

The Ministry of Education and Science of the Russian Federation  
Samara State Aerospace University  
(National Research University)

## **DETAIL DESIGN OF AIRFRAME PART**

Electronic Laboratory Guideline

SAMARA

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A method of executing laboratory works in accordance with the discipline of aircraft construction and design is described. A list of normative-technical documentation and reference materials that are needed for executing tasks, as well as examples of the work execution and preparation are offered.

The manual is intended for fourth - year students of the specialty 160201 “Airplane and Helicopter Construction” that study the discipline of aircraft construction and design and for the Masters programme «Designing, construction and CALS-technologies in Aeronautical Engineering» for education direction 160100.68 «Aeronautical Engineering».

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# CONTENTS

<b>PREFACE</b> .....	4
1 LABORATORY WORK №1. ANALYZING A TASK. SKETCHING PROTOTYPES.....	6
2 LABORATORY WORK №2. BALANCING THE PART. CHOOSING NORMALS. CHOOSING THE DESIGN SCHEME AND DEFINING STRESSES OF THE PART ELEMENTS .....	8
3 LABORATORY WORK №3. DEFINING THE PART DIMENSIONS OF THE REQUIRED STRENGTH WITH TAKING INTO ACCOUNT THE MANUFACTURING FACTORS AND RESTRICTIONS.....	11
4 LABORATORY WORK №4. MAKING THE PART DRAWING.....	13
BIBLIOGRAPHY .....	15

## PREFACE

A laboratory and practical work "Aircraft part design" logically continues a series of laboratory works of the course "Foundations of the airplane layout."

By executing this work a student passes from small particular engineering problems to the first full-fledged self-dependent work, which includes the whole design cycle: a specification, loads, a structural and load-carrying scheme, design estimations, manufacturing technologies and, finally, a designed part drawing.

The work is carried out in the room of aircraft constructions with using real samples of aeronautical parts and units.

The student obtains skills of design and engineering analysis of choosing possible design solutions based on estimating real design samples while executing this laboratory work.

The student learns to apply theoretical knowledge in practice, use reference books and standards and prepare technical documentation.

The laboratory and practical work consists of four separate two- hour lessons. The process of designing parts conditionally has four stages:

1. Analyzing a task and getting acquainted with prototypes.
2. Balancing a part. Choosing normals. Choosing a design scheme. Defining part elements stresses.
3. Defining part dimensions of the required strength with taking into account manufacturing factors and restrictions.
4. Making a part drawing.

Estimations of each stage are given in an explanatory note in accordance with requirements of preparing text documents.

The explanatory note should contain: substantiations of choosing the load-carrying scheme (LCS), all estimations, explanations of choosing normals, technological substantiations. The estimations are illustrated by sketches.

The part sketches and drawing are executed on separate paper sheets of the standardized format in compliance with UDDS (the Unified Design

Documentation System). The part drawing should be made with respect to the serial production and give the information about special requirements that are necessary for manufacturing and controlling the part.

# 1 LABORATORY WORK №1. ANALYZING A TASK. SKETCHING PROTOTYPES

The laboratory work contents:

1.1. Getting the task.

1.2. Analyzing the task. Defining a purpose of the part and its work conditions. Developing the part requirements.

1.3. The engineering analysis of prototypes. Sketching the parts and its separate elements.

The necessary explanations and recommendations:

1.1 The task library ([Appendix](#)) contains a variety of brackets of elevator hinge, aileron hinge, flap hinge (the tasks № 1, 2, 3) and control cranks (the tasks № 4,5). Moreover, in tasks № 1, 2, 3 it can be proposed to design brackets of the wing or stabilizer sides, or brackets of the elevator, aileron or flap sides (for example, the task № 1 st. - the stabilizer bracket, the task № 1 e. - the elevator bracket).

The initial part design data is defined while designing the unit, which contains this part. The sketch shown in the task contains the information about the part function, its relationship with other parts, overall limits (the space amount, in which the part can be placed). The design conditions of the part are in the table.

1.2 After receiving the task, you should define the part function, work conditions, loading conditions. Then you should analyze the work of elements, which are connected by the given part. After understanding the functional characteristics and work conditions of the main elements you can easily go on to develop the requirements of the design part.

The part requirements determine generally all part properties and are defined by the purpose and work conditions with taking into account statistics of manufacturing and maintaining prototypes.

When you start to develop the part design you should define at the least functional requirements, requirements of the part minimum weight and

manufacturing requirements.

The study periodical material ought to help you to execute this work [[1](#), [2](#), [3](#), [4](#)].

1.3 You can compliment information about the part work conditions by the engineering analysis of prototypes represented in the room of aircraft constructions.

The engineering analysis of the parts requires studying the accumulated experience with the purpose of using already developed and tested elements and approved design approaches and methods. The experience of predecessors allows solving particular tasks that arise while designing parts with the minimum time outlay on. This step involves the following tasks:

1. Defining a part function and its work conditions.
2. Defining a material and a manufacturing method.
3. Designing separate part elements (eyes, bases, a part body and зон перехода).
4. The qualitative assessment of part manufacturability.
5. The possible variant of the loading diagram that is used for designing the part.
6. Defining characteristics of the chosed normals.

Then you should pick up 3 - 4 prototypes installed in the room of aircraft constructions and give the necessary explanations that respond to assigned questions. Also you should make sketches of the prototypes.

## 2 LABORATORY WORK №2. BALANCING THE PART. CHOOSING NORMALS. CHOOSING THE DESIGN SCHEME AND DEFINING STRESSES OF THE PART ELEMENTS

The laboratory work contents:

2.1 Balancing the part. Choosing the normals (bearings, bolts, rivets, rods and etc.).

2.2 Developing and analyzing possible variants of the structural and load-carrying scheme (SLCS).

2.3 Choosing the design scheme of the part.

2.4 Defining stresses of the part elements.

The necessary explanations and recommendations:

2.1 Forces in attaching points and joints of setting mate control rods are defined by results of balancing forces that act on the part. The method of balancing forces defines nature of loading the attachment elements that connect the design part with the mate parts.

The type of the normalized part is usually defined by the design part requirements. The dimensions are determined by the stated load of the part  $P^p$ .

**Note.** The design load  $P^p$  is given in your task. According to strength requirements it is obtained from the normalized operational load:

$$P^p = P^o f,$$

where  $f$  – the safety factor.

While acting the design load ( $P_p$ ) the stresses of design sections should be equal to the failing stresses, and strength conditions are:

$$\sigma^p \leq \sigma^e, \tau_p \leq \tau_e.$$

The normalized parts define the dimensions of the design part in junctions. It is necessary to select the bearings (friction and frictionless bearings), the

attachment parts (bolts, rivets), the control rods and etc. The bearings are selected according to static breaking loads [5].

The bolts are selected according to static breaking loads of tension and shear that are given in [6].

The strength excess coefficient is defined for each normalized part.

2.2 It is reasonable to carry out the development of the part structural and load-carrying scheme and its analysis in the form of sketches.

You can draw all known geometrical information of the part on 2-3 formsheets. Also it is useful to plot bolt and bearing holes if their dimensions are known.

Then try to make several sketches of the part, as you think it should be. The previously made sketches of prototypes, professor's advices and your own ideas about nature of acting forces will help you.

Then you should analyze critically each variant using the plan used for analyzing the prototypes.

The main criteria of choosing the SLCS is already developed manufacturing requirements (MR), so you should prefer the part that more fully satisfies the MR.

The issue of choosing the SLCS is easily solved after comprising the parts by the criteria "Load-carrying factor" [16].

2.3 The design scheme states a way of estimating the construction, and it is design in a way as to simplify the strength calculations with retaining the acceptable accuracy. Thus, the part design made as the sketch is represented in the form of elementary constructions (rods, bars, beams, frames, etc.), whose calculation methods are well-known.

The transition from the real part design to the design scheme is carried out with a number of simplifications (a rigid connection is replaced by the hinge connection, some elements are not considered and etc.). The calculation accuracy can be achieved only on the understanding that ways and methods of transferring forces in the part are correctly defined by the design scheme.

The description of the design scheme of the chosen SLCS should be given in the explanatory note.

2.4 The stresses of the part elements are defined on the basis of the chosen part elements: the normal force of the rod, the bending moment and intersecting load of the beam cross-section, the rotational moment of the shaft. It is convenient to represent the carry-load factors in the form of diagrams.

### **3 LABORATORY WORK №3. DEFINING THE PART DIMENSIONS OF THE REQUIRED STRENGTH WITH TAKING INTO ACCOUNT THE MANUFACTURING FACTORS AND RESTRICTIONS**

The laboratory work contents:

3.1 Choosing the part material.

3.2 Making calculations of the eyes parameters.

3.3 Calculating the part sections parameters of the required strength.

3.4 Modification of the sections according to the manufacturing factors and restrictions.

The necessary explanations and recommendations:

3.1 The choice of the material is made in such way, that the minimum part weight is provided under the given estimation conditions and suggested manufacturing method. The criteria of choosing the material to a first approximation are strength-to-weight ratio characteristics [3].

The strength-to-weight ratio value of the chosen material is calculated on the basis of its failing stress. This stress is defined according to the influence of the operation time, the load intensity and nature, the operating temperatures, the manufacturing method, the environment exposure and etc. on the material durability.

The chosen failing stress value is submitted to your professor. The heat treatment mode of the material should be given in the explanatory note and, then, it is should be placed on your drawing in the field of the technical requirements.

In the case, when the manufacturing method is known, the material range decreases, so it is easier to make a choice. The recommendations of choosing the material according to the manufacturing method are given in [7].

The additional information about the strength and manufacturing properties of materials is given in [8].

3.2 The calculations of the eyes should be done in accordance with the recommendations given in [9].

3.3 The dimensions of the part section (the rib cross-section area, the wall thickness, the base thickness and etc.) for each unsafe cross-section should be defined according to the calculated stresses; when it is necessary to specify the law of the lengthwise section variation, the intermediate section dimensions should be defined, the dimensions of all possible fracture places and shapes are also should be defined. You can find all necessary recommendations and formulas in [2, 9].

3.4 The modification of the part sections with taking into account the manufacturing factors and restrictions is made according to the requirements and recommendations of manufacturability [7]. The satisfaction of these requirements provides the acceptable part quality, productivity and deterioration of the manufacturing equipment.

When you save the calculated section areas, you should select the following elements for the part is made by:

- the hot stamping method: the rational shapes of the part and its elements; the surface orientation of the die parting; the thickness and angle of the flat slope; the area of lightening holes that are punched; the thickness and height of ribs, the distance between ribs; the radiuses of conjugations, curves and transitions и переходов; the stamping angles; the limit deviations (tolerances) of the unmachined dimensions;

- the founding method: the founding method, the rational shapes of the part and its elements, that provide the evenness of the foundry cooling-down; the cast parting face; the founding angles; the minimum wall thicknesses; the thickness of ribs and the distance between them; the radiuses of conjugations and the rounded radiuses; the limit deviations (tolerances) of the dimensions.

It should be noted, that the choice of the part dimensions should be made with taking into account the following machining the conjugate surfaces and, seldom, lightening or weight fitting the part. After choosing the part dimensions you should select the antirust covering of the part (use the recommendations [12]).

## 4 LABORATORY WORK №4. MAKING THE PART DRAWING

The laboratory work contents:

- 4.1 Making the part drawing.
- 4.2 Technical description of the designed part.

The necessary explanations and recommendations:

4.1 The part drawing is made according to the requirements of GOST 2.109-70. The drawing should contain all information that is necessary for manufacturing the part and its control, and also developing the drawings of production tools.

The drawing is executed on the paper sheet of the standardized format (the format A3 is advised).

It is usually enough to give two main views and two-three section views that explain the part shape (it is better to use the small number of lines to explain the part shape).

Then all necessary dimensions and their limit deviations should be plotted on the drawing. The dimensions should be shown from bases of the mechanical operations (usually these bases are assembly bases).

The places of the mechanical operations should have the necessary surface roughness. The finish and its accuracy should be linked with each other.

The manufacturing requirements of the drawing should comprise the heat treatment, the covering method, control requirements, the weight fitting method and the method of marking [10].

The drawing frame should contain the material and weight of the part.

The drawing symbols are done according to 57A0. The recommendations can be found in [II].

- 4.2 In conclusion you should give the brief description of the part:
- the function and work conditions of the part;
  - the manufacturing method and the material;

- the operation features.

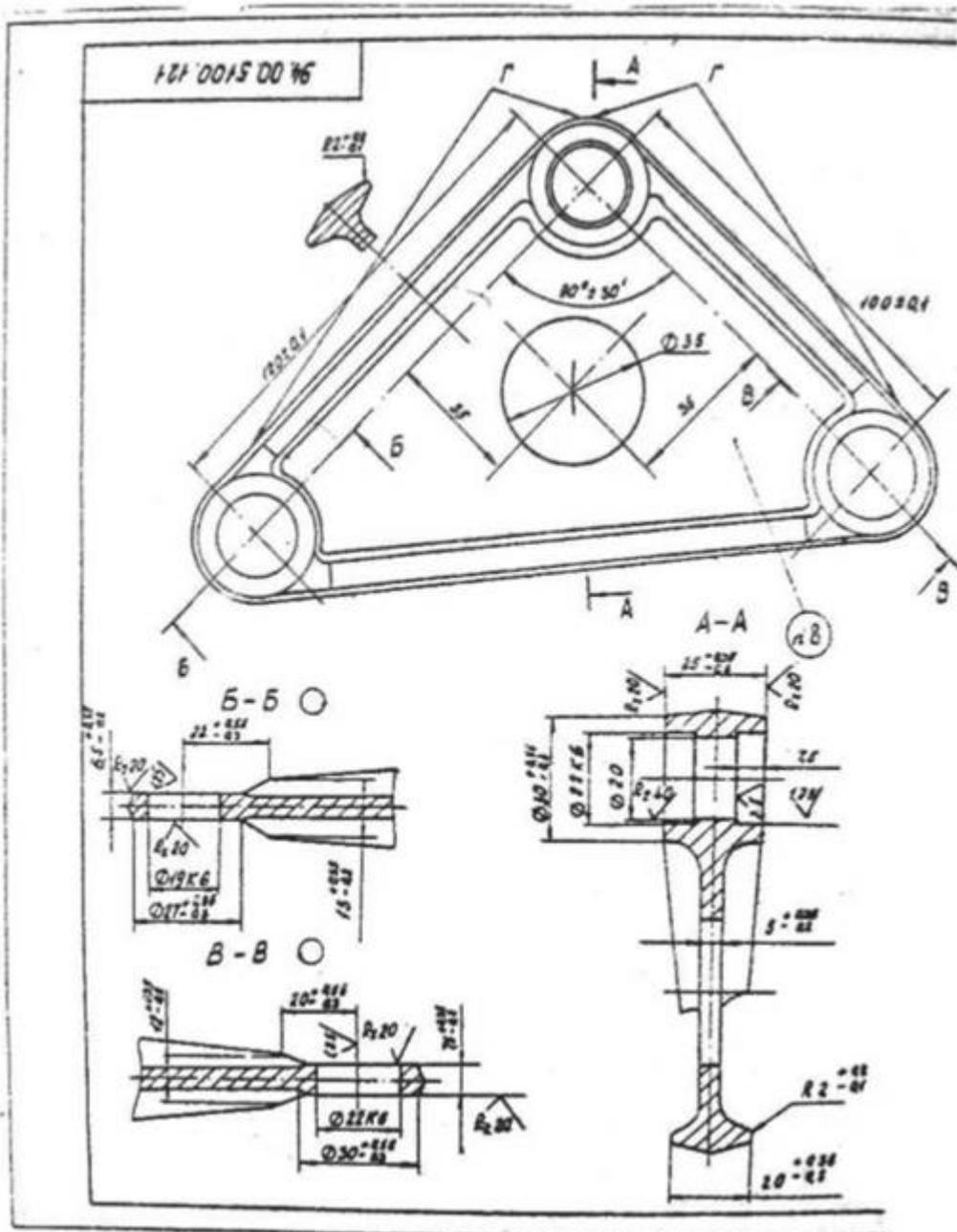
The contents and the bibliography should be given at the end of the explanatory note.

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## 4.1 The part drawing

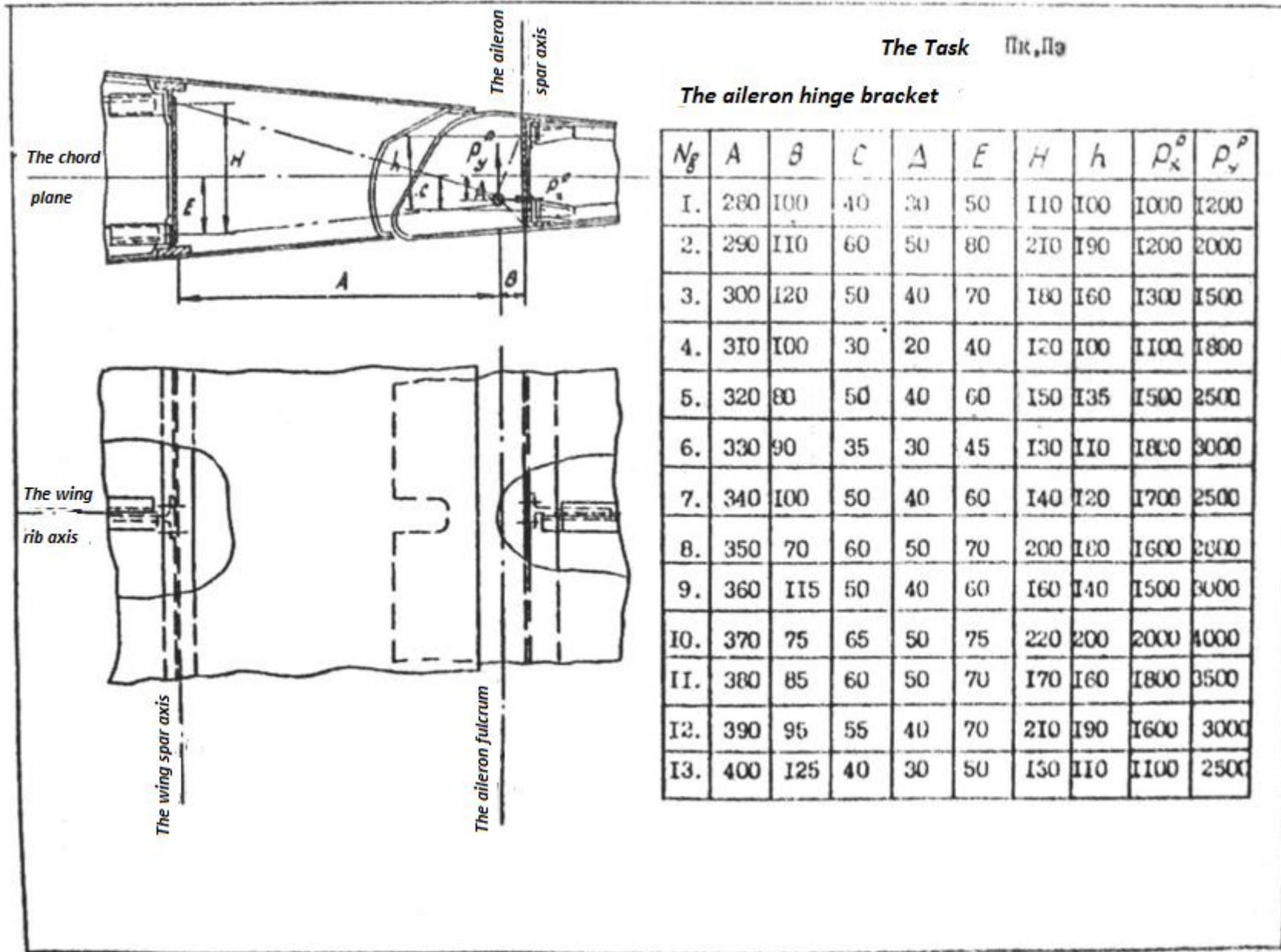


✓(✓)

1. Technical requirements of the stamping according to OCT 1.90073-72  
The control group **II** check the lack of cracks
2. The stamping angles  $5 \pm 1$ .
3. The unplotted stamping angles 5 mm
4. The limit deviations of the stamping dimensions  
no OCT 1.41187-78, the degree of finish 4
5. The unplotted limit deviations of the machined surface dimensions  
according to OCT 1.00022-80
6. The heat treatment: *сальца и искусственно старить;  $\sigma_B = 340 \div 360$  МПа*
7. The covering *Ан. Окс. Хр. Тр. АЛ-1, IV.А. ПН-3602 OCT 190055-78*
8. Marking **Чу** by the font **ПО-2** and **Ку**.
9. The maximum weight is no more than 1,4 kg,  
The weight fitting can be made by decreasing angles of the zone  $\Gamma$  ( $R_{150}$ )

		94.00.5100.121	
Сделано по чертежу	Sign.	Crank	Sum Weight Scale
Разработано	Dat		1,2 кг 1:1
Проверено			Исполн. Установл.
Конт.		АК-6	SSAU
Умол.		Окт 1. 80070-72	

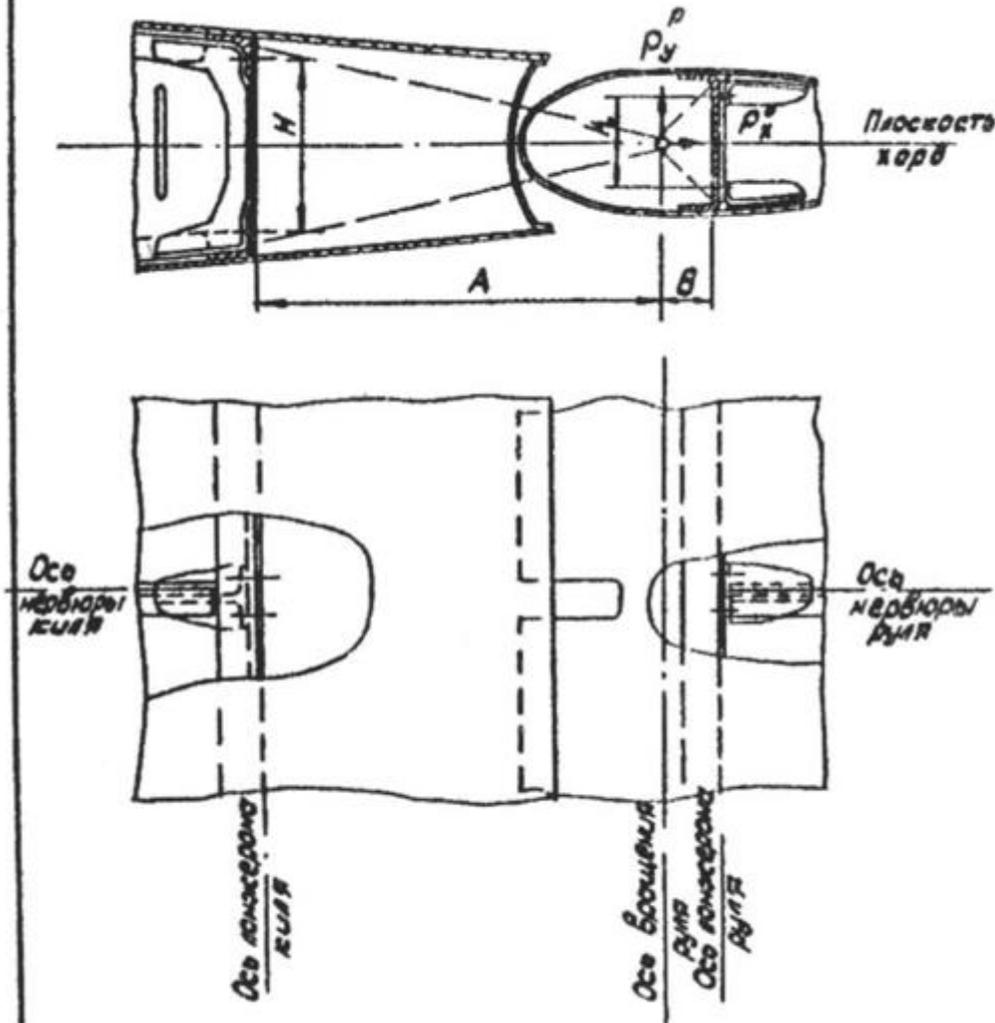
The laboratory work tasks. The Appendix



The task  $I_{от}, I_p$

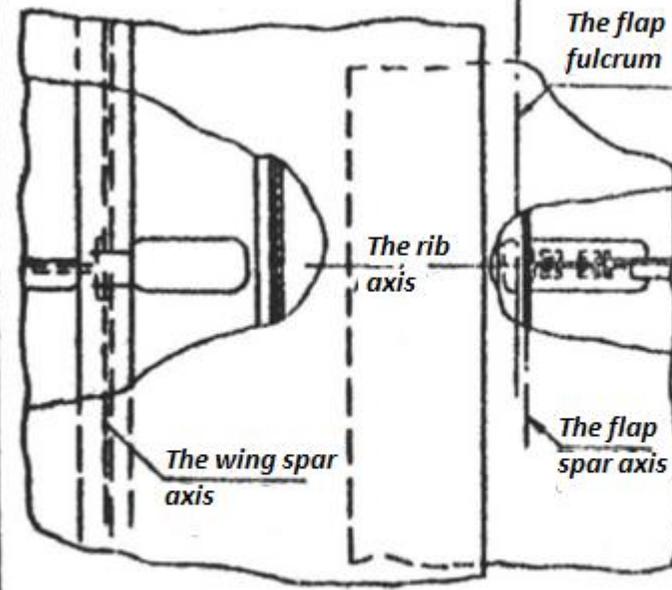
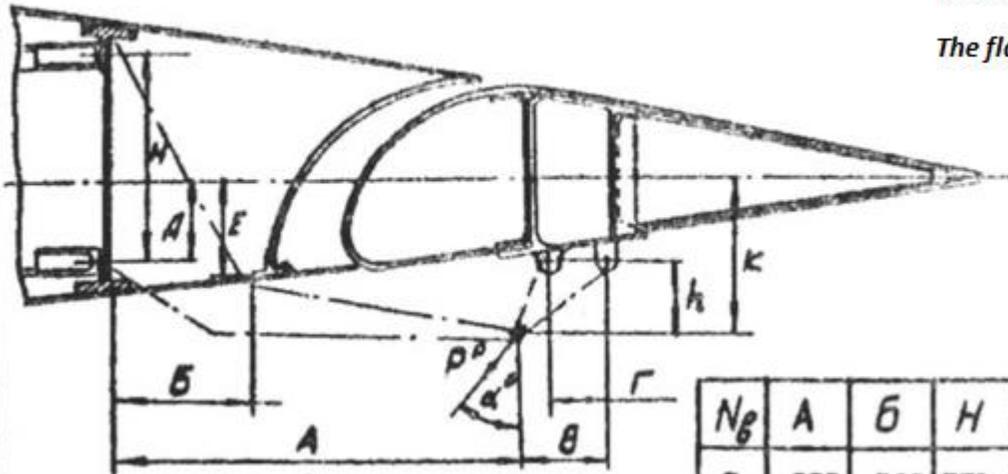
The stabilizer hinge bracket

№	A	B	H	h	$\rho_y^p$	$\rho_x^p$
1	150	80	170	100	2000	1100
2	160	90	130	90	4000	1800
3	170	70	100	80	3500	1600
4	180	100	200	160	2500	1400
5	190	70	120	100	4000	2100
6	200	80	150	120	3500	1900
7	210	90	110	70	2000	1200
8	230	70	140	120	2500	1500
9	250	80	190	130	2500	1800
10	270	90	120	110	3000	2000
11	290	100	220	130	2000	800
12	300	70	160	110	3000	1700
13	320	80	220	150	3000	2000
14	340	90	140	100	3500	1800
15	360	100	250	180	2500	1000

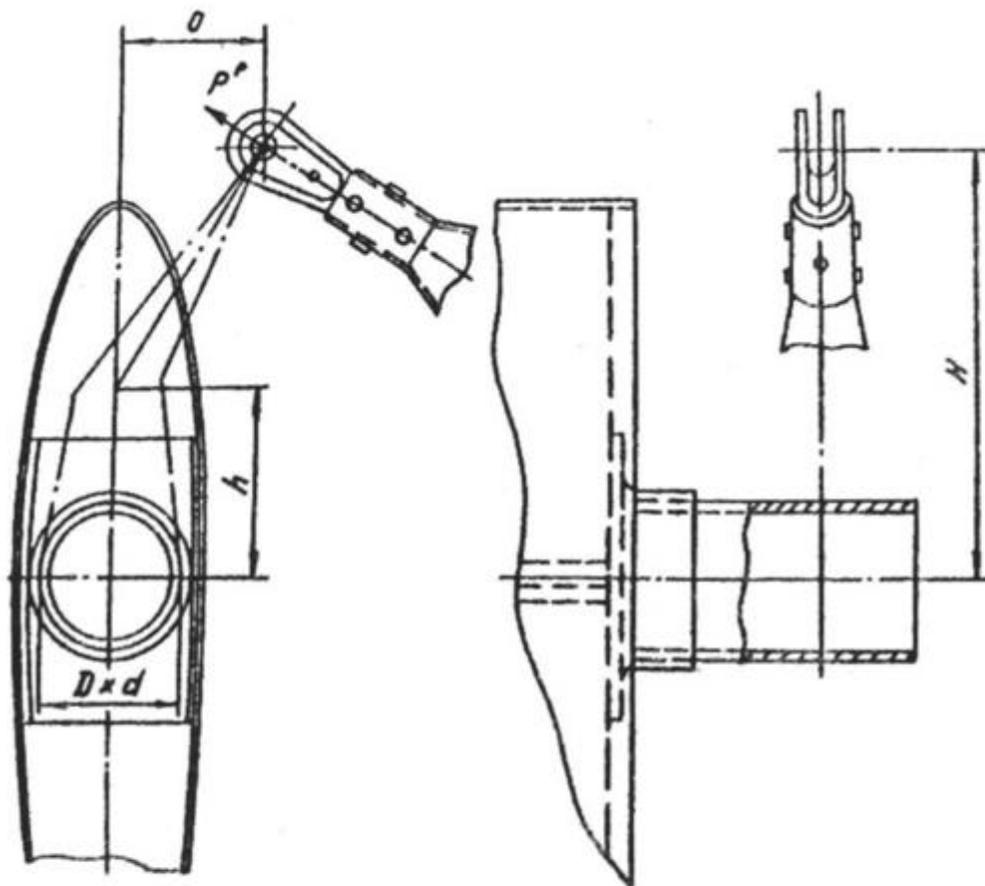


The Task III, IIIa

The flap hinge bracket



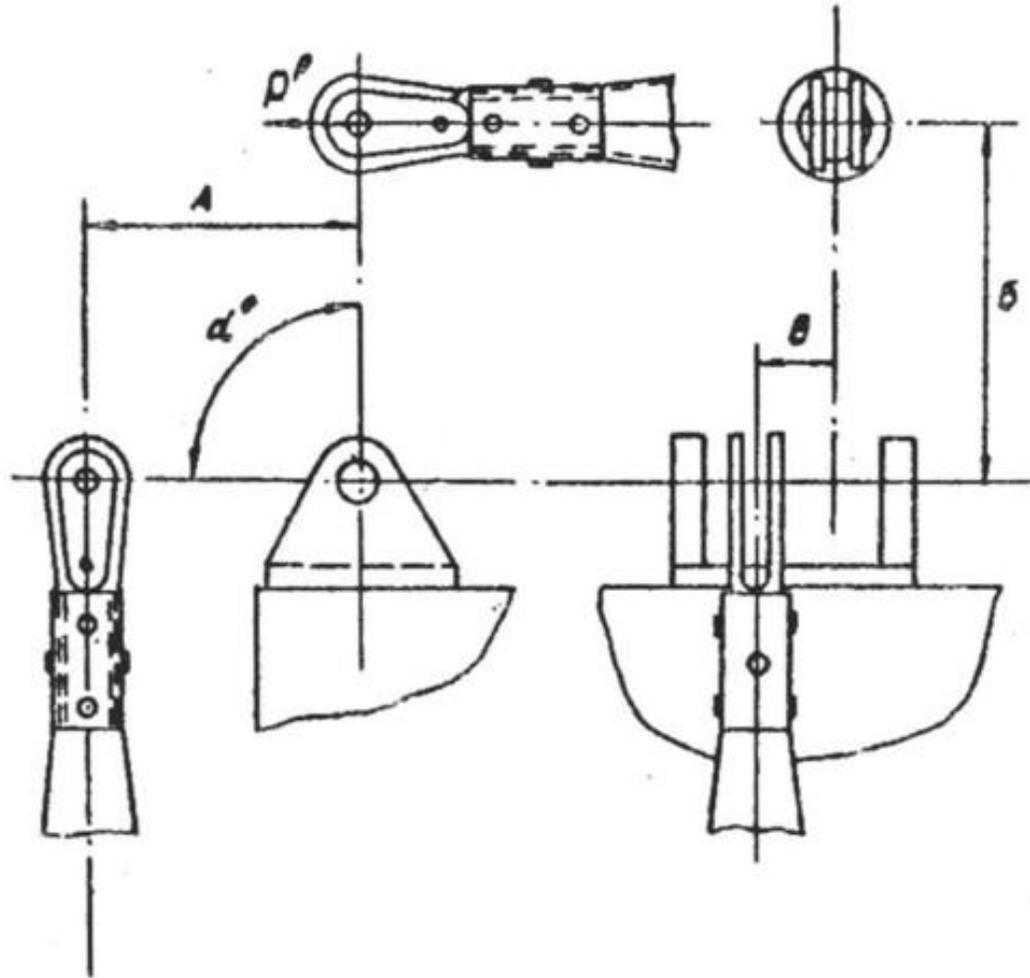
$N_{\theta}$	A	B	H	$\Delta$	E	$\rho^{\circ}$	$\alpha^{\circ}$	$\Gamma$	K	h	
1	250	100	150	50	70	3000	45	100	60	140	80
2	270	110	160	50	70	3500	60	105	60	145	85
3	290	115	170	60	80	2800	50	110	70	150	90
4	300	120	180	60	80	4000	40	115	70	155	95
5	310	130	190	70	90	4300	70	120	80	160	80
6	330	140	200	70	90	5000	50	125	80	165	85
7	350	150	210	80	100	3200	45	120	90	170	100
8	370	160	220	80	100	3000	60	115	90	180	95
9	390	170	230	90	110	4000	40	125	100	190	90
10	400	180	240	90	110	3500	60	130	100	200	110



The task IV

управления рулем

$N_{г}$	$a$	$H$	$h$	$D \times d$	$p$
1	30	180	60	50x48	700
2	40	190	80	55x52	1200
3	80	200	100	60x57	1200
4	50	210	80	65x62	1800
5	0	220	120	70x66	1800
6	100	230	100	75x71	1800
7	70	240	80	85x81	1600
8	0	260	120	90x85	1400
9	50	280	110	95x90	1200
10	100	300	120	100x94	1000



The Task 3  
The control crank

$N_f$	A	B	$\beta$	$\alpha^\circ$	$\rho^\circ$
1	120	180	0	90	1500
2	130	200	0	100	1600
3	140	220	0	60	2000
4	150	210	50	45	1800
5	160	250	0	120	1500
6	120	220	0	70	1700
7	130	150	70	90	1800
8	140	160	100	60	2000
9	150	180	0	45	1800
10	160	180	80	0	1600
11	140	100	50	90	2100
12	130	110	100	0	2000