UNICHECK

Ім'я користувача:

ID перевірки:
1013358486

Дата перевірки:
29.12.2022 19:11:29 EET

Тип перевірки:
Doc vs Library

Дата звіту:
29.12.2022 19:14:19 EET

ID користувача:
43673

Назва документа: B31

Кількість сторінок: 66 **Кількість слів:** 11102 **Кількість символів:** 70003 **Розмір файлу:** 6.91 MB **ID файлу:** 1013124073

89.9% Схожість

Найбільша схожість: 69.6% з джерелом з Бібліотеки (ID файлу: 1009725278)

Пошук збігів з Інтернетом не проводився

89.9% Джерела з Бібліотеки | 224 .... Сторінка 68

0% Цитат

Вилучення цитат вимкнене

Вилучення списку бібліографічних посилань вимкнене

0% Вилучень

Немає вилучених джерел

Модифікації

Виявлено модифікації тексту. Детальна інформація доступна в онлайн-звіті.

Замінені символи | 30

MINISTRY OF EDUCATION AND SCIENCE OF UKRAINE

National Aerospace University

Kharkiv Aviation Institute

Aircraft Engineering Faculty

Department of Aircraft Manufacturing Technologies

Explanatory Note

of Thesis for Bachelor's Project

Bachelor

(Degree)

Topic: « Technological production of assembling for the airplane rib No 21 and manufacturing of the cover by dimensional working»

ХАІ.104.144F.22B.134.RecordBook# ПЗ

Performed by student of 4th year, group 144FJ
Field of study 13 Mechanical Engineering
(Code and Name)
Programme Subject Area
134 Aerospace Engineering
(Code and Name)
Educational Program ______________________
Technologies of Aircraft Manufacturing and Repair
(Name)

(Surname and Initials)

Supervisor:

(Surname and Initials)

Reviewer:

Surname and Initials)

Kharkiv – 2022

NATIONAL AEROSPACE UNIVERSITY

Kharkiv Aviation Institute

Faculty Aircraft Engineering

Department Aircraft Manufacturing Technologies

Higher Education level Bachelor (the first) level

Program Subject Area 134 “Aerospace engineering”

(Code and Name)

Educational program “Technologies of Aircraft Manufacturing and Repair”

(Name)

APPROVED by

Head of Department

“____” __________________2022

T A S K

FOR THESIS FOR BACHELOR'S DEGREE

____

(Surname, Name)

1. Subject of Thesis: Technological production of assembling for the airplane rib No 21 and manufacturing of the cover by dimensional working.

Supervisor:

(Surname, Name, Scientific Degree, Academic Status)

approved by University order from “____”____________20___ No _____

2. Thesis presentation deadline

3. Initial data for Thesis practical experience in assembling of the wing rib no.21 of the passenger airplane, calculation and graphic materials for the manufacturing by machining, coordination diagrams developed in practice, economic data from open sources for calculating the cost of the assembly process.

4. Content of explanatory note (list of problems to solve) development of the wing rib no.21 of the passenger airplane, technical description and design manufacturing analysis of the wing rib no.21 assembly, working out of a technological route for part manufacturing by machining, working out of the machining technological operations modes and designing of the special jig for the part machining, development of directive technological material for the wing rib no.21 of the passenger airplane, calculating the error of assembling for the wing rib no.21 of the passenger airplane, the cost calculation on assembling work for two assembly methods

5. List of drawings to be made Wing rib no.21, Part list wing rib no.21, Coordination diagram.

6. Advisers of Final Work's Sections

Section	Surname, Initials, Position of Adviser	Signature, Date	
		Task is given	Task is passed
1. Designing section			
2. Technological section			
3. Economic section			

7. Date when task is given ____

CALENDAR PLAN

No	Final Work milestones	Work milestones deadline	Notes
1	Designing section		
2	Technological section		
3	Economic section		

Student _____________
(signature) (Surname, Name)

Supervisor _____________
(signature) (Surname,Name)

Contents

INTRODUCTION

The bachelor project thesis is an important document which resembles the overall work of an engineering student. This thesis of manufacturing specialization reflects the overall knowledge of student in the field of designing and technological development of the different kinds of material and parts which are being used or unused in aircraft industry. This thesis consists of 3 sections which are:-

(1) Designing Section

(2) Technological section

(3) Economic section.

In designing section, the complete analysis and checking of Rib No.21 of An-148 aircraft. The section comprises of drawing which are substances dimensions and technological requirements for its effective manufacturing. The section has checking of mass calculation after changing material and using different approach for joining stringers with skin.

In the technological section, the development of plate by machining process. In the second part of technological section we developed the assembly process for this Rib No.21 of airplane An-148.the scheme of assembling and procurement of assembly equipment is chosen by certain calculation. Assembly scheme, tolerance and error of assembling. The technological process of assembling is considered and its scheme is developed.

The complete examination of the economic elements of manufacturing aircraft in real world parameters can help us in the economic section analysis and select the effective mode of assembly by analyzing the challenge facing engineers in the real world and the right conclusions will be reached following the analysis.

1. DESIGNING SECTION

The An-148 aircraft is a high-wing monoplane with two turbofan jet engines mounted in pods under the wing. This arrangement protects the engines and wing structure against foreign object damage. A built-in auto diagnosis system, auxiliary power unit, and the wing configuration allow the An-148 to be used at poorly equipped airfields. Flight and navigation equipment features five 15 by 20 cm (5.9 by 7.9 in) liquid crystal display panels built by Russia's Aviapribor and a fly-by-wire system, which enables the An-148 aircraft to operate day and night, under instrument flight rules and visual flight rules weather conditions on high-density air routes. Similar to the Boeing 737, the main landing gear rotates into the belly of the aircraft when in flight, with partial doors covering the legs, and the sides of the tires remaining exposed. Built-in entrance stairs enable boarding and disembarking the aircraft without extra ground equipment. The manufacturer claims high fuel efficiency of the Motor Sich D-436-148 engines.

Figure1 - Antonov-148

Table 1.1 General characteristic of plane An148.

Crew	5 (captain, first officer, navigator, flight engineer, loadmaster)
Capacity	up to 85 passengers or 5.15 tons of cargo
Length	29.13 m
Wingspan	28.91 m
Height	8.19 m
Wing area	87.32 m^2
Empty weight	22000 kg
Gross weight	43700 kg
Maximum speed	870 km/h
Range	4400 km

1.1Develop the aircraft rib structure

In an aircraft, Ribs are forming elements of the structure of a wing, especially in traditional construction.

By analogy with the anatomical definition of "rib", the ribs attach to the main spar, and by being repeated at frequent intervals, form a skeletal shape for the wing. Usually ribs incorporate the air foil shape of the wing, and the skin adopts this shape when stretched over the ribs.

Figure1.1 – Ribs in wing

The component in question here is the 8th rib of the aircraft AN-148 (Figure1.1). It is situated in the end of the wing structure. It is a reinforced whose main purpose is handle loading and bending moments caused mainly by the engine. It also handles loading from some units that are attached to the wing like landing gear, aileron attachments and transfers them to the spars and skin. If broken down individually each element of the structure serves a specific purpose. The cross sectional area of a beam is an extruded section which is normally supported by pillars known as stiffeners. In some cases the rib is made of monolithic web and in other cases trusses are used altogether. The main purpose of the designer is to come up with beam profile shape that can handle aerodynamic loads and forces generated by the bending of the wing in both tension and compression. During selection of beam cross section one has to take into account processes that the element will undergo. These include ease of manufacture and fastening conveniences. Rib caps can take up a T or L cross section. These can be connected to the rib web by use of fastener to increase stability of part. Stiffeners on the other hand are made of standard profiles.

The rib’s web can be cut out from a sheet metal using either shears or laser for higher quality of cut surface. Since shear force acting on the ribs web is variable but web thickness is a constant, we can use this information to reduce the amount of material used in construction of our rib cross section. Choice of material to be used in construction is very critical as both physical and mechanical properties of the material should meet all requirements. The ideal material should cater to requirements in strength and rigidity whilst having minimal mass to lower material costs. It should also ideally be easy to manufacture and with anti- corrosive properties as well. The most important properties of our material should be strength rigidity and density. In this case the aluminum D16T has very desirable properties such as high strength and fatigue resistance. It is very manufacture- friendly for it can be forged, rolled and even welded. There way creating a wide field of possibilities in the manufacturing process. It is of low cost and has high specific strength and low density making it quite ideal for this design module.

Although all this is favorable other aluminum alloys can be considered for the task at hand. For example, the alloy D16 (duralumin) has very good flexibility and allows wide use in machining of lightening holes. The aircraft is constructed primarily from thin metal skins which are capable of resisting in plane tension and shear loads but buckle under comparatively low values of in-plane compressive loads. The skin therefore is stiffened by longitudinal stringers which resist the in-plane compressive loads and at the same time resist small distributed loads normal to the plan of the skin. For aerodynamic reasons the wing contours in the chord wise direction must be maintained without appreciable distortion. Therefore to hold the skin-stringer wing surface to contour shape internal structural support units are presented which are referred to as wing rib.

Requirements to the design:

a) Aerodynamic requirements (geometrical parameters to ensure the aerodynamic quality of stability and control). Figure 1.2 (A)

b) Strength requirements.

c) Rigidity requirements.

d) Survivability requirements.

e) Operating requirements.

f) Technological requirements.

Figure-1.2(A)

Figure 1.2 (B)

1.2 Substantiate decisions being made with calculations.

This modification to design aims to analyze the difference between the material D16T and Titanium and steel to choose the better one to withstand the local aerodynamic loads, both are the components different but there is a difference in strength which helps to Cap become stronger.

The following is a computation for Upper Cap.

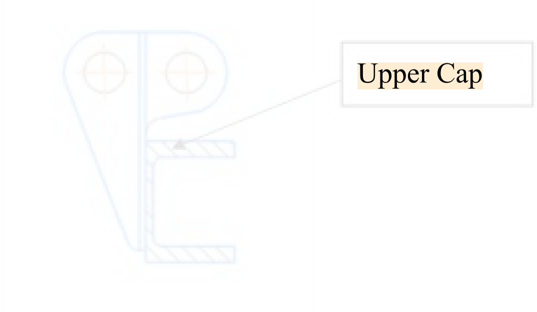


Figure 1.3 - Upper Cap

Initial data and design calculations

I am choosing various kinds of materials for the cap in order to calculate the most appropriate material for it with the least amount of mass and the greatest capacity to endure increased stress and pressure.

Table 1.2 - Initial data for calculation

	D16	30ХГСА	Titanium	Ak6
σ_b, dN/mm^2	40	110	80	42
ρ, g/mm^3	$2.76\cdot10^{-3}$	$7.85\cdot10^{-3}$	$4.4\cdot10^{-3}$	$2.75\cdot10^{-3}$

Where, D16 is an aluminum alloy, 30ХГСА is steel and Ak6 is a forgeable aluminum alloy.

It is necessary to use the following formulae in order to calculate

$$P = A \cdot \sigma_b \quad (1.1)$$

Where;
P- Force on cap
A- cross-section area of angle bracket
σb- ultimate tensile strength

$$m = A \cdot s \cdot \rho \quad (1.2)$$

Where;
s-Thickness (Assumption s=4mm)
ρ- Density of material

Calculate according to formula (1.1)

- For D16:

$$P = A \cdot \sigma_{b_{D16}}$$

$$P = 221.19 \cdot 40 = 8847.6 dN$$

$$M_{D16} = A_{D16} \cdot s \cdot \rho_{D16}$$

$$M_{D16} = 221.19 \cdot 4 \cdot 2.76 \cdot 10^{-3} = 2.44\ g$$

- For 30ХГСА:

$$A_{30ХГСА} = \frac{P}{\sigma_{b_{30ХГСА}}}$$

$$A_{30ХГСА} = \frac{8847.6}{110} = 80.43 mm^2$$

$$m_{30ХГСА} = A_{30ХГСА} \cdot s \cdot \rho_{30ХГСА}$$

$$m_{30ХГСА} = 80.43 \cdot 4 \cdot 7.85 \cdot 10^{-3} = 2.526\ g$$

- For titanium:

$$A_{Ti} = \frac{P}{\sigma_{b_{Ti}}}$$

$$A_{Ti} = \frac{8847.6}{80} = 110.595 mm^2$$

$$m_{Ti} = A_{Ti} \cdot s \cdot \rho_{Ti}$$

$$m_{Ti} = 110.595 \cdot 4 \cdot 4.4 \cdot 10^{-3} = 1.946\ g$$

- For Ak6:

$$A_{Ak6} = \frac{P}{\sigma_{b_{Ak6}}}$$

$$A_{Ak6} = \frac{8847.6}{42} = 210.6\ mm^2$$

$$m_{Ak6} = A_{Ak6} \cdot s \cdot \rho_{Ak6}$$

$$M_{Ak6} = 210.6 \cdot 4 \cdot 2.75 \cdot 10^{-3}$$

$$= 2.32\ g$$

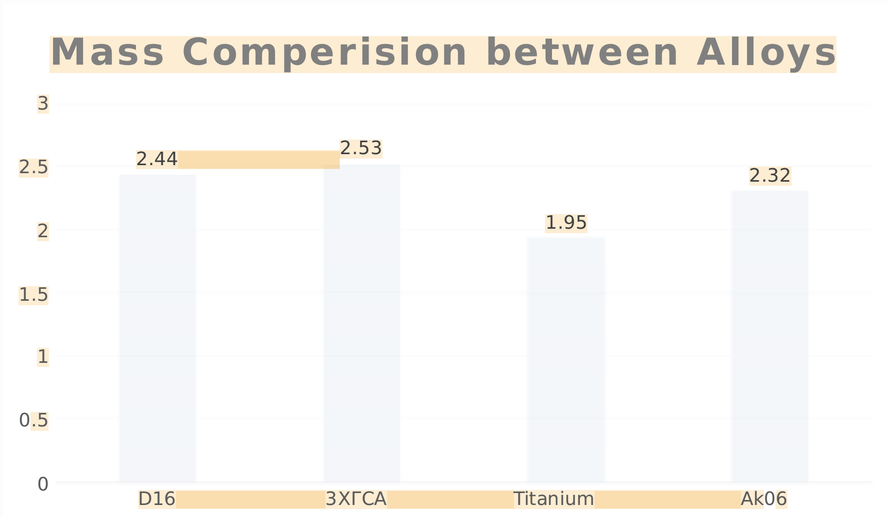


Figure 1.4 Conclusion graph

Conclusion

From graph, it is proved that 30ХГСА has maximum mass while, titanium has minimum mass. From given data, 30ХГСА has highest ultimate tensile strength while, D16 has minimum. So, it is concluded that 30ХГСА is not appropriate for cap as D16 also has very low ultimate tensile strength it is also not appropriate because it is not able to withstand with higher force.

Titanium is very costly and not good manufacture. Ak6 has average of mass and tensile strength too. So, it is concluded that Ak6 is appropriate material for angular bracket.

For Cap:
Material- Ak6
Area of cross-section- 210.6 mm^2

1.3 Technical description and design manufacturing analysis of the unit

The rib is fortified whose primary design is to deal with stacking and twisting minutes caused predominantly by the motor. It additionally handles stacking from certain units that are appended to the wing-like landing gear, aileron connections, and moves them to the competes and skin. Whenever separated independently every component of the structure fills a particular need. The cross-sectional region of a bar is an expelled area which is ordinarily upheld by columns known as stiffeners. Now and again, the rib is made of solid web and in different cases, supports are utilized inside and out. The primary motivation behind the architect is to contact a shaft profile shape that can deal with streamlined loads and powers created by the bowing of the wing in both strain and pressure. During the choice of bar, cross-area one needs to consider the procedures that the component will experience. These incorporate simplicity of production and affixing accommodations. Rib tops can take up a T or L cross-segment. These can be associated with the rib web by the utilization of clasp to build the steadiness of part. Stiffeners then again are made of standard profile

1.4 Technical specifications for the assembly unit of the aircraft

1. Parts to be made according to templates with a master plate.
2. Unspecified limit deviations of the dimensions of the location of surfaces according to OST1 00022-80
3. Coating of parts BC AN OKCHxp/primer 31-0215400 OST1 90055-85. in detail pos1 8 9 10 surfaces not primed in case of gluing rubber gaskets to them.
4. Covering of heads of rivets, nuts GR. EP-0214,416 OCT 1 90055-85.
5. Mark and brand according to Pi-63-90X.
6. Metallization according to OST 101025-82 using rivets.
7. Riveting on ti-412-90 "x" and pi-249-78. Riveting automatic and press not less than

70%
8. The upper and lower belts are equidistant to the theoretical contour. 9. Roughness of machined surfaces dem.B432
10. Details from D16AM to heat, heat treatment control group 5 according to OST1 00021-78.
11. Sealing according to instructions 77 TI16-500-88. glue
12. Gaskets pos. 19, 20, 21 glue with compensator pos. KR-5-18 according to Pi2031-77
13. Round sharp edges with a radius of 0.5 mm.
14. Manufacture and control of warhead dem. according to pi14.1977-89

2. TECHNOLOGICAL SECTION

2.1 Working out of a technological route for part manufacturing by machining.

The part which designed it will use in aircraft structure. It's quite similar to holder of aircraft structure. Lid are used throughout the aerospace industry in Frames assembly and aircraft structure.

1. Mass= 829.38 grams.

2. Volume= 311781.36 cubic millimetres.

3. Surface Area= 14661.17 square millimetres.

Figure 2.1 Sketch of the lid

The part is made of Aluminium and the process is production is Casting. Casting is used since at material is Al 9 GOST 2188-88 casting Al. Casting is selected because in casting it requires more machining process, and we can’t get accurate finished product.

The **main advantages of Casting** are:

Smooth Finish. Investment casting uses a ceramic mold that can produce a much smoother finish, typically averaging 125 RA surface finish as cast.

Faster Production. ...

Tight Tolerances. ...

Affordable Tooling. ...

Vast Size Range. ...

Material Variety.

Figure 2.2 – Machined Surfaces

Table 2.1- Specification of Surfaces and their Designations

Designation of the machined surface	Allocation of the surface	Shape of the surface	Dimensions	Class of accuracy of dimension tolerance	Surfac e finish
Surface 1	Outer	Cylindrical	Ø75mm	h12	Ra0.35
Surface 2	Inner	Cylindrical	Ø47mm	H7	Ra 0.3
Surface 3	Inner	Cylindical	Ø35mm	H9	Ra 0.4
Surface 4	Inner	Flat	L=4mm	H12	Ra 0.8
Surface 5	Inner	Flat	L=8mm	H12	Ra 0.8
Surface 6	Inner	Flat	L=14mm	H7	Ra0.21
Surface 7	Outer	Flat	L=20mm	H12	Ra 3.2
Surface 8	Outer	Slot	L=4mm	h12	Ra 3.2
Surface 9	Inner	Hole	Ø 6.2mm	H12	Ra 3.2
Surface 10	Outer	Chamfer	R=2mm	H10	Ra 0.8
Surface 11	Outer	Cylindrical	Ø 56mm	H7	Ra 0.4
Surface 12	Inner	Cylindrical	Ø 39mm	H9	Ra0.8

Surface 13	Outer	Cylindrical	Ø 56mm	H7	Ra 0.4

2.1.1Calculate allowances for each processing step, determine the dimensions of the blank (casted, stamped or forged).

Selection of the initial stock is determined by a number of factors. The main factors are: the production volume, requirement to mechanical properties of the part, stock utilization factor. As a rule, the working drawing of the part must contain information concerning initial stock. In the absence of such information student must ground this selection. After the selection the stock it is necessary to calculate the machining allowance by its summation for all operation of the surface, determining overall dimension of the part. According to [2, p.13].\

Unilateral intermediate allowance is calculated according to equation:

$$2Z = 2\left[R_z + h + (\rho_a + \varepsilon_\delta)\right] + \delta, \qquad (2.1)$$

Where Z – is a nominal intermediate allowance =:

R_z = is a height of the micro roughness (roughness coefficient for corresponding surface finish class);

h = is thickness of the defect layer produced at previous operation;

ρ_a = is a vector deviation of the related surfaces of the machined work piece produced at previous;

ε_δ = is an accuracy of the positioning during machining;

δ = is a tolerance during previous machining operation.

Table 2.2 – Type of machined Surface: Flat Surface

Type of the machining	Rz,mkm	h, mkm	δ, mkm	Calculated allowance,mkm	Calculated operational dimension, mm	Adopted dimension of the stock, mm
For Inner Flat Surface (4) L=4mm						

casting	130	500	350		11.72	11
Rough Boring	20	50	150	980	4.22	5
				220	5	
For Inner Flat Surface (5) L=8mm						
Rough Boring	50	60	70	980	8.34	9
				180	9	
For inner Flat Surface (6) L=14mm						
Casting	60	80	75	320	14.45	15
Rough Boring	50	60	70		14.32	
Finish Boring	3	30	150	405	14.247	
				180	15	
For outer Flat Surface (7) L=20mm						
Casting	50	60	70		20.56	21
Rough Boring	50	60	70		20.56	
				180	21	

Table 2.3 – Outer Cylindrical Surfaces of Revolution

Type of the machining	Rz, mkm	h, mkm	δ, mkm	Calculated allowance, mkm	Calculated operational dimension, mm	Adopted dimension of the stock, mm
For Outer Cylindrical Surface (1) Ø75mm						
Casting	130	500	350		76.45	77

Rough Milling	60	45	250	980	75.455	
				355	75	
For Outer Cylindrical Surface (2) Ø 47mm						
Casting	30	60	280		39.87	40
Rough Turning	20	50	150	980	47.67	
Finish Turning	70	35	300	405		47
				980	47	
For Outer Cylindrical slot Surface (8) L=4mm						
Rough Turning	30	45	170	560	4.56	5
				560		
For Outer Cylindrical Surface (10) R=2mm						
Rough Turning	50	60	70	980	1.34	2
				180	2	
For Outer Cylindrical Surface (1) L= 11mm						
casting	130	500	350		11.72	11
Rough milling	20	50	150	980	4.22	5
				220	5	
For Outer Cylindrical Surface (11) Ø 56mm						
casting	130	500	350	405	57.58	58
Rough Turning	20	50	150	980	56.34	
Finish Turning	70	35	300	405		56
				980	56	
For Outer Cylindrical Surface (12) Ø 39mm						

Rough Boring	50	60	70		39.58	40
Finish Boring	3	30	150	405	39.46	
				180	40	

Table 2.4 – Cylindrical Holes

Type of the machining	Rz, mkm	h, mkm	δ, mkm	Calculated allowance, mkm	Calculated operational dimension, mm	Adopted dimension of the stock, mm
1	2	3	4	5	6	7
For Inner Cylindrical Surface (3)Ø35mm						
casting	130	500	350		30.615	30
Rough Drilling	70	35	300	980	34.595	34
				405	35	
For Inner Cylindrical Surface (2) Ø6.2mm						
Rough Drilling	70	35	300		6.278	5
				57	7	

Figure 2.3 – Sketch of the blank

2.1.2 Select processing bases for each operation (or processing step) and work out chart of sketches (locating charts for all operations) for locating the part during its processing.

In this section we will determine how the lid part is produced in Machine step by step. In below chart of sketches we have determined detailed, like which area is machined in which Universal Machine. We have to select which processing base is needed to hold the part while machining. As you can see, in this case, the principle of the constancy of technological datum, which increases the precision machining.

010-Rough turning
13
Ø66
5
020-Rough turning
7
8
1
Ø52
Ø56
030-Rough drilling
Ø6,2
4 holes
3
Ø35
9
040-Rough boring
6
5
Ø37
Ø45

Figure 2.4 – Operation sketch

2.1.3 Work out the technological route (sequence of operations) for the part processing.

Here in this table we need to determine the Sequence of the part manufacturing processing. We have to mention what kind of Equipment and tools we have used in this Process. The step by step process of part manufacturing has been given below.

Table 2.5 – Technological route

Operation	The name and working process of operation	Equipment and tools	Machining
1	2	3	4
05	Inspection: Examine the information of the process and inspect the working materials	Ultrasonic Detector	Working Bench010

	condition and check for damage and check for tiny holes using ultrasonic detector or any other checking devices.		
010	Turning: Remove the Surface 1 of Ø86mm; Surface 3 of Ø35mm; Surface 13 of Ø56mm	Lathe Machine	Turning
020	Turning: Cut the surface 7 of Ø 56mm; Surface 8 of L 4mm Turning: Cut the surface 10 of R2mm	Lathe Machine	Turning
030	Drilling: Drill holes of Ø35mm in surface 3 Drill holes of Ø6.2mm in surface 9	Drilling Machine	Drill bit
040	Rough Boring: Cut the surface 4 Ø35 mm; Surface 12 Ø39 mm; Surface 5 L= 8mm; Surface 6 L= 14mm.	Lathe Machine	Boring tool bit in lathe
050	Finish Boring: Repeat the process of 050 operation.		
060	Side Milling: Cut the surface of 1 Ø86mm, R 7mm and R32.5 mm.	CNC Milling Machine	Special Jig End mill.
070 Inspection	Verify the size, surface roughness, weight and look for mechanicsm.	Vernier callipers, roughness samples, scales	Control plate

2.1.4 Create 3-dimensional computer models of the part and blanks, fulfil there drawings from models.

By using SolidWorks Software, the 3D of the part (Fig 2.7), Casting Blank (Fig 2.9) has been created. As we saw my part is circular component which have large number of small holes in it, 4 holes and one big hole in center of part. At backside my part has many depth cuts, and circular grooves etc.

Figure 2.5 – 3D model of part

2.2 Working out of the machining technological operations modes and designing of the special jig for the part machining.

2.2.1 Work out one of the technological operations (for CNC machining) in detailed way. Develop technological chart for CNC processing

As, in the operational Scheme most of the surface are machined by the CNC Milling machine. So, we need to describe how CNC works and mention the toolpath, which is mentioned below in Figure 2.6

Figure 2.6 – Technological chart for CNC Milling

Computer-aided design & computer-aided manufacturing (CAD/CAM). Computer-aided design & computer-aided manufacturing (CAD/CAM) software is used to design and manufacture prototypes, finished products, and production runs. An integrated CAD/CAM system offers one complete solution for design through manufacturing. CAD/CAM applications are used to both design a product and program manufacturing processes specifically, CNC machining. CAM software uses the models and assemblies created in CAD software to generate tool paths that drive machine tools to turn designs into physical parts. CAD/CAM software is used to design and manufacture prototypes, finished parts, and production runs.

Advantages of CAM:

- Requires low labour input.

- Mass production of components.

- Greater accuracy and greater finished products.

Disadvantages of CAM:

- It requires high skilled workers for operating machines.

- It requires more workspace.

- It demands each and every planning of parts before manufacturing, more than a normal work machine.

- We can’t produce another part suddenly in between operation, because the machines work from start to end.

2.2.1.1 Calculation of cutting parameter for CAM machining

Milling tool Cutting speed can be calculated using the following formula:

$$Vc=(x\,D\,x\,n)/1000, \quad (2.2)$$

where D = Mill tool diameter;

n = rotational speed of the main spindle.

D=10 mm and n=675.135 rpm

Hence V_c = 21.20 m/min.

Milling speed is 21.20 m/min.

Feed of main spindle (V_f).

Spindle feed can be calculated using the following formula:

$$Vf=(f\,x\,n), \quad (2.3)$$

Where, f=0.2 mm/rev is the feed per revolution;

n=675.135 rpm is the rotational speed of the main spindle.

Hence V_f = 135.02 mm/min.

Feed of main spindle is 135.02 mm/min.

Milling time (T_c).

Milling time can be calculated using following formula:

$$Tc=Id/Vf, \quad (2.4)$$

where, I_d = 153.52 mm milling tool travel distance;

V_f = 135.02 mm/min is the feed of main spindle.

Hence T_c = 1.13 min.

Milling time is 67.8 second.

2.2.2 Create 3-dimensional computer models of the special holding device for the part machining during the milling operation. Define the special holding device arrangement and the technique of it using while the part processing

I have created a 3D dimensional holding for my part for doing milling operation. I have 2-Blocks in it to hold circular component, which have sliding on the main holed by screw. It will lock all six degree of freedom. These blocks and component hold by holder in main base block bed. The milling tool come from top to downwards directions, to mill the model for required shape by side milling with their trajectory.

Figure 2.7 – 3D model of standard vise.

2.2.1.1 Calculating the locating errors of part in the jig and design special jig

In the case of drilling the holes with the help of a manual power tool it is necessary to take into consideration the possible dis-balance of the holes axis as a result of the clearance between the hole in the drill bushing and the drill.

$$\delta_{milltool} = \frac{l_i}{h_{buhing}} \left(z_{max} + k \frac{l_{i+h_{bushing}}}{100} \right) \qquad (2.5)$$

where, l_i is the distance between the lower end of the bushing to the top of the drill; h_{buhing} is the drill bushing height ; $z_{max=D_{tool_{max}}-D_{tool_{min}}}$ is maximum clearance between the mill tool and the mill bushing , considering its wear ($D_{tool_{max}}$ is maximum mill bushing diameter, $D_{mill_{min}}$ is minimum tool diameter); k is the tool reverse taper.

$i=¿1..1.5 mm$
$l_{¿}$

$i=¿1.5 mm$
$l_{¿}$

$h_{bushing}=¿$ 23 mm

K=0 $\rightarrow$ *for cylinderical mill tool*

K=1 $\rightarrow$ for conical mill tool

$D_{tool_{max}}=10.5 mm$

$D_{tool_{min}}=10.2 mm$

z_{max} = 10.022 – 10 = 0.022mm

$$\delta_{tool}=\frac{1}{23}\left(0.022+0\frac{1.5+23}{100}\right) = \frac{1}{23}(0.022)$$

δ_{tool} = 0.00095 mm

2.3 Development of directive technological materials for assembling the rib № 21

2.3.1 Perform the estimation of technological effectiveness (processability) of the considered assembly unit Rib No.21:-

Aircraft are evaluated by sum of technical characteristics and production indicators. These depend on the technologically advanced main production of the serial plant and technologically design production facilities.

To increase production efficiency, the manufacturability of the structure is crucial. Manufacturability is understand as the set of design properties of the component of the aircraft glider, resulted in the possibility of optimal labor expenses, funds, materials and time for technical preparation of production, manufacture, operation and repair, compared with the corresponding indicators of the same component structures of the same purpose, ensuring the established values of quality indicators and the accepted conditions of manufacture, operation and repair.

In general, the manufacturability of the structure directly determines all production indicators: labor intensity, cost, production cycle, qualification of workers, production areas, size.

The manufacturability of the structure is determined by qualitative and quantitative indicators.

Let's carry out a qualitative assessment of manufacturability of the Rib No.21. Qualitative assessment is carried out on the following indicators:

1) Simplicity of forms of a surface of assembly unit (AU) components.

In a rib №8 surfaces of single curvature are applied that provides:

-Simplicity, accuracy and efficiency of geometrical calculations of contours and surfaces at preparation of CNC programs for the equipment;

-high accuracy and simplicity of coordination of components of Rib No.21;

-Extreme simplification of processing tooling of working contours and surfaces of flat and volume tooling;

-increasing the number of similar parts;

-reduction of labor intensity of production of technological tooling and its nomenclature.

2) Rational division of the aircraft design into elements.

This Rib No.21 is divided into a small number of parts. This allows:

-increase the front of assembling and mounting works, reduce production time and improve the quality of the assembly unit;

-expand the use of mechanization and automation of Rib No.21 components assembly work;

-increase the productivity and working conditions of workers, assembly fitters;

-reduce the cost of assembling and mounting work.

3) Application in a design of normalized and standard elements as much as possible, their unification (reduction of the nomenclature):

In a design standard part - caps, compensators, stiffeners are applied. Due to it, time of preparation, the cost of a product, a kind of technical processes, equipment decreases.

4) The maximum use in a design of easily processed materials.

In the design of the rib is used aluminum-lithium alloy 1420, which is corrosion-resistant, weldable; the mechanical properties of the alloy in the aging process at 200°C do not change, which allows to perform all sorts of technological operations for deformation in the hardened state. Application of this alloy allows to reduce considerably labor intensity of processing of parts, to facilitate their deformation at change of the form, to simplify cutting of holes. This increases labor productivity, as well as the material utilization rate.

5) Existence of open access to joints and using compensators.

To reduce the requirements for the accuracy of the mating elements of the structure and reduce the fitting operations. The cap of a Rib No.21 provides free access to joints and also in rib compensators are used to join caps of a rib to skins.

6) Quantitative assessment of the manufacturability of the aircraft design

The main quantitative indicators of manufacturability are:

-coefficient of level of manufacturability by labor intensity:

$$K = \frac{M_{d.p.}}{M_{b.p.}} \quad (2.1)$$

Where; $M_{d.p.}$- manufacturability of the designed product,

$M_{b.p.}$- Manufacturability of the base product.

-coefficient of the level of manufacturability by cost:

$$K_C = \frac{N_{d.p.}}{N_{b.p.}} \quad (2.2)$$

Where;$N_{d.p.}$– the cost of the designed product,

$N_{b.p.}$ -the cost of the base product.

After conducting analysis on the manufacturability of the Rib No.21 design, it may be concluded that the design the rib is quite technological.

2.3.2 Analysis of the possible variants of assembly methods, schemes (sequences) of assembling of considered assembly unit Rib No.21 and schemes of tooling coordination.

The purpose of the assembly process is to obtain new properties of the object by combining its components for 'co-working'.

The structure of assembly process includes the following sequential work:

-Locating and clamping work to determine the position of the components relative to the main bases or with respect to each other;

-Fixation of the reached state by type of joint given in design.

The assembly method determines by what methods and means the parts and assembly units are located with respect to each other in the order of assembly to ensure their correct and accurate arrangement.

The combination of the locating scheme with the techniques and means of locating the parts and subassemblies in a given position is a method of assembly.

The most common in modern aircraft manufacturing are the following methods of assembling:

1) Assembly methods without jig (assembly methods without base in the assembly jig, base in the system

-Assembly method by assembly holes (AH);

-Locating by marking;

-Assembling by marking;

-Method of assembling by faying surfaces on parts.

2) Assembly methods in the Assembly Jig (AJ):

-With locating of part or unit on special holes (CFH, BFH);

-Locating parts and assemblies on their surfaces and contours.

1. Assembly methods without Jig.

Assembly on assembly holes (AH): In this case, the parts are set in the desired position, combining the holes in the base and the incoming parts, and then fix them with a cylindrical clamp. The accuracy of locating is provided by accuracy of coordination of holes in parts and the accepted sizes of a clamp.

At assembly on AH no special AJ is required and low technological cost of assembly and mounting work (AMW) is provided.

Assembly by marking: In this method, the parts are located along the marking lines applied to the base part. The method is applicable for the assembly of flat assemblies and cylindrical panels.

Low tooling costs and a relatively small production preparation cycle due to using markup templates or laser marking method uses in small-scale production.

The disadvantage of this method is higher as compared to the assembly by AH, labor intensity and reduced accuracy.

Assembly on faying surfaces (“assembling according to the drawing"): In this method, one of the parts of the unit is selected as the main, which carries the bases for the locating of incoming parts having the corresponding locating bases. The accuracy of the locating of parts is determined by the accuracy of the mating surfaces and is ensured by fits and tolerances adopted in mechanical engineering.

2. Assembly methods in the assembly jig. In these methods, the base surfaces of the AU are combined with the support surfaces of the AJ and fixed in this position for the period of joining operations. AC are delivered for assembly with finished form and the sizes (according to Technical Inspection). When assembling in the AJ, the base surfaces of the locaters are made with great accuracy in accordance with the geometry of the disassembled parts of the subassemblies. The AJ provides the mutual position of all AC, with the big accuracy transfers the form and the sizes on the unit collected in it, simplifies and facilitates assembly process, some of assembly operations may be

mechanize. The assembly method in the jig provides a high level of interchangeability of the assembled units.

Assembly scheme is a graphic representation (in the form of symbols) of the assembly sequence of the AU or the glider or the aircraft as a whole.

Depending on the degree of division of the glider and airborne systems of the aircraft to AU and the degree of differentiation of assembling, mounting work, the assembly and mounting cycle can be carried out according to three schemes:

-Sequential;

-Parallel;

-Parallel-Sequential;

Sequential scheme: Assembly is typical for the conditions of small-scale and experimental production or when assembling simple components or small units. In such scheme parts and no more than one subassembly are supplied for assembling.

Parallel assembly diagram: This scheme is used to assemble aggregates and compartments, divided into panels and assemblies, which are assembled independently of each other - in parallel. With a parallel assembly scheme, only subassemblies are supplied to the assembly, parts are not supplied.

Parallel-parallel assembly diagram: It is used when assembling units disassembled on the panel, which are assembled in parallel, then joined, and then perform mounting work on the assembled unit (compartment). In a parallel-sequential scheme, both subassemblies (more than one) and parts are supplied to the assembly.

Since rib is considered a flat unit and has relatively small range of incoming parts, it is advisable to use a sequential scheme, when the part will be sequentially layered one by one.

In the manufacture of the wing rib, it is possible to use the following options for coordination tooling: Loft Template method (LTM), Standard-template method (STM), Loft-instrumental method (LIM), Program instrumental method (PrIM), etc.

The method of coordination: the nature of the combination of types of primary origin of coordination and means of coordination.

The Loft-template method (LTM): is a method of dependent formation of shapes and sizes of mating elements of the aircraft structure and technological tooling necessary for the manufacture and assembly of these elements. The method is based on the transfer of shapes and sizes of parts and equipment from a single standard of shapes and sizes, which is a drawing of a product in full size with projections and sections - a Theoretical Loft (TL).

Standard-template method (STM): When using this method of coordination, the initial element (primary origin of coordination) is a standard surface (SS), which is used to obtain the contours of the working technological and checking tooling for copying shapes and sizes on the assembly jigs.

On the basis of STM assume application of the wide nomenclature of measuring tooling: loft, templates, standards of a surface of units (compartments), counter standards (CS), mounting standards (MS) and master plates. When using this method, the SS completely reproduces the natural surface of the aircraft unit, its shape and size, representing a kind of spatial landslide.

Loft-instrumental method (LIM): LIM is characterized by the use of universal coordination means - a loft conductor and an instrumental stand, providing accurate fixation of the coordinate of a point in space. This method provides high accuracy of tooling on contours and surfaces, but is less exact at coordination on joints. In comparison with the standard-template method it is simpler, provides shorter terms of preparation of production.

Program instrumental method (PrIM): The essence of PRIM is that the elements of the blanking and assembly tooling, corresponding to the design of the product, are performed on the special software first, on the basis of analytically obtained data. The origin of coordination tooling elements and structural parts are mathematical models of surfaces (MMS) and joints of the product.

PRIM as an independent method of coordination is distinguished by the presence of digital models of product shapes and its parts, sufficient for the reproduction and checking of parts and technological tooling. The method is based on the use of a computer to set and process the origin of information about the geometry of objects and the use of CNC equipment for the manufacture of tooling and structural parts. PRIM allows to use widely means of automation of technological processes at all stages of production of tooling and aircraft parts.

All the considered methods are different in accuracy of manufacturing and coordination of equipment, terms of preparation of production, cost of products.

Use of STM allows to receive the highest accuracy of coordination of objects assembly of and tooling by junctions. However, the production preparation cycle and costs are the largest.

LIM provides high accuracy of equipment on contours, but is less accurate at coordination of junctions of aircraft design. The production preparation cycle and costs are reduced.

LTM is simple and not expensive, however, it is less accurate at production and coordination of assembly tooling of sections, compartments, aggregates of the airplane.

PRIM is the most promising given the development of methods due to using mathematical software of advanced CNC equipment. Its use guarantees high accuracy of production and coordination of tooling and objects of aircraft design. Significantly improves the mobility of production when changing manufactured parts, reduces the range of blanking and assembly tooling in the shops and can reduce the cost of production of aircraft.

2.3.3 Calculate the tolerance (upper and lower deviations) for outline of the considered assembly unit for two variants of assembling and coordination.

It is possible to determine the rationality of using one or another method of assembling Rib No. 21 and the method of coordination of blanking and assembly tooling by comparing the assembly error with the unit tolerance, but in the technical specifications (TS) for assembly tolerances are provided only for aggregates like wing, fuselage. Tolerances are not set on the contours of the incoming unit, as it is assumed that the manufactures' may use different methods of assembly and coordination depending on the production conditions. This requires a unit tolerance calculation considering known aggregates tolerance.

The formula for determining the tolerance is:

$$\delta_{rib} = \delta^{TS}_{wing.} - \delta_{rib-wing.}$$

In TS the tolerances for assembly of a wing is given $\delta^{TS}_{wing.} = \pm 2\,mm$

Calculation of the unit tolerance on the rib in the jig.

a) Loft-instrumental method of coordination (LIM):

-compose a chain of transfer of the sizes by LIM:

Figure 2.8 Size transfer chain by LIM

-Calculate the error of coordination tooling for the Rib No.21:

$$C_{rib-wing} = \pm\sqrt{4(0.2)^2 + 3(0.1)^2} = \pm 0.44\,mm$$

-Determine the primary tolerance:

$$\delta_{rib} = \pm(2 - 0.44) = \pm 1.56\,mm$$

b) Program-instrumental method (PrIM):

-compose a chain of transfer of the sizes by PrIM:

Figure 2.9 Size transfer chain by PRIM

-Calculate the error of coordination tooling for the rib:

$$C_{rib-wing}=\pm\sqrt{2(0.01)^2+3(0.15)^2+2(0.1)^2}=\pm 0.3\,mm$$

-Determine the primary tolerance:

$$\delta_{rib}=\pm(2-0.3)=\pm 1.7\,mm$$

2.3.4 Calculate the error of assembling for the considered assembly unit outline, compare with the unit tolerance, and make the conclusion.

Calculating the accuracy of the assembling of the Rib No.21 by contours for the assembling methods (in the jig and on the AU) and shown below two methods of coordination (LIM and PRIM).

Calculation of a rib assembly error in the jig without error compensation.

The assembly error of Rib No. 21 in the device is determined by the following components:

-Error Ejig of the carrier of the sizes.

-Error Ecomb.bases of the locating part. The magnitude of the combine base error is characterized by the gap between the locating of the jig and the surface of the part. This gap can be reduced by pressing the part to the surface of the locating. At the same time the part is elastically deformed, and further is fixed by rivets or bolts.

-Errors Efix to joint and displacements caused by the formation of joints. Deflections of the jig during assembly and other reasons that do not depend on the method of assembly.

Here E_{fix} is about 40% of the total error,

$$E_{fix}=0{,}4E_{total}, \quad (2.9)$$

The gap between the locating and the part is equal to the error of the coordination of the device and the part of the Contour is,

$$E_{base.comb.}=C_{jig-cap}\cdot k_{fix} \quad (2.10)$$

So, the tolerances to the assembly in the device without compensation is determined by the formula:

$$E_{as}=E_{jig}+k_{fix}\cdot C_{jig-cap}+E_{other} \qquad (2.11)$$

Calculating the error of the jig according to the formula:

$$E=\Sigma\,\Delta_i\pm\sqrt{\Sigma\left(\frac{\delta_i}{2}\right)^2} \qquad (2.12)$$

Determine the assembly error of the Rib No.21 in the jig by different coordination methods:

a) Loft-instrumental method of coordination:

-Chain of transfer of the sizes by LIM:

Figure 2.10 Size transfer chain by LIM

-Calculate the error of the jig:

$$E_{jig}=\pm\sqrt{6(0.2)^2+(0.1)^2+(0.3)^2}=\pm 0.58\,mm$$

-Determine the error of coordination of cap and the jig:

$$C_{jig-cap}=(-0.05+0.15)+(\pm 0.4)\,mm=\begin{pmatrix}+0.5\\-0.3\end{pmatrix}$$

-Calculating the error of assembly

$$E_{as}=E_{jig}+k_{fix}\cdot C_{jig-cap}+0.4\,E_{rib}$$

$$E_{as}=\pm 0.58+(0.5)\begin{pmatrix}+0.5\\-0.3\end{pmatrix}+0.4\,(1.56)=\begin{pmatrix}+1.454\\-0.106\end{pmatrix}$$

b) Program-instrumental method:

-Chain of transfer of the sizes by PRIM:

Figure 2.11 – Size transfer chain by PrIM

Calculate the error of the jig:

$$E_{jig} = \pm\sqrt{(0.2)^2 + (0.15)^2 + (0.3)^2} = \pm 0.39\,mm$$

-Determine the error of coordination of jig and cap:

$$C_{jig-cap} = \pm 0.15\,mm$$

-Calculating the error of assembly

$$E_{as} = E_{jig} + k_{fix} \cdot C_{jig-cap} + 0.4\,E_{rib}$$

$$E_{as} = \pm 0.39 + (0.5)(\pm 0.15) + 0.4(1.7) = \left(\begin{matrix} +1.145 \\ -0.46 \end{matrix}\right) \quad \backslash$$

I conclude that the unit tolerance of Loft-instrumental Method will not be suitable for me because there will be lot of wastage of the unit to be produced, so it is not advisable to go with LIM option. Since the assembly error of frame of PrIM is smaller than LTM, it has contributed to my choice of selecting PrIM for the assembly of rudder root rib.

2.3.5 Work out the diagram of assembling and tooling coordination of root rib:-

The diagram of assembling and coordination for the blanking and assembly tooling is one of the most important directive technological materials, which reflect the set of basic solutions for assembly process of the unit to be considered and for processes of the unit assembly components manufacturing. With using parts for manufacturing the numerical control programs (Pr), labour input is reduced and increase level of labour automation, and so reducing the time and expenses for preproduction and manufacturing. Also, accuracy calculations clarify the use of the PrIM as the method of coordination for rudder root rib manufacturing.

All the small parts of the rib and the assembly jig manufacturing starts from the developing of 3D model. Then we develop 3D models for tooling, which are the origin of information. The coordination origins are program and CNC machines, from there it creates the parts by using the necessary equipment and tooling in respect to the difficulties of the part to be produced. The element of interchangeability let the manufacturer to decide what they must to do by the tooling and equipment they have for manufacture and all required parts to be assembled. The same goes with manufacturing of the AJ. Most of the elements of the assembly jig are located by the template of jig (TJ).

2.3.6 Locating Chart for Assembly Components of the Root Rib

In the designs of assembled objects, each part or unit occupies a strictly defined position relative to other parts and relative to the design bases. During assembly or mounting, each structural element must be coordinated in accordance with the position indicated in the drawing. This is achieved by the accepted method of locating the elements on the corresponding base surfaces of individual parts.

The locating chart– set of technological bases necessary and sufficient for locating of parts and AU.

The scheme of locating is made out in the form of the sketch of the assembled product with the set of the accepted technological bases.

In aircraft and helicopter construction, parts, assemblies, units during assembly are based on:

-Assembly holes (AH);

-External surface of skin;

-Inner surface of a skin;

-Joint base holes (JBH);

-Locating and fixing holes (LFH, CFH, AFH)

Assembly based on AH is a process in which the relative position of the assembled parts is determined by the position of the assembly holes available on them, into which clamps are inserted for the period joining of parts.

AH method is used in two cases: when forming the outer contours of the assembled product, and when locating the rib elements in the assembly position.

Assembly with locating on an external surface of a skin - at this method of locating the panel parts are pressed by an external surface to a working surface of assembly locating for the period of its join in the rib of caps to skin through an intermediate part which is compensator.

Assembly with locating on an internal surface of a skin - at this method of locating the parts are pressed by an internal surface to basic surfaces of the jig (special mock-up ribs or frames) for the period of its connection to a framework through the compensator.

Assembly based on JBH - a process in which the joints, profiles and brackets are installed in the assembly position on the available holes for joint and the corresponding holes in the elements of the assembly.

Figure 2.12 Scheme of locating the components of the rib

2.3.7 Develop enlarged technological process (TP) for assembling of the considered unit.

The technological process of assembly is a sequence of locating in assembly position of parts and their fixing and joining among themselves in the ways provided by the drawing, selecting of a specialty, the category and quantity of workers, and also norms of time, a choice of the tool and the equipment. The development of the working technological process of assembly for serial production is carried out in accordance with the drawings of the product design and assembly scheme.

In the general case, the assembly process is performed in the following order:

1) Preparation of parts for assembly;

2) Locating of parts in the position set by the drawing;

3) Fixation of parts in the position set by the drawing;

4) Preparation of parts for joining;

5) Joining of parts;

6) Inspection of accuracy and quality of joining;

7) Final works.

Table 2.8 Enlarged technological process of Rib No.21

No.	Technological steps	Tooling
1	Prepare work station for assembly, Check tooling, and Check the kit of parts for correspondence to documentation and absence of damages.	Assembly jig
2	Locate the upper and lower cap in the jig to outline contour locators and clamp it.	
3	Locate the web onto upper cap by 2 AH with 2 clips and clamp it.	Clips
4	Locate the stiffeners into the jig by jig locators	
5	Locate the 4 knees and 3 compensator to upper cap by 19 GH	
6	Locate the 7 knees to lower cap by 14 GH	
7	Drill the bolt and rivet holes to upper and lower cap for knees, stiffeners and compensator according to technical requirements.	Drill gun, drill, counter sinker, reamer
8	Attach the stiffeners, knees and compensator by riveting to the upper and lower cap	Riveting press
9	Do inspection of the whole rib after assembly that every parts should be attached properly	Visually
10	Remove the rib from the assembly jig	
11	Remove extra materials, clean the assembly jig and prepare for the next rib	Metal brush

2.3.8. Technical Requirements of Assembly Components Supply for Assembling Rib No.21 According To Considered Unit Assembling TP

Table 2.9-. Technical Requirements for the rib Assembly Components Supply for Assembling

Assembly Component Name	Drawing Number	ntAmou	Availability of holes (GH, AH)
Compensator	D104.BDP.144F.17.0 01.AD	3	Without allowance, 11 AH ⌀4 mm
knees	D104.BDP.144F.17.0 02.AD	11	Without allowance 22 GH ⌀4 mm,
Upper cap	D104.BDP.144F.17.0 03.AD	1	9 Jig locators
Lower cap	D104.BDP.144F.17.0 04.AD	1	9 Jig locators
Stiffeners	D104.BDP.144F.17.0 05.AD	4	Without allowance 24 AH ⌀5 mm
Web	D104.BDP.144F.17.0 06.AD	1	Without allowance 2 AH ⌀4 mm

2.4 Developing of the assembly jig for Rib No.21

One of the peculiarities of the aircraft manufacturing is the necessity in big amount of assembly jigs (AJ). This is due to specific of aircraft as the object of assembling (low stiffness of parts, complexity of its spatial shapes, and high demands to the accuracy of produced items). This implies the main purpose of the AJ: locating of parts and subassemblies at the position given in the assembly drawing with the required accuracy, adding rigidity to them and fixing during the period of joining with other parts.

The design of the AJ must be rational, simple, allowing the possibility of standardization, processable (technologically effective) during the manufacturing, servicing and repairing of the jig itself. All these resulted in the additional purposes of an assembly jig: increasing of labour productivity; ensuring of the assembly process convenience and safety; tools guiding with respect to the produced items.

Variants of the AJ design are diverse and depend on sizes and type of the produced assembly unit, its design features, dominant jointing type, adopted locating chart and types of subassemblies, program and volume of the manufacturing and other factors. It should be noted that the assembly jigs can be conditionally classified in such a way: non-separable special, mountable-and-dismountable, specialized adjustable, universal non-adjustable and universal mountable ones.

2.4.1Work out the Technical Requirements for The Assembly Jig Designing Procedure

A continuous increase in the requirements for accuracy and interchangeability of assembled aircraft structural components, for increased labour productivity, leads to higher technical requirements for assembly jigs. Main technical requirements:

Table 2.10

1	Function	For pre-assembling for the rib (with further sealing and press riveting
2.	Priority	Tooling of the first waiting line, developed for the first time
3.	Assembly components list	Top-bottom cap, web, stiffeners, knees, compensators
4.	Status of supply	with the allowance, for assembling and technological holes according to the technical requirements for the supply
5.	Order of assembly	Locating of assembly components
6.	Locating charts or list of bases	Locating web by AH
7.	Tools for assembly work	Hand mechanized pneumatic tools
8.	Tooling for products removing from the jig	By hand (manually)
9.	Technical requirements to	a) Item position – vertical, as in a

	assembly jig design	flight b) The facilities of the jigs mechanization not required; c) Means of mounting (coordination)-standard of the rib

Other cautions are;

Ensuring the assembly accuracy specified in the technical specifications, which should be linked to the degree of accuracy of the assembly jig;

Maintaining the accuracy of the assembly device during the entire period of operation;

Maintaining a stable position of the base points, holes and surfaces specified by the technical specifications for assembly and reliability of fixation of the assembled elements;

Constancy of the given sizes irrespective of temperature fluctuations;

Use in the design of the assembly jig a large number of standard elements to reduce the cost of the assembly jig and reduce the time for technological preparation of production;

The rational size of jigs for the better use of production facilities;

Compliance with safety regulations.

2.4.2 Selection of the scheme and layout of the assembly device

Considering the requirements to assembly jig design mentioned above it was developed the scheme of jig for assembling the Rib No. 21. It was chosen the Vertical scheme for providing the convenience of work for assembly fitters. The structural elements of this jig (locators of contours and AH, clamps) placed on the standardised frame. Mounting procedure for this jig is fulfilled by attaching all the locating elements to the jig and fixing then to the frame.

Figure 2.33 Scheme of the assembly jig

1– Frame;

2 – Bed;

3- Fixing elements;

4- Lock with lever-screw clamp;

5 – Ribs;

6 – Compensators;

7- Knees;

8- Rotary units.

3. ECONOMIC SECTION

The Cost Calculation on Assembling Work for Two Assembly Methods

3.1 Introduction:

The two assembly methods which I consider for the cost calculation on assembling work are assembling by Assembly Holes (AH) and in jig. In assembling by AH method the mutual position of the assembled parts is determined by coincidence of the coordinated AH, which in advance are done with the help of the coordinated templates. A jig's primary purpose is to provide repeatability, accuracy, and interchangeability in the manufacturing of products. The cost calculation is performed with using specific indicators/parameters by the technique described in technological part description. Variables related to the assembling by assembly holes have the subscript "AH". Accordingly, the indicators for the assembling in the jig used subscript "j". Costs and capital expenditures are one of the main criteria for economic evaluation developed processes. Cost of production is the valuation used in the course of production of natural resources, raw materials, fuel, energy, fixed assets, labor and other costs of its production and sales. The cost of production includes: wages of manufacturing workers (W), operating costs (OC), cost price of assembly (Cass), and expenditures for tooling (ET).

3.2. Initial Data:

3.2.1. Dependence of the tooling specific cost on the assembly method:

Tooling specific cost data C_{tool} are given in Table 28 [ ], where bigger values are for agtooljgregates, assemblies or panels of complex structural design.

The values of tooling specific cost for the considered assembly unit UAH / kg:

$C_{tool\,.\,AH}=300$ $C_{tool\cdot j}=1400$

3.2.2. The annual production rate of the considered assembly unit, Pcs. / Year:

$$N=60$$

3.2.3. Specific labor input

The values of the specific labor input are taken according to Annex 5 [ ], depending on the weight and type of the assembly unit.

The full specific labor input, man-hour / kg:

$k_{sp.\,full}=2.2$

The specific labor input of assembling in jig, man-hour / kg:

$k_{sp.j}=1.7$

The specific labor input of the assembling by AH approximately must be taken in calculations as

$k_{sp.AH}$ = 0,9*$k_{sp.full}$ (man-hour / kg). If we take k=0.9, then

$$k_{sp.AH}(k_{sp.full})=k.k_{sp.full}$$

$k_{sp.AH}(k_{sp.full})=1.98$

3.2.4. Actual annual fund of tooling cost productivity (Ft) depends on assembly tooling repair complexity (2030 - for complex repair, 2080 - for simple repair), hours:

$F_{t.AH}=2070$

$F_{t.j}=2030$

3.2.5. The average number of simultaneously working persons in the same jig (P), man:

$P_{AH}:=2$

$P_j:=2$

3.2.6. The average height of the shop (usually 10 ... 14 m), m:

$H=12$

3.2.7. The area of one workplace (S) for comparable variants defined by dimensions of jig (workbench) and width of passageways, m2:

$$S_{AH}=8$$

$S_j=5$

3.2.8. Weight of the object being assembled, kg:

$G=9.31$

3.2.9. The working rate for assembly workers, UAH/ hour:

$a_{AH}=90$

$a_j=80$

The values are calculated parameters for the production rate.

3.3. Wages of manufacturing workers (W), UAH:

$$W_{AH}=k_{sp.AH}(k_{sp.full})\cdot G.a_{AH} \quad (3.2)$$

$$W_j=k_{sp.j}\cdot G.a_j \quad (3.3)$$

W_{AH}=1659.04

W_J=1266.016

3.4. Estimated amount of similar jigs to perform the annual production rate for the compared variants:

$$m_{p_{AH}}(n)=\frac{k_{sp.AH}(k_{sp.full})\cdot G\cdot n}{F_{t.AH}\cdot P_{AH}} \quad (3.4)$$

$m_{p_{AH}}(N)=0.267$

$$m_{p_j}(n)=\frac{k_{sp.j}\cdot G\cdot n}{F_{t.j}\cdot P_j} \quad (3.5)$$

$m_{p_j}(N)=0.234$

3.4.1. Defining of the rounding functions of the calculated jigs amount to a whole number.

$round(x)=if(x-floor(x)<.5, floor(x), ceil(x))$

$Upto1(x)=if(x<1,1,round(x))$

3.4.2. Accepted amount of similar jigs for production the annual program, pcs:

$m_{j_{AH}}(n)=Upto1(m_{p_{AH}}(n))$

$m_{j_j}(n)=Upto1(m_{p_j}(n))$

$m_{j_{AH}}(N)=1$

$m_{j_j}(nN)=1$

3.4.3. Factor of jig usage for the compared variants (should be in the range 0.75 ... 1.15 if possible)

$$\eta_j=\frac{m_{p_j}(N)}{m_{j_j}(N)} \quad (3.6)$$

$$\eta_{AH}=\frac{m_{p_{AH}}(N)}{m_{j_{AH}}(N)} \quad (3.7)$$

$\eta_j=0.234$

$\eta_{AH}=0.267$

3.5. Expenditures for tooling for the compared variants (ET), UAH:

$$ET_{AH}(n) = \frac{G \cdot C_{tool.AH}}{2 \cdot n} . m_{j_{AH}}(n) \qquad (3.8)$$

$$ET_{j}(n) = \frac{G \cdot C_{tool.j}}{2 \cdot n} . m_{j_j}(n) \qquad (3.9)$$

$$ET_{AH}(N) = 23.275$$

$$ET_{j}(N) = 108.617$$

3.6. Operating costs for the compared variants (OC), UAH:

$$OC_{AH}(n) = 0.625 \cdot \frac{h \cdot S_{AH} . m_{j_{AH}}(n) . n_{AH}}{n} \qquad (3.10)$$

$$OC_{j}(n) = 0.625 \cdot \frac{h \cdot S_{j} . m_{j_j}(n) . n_{AH}}{n} \qquad (3.11)$$

$$OC_{AH}(N) = 1$$

$$OC_{j}(N) = 0.625$$

3.7. Cost price of assembly (Cass) for the compared variants, UAH:

$$C_{ass_{AH}}(n) = W_{AH} + ET_{AH}(n) + OC_{AH}(n) \qquad (3.12)$$

$$= 1683.32$$

$$C_{ass_j}(n) = W_{j} + ET_{j}(n) + OC_{j}(n) \qquad (3.13)$$

$$= 1375.4$$

The values of the cost price for a given range of the production rate.

NT to 1(x) =if(x>60, x-60, 1)

- Detection function of the left boundary of range for the table

The boundaries and steps of the production rate range for performed tabular calculations.

$N_{min} = NT¿1(N)$

$N_{max} = N + 60$

$Step = 10$

$n = N_{min}, N_{min} + step .. N_{max}$

- Determining of the argument variation range (the production rate)

3.8. Dependence between the amount of jigs and cost price of assembly from production rate for different assembly methods.

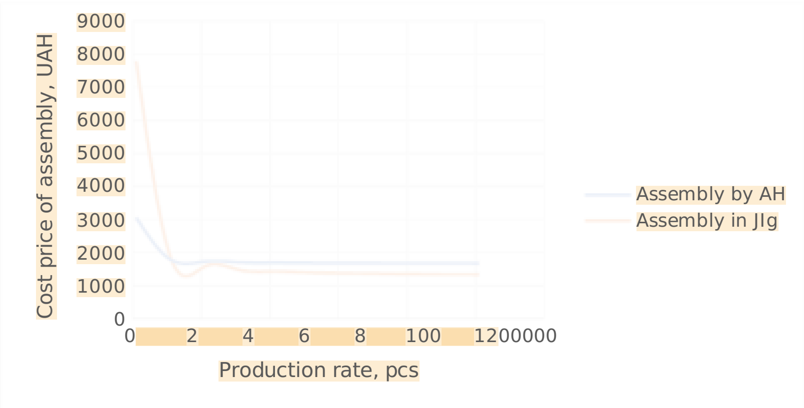
Table 3.1. Assembling by AH, in UAH

n	$m_{p_{AH}}(n)$	$m_{j_{AH}}(n)$	$C_{ass_{AH}}(n)$
1	0.004453	1	3056.542
11	0.048979	1	1786.997
21	0.093505	1	1726.542
31	0.138031	1	1705.09
41	0.182557	1	1694.103
51	0.227083	1	1687.424
61	0.271609	1	1682.935
71	0.316135	1	1679.711
81	0.360661	1	1677.283
91	0.405187	1	1675.388
101	0.449713	1	1673.869

Table 3.2. Assembling in the jig

n	$m_{p_j}(n)$	$m_{j_j}(n)$	$C_{ass_j}(n)$
1	0.003898	1	7783.785
11	0.042881	1	1859.24
21	0.081864	1	1577.118
31	0.120847	1	1477.011
41	0.15982	1	1425.736

	9		
51	0.19881 2	1	1394.569
61	0.23779 5	1	1373.621
71	0.27677 8	1	1358.574
81	0.31576	1	1347.242
91	0.35474 3	1	625.041
101	0.39372 6	1	617.91



s

Fig 3.1. The dependence of the cost for assembling by two assembly methods (by AH and in jig) from the output manufacturing program

The dependence graphs shows that the cost of assembly by jig is greater than the cost of assembly by assembly holes. With the increase of production rate the cost of assembly gradually decreases in both assembly methods. Even though, the cost of assembly of both methods decreased, the cost price for assembling by jig is still greater than AH. After some amount of production rate range the cost price for both methods will be stabilized by a small amount.

3.9. Results of the calculation:

Initial data's and the results of the calculation done in the overall process is tabulated for better understanding below in table 3.9.1.

Table 3.9.1. Initial data's and result of calculation

No.	Parameter		Size	Units
1	Tooling specific cost, C_{tool}	AH, $C_{tool.AH.}$	300	UAH/kg
		Jig, $C_{tool.j.}$	1400	UAH/kg
2	Annual production rate, N		60	Pcs/year
3	Specific labor input of assembling , k_{sp}	Jig, $k_{sp.\,j}$	2.2	man-hour / kg
		AH, $k_{sp.\,AH.}$	1.7	man-hour / kg
4	Annual fund of tooling cost productivity, F_t	Jig, $F_{t.\,j}$	2030	hours
		AH, $F_{t.\,AH}$	2070	hours
5	Average number of working persons, P	Jig, P_j	2	man
		AH, P_{AH}	2	man
6	Average height of shop, H		12	meter
7	Area of workplace, S	Jig, S_j	5	$meter^2$
		AH, S_{AH}	8	$meter^2$
8	Weight of object being assembled, G		9.31	kg
9	Working rate of assembly workers, a	Jig, a_j	80	UAH/hour
		AH, a_{AH}	90	UAH/hour
10.	Wages of Manufacturing workers, W	Jig, W_j	1266.16	UAH
		AH, W_{AH}	1659.04	UAH
11	Expenditures for tooling, ET	Jig, $ET_j(N)$	108.617	UAH
		AH, $ET_{AH}(N)$	23.275	UAH
12	Operating costs, OC	Jig, $OC_j(N)$	0.625	UAH
		AH, $OC_{AH}(N)$	1	UAH
13	Cost price of assembly, C_{ass}	Jig, $C_{ass_j}(N)$	1375.4	UAH
		AH, $C_{ass_{AH}}(N)$	1683.32	UAH

CONCLUSION

After assembling by jig, the section is given the finishing works and then carried out the mounting process in assembly and mounting works AMW, where the structural elements are installed and mounted for which it is not necessary for fixation in jig. This reduces the cycle of work in the assembling by assembly jig process. We have the high cost of tooling in this method, significant expenses for tooling are resulted from the different designs of the assembled units, and so assembling of each individual unit with required accuracy can be achieved. The main advantage of the assembling in the jig is the ensuring of identities and interchange ability of subassembly. To improve the accuracy of AH coordination for basic and incoming parts of the unit in independent AH systems, it should be done by solving of specific functional problems. To provide uniformity of tooling items the AH diameter should be chosen from the recommended line of dimensions. Assembling by AH is used for simple assemblies with low requirements of accuracy. The advantage of assembling by AH is that it doesn't require special assembly tooling, assembling is performed on special workbenches, machines or in simple supporting jigs. This causes minimum expenses for assembly tooling and low expenditure of labour, time and money for assembling. Disadvantage is the increasing of the labor input of parts manufacturing and preproduction of sheet machining manufacturing. The cost of assembling depends on the volume of production.

Based on the values calculated, we conclude that the cost of the assembly in the Jig is greater than in the assembly according to the AH. However, since our task is to ensure high quality product and effective production process, we choose assembly jig since it gives higher accuracy options and ensures good interchange ability.

APPENDIX

Формат	Зона	Поз.	Обозначение	Наименование	Кол.	Приме-чание
				Документация		
А1			K104.BDP.22.000.000	Сборочный чертеж		
				Детали		
Б4	7В	1	K104.BDP.22.000.011	Web	1	
Б4	4В	2	K104.BDP.22.000.013	Upper Cap	1	
Б4	4А	3	K104.BDP.22.000.015	Lower Cap	1	
Б4	6А	4	K104.BDP.22.000.017	Stiffener	1	
Б4	5А	5	K104.BDP.22.000.019	Stiffener	1	
Б4	5А	6	K104.BDP.22.000.021	Stiffener	1	
Б4	5А	7	K104.BDP.22.000.023	Stiffener	1	
Б4	5В	8	K104.BDP.22.000.003	Compensator	2	
Б4	5В	9	K104.BDP.22.000.005	Compensator	1	
Б4	6А	10	K104.BDP.22.000.007	Shim	2	
Б4	5А	11	K104.BDP.22.000.009	Shim	1	
А3	6В	12	K104.BDP.22.003.001	Knee	2	
А3	4В	13	K104.BDP.22.004.001	Knee	1	
А3	6А	14	K104.BDP.22.005.001	Knee	1	
А3	6А	15	K104.BDP.22.006.001	Knee	3	
А3	5А	16	K104.BDP.22.007.001	Knee	2	
А3	4А	17	K104.BDP.22.008.001	Knee	1	

Перв. примен.

Справ. №

Подп. и дата

Инв. № дубл.

Взам. инв. №

Подп. и дата

Инв. № подл.

K104.BD.00.22.000.000

Изм.	Лист	№ докум.	Подп.	Дата
Разраб.		Ashok Devarsh		
Пров.		Prof.Pavlenko O.A		
Н.контр.				
Утв.				

Rib №21

Лит.	Лист	Листов
У	1	2

Khai gr 144 fj

Копировал   Формат A4

Формат	Зона	Поз.	Обозначение	Наименование	Кол.	Приме-чание

A–A
Cover
K104.BDP.22.000.001

K104.BDP.22.000.002
Ø134
Ø40
15
32
11
Ø30
Ø150
K104.BDP.22.000.002
Cover
(forging)
Лит.
Масса
Масштаб
1:1
Изм.
Лист
№ докум.
Подп.
Дата
Разраб.
Ashok Devarsh
Пров.
Prof. Pavlenko
Т.контр.
Н.контр.
Утв.
Лист
Листов 1
Khai gr 144 fj
Перв. примен.
Справ. №
Подп. и дата
Инв. № дубл.
Взам. инв. №
Подп. и дата
Инв. № подл.
KOMPAS-3D v21 Учебная версия © 2022 ООО "АСКОН-Системы проектирования", Россия. Все права защищены.
Не для коммерческого использования
Копировал
Формат A4

Номер опорной точки	Координаты точек, мм		
	x	y	z
0	150,0	150,0	10,0
1,1	41,02	92,23	3,0
2	108,26	70,56	3,0
3	102,28	51,53	3,0
4	86,79	40,52	3,0
5	73,77	41,63	3,0
6	64,78	60,8	3,0
7	64,78	88,29	3,0
8	93,35	106,51	3,0
0	150,0	150,0	10,0

Rib №19
Assembly jig
Upper Cap
Lower Cap
Web
Stiffeners
Knees
Compensator
Frame
Contour locator of Stiffeners
Contour of Caps
Outline contour, AH,GH
Outline contour, AH,GH
Contour, AH
Contour
Contour, AH
Contour, AH
Contour
Contour
Cutting Die
Press
Pendulum Saw
CNC MM
CNC MM
CNC
CNC MM
CNC
CNC
TW
CNC
CNC
TJ
Pr
AJ Drawing
3D of Part Tooling
TT,MM
3D Wing
3D Rib
3D of Assembly Tooling

Схожість

Джерела з Бібліотеки 224

1	**S09**	ID файлу: **1009725278**	Навчальний заклад: **National Aerospace University Kharkiv Aviation Institut**	45 Джерело	69.6%
2	**B33**	ID файлу: **1011518217**	Навчальний заклад: **National Aerospace University Kharkiv Aviation Institute**	9 Джерело	39%
3	**B53**	ID файлу: **1004213486**	Навчальний заклад: **National Aerospace University Kharkiv Aviation Institute**	8 Джерело	38.3%
4	**B58**	ID файлу: **1004206569**	Навчальний заклад: **National Aerospace University Kharkiv Aviation Institute**	5 Джерело	24.4%
5	**DESIGNING SECTION PDF.docx**	ID файлу: **2122787**	Навчальний заклад: **National Aerospace University Kharkiv Av...**		19.5%
6	**B65**	ID файлу: **1004221635**	Навчальний заклад: **National Aerospace University Kharkiv Aviation Institute**		18.1%
7	**B30**	ID файлу: **1013124035**	Навчальний заклад: **National Aerospace University Kharkiv Aviation Institute**		18%
8	**B45**	ID файлу: **2122803**	Навчальний заклад: **National Aerospace University Kharkiv Aviation Institute**	2 Джерело	16.8%
9	**B70**	ID файлу: **1004203876**	Навчальний заклад: **National Aerospace University Kharkiv Aviation Institute**		16.4%
10	**B6**	ID файлу: **1008371723**	Навчальний заклад: **National Aerospace University Kharkiv Aviation Institute**		15.2%
11	**Bachelor work full.docx**	ID файлу: **2122818**	Навчальний заклад: **National Aerospace University Kharkiv**	2 Джерело	15%
12	**B59**	ID файлу: **1004213489**	Навчальний заклад: **National Aerospace University Kharkiv Aviation Institute**		14.9%
13	**BDP Final report. Gnanasekaran.P. 2017.docx**	ID файлу: **2122801**	Навчальний заклад: **National Aerospac**	3 Джерело	14.8%
14	**B19**	ID файлу: **1008417311**	Навчальний заклад: **National Aerospace University Kharkiv Aviation Institute**		14.6%
15	**B22**	ID файлу: **1008421790**	Навчальний заклад: **National Aerospace University Kharkiv Aviation Institute**		14.1%
16	**B63**	ID файлу: **1004201497**	Навчальний заклад: **National Aerospace University Kharkiv Aviation Institute**		12.8%
17	**B52**	ID файлу: **1004213491**	Навчальний заклад: **National Aerospace University Kharkiv Aviation Institute**		12.5%
18	**B31**	ID файлу: **1008433413**	Навчальний заклад: **National Aerospace University Kharkiv Aviation Institute**		12.5%
19	**Bachelor work.docx**	ID файлу: **2122815**	Навчальний заклад: **National Aerospace University Kharkiv Aviation Inst...**		12.3%
20	**B66**	ID файлу: **1004221636**	Навчальний заклад: **National Aerospace University Kharkiv Aviation Institute**		12%

21	ECONOMIC SECTION.docx	ID файлу: 2055179	Навчальний заклад: National Aerospace University Kharkiv Aviation...	11.5%
22	ECONOMICAL SECTION.docx	ID файлу: 2122786	Навчальний заклад: National Aerospace University Kharkiv Aviat...	11.5%
23	B31	ID файлу: 1011513001	Навчальний заклад: National Aerospace University Kharkiv Aviation Institut 32 Джерело	11.4%
24	B26	ID файлу: 1013115874	Навчальний заклад: National Aerospace University Kharkiv Aviation Institute	11.3%
25	B49	ID файлу: 2122789	Навчальний заклад: National Aerospace University Kharkiv Aviation Institute	10.9%
26	B46	ID файлу: 2122788	Навчальний заклад: National Aerospace University Kharkiv Aviation Institute	10.7%
27	ECONOMIC SECTION.docx	ID файлу: 2122794	Навчальний заклад: National Aerospace University Kharkiv Aviation...	10.3%
28	B49	ID файлу: 1005778650	Навчальний заклад: National Aerospace University Kharkiv Aviation Institute	10.2%
29	B8 (1)	ID файлу: 1008385676	Навчальний заклад: National Aerospace University Kharkiv Aviation Institute	10%
30	B71	ID файлу: 1004215303	Навчальний заклад: National Aerospace University Kharkiv Aviation Institute	9.69%
31	B20	ID файлу: 1013116197	Навчальний заклад: National Aerospace University Kharkiv Aviation Institute	9.53%
32	B29	ID файлу: 1013119654	Навчальний заклад: National Aerospace University Kharkiv Aviation Institute	8.88%
33	B30	ID файлу: 1011511324	Навчальний заклад: National Aerospace University Kharkiv Aviation Institute 2 Джерело	8.81%
34	Bachelor thesis final .docx	ID файлу: 2295127	Навчальний заклад: National Aerospace University Kharkiv Aviatio...	8.14%
35	B48	ID файлу: 1005778664	Навчальний заклад: National Aerospace University Kharkiv Aviation Institute	8.03%
36	S12	ID файлу: 1009729595	Навчальний заклад: National Aerospace University Kharkiv Aviation Institute 2 Джерело	7.92%
37	B23	ID файлу: 1008421800	Навчальний заклад: National Aerospace University Kharkiv Aviation Institute	7.88%
38	B33	ID файлу: 1008434302	Навчальний заклад: National Aerospace University Kharkiv Aviation Institute	7.3%
39	B45	ID файлу: 1005762638	Навчальний заклад: National Aerospace University Kharkiv Aviation Institut 10 Джерело	6.98%
40	B60	ID файлу: 1004219644	Навчальний заклад: National Aerospace University Kharkiv Aviation Institute	6.91%
41	B21	ID файлу: 1008421786	Навчальний заклад: National Aerospace University Kharkiv Aviation Institute	6.22%
42	B27	ID файлу: 1013118117	Навчальний заклад: National Aerospace University Kharkiv Aviation Institute	5.98%

43	**B1**	ID **файлу**: **1011424571**	**Навчальний заклад**: **National Aerospace University Kharkiv Aviation Institute**	**5.29%**
44	**TECHNOLOGICAL SECTION.docx**	ID **файлу**: **2054582**	**Навчальний заклад**: **National Aerospace University Kharkiv A...**	**5.22%**
45	**S08**	ID **файлу**: **1009724307**	**Навчальний заклад**: **National Aerospace University Kharkiv Aviation Institute**	**4.83%**
46	**B28**	ID **файлу**: **1013118116**	**Навчальний заклад**: **National Aerospace University Kharkiv Aviation Institute**	**4.69%**
47	**Bachelor compilation.docx**	ID **файлу**: **2122821**	**Навчальний заклад**: **National Aerospace University Kharkiv Aviatio...**	**4.54%**
48	**B30**	ID **файлу**: **1008433411**	**Навчальний заклад**: **National Aerospace University Kharkiv Aviation Institute**	**4.49%**
49	**B23**	ID **файлу**: **1011498638**	**Навчальний заклад**: **National Aerospace University Kharkiv Aviation Institute**	**4.44%**
50	**LIST OF ABBREVIATIONS.doc**	ID **файлу**: **2122811**	**Навчальний заклад**: **National Aerospace University Kha** 2 Джерело	**4.22%**
51	**S11**	ID **файлу**: **1009728114**	**Навчальний заклад**: **National Aerospace University Kharkiv Aviation Institute**	**3.93%**
52	**B69**	ID **файлу**: **1004240458**	**Навчальний заклад**: **National Aerospace University Kharkiv Aviation Institute**	**3.84%**
53	**Technological Section.docx**	ID **файлу**: **2076586**	**Навчальний заклад**: **National Aerospace University Kharkiv Aviati...**	**3.79%**
54	**B14**	ID **файлу**: **1008425354**	**Навчальний заклад**: **National Aerospace University Kharkiv Aviation Institute**	**3.7%**
55	**B25**	ID **файлу**: **1013115702**	**Навчальний заклад**: **National Aerospace University Kharkiv Aviation Institute**	**3.64%**
56	**B32**	ID **файлу**: **1011514487**	**Навчальний заклад**: **National Aerospace University Kharkiv Aviation Institute**	**3.61%**
57	**B39**	ID **файлу**: **1011517838**	**Навчальний заклад**: **National Aerospace University Kharkiv Aviation Institute**	**3.53%**
58	**B22**	ID **файлу**: **1013101373**	**Навчальний заклад**: **National Aerospace University Kharkiv Aviation Institute**	**3.52%**
59	**B9**	ID **файлу**: **1011441571**	**Навчальний заклад**: **National Aerospace University Kharkiv Aviation Institute**	**3.38%**
60	**technological section.docx**	ID **файлу**: **2295125**	**Навчальний заклад**: **National Aerospace University Kharkiv Aviatio...**	**3.32%**
61	**B26 (1)**	ID **файлу**: **1008433383**	**Навчальний заклад**: **National Aerospace University Kharkiv Aviation Institute**	**3.26%**
62	**B57**	ID **файлу**: **1004213488**	**Навчальний заклад**: **National Aerospace University Kharkiv Aviation Institute**	**3.25%**
63	**B21**	ID **файлу**: **1013100626**	**Навчальний заклад**: **National Aerospace University Kharkiv Aviation Institute**	**3.19%**
64	**B29**	ID **файлу**: **1008427838**	**Навчальний заклад**: **National Aerospace University Kharkiv Aviation Institute**	**3.1%**

65	**B11**	ID файлу: **1008375394**	**Навчальний заклад**: National Aerospace University Kharkiv Aviation Institute	3.05%
66	**B38**	ID файлу: **1011517784**	**Навчальний заклад**: National Aerospace University Kharkiv Aviation Institute	3%
67	**B68**	ID файлу: **1004221633**	**Навчальний заклад**: National Aerospace University Kharkiv Aviation Institute	2.98%
68	**B67**	ID файлу: **1004203874**	**Навчальний заклад**: National Aerospace University Kharkiv Aviation Institute	2.94%
69	**B20**	ID файлу: **1008421608**	**Навчальний заклад**: National Aerospace University Kharkiv Aviation Institute	2.78%
70	**B17**	ID файлу: **1013090718**	**Навчальний заклад**: National Aerospace University Kharkiv Aviation Institute	2.62%
71	**M05**	ID файлу: **1000075060**	**Навчальний заклад**: National Aerospace University Kharkiv Aviation Institute	2.47%
72	**B3**	ID файлу: **1011436596**	**Навчальний заклад**: National Aerospace University Kharkiv Aviation Institute	2.44%
73	**Contents.docx**	ID файлу: **2076581**	**Навчальний заклад**: National Aerospace University Kharkiv Aviation Institute	2.39%
74	**B25**	ID файлу: **1008433776**	**Навчальний заклад**: National Aerospace University Kharkiv Aviation Institute	2.21%
75	**B28**	ID файлу: **1008427650**	**Навчальний заклад**: National Aerospace University Kharkiv Aviation Institut 2 Джерело	2.17%
76	**S07**	ID файлу: **1009674516**	**Навчальний заклад**: National Aerospace University Kharkiv Aviation Institute	2.09%
77	**B37**	ID файлу: **1011517745**	**Навчальний заклад**: National Aerospace University Kharkiv Aviation Institute	2.05%
78	**B36**	ID файлу: **1011517425**	**Навчальний заклад**: National Aerospace University Kharkiv Aviation Institute	2.03%
79	**B40**	ID файлу: **1011518989**	**Навчальний заклад**: National Aerospace University Kharkiv Aviation Institute	1.97%
80	**B34**	ID файлу: **1011515978**	**Навчальний заклад**: National Aerospace University Kharkiv Aviation Institute	1.88%
81	**B14**	ID файлу: **1009739227**	**Навчальний заклад**: National Aerospace University Kharkiv Aviation Institute	1.78%
82	**S10**	ID файлу: **1009728079**	**Навчальний заклад**: National Aerospace University Kharkiv Aviation Institute	1.7%
83	**B23**	ID файлу: **1013103717**	**Навчальний заклад**: National Aerospace University Kharkiv Aviation Institute	1.66%
84	**ECONOMICAL-SECTION.docx**	ID файлу: **2295124**	**Навчальний заклад**: National Aerospace University Khar 2 Джерело	1.46%
85	**B090**	ID файлу: **2128040**	**Навчальний заклад**: National Aerospace University Kharkiv Aviation Institute	1.37%
86	**Technological Section.docx**	ID файлу: **2054579**	**Навчальний заклад**: National Aerospace University Kharkiv Aviati...	1.08%

87	**B7**	ID **файлу**: **1011437838**	**Навчальний заклад**: **National Aerospace University Kharkiv Aviation Institute**	**0.85%**
88	**Contents.docx**	ID **файлу**: **2054567**	**Навчальний заклад**: **National Aerospace University Kharkiv Aviation Institute**	**0.77%**
89	**CONTENTS.docx**	ID **файлу**: **2295122**	**Навчальний заклад**: **National Aerospace University Kharkiv Aviation Institute**	**0.65%**
90	**B6**	ID **файлу**: **1011436829**	**Навчальний заклад**: **National Aerospace University Kharkiv Aviation Institute**	**0.45%**
91	**B8**	ID **файлу**: **1011439126**	**Навчальний заклад**: **National Aerospace University Kharkiv Aviation Institute**	**0.44%**
92	**W11**	ID **файлу**: **8725505**	**Навчальний заклад**: **National Aerospace University Kharkiv Aviation Institute** 21 Джерело	**0.14%**