions;

– Aspect ratio λ = 9.58;

– Taper ratio η = 4.05;

– 1/4 chord sweep $\chi_{1/4}$ = 25°.

The computational studies were performed using modern three-dimensional numerical CFD (TsAGI software) wing design techniques that significantly reduced the amount of pipe testing. The number of basic airfoils, the profiles themselves, the angles of geometric twisting, the laws of formation of the outer surface, the parameters of the relative position of the wing and fuselage and other characteristics were optimized during the computational studies.

At the end of the computational studies, four wing variants in the flight configuration were selected: K19A, K21A, K23A, and K20A for comparative experimental studies of the T-106M wind tunnel (WT) of TsAGI in a wide range of Mach and Reynolds numbers.

In 2000 to 2001 the model of the An-148 aircraft with four wing variants – K19A, K20A, K21A and K23A has been tested in WT T-106M TsAGI. The maximum reached critical Mach number (when $dC_{x_{sw}}/dM = 0.1$) $M_{cr} = 0.785$ at $C_y = 0.45$ was provided by the K19A wing. At a cruising Mach number of $M = 0.78$, the maximum values of the maximum lift coefficient $C_{y_{max}}$ and critical angle of attack α_{cr} of the full model were also provided by the K19A wing.

The aerodynamic layout of the K19A wings was based on the P-68a supercritical airfoils developed at the ANTONOV Company (Fig. 3.3).

Theoretical contours of the upper and lower surfaces of the K19A wing are formed on seven base airfoils on spline dependences along the wing span.

The maximum relative thickness of the wing airfoils gradually decreases from the value $\bar{c}_{max}$ = 15.5 % in the cross section to $\bar{c}_{max}$ = 11 % in the final cross section. The use of such "thick" supercritical airfoils at a sufficiently high value of wing aspect $\lambda = 9.58$ provided a high level of aerodynamic characteristics of the aircraft at all stages of flight. With a considerable relative thickness of the airfoils of the integral tank of the wing increases the capacity of the wings located in the integral tank of a wing of the fuel tanks, which ensures that the specified range of flight.

It should be noted that the maximum relative thickness of the wing profiles K19A of An-148-100 / An-158 aircraft is greater than the relative thickness of the wings of aircraft Airbus A320 and An-124 (Fig. 3.4).

The refinement in the process of constructing the angle of setting of the wing from 2.2 to 3 ° and change in the position of the axis of the wing geometric twisting by 15 % in the chord plane led to the modification of the wing, which was designated as K19-4A (wing angle of setting φ_{set} = 3 ° minimizes aerodynamic drag of the aircraft and provides the necessary position of the fuselage in flight α_f = 1…2 °).

A comparison of the study results of the wing airfoil section of the An-148 aircraft in the wind tunnel ADT-106M TsAGI with prototypes (airfoils developed in TsAGI) showed a significant advantage of the wing airfoil P-68a4 ($\bar{c}_{max}$ = 11.3 %) for all evaluated parameters:

– The value of the critical Mach number;

– Lifting power $C_{y_{max}}$, $C_{y_{add}}$;

– The value of effective concavity ($\Delta\alpha_0$ = 0.6 °);

– The magnitude of the reduced aerodynamic quality K_r (at C_y = 0.5; M = 0.78).

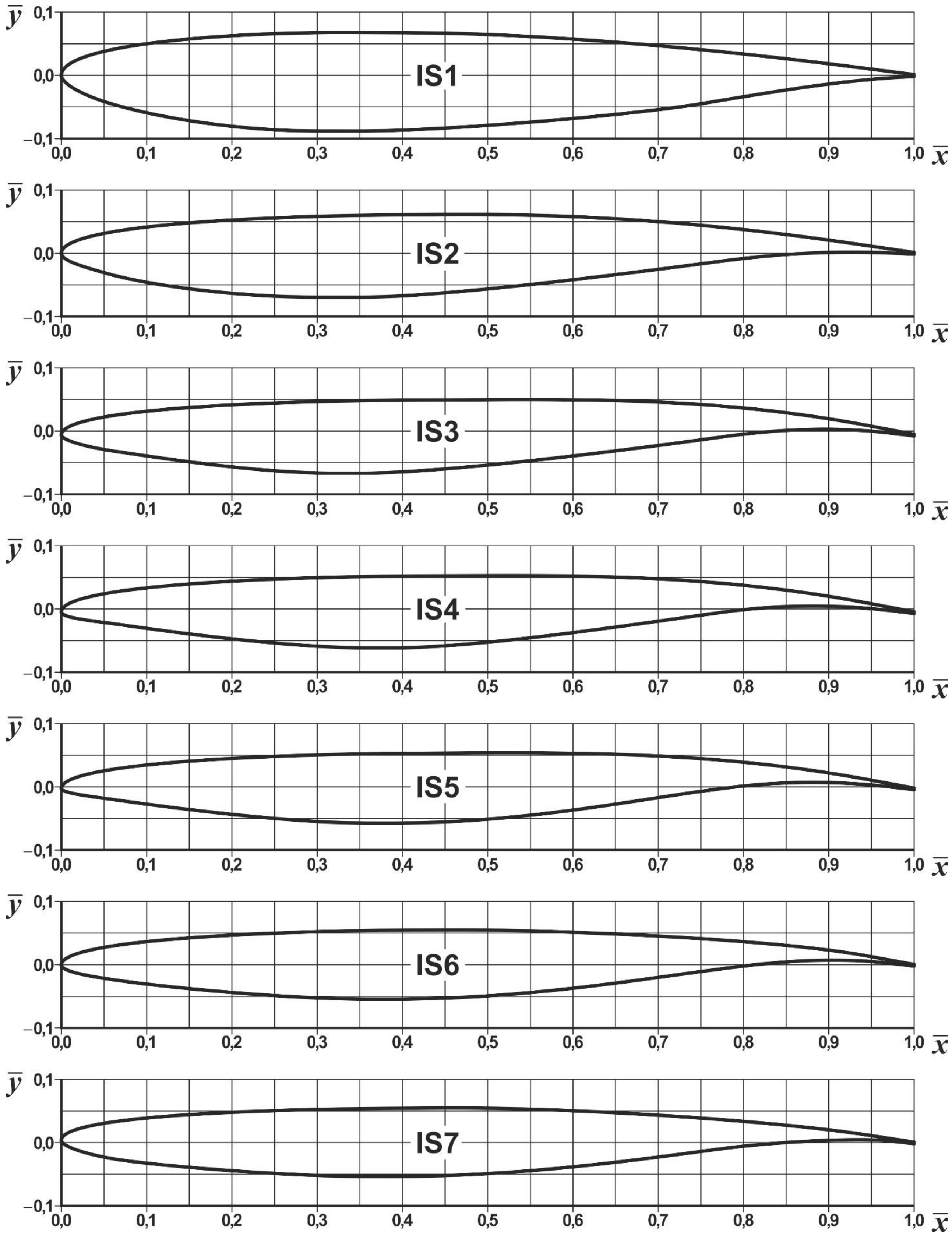


Fig. 3.3. Wing Shapes of Aircraft

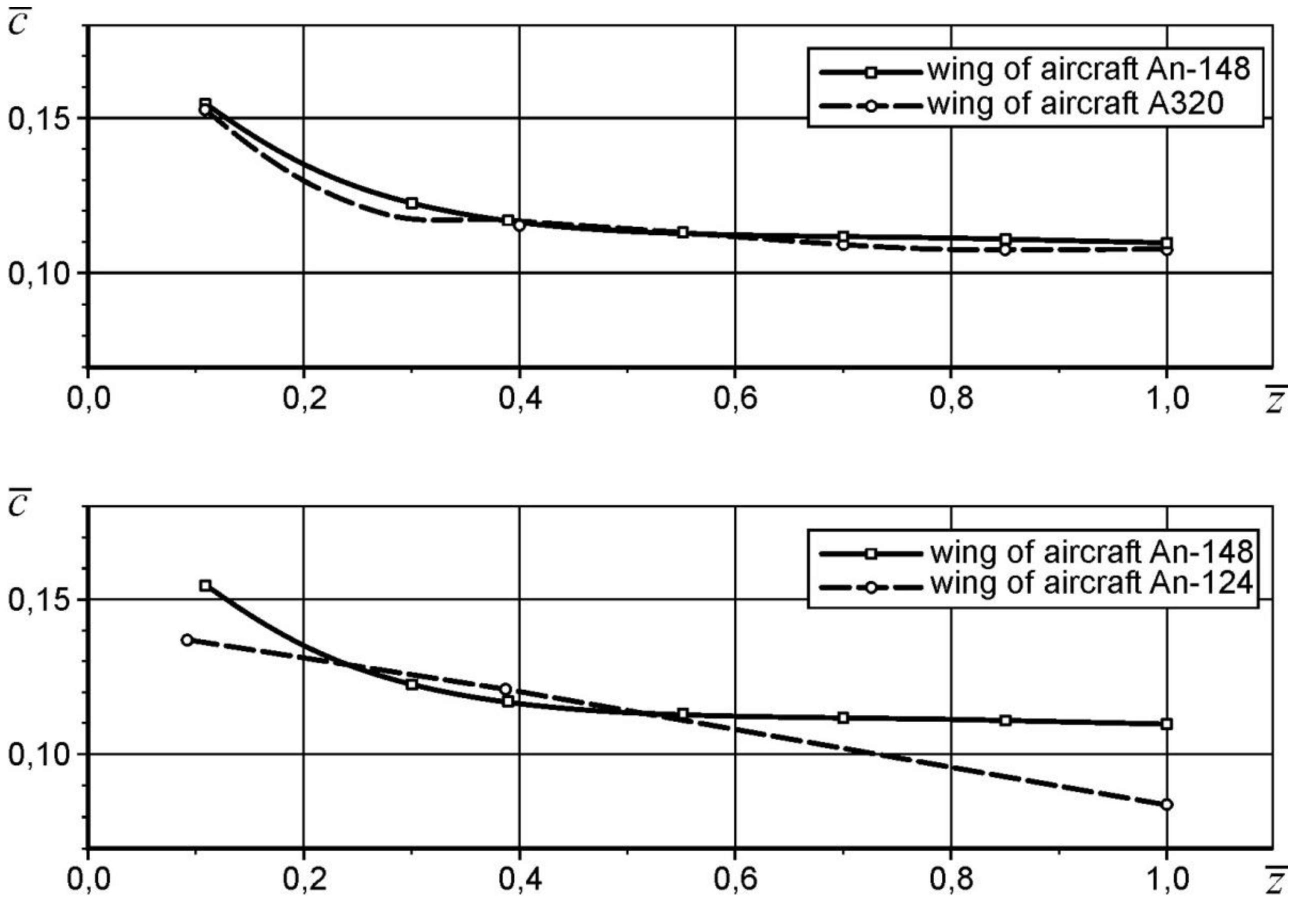


Fig. 3.4. The An-148 Aircraft. Airfoil Thickness
vs Aspect Ratio

On the basis of a comprehensive comparative analysis of the obtained blowdown results, the K19A wing was selected for further aircraft design.

To ensure the required height of the passenger compartment, the wing centre section on the An-148-100 / An-158 aircraft is not "recessed" into the fuselage, but is located above the fuselage.

Computational and experimental studies have shown that, with a typical wing-to-body fillet Z1 for such a high wing position relative to the fuselage on cruise modes of flight in the area of the wing centre section, a system of normal shocks propagating along the wingspan appeares with the increase of the M number value. Thus, new variants of fillets to increase the M number critical value and decrease the shock wave – fillets Z2, Z3, Z4, Z7 and Z8 – have been developed. Therefore, in compliance with the results of complex aerodynamic and weight analysis the aerodynamic layout of fillet Z4M, which provided the necessary value of the critical M number have been developed.

After approval of the aerodynamic layout of the aircraft in the cruise (flight) configuration by the Chief Designer, the aircraft executive model has been designed and manufactured for testing in the T-106M high-speed wind tunnel of TsAGI.

Based on the results of these tests, the initial aerodynamic characteristics of the aircraft have been calculated to determine the flight characteristics, as well as the stability, controllability and flight dynamics characteristics of the aircraft in flight configuration.

The cruise aerodynamic quality of the An-148 ($M = 0.75$; $C_y = 0.5$) is $K = 15.8$, obtained by the results of the executive model in the T-106M WT of TsAGI and confirmed by flight tests of the experimental aircraft. The achieved level of aerodynamic excellence of the aircraft ensured the fulfillment of the set requirements for the maximum speed and altitude of cruise flight, as well as the range of flight with different payload.

In terms of aerodynamic excellence, the An-148-100/An-158 aircraft family is not inferior to its foreign analogues (Fig. 3.5).

The aerodynamic layout of the An-158 aircraft differs from that of the basic An-148 aircraft in some features – an elongated fuselage that provides the cabin capacity up to 99 passengers and wing-mounted end aerodynamic surfaces.

Aerodynamic Design of Wing High-Lift Devices. The high lifting properties of the airplane wing at take-off and landing modes are ensured by the use of effective high-lift devices of the trailing edge of the wing by using the slotted flaps and high-lift devices of the leading edge of the wing by using the slats and deflected leading edge.

During the preliminary design phase of the An-148-100 aircraft, based on the main requirements for aircraft grounding, large-scale parametric studies have been performed on the choice of wing high-lift devices type and its parameters (relative span, relative chord, relative extensions and deflection angles on landing modes), including viscosity and separation flow.

In order to carry out experimental parametric studies in the AT-1 wind tunnel of the ANTONOV Company, for further optimization of the parameters of wing high-lift devices, a rectangular mechanized wing section has been made on the characteristic cross section of the wings of the relative span of $Z = 0.55$.

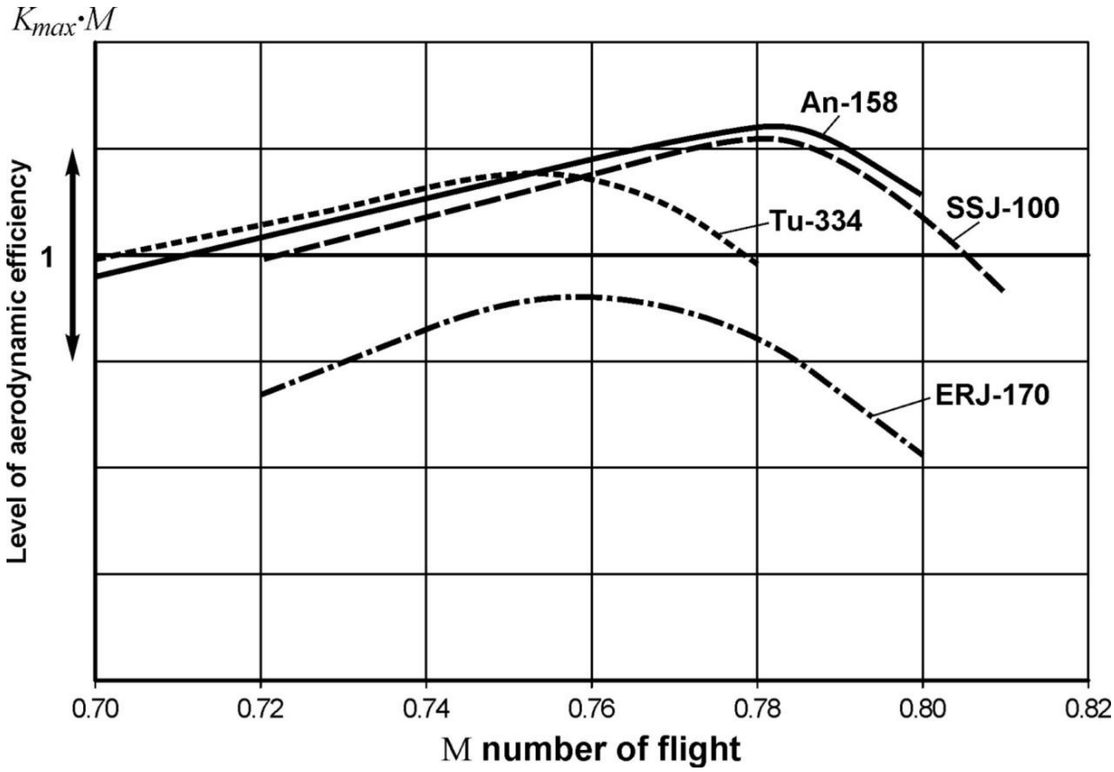


Fig. 3.5. Comparison of Aerodynamic Quality Level of Regional Aircraft

According to the results of analytical and experimental studies, the aerodynamic layout of the aircraft wing high-lift devices has been developed, which formed the basis for the mathematical model preparation and the theoretical drawings of the wing leading edge and trailing edge.

Accepted and installed on the aircraft wing high-lift devices are made in the form of two-slotted flaps with a fixed deflector, slotted slats on half-wing and non-slotted rotary (deflected) LE in the area between ribs 3 and 7 of the half-wing.

As a result of the studies of the high-lift devices of the wing leading edge, the maximum LE angle of deviation is adopted as follows: $\delta_{WLE} = 22°$ (in flight direction), and its relative chord $\bar{b}_{WLE} = 0.096 \ldots 0.108$. The maximum angle of deflection of the slats is $\delta_S = 19\,°$, and the relative chord of a flap is $\bar{b}_S = 0.133$ through 0.1674. To increase the efficiency of the slats, their controls and hinges are made compatible.

Flaps with relative chord $\bar{b}_f = 0.28 \ldots 0.30$ and relative span $\bar{l}_f = 0.6415$ are produced by a conical law. For take-off, the angles of deflection of the flaps are accepted as $\delta_f = 10$ or $20\,°$, for landing the angles of deflection of the flaps are $\delta_f = 20$ or $40\,°$.

On both half-wings, the wings have five sections of spoilers. The relative chord of spoilers is $\bar{b}_{SP}$ = 0.148. Two internal sections of the spoilers (on each half-wing) with a maximum deflection angle δ_{SP} = 50 ° help in braking. The three outer sections of the spoilers (on each half-wing) with a maximum deflection angle of δ_{SP} = 40 ° function as electronic, glide, and brake spoilers.

A mechanized model of the aircraft for testing has been designed and manufactured in the AT-1 wind tunnel of the ANTONOV Company. The maximum values of lift coefficients $C_{y_{max}}$ achieved in these tests for the landing position of wing high-lift devices when recalculated to Reynolds natural numbers provided the values of the take-off and landing speed characteristics for which the landing requirements were fully met. As a result of these tests, the initial aerodynamic characteristics have been calculated to determine the runway characteristics, as well as the stability, controllability and flight dynamics characteristics.

3.1.2 Design and Development Works to Provide the Required Characteristics of Aircraft Stability, Controllability and Dynamics of Flight

Required stability, controllability and flight dynamics characteristics of the An-148-100/An-158 (An-148-100A, An-148-100B, An-148-100E, An-158) aircraft family are provided with aircraft aerodynamic layout and automatic controls of the wheel conrol system.

For the An-148-100/An-158 aircraft family, a tail unit scheme with a horizontal stabilizer on the top of the fin has been selected. This scheme allows to reduce the size of the tail, reduce tail drag and improve the aerodynamic efficiency of the aircraft. To simplify the design of the aircraft a stabilizer is fixed, the issues of pitch trim and control are solved using an elevator with a large relative chord. The rationality of this variant of the decision is confirmed by many years of experience in operating the An aircraft (An-74, An-124, etc.). To solve the problems of yaw trim of the airplane in flight with asymmetrical thrust, the rudder of a large reference chord has been used. The roll controls consist of ordinary ailerons and aileron-spoilers, which are deflected wing surfaces; and they are located above the LE of extandble slotted flaps. Such aileron-spoilers, whose efficiency increases with increasing flap deflection angle, provide the necessary roll angular velocity in all flight modes, including aircraft landing mode.

To obtain reliable aerodynamic characteristics of the aircraft, which affect its stability and controllability, a large volume of weight tests of the aircraft model was performed in the T-106M high-speed wind tunnel of TsAGI and the mechanized model in the AT-1 WT of the ANTONOV Company. The influence of ice formation on the aerodynamic characteristics of the aircraft was investigated on the model of the isolated tail of the aircraft, the model of a half-wing with aileron and the wing compartment with a flap. The characteristics of the hinged torques of the aircraft controls were investigated on the same models.

In order to reduce the size and weight of the tail of the An-148-100/An-158 family of aircrafts, the concept has been implemented according to which the aircraft is designed with reduced reserves of its own pitching stability and yawing static stability.

Stability, controllability and flight dynamics compliance with the requirements of Airworthiness Standards is provided by automatic systems for improving the stability and controllability of the aircraft. To solve this issue, the An-148-100/An-158 aircraft has a digital fly-by-wire control system (FWCS).

Complete failure of the FWCS in the longitudinal and directional axes or all hydraulic systems of the aircraft is permitted. In these cases, the control system goes from basic to standby control. Aircraft pitch and yaw control is performed via mechanical linkage and autonomous actuators (AA). The roll control is carried out using aileron-spoilers, which are deflected by autonomous servo units (SERVO) on signals through electrical wiring.

The aircraft's own static stability reserves, the efficiency of its controls and the kinematics of the control system ensure the safe completion of the flight in the standby control mode.

In the longitudinal and directional axes of the standby mechanical control system, steering columns and pedals are used to connect the control levers to the autonomous actuators. To simplify the design, the load feel mechanism of the control levers are made in the form of simple ("passive") springs. In this regard, trimming efforts on control levers in all axes is performed by replacing the signal of the control lever moving by the deviation of the control from the trim selector. All the algorithms of the FWCS operation are also implemented due to the deflection of the respective control unit. A similar principle for the formation of the FWCS algorithms has been mastered on transport aircraft An-70.

The algorithm of operation of the wheel control system of the aircraft in the main and standby control modes is formed as a result of numerous calculations, simulations and researches on a flight simulator (FS) with the participation of pilots. The results of this work are outlined in the requirements in part of aerodynamics and flight dynamics to the wheel control system of the An-148-100/An-158 aircraft family.

The elevator control system in the main control mode provides for:

– Change of gears in control algorithms according to flap position and flight speed;
– Increase in longitudinal static stability according to the values of flight speed and M number;
– Improving the characteristics of static controllability in accordance with the values of acceleration and dynamic stability, depending on the signal of the angular velocity of the pitch;
– Limiting the angle of attack by the system of limiting the boundary mode OGR-α;
– Tactile input (steering wheel shake) when approaching the stall mode.

The rudder control system in the main control mode provides for:

– Change of gears in control algorithms according to flap position and flight speed;
– Limiting the slip angle by the OGR-nZ system;
– Damping oscillations in the yaw channel, including interconnected lateral oscillations (Dutch pitch);
– Coordinated movement when controlling ailerons and rudder.

The transverse control system in the main mode provides for:

– Change of nonlinear kinematic dependences according to the position of flaps and flight speed;
– Damping oscillations in the roll axis.

The stability, controllability and flight dynamics of the An-158 aircraft according to the results of the computational and experimental studies, as well as the flight tests, are virtually indistinguishable from those of the An-148-100 aircraft.

3.1.3 Mathematical Modeling of Flight Performance and Stability and Controllability Performance

During the stages of aerodynamic design of the aircraft, its flight tests and the preparation of evidentiary documentation for certification, mathematical models of aircraft movement were used, based on the following:

- Aerodynamic characteristics of the aircraft obtained by recalculating the characteristics of analog aircraft, and according to the results of tests of aerodynamic models of the aircraft in the AT-1 wind tunnel of the ANTONOV Company and T-106M WT of TsAGI;
- Geometric and mass-inertial characteristics;
- High-speed thrust-consumption characteristics of the power plant;
- Known equations for moving the airplane as a material point and as a body with six degrees of freedom.

With the help of these mathematical models, implemented in the form of a set of programs, such calculations were performed:

- Take-off and landing characteristics with different positions of wing high-lift devices under expected operating conditions at different runway (RWY) surface conditions;
- En-route flight performance, both in dry air and in icing conditions;
- Performance of stability, controllability and dynamics of flight.

All calculations have been performed both under conditions of normal functioning of engines and aircraft systems, and with various functional failures.

The mathematical models of flight performance obtained based on the test results of models in wind tunnels have been tested and refined in the course of certification flight tests.

The creation of mathematical models of the flight performance of the aircraft, which correspond to its actual characteristics, allowed to significantly reduce the volume and duration of flight tests, to determine the flight performance of the aircraft for the expected operating conditions.

Among the basic flight performance of the An-148-100/An-158 family of aircraft are the following:

– Operation at aerodromes with different coverage conditions, including poorly prepared ground and snowfields;
– Provision of take-off / landing at high altitude airfields (up to 4 100 m altitude) and at high ambient air temperatures;
– Take-off on low engine modes (to improve service life performance);
– Cruising flight at altitudes up to 12 200 m;
– Providing flight altitudes with one engine running up to 4 000 to 6 000m, which ensures safe operation in high mountains and at high ambient temperatures;
– Cruising flight at speeds of 800 to 850 km/h TAS (true airspeed), which reduces flight time and increases aircraft operation.

The maximum speed of cruising flight is 870 km/h TAS;

– Low hourly fuel consumption when performing level flight – 1510 to 840 kg/h;
– Possibility of landing according to category IIIA ICAO.

The flight performance determined by mathematical models were used to form the Flight Maintenance Manual.

The main flight performance of the An-148-100/An-158 aircraft family (models An-148-100A, An-148-100B, An-148-100E and An-158) are shown in Table 3.1.

The compliance of the stability, controllability and flight dynamics characteristics of the An-148-100 / An-158 family of aircraft with the AP-25 Airworthiness Standards for the standard operation of the FWCS is confirmed by calculations and studies carried out on a flight simulator of the An-148-100 / An-158 family of aircraft (FS-148). The characteristics of stability, controllability and flight dynamics of the aircraft in failure situations have been investigated using the calculations and the flight simulator.

Calculation of the stability and controllability performance of the aircraft, mathematical modeling of flight dynamics and synthesis of control system algorithms were performed using specialized software developed by the ANTONOV Company.

During the flight tests, minor correction has been made to the algorithms of the FWCS.

Consequently, certification flight tests of the An-148-100/An-158 family of aircraft have confirmed the full compliance of their stability, controllability and flight dynamics with the requirements of the Certification Basis for both normal and emergency situations submitted for flight tests.

Table 3.1

Main Performances of Regional Passenger Aircraft Family

No.	Performances	An-148-100/An-158 Aircraft Family Д-436-148Д (D-436-148D) Engine			
		An-148-100A	An-148-100B	An-148-100E	An-158
1	Airplane Weight, kgf:				
	– maximum take-off	38 950	41 950	43 700	43 700
	– maximum landing	37 800		38 800	
2	Maximum payload, kgf	9 000		9 800	
3	Characteristics of Deployment:				
	– aerodrome class	A, B, C			
	– airfield altitude above sea level, m	up to 2 200			
	– state of the artificial runway (ARWY) ($\mu \geq 0.3$):	– dry, wet, covered with thin layer of water; – with separate areas of stagnant water; – covered with hoarfrost or frost; – covered with slush layer of up to 15 mm; – with a layer of dry snow – no more than 50 mm thick; – with a layer of dry snow – no more than 50 mm thick			
4	Take-off characteristics (ARWY, $\mu \geq 0.6$, SA, H=0, calm, $\delta_{flap} = 20°$):				
	– take-off run, m	1 050	1 235	1 335	1 335
	– take-off distance up to H = 10.7 m, m	1 365	1 595	1 725	1750
	– Balanced field length (Stopway = 400 m), m	1 485	1 730	1 885	1 900
5	Route characteristics:				
	Maximum altitude, m	12 200		11 580	
	Cruising altitude, m	10 100…12 200		10 100…11 580	
	TS (true speed), maximum cruising speed (maximum continuous power rating, H = 10 100 m), km/h	870			
	TS, cruising speed with cruising power rating, km/h	800…850			
	Hourly fuel consumption at cruising altitude and speed, kg/h	1 640… …1 510	1 760… …1 510	1 840… …1 510	1 840… …1 560

Table 3.1 (End)

<table>
<tr><td rowspan="2">No.</td><td rowspan="2">Performances</td><td colspan="4">An-148-100/An-158 Aircraft Family
Д-436-148Д (D-436-148D) Engine</td></tr>
<tr><td>An-148-100A</td><td>An-148-100B</td><td>An-148-100E</td><td>An-158</td></tr>
<tr><td rowspan="10"></td><td colspan="5">Practical range ($G_{t-off\ \max}; H_{opt}; V_{opt}$; fuel reserve– 1300 kg), km:</td></tr>
<tr><td>♦ with maximum load</td><td>1 240
(9000 kgf)</td><td>2 570
(9000 kgf)</td><td>3 290
(9000 kgf)</td><td>2 270
(9800 kgf)</td></tr>
<tr><td rowspan="2">♦ with passengers *)</td><td>1 940
(80 pas.)</td><td>3 280
(80 pas.)</td><td>3 990
(80 pas.)</td><td>2 460
(99 pas.)</td></tr>
<tr><td>2 180
(75 pas.)</td><td>3 520
(75 pas.)</td><td>4 240
(75 pas.)</td><td>2 930
(89 pas.)</td></tr>
<tr><td>♦ with maximum fuelling/number of passengers*</td><td>5 220/16</td><td>4 890/47</td><td>4 700/65</td><td>4 110**)/ 64</td></tr>
<tr><td>♦ ferry flight distance</td><td colspan="2">5 460</td><td colspan="2">4 880
fuel reserve**)</td></tr>
<tr><td>Technical range, km:
♦ with N passengers;</td><td>2 860/75</td><td>4 200/75</td><td>4 920/75</td><td>3 310/99</td></tr>
<tr><td>♦ maximum fuelling / number of passengers</td><td>5 970/16</td><td>5 600/47</td><td>5 400/65</td><td>4 950/64</td></tr>
<tr><td>Fuel efficiency, g/pas×km</td><td>28.04
(80 pas.)</td><td>27.73
(80 pas.)</td><td>28.03
(80 pas.)</td><td>24.65
(99 pas.)</td></tr>
<tr><td rowspan="3">6</td><td colspan="5">Landing characteristics (ARWY; $\mu \geq 0.6$; $H_{aer} = 0$; SA; calm; glideslope $\theta = -3°40'$; wing configuration $\delta_{flap} = 40°$):</td></tr>
<tr><td>♦ landing run, m</td><td colspan="2">765</td><td colspan="2">795</td></tr>
<tr><td>♦ RWY required length, m</td><td colspan="2">1 950</td><td colspan="2">2 045</td></tr>
</table>

*) – weight of one passenger with baggage is accepted equal to 95 kgf;
**) – fuel reserve for 1 flight hour at altitude above the airfield.

Aircraft as control objects in normal and emergency situations have been highly appreciated by the pilots, which are an important factor in the formation of orders for these aircraft by potential operators.

Below a list of technical reports, engineering analyzes and technical informative papers is given concerning aerodynamics, performances, air stability, controllability and flight dynamics of An-148-100/An-158 aircraft:

♦ The An-148-100 aircraft. Aerodynamics. Book 1. Flight characteristics. Part 1.

Aerodynamic Design Source Data. Technical Report.

- An-148-100 aircraft. Aerodynamics. Book 1. Flight characteristics. Part 2. Take-off, landing and enroute characteristics. Technical Report.
- The An-148-100 aircraft. Aerodynamics. Book 1. Flight characteristics. Part 5. Drag Calculation. Technical Report.
- The An-148-100 aircraft. Aerodynamics. Book 2. Stability, controllability and flight dynamics. Part 1. Source data for calculation of stability, controllability and flight dynamics characteristics. Technical Report.
- The An-148-100 aircraft. Aerodynamics. Book 2. Stability, controllability and flight dynamics. Part 2. Features of stability, controllability and flight dynamics. Technical Report.
- The An-148-100 aircraft. Aerodynamics. Book 2. Stability, controllability and flight dynamics. Part 3. Features of stability and controllability under conditions of stalling, nose spinning and nose diving after spinning. Technical Report.
- The An-148-100 aircraft. Characteristics of stability and controllability in the separation of main power plant. Engineering Analysis.
- The An-148-100 aircraft. Justification of possibility to remove the anti-icing system from the horizontal tail provided that the required characteristics of longitudinal stability and controllability are maintained. Engineering Analysis.
- The An-148-100 aircraft (Ан-148-100А, Ан-148-100В, Ан-148-100Е Models). Aerodynamic characteristics. Part 1. Engineering data for performance computation. Engineering Analysis.
- The An-148-100 aircraft (An-148-100A, An-148-100B, An-148-100E Models). Aerodynamic characteristics. Part 2. Engineering data for computation of stability, controllability and flight dynamics characteristics. Engineering Analysis.
- The An-148-100 aircraft (An-148-100A, An-148-100B, An-148-100E Models). Performances in expected operating conditions. Engineering Analysis.
- The An-148-100 aircraft (An-148-100A, An-148-100B, An-148-100E Models). Critical time interval with engine and automatic engine control system being failed. Technical Informative Note.

- The An-148-100 aircraft (An-148-100A, An-148-100B, An-148-100E Models). Compliance of Aircraft Equipped with TCAS-2000 system with the СТУ (STU)/148-F.1.1.3.18,19 CB-148 Certification Basis requirements: PERFORMANCES. Engineering Analysis.
- The An-148-100 aircraft (An-148-100A, An-148-100B, An-148-100E Models). Features of stability and controllability in conditions of natural icing. Engineering Analysis.
- The An-148-100 aircraft. Aerodynamics. Main results of structural, wind tunnel and flight tests (1999 – 2005). Technical Report.
- The An-148-100 aircraft (An-148-100A, An-148-100B, An-148-100E Models). Friction coefficient when braking on a wet artificial runway. Engineering Analysis.
- The An-148-100 aircraft (An-148-100A, An-148-100B, An-148-100E Models). Stability and maneuverability characteristics on an artificial runway covered with precipitation. Engineering Analysis.
- The An-148-100 aircraft (An-148-100A, An-148-100B, An-148-100E Models). Flight characteristics in icing conditions. Engineering Analysis.
- The An-148-100 aircraft (An-148-100A, An-148-100B, An-148-100E Models). Take-off/landing characteristics on artificial runways covered with precipitation. Engineering Analysis.
- The An-148-100 aircraft (An-148-100A, An-148-100B, An-148-100E Models). Estimated dive rate. Speed characteristics. Unbalanced Aircraft Characteristics. Engineering Analysis.
- The An-148-100 aircraft. Features of stability and controllability at failures of functional systems. Technical Report.
- The An-148-100 aircraft (An-148-100A, An-148-100B, An-148-100E Models). Minimum control speeds. Engineering Analysis.
- The An-148-100 aircraft. Comparison of calculated and experimental original take-off and landing trajectories for noise certification. Technical Informative Note.
- The An-148-100 aircraft (An-148-100A, An-148-100B, An-148-100E Models). Calculation of the air exchange level in tail unit fire hazardous areas. Technical

Informative Note.

- ♦ The An-148-100 aircraft (An-148-100A, An-148-100B, An-148-100E Models). Evaluation of Hazard Degree Under Conditions of Unit Destruction. Engineering Analysis.
- ♦ The An-148-100 aircraft (An-148-100A, An-148-100B, An-148-100E Models). Performances under conditions of functional system failures. Engineering Analysis.
- ♦ The An-148-100 aircraft (An-148-100A, An-148-100B, An-148-100E Models). Compliance with requirement 25.1001(a) of CB-148: emergency fuel drainage system. Technical Informative Note.
- ♦ The An-148-100 aircraft (An-148-100A, An-148-100B, An-148-100E Models). Stability and buoyancy in case of emergency landing on water. Technical Report. VSS-100 Computing Aircraft Piloting System. An-148-100 Aircraft (An-148-100A, An-148-100B, An-148-100E Models) Performances. Technical Report.
- ♦ The An-148-100 aircraft (An-148-100A, An-148-100B, An-148-100E Models). Performances in expected operating conditions with increased take-off weight and increased weight without fuel. Engineering Analysis.
- ♦ The An-148-100 aircraft (An-148-100A, An-148-100B, An-148-100E Models). Stability and controllability characteristics during landing. Engineering Analysis.
- ♦ The An-148-100 aircraft (An-148-100A, An-148-100B, An-148-100E Models). Calculation of maximum allowable wind speed for taxiing. Engineering Analysis.
- ♦ The An-148-100 aircraft (An-148-100A, An-148-100B, An-148-100E Models). Take-off/landing, stability and controllability characteristics when operated on unpaved runways. Engineering Analysis.
- ♦ The An-148-100 aircraft (An-148-100A, An-148-100B, An-148-100E Models). Determination of influence of external surface configuration deviations on the "configuration/deviation list" project upon the aerodynamic characteristics and performances. Engineering Analysis.
- ♦ The An-148-100 aircraft (An-148-100A, An-148-100B, An-148-100E Models,

Ан-158). Compliance with the CB-148 requirements on performances, stability and controllability characteristics in connection with implementation of the "Increase in base aerodrome altitude" main modification of type design. Engineering Analysis.

- The An-148-100 aircraft (An-148-100A, An-148-100B, An-148-100E Models). Take-off/landing characteristics with one wheel brake system being disconnected and one MLG brake system being failed. Engineering Analysis.
- The An-148-100 aircraft (An-148-100A, An-148-100B, An-148-100E Models). Compliance with the CB-148 requirements with regard to performances, stability and controllability characteristics in connection with implementation of the "Increase of maximum landing weight to 37 800 kgf" main modification of type design. Engineering Analysis.
- The An-148-100 aircraft (An-148-100A, An-148-100B, An-148-100E Models). aircraft take-off characteristics on artificial runways covered with precipitation, at $V_1 < V_R$. Engineering Analysis.
- The An-148-100 aircraft (An-148-100A, An-148-100B, An-148-100E Models). Evaluation of airplane functional system failure influence in connection with implementation of the "Increase of maximum landing weight to 37 800 kgf" main modification of type design (wheel steering mode). Engineering Analysis.
- The An-148-100 aircraft (An-148-100A, An-148-100B, An-148-100E Models). aircraft performances when flying with landing gear being extended. Engineering Analysis.
- The An-148-100B aircraft. Performances with maximum take-off weight increased up to 42.55 tons. Engineering Analysis.
- The An-158 aircraft. Design data for calculation of Performances. Research&Technical Report.
- The An-158 aircraft. Performances. Research&Technical Report.
- The An-158 aircraft. Features of stability, controllability and flight dynamics. Research&Technical Report.
- Comparison of stability, controllability and flight dynamics characteristics of the An-158 and An-148-100 aircraft based on flight test done under conditions being subjected in approaching according to ICAO I, II, and IIIA categories.

Research&Technical Report.

- ♦ The An-158 aircraft. Buoyancy and stability in emergency landing on water. Engineering Analysis.
- ♦ The An-158 aircraft. Stability, Controllability and Flight Dynamics. Engineering Analysis.
- ♦ The An-158 aircraft. Performances. Engineering Analysis.
- ♦ The An-158 aircraft. Aerodynamic characteristics based on flight test results. Engineering Analysis.
- ♦ The An-158 aircraft. Comparative analysis of the An-158 and An-148-100 aircraft aerodynamic characteristics to evaluate consequences of the An-158 functional system failures. Engineering Analysis.
- ♦ The An-158 aircraft. VSS-100 Computing Aircraft Piloting System. Performances. Technical Report.
- ♦ The An-148-100 aircraft type (An-158 model). Compliance with CB-148 requirements for performances, stability and controllability in connection with implementation of the "Increase of maximum landing weight to 37 800 kgf" main modification of type design. Engineering Analysis.
- ♦ The An-158 aircraft. Airplane flight characteristics when flying with non-retracted landing gear. Engineering Analysis.
- ♦ The An-148-100 aircraft (An-148-100A, An-148-100B, An-148-100E, An-158 Models). Compliance with the CB-148 requirements with regard to take-off characteristics in connection with implementation of the "Performing take-off with engine power less than take-off power" main modification of type design. Engineering Analysis.
- ♦ The An-148-100, An-148-200, An-158 Aircraft. Compliance with the CB-148 requirements with regard to performances, stability and controllability in connection with implementation of the "Increase in base aerodrome altitude over 2 200 m" main modification of type design. Engineering Analysis.

All these technical reports, engineering analyzes and technical informative papers are included in the list of required supporting documentation for the airplane further certification.

3.1.4 Experimental Aerodynamic Studies

Experimental aerodynamic studies are an important step in the development of the aerodynamic configuration of the An-148-100/An-158 aircraft family and for determination of their aerodynamic characteristics necessary to calculate the performances, as well as stability, controllability and flight dynamics characteristics.

Experimental aerodynamic studies of the An-148-100/An-158 aircraft family were conducted in the following wind tunnels (WT):

– AT-1 Subsonic WT at the ANTONOV Company;

– T-106M Transonic WT at TSAGI (Russian Federation).

AT-1 is a closed-loop subsonic wind tunnel with an open working section. The flow velocity in the wind tunnel working section was abvout 50 m/s to test the models.

The following types of tests were performed in the AT-1 wind tunnel:

- Weight tests to determine the total aerodynamic characteristics of aircraft models with both engine nacelle mock-ups and main engines simulators;
- Drainage tests to determine the pressure distribution pattern over the surfaces of the model parts;
- Tensometric tests for determining the hinge moments of the controls;
- Physical studies on the visualization of flow lines and flow patterns.

Figures 3.6 – 3.9 show photos of An-148-100 and An-158 aircraft models in the AT-1 WT working section when conducting experiments.

The T-106 is a closed-loop, continuous-acting, variable-density, transonic wind tunnel with a closed working section. The studies in this WT allowed to determine the effect of compression by Mach number (M number) and thickness of the boundary layer by Reynolds number (Re number) on the aircraft aerodynamic characteristics.

The flow velocity in the wind tunnel working section varied within the range of $M = 0.15 \ldots 0.9$, and the Re number varied within the range from $1.51 \cdot 10^6$ to $7.1 \cdot 10^6$ depending on the type of test.

The following types of tests were performed in the T-106M WT at TsAGI:

- Determination of the model total aerodynamic characteristics on electromechanical and tensometric scales;
- Measurement of pressure distribution on the model surface with electronic pressure modules;

– Physical studies on the visualization of flow lines and flow patterns.

Fig. 3.6. Visual Testing of An-148 Aircraft Model by Tuft Method in AT-1 Wind Tunnel

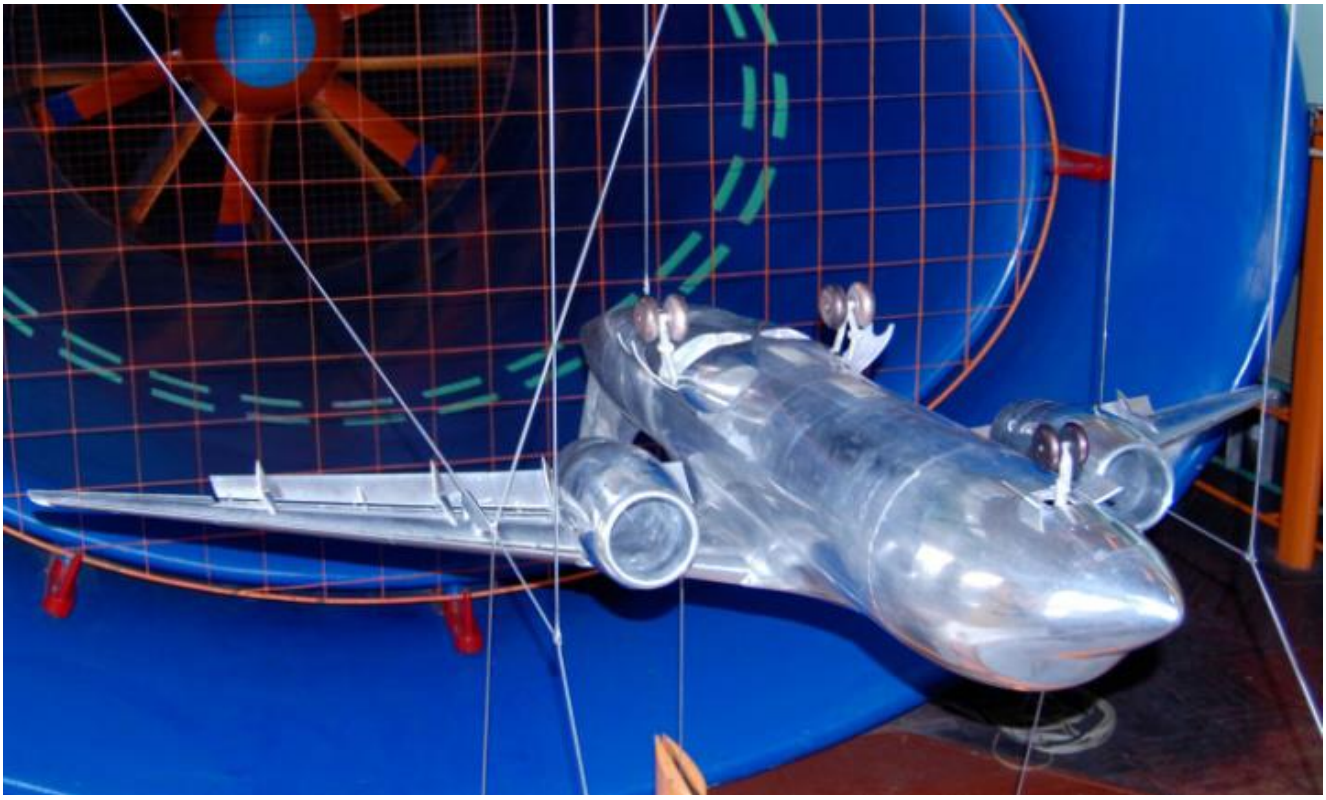


Fig. 3.7. An-148 Aircraft Model fitted with High-lift Devices in AT-1 Wind Tunnel

Fig. 3.8. An-158 Aircraft Model fitted with High-lift Devices
in AT-1 Wind Tunnel

Fig. 3.9. An-148 Aircraft Model Close to Screen in AT-1 Wind Tunnel

Figures 3.10 – 3.12 show photos of An-148-100 aircraft model in the T-106M working section at TsAGI when conducting experiments.

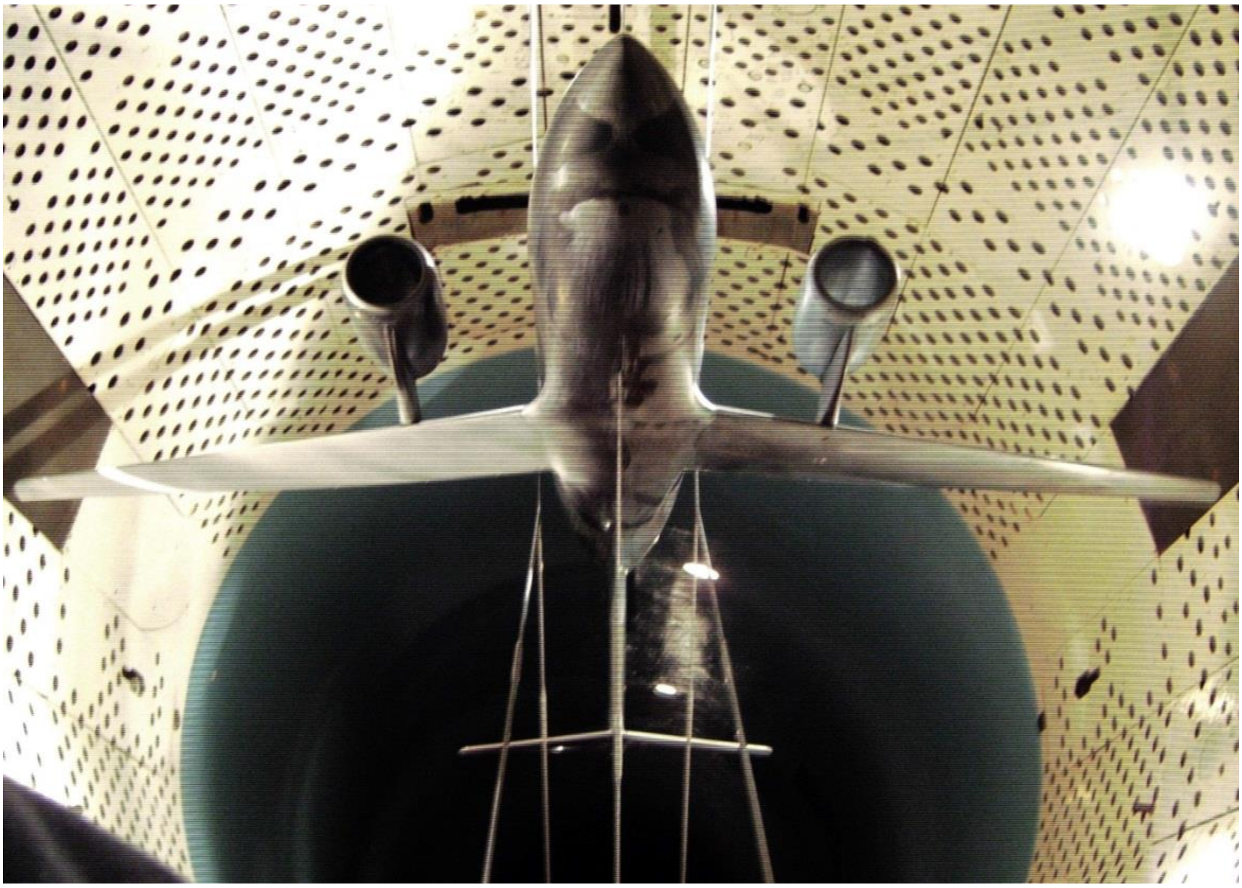


Fig. 3.10. Model of An-148-100 Aircraft
in the Working Section of WT T-106M of TsAGI. Weight Tests

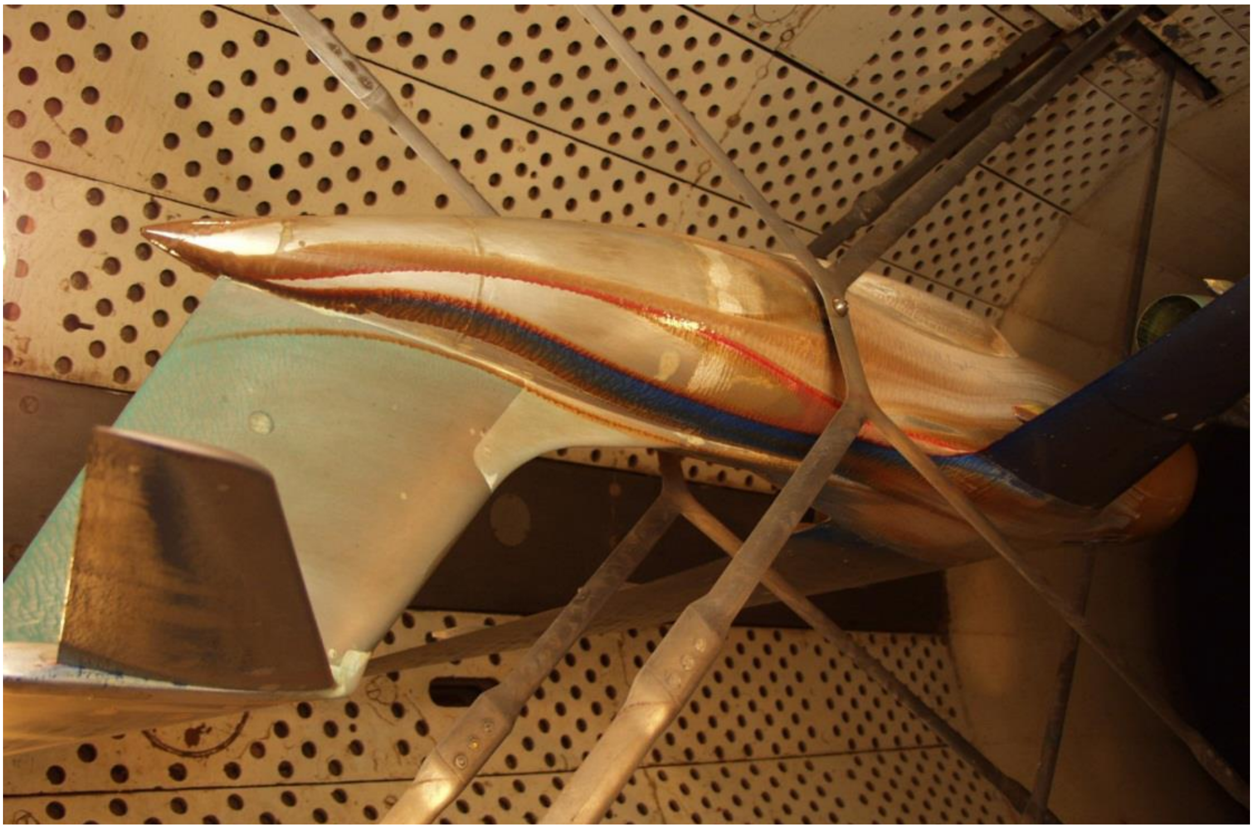


Fig. 3.11. Physical Studies of Flow about Model

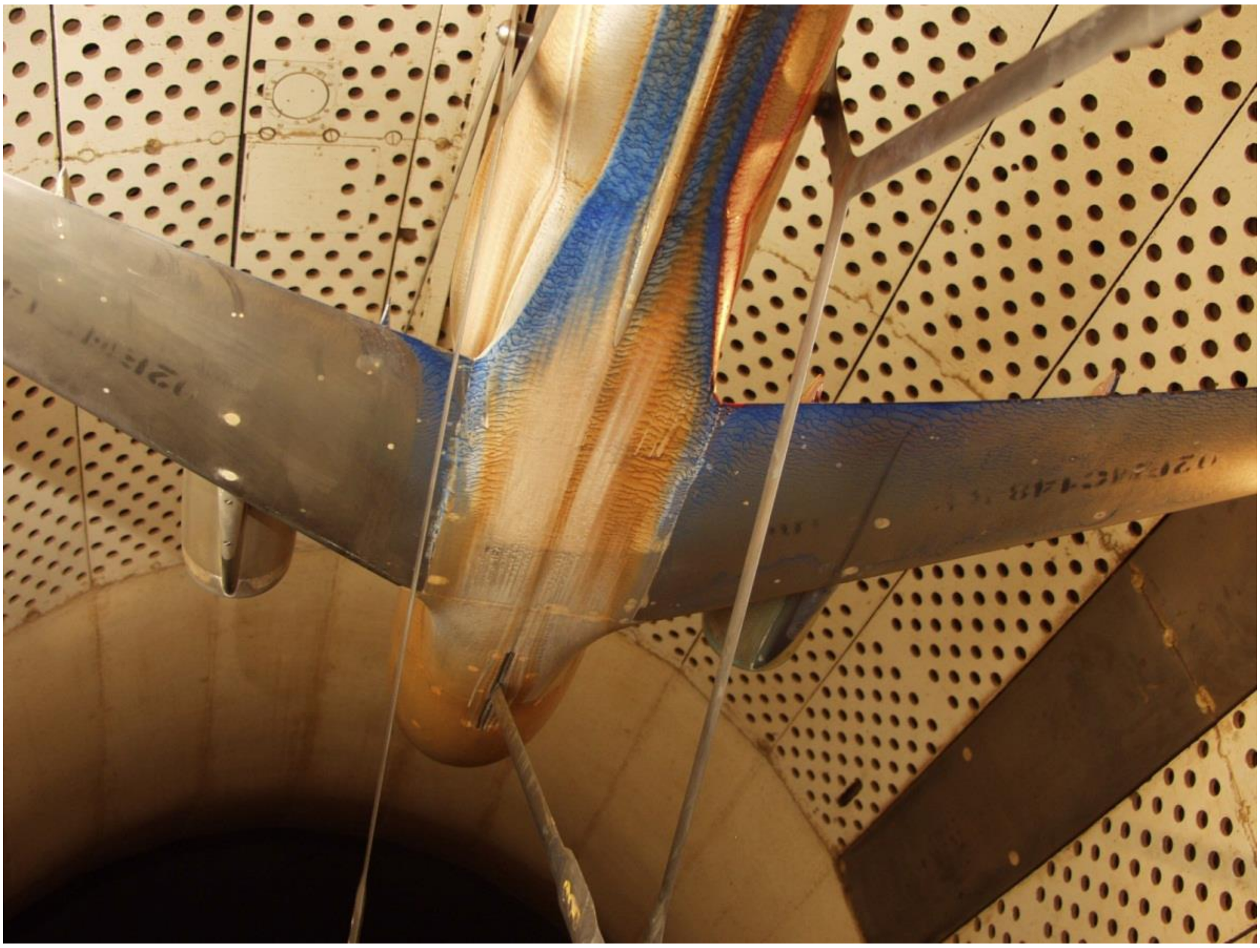


Fig. 3.12. Physical Studies of Flow about Model

Aircraft take-off/landing conditions were investigated in AT-1 WT using the following models:

- 03MS148.001 – complete model of aircraft fitted with high-lift devices, engine nacelle mock-ups and with propulsion engine simulators made in a scale of 1:12;
- 10MOK148.001 – section of wing fitted with high-lift devices having chord b = 0.5 m and two drainage sections;
- 08PMK148.001 – model of the wing console fitted with high-lift devices made in a scale of 1: 6 with strain gauges placed on spoilers and aileron;
- 04MNO148.001 – model of the separated tail unit made in a scale of 1:5 with strain gauges placed on rudders and elevators.

Studying of the flight cruise conditions and improvement of its aerodynamic configuration were performed in T-106 WT using the following models:

- 002(B,V,I) MS148.106 – full aircraft model in cruise configuration made in a scale of 1:16 and its modifications;

– 014MOK148.106 –wing airfoil section with chord b = 0.3 m and one drainage section;
– 007MS148.106 – complete drained aircraft model in cruise configuration in a scale of 1:16.

The characteristics of the aircraft spin and spin recovery motion were investigated in the T-105 wind tunnel of TsAGI on model 005MS148.105, made in a scale of 1:25.

To investigate the aircraft emergency landing on water, tests were done on model 006KMS148.GK at the stand of the TsAGI hydrodynamic laboratory.

Airplane models for all types of wind tunnel tests were designed and manufactured at the ANTONOV Company.

Total test duration of the models in AT-1 WT was 3800 hours, and in T-106 WT was 3350 hours.

Obtained results of aerodynamic studies were used to finalize the aerodynamic configuration of the whole aircraft and of its individual units.

Below a list of reports on the investigation of the aerodynamic characteristics of the AN-148 aircraft models in the AT-1 wind tunnel of ANTONOV Company is given:

♦ Investigation of the An-148 airplane model (02BMS148.106) in the AT-1 wind tunnel regarding improvement of local aerodynamics. Report.
♦ Results of experiments and design studies on the selection of prearrangement of the air pressure intake plates on An-148 aircraft. Technical Informative Note.
♦ Results of testing the rectangular section model (10MOK148.001) of the An-148 aircraft wing middle section in the AT-1 wind tunnel for determining the efficiency of high-lift devices. Report.
♦ AT-1 wind tunnel testing the efficiency of two types of reverser using the An-148 model engine simulators. Report.
♦ AT-1 wind tunnel test results of the An-148 wing section model (10MOK148.001) for determining the impact of flap & slat installation parameters upon their efficiency. Report.
♦ AT-1 wind tunnel test results of the An-148 selected configuration model fitted with high-lift devices. Report.

- ♦ AT-1 wind tunnel test results of the An-148 selected configuration model (03MS148.001) regarding efficiency of horizontal tail, rudder and elevator. Report.
- ♦ AT-1 wind tunnel test results of the An-148 selected configuration model with regard to determine the efficiency of ailerons and interceptors. Report.
- ♦ AT-1 wind tunnel test results of the An-148 model (03MS148.001) regarding elimination of pitch instability at subcritical angles of attack in cruising configuration. Report.
- ♦ AT-1 wind tunnel test results of the An-148 tail unit model (04MXO148.001) with regard to determine aerodynamic characteristics, effectiveness of the rudder and elevator and influence of ice simulators on the vertical and horizontal tail units. Report.
- ♦ AT-1 wind tunnel test results of An-148 rectangular wing section model (10MOK148.001) fitted with high-lift devices with regard to determine pressure distribution patterns and to evaluate the impact of an ice simulator. Report.
- ♦ Wind tunnel test results of An-148 model (03MS148.001) with regard to determine the aileron hinge moments, efficiency of the controls with flaps being set at 20°, and the lateral aerodynamic characteristics near ground. Technical Informative Note.
- ♦ Wind tunnel test results of An-148 model (03MS148.001) regarding the study of the trajectory of the emergency exit door motion for escape in emergency during factory tests. Technical Informative Note.
- ♦ AT-1 wind tunnel test results of the An-148 tail unit model (04MNO148.001) with regard to determine hinge moments of elevators and ruders as well as influence of ice simulators. Report.
- ♦ AT-1 wind tunnel test results of An-148 model (03MS148.001) with regard to determine local angles-of-attack within the area where angular sensors of angle-of-attack to be installed. Report.
- ♦ AT-1 wind tunnel test results of An-148 model (03MS148.001) with regard to determine aerodynamic characteristics when fitted with engine simulators operating at direct and reverse thrust. Report.
- ♦ AT-1 wind tunnel test results of An-148 model (03MS148.001) with regard

to determine efficiency of brake spoiler sections. Technical Informative Note.

- ♦ AT-1 wind tunnel test results of model 03MS148.001 with regard to determine pressure distribution on the fuselage tail part and nose LG doors. Technical Informative Note.
- ♦ AT-1 wind tunnel test results of An-148 model with regard to determine aerodynamic characteristics and efficiency of controls at high angles-of-attack. Report.
- ♦ AT-1 wind tunnel test results of An-148 model (02B.MS148.106) with regard to determine efficiency of vertical and horizontal wing airfoil surfaces. Technical Informative Note.
- ♦ AT-1 wind tunnel test results of An-148 wing section model (010MOK148.001) with regard to estimate the effect of ice simulators upon aerodynamic characteristics, which correspond to ice accretion with anti-ice system being failed. Technical Informative Note.
- ♦ AT-1 wind tunnel test results of An-148 model with regard to estimate effect of tabs upon flow about low emergency door. Technical Informative Note.
- ♦ Test results of An-148 model (03MS148.001) with regard to determine effect of ice simulators on fuselage nose upon aerodynamic characteristics, local angles-of-attack as well as values of total and static pressure within the area of placement of the onboard instrument receivers. Technical Informative Note.
- ♦ AT-1 wind tunnel test results of An-148 model (03MS148.001) with regard to determine effect of icing sensor model on the local angles-of-attack and total pressure at places of installation of flow angle sensors and the PPD-1M total pressure tube. Technical Informative Note.
- ♦ AT-1 wind tunnel test results of An-148 model (03MS148.001) on the study of the effect of engine nacelle vortex generators and wing partitions. Report.
- ♦ AT-1 wind tunnel test results of the An-148 wing section model (10MOK148.001) to evaluate the effect of ice simulators with different output on the airfoil nose upper surface. Technical Informative Note.
- ♦ AT-1 wind tunnel tests to determine the resistance of the D-436 engine rear attachment unit model of the An-148 aircraft. Technical Informative Note.
- ♦ AT-1 wind tunnel test results of the An-148 and An-74TK-300 aircraft models to study directional stability and efficiency of vertical tail unit. Report.

- AT-1 wind tunnel test results of the separated An-148 tail unit model (04MXO148.001) with regard to determine pressure distribution patterns. Technical Informative Note.
- AT-1 wind tunnel test results of An-148 aircraft drained model (07MC148.001) to determine the impact of displacement bodies installed in the pylon-to-wing area of contact. Technical Informative Note.
- AT-1 wind tunnel test results of An-148 aircraft model (03MS148.001) with ice simulators on the wing. Technical Informative Note.
- AT-1 wind tunnel test results of An-148 aircraft model (03MS148.001) on increasing lift in the landing configuration. Report.
- AT-1 wind tunnel test results of An-148 aircraft model (03MS148.001) to determine the spoiler efficiency for the various options of deflection of their sections. Technical Informative Note.
- AT-1 wind tunnel tests of the An-148 airplane wing console model (08PMK148.001) to determine influence of ice simulators on aerodynamic characteristics of model and hinged moments of aileron and spoilers. Research & Technical Report.
- AT-1 wind tunnel test results of An-148 aircraft model (03MS148.001) to study the flow of flammable fluids from drainage zones. Technical Informative Note.
- AT-1 wind tunnel test results of the An-148 wing section model (10MOK148.001) to evaluate the impact of a simulator of the residual ice forming on the wing upper surface beyond the heating zone. Technical Informative Note.
- AT-1 wind tunnel test results of the An-148 aircraft model to study the effects of vortex generators installed on the engine nacelles. Report.
- AT-1 wind tunnel test results of the An-148 wing console model (08PMK148.001) with regard to determine influence of end aerodynamic surface ZC6 on model aerodynamic surfaces and aileron hinged moments. Technical Informative Note.
- AT-1 wind tunnel test results of An-148 tail unit model (04MNO148.001) to determine influence of the ice simulator, which simulates ice accretion in the absence of anti-ice system on the horizontal tail unit. Technical Informative Note.

- ♦ AT-1 wind tunnel test results of An-148 model (03IMS148.001) in landing configuration regarding to means designed to prevent wing drop. Research&Technical Report.
- ♦ AT-1 wind tunnel tests of model 03KMS148.001 in landing configuration with regard to facilities intended to prevent wing drop. Research&Technical Report.
- ♦ AT-1 wind tunnel test results of the An-148 model (10MOK148.001) to evaluate influence of vortex generators on the high-lift device components. Report.
- ♦ The results of weight and drainage tests in the AT-1 wind tunnel of An-148 wing rectangular section fitted with high-lift devices (10MOK148.001) to evaluate influence of a deflected spoiler upon the model aerodinamic characteristics and pressure distribution patterns. Report.

The list of reports on the test results of the An-148-100 models in TsAGI:

- ♦ Post-flight Report. 002.MC74-68.106 model and wing K20A. ADT-106M Wind Tunnel Test Results.
- ♦ Post-flight Report. 002.MC74-68.106 model with wing K23. ADT-106M Wind Tunnel Test Results.
- ♦ Post-flight Report. 002.MC74-68.106 model with wing K21. ADT-106M Wind Tunnel Test Results.
- ♦ Post-flight Report. 002.MC74-68.106 model with wing K19A. ADT-106M Wind Tunnel Test Results.
- ♦ Post-flight Report. Additional test results to study influence of some elements of model 002.MC74-68.106 with wing K19A upon aerodynamic characteristics performed in ADT-106M Wind Tunnel.
- ♦ Post-flight Report. Test results studying the effects of the nose part (H3) and the wing-fuselage fairing (Z2) of model 002.MS74-68.106 including wing K19A upon aerodynamic characteristics in ADT-106M Wind Tunnel.
- ♦ Post-flight Report. Test results of studying influence of wing-to-fuselage fairing (Z2 and Z3t) of model 002.MC74-68.106 including wing K19A upon aerodynamic characteristics in ADT-106M Wind Tunnel.
- ♦ Research&Technical Report. Test results of studying influence of wing-fuselage fairing (Z2Д, Z4, Z6), LG fairing OSh5 and elongation of the fuselage cylindrical part upon the aerodynamic characteristics of model

002.MC74-68.106 including wing K19-4 in ADT-106M Wind Tunnel.

- Research&Technical Report. Test Results of model 002BMC148.106 including wing K19-4A in ADT-106M Wind Tunnel.
- Research&Technical Report. Results of experimental studies of the wing profiled compartment 14MOK148.106 of the An-148 model in ADT-106M Wind Tunnel.
- Research&Technical Report. Preliminary conclusion about the An-148 spinning maneuver.
- Report. Supplement to preliminary conclusion about the An-148 spinning maneuver.
- Visual studies of the An-148 preliminary model 002.MS74-68.106 in ADT-106M Wind Tunnel at TsAGI.
- Investigation of the An-148 model spinning maneuver characteristics in the T-105 vertical wind tunnel.
- Report. Test results of the An-148 selected configuration model in ADT-106M Wind Tunnel at TsAGI.
- Research&Technical Report. Study of the An-148 model landing on water.
- Post-flight Report. Determination of pressure distribution on the wing K19-4A, nacelles, pylons, flap actuator fairing. Book 1.1 (Wing – Part 1).
- Research Report. Processing and analyzing of test results of the An-148 drained model in ADT-106M Wind Tunnel at TsAGI.
- Report. Analysis of test results of the An-148 drained model on a belt suspension in ADT-106M Wind Tunnel at TsAGI.
- Post-flight Report. Determination of pressure distribution over the K19-4A wing, engine nacelle, pylon, flap actuator fairing. Book 1.2 (Wing – Part 2).
- Post-flight Report. Determination of pressure distribution over the K19-4A wing, engine nacelle, pylon, flap actuator fairing. Book 1.5 (Flap actuator fairing – Part 1).
- Post-flight Report. Determination of pressure distribution on the wing K19-4A, engine nacelle, pylon, flap actuator fairing. Book 1.6 (Flap actuator fairing – Part 2).
- Post-flight Report. Determination of pressure distribution over the K19-4A

wing, engine nacelle, pylon, flap actuator fairing. Book 1.7 (Flap actuator fairing – Part 3).

- Report. Processing and analyzing test results of the An-148 drained model in ADT-106M Wind Tunnel at TsAGI. Book 1 (Wing – Part 1).
- Report. Processing and analyzing test results of the An-148 drained model in ADT-106M Wind Tunnel at TsAGI. Book 2 (Wing – Part 2).
- Report. Processing and analyzing test results of the An-148 drained model in ADT-106M Wind Tunnel at TsAGI. Book 3 (Horizontal tail).
- Report. Experimental studies of the An-148 aerodynamic model 002IMS148.106 in the T-106M wind tunnel with variants of fairing and the MG-10 nacelle.
- Post-flight Report. Definition of pressure distribution over fuselage, horizontal and vertical tails, and fairing. Book 2.1.a (Fuselage – Part 1.a).
- Post-flight Report. Definition of pressure distribution over fuselage, horizontal and vertical tails, and fairing. Book 2.1.b (Fuselage – Part 1.b).
- Post-flight Report. Definition of pressure distribution over fuselage, horizontal and vertical tails, and fairing. Book 2.2.a (Fuselage – Part 2.a).
- Post-flight Report. Definition of pressure distribution over fuselage, horizontal and vertical tails, and fairing. Book 2.2.a (Fuselage – Part 2.b).
- Research Report. Estimated studies of the An-148 end aerodynamic surfaces.
- Report. Experimental studies of the An-148 aerodynamic model 002IMS148.106 in the T-106M wind tunnel with faring variants and the MG-10 engine nacelle.
- Report. Experimental studies of the An-148 aerodynamic models 002IMS148.106, 002KMS148.106, 002LMS148.106 in the T-106M wind tunnel.
- Research Report. Experimental studies of the An-148 aerodynamic model 002MS148.106 of the aerodynamic configuration option in the T-106M wind tunnel. Weight Tests.
- Research Report. Experimental studies of the An-148 aerodynamic model 002MC148.106 of the aerodynamic configuration option in the T-106M wind tunnel. Physical Tests.

- ♦ Report. Analysis of test results and evaluation of the An-148 aircraft aerodynamic configuration evolution.
- ♦ Post-flight Report. Definition of pressure distribution over fuselage, horizontal and vertical tails, and fairing.
- ♦ Post-flight Report. Definition of pressure distribution over fuselage, horizontal and vertical tails, and fairing. Book 2.1.б (Fuselage – Part 1.b).

The list of reports on the results of studying the An-158 aerodynamic characteristics using its models in the ANTONOV Company AT-1 wind tunnel.

- ♦ AT-1 wind tunnel test results of the An-148-200 selected configuration model fitted with high-lift devices (003KMC148.001). Research & Technical Report.
- ♦ AT-1 wind tunnel test results of the An-148-200 airplane selected configuration model (03KMC148.001) with regard to determine the efficiency of horizontal tail, rudder and elevator. Report.
- ♦ AT-1 wind tunnel test results of the An-148-200 airplane selected configuration model (003KMC148.001) with regard to determine the efficiency of ailerons and spoilers. Report.
- ♦ AT-1 wind tunnel test results of the An-158 airplane model (003KMC148.001) with regard to determine local angles of attack and static pressure in the area of placement of receivers of onboard measuring instruments. Technical Informative Note.
- ♦ AT-1 wind tunnel test results of the An-158 airplane model (003KMC148.001) with regard to determine the influence of the studied variants of tip aerodynamic surfaces. Research&Technical Report.
- ♦ AT-1 wind tunnel test results of the An-158 airplane model (003KMC148.001) with regard to determine the basic aerodynamic characteristics under circular blowing. Technical Informative Note.
- ♦ AT-1 wind tunnel test results egarding evaluation of two versions of the LG fairings of the An-178 aircraft on the An-158 aircraft model (003KMC148.001). Technical Informative Note.
- ♦ AT-1 wind tunnel test results of the An-158 airplane model (003KMC148.001) with regard to determine the aerodynamic characteristics and efficiency of the rudder at high angles of attack. Report.

- AT-1 wind tunnel test results of the An-158 aircraft wing cantilever part model (008PMK148.001) with regard to determine the effect of reducing the undercut of airfoil 68a in the aileron region on the aerodynamic characteristics of the model and the aileron hinge moments. Technical Informative Note.

The list of reports on the test results of the An-158 aircraft models in TsAGI:

- Research&Technical Report. Studying landing on water of the An-148-200 aircraft model.
- Report on Scientific and Technical Work. Experimental studies of the An-148-200 aircraft aerodynamic model 002MS148.106 with KAP12A3 in the T-106M wind tunnel.
- Report on scientific and technical work. Investigation of the spinning maneuver characteristics of the An-158 aircraft model in the T-105 vertical wind tunnel.

The test matter of the An-148/An-158 aircraft family executive models were taken as the basis for development of the source aerodynamic characteristics for further calculation of the aircraft take-off & landing and flight characteristics, as well as stability, controllability and flight dynamics features.

3.1.5 Main Conclusions About Aircraft Aerodynamics

1. The achieved level of the aircraft aerodynamic perfection ensured that the preset requirements have been matched with the performances such as maximum speed, cruising altitude and flight range while carrying different commercial loads.

2. The aerodynamic configuration has been developed, which allowed to create a family of regional high-wing passenger aircraft with a flight speed of up to 870 km/h TAS (M = 0.8), which has no analogues in the world practice of aircraft construction.

3. The aerodynamic configuration of the moderately swept wing of the An-148-100/An-158 aircraft family is based on the new generation supercritical airfoils developed for it with large maximum thickness ratio (greater, for example, than of the Airbus A320 and An-124). The aircraft lift-to-drag ratio in cruising flight is K_{cruis} = 15.8, which corresponds to the world level.

4. The aerodynamic configuration of the wing high-lift devices was developed, which provides high carrying properties of the wing during take-off and landing, which allowed to fully meet the requirements for the required length of the base airfield

runways L_{RWY} = 1485…1950 m.

5. Characteristics of stability, controllability and flight dynamics required by the rules and regulations for the main control mode are provided by the developed algorithms, which are implemented in the electric remote control system. Selected margins of the aircraft's own static stability, efficiency of its controls ensure the flight safety in standby control mode.

6. The An-148-100/An-158 aircraft certification flight tests have confirmed full compliance of the take-off/landing and flight technical characteristics, as well as the characteristics of stability, controllability and flight dynamics with the requirements of the Certification Basis in both normal and failure conditions observed in flight tests.

7. Airplanes as objects of control in normal and failure conditions were highly praised by pilots, which is an important factor in issuing the orders for these aircraft by potential operators.

3.2 New Airframe Design Features

The design and construction process of the regional passenger aircraft has been performed in accordance with the basic airworthiness requirements for transport aircraft [79].

The airplane design should not have such features and parts that create emergency conditions or are unreliable. Suitability of such parts and components must be determined by appropriate design and experimental studies [14, 15, 19, 21, 23, 30, 40, 45, 48, 49, 52, 55].

3.2.1 Design and Engineering Work on Airframe

The airframe design strategy was based on the principle of safely damaged construction. In accordance with this principle the rational materials [26] and production technologies have been choosen on the basis of experience and tests, so as to ensure consistency of quality of the airframe design. Calculated values of the material strength characteristics have been determined taking into account reduced probability of structural damage due to variability of material properties and influence of environmental conditions, such as temperature, humidity, etc.

It is possible to perform periodic inspection of the structural elements including non-destructive control with tools.

The aircraft has been designed in such a way that in all its configurations and under all design conditions there is no aeroelastic instability.

The airframe has been designed using three-dimensional parametric modeling CAD system and product data management system (Fig. 3.13). Finite-element CAD/CAE systems such as MSC.Software, Front and other have been used for calculation, optimization and engineering analyzes.

The An-148/An-158 aiplanes are the first ANTONOV aircraft designed in computer-aided integrated design systems using these software products (Fig. 3.14).

The essence of the development process in computer-aided integrated design systems is that characteristics of the future product are determined at the conceptual stage (technical proposal and preliminary design) [56, 67].

At the stage of detail engineering, a design was created on the basis of a product single digital model that meets these characteristics. At the manufacturing stage and when testing the prototype, flight and ground tests were performed to obtain and confirm the characteristics in order to get the product certificate. According to the test results, the digital model and electronic drawings for serial production have been issued.

Fig. 3.13. Regional Passenger Plane. Master Geometry

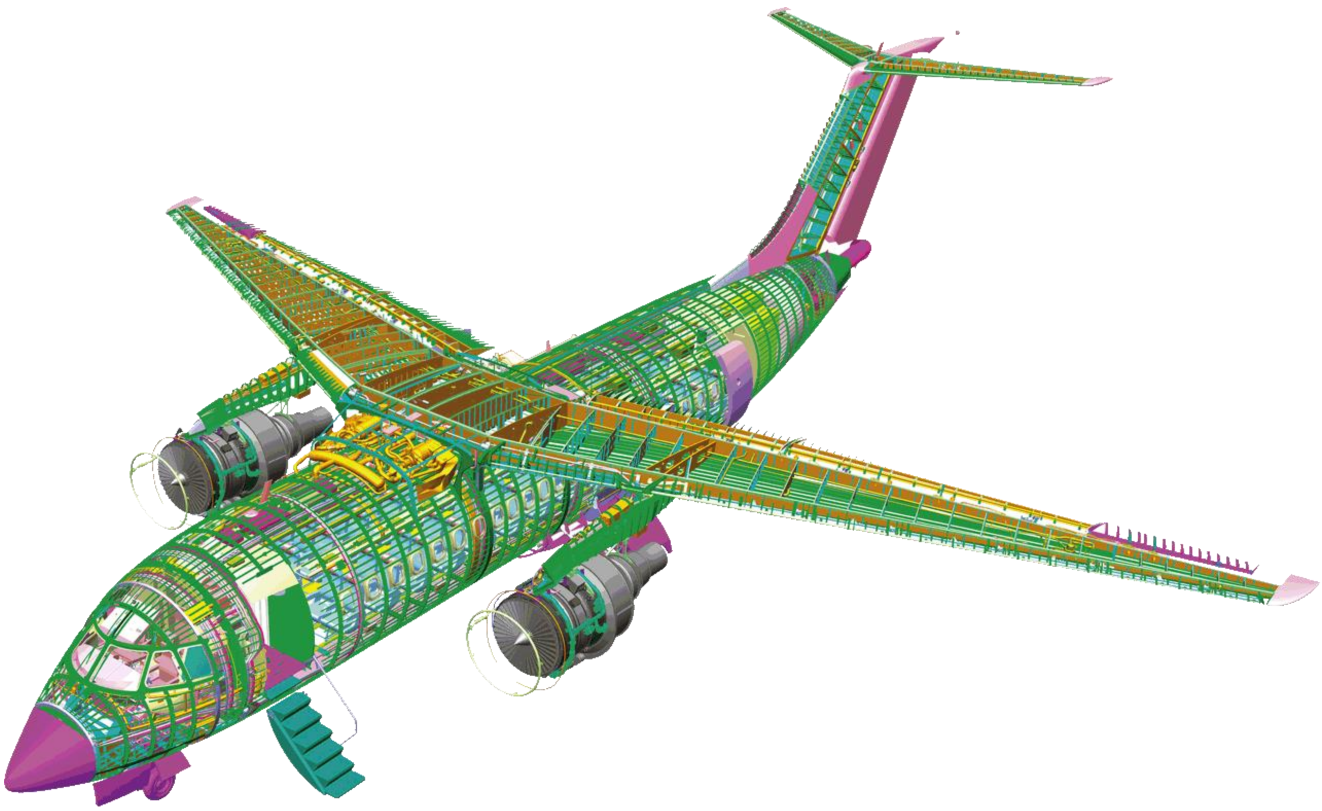


Fig 3.14. An-148 Airplane Full Definition. Model Fragment

With this approach, at the conceptual stage, a digital virtual prototype was created for computational computerised definition and monitoring of system characteristics. At the stage of detail engineering the model parameters were refined through the parameters and characteristics of the developed design. At the stage of manufacturing a prototype, the model was adjusted and its characteristics were refined, as well as flight and ground tests were performed in a limited amount to obtain and confirm the characteristics for product certification. On the basis of the corrected model electronic drawings for serial production have been issued.

It is impossible to avoid high-stress zones in the airframe load-bearing structure. These are so-called irregular zones. Such zones include transverse skin-to-panel joints, stringer ends, all sorts of cutouts, joints, reinforcement in the form of overlays, and so on (Fig. 3.15). The increased concentration of stresses leads to necessity for a significant reduction in stresses in these zones or to the early appearance of cracks relatively to regular zones. The design of such zones was performed on the basis of finite-element optimization on models having different levels of modeling details depth using the experience of previous design solutions.

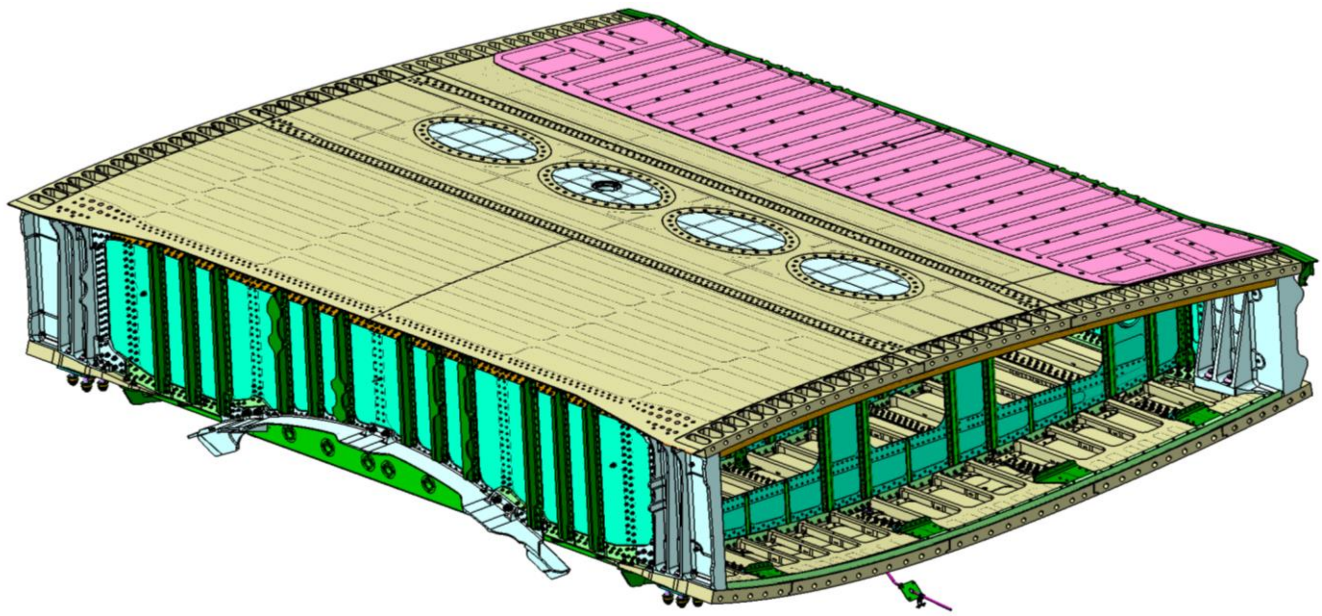


Fig. 3.15. An-148 Aircraft Center Wing Section. Model Fragment

Depending on the degree of the structural design detailing and the structural member size that was modeled, three levels of modeling were implemented.

The level of the general stress-strain state (the whole airframe structure assembly has been modeled). This model was used to calculate distribution of the main force flows in the assembly, for calculations of the total stress-strain state (SSS), optimization problems for distribution of stiffness and structural weight shares and others.

The level of modeling of local SSS in the compartments of units was the second level of modeling. Such models were used to calculate local SSS in a more accurate formulation, to determine the structure bearing capacity, to assess the structure survivability, to obtain data for a detailed analysis of the lifetime characteristics.

At the third level the assemblies, fittings, joints and structural members were modeled (Fig. 3.16). At the same time, local SSS calculations were performed at the most detailed level, contact stresses, distribution of fastening forces were determined, and fatigue and survivability characteristics were analyzed.

In this case, all geometric information was obtained from the master geometry model. The use of MSC.Software systems allowed to perform Engineering Analysis in the form of multidisciplinary complex analysis based on interdependent products to solve analytical problems in different areas (loads, static and fatigue strength, survivability, tightness, etc.) while ensuring data compatibility and possibility of using the same models or taking data from different models. At the same time, quality of the designed products has benn significantly increased while accelerating the design development process. It became possible to create a structure with a minimum weight, which largely meets the stated design parameters.

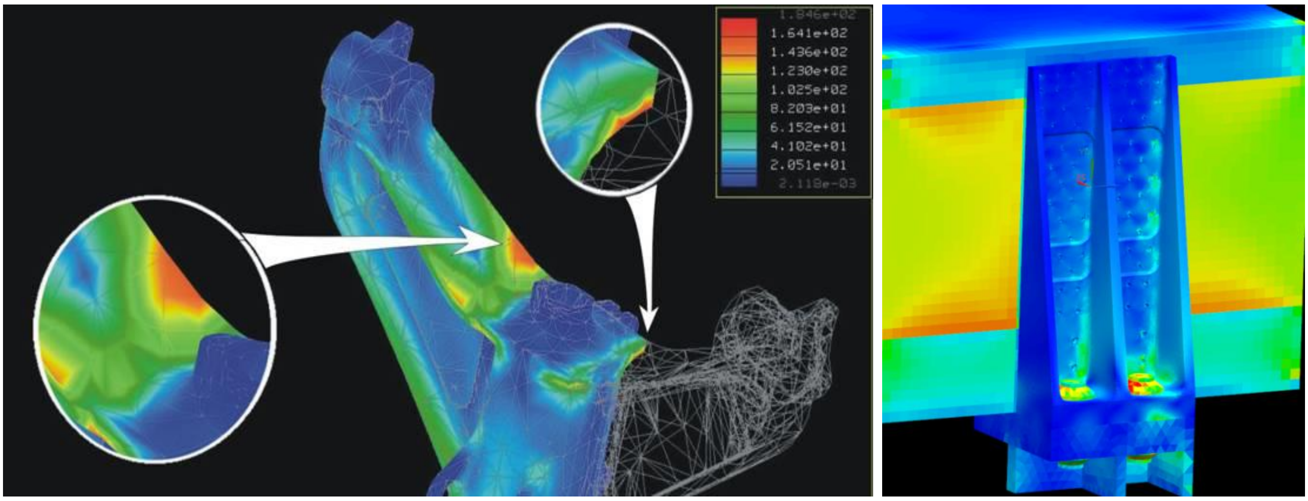


Fig. 3.16. Aircraft Structural Element Assemblies.
Pattern of Stress-Strain State Distribution

The An-148-100/An-158 family of aircraft has been designed and manufactured in all-climatic version in compliance with all requirements for corrosion protection for this type of design.

The airframe consists of a fuselage, a wing, pylons to attach engines and tail unit. Irregularities have been realized in the airframe design taking into account maximum neutralization of stress concentration, the concept of multiway load transfer with ensuring a sufficient level of residual strength. Widely used design and technological solutions that increase the lifetime characteristics of the torsion box structural elements (attachmnet in preloaded state, various types of reinforcement, optimal reinforcements in zones of stress concentration) [72, 78].

3.2.2 Passenger Cabin Facilities

The passenger equipment of the An-148-100/An-158 airplane family is intended to provide comfortable conditions for passengers onboard during flight and on ground. In addition to decorative and ergonomic functions, interior lining protects installations and equipment of aircraft systems from damage and interference. Lining also provides sound-proof properties therefore joints of panels are densed.

The aircraft passenger cabin layout is divided into nose vestibule, passenger compartment and aft vestibule. The schematic diagram of the interior in the basic version is shown in Fig. 3.17.

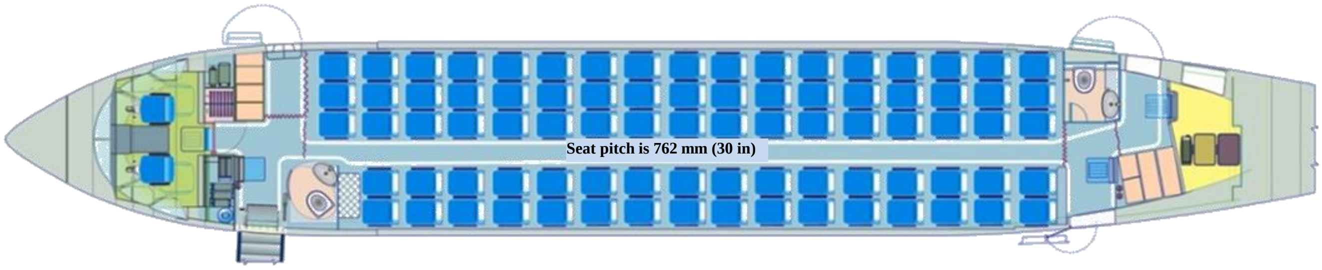


Fig. 3.17. Interior in the Basic Version
for Carrying 83 Passengers (Seat Pitch – 762 mm (30″)). Schematic Diagram

To ensure that noise and vibration level in the cabin do not exceed the specified values, the fuselage inner surface is covered with thermal and sound insulation (TSI), and additional self-adhesive vibration-absorbing lining is applied to the fuselage skin in the area of frames No 28 to 39. An additional TSI is applied to the passenger compartment lining.

The passenger compartment is illuminated by reflected light given by the fluorescent lamps installed in four longitudinal boxes. The upper two boxes are behind the ceiling central panel, and the two side boxes are placed on the sides, at the junction of window panels and service panels.

The aircraft interior structural components are mainly made of fiberglass and three-layer panels with honeycomb filler of polymer paper.

Sections (modules) of the ceiling, luggage racks, service panels, window panels, bottom panels, sideboards, coat stowage are assembled outside the aircraft with the subsequent installation on the fuselage mounting units mounted on the proper fittings.

Paint and varnish coating or, at the customer's request, protective and decorative films are used as decorative and finishing materials in the passenger cabin interior. The interior color pattern can be chosen by the plane customer.

For the convenience of servicing the aircraft systems, the passenger service panels, luggage racks and ceiling panels are made hinged, and the window panels and lower panels are easily removable.

The passenger cabin in the basic layout is designed to accommodate 80 passengers in economy class with a seat pitch of 30 inches (762 mm). On the starboard side there are triple blocks of seats, on the left – double blocks of seats. Aisle width at the level of the armrests is 483 mm. A typical cross-section of the passenger cabin interior is shown in Fig. 3.18.

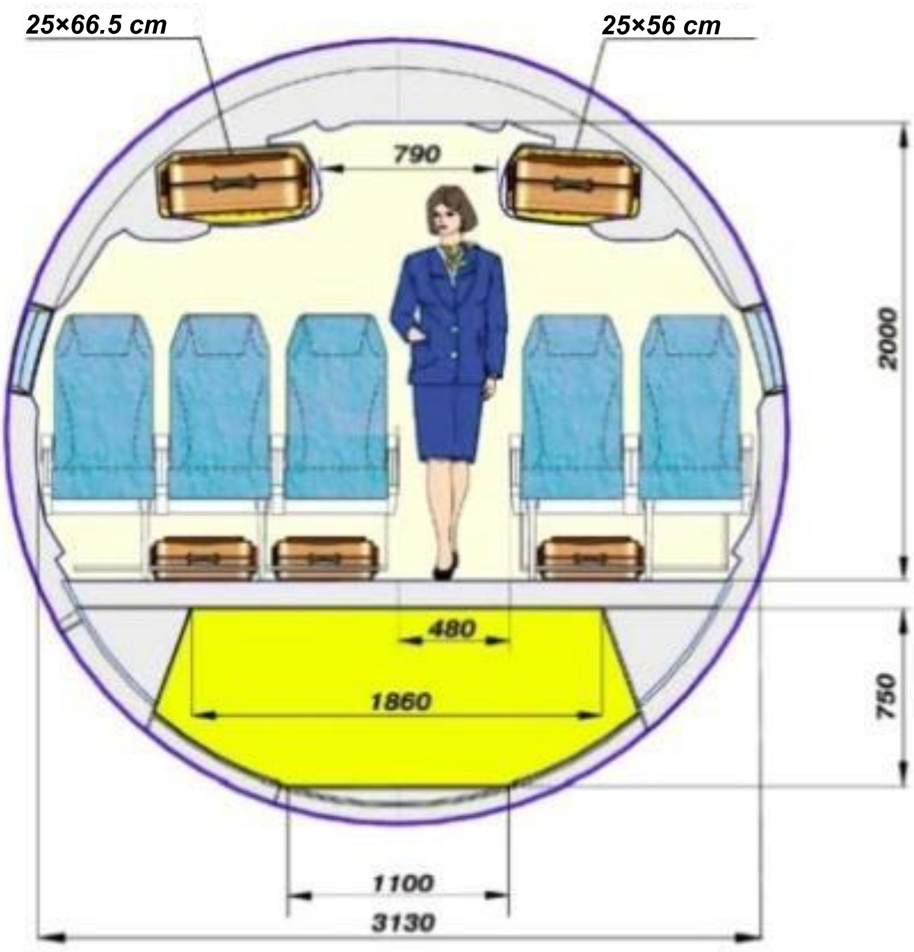


Fig. 3.18. Passenger Cabin Typical Cross-section

Along the entire length of the passenger compartment, the interior has the same geometry of the cross-section, corresponding to its theoretical contour, despite the fuselage narrowing in the tail part. Units and interior panels have a modular design that ensures their interchangeability and ease of maintenance.

The interior contains the following constructive-technological and functional zones:

– Ceiling;

– Luggage racks for hand luggage of passengers;

– Passenger service panels;
– Lining of side lighting boxes;
– Window lining;
– Lower panels;
– Carpet flooring.

The ceiling of the cabin consists of central and side panels. The central panels contain lighting domes and are fastened with hinges and locks. The locks are opened with a hex key. The panels are folded to the starboard side, providing access for the inspection and maintenance of equipment installed behind the ceiling. When opening the panels, hold them with your hands to avoid breakage and damage.

The side panels are fastened with clamps and locks. If necessary, they can be completely removed.

Between the central and side panels of the ceiling there are profiled channels for blowing air from the air conditioning system.

Luggage shelves are of closed modular type, with an approximate volume of 4.1 m^3, can hold standard luggage of 560×450×250 mm, which meets the requirements of the European Airlines Association, and provide a volume of 0.0512 m^3 or weight of 9.9 kg per passenger in the basic layout.

Shelves can hold long luggage up to 2.1 m long. The allowable load of one shelf module is 72 kg.

Luggage shelves are attached to the fuselage with brackets and special vibration-absorbing bushings, which reduces interior vibration and further reduces noise in the cabin.

To open the shelf, press the lock key on the luggage rack and remove your hand. The door itself will open under action of the actuator-damper. The door is closed manually until the lock is locked.

For inspection and maintenance of aircraft systems, the shelf can be tilted on the mounting axis. To do this, first remove the upper flanges by unscrewing the screws with a screwdriver, and then use a hex key to unscrew the axles of the luggage rack and tilt the shelf down holding it with your hands.

Passenger service panels are installed under the luggage racks, where individual lighting fixtures, individual ventilation nozzles, flight attendant call buttons, information boards and radio dynamics are mounted. Blocks with automatic emergency oxygen masks are placed between the service panels above each row of seats. At the request of the aircraft customer, the entertainment system TV monitors can be arranged between the service panels. In addition, the service panels are equipped with light indicators showing numbers of passenger seats.

To move the service panel aside insert a flat object (such as a metal ruler) between the service panel and the spacer (on both sides of the lock) and press the lock lever until the panel opens.

Between the service panels and the window panels there are panels lining the side boxes of the interior lighting. To replace the lamps, these panels are easily moved without the use of tools.

Window panels are made in the form of modules for three windows. The panels accommodate sun-shields (light filters), the third window and the intermediate edging to reduce noise in the cabin. Window panels on the top edge are fasten by means of spring clips, and on the bottom edge are fasten by means of rotary locks.

The lower panels cover the side area from the window panels to the floor. Through longitudinal openings in niches of the lower panels the used air is taken by the air conditioning system out of the passenger cabin. The lower panels are fastened on the upper edge by means of spring clamps, and on the lower edge – by means of screws.

The carpet covers the whole area of the cabin floor and is fastened to the floor by means of an adhesive tape and profiled clamps on seat mounting rails. To ensure access to the equipment installed in the space under the floor, the central part of the carpet can be rolled into a roll in any direction. On the sides of the carpet edges rise to the lower panels up to the height of the niche. In addition to the decorative function, carpets play role of an additional thermal and sound insulation.

The nose vestibule is located between the crew cabin and the passenger compartment and, depending on the layout, can be separated from the passenger compartment by a curtain, a toilet on the port side and a coat stowage on the starboard side. The vestibule is separated from the crew cabin by an "avionics" shelf on the port side and the coat stowage for the crew members on the starboard side.

The nose vestibule is at the same time the work area of the flight attendant, the attendant’s seat and galley are installed here. The galley area is separated by a longitudinal curtain. Part of the coat stowage on the starboard side at the request of the customer can be equipped with an additional galley module.

Vestibule lining and ceiling are made of composite materials on the basis of fiber glass and are decoratively treated similarly to passenger salon.

The floor in the vestibule is covered with a special anti-friction moisture-resistant coating. The lobby is illuminated by a round dome mounted on the ceiling.

The aft vestibule is located between the passenger compartment and the rear luggage compartment and is separated from the cabin by a toilet on the starboard side, a curtain on the aisle and a partition on the port side. The top transparent part of this partition is made folding for simplification of loading and unloading of patients on a stretchers. In addition, it provides a direct overview of the passenger compartment from the flight attendant's seat. To displace the glass, open the lock at the top of the glass by pressing a button on it with your finger and, holding the glass, carefully move it to the lowest position.

The aft vestibule, similar to the nose vestibule, is a work area for two flight attendants, there are also two seats and a galley. The galley area is separated by a cross curtain. To the right of the flight attendant's seat on the starboard side there is a garbage container.

Lining, ceiling, decorative finishing, floor covering and illumination of the aft vestibule are the same, as in the nose vestibule.

Galleys are universal modules with sockets for placement of replaceable galley equipment. Structurally, the gallyes are assembled from honeycomb panels. All equipment is reliably fixed in the sockets by rotary locks for ensuring safety during take-off and landing. The design of galleys provides an opportunity of placement of the equipment in various options of a complete set.

Maximum complete set of a nose galley contains the following items:

– 2 containers of the ATLAS standard;
– 3 half-sized carts of the ATLAS standard;
– 1 coffee maker (model 416-0001-29 of B/E Aerospace);

– 2 convection ovens (model DF-300 of B/E Aerospace).

The nose galley is also equipped with a folding table and a waste compartment.

Maximum complete set of an aft galley contains the following items:

– 4 containers of the ATLAS standard;
– 2 half-sized carts of the ATLAS standard;
– 2 full-sized carts of the ATLAS standard;
– 2 coffee makers (model 416-0001-29 of B/E Aerospace);
– 2 convection ovens (model DF-1075 or DF-115 of B/E Aerospace).

The aft galley is also equipped with a folding table.

Water supply of the galleys is provided from a tank of the plane water supply system. The tank is filled through the panel of the centralized filling with water. Water is suitable for coffee makers. Coffee makers are used for making coffee and heating water, easily removed from a permanently installed stand. The design of the galleys provides small tanks for draining water spilled during operation of the coffee maker. As they fill, these tanks must be removed and the water drained (into the toilet).

Convection ovens are intended for heating and storage of food.

At the request of the buyer, the aircraft can be delivered in different configurations (see Figs 3.19 – 3.24).

The category of options supplied as included in the commercial load are the following:

– Curtains;
– Partitions between classes;
– Nose toilet;
– Forward coat stowage;
– Aft additional galley.

The forward coat stowage may be provided in two options –a coat stowage or a coat stowage with a galley module.

Additional aft galley is placed in the front section of the aft luggage-baggage stowage and it may contain the following items:

– Option 1: one half-size cart and 2 containers (ATLAS);
– Option 2: 6 containers (ATLAS).

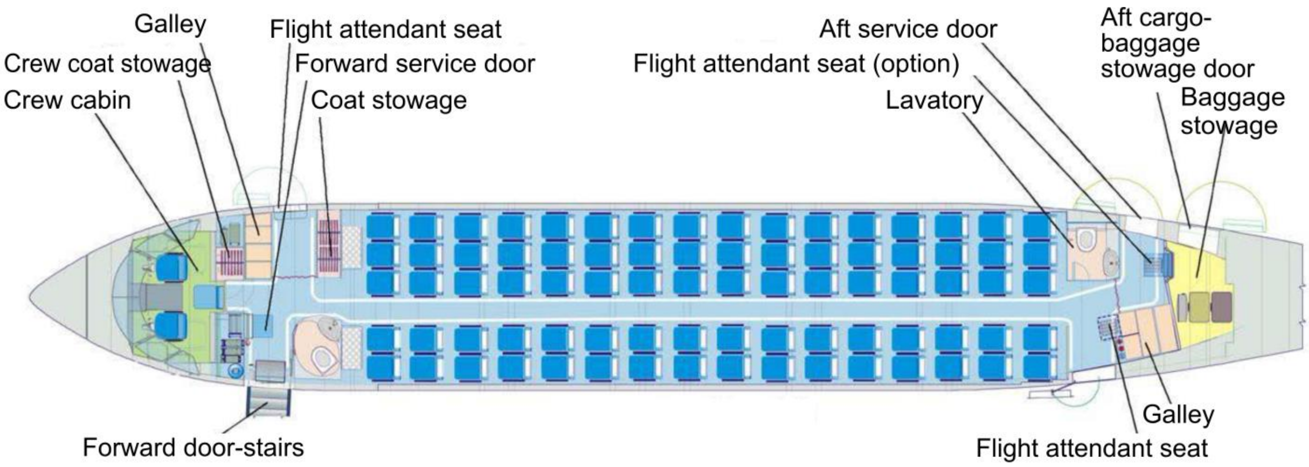


Fig. 3.19. An-148 Aircraft Layout for 80 Passengers
(Seat Pitch – 762 mm (30″))

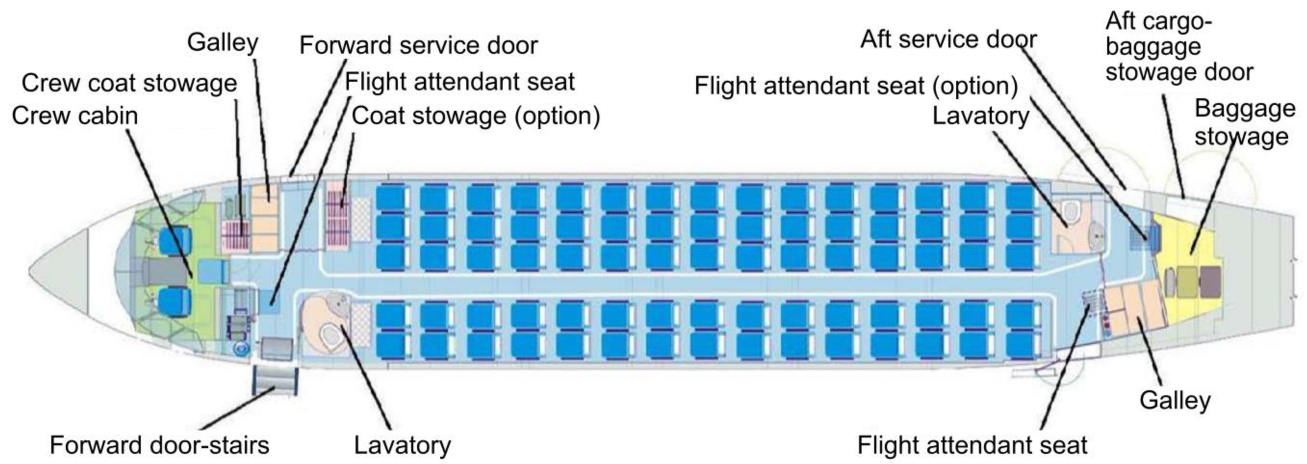


Fig. 3.20. An-148 Aircraft Layout for 75 Passengers
(Seat Pitch – 813 mm (32″))

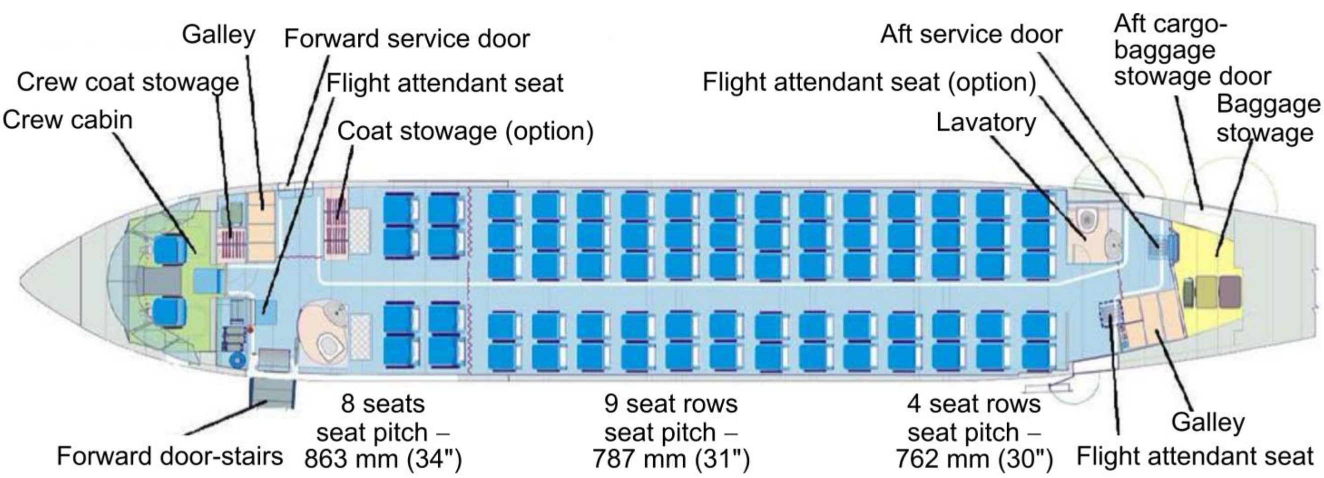


Fig. 3.21. An-148 Aircraft Layout for 73 Passengers

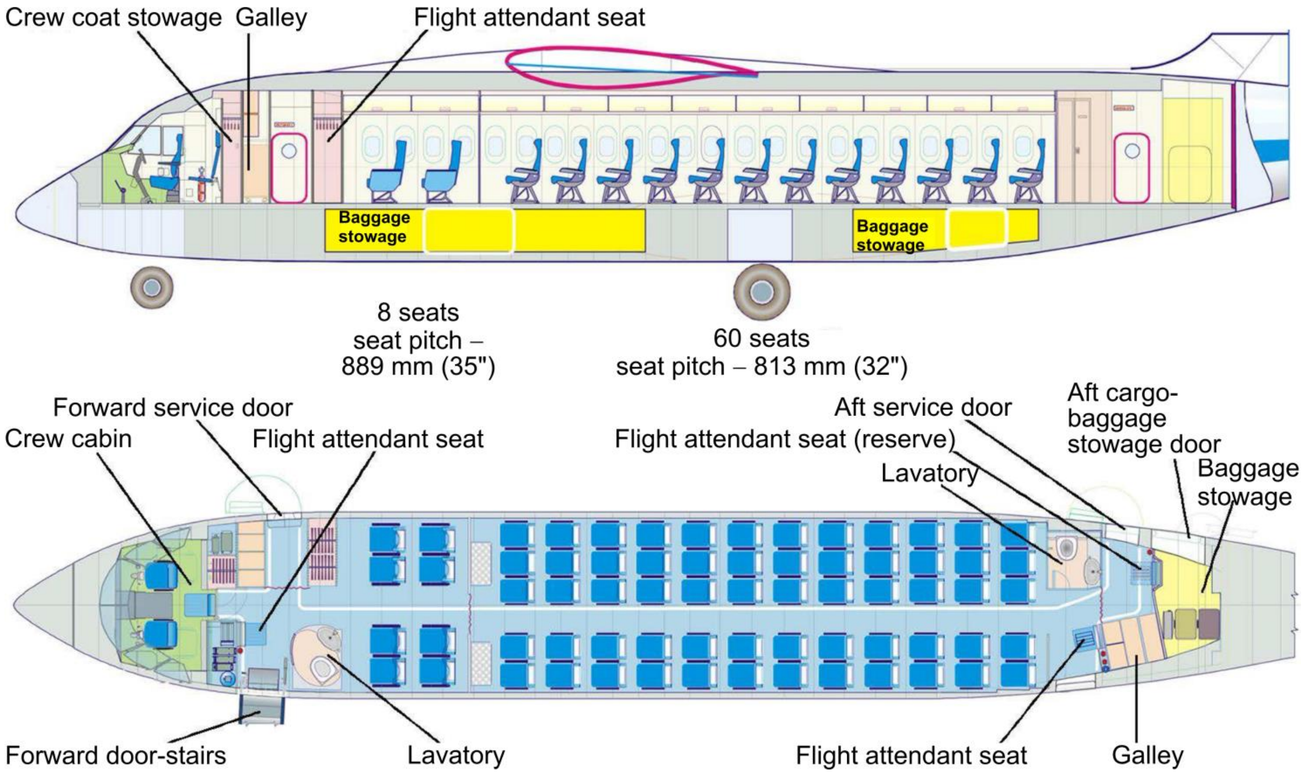


Fig. 3.22. An-148 Aircraft Layout for 68 Passengers

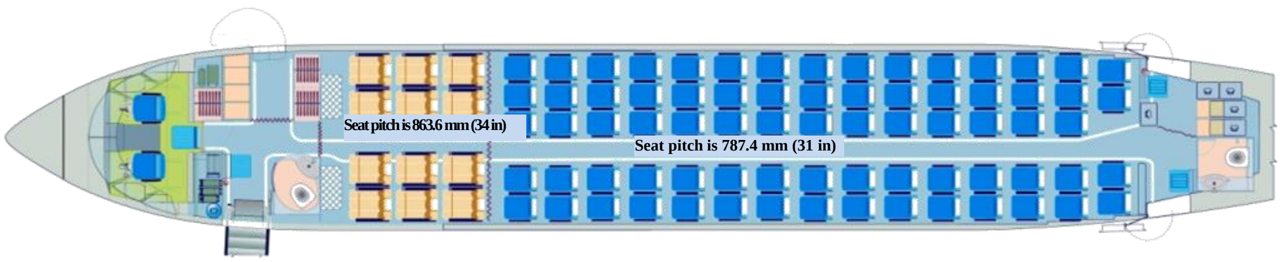


Fig. 3.23. An-158 Aircraft Two-class Layout for 86 Passengers

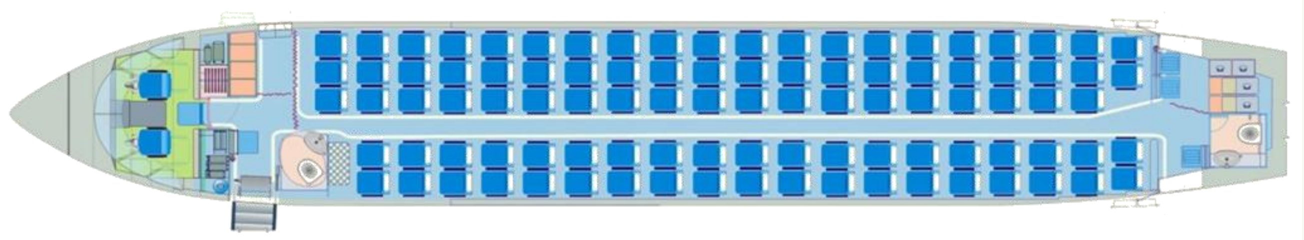


Fig. 3.24. An-158 Aircraft Single-class Layout for 97 Passengers

3.2.3 Emergency and Rescue Equipment

The An-148-100/An-158 aircraft is equipped with a system of emergency and rescue equipment in accordance with the AP-25 Airworthiness Standards. The rescue equipment includes: passenger seats, pilot seats, visor, inspector's seat, flight attendant's seat on frame No. 8, flight attendant seats on frames No. 37 and 39, handrails, cradles, ropes, ax, light path, life jackets, life rafts, emergency cradles, electromegaphone, bracket at the front entrance door, handrails above the flight attendant's seat at frame No. 8, inscriptions and icons, limiters of doorways, children's belts, inserts for fat passengers, demonstration sets and waterproof guards.

The design of emergency and rescue equipment does not have such features and parts that, as experience has shown, create emergency conditions or are unreliable. The suitability and durability of materials used for the manufacture of parts of emergency and rescue equipment, the breakdown of which may affect safety, are determined by the operating experience of the "An" brand certified aircraft.

Inspection and tests of the emergency equipment main components have been done, replacement of components that usually require replacement, adjustment and lubrication are done according to the airworthiness requirements. The conditions and technology of inspection of each product correspond to the interval of this inspection.

Each seat, seat belts, belts and the airplane parts adjacent to each seat intended to accommodate people during take-off and landing shall be designed so that a person who uses these equipment properly does not suffer serious injury in emergency landing. as a result of inertial forces.

All seats are equipped with energy-absorbing supports, which are designed to support the arms, shoulders, head and spine, equipped with combined restraint systems consisting of waist and shoulder straps with single-point unbuckle drives. The backs of all passenger seats provide stable support for the hands and allow people to maintain balance while moving in the aisle under conditions of moderate turbulence. In addition, the recesses are made in the luggage racks for the same purpose.

Every protruding object that can injure people sitting or moving inside the plane in normal flight has a soft upholstery.

Annunciators indicating when the seat belts should be fastened are installed on the personal passenger service panels above each seat block. The annunciators are switched on/off from each pilot's seat and, when switched on, are easy to read by each person sitting in the passenger compartment under all possible conditions of the crew cabin lighting.

The floor surface of all compartments that can become wet during operation has a carpet and linoleum, which have anti-slip properties.

The crew cabin and passenger compartments in all variants of aircraft operation are equipped with emergency exits and light markings of emergency exits and evacuation routes, which provide rapid evacuation in case of emergency landing, taking into account possibility of fire on the aircraft.

Each emergency exit for passengers is easily accessible to them and is located where it will be the most effective means of evacuating passengers.

Emergency exits for passengers (forwartd entrance door-stairs and aft entrance door on the port side and both service doors on the starboard side) are made in the form of sliding doors that open to the outside. Emergency exits for the crew are made in the form of windows that is thrown away (right) and shifted (left). All emergency exits provide unobstructed access to the outside, which is confirmed by the results of the demonstration of emergency evacuation during the aircraft certification ground tests.

Each emergency exit opens from the inside and outside. The possibility of opening each emergency exit in the absence of deformation of the fuselage is provided.

Facilities for opening the emergency exits are easy in use, visible and do not require excessive efforts.

The windows of the crew cabin are opened in one motion, after which the left window is moved back, and the right is removed inwards.

Minimization of the emergency exit jamming probability as a result of the fuselage deformation during landing with a minor failure is provided by gaps between the structural elements of doors and hatches and the surrounding fuselage structure, as well as eliminating possibility of jamming the actuating mechanisms. Sufficient strength and rigidity of the fuselage cutout edges have been provided to absorb loads.

Each emergency exit for passengers, means of approach to it and means of its opening have well-marked indication.

Location of each emergency exit for passengers is marked by a light board and ensures its recognition at a distance equal to the width of the cabin.

There is a system of floor marking of the emergency exit path (light path) along the longitudinal and transverse passages to the emergency exits and light boards indicating emergency exits located at such a height from the floor that help people find exits in thick smoke.

Location of each emergency exit for passengers is marked by a board that people can see when they approach the main longitudinal passage for passengers.

he aircraft has an emergency lighting system that does not depend on the main lighting system and has its own power sources.

The emergency lighting system contains light boards indicating location and marking of emergency exits, sources of the cabin general lighting, internal lighting of emergency exit areas and located near the floor marking of the evacuation route and external emergency lighting.

The aircraft is equipped with an aircraft intercom loudspeaker system, which operates independently of the passenger alert network and provides two-way communication between the crew cabin and each passenger cabin in the transport cabin. It is easily accessible for immediate use from any of the pilot's workstations in the crew cabin.

The speakerphone system ensures its use from flight attendant workstations so that all emergency exits at floor level in each vestibule can be viewed from these flight attendant workstations, has an audible and visual warning system for two-way communication between flight attendants and flight crew. At the same time the warning system provides accurate recognition of usual and emergency calls. The speakerphone system provides two-way communication on the ground between ground personnel and both crew members.

The aircraft is equipped with one portable megaphone with autonomous power supply, which is easily accessible from the conventional seat of the flight attendant, directly responsible for the emergency evacuation of passengers. The megaphone is located in the aft section of the passenger cabin.

On the plane there are places of installation and means of fastening of emergency first-aid kits AB-50 (2 pieces) for rendering the first medical aid in flight and in an emergency situation on the ground. First aid kits are located in easily accessible places for the flight attendant in the coat stowage near the flight attendant's seat.

For flights over desert, arctic or tropical areas, the aircraft is provided with the capability of placing equipment with live sustenance and alarms in accordance with the conditions of the area to be flown over. Special easily accessible places in luggage shelves of passenger cabin are provided for placement and fastening of such equipment.

One emergency ax is installed in the crew cabin.

The An-148-100 airplane carries out passenger transportation over large water areas. The aircraft takes all practicable design measures compatible with aircraft general charcteristics, which minimize the likelihood that in an emergency landing the behavior of the aircraft will cause direct injury of passengers or will prevent them from leaving the aircraft. For this purpose, local and general static strength of the aircraft fuselage structure, including entrance and service doors, luggage doors and hatches, is provided for the perception of probable external hydrostatic pressures that occur when the aircraft lands on the water surface. The static strength of all seats to accommodate people on the aircraft, their fastening systems and components of their attachments to the aircraft structure is provided.

To exclude probability of passenger or crew member injury due to overloads all equipment in the transport cabin and in the crew cabin is rigidly fixed or moored. Cargo and luggage located on the same level as people in the rear baggage-luggage compartment are moored to prevent dangerous movement of items.

The aircraft is arranged based on the requirements to ensure passenger evacuation in an emergency landing, and has sufficient passages along the transport cabin and to the emergency exits.

For correct behavior in an emergency and use of emergency rescue means the original model of the instruction on safety which gives to passengers information on necessary actions in case of forced landing on water surface is developed.

Given the possible state of the water surface, the time the plane is afloat and its balanced position will allow people to leave the plane and take their places in life rafts. The plane with two external doors open after evacuation of people is kept afloat until the wing is immersed in water, which contains empty fuel tanks after draining the fuel before landing on the water, about 18.5 hours. The time for evacuation of passengers from the aircraft, determined under the condition of the aircraft immersion to the level of the floor surface near the front entrance and service doors at the forward CG position and which can be expected, is 3.5 minutes. Thus, the time the aircraft is afloat and its balanced position will allow people to leave the plane and take seats in life rafts. In emergency exits, where the openings are located below the waterline, the water screens are provided that prevent water from entering the cabin when the door is open. A tethered halyard attached to the emergency exit helps the passenger to get on the life raft.

The necessary rescue equipment used by the crew in an emergency is readily available. Its location shall be such that direct access to the equipment is provided and its location is obvious. Crew rescue equipment is protected from accidental damage.

Life rafts are located near the exits through which they can be lowered in an emergency flood. Life jackets are placed within easy access for each person sitting. The number of rafts is sufficient in case of loss of one raft to accommodate all passengers and crew members. The locations of each life raft ensure its quick disconnection and removal for use through the proposed emergency exits. The rafts are secured with mooring straps that prevent them from breaking in the event of an emergency landing. Rafts have towing and tethering halyards designed to hold the rafts close to the aircraft, as well as means that separate it when the aircraft is completely submerged.

The long-range emergency radio beacon is located near the door in the crew cabin. It must be taken by one of the pilots for use on one of the rafts in an emergency landing.

Thus, the aircraft An-148-100 (An-148-100A, An-148-100B, An-148-100E Models) of standard design has the emergency rescue equipment, which provides all practically feasible design measures to be taken to rescue passengers and crew members in all possible emergency situations, at emergency landing on ground and water.

3.2.4 Doors, Hatches, Canopy, Windows

The fuselage has a system of doors and hatches. All doors and hatches are opened outwards (Fig. 3.25). All doors and hatches (except for the escape hatch) are attached in such a way that when exposed to excess pressure inside the fuselage, they all work as plugs with point support on the transverse beams of the edging.

Doors and hatches are based on frame structure, formed by transverse and longitudinal beams, edging, as well as by skin, which goes to the fuselage outlines and absorbs excess pressure.

The forward door is made in the form of entrance stairs (see Fig. 3.25). In the open position it rests upon two hinges on the threshold and is held by two struts without resting on the ground.

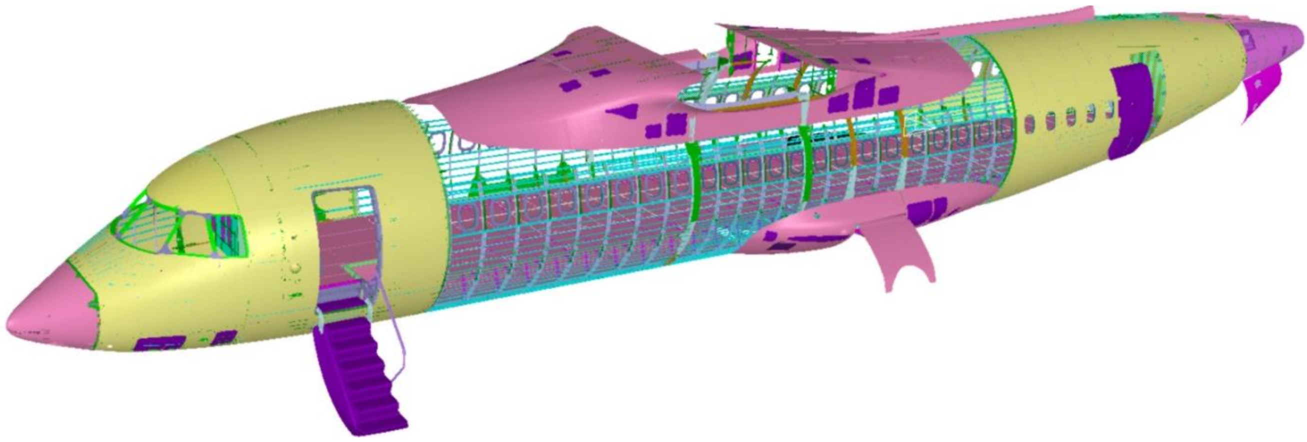


Fig. 3.25. An-158 Fuselage Load-Bearing Structure. Model Fragment

Doors and hatches have means to prevent them from opening in flight as a result of mechanical failure of any structural element. They are designed in such a way that in flight with both pressurized and unpressurized cabin, their unlocking from a completely closed, locked and blocked position is almost impossible. The door design provides means to prevent the door opening in flight due to unintentional actions of people. In addition, constructive measures are provided to minimize likelyhood of the door intentional opening in flight.

The retaining and locking mechanisms are designed so that with all variants of the airplane loading in flight and on the ground with the doors closed, there are no forces or moments that are aimed at opening the locks. In this case, possibility of unlocking the locks when the stoppers are in the locking position is excluded.

An expressive door control facility is provided on the door control panel to indicate that all necessary actions regarding closing, retaining and locking the doors have been completed. There are visual alarms, as well as an audible alarm provided in the crew cabin that alerts pilots if one of the doors is not completely closed, retained and locked.

Crew cabin canopy is located in the upper part of the F-1 compartment between frames No. 2 – 6 (Fig. 3.26).

The canopy frame is made in a form of all-welded spatial rod structure made of profiles and forgings of 30KhGSA material (Fig. 3.27).

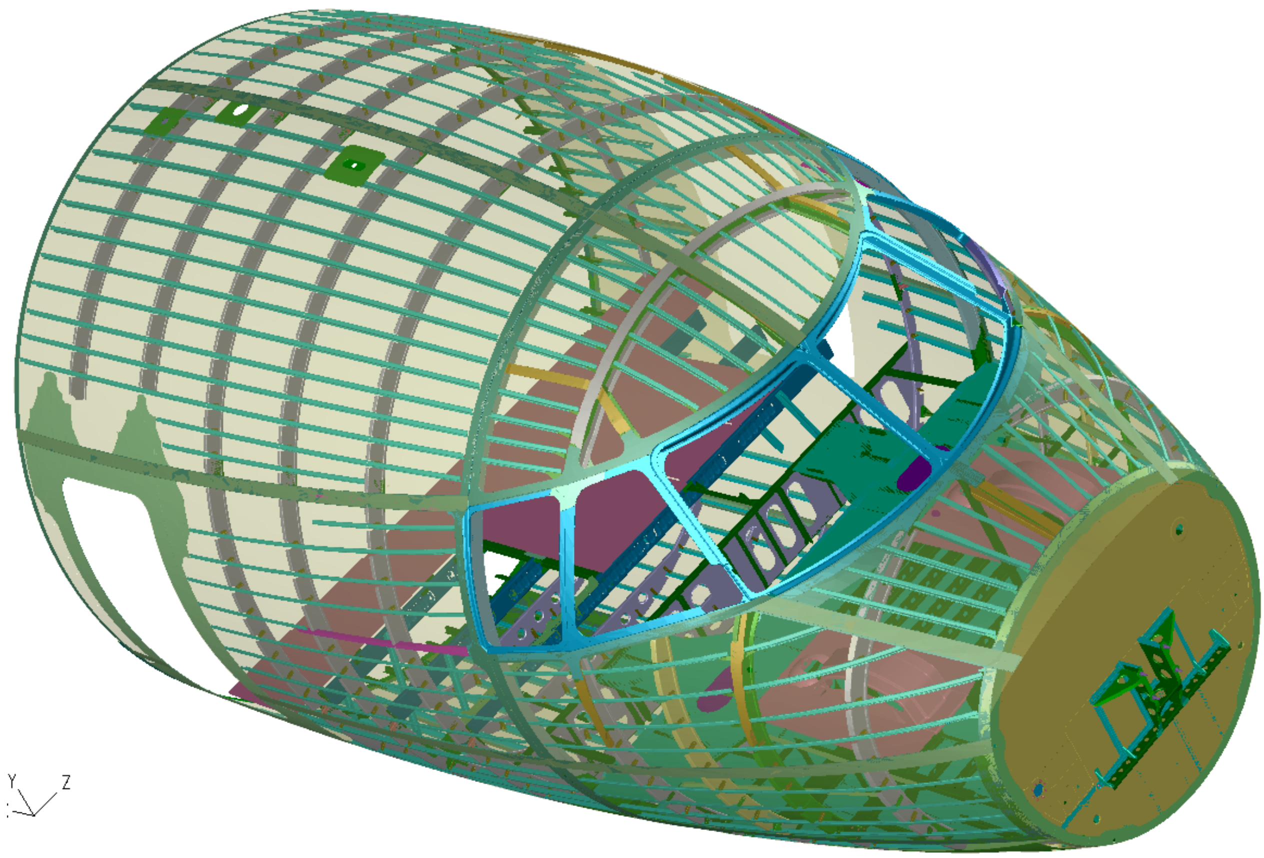


Fig. 3.26. An-158 Fuselage Compartment F-1. Fragment of Load-Bearing Structure

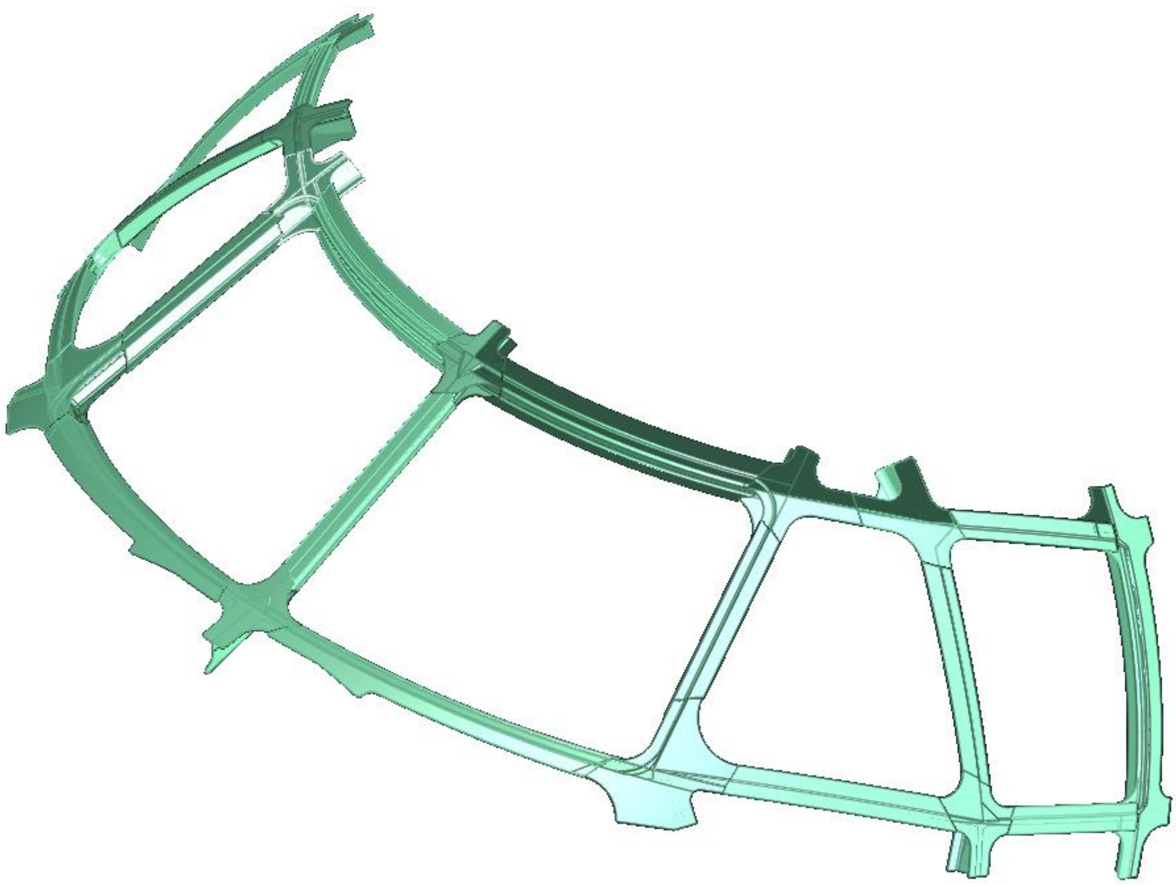


Fig. 3.27. Canopy Frame

The crew cabin canopy provides a sufficiently wide, unobstructed and undistorted view fot the crew, which allows to perform safely all maneuvers within operational limits, including taxiing, take-off, approach and landing.

In the presence of precipitation, there are means provided to ensure the cleanliness of the windshield so that both pilots have a wide view along the flight path in the aircraft normal position.

Means are provided that prevent fogging of the windshield panels and windows inside in the area sufficient to maintain visibility. The inner window panels are made of material that cannot be broken into fragments. The windshield and the canopy structural elements located in front of the pilots' work stations withstand the regulated hit by the bird in accordance with the AP-25 Standards [79].

On portside and starboard located are the windows of the passenger compartment (Fig. 3.28).

Windows (Fig. 3.29) are designed to withstand maximum pressure drop in the passenger compartment in combination with critical aerodynamic pressure and temperature.

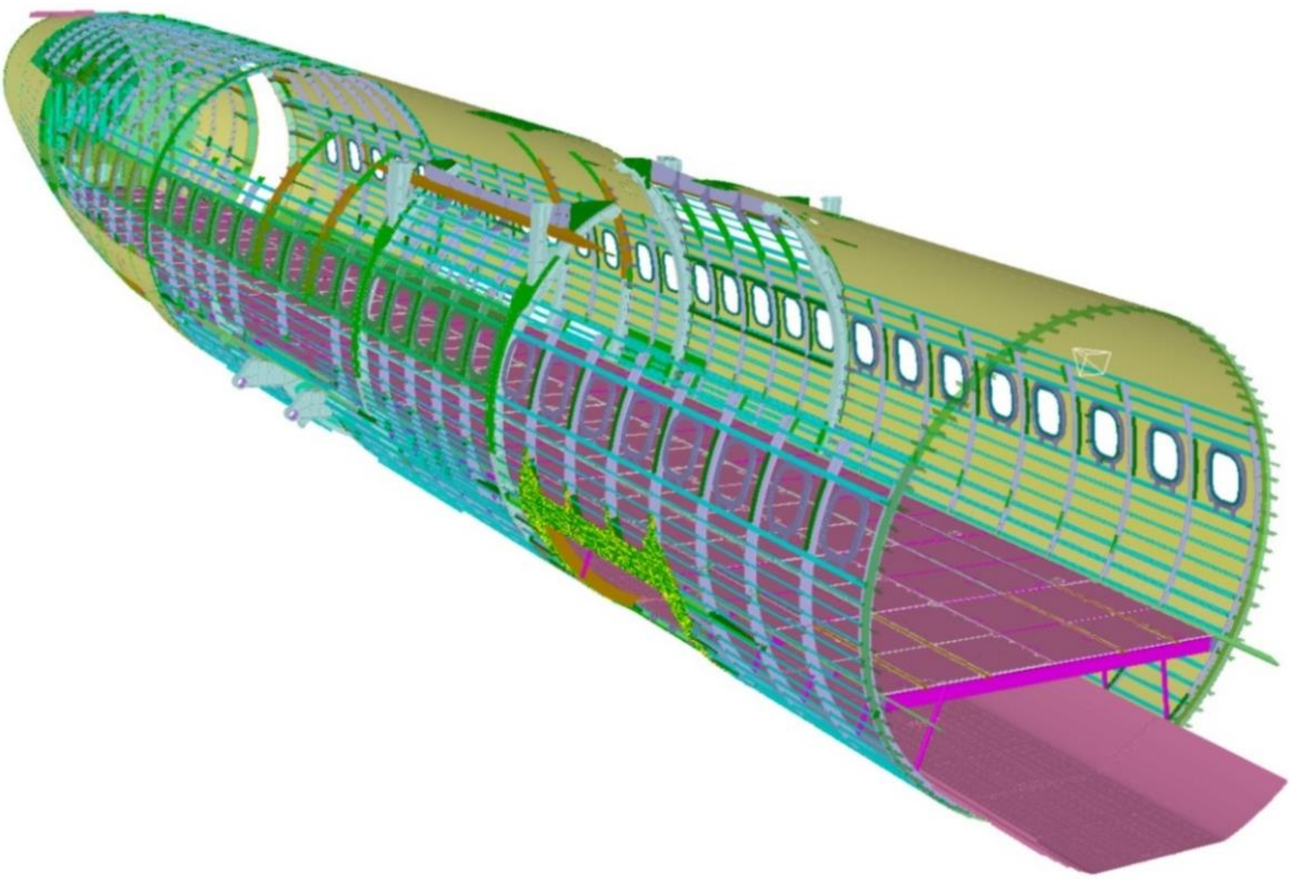


Fig. 3.28. An-158 Fuselage. Fragment of Load-Bearing Structure

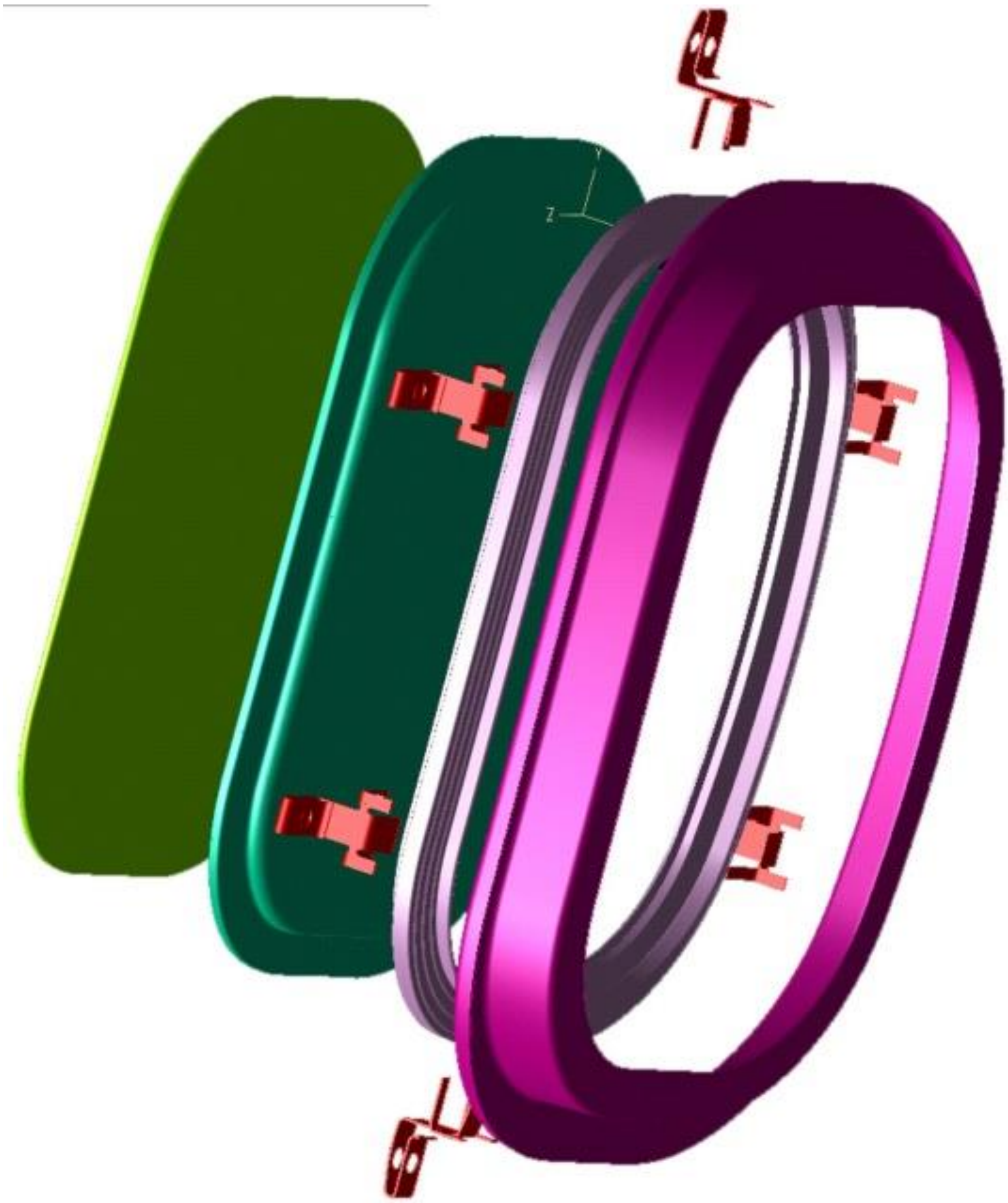


Fig. 3.29. Passenger Cabin Window. Model

In normal operation, overpressure, aerodynamic and temperature loads are accepted only by the outer glass, the inner glass is included in the work only in case of destruction of the outer glass.

To ensure compliance of the airframe structure with the requirements of the AP-25 Section D (engineering and construction) [79] a set of scientific, technical and engineering works has been done:

- The An-148 aircraft. Consolidated data relative to the wing static strength. G = 36.4 tons (Book 1).
- The An-148 aircraft. Calculation of wing transverse joint strength.
- The An-148 aircraft. Calculation of wing center section strength.

- The An-148-100 aircraft. Wing torsion box. Analysis of the stress-strain state and strength of the outer wing section ribs on the mounting units of flaps and ailerons.
- The An-148-100 aircraft. Wing torsion box. Analysis of the stress-strain state and strength of the outer wing section ribs on the mounting units of main power plant pylons.
- The An-148 aircraft. Calculation of excess fuel pressure in the wing torsion boxes.
- The An-148-100 aircraft. Wing torsion box. Analysis of the stress-strain state by the finite-element method (from 01 – 01 to 01 – 03).
- The An-148-100 aircraft. Wing torsion box. Analysis of the stress-strain state of mass-produced wing by the finite-element method (NASTRAN).
- The An-148-100 aircraft. Comparative analysis of computational and experimental data of wing torsion box SSS.
- The An-148-100 aircraft. Calculation of wing torsion box with regulated damage for residual strength.
- The An-148-100 aircraft. Strength evaluation of the center wing section integral fuel tank for case of emergency landing in accordance with the requirements of CB-148 para 25.963 (d).
- The FEM stability study of An-148-100 monolithic wing panel samples.
- Calculation of the coefficients to transit from the theoretical masses of the wing torsion box longitudinal set to the real masses of the wing units.
- The An-148-100 aircraft. Power plant attachment pylon. SSS Analysis of the pylon torsion box using FEM (for serial production).
- The An-148 aircraft. Wing nose part. Calculation of static strength.
- The An-148 aircraft. Deflectable nose. Calculation of static strength.
- The An-148 aircraft. Spoilers. Calculation of static strength. Part 1.
- The An-148 aircraft. Wing tail part. Calculation of static strength.
- The An-148 aircraft. Aileron. Calculation of static strength.
- Selection of modeling options for three-layer structures from composite materials in MSC/NASTRAN. Calculations of the wing high-lift devices with damage allowed to take off from an off-base aerodrome.

- The An-148-100 aircraft. Substantiation of compliance of the fuselage structure and equipment mounted therein with the CB-148 requirements regarding static strength.
- The An-148-100 aircraft. Substantiation of compliance of the fuselage pressurized cabin with the CB-148 requirements regarding static strength.
- The An-148-100 aircraft. Substantiation of compliance of the fuselage structure in emergency landing on ground with the CB-148 requirements regarding static strength.
- The An-148-100 aircraft. Substantiation of compliance of the fuselage structure in emergency landing on water with the CB-148 requirements regarding static strength.
- The An-148-100 aircraft. Substantiation of compliance of the fuselage and windshield structure in a collision with a bird with the CB-148 requirements regarding static strength.
- The An-148-100 aircraft. Substantiation of compliance of the fuselage structure when it is damaged by non-localized fragments of mid-flight engines and the auxiliary power unit with the CB-148 requirements regarding static strength.
- The An-148-100 aircraft. Substantiation of compliance of the fuselage butt joints with the CB-148 requirements regarding static strength.
- The An-148-100 aircraft. Substantiation of compliance of the fuselage structure and equipment installed therein made of casting with the CB-148 requirements regarding static strength.
- The An-148-100 aircraft. Rationale for additional safety factors for fuselage structural elements made of composite materials and accepted design characteristics of composite materials used in the fuselage structure with the CB-148 requirements.
- The An-148-100 aircraft. Assessment of the fuselage structure residual strength.
- The An-148-100 aircraft. Substantiation of compliance of the means for fixing on-board equipment in the crew cabin and transport cabin with the CB-148 requirements regarding static strength.
- The An-148-100 aircraft. Substantiation of compliance of the pilot, inspector, crew and passenger seats, their safety systems and mounting units with the

CB-148 requirements regarding static strength.

- The An-148-100 aircraft. Conclusion on compliance of passenger seats, their safety systems and attachment points with the CB-148 requirements regarding dynamic strength and safety.
- The An-148-100 aircraft. Rationale for choosing the points on the fuselage structure to perform impacts during dynamic tests simulating collision with a bird in accordance with CB-148 paras 25.571 (e) (1), 25.631, 25.775 (b), (s).
- The An-148-100 aircraft. Rationale for compliance of the fuselage structure with LG destructed tires with the CB-148 requirements regarding static strength.
- The An-148-100 aircraft. Assessment of structural rigidity of the device intended for testing the crew cabin door for resistance to violent intrusion.
- The An-148-100 aircraft. Substantiation of compliance of panels and transverse beams of the transport cabin floor after exposure to high temperatures with the CB-148 requirements regarding static strength.
- The An-148-100 aircraft. Substantiation of compliance of the static and fatigue strength of the electrically heated glass framing TSK 008U.01.000 installed in the crew cabin.
- The An-148-100 aircraft. Substantiation of compliance of the pilot, inspector, crew and passenger seats, their safety systems, mounting units and fuselage structure in the area of the seat installation with the CB-148 requirements regarding static strength.
- Strength assessment for case of distribution of the APU non-localized fragments installed on the fire screen.
- The An-148-100 aircraft (An-148-100A, An-148-100B, An-148-100E Models). Substantiation of compliance of means fixing onboard equipment in the crew cabin and transport cabin with the CB-148 requirements regarding static strength. Engineering Analysis.
- The An-148-100 aircraft (An-148-100A, An-148-100B, An-148-100E Models). Substantiation of compliance of the passenger seats, their safety systems and rails for the seat installation with the CB-148 requirements regarding static strength. Engineering Analysis.
- The An-148-100 aircraft (An-148-100A, An-148-100B, An-148-100E Models).

Substantiation of compliance of means fixing newly installed equipment in the cabins with the CB-148 requirements regarding static strength. Engineering Analysis.

- The An-148-100 aircraft (An-148-100A, An-148-100B, An-148-100E Models). Substantiation of compliance of luggage racks, modified by memo 148.01.02.1091.131 with the CB-148 requirements regarding static strength.
- The An-148-100 aircraft (An-148-100A, An-148-100B, An-148-100E Models). Conclusion on conformity of the An-148-100 aircraft (An-148-100A, An-148-100B, An-148-100E Models) with GEVEN seats installed therein to the CB-148 requirements regarding the dynamic strength and safety of passengers (single-class layout for 83 passenger seats).
- The An-148-100EM aircraft. Substantiation of compliance of the passenger seats and couch, safety systems and their mounts and the fuselage structure in the seat and couch installation area with the CB-148 requirements regarding static strength. Engineering Analysis.
- Engineering analysis of conformity of non-metallic materials used in the typical interior designs of the An-148-100 aircraft (An-148-100A, An-148-100B, An-148-100E Models) to the requirements of the CB-148 Certification Basis, paragraphs 25.853 (a), 25.853 (d) and 25.853 (e).
- Conclusion on the design of passenger seats, their safety systems and attachment points to the CB-148 requirements in terms of dynamic strength and safety.
- The An-148-100 aircraft (An-148-100A, An-148-100B, An-148-100E Models). Substantiation of compliance of means fixing on-board equipment in the crew cabin and transport cabin with the CB-148 requirements regarding static strength.
- The An-148-100 aircraft (An-148-100A, An-148-100B, An-148-100E Models). Substantiation of compliance of the galley electrical equipment with the CB-148 requirements.
- The An-148-100 aircraft (An-148-100A, An-148-100B, An-148-100E Models). Substantiation of compliance of the passenger, instructor, flight attendant seats, their safety systems, mounting units and fuselage structure in the area of seat installation with the CB-148 requirements regarding static strength.

♦ The An-148-100 aircraft (An-148-100A, An-148-100B, An-148-100E Models). Certification tests of rescue equipment.

♦ The An-148-100 aircraft (An-148-100A, An-148-100B, An-148-100E Models). Certification fire tests of structural elements locxated in the passenger cabin and crew cabin.

♦ The An-148-100 aircraft (An-148-100A, An-148-100B, An-148-100E Models). Substantiation of compliance of safety measures provided during an emergency landing on water with the CB-148 requirements.

♦ The An-148-100 aircraft (An-148-100A, An-148-100B, An-148-100E Models). Assessment of the design of emergency exits and emergency equipment with the CB-148 requirements.

♦ The An-148-100 A, B, E aircraft. Results of ground certification tests for the assessment of rescue equipment.

3.2.5 Key Conclusions Regarding Airframe Design

A number of new design and technological solutions has been used in the airframe of the An-148-100/An-158 family of aircraft (fuselage, wing, pylons for attahment of power plants and tail units):

1. The scope of application of composite materials has been expanded in the fuselage, including floor beams and supports for their attachment to fuselage structural members.

2. The auxiliary power unit compartment is made entirely of composite materials.

3. Skin is attached to the fuselage frame using rivets with compensators, which ensure high quality of the outer surface and eliminate the need for milling the rivet heads after installation.

4. The canopy frame is made by welding, which greatly simplified the assembly technology.

5. A two-support joint scheme for attachment and control of extension of the slat sections using involute gearing in the extending/retracting actuators is applied – the slat is moved by the hinge mechanisms in the form of a pair of a gear wheel and a gear rack.

Due to the use of articulated bearings in the points of attachment of the rails with the slats brackets and the eye-lugs, the latter move and rotate relative to the plane of the mechanism as a result of changing the distance between the supports of the slat sections under their deformation and bending of the wing box because of loading in flight.

This made it possible to eliminate mutual loading of the wing slat and the wing torsion box due to arising movements and to ensure reliable contact and operation of the wheel-rack gear mechanism.

6. A rational design of the wing torsion box with a theoretical surface of a double curvature has been developed, which ensures high manufacturability and serviceability, survivability and long lifetime.

7. A seven-link flap extension-retraction mechanism has been developed that provides a predetermined trajectory of the flap extension.

8. A combined design of a flap with a metal torsion-box, nose and tail parts, and a deflector made of composite materials (CM) was developed.

9. A molybdenum coating was applied, which increases the wear resistance of the highly loaded parts from titanium alloys by more than 20 time.

10. A monolithic integrated design of CM interceptors and ailerons has been developed.

11. The pylon rational design for attachment of the main power plant was developed with the provision of optimal stiffness values to achieve the specified characteristics of flatter safety, wide application of composite materials in the tail and nose sections.

12. The design of caps made from pressed semi-finished products with two tips has been developed.

13. An integrated design of the rudder and elevator made of composite materials has been developed.

3.3 NEW STRUCTURAL AND TECHNOLOGICAL SOLUTIONS TO ENSURE STATIC STRENGTH AND LIFETIME

Ensuring flight safety and lifetime of aircraft structures are the urgent problems in development of aircraft. The specified static strength, lifetime and reliability of aircraft are to be established during the engineering and construction stages, provided in production and achieved in operation [1 – 5, 7 – 13, 59 – 61, 63, 77].

Engineering process of modern aircraft based on the principle of tolerance for damage is a complex scientific and technical problem, which is solved through integration of scientific research by specialists in the aviation industry and research centers.

Main factors that lead to violation of the aircraft performances or failures of parts, components and assemblies are fatigue, corrosion, wear, fretting corrosion, and the human factor [95, 99]. These factors largely depend on the state of the surface of the parts, its physical and chemical properties. By changing the surface properties, it is possible to improve the fatigue, tribotechnical and corrosion characteristics of aircraft structures.

Destruction of structural elements due to fatigue is the result of cyclic dynamic loads and additional factors (structural properties, operational, production, environmental conditions, quality of materials, coatings, manufacturability of production, monitoring the state of the structure throughout its life cycle) [57, 64, 67, 72, 86].

The aircraft operational experience has shown that it is impossible to completely eliminate corrosion of the aircraft structural materials. The material, its coating, structural solution are selected based on the specific types of corrosion damage and location of a particular structural member taking into account the corrosion behavior, schedule of periodic inspections and routine maintenance.

Wear issues for parts of aircraft mechanisms are relevant. The following types of wear are distinguished: oxidative, adhesive, abrasive, erosive, fretting. The fretting wear is the most dangerous for the aircraft units [86].

Safe operation on strength conditions is implemented on the basis of the tolerance for damage principle. Admissibility of damage provides a guarantee of the structure safety by establishing a time period for its inspection in operation to identify possible damage and to repair or to replace damaged elements prior to the moment when defects and damage could reach critical dimensions and lead to structural destruction.

When choosing structural materials to ensure the lifetime we took into account their static strength, plasticity, fatigue resistance, static and cyclic crack resistance, corrosion resistance, resistance to stress corrosion cracking, mechanical corrosion fatigue, wear resistance, and fretting fatigue resistance [26].

In accordance with the Aviation Regulations [79] it is necessary to show that an emergency or catastrophic situation due to fatigue, corrosion, manufacturing defects or accidental damage can be avoided throughout the entire life of the aircraft when analyzing strength, design level and production quality. This analysis should be carried out for the principal structural elements (PSE), which absorb a significant part of loads in flight and on ground, or overpressure loads, and destruction of which can lead to an emergency or catastrophic situation. Such elements include parts of the wing, tail unit, control, systems, fuselage, engine mounts, landing gear and their main attachment points.

When conducting the analysis, appropriate margins (reliability factors) should be applied.

Each analysis should be based on the following:

– Typical load spectrum, temperature and humidity expected in operation;
– A list of the main power elements and individual structural components (and their critical places), which being damaged could lead to an emergency or catastrophic situation;
– Results of test, which, as a rule, are done on full-scale models, and calculation of the principal load-bearing structural members and individual components;
– Data on operation of the similar aircraft.

The aircraft load-bearing structure in a whole must meet the requirements for permissible damage. An exception may be done for those parts (elements, parts) of the structure where the requirements for the admissibility of damage can not be realized in practice, for example, parts of landing gear.

Airframe constructions designed according to the principle of safe damage or those that are operated according to their technical condition must have sufficient survivability and lifetime (T) in presence of subcritical fatigue cracks in their elements.

$$T = \frac{N_{in.dur}}{\eta} + \frac{N_{w/crack}}{\eta_{cr}},$$

where $N_{in.dur}$ – durability prior to crack origination;

$N_{w/crack}$ – durability from the moment of crack origination to structural failure;

η, η_{cr} – reliability factors.

Durability of structures previously designed according to the safe lifetime principle and currently being in operation can be significantly increased by using integrated methods to delay development of fatigue cracks and to restore strength and tightness [24, 41, 63, 66, 98].

For structural places being critical in terms of fatigue strength conditions, fatigue resistance should be provided at the engineering stage taking into account the established lifetime values. It is recommended that the interval to the first inspection under conditions of fatigue resistance should be not less than 50% of the established lifetime. To do this pay attention to the choice of the appropriate material, overall structural strength, maximum possible reduction in stress concentration, as well as maximum increase in fatigue resistance through implementation of appropriate structural and technological provisions. Production processes for aircraft structural members and their assemblies should ensure stability of characteristics that affect the performances and fatigue resistance within the specified lifetime under the expected operating conditions.

Effectiveness of the provisions is checked by laboratory tests of individual structural elements (assemblies, joints, panels, compartments, etc.).

For structural points critical in terms of corrosion resistance, specified on the basis of accumulated experience, effective anticorrosion protection should be provided at the detail engineering stage. At the same time, you should pay attention to the choice of the appropriate structural material, take into account its stress corrosion susceptibility and other types of corrosion, and also consider the degree of environmental aggressiveness. Particular attention should be paid to the surfaces of mating elements that allow mutual movement during the loading process, as well as to those structural elements where corrosion may occur under stress, where it is necessary to provide measures that ensure absence of significant internal residual stresses (mounting, welding, technological, etc.).

Based on works performed an appropriate analysis should be done and possibility as well as conditions (measures) to operate the aircraft during the assigned lifetime should be proved. A procedure (system) for ensuring and supporting the structural safety has to be developed and proved according to the strength conditions during long-term operation based on the account and analysis of research and testing results as well as accumulated experience in operating the aircraft of this type. For this purpose it is recommended to use the ISO instructions of clause 7 regarding the phased establishment and increase of assigned lifetime (service life) for home-produced aircraft that are operated in foreign countries. In other cases, for example, when selling deomestically produced aircraft abroad or operating foreign aircraft, other procedures can be developed that provide equivalent safety, including the experience accumulated in the world aviation community.

Engineering, production, testing and operation of long-life aircraft based on the safe damage principle need the efforts of many scientists and engineers, who know how to apply the methodology of integrated design, production and engineering analysis using systems CAD\CAM\CAE\PLM.

This section provides only some of the research results and recommendations for ensuring the static strength and fatigue life of the An-148 and An-158 regional passenger aircraft (Figs 3.30, 3.31).

Fig. 3.30. An-148 Regional Passenger Aircraft

Fig. 3.31. An-158 Regional Passenger Aircraft

3.3.1 Providing Static Strength

The design of the airframe and systems was developed according to the AP-25 Aviation Regulations [79]. Operational and design loads (operational loads multiplied by the corresponding safety factors) have been determined using the proposed method for the full range of the aircraft design speeds and altitudes, overloads, weights and balances, fuel weight, cargo weight and various possible combinations of their distribuution, taking into account the following:

- ♦ Dynamic loading and elastic features of the aircraft structure when flying in turbulent air and during landing;
- ♦ Dynamic loading of the control system structure in case of wind gusts on ground;
- ♦ System failures and malfunctions that directly affect strength characteristics (§25.302 of the CB-148 Certification Basis).

Reliable methods have been applied to determine the loads intensity and distribution and to balance them under the flight and ground loading conditions, taking into account the effect of the structural elastic deformations.

To determine the aerodynamic loads that act in the design cases of loading, the test results of the An-148 aircraft models in the T-106 wind tunnel of TsAGI and AT-1 wind tunnel of the ANTONOV Company were used (Fig. 3.32).

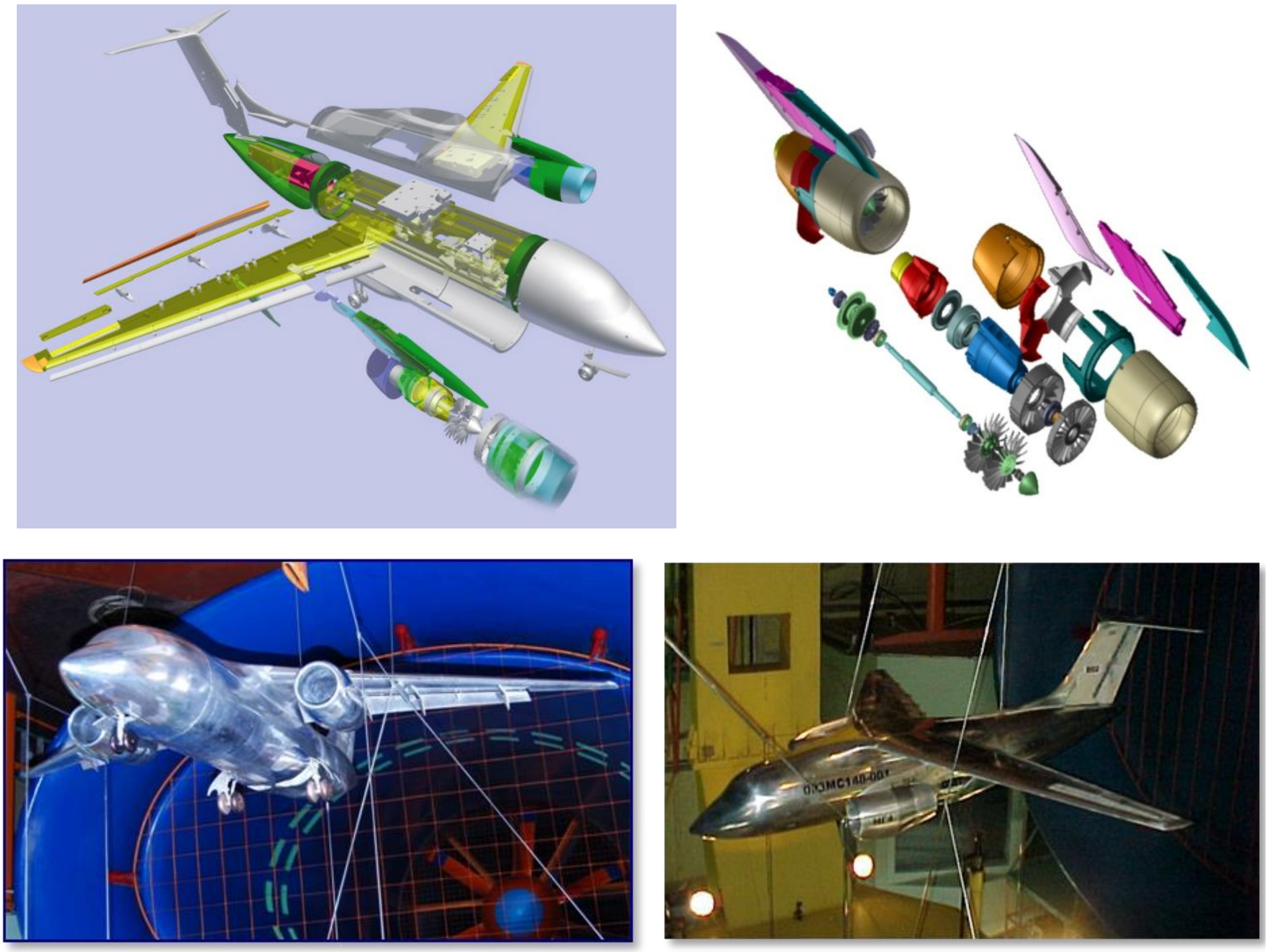


Fig. 3.32. Model in Wind Tunnel Tests

The accepted load values have been confirmed by the flight tests of the An-148 aircraft No. 01-01 and No. 01-02. According to the flight test results of the An-148 aircraft, the level of loading that rises under an aerobuffet and vibrations at the moment the aircraft reaches maximum speeds or stall speeds have been also determined.

For ground cases, the loads were selected taking into account the LG shock absorbing characteristics, checked by the dynamic drop tests of the main and nose landing gear legs. Sufficient level of accepted loads on the landing gear and airframe structure in ground cases has been confirmed by the flight test results of the An-148 aircraft.

Design loads also have been identified in case of system malfunctions or failures. Sufficient level of loads for various failures accepted in calculations has been confirmed by the results of the aircraft certification tests when simulating failure conditions.

The design conditions for ensuring static strength have been accepted, and they were used to establish operational limitations on strength.

Flight tests were conducted on the An-148 aircraft No. 01-01 and No. 01-02. During certification flight tests, the loads on every aircraft primary unit have been measured within the ranges of expected operating conditions, including testing at extreme flight conditions in terms of strength, under stall conditions, while studying speed characteristics, determining the boundaries of buffeting. According to the flight test results the consistent patterns of loading the aircraft primary units accepted in the calculations were confirmed. That is for the wing, high-lift devices, tail unit, engine mount, landing gear, fuselage, and control system.

The loads measured in flight tests did not exceed maximum operational loads accepted to ensure strength.

The flight test results have shown that the An-148-100/An-158 aircraft typical structure under conditions of static strength does not have features and parts that develope emergency conditions or are unreliable. The results of flight tests have confirmed the correct choice of the established operational limitations given for inclusion into the Flight Operations Manual (FOM).

The materials used in the aircraft structure possess stability properties guaranteed by manufacturers and confirmed by the Material Certification Center.

To determine the strength characteristics of structures made of polymer composite materials (PCM) at the engineering stage, the basic calculated values were used (using the "B" basis), and the technological features of manufacturing structures, degradation of material properties under prolonged influence of climatic factors and possibility of local damage due to mechanical influences were taken into account by introducing special coefficients for reducing the calculated values. On the An-148-100/An-158 aircraft, units using PCM have been made according to standard design patterns with application of proven materials and technologies that were used on the certified An-124, An-72, An-74, An-140 aircraft, and on the An-70 aircraft, taking into account the experience of designing and many years of operation of similar structures and corresponding PCM in various climatic zones. Materials and semi-finished products have been certified and delivered in accordance with the VIAM approved specifications. The structural elements made of composite materials (CM) were manufactured and tested according to the process documentation compiled at the ANTONOV Company and introduced into serial production. This documentation has passed many years of testing in production of the ANTONOV certified aircraft. Quality of units made of composite materials in serial production and their strength were tested during static tests of the units of the An-148 No. 01-03 aircraft (sections of the flap, slat, deflected nose, aileron, spoiler, elevators and rudders), which are manufactured at the batch production factory.

Strength analysis of PCM structures was carried out using reliable methods of computational modeling (including NASTRAN) (Fig. 3.33) and was tested with tensometry during static tests of units.

Strength characteristics of materials and their calculated values, which were determined on the basis of the applied criteria, as well as the technology for the manufacture of units satisfy the AP-25 requirements [79].

Static strength of the An-148-100/An-158 aircraft having typical structure has been confirmed by strength calculations, static tests of the units of An-148 aircraft No. 01-03 and static tests of individual structural elements of An-148 No. 01-03 aircraft at the test stands.

An-148 No. 01-03 aircraft was subject to static tests conducted in the strength laboratory of the ANTONOV Company (Fig. 3.34) according to the program agreed with TsAGI included loading the structure with operational loads and loads up to the design load for at least 3 seconds with necessary checks in accordance with the AP-25 requirements [79]. The static test program has been fully implemented.

In order to use the static test results of An-148 No. 01-03 aircraft, the following calculations were performed to confirm static strength of the An-148-100 aircraft having typical structure:

– The strength analysis of the airframe units by the finite-element method for maximum operational loads (67 % P_p) of design cases, implemented during the aircraft static tests using tensometry;
– Comparison of the tensometry results of the airframe structural members obtained during static tests with corresponding results of the strength analysis by the finite-element method.

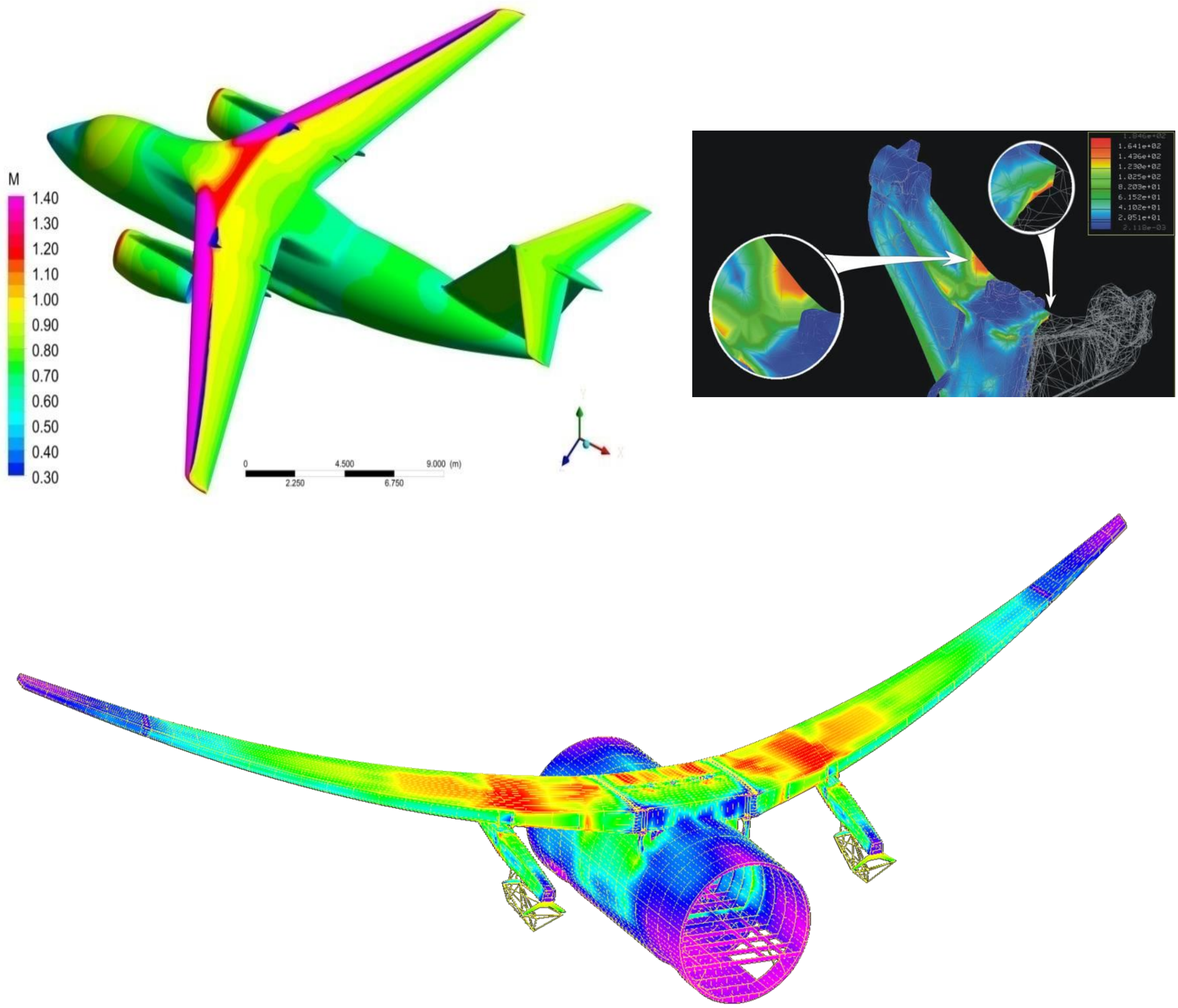


Fig. 3.33. General and Local Stress-Strain State. Pattern of Load Distribution

Fig. 3.34. Stand for Airframe Static Tests and Proving Its Lifeime

Strength calculations of the An-148-100/An-158 units having typical structure were performed taking into account all the improvements aimed at introducing into series production in design cases of loading using models refined by the results of comparing tensometry in static tests with the airframe calculation by the finite-element method.

Determination of the structure stress-strain state was carried out by the finite-element method with the use of skin reduction in compressed zones. Critical stresses of the overall loss of stability were determined using diagrams of material deformation and skin reduction, as well as taking into account the results of compression tests of full-scale panel samples.

The results of static tests have shown that the An-148100/An-158 aircraft typical structure under conditions of static strength does not have features and parts that could cause emergency conditions or are unreliable.

When conducting static tests after the units had been loaded with operational loads and then unloaded, and also after completion the tests with maximum loads, ability to open and close hatches and doors, landing gear extension/retraction was checked, and the wheel steering mechanical control linkage was tested for jamming.

There were no comments on the functioning of the tested units.

Regarding the An-158 aircraft its wing and fuselage structure were reinforced to ensure its strength because of increase in load. Moreover, the static strength has been provided at the level of the An-148-100 aircraft in a whole.

3.3.2 Provision of Lifetime and Service Life

The conditions for operation of the An-148-100/An-158 aircraft family with a design lifetime of 30 years were determined on the basis of a comparative analysis of the Antonov aircraft structure corrosion resistance with service life exceeding 30 years, and TsAGI recommendations.

The An-148-100/An-158 aircraft have been designed and manufactured in all-climatic versions in compliance with all requirements for corrosion protection for these versions.

The load-bearing structure of the An-148-100/An-158 aircraft comprises pressed, rolled and forged semi-finished products from the traditional alloys D16T, D16chT, from the new alloys 1161T, 1163T, 1933T3, as well as from the traditional alloy V95pch, heat-treated according to T2 mode.

Having compared with the An-12, An-22, An-24, An-26, An-30 aircraft, which reached a service life of 40-45 years, the materials and their heat treatment modes were selected with the aim to improve the corrosion resistance of the aircraft power structure without compromising endurance and crack resistance characteristics.

So, the upper panels of the wing center section and the wing tip sections were made of pressed panels, respectively (Fig. 3.35), as well as of sheets and profiled sections of 1973 and B95pch alloys, heat-treated according to T2 mode. The upper panels of the wing center section, middle and tip sections of the An-12, An-22, An-24, An-26, An-30 aircraft are made from semi-finished products of alloy B95, heat-treated according to T1 mode.

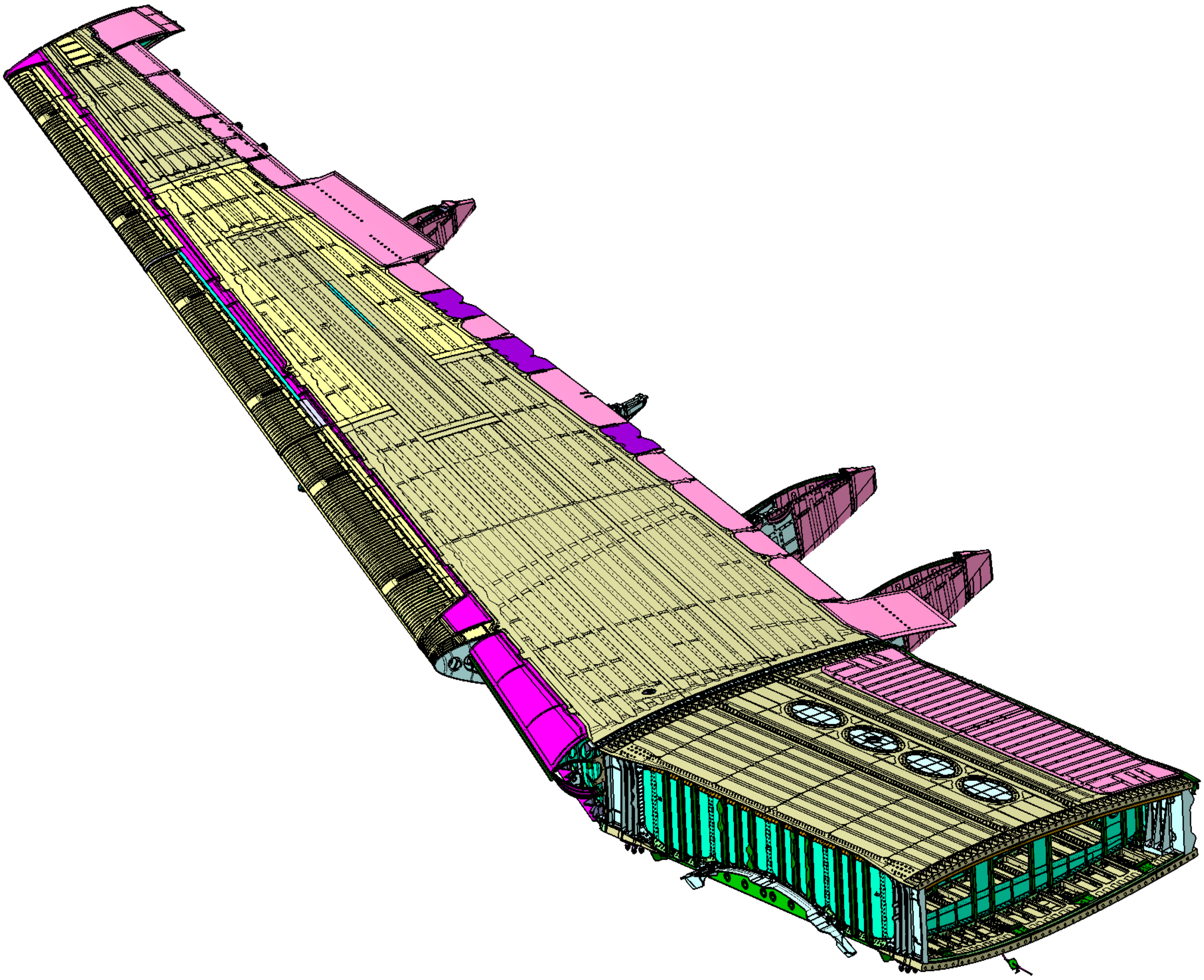


Fig. 3.35. Wing Center Section and End Section

The two-stage aging mode T2 compared to the single-stage mode T1 significantly improves the delamination resistance and the corrosion cracking of semi-finished products from alloys 1973 and B95 (Ref. Table 3.2).

The stringer set located in the area under the fuselage floor compared with the An-148-100/An-158 aircraft is made of extruded profiled sections of alloy D16T, D16chT. The operating experience of these aircraft showed insufficient corrosion resistance of the profiled sections of alloy D16T, D16chT, especially in relation to delamination. Therefore, on An-148-100/An-158 aircraft, the entire stringer set, which is located under the fuselage floor, is made of sheets of V95pchA alloy, heat-treated under conditions of the two-stage mode T2.

Table 3.2

No.	Primary Load-bearing Structutral Elements	An-24, An-26, An-30, An-32, An-12, An-72, An-74, An-22			An-148-100/An-158		
		Alloy	Corrosion under stress (stress limit), kg/mm^2	Delamination, points	Alloy	Corrosion under stress (stress limit), kg/mm^2	Delamination, points
1	Upper panels of the wing center, middle and tip sections	V95T1 V95pchT1	5	6 – 7	1973T2 V95pchT2	17.5	2 – 3
2	Lower panels of the wing center, middle and tip sections	D16T D16chT	5	6 – 7	1161T D16chT 1163T	5 – 6	6 – 7
3	Upper caps of wing spar	V95T1 V95pchT1	5	6 – 7	V95pchT2	17.5	2 – 3
4	Lower caps of wing spar	D16T D16	5	6 – 7	D16chT 1163T	5 – 6	6 – 7
5	Spar caps of stabilizer and fin	D16T D16	5	6 – 7	D16chT 1163T	5 – 6	6 – 7
6	Brackets and fittings of wing and fuselage, sidewalls of fuselage frames	AK6T1	5 – 6	6 – 7	1933T3	24	2
		V93T1	5 – 6	6 – 7			
		V93pchT2	15	4			
		1933T3	24	2			
7	Fuselage stringers	D16T D16chT			V95pchAT2	17.5	2 – 3
		01420					

All highly loaded brackets, wing and fuselage fittings, and sidewalls of the fuselage frames on the An-148-100/An-158 aircraft are made of 1933T3 alloy stampings. Alloy 1933, heat-treated according to the two-stage regime T3, in comparison with alloys AK-6T1 and V93pchT1, from which similar structural elements of An-12, An-22, An-24, An-26 and An-30 aircraft are made, significantly exceeds the latter in terms of resistance to corrosion cracking and delamination (Ref. Table 3.2).

Materials used in the An-148-100/An-158 aircraft construction have not shown to possess degraded properties (mechanical, fatigue resistance and crack resistance) in the fleet of the Antonov aircraft with a service life of more than 40 years. Consequently, the

An-148-100/An-158 aircraft developed to have a design life of 30 years does not require special measures in operation to replace strong members or to strengthen them under conditions of material degradation.

The aircraft used a number of design and technological solutions to protect against worsening strength in operation due to atmospheric influences, corrosion and wear. Below a list of the solutions is given.

1. Most of the fuselage typical stringers of the An-148-100/An-158 aircraft consist of bent profiled sections made of D16AT and V95pchAT2. Curved profiled parts are made of clad sheets, and due to the cladding the curved profiled sections have increased corrosion resistance compared to pressed profiled sections.

2. In order to exclude possible accumulation of water, to ensure ventilation and inspection of the skin and the internal condition, the heat and sound insulation does not stick, as in previously designed aircraft, but is suspended so that there is a gap between the insulation and skin.

3. To prevent formation of stagnant zones (moisture accumulation) in the fuselage there are drainage holes, drainage valves and slots.

4. Compact water-vacuum toilet system eliminates the ingress of aggressive liquids into the fuselage underfloor space.

5. When designing removable hatches and detachable panels the regulated gaps were provided, which are filled with sealant, and their removal to lubricate is ensured.

6. Construction details that go out to the external outlines are anodized after fitting, drilling and countersinking the holes. In pressurized compartments the rivets are sealed.

7. Main power plant and auxiliary power unit are arranged so as to eliminate ingress of exhaust gases to the structural elements.

8. The main method of corrosion protection of parts made of aluminum alloys is sulfuric acid anodic oxidation, followed by the application of paintwork. The thickness of the anode-oxide coating on the skin clad sheets for the An-148-100/An-158 aircraft is of 6 to 12 microns. On the details of pressed semi-finished products that go out to the external outlines as well as on the strong members of the critical internal set made of pressed semi-finished items, the thickness of the anode-oxide coating is at least 6 μm. The thickness of the anodic-oxide coating on the parts of previously designed aircraft is

of at least 4 microns.

9. Skin sheets in the area under fuselage floor, of the lower wing and tail surfaces, where condensation and moisture accumulation are possible, have double-sided cladding with a thickness of at least 40 microns on each side.

10. Rivets of all units, with the exception of metallization rivets, were subjected to anodic oxidation in sulfuric acid with filling the coating in a solution of potassium dichromate. The milled rivet heads as well as the metallization rivets undergo local chemical oxidation prior to final painting.

11. Parts of torsion box integral tanks are subject to sulfuric acid anodic oxidation with filling the coating in a solution of potassium dichromate. The inner surface of the torsion box integral tanks is covered with a fuel-resistant coating (primer EP-0215).

12. To protect parts that go out to the external outlines, the following painting options are applied:

- Based on perchlorovinyl enamels;
- Based on epoxy enamels;
- Based on polyurethane enamels.

13. Closed areas of the structure are additionally protected by a preventive, periodically renewed in use, anti-corrosion compound of the Dinitrol type.

14. Production processes for manufacture of the An-148/An-158 aircraft parts comprise the following operations:

- Anodizing of parts from *Al* and *Ti* alloys;
- Oxidation of parts from *Al* and *Mg* alloys;
- Cadmium plating, phosphating, hard chrome plating of parts from structural steels;
- Application of special types of chemical-thermal treatment (nitriding, cementation);
- Application of appropriate primers and coatings, made in accordance with the requirements to all-climatic version.

15. Structure provides possibility of easy access to closed areas as follows:

- In fuselage – removable floor panels, hinged panels of the power fillet;
- In wing – manholes on the upper (for center section) and lower (for wing console) torsion box panels, hinged panels on the wing and wing-to-fuselage fillet;

– In tail init – removable panels and hinged paneks on the stabilizer and fin.

16. The operation manual of the An-148-100/An-158 aircraft (Section 51) provides standardized processes for removing corrosion and preventing its origination.

The effectiveness analysis of the accepted design solutions, selected construction materials, heat treatment modes and protective coatings has been performed. There, the acceptable periods between inspections for the main strong elements are determined and the periods to be included in the aircraft maintenance program are recommended.

Thus, it can be stated that the main strong elements of the An-148-100/An-158 aircraft type design are protected from worsening or losing strength in operation for any reason, including atmospheric effects, corrosion and wear, as well as provided with sufficient means of ventilation and drainage.

To confirm the structural safety subject to acoustic influence, an assessment of strength and fatigue at high frequency load caused by pulsations of aerodynamic pressure that occur in operation of the D-436-148 power plant was performed. The calculated data are confirmed by the test results of samples and units having similar structure, as well as by the operating experience of similar aircraft.

The results of the work allow us to state:

♦ Occurrence of fatigue cracks due to acoustic loads in any part of the aircraft structure subjected to acoustic influence is not likely;
♦ Accidental or catastrophic failure due to a crack developed due to acoustic loads is not likely.

Structural elements made of materials based on carbon, glass, organic, combined fibers and their textile forms using polymer thermosetting matrix (PTM) are used in the An-148-100/An-158 fuselage, wing, pylons of the main engines and tail unit. They can be conditionally divided into the following groups:

♦ *Made of fiberglass or organoplastic*: radar fairing, fairings of the main LG legs, wing-to-fuselage fillet, dorsal fin radiolucent compartment, forward fin fairing, rear part of fin tab, elements of pylons for attachment of main engines, fairings of wingtips, movable and stationary shells of flap actuator fairings, panels of wing center section fillet;
♦ *Made of carbon fiber*: main LG doors, floor cross-beams, spoiler frames,

elevator, rudder, wing tail section panels, fin and stabilizer, aileron frames, flap structural elements.

The main load-bearing structural elements comprise transverse floor beams made of carbon fiber, spoiler frames, elevator (Fig. 3.36) and rudder (Fig. 3.37), as well as ailerons.

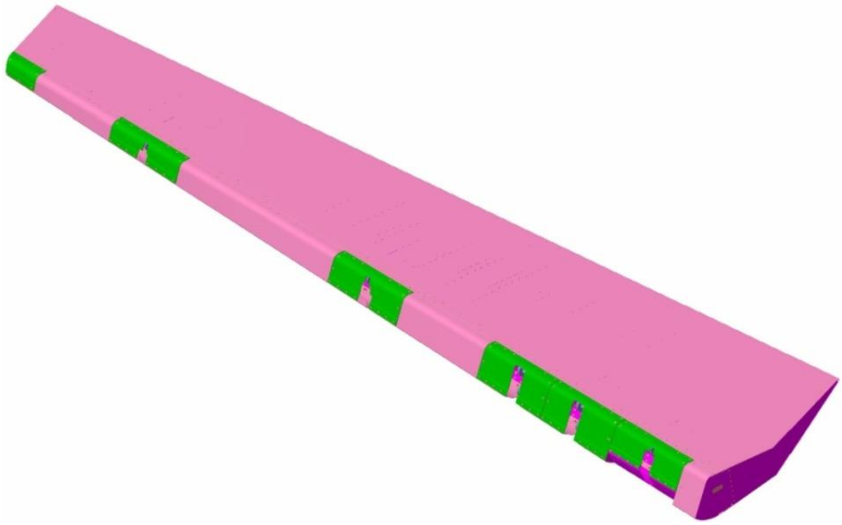


Fig. 3.36. Elevator

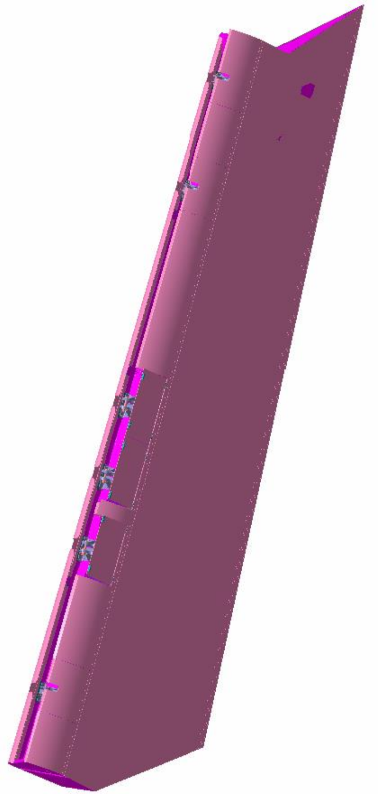


Fig. 3.37. Rudder

Polymeric thermosetting matrix (PTM) units have such features:

♦ High fatigue resistance with optimal fiber content compared to metal alloys and absence of the fretting corrosion effect on the fatigue of mechanical joints;

♦ Insensitivity of strength and fatigue to small stress concentrators commensurate with the transverse size;

♦ Saturation with moisture and subsequent worsening of both the material mechanical properties and load-bearing capacity of structures, especially under compression (shearing) at operating temperature.

When choosing the structural implementation of the specfified units, the experience of designing, manufacturing and more than 20 years of operation of composite units of the An-70 aircraft was applied. In particular, a proven integrated structure has been applied.

Due to the fact that durability of structures is significantly affected by the environment, effective methods of protecting surfaces and especially the tips of composite parts from moisture penetration by means of sealants, paints and special protective coatings have been applied to protect them.

In addition, durability of composite structures is affected by local damage to the structural material due to mechanical shock. For units from the polymer composite materials of the An-148-100/An-158 aircraft, targeted inspections are provided in operation, both visual and using instrumental control methods (acoustic), and corresponding non-destructive testing cards have been developed.

To confirm possibility of operation during the project lifetime and service life of PTM units, they have been tested for fatigue with simulated typical accidental damage during maintenance, as well as for residual and climatic strength and survivalability in accordance with the "Integral Schedule to Ensure Strength and Service Life of the An-148 Structure".

Therefore, it can be argued that according to the results of the work performed and taking into account the scheduled strength tests, it is possible to establish a design life-time and service life of the PTM units.

To ensure and to support safe operation of the An-148-100/An-158 structure according to the strength conditions during long-term operation, the principle of phased establishment and prolongation of the assigned lifetime and service life has been taken as the basis, which allows organizing effective interaction between the aircraft designer and operator thereof.

The following main issues of the adopted approach can be highlited:

♦ The initial assigned lifetime should not exceed 27% of the design value and amounts to 20,000 flight hours, 10,000 flights for the An-148-100A, An-148-100B and 8 000 flights for the An-148-100E, An-158 aircraft. The specified values have been confirmed by the fatigue tests of the An-148-100 aircraft No. 01-03 and are based on the calculations, as well as they take into account the requirement for the ratio of the aircraft maximum allowable operating time in operation;

♦ The initial assigned service life should not exceed maximum service life achieved for prototype aircraft until the first overhaul (or CWR) and is 10 years;

♦ An increase in lifetime and service life should be carried out on the basis of an analysis of operational data (service information, data on identified malfunctions and flight information from airborne registration devices and the RPP-148 strength parameter recorder);

- ♦ Reading, preliminary processing (including preliminary analysis) and accumulation of information should be carried out during line maintenance;
- ♦ The accumulated operational data should be transferred to the ANTONOV Company once a year;
- ♦ Continuous (if necessary) updating of the aircraft operational technical documentation (OTD) and timely informing the Operator on these issues (if necessary, through the Aviation Departments).

The above provisions are reflected in the operational documentation (OTD) of the An-148-100/An-158 aircraft. The design lifetime (service life) should be spent in stages. The current stages of design lifetime (service life) should be indicated in the "Airworthiness Limitations" Section in the Flight Operations Manual (FOM). ANTONOV Company provides the lifetinme (service life) prolongation in advance by preparing proper proving documents in accordance with the AP requirements and submitting them to the IAC Aviation Register and the State Aviation Administration of Ukraine.

FOM Section 04 named "Airworthiness Limitations" establishes special requirements for the operating conditions of the main strong elements of the aircraft structure, which provide possibility of detecting accidental and corrosion damage, and in some cases, fatigue damage. For the current stage of the design lifetime, the allowable operating time for the airframe, engine mounts, landing gear and mechanical elements of their extension/retraction system, mechanical elements of the control and configuration system, structural elements that provide mutual power connection of the airframe parts and aircraft units are established.

For the aircraft construction (power elements and critical places), periodic maintenance includes the following forms.

- ♦ Form **sA**. To be performed every 300 flights or 6 months;
- ♦ Form **sC**. To be performed every 3 000 flights or 36 months;
- ♦ Work on individual aging control programs. To be performed for aircraft that have been operated for 15 000 flights or 10 years, according to forms multiple of **sC**.

The ANTONOV Company ensures safe aircraft operation within the specified lifetime (service life) by doing the following:

- ♦ Making clarifications into OTD;
- ♦ Issuing bulletins, lists of replacements of parts (units of equipment) with limited lifetime (service life), technical documentation (TD) for repairs and refinements (if necessary);
- ♦ Issuing recommendations for the aircraft technical operation in the detection of defects beyond the OTD;
- ♦ Development of individual aging control programs for each aircraft;
- ♦ Information support for aircraft operation.

To ensure operation during the design lifetime and to eliminate restrictions in advance in accordance with the requirement, a set of fatigue and functional tests has been done, as well as survivability and residual strength were tested also. This provides double operating time of the structure in advance during fatigue tests regarding the aircraft fleet flight hours.

Airworthiness in terms of providing lifetime (service life) is provided subject to the Operator should observe the following:

- ♦ Requirements of operational documentation;
- ♦ Works according to individual Aging Control Programs for labor-intensive maintenance forms for aircraft that have been operated for 15 000 flights or 10 years;
- ♦ Operator of the aircraft should transfer to the Antonov State Company data on aircraft operation time in hours and flights, failures and malfunctions, operating conditions, including readings of the RPP-148 instrument and the BUR-95-02 flight recorder for analysis. In cases of untimely and incomplete data transfer to the ANTONOV Company the conservative approach to be used to extend the assigned lifetime and service life.

The strength assessments performed have shown that an emergency or catastrophic situation due to fatigue, corrosion, manufacturing defects or accidental damage can be avoided throughout the whole life of the aircraft.

Regarding the An-158 aircraft, the design life and airframe life during operation according to the technical condition correspond to the similar data of the An-148-100E aircraft and are provided by appropriate modifications of the strong elements. The lifetime and service life are worked out in accordance with the aircraft operational documentation.

The following list contains technical reports, engineering analyzes, and technical informative notes on durability, life, and service life of the An-148-100/An-158 aircraft:

- ♦ The An-148 aircraft. Calculation of external loads.
- ♦ The An-148-100 aircraft (An-148-100A, An-148-100B, An-148-100E Models). Substantiation of the structure static strength. Summary data.
- ♦ Report on static tests of the An-148 aircraft inspector's seat, seat fastening units and AM SAFE 4137-1-0113577 fastening system on the crew cabin door.
- ♦ Report on static tests of the An-148-100 flight attendant's seat, seat fastening units and fastening units of the AM SAFE model 4057 fastening system.
- ♦ Reports on static tests of the Geven passenger seats.
- ♦ The An-148-100 aircraft (An-148-100A, An-148-100B, An-148-100E Models). Substantiation of conformity of static durability of the wing torsion box structure to the CB-148 Certification Basis requirements (Consolidated data).
- ♦ The An-148-100 aircraft (An-148-100A, An-148-100B, An-148-100E Models). Substantiation of compliance of static strength of the wing high-lift devices' structure with the CB-148 requirements (Consolidated data).
- ♦ The An-148-100 aircraft (An-148-100A, An-148-100B, An-148-100E Models). Substantiation of compliance of static strength of the tail unit structure with the CB-148 requirements (Consolidated data).
- ♦ The An-148-100 aircraft (An-148-100A, An-148-100B, An-148-100E Models). Landing gear. Consolidated data on substantiation of strength. Engineering Analysis.
- ♦ The An-148-100 aircraft. Calculation of strength of the hydraulic units.
- ♦ The An-148-100 aircraft (An-148-100A, An-148-100B, An-148-100E Models). Consolidated data on the power plant static strength.
- ♦ The An-148-100 aircraft (An-148-100A, An-148-100B, An-148-100E Models). Substantiation of compliance of static strength of the main power plant attachment pylon structure with the CB-148 requirements (Consolidated data).
- ♦ The An-148-100 aircraft. Substantiation of compliance of static strength of the fuselage structure and equipment installed therein with the CB-148 requirements. Engineering Analysis.
- ♦ The An-148-100 aircraft (An-148-100A, An-148-100B, An-148-100E Models).

Substantiation of compliance of static strength of the pilot seats, instructor seats, flight attendant seats, their fastening systems and installation units, as well as the fuselage frame in the area of the seats installation with the CB-148 requirements. Engineering Analysis.

- ♦ The An-148-100 aircraft. Consolidated data on the substantiation of strength of the main control linkage structure of the An-148-100 airplane, regarding the An-148-100A, An148-100B, An-148-100E models. Engineering Analysis.
- ♦ The An-148-100 aircraft (An-148-100A, An-148-100B and An-148-100E Models). Equipment of luggage and cargo compartments (Consolidated data on strength).
- ♦ Results of copra tests for workload and repeated drop of the An-148 nose LG support.
- ♦ Results of copra tests for workload and repeated drop of the An-148 MLG support.
- ♦ The An-148-100 aircraft. Certification flight tests to study the loading patterns of the airframe units in the range of operational limitations and in boundary modes with regard to strength. Technical Report.
- ♦ The An-148-100 aircraft (An-148-100A, An-148-100B, An-148-100E Models). Certification flight tests to determine vibration and buffing safety. Technical Report.
- ♦ Conclusion on conformity of the materials used in the An-148-100 aircraft typical structure (An-148-100A, An-148-100B, An-148-100E Models) to the requirements specified in paras 25.603, 25.609 and 25.613 of the CB-148 Certification Basis.
- ♦ The An-148-100 aircraft. Evaluation of conformity of the structure in case of damage by nonlocalized engine fragments to the requirements specified in para 25.571 (e) of CB-148.
- ♦ The An-148-100 aircraft (An-148-100A, An-148-100B, An-148-100E Models). Strength evaluation of the protection against scattering of the APU non-localized fragments when installed on the fire screen.
- ♦ The An-148-100 aircraft (An-148-100A, An-148-100B, An-148-100E Models). Substantiation of structural strength in case of damage caused by collision with

a bird in accordance with the requirements of CB-148 paras 25.571 (e) (1) and 25.631 (as for wing, main power plant attachment pylon, tail unit).

- The An-148-100 aircraft (An-148-100A, An-148-100B, An-148-100E Models). Substantiation of structural strength in case of damage caused by collision with a bird to the requirements of CB-148 paras 25.571 (e) (1) and 25.631 (fuselage and crew cabin windshield).
- Windshield TSK 008U.01.000. Report on the results of bench dynamic tests.
- The An-148-100 aircraft (An-148-100A, An-148-100B, An-148-100E Models). Substantiation of compliance of the pressurized fuselage static strength with the CB-148 requirements. Engineering Analysis.
- The An-148-100 aircraft (An-148-100A, An-148-100B, An-148-100E Models). Substantiation of compliance of the fuselage structure static strength in case of an emergency landing with the CB-148 requirements. Engineering Analysis.
- The An-148-100 aircraft. Flight Manual.
- The An-148-100 aircraft. Weight and Balance Manual.
- Technical Specifications for manufacture, control, acceptance and supply of An-148 aircraft No. 01-03, designed for strength tests.
- The An-148-100 aircraft No. 01-03. Analysis of the causes of the fuselage structural destruction during static tests. Substantiation of sufficiency of the executed reinforcements of a typical fuselage structure. Engineering Analysis.
- Wing torsion box. Consolidated data on static strength.
- Pylon. Consolidated data on static strength.
- Wing high-lift devices. Consolidated data on static strength.
- Consolidated data on static strength of the fuselage and equipment installed therein.
- Tail unit. Consolidated data on static strength.
- Landing gear. Consolidated data on static strength.
- The An-148-100 aircraft. Technical Report. Calculation of spectra of overloads and fatigue loads on structural elements in the predicted conditions of typical operation.
- The An-148-100 aircraft. Certification ground tests to determine main operational and technical characteristics. Technical Report.

- The An-148-100 aircraft. Special certification flight tests to determine statistical characteristics of load recurrence on the typical operation modes. Technical Report.
- The An-148 aircraft. List of critical structural members.
- Report on the results of strain gauge measurements of the An-148-100 aircraft No. 01-03 during fatigue tests.
- Report on the fatigue test results of the An-148 aircraft No. 01-03.
- The An-148-100 aircraft. Fatigue test program for the An-148-100 aircraft No. 01-03. ANTONOV Company, Explanatory Document No. 615, TsAGI, TsAGI-TEST SC.
- The An-148-100 aircraft. Explanatory Document to the Fatigue Test Program No. 148.00.0132.006 PM of the An-148-100 aircraft No. 01-03.
- The An-148 aircraft. Test program for endurance and functional efficiency of the LG extention/retracton and LG doors mechanisms. The ANTONOV Company.
- The An-148 aircraft. Test program of system turning the nose LG leg regarding lifetime and operation.
- The An-148-100 aircraft (An-148-100A, An-148-100B, An-148-100E Models). Conclusion on the establishment of the initial assigned lifetime of 20,000 flight hours, 10,000 flights, 10 years for critical members, components and units of functional LG systems under conditions of fatigue strength and operation during long operation.
- The An-148-100 aircraft. Conclusion on the conformity of the An-148-100 aircraft standard structure to the CB-148 Sertification Basis requirements in terms of protection from flutter, reverse and divergence.
- The An-148-100 aircraft. Substantiation of the wing design lifetime.
- The An-148-100 aircraft. Calculation of equivalents between loads during fatigue tests according to the Program No. 148.00.0132.006 PM and loads under expected operating conditions.
- The An-148-100 aircraft. Substantiation of the fuselage design lifetime.
- The An-148-100 aircraft. Substantiation of the tail unit design lifetime.
- The An-148-100 aircraft. Analysis of the residual strength and stress levels in

the structures of the wing, APU attachment pylon and tail unit to determine the damage tolerance (safe failure) in accordance with paras 25.571 (a), (b) of the CB-148 Certification Basis. Engineering Analysis.

- The An-148-100 aircraft. Substantiation of the design lifetime of the D436-148B engine mounting pylon and AI-450-MS APU mounting.
- The An-148-100 aircraft. Substantiation of the design lifetime of the deflectable flaps, slats and noses.
- The An-148-100 aircraft. Substantiation of the design lifetime of the elevator, rudder, aileron and spoilers with their attachment elements.
- The An-148-100 aircraft. Substantiation of the landing gear design lifetime.
- The An-148-100 aircraft. Calculation of LG struts fatigue life.
- The An-148-100 aircraft. Substantiation of the design lifetime of the wheel steering system linkage in the crew cabin and control system of flaps, slats and deflectable noses.
- An-148-100 aircraft. Test program for fatigue resistance and functional characteristics of the aircraft deflectable nose and flap together with the mechanical control system.
- The An-148-100 aircraft. Test program for fatigue resistance and functional performance of the flap together with the mechanical control system.
- The An-148-100 aircraft. Test program for fatigue resistance and functional performance of the rudder with elements of its attachment and control.
- The An-148-100 aircraft. Test program for fatigue and operation of wheel steering system mechanical linkage in F1.
- The An-148-100 aircraft. Maintenance planning document (DPTO / MPD).
- List of materials of the main load-bearing members of the An-148-100 aircraft.
- The An-148-100 aircraft. Substantiation of the aircraft structure design service life of 30 years under conditions of corrosion resistance.
- Summary data on the assessment of fatigue strength under acoustic loads.
- The An-148-100 aircraft. Initial data for maintenance planning.
- The An-148-100 aircraft. Maintenance Regulations.
- The An-148-100 aircraft. Fatigue test program for the aircraft main and nose

landing gear legs.

- The An-148-100 aircraft. Test program for resistance to pylon fatigue and engine mounting D-436-148B.
- The An-148-100 aircraft (An-148-100A, An-148-100B, An-148-100E Models). Estimation of the fuselage structure residual strength in case of regulated damages. Engineering Analysis.
- The An-148 aircraft (An-148-100A; An148-100B; Ан-148-100E Models). Substantiation of conformity of the D-436-148 engine attachment structure to para 25.571 (a), (b) of the CB-148 Certification Basis requirements [Damage tolerance analysis (safe failure)]. Technical Informative Note.
- The An-148 aircraft (An-148-100A; An148-100B; Ан-148-100E Models). Analysis of changes in aircraft lifetime characteristics with different systems of automatic pressure regulation.
- Conclusion on the conformity of the An-158 aircraft to the CB-148 Sertification Basis requirements with regard to static strength.
- Conclusion on the conformity of the An-148-100 aircraft type (An-158 Model) in connection with implementation of the "Increase of maximum landing weight to 37 800 kgf" main modification of type design to the CB-148 Certification Basis requirements with regard to static strength.
- Conclusion on the conformity of the An-148-100 aircraft type (An-158 Model) to the CB-148 Certification Basis requirements with regard to structural strength during long operation with increased maximum landing weight up to 38 800 kgf.
- The An-158 aircraft. Substantiation of the design lifetime and service life of 80 000 flight hours, 30 000 flights, 30 years with regard to strength during long operation.
- The An-158 aircraft. Conclusion on the conformity of the An-158 aircraft type design to the CB-148 Certification Basis requirements under conditions of protection from flutter, reverse and divergence.
- The An-158 aircraft. Conclusion on the conformity of the An-158 aircraft type design to the CB-148 Certification Basis requirements and establishing the initial assigned lifetime and service life of 20 000 flight hours, 8 000 flights, 10 years with regard to structural strength during long operation.

All these reports are included in the list of required supporting documents for further certification of the aircraft.

Basic Conclusions with Regard to Providing Strength

Based on the results of complex of calculations, experimental and research works done to ensure strength and safety of the An-148-100/An-158 aircraft structure that enhances design lifetime and service life the life values reached 80 000 flight hours, 60 000 flights for the An-148 -100A model, 40000 flights for the An-148-100B model, 30 000 flights for the An-148-100E model, 50000 flights for the An-158 model, 30 years under conditions of structural durability during long operation:

- Possibility of aircraft operation during the design lifetime and service life under fatigue durability conditions (including acoustic loads) and corrosion resistance has been proved;
- Conditions (measures) of providing operation during the design lifetime and service life have been defined and justified;
- Principles of providing and keeping operational safety have been defined.

Possibility to establish conformity of the type design of the An-148-100/An-158 (An-148-100A, An-148-100V, An-148-100E models and An-158) aircraft under the conditions of durability during prolonged operation with the requirements of the AP-25 Aviation Regulations has been confirmed with regard to the strength characteristics.

3.4 CONCLUSIONS

1. In the airfarme design (fuselage, wing, pylons for attachment of power plants and tail unit) of An-148-100/An-158 jet regional passenger aircraft family a number of new structural and technological solutions was applied:

– The scope of application of composite materials in fuselage has been expanded, including floor beams and their brackets for attachment to the fuselage structural members; fastening skin to fuselage framework is made by means of rivets with the compensator that provides high quality of an external surface and eliminates the necessity of milling the heads of rivets after their installation; auxiliary power unit compartment is fully made of composites;

– The rational design of a wing torsion box with a theoretical surface of double curvature, high adaptability and efficiency, ensuring survivability and long lifetime has been developed;

– The rational design of the pylon intended for the attachment of main power plant was developed providing optimal rigidity characteristics for achievement of the flutter safety given characteristics, wide application of composite materials in the tail and nose parts;

– The design of caps made of pressed semi-finished products with two end elements;
– The integral design of the rudder and elevatore of composite materials have been developed.

2. The high-wing configuration has been developed that allowed to design a family of regional passenger aircraft having an average flight speed of up to 870 km/h TAS (M = 0.8), which has no analogues in the world aircraft industry practice. As the basis of the aerodynamic layout of the high-speed wing of the An-148-100/An-158 aircraft family the next-generation supercritical airfoils are used, which were designed for it with a large maximum thickness ratio (greater than, for example, of the Airbus A320 and An-124 aircraft). The aircraft lift-to-drag ratio in cruise flight is K_{cruis} = 15.8, which corresponds to the world level.

3. Based on the results of complex of calculations, experimental and research works were done to ensure strength and safety of the An-148-100/An-158 aircraft structure that enhances design lifetime and service life the life values reached 80,000 flight hours, 60.000 flights for the An-148-100A model, 40000 flights for the An-148-100B model, 30.000 flights for the An-148-100E model, 50000 flights for the An-158 model, 30 years under conditions of structural durability during long operation.

Chapter 4
PASSENGER REGIONAL AIRCRAFT FAMILY INTERGRATED DESIGN AND PRODUCTION METHODS IMPLEMENTATION SPECIAL FEATURES

4.1 REGIONAL PASSENGER AIRCRAFT PRODUCTION SPECIAL FEATURES

Production of the An-148-100 aircraft in Ukraine started in 2007 at Kyiv’s state aviation factory "AVIANT" incorporated in 2010 into the ANTONOV Company and obtained a new brand as a subsidiary of the ANTONOV Company being renamed into the "Antonov series factory" (Fig. 4.1).

Fig 4.1. Final Assembly Shop at ANTONOV Company ("Antonov" series factory)

Preproduction and manufacturing of An-158 started in 2010 at the "Antonov series factory" being the subsidiary of the ANTONOV Company.

About 214 companies from 15 countries worldwide have been involved into aircraft production. The following companies are the suppliers of the main units and components: Kharkiv State Aircraft Manufacturing Company, State Enterprise "Production Association Yuzhny Mashinbuilding Plant named after A.M. Makarov" (Dnipro city), MOTOR SICH JSC; Zaporizhzhya is the supplier of the engines. Materials and vendor items are mainly supplied by the factories and companies of Ukraine Germany, France, Great Britain, United States of America.

4.1.1 Organization of An-148-100, An-158 Aircraft Production at "Antonov" Serial Production Plant of the ANTONOV Company Subsidiary

1. More than 20500 sets of documents have been issued and presented into production companies by the Developer after design and production procedures processing in the course of putting the An-148-100 aircraft putting into production Complete set of documentation contains documentation paper carrier complete set of 3D electronic models of master-geometry and a set of 3D electronic models parts and units. Electronic models have been developed and obtained using CADDS-5 system.

2. Wide cooperation has been organized as per aircraft airframe and structural components under start-up of new aircraft type for making cycle shorter and cost distribution for preproduction.

Production of main components has been distributed between companies in the following way:

– Nose and mid section of fuselage as well as outer wing be manufactured in Kyiv;
– Canopy and pilot cabin wind-shield, tail unit of fuselage, doors, vertical and horizontal stabilizers, wing high lift devices and its control systems pylons and engine nacelles be manufactures in Voronezh;
– Center section be fabricated in Kharkiv;
– Landing gear struts be made in Dnipro.

More than 30 specifications for components, units and parts supply have been developed, agreed and approved for the accurate distribution of works between cooperative companies and organization of mutual supply of aircraft airframe assemblies supple according to cooperation.

3. An-158 aircraft airframe differs from the An-148-100 aircraft airframe at 1700 mm with reference to the length, fuselage middle section, fuselage tail section wing strong center section and availability of tip aerodynamical surface at outer wing. Part of aircraft systems has been replaced, particularly, the СУИТ-148 (SUIT-148) fuel measuring system of Russian production has been replaced by the ТИС-158 (TIS-158) system of Ukrainian production.

4. Contrary to cooperation plan as far as An-148-100 aircraft is concerned, production of fuselage (Fig. 4.2), fin and stabilizer for An-158 aircraft has been performed by the "Antonov" serial production plant", a subsidiary of the ANTONOV Company enabling to reduce dependence on the suppliers to make cycle shorter and to decrease cost.

Fig 4.2. Assembly and Attachment Rig of Fuselage Component

4.1.2 Preproduction Procedure

1. When putting the An-148-100 aircraft into production, preproduction procedures have been performed for more than 65 000 parts, units and components.

Norms for of material expendure have been specified for 52 600 parts to be manufactured using 5682 specified types of materials. Due to application of a great number of new materials, a scope of work has been done to winder materials reference coders reference books of standard products followed by their use for operation in ETHERNET network.

2. Intensive work of production services and preproduction shops has been required to provide manufactures of the An-148-100 aircraft with technological facilities.

Totally, more than 19300 pieces of special technological facilities and tools have been designed and produced. Labour intensity of the works for providing facilities accounted more than 1 250 000 norms-hours. More than 75 000 sets of working production documentation have been developed for the procedures of manufacture, assembly, monitoring and testing.

3. Additional technological preproduction procedures for manufacturing more than 12314 parts, assembly units, and components have been done when putting the An-158 aircraft into production. More than 72 648 pieces of special technological facilities and tools have been designed and produced. Labour intensity of works for facilities provision accounted more than 2 270 998 norms hours.

4.1.3 Mastering and Implementation of Technological Procedures Prefabrication and Stamping of Pieces

Mastered, upgraded and implemented new technological procedures including:

- Fabrication of stringers profile blanks and frames outlines from sheet using limited bending technique;
- Members fabrication of thin-walled welded high lifetime pipelines from titanium and aluminium alloys including solution of problems associated with fabrication of pipeline titanium members of "elbow" and "triangle" type as well as calibration of pipeline member ends for welding;
- Mastering and implementation of technological procedures in fabrication of pipelines from АМг2М with soundproof partitions;
- Multitransitional processes in manufacture of thermal plugs of wing pressurized torsion box (more than 44 piece type);
- Stamping procedure and reaching a depth of 4.0 and 5.0 mm by special cutting;
- Manufacturing procedures of wing assembly parts and tanks using the procedure of deep extrusion with application of QAB-31.5 pressing machine;
- Procedures in fabrication of pipelines from polymeric composite materials;
- Procedures in manufacture of beams and supports from УОЛ-300-2А carbon fibres;
- Procedures in pressurized connection of pipes with transitional diameters having new type sizes;
- Procedures in development of new nomenclature and production of metalfluorideplastic sleeves according to Industry Standard ОСТ 1 10289-78.

Highly productive program controlled HANG WANG FL-3015 machine has been implemented to provide highly accurate cutting of sheet blanks using industrial laser (Fig. 4.3).

Fig 4.3. Materials Laser Cutting Section

After termination of the research works these facilities have enable to reduce significantly tolerances for cutting sheet blanks followed by upgrading accuracy of their fabrication as well as fabricating some aircraft parts without any next processing. Now, this machine is used for fabrication of low loaded parts of aircraft and templates that resulted in significant reduction of cycle and labor intensity.

Mechanically Assembly Production

In the period of putting the An-148-100 and An-158 aircraft into serial production an advanced vendor tools of Guhrring, UFP, Sandwik Coroment companies have been tested and implemented; cutters, side cutters, drills, markers from hard alloys and high speed cutting steels for cutting high strength corrosion resistant steels and titanium alloys enabling high productivity of labour, high quality and accuracy of processed parts. New types of lubricating and cooling materials have been tasted and put into production under mechanical processing by cutting that have significantly increased strength of tools and made it possible to use high speed processing condition.

Operations have been performed to restore workability and to modify technical facilities 500 machine tools have been deeply repaired and 160 cutting machines have been modified by replacing old systems of programmable numerically controlled machines (NCM) with the new ones, new metal processing tools have been obtained and put into production:

– Lathe tools of CA564C200Ф10 (2 pcs) and CA564C150Ф10 (9 pcs) models, precision lathe tool with automatic cycle control system E50 of "WEILER" company;
– High speed machine tool with belt type sew of "Behringer" company (2 pcs);
– Tool with belt sew of the "Behringer" company for cutting blanks along straight line with plate dimension of 1600×400×400 mm;
– Programmable NC machine of hydroabrasive type "Idroline 2040" of "CMS" company for figural cutting of blanks from plate with dimension of 2000×400×250 mm;
– High precision universal cutting machine of FSS450NS.01 models (10 pcs) and OMM67 model (6 pcs);
– 5-coordinate vertical cutting machine DMU-60, DMU-80, DMU-100 Blok Mono (3 pcs), DMU-100 Blok Duo and MCFV-1060 machine with support of Haidenhai1 company incorporated in general network (Fig. 4.4);
– 5-cordinate programmable cutting NC machine for fabrication of parts like stringers and spar webs at a length of maximum 12 000 mm (Fig. 4.5);
– Teeth striking machine 5M161 (2 pcs);
– Electro-erosive precision intruding wire cutting machine with linear servo-drives AQ537LLP33W;
– Unit for abrasion free ultrasonic finishing processing (AUFP), universe semi-automatic polishing machine Omicron-3620, polishing machine tool SIEFLEX-500;
– 5-coordinate polishing edging machine Norma of "SCHNEEBERGER" company.

Inspecting measuring machine Romer Arm – 2030 Sigma has been purchased for on line inspection of complicated configuration parts.

Fig. 4.4. 5-Coordinate Cutting Machine Section

Fig. 4.5. NC Cutting Machine for Fabrication of Long Wing Parts

New production procedures have been tested and implemented for fabricating parts of the assembly units and components:

- Outer wing panels;
- Preassembly of wing panels followed by prepararing skin joining surfaces between each other and with stringer, spar webs and attachment section;
- Fabrication of hot hinged bolts followed by making thread after heat treatment;
- Fabrication of highly precised blanks АНУ0314 (ANU0314);
- Barrier strengthening of holes in stringers of outer wing for fuel flowing;
- Finishing treatment of parts from stain less steels with self-setting head with diamond bars for obtaining hardness of 0.1;
- Fabrication of tooth sections of slats control system performing operation of teeth processing prior and after ageing;
- Fabrication of flaps transfer mechanisms from titanium alloys including polishing around molibdenium coating using contour-polishing machines;
- Manufacture, assembly and preoperation of slats transfer mechanisms followed by testing mark after contact by using technological facility specially designed and made;
- Fabrication of parts followed by spraying Бр010 (Br010) [БРА-7 (BRA-7)] on sub layer ВКНА (VKNA);
- Finishing treatment of landing gear parts prior to and after chromium plating;
- Fabrication of screws M3 with semiround head and cross-like slot No. 1.

Implementation of Parts Programmable Processing

The following operations have been performed to provide fabrication pf parts for An-148-100, An-158 aircraft using programmable numerically controlled machines:

– Procedures in development pf control programs (CP) and manufacturing procedures using CAD/CAM systems, Pro/ENGINEER and ГеММА-9.5 (GeMMA-9.5), have been promoted, modules IMSverify 3-Axis Verification (processing verification with material removal as per CL-files for 3-coordinate machine), IMSverify Upgrade to 5-Axis Verification (verification expansion to five axes), IMSverify Machine Simulation (CP processing simulation on machine module have been implemented enabling to upgrade CP quality, particularly, under 5-axis processing of parts;

– About 31 365 CP have been developed to provide manufacturing 2 390 kinds of parts;
– More than 150 NC machines have been renewed, modified and put into production including: FCQV with the support, Siemens 802D, CAM5, РФП-6 (RFP-6) with the support, NC-230, IM655 with the support, Siemens 802D and Neiron, BF-1-1 with the supports, NC-210, NC-220, 2FP-131 (2FP-131) with the supports S8600 and Siemens 840;
– Up-to-date controllers and IMP have been replaced the old information reading systems making possible to reject application of physical information carriers (perforated and matrix strips), practically all machines are connected to the companies unified network ADNC;
– Unified electronic archive of control programs (EACP) has been developed and implemented allowing to decrease significantly time required for record/rerecord and CP transfer to consuming shops.

Fabrication of Products from Composite and Non-Metal Materials

Autoclave 1-2880 20-41 and УПСТ-300 (UPST-300) and УПСТ-1000 (UPST-1000) units for fabric moisterizing have been subjected to deep modernization to meet requirements for the procedures in manufacture of units form carbon based materials new production procedures and manufacturing procedures if products complicated in fabrication have been promoted and implemented:

– Fabrication of floor beams from carbon materials ЭЛУР-ПА (ELUR-PA) and УОЛ-300-2А (UOL-300-2A);
– Fabrication of nose and tail sections and wing flaps from composite materials;
– Manufacture of great dimensional panels from PCM: landing gear fairings, landing gear doors and wing fairing with preassembly of LG fairing with door and hatch covers;
– Fabrication of transparent radome followed by adhesion of antennas and buses protecting from eightening;
– Fabrication of window glasses for passenger cabin;
– Manufacture of passenger cabin floor with investigation of structure and adhesive materials to provide strength.

Procedures have been promoted and section has been organized and provided with the equipment for fabrication of slide bearings with "ОРГАЛОН" ("ORGALON") coating.

Procedures have been promoted and section has been organized and provided with the equipment for fabrication of interior members including passengers servicing panels by forming sheet thermoplates of "Europlex" type by the use new vacuum forming machine made by "GEISS" company.

ВКР-20/60 (VKR-20/60) steam autoclave has been subjects to deep modernization permitting to make fabrication cycles of layer structure shorter specializing and unloading of the equipment available.

Metallurgy Production

Procedures complicated in production and new production procedures in fabrication of products by fording, stamping, melting and thermal manufacturing techniques have been developed and promoted:

– Stamping of ВКС-170 (VKS-170) alloy at ГКШП (KGShP);
– Fabrication of bolts from ВНС-5Ш (VNS-5Sh) на ГКМ-400 (GKM-400);
– Making tolerances for fording and stamping at "BERINGER" sew;
– Inspection by ОВЕНТРМ1-УР (OVENTRM1-UR) device to monitor temperature under fabrication of melted products;
– Drying technique of melting components and provisions in new flow for hot heating СДВ (SDV);
– Production procedure of melting facility on gypsium basis using 3D-printers;
– External inductional burning procedure of crosslength circular welding sieves of titanium pipelines;
– Hardening of 30ХГСА (30KhGSA) steel in modified vacuum electrical furnace СЭВ-5.5/11.5 (SEV-5.5/11.5);
– Gas nytrogening procedure under nytrogen expendure monitoring by rotameter;
– Procedure in applying titanium and titanium-nickelium coating using condensation technique with ion bombing in ННВ 6.6И1 (NNV 6.6I1);
– Heat treatment procedures of parts from high strength martensite ageing steel 03Н18ДО8М5Т-ВД (03N18DO8M5T-VD) (ВКС-170ВД) (VKS-170VD);
– Procedures in gaseous nitrogening of screws for flap lifting mechanisms.

Seven furnaces for heat treatment of parts have been subjected to overhaul.

New facilities and technological welding procedures have been experienced and promoted:

- DC power sources for welding stainless and titanium alloys Fronius Trans Tig 2600 for argon are welding by unmelting electrode at AC and DC, SELMA УДГУ-351 for welding aluminium alloys Fronius Magic Wave 3000;
- Welding open type heads MU IV 104 with control system Fronius FPA2000 and closed type heads MW65, MW115 with control system Fronius FPA2020 for automatic welding of thin wall pipelines from stainless steels and titanium alloys;
- Contact dot welding machines MT1917, MT 2023, MT 2024;
- Procedure in welding of circular turnable and nontrunable joints of pipelines from titanium alloys with a wall thickness of 0.6 mm;
- Procedure in welding of thin wall pipelines from aluminium alloys involving additional parameters in welding mode: balance and current frequency.

New equipment and production procedures of applying varnish-painting coatings have been developed and implemented:

- Varnish-painting facility of "Kremlin" company for air-free spraying of varnish-painting material under painting of aircraft;
- Procedures in painting of outer aircraft surface by polyurethane varnish-painting materials of AkzoNobel company;
- Procedures in painting of interior by varnish-painting materials Alexit.

New equipment and production procedures of chemical plating have been developed and promoted (Fig. 4.6):

- New lines have been put into operation after repair to provide chromium copper, tin plating, chlorine-ammonia, cadmium plating and coating by "tin-vismute" alloy;
- New galvanizing lines for treatment of titanium alloys and chemical passivation of stainless steels have been put into operation as well as preparation – parts for application of coatings.

New equipment and procedures have been obtained and implemented to provide check and inspection in central plant laboratory:

- Flux current defectoscope ВД-33Н (VD-33T) (for inspection of cracks);

Fig 4.6. Aircraft Parts Coating Plating Section

– Thickness meter УТ-31 (UT-31) (for metal thickness measuring in at points with difficult approach);
– Defectoscope УД-2-70 (UD-2-70) (for ultra-sonic testing of stamped and forged parts);
– Thickness meter "Constanta-5" (for thickness inspection of varnish-painting coatings and plated coats);
– Refractometer "ТУРІ 20 Е" (for measuring concentration of lubricating cooling liquid);
– Acoustic impedance defectoscope ИД-91 (ID-91) (for inspection of structures from composite materials).

Units and Components Assembly Production

A set of assembly facility and equipment has been designed, produced and put into operation to provide serial production of aircraft ensuring annual production of aircraft and 24 sets of outer wing with an account made for the supply in accordance with cooperation agreements (Fig. 4.7).

Designing of production facilities has been performed using EOM and 3D electronic mathematical models pf aircraft enabling to provide facilities connection to a single source with minimized usage of reference and calibrating pieces and to make design developing cycle shorter and to reduce labour intensity in fabrication and mounting of the facilities. Laser test and measuring set is used for checking jigs and fixtures to provide high measuring accuracy and capability to compare data obtained with the mathematical model.

Fig 4.7. General View of Jigs and Fixtures for Assembly of Wing Torsion Boxes

New production procedures have been developed and implemented in the course of preproduction period:

– Making riveting joints with the use of high liferivets АНУ-0314 (ANU-0314) to upgrade tightness, proofness and pressurization of aircraft sections and to exclude the necessity of milling rivet heads after riveting;
– Installation of parts using filling agent ВЗ-27М (VZ-27M) making it possible to avoid scrubbing procedure in joining parts of complicated configuration and to reduce significantly time required for their installation.

Outer wing assembly facility has been made for combined program of aircraft production at the ANTONOV Company and public "Voronezh Aircraft Joint-Stock Company":

– Fixtures in preassembly of wing upper and lower panels in mechanical assembly shop 21 for manufacture of long length parts;

– One set of jigs and fixtures for assembly of panels; two sets of jigs and fixtures for assembly of spars; three sets of jigs and fixtures unified for enabling assembly of An-148, An-158 wing torsion boxes, stand for milling outer wing-to-center section joint area sealant polymerizing chamber, stand for testing torsion boxes by fuel, three stands for jigs free assembly and final assembly of wing in shop.

Tail unit assembly is provided by jigs for general assembly vertical and horizontal stabilizer free of subassembly as well as stands for jigs-free assembly and processing of joint area. General assembly jigs and fixtures are used for enabling assembly of spars ad panels to provide annual production of 12 tail unit sets.

Fuselage assembly is provided with a set of accessories, jigs, fixtures and stands for assembly of frames, panels, sections, compartments and general assembly of fuselage to ensure assembly of 12 fuselage per year. New set of jigs and fixtures has been fabricated to provide assembly of An-158 fuselage and for assembly of unified fuselage tail section Available set of jigs and fixtures fir assembly of mid sections and joining stands have been subjected to modernization to enable fuselage production of An-148, An-158 aircraft followed by insignificant rearrangement and readjustment.

Preproduction procedures have been performed for avoiding dependence from the supply with reference to cooperation to provide manufacture of required production facilities and fabrication of aft doors and baggage hatch covers for An-148, An-158 aircraft has been developed; preproduction procedures have been performed to provide manufacture of production facilities for fabrication of forward doors and crew cabin canopy for these aircraft.

Preassembly shop has been allocated from fuselage assembly shop to optimize division of work scope and intended for fuselage provision with doors, windows, attachment units and system members as well as test procedures for strength, tightness and pressurization are performed. Technological supports instead of landing gear, simulators of outer wings together with the engines and tail unit have been manufactured to meet supporting and loading condition of fuselage under mounting of doors and interior members.

New types of wires have been implemented into production of electrical wires and engines including optic fibred and small sized enabling to meet requirements to operation of systems provided with new digital facilities.

General assembly and attachment of airframe and final assembly of aircraft is provided with a set of platforms to ensure approach to working area and with technological supports instead of landing gears and hydraulic lifting facilities. Five working stations have been fully equipped ensuring production of at least 12 aircraft annually. New facilities for testing aircraft systems and complexes of radioelectronic and aeronavigational equipment have been produced and implemented on modern element basic.

4.1.4 Implementation of Information Technologies

Company's information infrastructure has been developed being in progress now to provide high technological production of An-148, An-158 aircraft developed with wide application of digital design technologies.

Information networks have been organized to provide on-line information communication between company's divisions. They contain:

- Servers stations have been organized and lines between buildings have been established using optic fibre cable made by Corning company having high carrying ability as well as in buildings lines based on certified screened cable "twisted pair" that have connected main departments and shops of preparation and main production;
- DNC networks of NC machines have been developed in mechanical shops;
- Commutating facility (commutators or switchboards) have been installed at 20 commutating centres;
- Program hard and soft wares required for operation of network including certified programs of protection from external and internal attacks named Check-Point and licenced anti-virus protective software Kaspersky Business Space Security.

Some server's groups are now in use at the plant:

- Servers Version, SUN, HP on the basic of processors XEON and AMD Opteron at a period frequency of 2-3 MHz, are operated under control of OS Windows 2003 Server R2, Windows 2008 Server, Solaris 10 and play roles of PDC, SDC, DNS, DHCP, file servers;
- Antivirus renewal servers;
- Data base servers of InterBase, MS SQL Server 2008;

– Server PDM for Pro/ENGINEER, Unigraphics, AutoCAD;
– Information routes distribution server, Proxy-server, instrusion protection server CheckPoint, post server MS Exchange 2010.

Integrated automated production control system (APCS) has been developed and now under operation at the plant being grounded on the fulfillment of the main scope of computing operations at the central computation machine (complex ВК2М4602) capable to connect users for data review.

To provide interruption free and continuous operation of APCS available, complex ВК2М4602 modified into co of emulating central processor based on ПЭВМ (PC). The works performed have made it possible to extend lifetime of complex ВК2М4602 due to non-use of accumulation on magnetic discs and magnetic tapes that have been narrow point in complex operation.

Automated work stations have been organized on the basis of personal computers to increase work efficiency.

More than thirty automated systems are under operation in Ethernet network developed by VASUV programmers in medium of Delphi 7, Visual C++, C#, .net enabling to solve different applied problems at shops and departments.

The following operations have been performed in the period of An-148, An-158 aircraft development:

– Program softwares have been installed and adjusted such as: CADDS-5, PDM, OPTEGRA, PLM Windchill, DMS ORACLE;
– Geometric projects of An-148 units and components have been developed in OPTEGRA;
– The inter-case program communication on an electronic network is worked out;
– The electronic communication on a network (to the central server) of workstations is fulfilled: SUN in CU of plaits, SUN in CU of wings and two terminals, SUN in CU of power plants and two terminals, 8 HP workstations in a loft branch for work with CADDS-5;
– The ProEngineer (Creo) system for three-dimensional design of products and technological equipment on 60 work stations in the departments of the Chief Designer, Chief Technologist, Chief Metallurgist;

– Automated technological projects design system "Expert", "Expert-2" has been installed and implemented at main production shops;
– APM stamping system and APM casting system have been installed and implemented at chief metallurgist service;
– Program software has been installed and implemented on server of NC machine separate control;
– Loft automated drawing of electrical harnesses with reference to the models of harness laying;
– Plant network has been loaded and users access to mathematical models of parts and An-148 assembly pieces has been provided being supplied by the Developer.

4.1.5 Materials, Vendor Items and Aircraft Assembles Produced in Compliance with Cooperation

Measures have been taken and meetings are regularly conducted aimed at organizing mutually beneficial assistance to provide timely supply of materials, vendor items and assembles from a great number of suppliers involving new ones from foreign countries.

At start up of serial production financial problems have been solved and scope of materials and semi-fabricated products supply has been increased allowing to avoid production losses as a result of their untimely supply. Similar activity is conducted with the suppliers of vendor items but their high cost sufficiently limits progress in this business sphere.

Work with cooperative companies supplying assembly portions of the product has been finalized in the course of putting An-148-100 into serial production and it has allowed to make preproduction time shorter due to parallel work of all members involved in cooperative production.

4.1.6 Quality

The An-148-100 and An-158 aircraft have been put into production in compliance with the requirements specified in "Manual for ensuring quality under production of aviation engineering products" effective at the company since 2003 later this manual was subjected to periodic re-edition and actualization according to the requirements specified in "Manual 21.2 C as precertification and monitoring of aviation engineering production" and "Manual 21.2 D specifying certification procedure and monitoring of civil aviation engineering production" standards ISO9001-2009 and EN9100 "Quality Management Systems. Requirements". Quality systems efficiency is under continuous control of inside inspections.

The An-148-100 and An-158 aircraft production has been certified by Aviation Registry of International Aviation Committee (AR IAC) State aviation service of Ukraine. License and certificates certifying production have been obtained as a result of audit performed by these organizations:

– "Certificate certifying production No. ОП 14-ПВС (OP 14-PVS)", 07.07.2008;
– "Certificate certifying production СВ (SV) No.0001", 24.06.2008;
– "Certificate certifying production No. ОП 23-ПВС (OP 23-PVS)", 25.06.2010;
– "Certificate certifying production СВ (SV) No.0023", 02.08.2010;
– "Certificate certifying production No. ОП 23-ПВС (OP 23-PVS) ", 24.09.2012;
– "Certificate certifying production СВ (SV) No.0023", 27.09.2012.

4.1.7 Production Organization Main Conclusions

1. Aircraft production has been approved by Aviation registry of International aviation committee (AR IAC) and State Aviation Service of Ukraine. Appropriate documents have been obtained as a result of audit conducted by these organizations.

2. The An-148-100 and An-158 aircraft production is performed to meet the requirements as specified in "Manual 21.2 C as per specification and monitoring of aviation engineering articles production", "Manual 21.2 D as per certification procedure and monitoring of aviation engineering article production", standards ISO9001 2009 and EN9100 "Quality Management System. Requirements". Quality system functioning is under continuous monitoring due to conduction of inside inspections.

3. In the course of An-148-100 and An-158 aircraft putting into production:

– Preproduction procedures have been performed for more than 65000 parts, units and components. Norms of material consumption have been specified for 52620 parts with 5682 types of materials to be used for their production;
– More than 19300 types of special production facilities and tools have been designed and fabricated. Labour intensity for making facilities have counted

around 1250000 norms-hours;

- More than 75000 sets of working production documents have been developed for the procedures of fabrication, assembly, inspection and testing of parts, assembly units, components and aircraft systems;
- In the course of putting the An-158 aircraft into serial production additional pre-production procedures have been performed for more than 12314 parts, assembles and components. More than 72648 kinds of special production facilities and tools have been designed and fabricated with the labour intensity for this purpose to be around 227098 norms/hours;
- New production procedures have been developed modified and promoted to pre-fabrication-stamping, mechanical assembly unit and component assembly productions;
- Advanced metal processing tools have been tested and implemented into production;
- Operations have been performed for restoring working ability and modifying production facilities 530 machines have been subjected to over haul and 160 milling machines to modernization by replacing old fashioned NC machines into new ones;
- New production procedures in manufacture of parts and units NC machines have been developed and implemented;
- Technique in development of control programs has been used; 31365 control programs have been developed for fabricating 2390 kinds of parts and 1700 parts have been promoted in fabrication using NC machines, CP have been developed for manufacture of 200 kinds of production facilities;
- Difficult in fabrication and new production procedures in manufacture of products from composite and non-metal materials have been developed and put into production; as well as stamping, casting and heat treatment products;
- New equipment and welding procedures have been obtained and put into production;
- A set of assembly facilities has been designed manufactured and put into fabrication process to provide annual production of 12 aircraft with an allowance made for supply according to cooperation;

– New set of jigs and fixtures has been manufactured for assembly of unified tail unit of An-148/158 aircraft and available set jigs and fixtures for assembly of fuselage mid-section has been subjected to modernizing as well as adjustment stand to enable production of An-148/158 fuselage with insignificant readjustment;
– Preproduction facilities have been designed with the use of ECM and 3D electronic mathematical models of aircraft allowing to provide facility fixing with a single source followed by minimal use of models and calibration plates making it possible to decrease designing cycle and reduce labour intensity in fabrication and assembly of facility. Laser check-measuring complex is used to inspect jigs and fixtures ensuring high accuracy of measurement and ability to compare data obtained with mathematical model;
– New facility has been made and implemented for testing aircraft systems sets of airborne radioelectronic and aeronavigation equipment on modern elements basis;
– Company's information infrastructure has been created being now in progress;
– Automated production control system (APCS) has been developed on fulfilment of the main scope of computation operations at central computation machine with an ability of users connection to data review;
– Automate work stations have been organized based on personal computers (PC);
– Wide cooperation has been organized with reference to airframe units and components;
– Works have been done to meet standard requirements to production media condtions at manufacturing shops.

Measures have been taken and fulfilled for personnel hiring and training:
– Number of plant personnel has been increased at 870 persons including 500 workers at main production shops and 160 specialists;
– 696 trainees have been trained and obtained qualification grades;
– 3 260 workers and specialists have been trained.

Serial production of An-148, An-158 regional aircraft at the ANTONOV Company with the application of new production and information technologies result in creation of new working positions helping to restore aviation industry and increase economical level of the country.

4.2 Regional Passenger Aircraft Flight Tests Peculiar Features

Flight tests are the final stage in the process of new aircraft development or its modified versions. Peculiar features of flight tests lie in their condition under unexpected surrounding conditions. In doing so, measurement facilities are located on board of aircraft combined problems to be solved under single flight are developed to save total number of flying hours.

Flight tests of tested aircraft are performed by flight test adjustment bases (FTAB) located air airdromes.

The paper [74] specifies scope of ground operations in prepare of aircraft to the first test flight covering:

- Ground preparation operations on aircraft;
- Preparation of information measurement system;
- Prepare of flight crew;
- Determination of masses, center of gravity coordinates and inertia moments;
- Ground tests of operability and estimation of aircraft functional and systems and facilities to meet specified performance;
- All round evaluation of aircraft under taxiing at airfield and in air.

Report on aircraft readiness to the first flight is issued basing of the results of these operations.

The paper [74] specified techniques and programs of flight tests that cover:

- Test programs of aircraft under testing;
- First flight of aircraft under testing;
- Determination of aircraft strength and controllability characteristics;
- Specifying aircraft maneuverability characteristics;
- Determination of aircraft take-off and landing characteristics;
- Aircraft flight tests followed by determination of its strength characteristics;
- Aircraft testing under boundary area conditions;
- Specifying operational restrictions;
- Flight tests of power plants and their systems;
- Flight tests of flight-navigation equipment sets;
- Evaluation of safety under special extreme flight cases;

– Special flight tests methods of critical flight modes;
– Automated flight data processing techniques and flight experiment control;
– Characteristics identification methods;
– Flight certification tests.

As a result of these operations aircraft its engines and equipment characteristics are estimated within a total expected range of operation conditions and in compliance of aviation regulations requirements [79].

Modern regional passenger aircraft (Fig. 4.8) is a complicated dynamic system.

Fig. 4.8. An-148 Modern Regional Passenger Aircraft

Timely detection and elimination of all faults depend on quality and completeness of information obtained under flight tests capable to reduce flight safety or significantly limit its flight operational capabilities. Methodology of flight tests is a scientific search for conditions (procedures) to provide flight experiment that enables to reduce significantly required scope of tests flights with any decrease of proving data available in these experimental materials.

Organization of flight tests envisages development of reasonable structure and efficient control system capable to solve all assigned problems.

Flight tests regular preparation of modern tested aircraft covers different aspects and involves as following:

– Development of information and measurement system that ensures obtained all needed information in the scope required;
– Efficient techniques of flight experiment conduction needed to specify that aircraft performance meets effective norms and sequence of test flights conduction;
– Development of algorithms and programs for automated processing.

Estimation techniques of flight experiment results are grounded on the methods of communication theory, automatic control, signals transmission, systems theory as well as on many estimation techniques of one-to-one experiment based on the methods of mathematical statistics a proximity functions, identification and filtration theory, theory of optimal processes and mon-linear programming.

Two flying prototypes have been involved in conduction of flight tests of An-148-100 (An-148-100A, An-148-100B, An-148-100E versions) regional passenger aircraft.

The first flight of An-148-100 aircraft No. 01-01 has been conducted on November 17, 2004 and An-148-100 No. 01-02 on April 19, 2005.

An-158 aircraft version (Fig. 4.9) with higher passenger capacity up to 99 passengers in identical arrangement has been developed to upgrade economical efficiency and compatibility of An-148-100 aircraft family to be operated on routes at a length of up to 2 500 km.

Fig. 4.9. An-158 Regional Passenger Aircraft

One aircraft prototype has been used to conducti certification flight tests of An-158 aircraft.

The first flight of An-158 aircraft was conducted on April, 28, 2010.

Aircraft certification tests were performed with reference to the following:

– Definition of flight performance strength and control properties, maneuverability and aircraft functional systems and equipment characteristics under the following conditions:
  a) Close to standard ones;
  b) High temperatures of air and highlands environment;
  c) Low temperatures of environment;
  d) Natural icing;
– At high angles of attack;
– At limit strength modes;
– With reference to estimation of typical aircraft structure to meet certification basis CB-148 requirements under simulation of functional systems failures;
– With definition of strength and control properties with simulators of icing;
– At take-off and landing runways with low friction and at take-off and landing runways with different pavement;
– At take-off runways covered with snow;
– By specifying maneuverable characteristics to determine meteo minimum;
– From determination of aircraft meteo minimum at take-off landing;
– As per compliance of FNE, Radio Equipment, Nav Land, ATC, RCE characteristics to the requirements of CB-148 (Certification Basis) including conditions of low temperatures and under failure simulation for different equipment elements;
– On estimation of flights possibilities at international routes;
– From ergonomic evaluation of crew cabin arrangement;
– From estimation of possibility to detect fire and provide smoke exhaust;
– From estimation of emergency and life equipment, fire protection system, estimation of air purity and noise level in the compartments;
– From evaluation of external effects on operability of systems and equipment as well as basing on estimation of electromagnetic compatibility of systems and

equipment under their simultaneous operation.

To perform all above mentioned tests the specialists of the ANTONOV Company have developed complex programs of certification tests for An-148-100, An-158 aircraft on the basis of:

– Working programs (in an amount of 40);
– Special certification programs (in an amount of 12) with an account made for high level of making up aims and flight assignments in every test flight.

At the date of type certificate presentation on February, 26, 2007 (for the An-148-100 aircraft) and February 28, 2011 (for the An-158 aircraft) the actual number of flying hours accounted:

– 414 flights (672 hours) for the An-148-100 aircraft No. 0101);
– 267 flight (529 hours) for the An-148-100 aircraft No. 0102;
– Totally – 681 flights (1201 flying hours);
– 152 flights (262 hours) for the An-158 aircraft No. 0102.

Rate of tests is evaluated by monthly average amount of flights (flight/hours) of tested aircraft.

Number of test flights per one An-148-100 aircraft accounted monthly 13.5 flight and 24 hours, for An-158 aircraft – 15.2 flight and 26 hours. Temperature range of outside air varied form 52°C below zero (Fig. 4.10) to 45°C above zero (Fig. 4.11).

Fig. 4.10. Tests under extreme low temperatures (at minus 55°C), Yakutsk, Nerungri (Russia)

Fig. 4.11. Tests at high temperatures (up to plus 45°C) and under highland conditions (airfields height up to 4100 m.
Goumri (Armenia), Karshi (Uzbekistan), Iran, La-Paz (Bolivia)

To wide expected operating conditions of An-148-100/An-158 aircraft and to provide regular flights under low minimum conditions the aircraft was subjected to ground and flight tests performed by the specialists of the ANTONOV Company with the participation of certification center experts within a period of July – September at airports of Kyiv – Antonov, Boryspil, Donetsk and Simpferopol in compliance with the program "Additional Certification Tests with Reference to Estimation of Main Change of Typical Structure "Provision of Landing Minimum According to ICAO Category".

Totally, 111 test flights have been conducted with reference to this program. Technical report has been issued based on the results of tests performed.

To provide maximum use of An-148-100, An-158 aircraft (An-148-100A, An-148-100B, An-148-100E versions) and An-158 wide operation capabilities – to wide expected conditions of their operation at prepared unpaved airfields at a period from 03.11.07 till 09.11.07 the aircraft has been subjected to ground and flight tests in compliance with the program "Additional Ground and Flight Certification Tests at Unpaved Take-off and Landing Runways" (Fig. 4.12).

Flight tests have been conducted in airport of community company "Odesa international airport" under real weather conditions and actual state of unpaved runway.

12 tests flights have been conducted at a running speed with a total flying hours of 15 hours 15 minutes. Technical report has been issued basing on the test have been performed at airdromes located at a height of 2500 m (Shachrekord, Islamic Republic of Iran) and 1800 m (Kerman, Islamic Republic of Iran) to provide maximal use of wide operability of An-148-100 aircraft and to widen expected conditions of operation with reference to the height of airdrome base to be up to 2200 m 17 test flights have been conducted with a total number of flying hours being 19 hours 15 minutes. Technical report has been issued following the results of the tests performed.

Fig. 4.12. Tests at Unpaved Runway

Operations have been additionally performed at An-158 aircraft to widen expected conditions of operation with reference to the height of aerodrome base to be higher than 2200 m. Ground and flight tests have been conducted at airdromes located at heights of 2800 m (Latacunga, Equador) and 4058 m (La Paz, Bolivia).

Programmable unit set (PUS) AVIONICS-KI has been developed and implemented to record and display information received from airborne measurement facilities. The set includes compatible facilities to receive information from ГАММА-1101 (GAMMA-1101), ГАММА-3101 (GAMMA-3101) collection systems and from 64 aircraft information facilities ARINC-429. Programmable unit set (PUS) AVIONICS-KI enables simultaneous recording of up to 17000 parameters. Information display system is made on the basic of three personal computers allowing flight test engineer involved in test flight to come to the decision as far as the progress of flight experiment fulfilment is concerned. AVIONICS-KI system has been developed and authorized alongside with Independent Inspection Following the results of authorization the decision has been taken to use AVIONICS-KI PUS under flight tests of aircraft developed by the ANTONOV Company.

Two work stations for flight test engineers are installed at aircraft to conduct tests provide analyzing and recording of information. This stations comprises five computers as well as videoobserving systems allowing to see actions and operations done by the crew inside the aircraft and external observation of aircraft condition. Work stations have been provided with stand by instruments to indicate speed, height, acceleration as well as watches oxygen and communication equipment.

Ground set of automatic processing (GSAP) has been created being developed and realized as a net project with three servers on the basis of NOVELL 5.0 and 25 work stations on the basis of WINDOWS XP for processing of code information after completion of flight recorded by AVIONICS-KI PUS.

The work stations have been provided with special programmable software (SPSW) ГАММА-ПКС (GAMMA-PKS). SPSW has made it possible to process materials in full scope as well as on-line observation, obtaining physical values from codes and secondary processing.

Technical acts, protocols, subject report and other documents have been issued as well as test data and other documents based on the results of conducted ground and flight tests (every mentioned type of operations, inspections and tests). These materials have been used as a proving documentation to certify that the meet requirements specified in the CB-148 for every system or their description characteristics specified in the List of proving documentation that contain 68 books at a scope of 7200 printed pages, 7900 graphs and tables available in Supplements.

All proving documents from flight tests as well as more than 200 analytical documents (engineering analysis, protocols, reports following the results of pipes, stand tests, modelling, flights at aircraft flight simulator, conclusions of aviation industry branch institutes, etc.) have been agreed by Avia Register of International Aviation Committee and State Aviation Administration of Ukraine.

Alongside with the conduction of final certification tests continuous works were in progress to upgrade algorithms and programs of functioning, indication, systemizing, improvement of crew cabin ergonomic "comfort of passenger". Additional works have been performed related with continuation of flight conduction according to program and reading the level for aircraft to meet air worthiness requirements of flight norms and regulations under expected conditions of operation.

Under flight tests of An-148-100 aircraft a number of systems, sets, methods, techniques and data program products have been developed and implemented that made it possible to provide automatic process of collection, recording, on-line data estimation and processing and to ensure safety and conduction of final flights both at main base (aerodrome Kyiv-Antonov-2) and outside in geographical regions – Extreme North (airports Archangelsk – and – Nar-jan-Mar), Siberia RF (airports Jakutsk, Chulman, Novosibirsk, Krasnojarsk), Central Asia (airports Karshi, Buhara, Tashkent), Virmenia (airport Gomri), Crimea (aerodrome Kirivske) as well as other airports of CIS.

Among them is base test field and adequate procedure to conduct tests for measuring noise level at terrain, flight experiment control system, unique data program set and procedure of flight tests under condition of natural developer's test technique for estimation of flight conduction characteristics according to standard terminal procedures (SID, STAR, APPROACH, HOLD) as well as in system of precisions zonal navigation PRNAV, organization of test field in Crimea to test regimes "ГОРЫ" ("MOUNTAINS") of EGPWS, development of all round calculation techniques TLCH and FTCH according to data obtained under flight tests allowing to perform pre-estimation of tested characteristics in OYE including failure conditions of engines or functional systems of aircraft.

The following reports have been issued following flight tests results of the An-148 aircraft and its versions:

1. Certification flight tests to investigate loading features produced by airframe components within the range of operation restrictions and at boundary limits dictated by the regimes strength.
2. Certification flight tests to specify static characteristics of loads repetition under standard operation modes.
3. Tests to specify effects produced by vibration and shock loads on aircraft

equipment and airframe.

4. Tests to specify vibrostresses in pipelines of fuel system.
5. Tests to specify acoustic noise level acting on board equipment.
6. Tests to specify acoustic loads acting on airframe structure.
7. Tests to specify noise level produced by aircraft on terrain.
8. Tests to specify level of vibration and buffing safety.
9. Tests to specify effects produced by outer phenomena on the equipment.
10. Certification tests to specify flight performance, characteristics of maneuverability, strength and controllability Estimation of control systems.
11. Special certification flight tests to specify aircraft performance at high angels of attack and under stall.
12. Special certification flight tests under conditions of natural icing.
13. Special certification flight tests at different types of paved and unpaved runways.
14. Special certification flight test to specify maximum tolerable wind speed.
15. Special certification ground and flight tests under conditions of high temperatures and highlands.
16. Special certification and ground tests under conditions of low temperatures.
17. Special certification ground and flight tests to specify that respective aircraft performance meet requirement of airworthiness norms under simulation of functional system failures.
18. Certification ground and flight tests of main power plant with the Д-436-148 (D-436-148) engines.
19. Certification ground data flight tests of fuel system.
20. Certification ground and flight tests of APU with ВГТД (VGTD) AI-450-MC.
21. Certification ground and flight tests of power plant and APU fire fighting equipment.
22. Certification ground and flight tests of flight navigation equipment.
23. Certification ground and flight tests of radio equipment, navigation landing and air traffic control instruments.
24. Special certification flight tests to specify minimum of take off and landing.
25. Certification ground and flight tests of the ВСС-100 (VSS-100) aircraft com-

putation set.

26. Certification ground and flight tests of the СУОСО-148 (SUOSO-148) aircraft general equipment control systems.
27. Certification ground and flight tests of oxygen equipment.
28. Certification ground and flight tests of air preparation and conditioning systems.
29. Certification ground and flight tests of landing gear equipment.
30. Certification ground and flight tests of hydraulic system.
31. Certification ground and flight tests to estimate smoke distance detection under in intensive fire in the compartments.
32. Certification ground and flight tests of furnishing and sanitary equipment.
33. Certification ground and flight tests of electrical power supply system and light equipment.
34. Certification ground and flight tests of the БСТО-148 (BSTO-148) aircraft technical maintenance system.
35. Certification ground and flight tests of the БУР-92А-05 (BUR-92A-05) flight recording system.
36. Certification ground and flight tests of strength parameters recorder SPR.
37. Certification tests of emergency and rescue equipment.
38. Certification ground and flight tests of fire protection system and fire fighting equipment in baggage and cargo compartments.
39. Certification tests of aviation safety provision facilities.
40. Certification ground and flight tests of the КСЭИС-148 (KSEIS-148).
41. Flight tests to specify stability control characteristics and capability of flight safety completion under OPK operation in redundancy control mode.
42. Additional certification tests under making Principal revision "Provision of aircraft operation, type An-148-100 (An-148-100A version) (An-148-100B, An-148-100E versions) at prepared unpaved airfields".
43. Additional tests of baggage compartment fire protection system.
44. Additional certification tests in case of entering Principal revision in type structure "Provision of landing minimum according to IIIA category of ICAO".
45. Additional certification tests in case of entering Principal revision typical

structure "Provision of aerodrome base height".

46. Additional certification ground and flight tests in case entering Principal revision to the An-148-100 aircraft type structure "The An-158 aircraft".
47. Additional certification flight tests to specify decrements of aircraft structure vibration dampering after pulses of control surfaces in case of entering Principal revision to typical structure of An-158 aircraft "The An-158 aircraft".
48. Special certification flight tests to specify aircraft performance at high angles of attack and under stall in case of entering Principal revision to typical structure of the An-158 aircraft "The An-158 aircraft".
49. Additional certification ground and flight tests of fuel system with the ПВС-158 (PVS-158) fuel measurement system.
50. Additional certification tests in case of entering secondary revision to typical structure "Conduction of take off under engine operation regimes less than take off".
51. The An-158 aircraft. Additional certification tests of fire-protection system in compartments and baggage-cargo sections.
52. Additional certification tests in case of entering principal revision to typical structure "Increase of aerodrome base height at more than 2 200 m".
53. Additional certification tests associated with secondary revision entry to typical structure: "Implementation of main engines operation regime "Reverse low acceleration".

All these revisions are included in the list of additional documents required under the next aircraft certification.

4.3 REGIONAL PASSENGER AIRCRAFT SPECIAL FEATURES

Aircraft certification is a part of safety flight provision system in civil aviation aimed to ensure allowance of aircraft operation in civil aviation than meet national airworthiness and environment protection requirements. The fact that certification object meets specified airworthiness requirements is certified by the document issued by specially authorized office responsible for certification of objects to be used in civil aviation [74].

Certification of An-148-100 (An-148-100A, An-148-100B, An-148-100E versions) has been performed to meet procedures as specified in Part 21 of Ukraine Aviation Regulations (APU-21) UAR "Aircraft certification procedures" [27] and Part 21 of Aviation regulations of International Aviation Committee (AP-21) "Aircraft certification procedures" [92].

Certification basis CB-148 for aircraft of the An-148-100 type has been approved by Avia Register, IAC and Ukraaviatrans according to the Decision on simultaneous type certification of the An-148 aircraft in compliance with aviation regulations AP-25 and JAR-25 of the ANTONOV Company.

With airworthiness requirements to be met by civil transport aircraft taken into account the safety level of aircraft operation is ensured as well as with the aim to provide aircraft airworthiness of the An-148-100 type to meet requirements specified in aviation regulations of International aviation committee AP-25 effective in CIS countries (incompliance with an agreement between states with reference to civil aviation and use of airspace approved on December 30, 1991 in Minsk) as well as European norms of CS-25. CB-148 covers requirements specified in CS-25 (JAR-25, edition 16) which either unavailable in AP-25 or specify much higher level of airworthiness.

So, certification of An-148-100 has been performed according to CB-148 Certification Basis that contains as following:

– IAC aviation regulations, part 25 "Airworthiness Norms of Transport Category Aircraft" [79], with the corrections made for the fifth inclusive with an allowance made for the CS-25 requirements;
– Specifications for transport category aircraft that conduct all weather flights;
– Special specifications – additional ones as per aviation regulations, aircraft airworthiness requirements resulted in availability of new structural revisions to be those that make higher level off airworthiness.

As far as noise produced on the terrain the CB-148 certifies that the An-148-100 aircraft meets the requirements specified in the following documents:

– ICAO international standards, Supplement 16 to civil aviation International convention "Environment Protection", vol. 1 "Aviation Noise" (with the corrections made for the Seventh inclusive, Chapter 4);
– AP-36 "Aircraft certification as per noise produced on terrain with the correction

1, level 4.

As for emission the CB-148 is supposed to meet International standard requirements ICAO. Supplement 16 to Convention on International civil aviation "Environment Protection", vol. 2 "Emission of Aviation Engines" (with correction of type An-148-100 (An-148-100A, An-148-100B, An-148-100E versions) was presented on January 10, 2004 to Avia Register of International Aviation Committee (ARIAC) and to Aviation authority of Ukraine Aircraft certification basis of An-148-100 type was approved by State Aviation Administration of Ukraine on February 5, 2008 as well as by Aviation register of IAC on February 22, 2007.

According to three side (the ANTONOV Company, State Aviation Service of Ukraine and Aviation Register of IAC) "Decision on routine procedure in conduction of certification operations with reference to An-148-100 aircraft" accepted on March, 2005, factory certification tests as well as certifications check tests of An-148-100 aircraft type (An-148-100A, An-148-100B, An-148-100E versions) have been combined in single stage and conducted by special team of specialists from the ANTONOV Company and certification centers under the management and monitoring of Aviation Register of IAC and State Aviation Administration of Ukraine being agreed by all members involved in complex program of certification tests No. 148.700.008PM-2003.

Complex program of certification tests of An-148-100 aircraft type (An-148-100A, An-148-100B, An-148-100E versions) No. 148.700.008PM-2003 has been agreed by certification centers and approved by Aviation authority of Ukraine on September 2, 2005 and Aviation register of IAC on July 29, 2005.

Certification tests of An-148-100 aircraft type (An-148-100A, An-148-100B, An-148-100E versions) to specify and to prove that An-148-100 meets CB-148 requirements have been conducted in compliance with complex program No. 148.700.008PM-2003.

An-148-100 aircraft type (An-148-100A, An-148-100B, An-148-100E versions) have been subjected to certification stand tests and investigations including:

– Simulation of systems and equipment failure using ДПС-148 (FSS-148) flight simulation stand;
– Strength tests (static and fatigue) of An-148-100 No. 01-03 at static test stand of

aircraft airframe (see Fig. 3.34);

- Strength tests of control surfaces (at 12 stands);
- Check tests at stands of the "СибНИА" ("SibNIA") institute;
- Functional tests of hydraulic system, control column system, wing high lift devices and landing gear (Fig. 4.13) at one-to-one stands;

Fig. 4.13. Aircraft Landing Gear Operation Check Test

- Functional test of air preparation and conditioning system, automatic air pressure control system, ice protection system at complex stands and pipelines sections;
- Functional tests of electric power supply system at one-to-one stand;
- Functional tests of flight maintenance system;
- Tests for lightening protection of carbon-plastic structures, critical functional systems, fuel torsion boxes and antenna-feeder equipment of aircraft;
- Tests for fireproofness of structure doors and interior;
- Tests of air seats;
- Test of aircrafts airframes structural members in case of birds strike;

– Static, dynamic and ballistic tests of doors in crew cabin;
– A scope of operations to be performed for verification of vendor items to be installed at aircraft according to the main specification No. 148.00.0000.000.000.

Ground and flight certification tests of the An-148-100 aircraft type have been performed using two prototypes of An-148-100 No. 01-01 and No. 01-02 with reference to the following subjects:

– Specifying flight performance, maneuverability properties, characteristics of functional systems and equipment under the following conditions:
  • Close to standard;
  • High air temperature of environment and under highland conditions;
  • Low air temperatures of environment;
  • Icing (Fig. 4.14);
  • At high angles of attack (Fig. 4.15);
  • To strength limit conditions;
  – Estimation of aircraft typical structure to meet the CB-148 requirements under simulation of functional systems;
  – Specifying stability and controllability characteristics with ice simulators (Fig. 4.16);
  – Specifying characteristics under conditions of paved and unpaved runways (Fig. 4.17);

Fig 4.14. Aircraft Test Under Natural Icing Condition
at a Temperature of 20° below zero (Arkhangelsk-Naryan-Mar)

Fig. 4.15. Aircraft Test at High Angles of Attack

Fig. 4.16. Flight Tests with Ice Simulators

Fig 4.17. Flight Tests at Runways Covered with Falls

- Specifying aircraft performances when operating under crosswind conditions;
- Specifying aircraft meteorological minimum on ground and under landing;
- Specifying the fact that characteristics of FNE (flight navigation equipment) RT NLE (radio-technical navigation and landing equipment), air traffic control and radio communication equipment meet the CB-148 requirements;
- Ergonomic estimation of crew cabin;
- Estimation of capability to detect slow fire and smoke at far distance;
- Estimation of emergency life equipment, fire protection system, air cleanness and noise level in the compartments;
- Estimation of outside effects produced on systems and equipment operability as well as evaluation of systems and equipment electro-magnetic compatibility under their simultaneous operation.

With certification tests in progress, 673 flights including test flights, flights to destination of test points, flights to search icing conditions have been totally training flights counted 1193 flying hours at An-148-100 No. 01-01 and No. 01-02 aircraft including in general:

- 412 flights and 667 fly hours at An-148-100 No. 01-01 aircraft;
- 261 and 526 fly hours at An-148-100 No. 01-02 aircraft.

Basing on the scope of certification operations performed together with the ANTONOV Company, certification centres authorized by Aviation Register of IAC and Aviation authority of Ukraine it has been stated and approved that An-148-100 aircraft type (An-148-100A, An-148-100B, An-148-100E versions) with the Д-436-148 (D-436-148) main engines and АИ-450-МС (AI-450-MS) auxiliary power unit with operation manuals meet the CB-148 Certification Basis requirements within operational limits specified in aircraft operation and maintenance manuals.

Typical structure of An-148-100 aircraft type (An-148-100A, An-148-100B, An-148-100E versions) to prove that it meets requirements mentioned above is presented in the check set of design working documentation specified by the main specification 148.00.0000.000.000 having been corrected in compliance with the results of certification operation, and it has been checked, approved and kept according to the procedure specified in АП/АПУ-21 (AP/APU-21) at the ANTONOV Company.

The results of certification operations and list of scientific-technical verification documentation is available in the following certification documents:

- The An-148-100 aircraft (An-148-100A, An-148-100B, An-148-100E versions). Act No.148-100.700.094.D3-05 with reference to the results of certification operations approved by the Chief Designer of the ANTONOV Company on February 14, 2007, by the Director of "АСЦ ГосНИИ ГА" ("ASTs GOS NII GA"), by the Director of "СЦБО "Аэронавигация" ("STsBO Aeronavigatsia"), by the Director of "СЦ ЦАГИ-ТЕСТ" ("STs TsAGI-TEST"), by the Director of the "ЛИИ-ЦС" ("LII-TsS");
- "Complex conclusion №148-037-01-2007 that aircraft of An-148-100 type (An-148-100A, An-148-100B, An-148-100E versions) meets requirements of CB-148 certification basis" approved by the Chief Designer of the ANTONOV Company, by the Director of "ASTs GOS NII GA", by Director of "OTBO Aeronavigatsia", by the Director of "TsAGI TEST", by the Director of "LII-TSO";
- Table of the An-148-100 aircraft compliance with the requirements of the CB-148 Certification Basis (books 1-3), approved by the Chief Designer of the ANTONOV Company on February 9, 2007.

Compliance of An-148-100 aircraft including its versions with the requirements of CB-148 is authorized by the certificates of state aviation administration of Ukraine No.TL 0036 (Fig. 4.18) and by Aviation Register of International Aviation Committee No.CT264-An-148 (Fig. 4.19).

The An-148-100A, An-148-100B, An-148-100E aircraft have got allowance for serial production and commercial operation.

In addition, the "The An-158 aircraft" new modified version with an increased number of passenger seats ap to 99 passengers has been developed to upgrade operation capabilities of the An-148 aircraft family. The mentioned version has been specified as the main revision of the An-148-100 aircraft typical structure. Additional certification operations have been resulted in approved of the specified main revision by the State Aviation Service of Ukraine and Aviation Register of IAC and on February 22, 2011 the State Aviation Service of Ukraine issued a new edition of type certificate TL0036 with the inclusion of the An-158 to it and a supplement was issued and added to type certificate of IAC Aviation Register No. CT264-An-148-100/D05.

УКРАЇНА
МІНІСТЕРСТВО ТРАНСПОРТУ ТА ЗВ'ЯЗКУ
ДЕРЖАВНА АВІАЦІЙНА АДМІНІСТРАЦІЯ

UKRAINE
MINISTRY OF TRANSPORT AND COMMUNICATIONS
STATE AVIATION ADMINISRATION

СЕРТИФІКАТ ТИПУ
TYPE CERTIFICATE

№ ТЛ 0036

Цей Сертифікат, виданий: Державному підприємству «Антонов», Україна, 03062 м. Київ, вул. Туполева 1

засвідчує, що типова конструкція вказаних нижче виробів з обмеженнями та умовами, що викладені у Переліку даних Сертифіката типу, відповідає чинним в Україні Нормам льотної придатності, що встановлено згідно з національними процедурами сертифікації

This Certificate issued to *"ANTONOV COMPANY", 03062, Ukraine, Kyiv, Tupolev St. 1*

certifies that the type design of the following products with the limitations and conditions specified in the Type Certificate Data Sheet, complies with the Airworthiness Standards currently in force in Ukraine, and is in accordance with national certification procedures

Категорія (назва) виробів: Літак пасажирський, транспортної категорії
Class (name) of products *Transport Category passenger airplane*

Визначення виробів: Ан-148-100А, Ан-148-100В, Ан-148-100Е та Ан-158
Products designation *Antonov-148-100A, Antonov-148-100B Antonov-148-100E and Antonov-158*

Дія цього Сертифікату з Переліком даних, який є його невід'ємною частиною, не обмежена часом і тимчасово припиняється чи скасовується Державною авіаційною адміністрацією України у випадках, що передбачені законодавством України.

Duration of this Certificate with the Type Certificate Data Sheet, which is a part hereof, is unlimited and can be suspended or terminated by the State Aviation Administration of Ukraine in cases which are stipulated by the legislation of Ukraine.

Модель (модифікація) *Model (modification)*	**Дата подання Заявки** *Date of Application*	**Дата видання** *Date of issue*
Ан-148-100А	12.01.2004	26.02.2007
Ан-148-[illegible]	12.01.2004	26.02.2007
Ан[illegible]	12.01.2004	26.02.2007
А[illegible]	07.12.2009	22.02.2011

Під[illegible]: /А. Колісник/
Signa[illegible] /A. Kolisnyk/
Посада: За[illegible]ник Міністра транспорту та зв'язку України – [illegible]лова Державіаадміністрації
Title: *Deputy Minister of Transport and Communications of Ukraine – Chairman of the State Aviation Administration*

ДЕРЖАВНА АВІАЦІЙНА АДМІНІСТРАЦІЯ м. КИЇВ

АА №009441

Fig. 4.18. Certificate of State Aviation Administration of Ukraine No. TL 0036

Ц21.1
Форма А-1
Издание № 2
Issue № 2

МЕЖГОСУДАРСТВЕННЫЙ АВИАЦИОННЫЙ КОМИТЕТ
INTERSTATE AVIATION COMMITTEE

АВИАЦИОННЫЙ РЕГИСТР
AVIATION REGISTER

СЕРТИФИКАТ ТИПА
TYPE CERTIFICATE

№ СТ264-Ан-148

ИЗДЕЛИЕ — Самолет Ан-148-100
PRODUCT

Модели: Ан-148-100А
Ан-148-100В
Ан-148-100Е

ГОСУДАРСТВО РАЗРАБОТЧИКА — Украина
STATE OF DESIGN

НАСТОЯЩИЙ СЕРТИФИКАТ, ВЫДАННЫЙ — ГП "АНТОНОВ"
THIS CERTIFICATE ISSUED TO

г. Киев, Украина

УДОСТОВЕРЯЕТ, ЧТО ТИПОВАЯ КОНСТРУКЦИЯ УКАЗАННОГО ИЗДЕЛИЯ СООТВЕТСТВУЕТ ТРЕБОВАНИЯМ РАСПРОСТРАНЯЕМОГО НА НЕГО СЕРТИФИКАЦИОННОГО БАЗИСА на основе Авиационных правил, Часть 25 (АП-25) с Поправкой 5.

CERTIFIES THAT THE ABOVE-MENTION PRODUCT TYPE DESIGN MEETS ITS CERTIFICATION BASIS REQUIREMENTS

ОПИСАНИЕ ТИПОВОЙ КОНСТРУКЦИИ И СЕРТИФИКАЦИОННОГО БАЗИСА, ОСНОВНЫЕ ЭКСПЛУАТАЦИОННЫЕ ОГРАНИЧЕНИЯ, ХАРАКТЕРИСТИКИ ИЗДЕЛИЯ И ПЕРЕЧЕНЬ МОДЕЛЕЙ, НА КОТОРЫЕ РАСПРОСТРОНЯЕТСЯ ДЕЙСТВИЕ ДАННОГО СЕРТИФИКАТА, СОДЕРЖАТСЯ В КАРТЕ ДАННЫХ, КОТОРАЯ ЯВЛЯЕТСЯ НЕОТЪЕМЛЕМОЙ ЧАСТЬЮ НАСТОЯЩЕГО СЕРТИФИКАТА

THE DESCRIPTION OF TYPE DESIGN AND CERTIFICATION BASIS, BASIC OPERATING LIMITATIONS, THE PRODUCT PERFORMANCE AND LIST OF MODELS COVERED BY THE GIVEN CERTIFICATE ARE PRESENTED IN THE DATA SHEET WHICH IS AN INTEGRAL PART OF THIS CERTIFICATE

ДАТА И МЕСТО ВЫДАЧИ
DATE AND PLACE OF ISSUANCE

01 апреля 2010г.
г. Москва

Дата первоначальной выдачи
26 февраля 2007г.

АВИАЦИОННЫЙ РЕГИСТР
AVIATION REGISTER

А.В. Донченко
ПОДПИСЬ *SIGNATURE*

Генеральный директор Авиарегистра МАК
ДОЛЖНОСТЬ *TITLE*

Fig. 4.19. Certificate of Aviaregister of
International Aviation Committee No. CT264-AN-148

Additional certification operations have resulted in issuance of the following scientific-technical proving documents:

– "An-158 aircraft". Additional certification operations in connection with the main revision entry to the typical structure of An-148-100 aircraft approved by the President-Chief Designer of the "ANTONOV" Company, "АСЦ ГосНИИ ГА" ("ASTs GOS NII GA"), by tht Director of "СЦБО "Аэронавигация" ("STsBO "Aeronavigatsia"); by the Director of "СЦ "ПРОЧНОСТЬ", ("STs "PROCHNOST"); by the Director of "ЛИИ-ЦС" ("LII-TsS");
– "Supplement No. 9 to Table of An-148-100 compliance with the requirements specified in the CB-148 Certification Basis approved by the Chief Designer of the ANTONOV Company on January 14, 2011.

To upgrade compatibility and economic efficiency of An-148-100, An-158 aircraft family a number main revisions have been entered to the typical structure approved by Aviation authorities of Ukraine with the following among them:

1. Installation of new aircraft equipment ALT-4000, RDR4B, CAS-100 and EGPWS MARK V. Additional certification operations have resulted in issuance of Technical Act No. 148-100.700.018.D3-09 "An-148-100 aircraft (An-148-100A, An-148-100B, An-148-100E versions). Additional certification tests and checks in connection with entry of main revision to the typical structure "Installation of new equipment ALT-4000, RDR4B, CAS-100 and EGPWS MARK V", approved by the Chief Designer of the ANTONOV Company, by the Director of "АСЦ ГосНИИ ГА" ("ASTs GOS NII GA"), by the Director of "СЦБО "Аэронавигация" ("STsBO Aeronavigatsia").

2. Provision of aircraft landing minimum according to ICAO IIIA category. Additional certification operations have resulted in issuance of Technical Act No. 148-100.700.032.D3-09 of An-148-100 aircraft (An-148-100A, An-148-100B, An-148-100E versions). Additional certification tests in connection with entry of the main revision to the typical structure "Provision of landing minimum according to ICAO IIIA category approved by the Chief Designer of the ANTONOV Company, by the Director of "Aviation Certification Center State Research Institute of Civil Aviation", by the Director of "СЦБО "Аэронавигация" ("STsBO Aeronavigatsia"), by the Director of "СЦ "ПРОЧНОСТЬ" ("STs "Prochnost"); by the Director of "ЛИИ-ЦС" ("LII-TsS").

3. Aerodrome base height increase. Additional certification operations have

resulted in issuance of the Technical Act No. 148-100.700.003.D3-11 "The An-148-100 aircraft (An-148-100A, An-148-100, An-148-100E versions). Additional certification operations in relation to the main revision entry into the typical aircraft structure "Aerodrome basing height increase". Approved by the President – Chief Designer of the ANTONOV Company, by the Director of "Aviation Certification Center State Research Institute of Civil Aviation", by the Director of "СЦБО "Аэрона-вигация" ("STsBO "Aeronavigatsia").

4. Maximum landing weight increase of the An-148-100 aircraft up to 37800 kgf. Additional certification operations have resulted in issuance of the Technical Act No. 148-100.700.008.D3-11 "An-148-100 aircraft (An-148-100A, An-148-100B, An-148-100E versions). Additional certification operations in connection with the main revision entry to the typical structure "Maximum landing weight increase up to 37800 kgs" approved by the President – Chief Designer of the ANTONOV Company, by the Director of "Aviation Certification Center State Research Institute of Civil Aviation", by the "СЦБО "Аэронавигация" ("STsBO Aeronavigatsia"), by the Director of "СЦ "ПРОЧНОСТЬ" ("STs "PROCHNOST").

5. Conduction of take off under engine operation regime less than take off one. Additional certification operations have resulted in issuance of the Technical Act No. 148-100.700.002.D3-13 "The An-148-100 aircraft and its modified versions. Additional certification operations in connection with the Main revision entry "Conduction of take off under engine operation regime less than take off one", approved by the President – Chief Designer of the ANTONOV Company, by the Director of "Aviation Certification Center State Research Institute of Civil Aviation".

6. Provision of flights using P-RNAV system. Additional certification operations have resulted in issuance of Technical Act No. 148-100.704.052.D3-08 "The An-148-100 aircraft. Additional certification tests as per Main revision of the An-148-100 aircraft typical structure (An-148-100A, An-148-100B, An-148-100E versions) "Provision of flights using P-RNAV", approved by the Chief Designer of the ANTONOV Company, by the Director of "Aviation Certification Center State Research Institute of Civil Aviation", by the Director of "СЦБО "Аэронавигация" ("STsBO "Aeronavigatsia").

7. Widening of expected operation conditions of An-148-100 aircraft type (An-148-100A, An-148-100B, An-148-100E versions) with reference to operation at

prepared unpaved airfields. Additional certification operations have resulted in issuance of the Technical Act No. 148-100.700.048.D3-08 "The An-148-100 aircraft. Additional certification tests and checks in relation with the main revision entry to the typical structure "Widening of expected operation conditions of An-148-100 aircraft (An-148-100A, An-148-100B, An-148-100E versions) with reference to operation at prepared unpaved airfields", approved by the Chief Designer of the ANTONOV Company, by the Director of "Aviation Certification Center State Research Institute of Civil Aviation", by the Director of "СЦ "ПРОЧНОСТЬ" ("STs "Prochnost").

8. The An-148-100 aircraft available in English language version. Additional certification operations have resulted in issuance of Technical Act No. 148-100.700.027.D1-10 "The An-148-100 aircraft. Aircraft additional certification tests and checks in relation with main revision entry "The An-148-100 aircraft and its modified versions in English variant approved by the President – Chief Designer of the ANTONOV Company", by the Director of "Aviation Certification Center State Research Institute of Civil Aviation", by the Director of "СЦБО "Аэронавигация" ("STsBO "Aeronavigatsia").

9. Maximum landing weight increase of the An-158 aircraft up to 38800 kgf. Additional certification operations have resulted in issuance of Technical Act No.158.700.003.D3-13 "An-158 aircraft. Additional certification operations in relation of Main revision entry into typical structure "Maximum landing weight increase up to 38800 kgf" approved by the President – Chief Designer of the ANTONOV Company", by the Director of "Aviation Certification Center State Research Institute of Civil Aviation", by the Director of "СЦБО "Аэронавигация" ("STsBO Aeronavigatsia"), by the Director of "СЦ "ПРОЧНОСТЬ" ("STs "PROCHNOST").

10. The An-148-200 aircraft (An-148-200A, An-148-200B, An-148-200E versions). Additional certification operations have resulted in issuance of the Technical act №148.00.037.002.D3-13 "An-148-200 (An-148-200A, An-148-200B, An-148-200E versions). Additional certification operations in connection with the Main revision entry into the typical structure of An-148-100 aircraft type: "An-148-200 aircraft" approved by the first vice-President – Chief Designer of the ANTONOV Company.

11. Increase of airfield basing height up to 4 100 m. Additional certification operations have resulted in issuance of the Technical Act No. 148.100.700.018.D3-13 "The An-148-100, An-148-200, An-158 and their modified versions. Additional certifi-

cation tests in connection with the Main revision entry into the typical structure "Increase of airfield basing height over 2 200 m", approved by the President – Chief Designer of the ANTONOV Company, by the Director of "Aviation Certification Center State Research Institute of Civil Aviation", by the Director of "СЦБО "Аэронавигация" ("STsBO Aeronavigatsia").

In addition, around thousand secondary revision entry to the typical structure have been implemented to improve operation process of An-148-100 and An-158 aircraft family to upgrade comfort level in the compartment and to make aircraft performance better:

1. Additional certification tests have been conducted in relation with the secondary revision entry to the typical structure "Introduction of "Idle acceleration reverse" mode in operation of the main engines".

2. Increase of An-148-100B aircraft maximum take off weight at 600 kgf. Issuance of Engineering analysis No. RIO-11-23-12 "The An-148-100B aircraft". Flight performance followed by increasing of maximum take off weight 42 550 kgf".

Principle Conclusions with Reference to Certification

1. On the grounds of the scope of certification operations conducted by the ANTONOV Company together with certification centres, assigned by the Aviation Register of IAC and Aviation Authorities of Ukraine it has been stated and agreed that aircraft of An-148-100 (An-148-100A, An-148-100B, An-148-100E versions) type with the Д-436-148 (D-436-148) main engines and АИ-450-МС (AI-450-MS) auxiliary power unit and their operation documentation meet the requirements of CB-148 Certification Basis within the range of operational limits specified in aircraft operational documentation being certified on February 26, 2007 by the certificates of State Administration of Ukraine No. TL 0036 and Aviaregister of International Committee No.CT264-An-148.

2. Typical structure of the An-148-100 aircraft type (An-148-100A, An-148-100B, An-148-100E versions) being stated that they meet requirements above specified is presented in the check set of design documentation defined by the main specification 148.00.0000.000.000, having been corrected following the results of certification operations and being checked, approved and kept in compliance with the order established by

АП/АПУ-21 (AP/APU-21) at the ANTONOV Company".

3. To upgrade operation capabilities of An-148-100 aircraft family a new modified version "The An-158 aircraft" has been developed with a greater number of passenger seats for 99 passengers. Based on the results of additional certification operations the State aviation service of Ukraine and Aviaregister of IAC have approved specified Main revision of An-148-100 aircraft typical structure and on February 22, 2011 the State Aviation Service of Ukraine issued a new edition of type certificate TL 0036 with entry of new An-158 aircraft and issued a supplement to type certificate to Aviaregister of IAC No. CT264-An-148-100/D05.

4. The An-158 aircraft typical structure certified to meet requirements available in the CB-148 is represented in the set of working design documentation having been defined by the Main specification 148.20.0000.000.000, corrected according to the results of additional certification operations being checked, approved and kept in compliance with the order stated by APU-21 at the "ANTONOV" Company.

5. To upgrade compatibility and economic efficiency of the An-148-100 aircraft type fourteen main revisions have been introduced into the typical structurer approved by Aviation authorities of Ukraine and Aviaregister of IAC.

4.4 CONCLUSIONS

1. A scope of performed operations has made it possible to organize production of An-148-100 and An-158 aircraft according to the requirements of "Guidance 21.2C as per certification and manufacturing supervision of aviation engineering products", "Guidance 21.2D of certification procedure and monitoring of aviation engineering products manufacturing", ISO9001-2009 and EN9100 standards "Quality management system. Requirements", Quality system in progress is under continuous monitoring by providing inside inspections.

2. New production procedures in manufacturing of part and units using programmable numerically controlled machines have been developed and implemented.

3. New welding equipment and welding technological procedures have been acquired, studied and put into production.

4. Designing of production facilities has been performed using ECM and 3D

electronic mathematical models of aircraft having made it possible to ensure facilities fit with reference to a unified source with minimal use of standard models and calibration pieces and to make cycle of design works shorter and to reduce labour intensity and facilities erection. Laser checking and measuring set is used for monitoring jigs and fixtures providing high measurement accuracy and capability to compare obtained data with mathematical model.

5. A scope of operations performed to provide airworthiness of An-148-100 and An-158 aircraft family ensures their operational safety in complete compliance with the requirements specified in Aviation Regulations.

6. On the basis of certification operations performed by : the ANTONOV Company together with certification centres assigned by Aviaregister of IAC and Aviation authorities of Ukraine it has been stated and proved that aircraft of An-148-100 (An-148-100A, An-148-100B, An-148-100E versions) type with Д436-148 (D436-148) main engines and AI-450-MC auxiliary power unit and their operational documentation meet the requirements specified in CB-148 Certification Basis within the range of operation limitations specified in aircraft operations documentation certified by the certificates of State Administration of Ukraine No.TL 0036 and Aviaregister of International Aviation Committee No. CT264-An-148.

CONCLUSIONS

The main scientific result of the work is the solution of the significant scientifically applied problem that lies in the development of the philosophy and scientific grounds for the development of modern jet regional passenger aircraft. In compliance with the assigned target and goals in work activity the following results have been achieved:

1. A great scope of scientific-technical computations and design-structural works with the application of the developed automatic design system in 3D variant has been firstly performed in Ukraine under development and putting An-148-100 and An-158 aircraft family into production as well as required number of experimental researches have been conducted on the grounds and during the flight tests.
2. Methods in designing regional passenger aircraft have been upgraded by selection on aerodynamics structural-strength and volumetric-weight combinations have been defined as well as parameters, wing configuration, parameters of fuselage cross section, flight performance, take off and landing characteristics, engines, equipment and systems.
3. Aerodynamic arrangement has been developed having no similar analogues in the world practice of aircraft manufacturing that made it possible to develop regional passenger high-wing aircraft with a flight speed of 870 km/h (M = 0.8).
4. Methods in computation of general and local strain-stress state characteristics, aircraft strength and lifetime have been improved due to the use of CAD\CAM\CAE systems.
5. The energy of two centralized electrical AC electrical systems ("2H/2E" electrical complex diagram) is used at An-148-100 and An-158 aircraft instead of additional hydraulic systems to operate power drives ("boosters").
6. A new generation family of An-148-100/An-158 competitive, highly efficient jet regional passenger aircraft has been developed to be on the level of larger size airlines as per comfort of passenger being by their technical and operational characteristics at the level of the best world prototypes.
7. World single modern regional jet passenger aircraft has been developed capable

to operate from unpaved airfields.

8. Development, production and putting An-148-100/An-158 aircraft family into production have made it possible to create new working positions in Ukraine in the amount of more than 14 000 people.
9. Implementation of work provided by the ANTONOV Company resulted in development of new generation of regional jet passenger aircraft family and improvement of study and scientific level of training aircraft engineering specialists in the National Aerospace University "Kharkiv Aviation Institute".

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