Laboratory work number №5

INFLUENCE OF THE TYPE OF RIVETS AND THE NUMBER OF THEIR ROWS ON THE DURABILITY OF THE RIVETED JOINTS

Purpose of work – influence of the type of rivets and the number of their rows on the fatigue life of shear connections with eccentricity of load transfer.

Содержание работы

1. Acquaintance with typical riveted joints in modern aircraft airframe.
2. Acquaintance with typical variants of samples creation of shear riveted joints with eccentricity of load transfer.
3. The study of the methodology for calculating the cyclic durability of shear riveted joints.
4. The study of the influence of the types of rivets and numbers their rows on the durability of shear riveted joints with eccentricity of load transfer.

Calculation of the durability of shear connections

In the longitudinal and transverse joints of the wing linings and aircraft fuselage, single-shear lap joints are used (Fig. 5.1). The increase in the number of rows of rivets from one to three (fig. 5.2) significantly affects the fatigue life of the joint [7]. A further increase in the number of rows of rivets does not significantly increase the durability of the joint. Increasing the number of rows of shear joints above six in aircraft structures is considered impractical.

Riveting perform by countersunk and non-countersunk rivets. To increase the service life of the connections when installing fasteners in the last row and under the fairings, rivets with non-countersunk heads can be used. When making overlap joints, the magnitude of the transfer load eccentricity can reach a significant amount. So, when making longitudinal joints of the An-72 aircraft fuselage from D16ATV sheets of nominal thickness 1.5 mm , having outside the zone of connection after chemical milling a thickness of 0.85 ... 1.15 mm, the magnitude of the stiffness axis can reach 0.175 ... 0 , 325 mm. This leads to the additional bending moment caused by the eccentricity of the load transfer, which may cause of skin in joint area [7]. When loading these joints is most likely their destruction in the joints of the sheets, in the cross section along the axis of rivet or the non-weakened section at the boundary of rivet heads in a zone of intense fretting-corrosion and the maximum concentration of the bending stress.

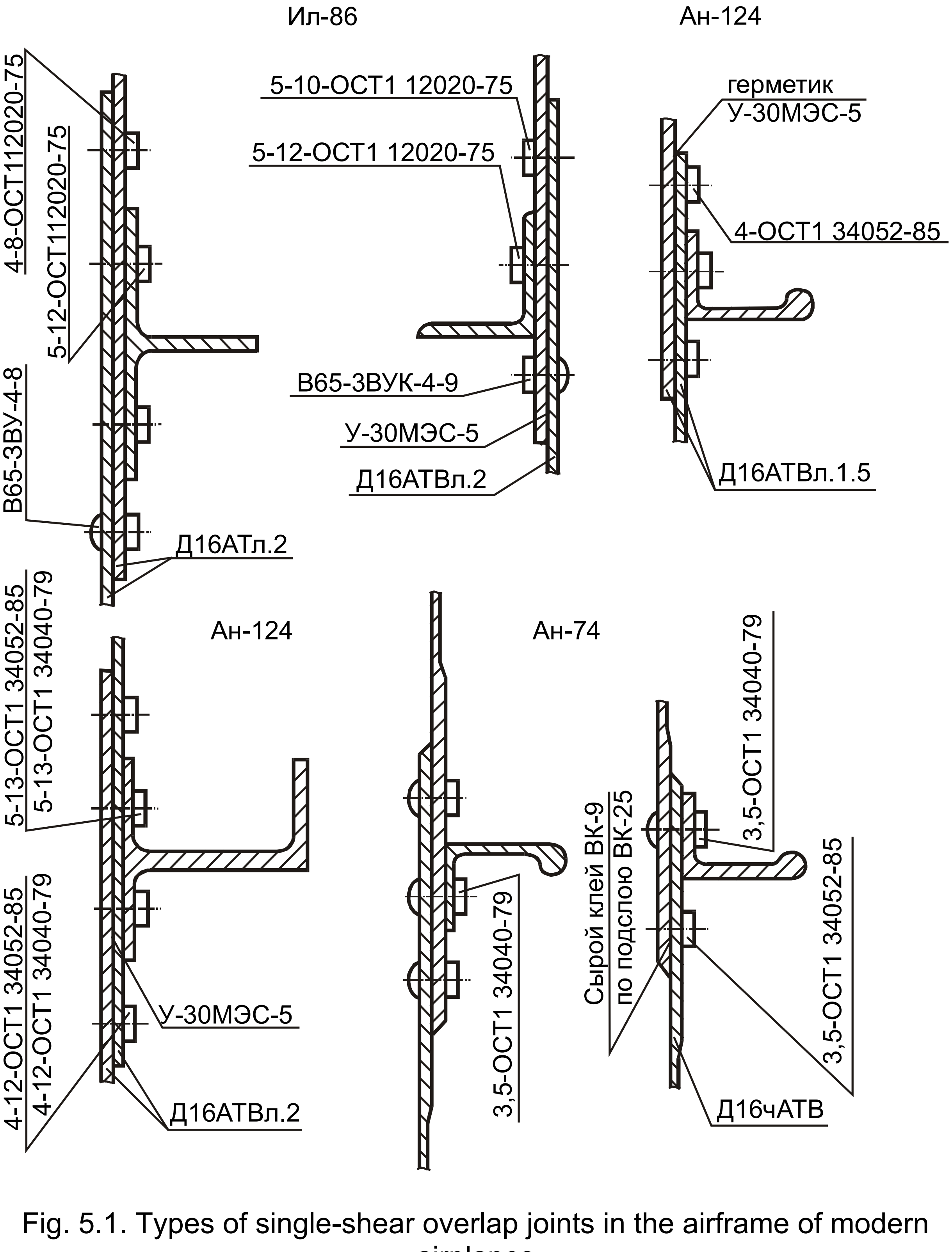


Fig. 5.1. Types of single-shear overlap joints in the airframe of modern airplanes

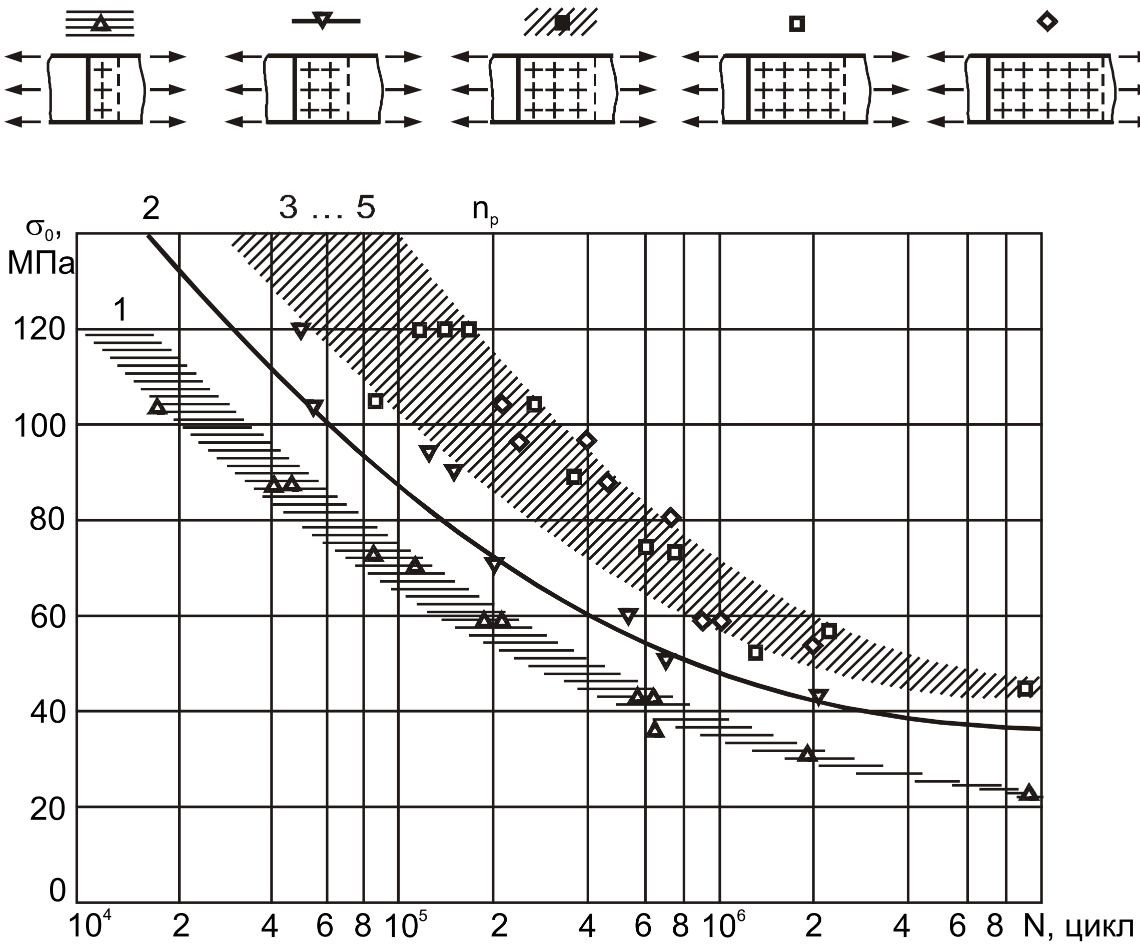


Fig. 5.2. The effect of the number of rows of rivets on the cyclic durability of shear rivet joints with overlap

In the case of destruction of the joint in section, weaken by rivet holes, its durability can be assessed using the above expressions for stresses [9]

$$\sigma_0 = k_{см}\sigma_{см} + \sigma_л + 0{,}5\sigma_и, \tag{5.1}$$

where σ_0 – stress in the plate with a hole filled with a rivet installed using the same technology as in the considering connection; $\sigma_{см}$ and $\sigma_л$ – stress due to the force in rivets of the considering row $P_{к.э1}$, and force ($P - P_{к.э1}$), passing along the sheet to the remaining rows of rivets; $\sigma_{см} = P_{к.э\,1}/ds$; $\sigma_л = (P - P_{к.э1})/Bs$; B and s – width and thickness of the sheet; d – diameter of the hole for the rivet; $\sigma_и$ –stress in the section of structural members along the axis of the holes, due to the action of the bending moment carryed by the connected elements; $k_{см}$ – factor equal to $k_{эф\,см}/k_{эф\,л}$, where $k_{эф\,см}$ and $k_{эф\,л}$ – effective stress concentration factors, respectively, for single-row connection and connection with not loaded with a shear rivet.

If baseline fatigue curves are known for this technology for joints with no rivets shear and dependence $k_{см} = f(N)$, the joint calculation simplified to determining the force distribution along the rows of fasteners and nominal bending stresses.

The fatigue tests carried out in the KhAI make it possible to write expressions for the base curves of D16 AT alloy plates with countersunk rivets OCT 134052-85 and non-countersunk rivets OCT1 34040-79 in the following form:

$$N\sigma_{бр\,0}^{4,833} = 1,7940 \cdot 10^{16}, \text{ or } \sigma_{бр\,0} = 2,3059 \cdot 10^{3} \cdot N^{-0,2069};$$

$$N\sigma_{бр\,0}^{4,415} = 5,8536 \cdot 10^{16}, \text{ or } \sigma_{бр\,0} = 3,7240 \cdot 10^{3} \cdot N^{-0,2265},$$

where $\sigma_{бр0}$ – stress of zero-to-tension cycle in “gross” section, caused by the action of tensile operating load, MPa; N –durability, cycle.

Coefficient $k_{см}$ according to TsAGI [9] can be written as

$$k_{см} = 0,063 \cdot N^{0,153}. \qquad (5.2)$$

The degree of outside rivet rows load can be calculated by the method described in [10], or evaluated by the diagram of Fig. 5.3 on the coefficient of load distribution non-regularity $K_{н1}$, equal to the ratio of load transmitted by outside row of fastening elements $P_{к.э\,1}$ *to* the average load $P_{ср}$, calculated on the assumption that it is irregularly distributed between the rows.

The magnitude of the bending stresses $\sigma_{и}$ in the structural members of a single-shear joint can be estimated taking into account the deformation of its elastic axis in the process of loading according to the method given in [11]. The results of calculations of bending stresses in the zone of the outside row of joints of sheets of material D16AT of nominal thickness 2 mm , made of rivets with a diameter of 4 mm , installed in increments 25 mm , with a total joint length ,equal to 454 mm (for example, the distance between the ribs for the cross-section of the wing) , According to this method are shown in Fig. 5.3 .

Knowing the dependence of the fatigue curve for a plate with a filled, unloaded hole and all the components of the right-hand side of dependence (5.1), one can calculate the durability of the considered shear joint with an eccentricity of load transfer using a calculation or graphical method.

For results comparison of fatigue tests performed by different researchers developed OCT 1 00872-77 [12] Regulated design samples of riveted joints (Figure 5.4.).

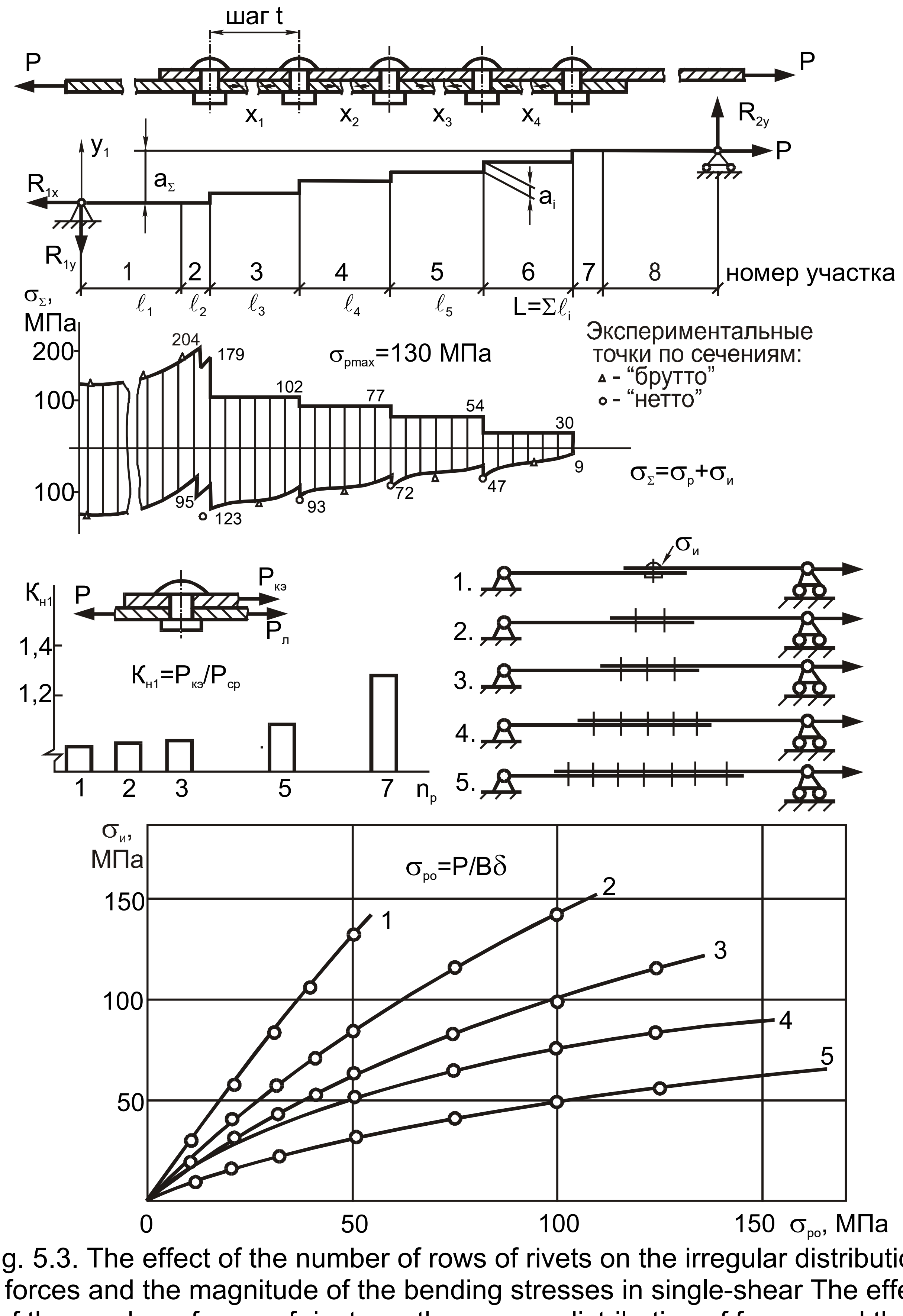
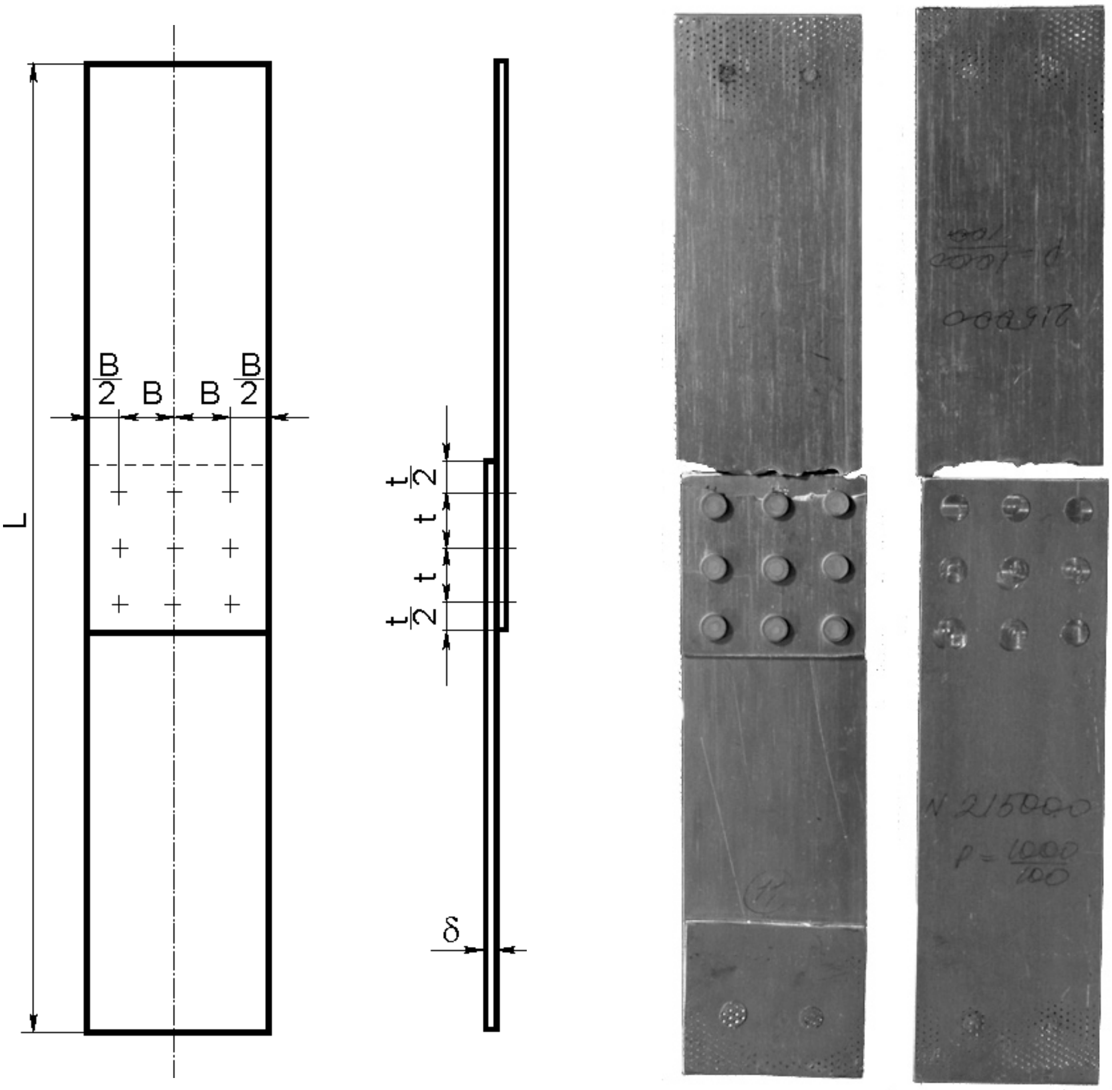


Fig. 5.3. The effect of the number of rows of rivets on the irregular distribution of forces and the magnitude of the bending stresses in single-shear The effect of the number of rows of rivets on the uneven distribution of forces and the magnitude of the bending stresses in single-shear joints overlap joints



a

b

Рис. 5.4. Sample of three-row overlap joint (a) and the nature of the destruction during fatigue tests (b)

The accuracy of the calculation of the durability of the joints according to the described method can be compared with the fatigue tests of three-row joints carried out in the KhAI, performed with rivets OCT 1 34052-85 with a diameter 4 mm . The experimental expression for the fatigue curve of joint is

$$N\sigma_{бр\,0}^{3,4623} = 1,1493\cdot 10^{12},\ \text{или}\ \ \sigma_{бр\,0} = 3,0437\cdot 10^{3}\cdot N^{-0,2888}.$$

Individual tasks for the calculations are presented in Table. 5.1. For all variants accepted that connections are made from sheet material Д16АТ with nominal thickness 2mm; diameter of rivets – 4 mm, rivets step – 25 mm.

Table 5.1.

Individual tasks for laboratory work

№ п/п	$\sigma_{бр\,0}$, МПа, variants		Rivets rows number		№ п/п	$\sigma_{бр\,0}$, МПа variants		Rivets rows number	
	1	2				1	2		
1	134	95	1	3	12	134	92	1	3
2	132	80	2	3	13	134	94	2	3
3	130	70	5	3	14	134	96	5	3
4	128	90	7	3	15	134	98	7	3
5	126	90	1	3	16	134	100	1	3
6	124	90	2	3	17	134	112	2	3
7	122	90	5	3	18	134	114	5	3
8	120	90	7	3	19	134	116	7	3
9	118	90	1	3	20	134	118	1	3
10	116	90	2	3	21	134	120	2	3
11	114	90	5	3	22	134	91	5	3