

MINISTRY OF EDUCATION AND SCIENCE OF UKRAINE

National Aerospace University
«Kharkov Aviation Institute»

Faculty of Aircraft Engineering

Airplane and Helicopter Design Department

Explanatory Note to Diploma Project of

Master
(degree)

Subject: Design of multipurpose transport aircraft fuselage frame. Aircraft structures alignment with distance sensors and CCD cameras

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Applicant of 2 Year 161F Group
Field of knowledge 13

Mechanical Engineering

Specialty: 134 Aerospace

Engineering

Educational program: Aircraft Designing

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Supervisor: Oleksandr SOBOLIEV

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Kharkiv – 2023

**Ministry of Science and Education of Ukraine
National Aerospace University
«Kharkiv Aviation Institute»**

Faculty Aircraft Engineering
 Department 103 Airplane and Helicopter Design
 Degree Master
 Field of knowledge 13 Mechanical Engineering
 Specialty 134 Aerospace Engineering
(Code and name)
 Educational Program Aircraft Designing
(Name)

**APPROVED by
Head of Chair**

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**TASK
FOR DIPLOMA PROJECT**

Zhu Zizheng

(Name)

Subject of qualification paper Design of multipurpose transport aircraft fuselage frame.
Aircraft structures alignment with distance sensors and CCD cameras

Supervisor of qualification paper Oleksandr SOBOLIEV

(name, degree, scientific degree)

Approved by University order No _____ from “ ” _____ 2023

Qualification paper presentation deadline _____

Initial data for the qualification purpose – passenger aircraft; flight range
– 3680 km; number of passengers – 68 people; takeoff distance – 620 m; cruise speed –
600 km/hr; cruise altitude –10.7 km.

Content of explanatory note (list of problems to solve)

INTRODUCTION

1.DESIGNING SECTION

1.1 Development of frame No. 37

1.2 Substantiate decision made with calculations

1.3 Technical Description and Technological Analysis of Frame No.37

1.4 Work out technical specification for the longitudinal beam

2. SPECIAL SECTION

2.1 Selecting of blank for manufacturing of part by stamping and technological scheme of the die.

2.2 Stamp designing. selection of equipment

2.3 Development of technological materials for fuselage frame No.37

2.4 Developing of the assembly jig design.

2.5 Aircraft structures alignment with distance sensors and CCD cameras

3. ECONOMIC SECTION

3.1 Introduction

3.2 Description of the product

3.3 Market Research

3.4 Initial data and calculations

3.5 Building graphs depending on the cost of the assembly of release

CONCLUSION

List of drawings (with the exact indication of obligatory drawings)

- Master geometry of aircraft surface, general view drawing.
 - Space distribution model (space-mass layout).
 - Load carrying structure layout of the aircraft.
 - Master geometry of the unit.
 - Space distribution model.
 - Analytical models of designed unit parts, subassemblies.
 - Theoretical drawing of the unit.
 - Assembly drawing of the unit.
 - Schematic diagram of the system.
 - Business plan scheme for the establishment of the airplane.
 - Aircraft qualitative criteria table.
-

Advisors of diploma project sections

Section	Name and duty of advisor	Signature, Date	
		Task is given	Task is submitted
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4			
5			

Normative inspection _____ **Oleksandr SOBOLIEV** _____ «18» 05 2023
 (Signature) (Name)

Date when task is given _____ **14.03.2023** _____

CALENDAR PLAN

№	Diploma project milestones	Diploma project milestone deadlines	Notes
1	Design Part	10.04.2023	
2	Special task	5.05.2023	
3	Economics	18.05.2023	

Applicant _____ **Zhu Zizheng** _____
 (Signature) (Initials and surname)

Supervisor of diploma project _____ **Oleksandr SOBOLIEV** _____
 (Signature) (Initials and surname)

Abstract

Assignment for diploma project: 81 pages, 40 figures, 6 tables, 11 sources.

Object of study: Design of multipurpose transport aircraft fuselage frame. Aircraft structures alignment with distance sensors and CCD cameras

The purpose of the work is to the aim of this diploma project is to design aircraft fuselage frame NO.37 of AN-72, including determining the take-off mass and geometric parameters in the three approximations, developing general view drawing and load-carrying structure, modeling aircraft master-geometry and space distribution model, calculating aerodynamic and flight characteristics, Production process of aircraft frame specific parts, cost calculation of manufacturing the designed aircraft.

Methods of analysis - statistical, analytical methods, methods of building mechanics, calculating aircraft strength, structural modeling in CATIA V5, software developed in departments 102, 103.

Diploma project result: as a result of the master's diploma project the following results were obtained:

1) Determined basic geometric and mass parameters of a long-range business jet aircraft. The influence of geometric parameters on the take-off mass of the aircraft in three approximations. The take-off mass of the aircraft in the third approximation is 34500 kg, and the masses of the main components of the aircraft: wing – 4418 kg; fuselage – 2719 kg; tail – 710 kg; landing gear – 2209 kg; power plant – 4823 kg; fuel – 15446 kg. The main geometric parameters are wingspan – 31.89 m, mean aerodynamic chord of wing – 2.89 m, fuselage length – 28.07 m, wing aspect ratio – 10, wing load – 500 daN/m².

2) Developed a master geometry and a space distribution model of an airplane. Models created using CATIA V5, General view and load-carrying structure created using KOMPAS-3D v-19.

3) Calculated aerodynamic and flight characteristics of the designed aircraft. Finally, the manufacturing using Assembly Jig was cheaper than that using Assembly Holes. So for the best sales price, I would encourage the use of Assembly Jig in the manufacturing process.

Keywords: business aircraft, wing, tail unit, fuselage, landing gear, aerodynamic characteristics, wing box, price of the aircraft.

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INTRODUCTION

There are many types of aircraft in the world, each with a different purpose, range and quality; Each plane has its own special processing technology. These are the details or elements of aviation manufacturing. As a result, the heavy use of materials and names leads to a lot of assembly and installation work, which in turn leads to high labor intensity. Due to the high precision requirements of aircraft geometry during pre-production and assembly, especially in modern aircraft and helicopters, we have to use special clamps and specific methods of coordination. This in turn leads to difficult, time-consuming and costly preparation of aircraft production assembly and installation facilities, thus ensuring that the required quality, quantity and quantity of aircraft are produced within the desired timeframe. A bachelor's thesis is a summary and response to your undergraduate knowledge. The topic of my thesis is part design, which is the pre-production plan to build the 37th fuselage stamping assembly part for 72 aircraft. This paper consists of design part, technical part and economic part. In the technical section, the production process of the bottle cap (nozzle) and the detailed manufacturing process from the base material to the finished product are analyzed. The technique of press frame is analyzed in detail, and the errors in fixture assembly are calculated and summarized. In the economic section, the economic aspects of the actual parameters of aircraft production are analyzed in detail, which helps us to analyze the practical application of the analysis of problems faced by engineers in choosing effective assembly methods. The analysis came to the right conclusion.

And then I also studied the role of CCD camera ranging in the alignment of aircraft fuselage production. As industrial technology advances by leaps and bounds, new production technologies need to be applied. I will explain in detail the role of CCD in my research.

DESIGNING SECTION

1.DESIGNING SECTION

1.1 Development of frame No. 37



Figure 1.1 – Real photo of An-72

The AN-72 is a transport aircraft designed and produced by the Antonov Design Bureau of the former Soviet Union. The NATO code name is "Coaler". It replaced the An-24 series powered by turboprop engines as a new generation of short takeoff and landing (STOL). The successor to the transport plane. The An-74 is a derivative of the An-72 developed for polar applications. The An-71 is a derivative of shipborne early warning. Other derivatives of the An-72 include the An-72S Vital Personnel transport aircraft and the An-72P Maritime patrol aircraft.

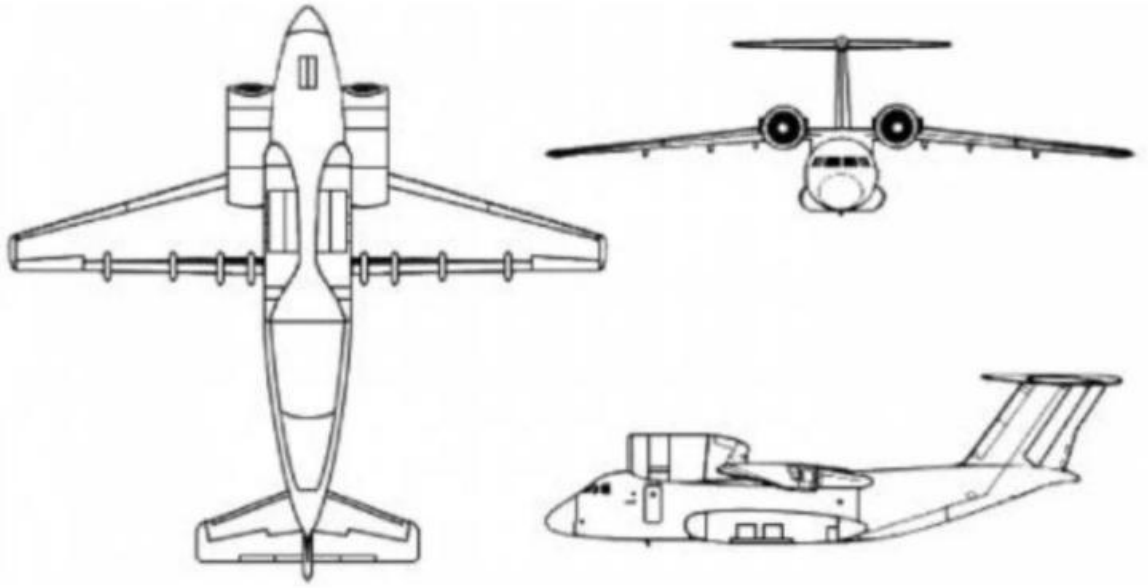


Figure 1.2 – An-72

The An-72's biggest feature is that its engine sits on the wing, blowing air over the upper surface of the wing. Using the wall attachment effect to generate a large amount of extra lift to improve the short-distance takeoff and landing ability; It also reduces the likelihood that the engine will suck in ground debris.

The fuselage is a semi-hard shell structure with beam and stringer, and the cargo door is located between racks 30 and 46.

The frame is the transverse structural member of the fuselage. They are carried out as annular closed frame systems and approach their shape. They bear external forces and are balanced on the skin by the flow of tangential forces. Lateral and axial forces and bending moments are determined by structural mechanics.

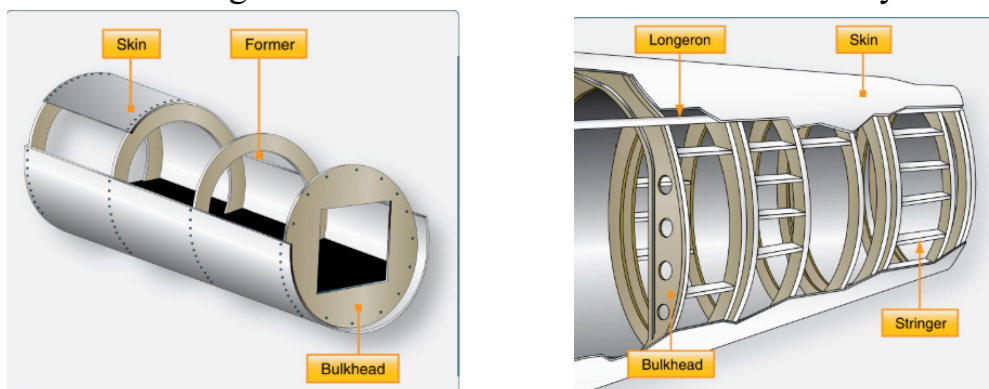


Figure 1.3 - Bulkhead (pressure frame)

The frame in question is Frame 37, located above the ramp. The structure of the frame is composed of web, top cover, bottom cover, plate and strengthening material.

Fuselage design No. 37 72.00.0937.200.000 S Wip is attached to Appendix A.

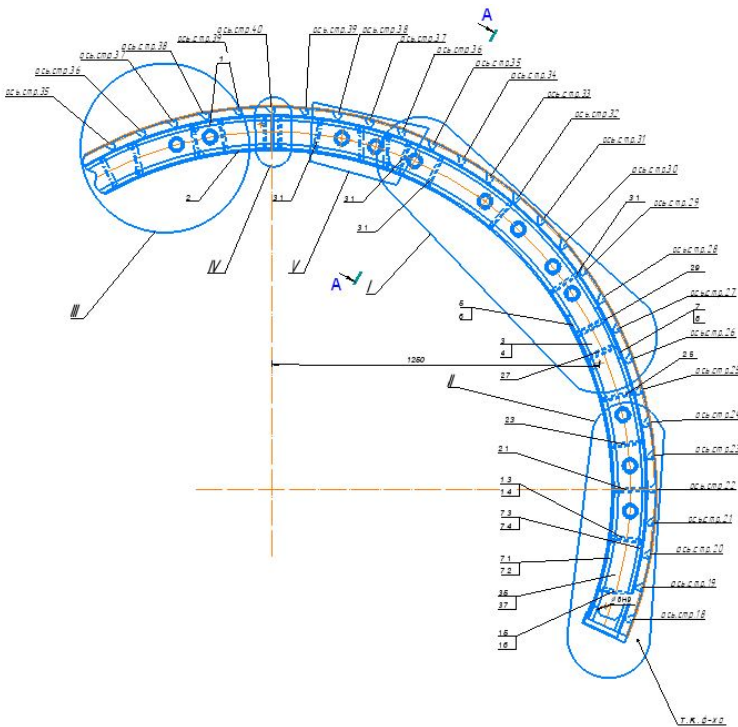


Figure 1.4 - General view of the frame No. 37

The most important feature of the An-72 is that its engine is placed on the wing, blowing air over the upper surface of the wing, using the wall to generate a large amount of additional lift, improving short-range capability - distance take-off and landing; The possibility of inhalation of ground debris.

The an-72 is a light short take-off and landing jet transport designed to operate on non-equipped runways. Powerful wing lift devices and improved thrust-to-weight ratios ensure the aircraft's ability to take off and land short distances. An engine mounted above the upper surface of the wing provides lift enhancement during takeoff and landing because the wing and the flap upper surface of the central part of the wing are blown by the engine exhaust jet (wall effect). The AN-72 was produced continuously at Kharkiv Aircraft Manufacturing Company, with 114 aircraft of this type built between 1984 and 1992.

The frame consist of rims, fittings for attaching horizontal tail, belts, wall, racks. Belts and racks are made in the form of special profiles, the wall is made of sheet material.

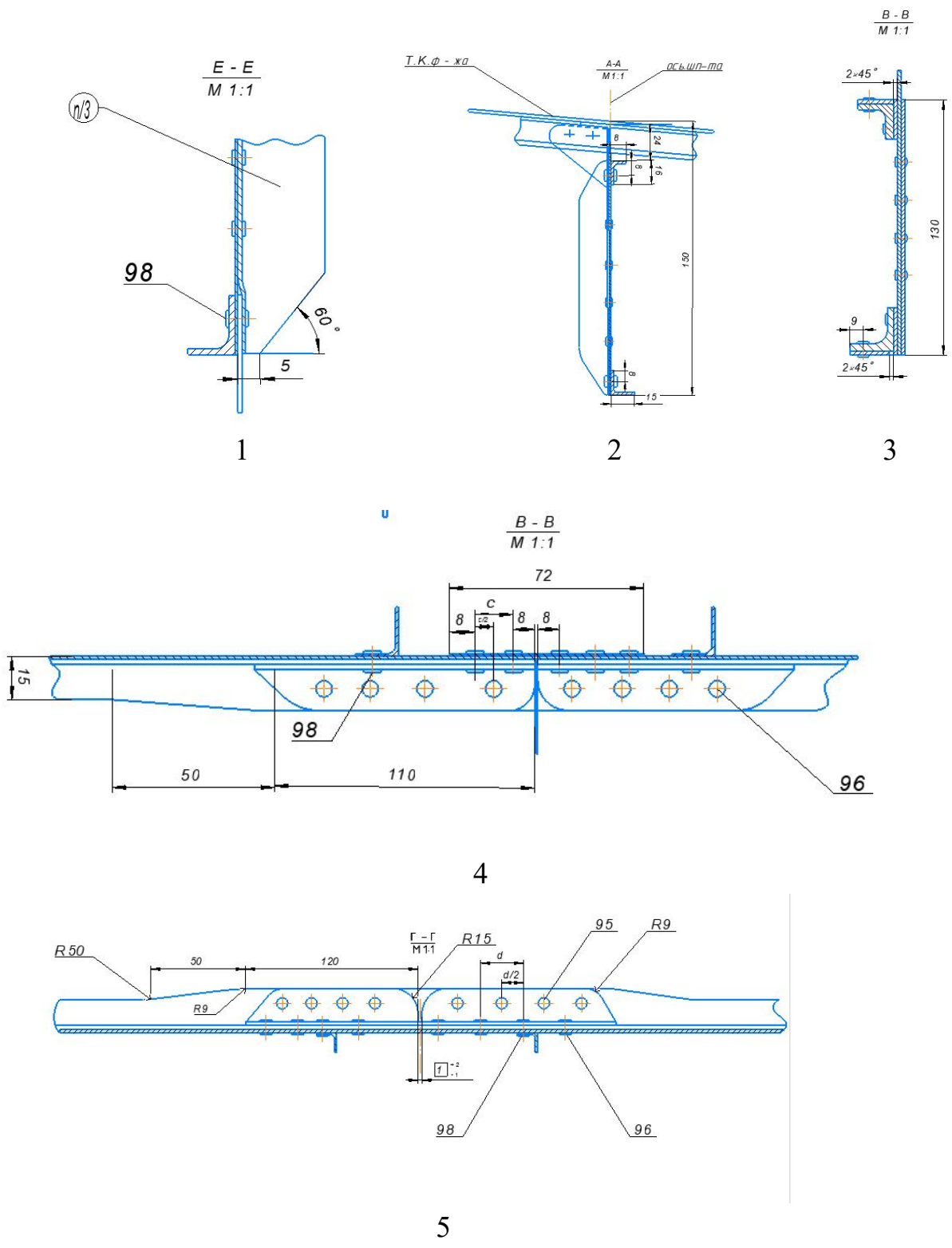


Figure 1.5 - Structure of pressure frame No. 37 of An-72 and their cross section views

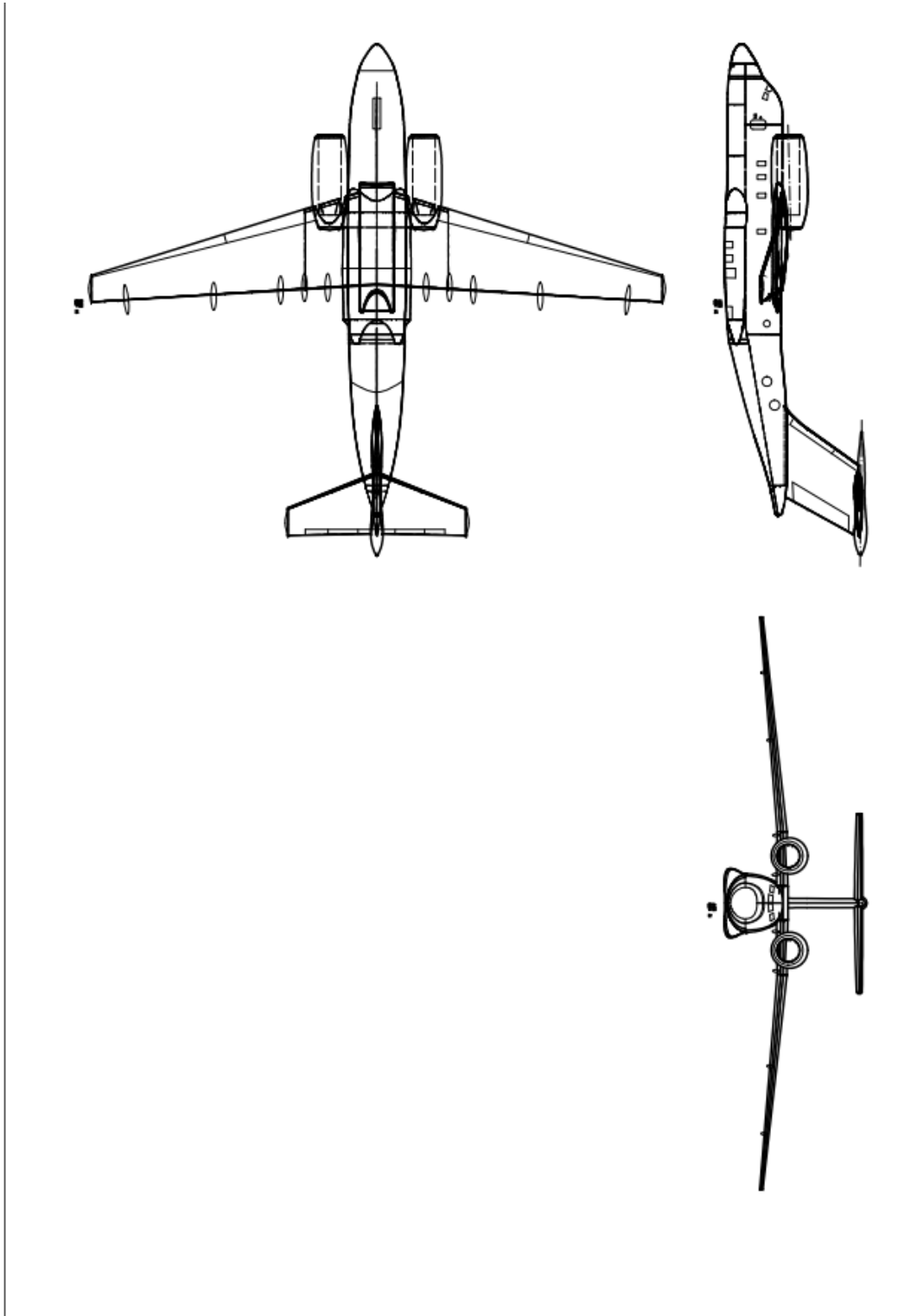


Figure 1.6 - Three View of An-72

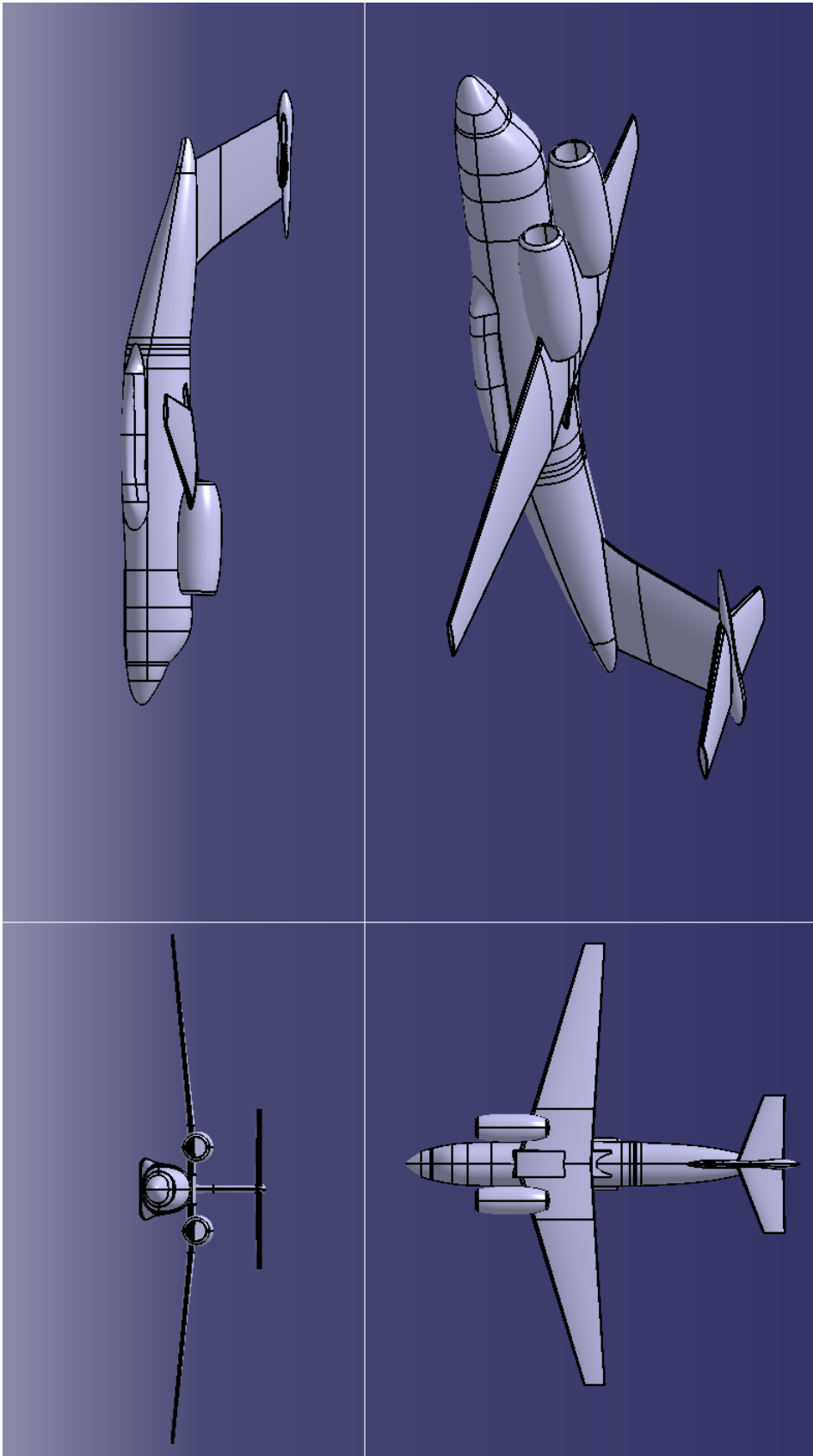


Figure 1.7 - 3D Model Drawing of An-72

The An-72 made its first flight on 22 December 1977, and was most likely developed as a response to the never-built U.S. Air Force Advanced Medium Short Takeoff and Landing Transport (AMST) launched a decade earlier. Produced alongside the An-72, the An-74 variant adds the ability to operate in severe weather conditions in polar regions, as it can be fitted with wheeled ski landing gear, deicing equipment and many other upgrades that enable the aircraft to support operations in Arctic or Antarctic environments. Other An-72 versions include the An-72S VIP transport aircraft and the An-72P Maritime patrol aircraft.

The an-72 is a light short take-off and landing jet transport designed to operate on non-equipped runways. Powerful wing lift devices and improved thrust-to-weight ratios ensure the aircraft's ability to take off and land short distances. An engine mounted above the upper surface of the wing provides lift enhancement during takeoff and landing because the wing and the flap upper surface of the central part of the wing are blown by the engine exhaust jet (wall effect). The AN-72 was produced continuously at Kharkiv Aircraft Manufacturing Company, with 114 aircraft of this type built between 1984 and 1992.

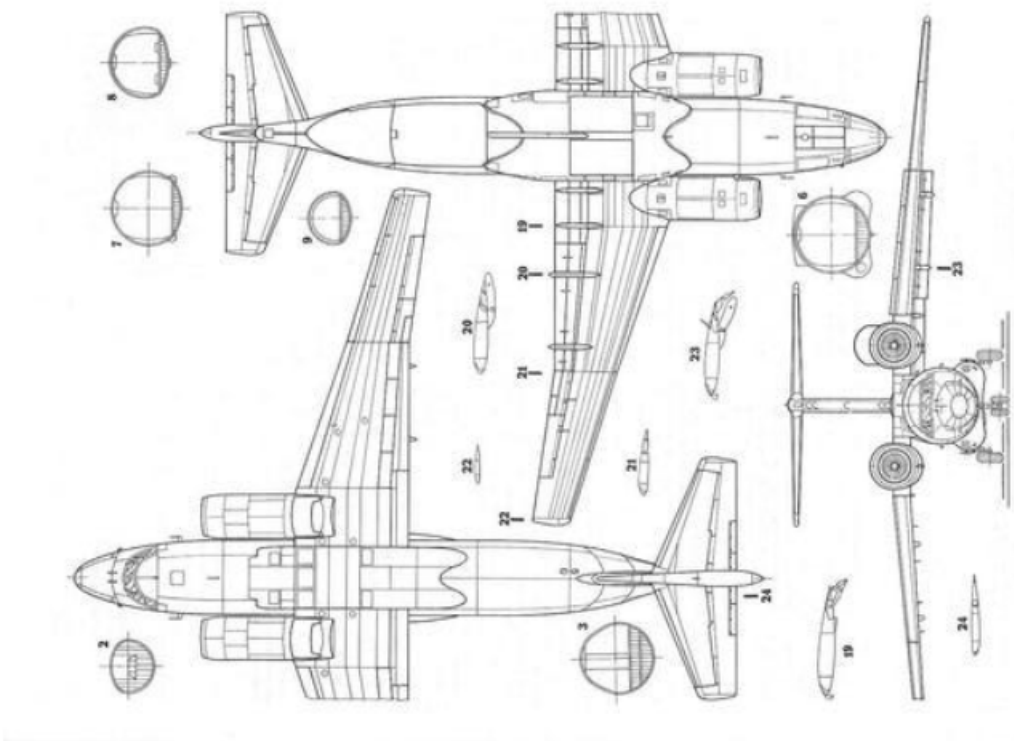


Figure 1.8 - Cross-Section Drawing of An-72

1.1.1 A brief description of the design of an aircraft type An-72

General characteristics of airplane An-72



Figure 1.9 - Actual Photo of An-72

General characteristics:

- Length: 28.10 m (92 ft 1 in)
- Wingspan: 31.90 m (104 ft 7 in)
- Height: 8.70 m (28 ft 8 in)
- Wing area: 51 m² (549 ft²)
- Empty weight: 18610kg (38240 lb.)
- Max. takeoff weight: 34500 kg (76058 lb.)
- Alternate power plant Pratt & Whitney PW127A turboprops, 1,900 kW
- Crew: two
- Capacity: 68passengers

Performance:

- Maximum speed: 705 km/h (438 mph)

- Cruise speed: 600 km/h (373 mi)
- Range: 2000 km
- Ferry range: 3680 km (2290 mi)
- Service ceiling: 10700m
- Rate of climb: 83 m/s

1.2 Substantiate decision made with calculations

Indicative Performance Data

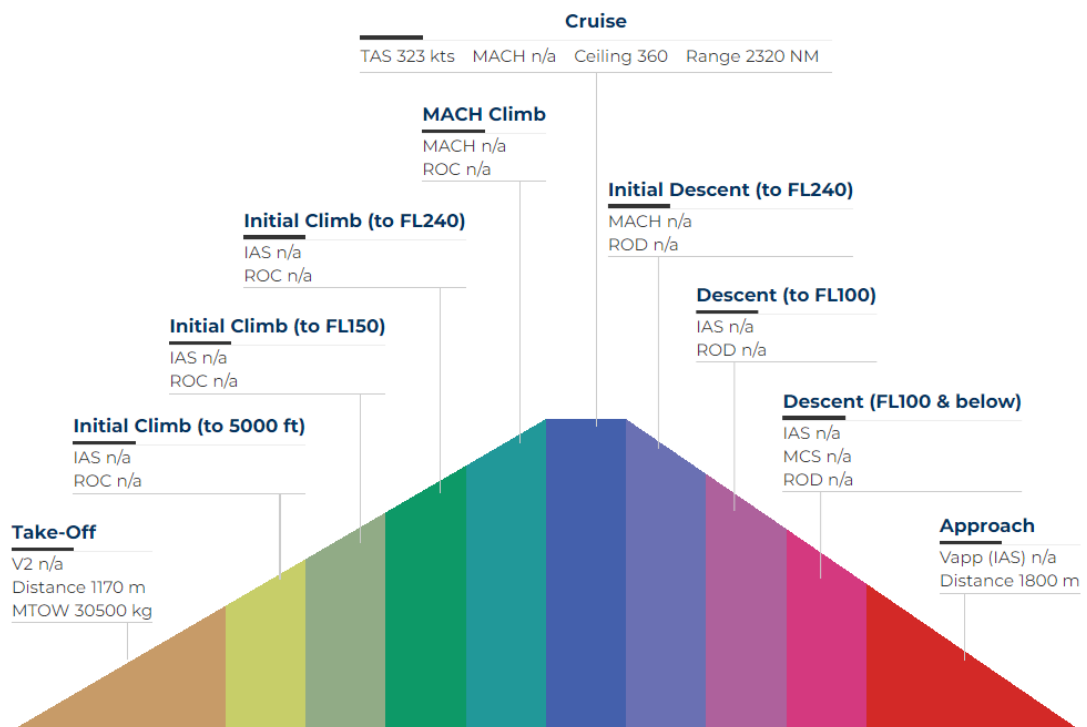


Figure 1.10 - Basic parameters of the aircraft

In a steady level flight, the balancing load on the horizontal tail (HT) is calculated from the condition of equality of two moments of forces relative to the center of mass of the aircraft [1]:

$$M_{(\text{horizontal tail})} + M_{\text{longitudinal}} = 0 \quad (1.1)$$

where (1.2) $M_{(\text{horizontal tail})} = P_{\text{Bal.hor}} L_{\text{TO}} - \text{longitudinal moment}$;

$P_{\text{Bal.}}$ – Balancing load

$L_{\text{horizontal tail}}$ - the distance from the center of mass of the aircraft to the center of pressure by the aerodynamics;

load of horizontal tail, $L_{\text{horizontal tail}} = 9,75 \text{ m}$

$M_{\text{longitudinal}}$ – the longitudinal moment of the aircraft without horizontal.

The longitudinal moment is determined by the dependence: $M_{\text{longitudinal}}$

$$M_{\text{longitudinal}} = m_{\text{A.O.A}} S_{\text{wp}} b_{\text{cax}} q, \quad (1.3)$$

where is the moment coefficient of the aircraft without horizontal relative to its center $m_{\text{A.O.A}}$ –

mass at a given angle of attack, calculated from the results blowing the aerodynamic model or theoretically by aerodynamic relationships $m_{\text{A.O.A}} = 0,05;$

S_{w} – wing area $S_{\text{w}} = 51 \text{ m}^2;$

c_{w} – wing aerodynamic chord, $C_{\text{w}} = 2,409 \text{ m};$

q - velocity head, ($\rho = 0.5894 \text{ kg / m}^3$ at

$$q = \frac{\rho V^2}{2} = 11298 \text{ Pa}$$

$V = V_{\text{max}} = 705 / 3.6 = 195.8 \text{ m/s}.$

Then the longitudinal moment will be: $M_{\text{longitudinal}}$

$$M_{\text{longitudinal}} = 0.05 * 51 * 2.05 * 11298 = 59060.3 \text{ Nm}$$

Knowing and determining the balancing operational power of GO: $M_{\text{z без го L}_{\text{го}}$

$$P_{\text{bal}} = M_{\text{longitudinal}} / L_{\text{horizontal}} = 59060.3 / 9.75 = 6057.5 \text{ N} \quad (1.4)$$

Multiplying the obtained value by the safety factor f and the operational load factor during maneuver, we find the value of the maneuverable load on the GO: n_{ymax}^3

$$P_{\text{M}} = P_{\text{bal}} \cdot f \cdot n_{\text{ymax}} = 6.57.5 * 1.5 * 2.5 = 22783.1 \text{ N} \quad (1.5)$$

The value of the moment M_0 will be found by the formula:

$$M_0 = \frac{P_{\text{M}}}{2} \cdot z_{\text{c}_w} = 22783.1 * 1.27 / 2 = 14467.3 \text{ Nm} \quad (1.6)$$

From the action of the cutting force in the sections of the beam, a reaction q arises, distributed along the entire length of the beam: P_{M}

$$q = \frac{P_{\text{M}}}{2Rk} = 22783.1 / (2 * 0.875 * 0.9) = 14466 \text{ N/M} \quad (1.7)$$

where R is the radius of the frame, $R = 0.875 \text{ m};$

k is the reduction coefficient, $k = 0.9.$

The design scheme is presented in Figure 1.2.2.

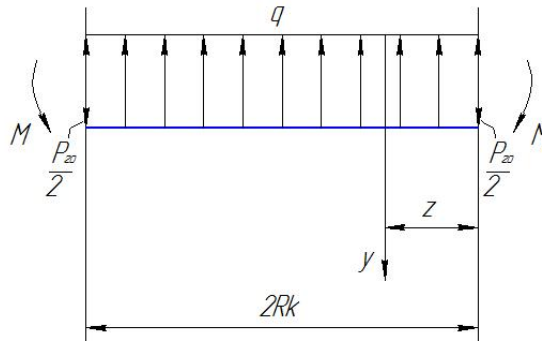


Figure 1.11 - Calculation scheme

The values of the cutting forces and bending moments in the beam sections are equal to: $Q_y M_x$

$$Q_y = \frac{P_M}{2} - q \cdot z \Big|_{z=0} = 11392\text{N} \quad N \Big|_{z=2Rk} = 11392 - 14466 \cdot 2 \cdot 0.875 \cdot 0.9 = -11392\text{N}$$

The function therefore has an extremum on the diagram of bending moments.

$$Q_y = 0,7875 \text{ m}$$

$$M_x = M_0 + \frac{P_M}{2} z - \frac{qz^2}{2} \Big|_{z=0} = 14467.3\text{Nm} \quad \text{Nm} \Big|_{z=2Rk} =$$

$$14467.3 + 11392 \cdot 2 \cdot 0.875 \cdot 0.9 - (14467.3 \cdot 4 \cdot 0.875 \cdot 0.875 \cdot 0.9 \cdot 0.9 / 2) = 14467\text{Nm}$$

Function extremum value:

$$M_x \Big|_{z=0,7875} = 14467 + 11392 \cdot 0.7875 - (14467 \cdot 0.7875 \cdot 0.7875 / 2) = 18952\text{Nm}$$

The figure is shown in Figure - 1.7

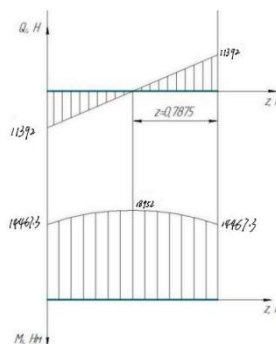


Figure 1.12 - Diagram of distribution loads

The action of the bending moment is perceived by the cap of the beam, in which there are axial forces N , determined by the formula:

$$N = \frac{M_{\max}}{L_{c.g.}}, \quad (1.8)$$

where $L_{c.g.}$ is the distance between the centers of mass of the shelves (figure 1.5).

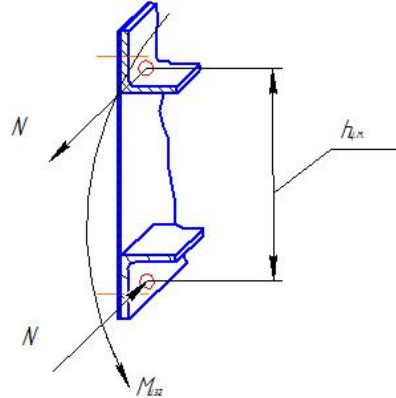


Figure 1.13 - Structural diagram of the beam

Knowing the value of the maximum bending moment, you can determine the axial forces N : $L_{c.g.} = 0,146 \text{ m}$ $M_{\max} = 18952 \text{ Nm}$

$$N = \frac{M_{\max}}{L_{c.g.}} = \frac{18952}{0.146} = 129808 \text{ kN}$$

The allowable stresses arising in the sections of the zones, we calculate by the formula:

$$\sigma_{\text{allowable}} = \frac{N}{F}, \text{ moreover,} \quad (1.9)$$

$\sigma_{\text{critical stress}}$ - critical stresses of local buckling.

Knowing the parameters of the section of the cap, we determine the real and critical stresses. A sketch of the section of the cap is shown in Figure 1.8

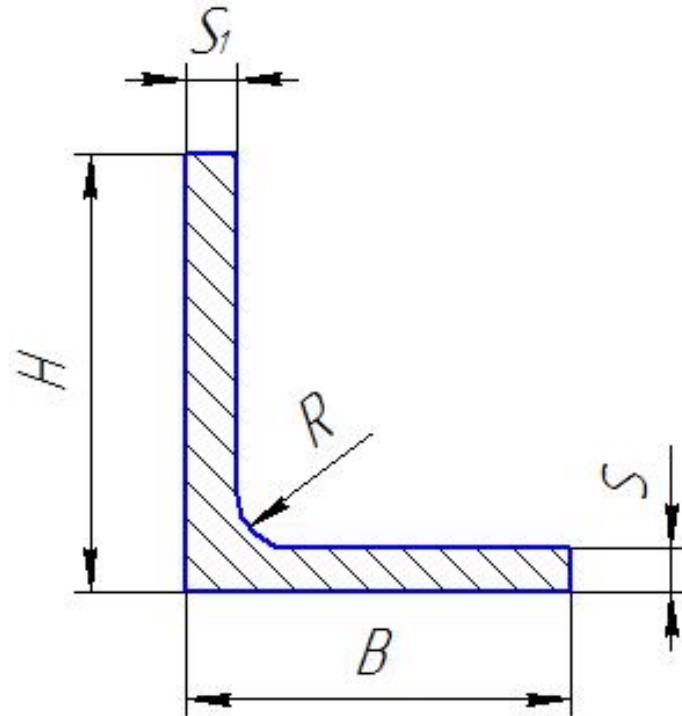


Figure 1.14 - Sketch section of the Cap

$H=16\text{mm}$ $B = 15\text{mm}$ $S_1= 2\text{ mm}$ $S=3\text{ mm}$ $R=4\text{ mm}$ $F=0.76\text{ cm}^2$

$$\sigma_{\text{allowable}} = \frac{N}{F} = \frac{129808}{0.76 \cdot 0.0001} = 170\text{ MPa}$$

Cap material in the compressed zone - D16T:

$$\sigma_B = 440\text{ MPa}; \sigma_{0.2} = 290\text{ MPa}; E = 72\text{ GPa}.$$

Then

$$\sigma_{\text{critical stress.}} = \frac{0,9 \cdot k \cdot E}{\left(\frac{b}{s}\right)^2} = \frac{0,9 \cdot 0,45 \cdot 72 \cdot 10^9}{\left(\frac{55}{5}\right)^2} = 292\text{ MPa}, \quad (1.10)$$

where k is the coefficient of support, $k = 0.45$;

E is the modulus of elasticity;

b and s are profile parameters.

Actual stresses do not exceed destructive, therefore, the structural strength is ensured.

The main purpose is to compare the two materials and choose better one, we need to select it according to the characters of the two materials. The main physical and mechanical properties of materials D16T and 1420 are given in table 1.1.

Al – Mg – Li – Cu ~8%~10%

Table 1.1 - Physico-mechanical properties of alloys D16T and aluminium alloy 1440

Parameter	D16T	Alloy 1420
σ_B , MPa	440	450
$\sigma_{0.2}$, MPa	290	290
δ , %	10	10
ρ , kg / m ³	2770	2560
E, GPa	72	80

According to the table shows that the strength of the alloy 1420 slightly exceeds the strength of the alloy D16T. Therefore, replacing the material, the dimensions of the cross section of the cap remain unchanged. The main criterion is density.

The mass of cap made of D16T material is:

$$m_{D16T} = \rho V, \quad (1.11)$$

where is the volume of the Cap,

$$V = 4 \cdot 4,98 \cdot 10^{-4} \cdot 0,875 \cdot 0,9 = 1,569 \cdot 10^{-3} \text{ m}^3$$

Then

$$m_{D16T} = \rho V = 2770 \cdot 1,569 \cdot 10^{-3} = 4,346 \text{ kg.}$$

The mass of cap made of material 1420 will be:

$$m_{1440} = \rho V = 2560 \cdot 1,569 \cdot 10^{-3} = 4,017 \text{ kg.}$$

The decrease in beam mass will be:

$$\delta = \frac{m_{D16T} - m_{1440}}{m_{D16T}} \cdot 100\% = \frac{4,346 - 4,017}{4,346} \cdot 100\% = 7,6\%. \quad (1.12)$$

Thus, replacing the material will reduce the weight of the structure by 7.6%, providing the necessary strength and increased crack resistance.

1.2 Technical Description and Technological Analysis Of Frame No.37

The frame No.37 consists of web, top cap, bottom cap and stiffeners. The frame is located near the door of the cargo that is above the ram. The frame has one type of stiffener riveted to the web.

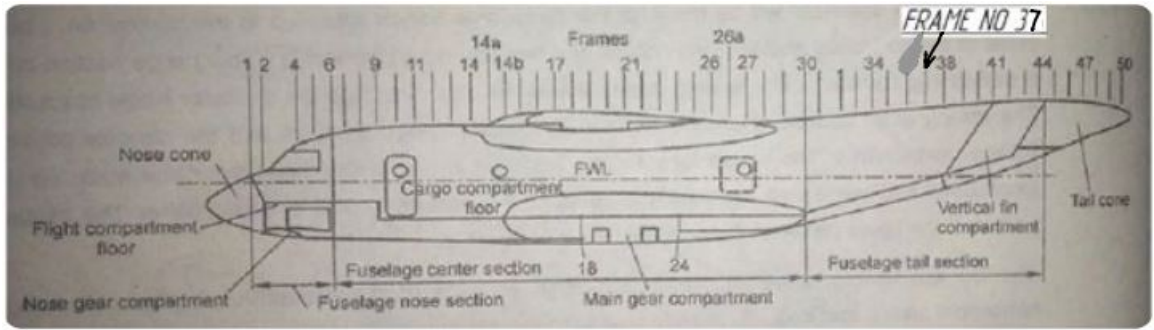


Figure 1.15 – Side view of An-72

All processes are carried out in accordance with modern aviation standards, so the calculation process and material comparison are all standardized.

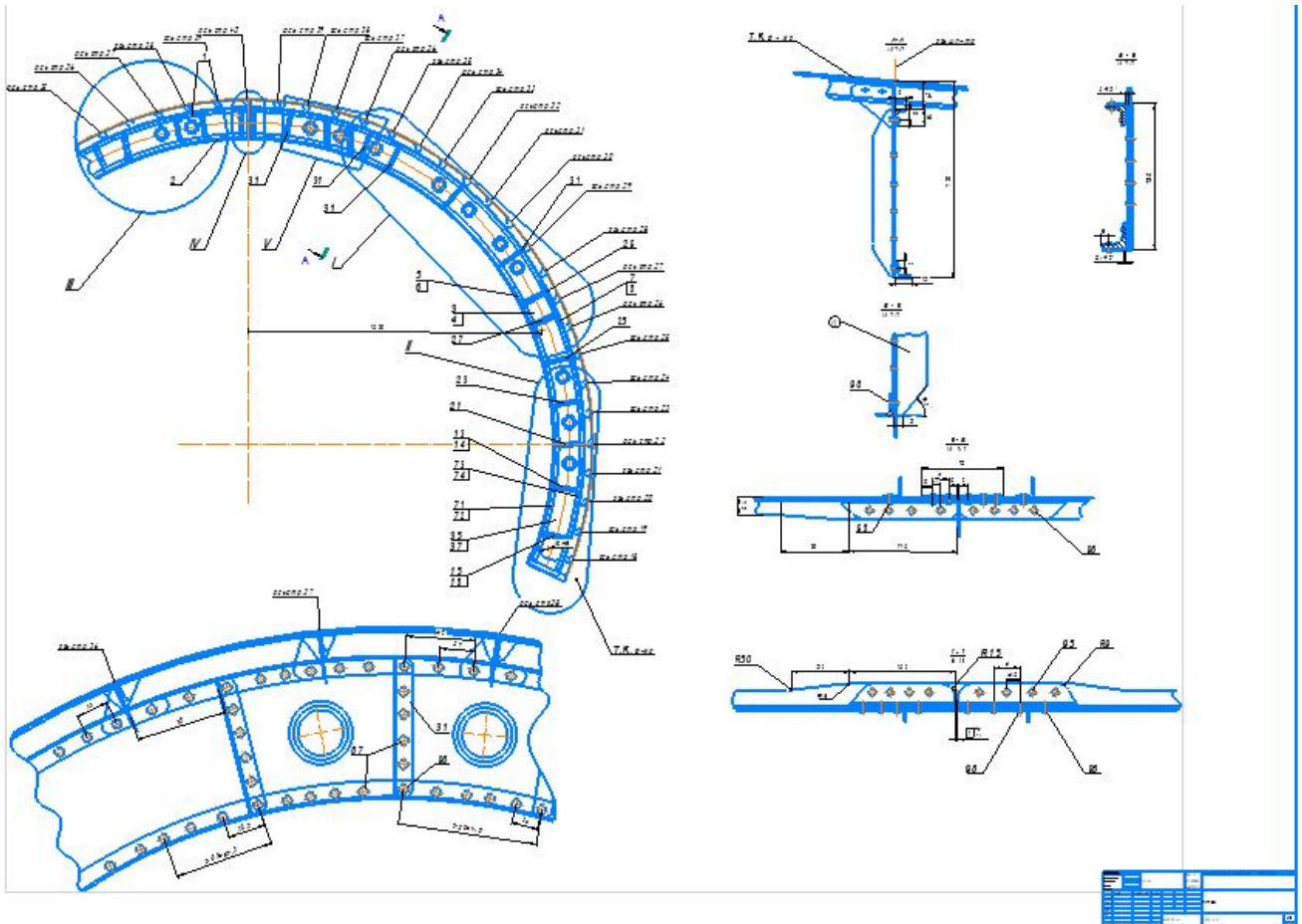


Figure 1.16 – Drawing of Frame No.37 of Fuselage

1.4 Work out technical specification for the longitudinal beam

The technical specifications relate to alignment accuracy, the completeness of the components that make up the assembly units, possible deviations in shape and size, requirements for making joints and platforms, surface cleanliness, heat treatment, and testing and control conditions for the assembled products. The following requirements are imposed on this node:

1. Unspecified limit deviations of sizes, shapes and locations of surfaces according to OST100022-80.
2. Installation of bolts according to PTM 1.4.1941-89 on the ground EP-0215.TU 6-10-1966-84. Repl. to process under bolts, PTM 1.4.1935-89. $H7 \sqrt{1,6}$
3. Coating the heads of bolts, nuts, protruding threaded parts enamel EP-140, dark green, 473, OST190055-85.
4. Bolt Tightening:

$$M5 - M_{\text{torque}} = (5,48 \pm 0,5)\text{Nm}[(0,56 \pm 0,06)\text{kgs} \cdot \text{m}]$$

$$M6 - M_{\text{torque}} = (6,3 \pm 0,7)\text{Nm}[(0,65 \pm 0,07)\text{kgs} \cdot \text{m}]$$

$$M8 - M_{\text{torque}} = (15,97 \pm 1,59)\text{Nm}[(1,63 \pm 0,16)\text{kgs} \cdot \text{m}]$$
5. Rivet on TI-412-90 "X". The riveting is automatic, press.
6. Coating the rivet heads after riveting enamel EP-140, dark green, 471, OST190055-85.
7. Metallization according to OST101025-82 with rivets.
8. If there is a gap between the plane of the fittings, belts and rims up to 1 mm, gaskets with a thickness of up to 0.5 mm are allowed. Gaskets D16-AT OST290346-77 coated An.Oks.N.hr./ enamel EP-140, dark green, 457, OST190055-85.

Conclusion

After going through the first part of the design, we chose a better material to replace, the new material also has better performance, everything meets the standard requirements

SPECIAL SECTION

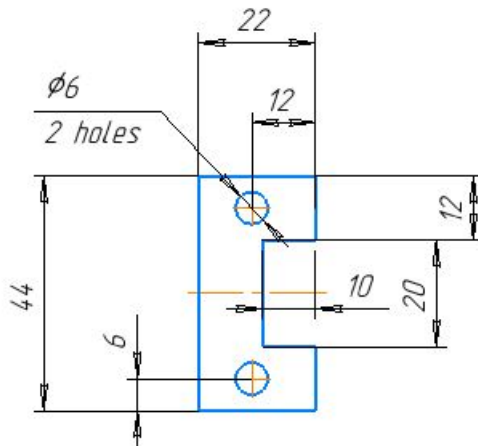
2.SPECIAL SECTION

2.1 Selecting of blank for manufacturing of part by stamping and technological scheme of the die.

2.1.1 Determining the shape and sizes of blank for stamping, selecting the most rational sheet size. part description and analysis of part geometry

According to my part, the concave section I need to press is 44 mm long, 22 mm wide and 1.4 mm thick. The concave section has two holes of 6 mm diameter, as shown. The material used for this part is S T E E L 1 0 and has the following strength.

Operational sketch



1. Material Steel 10 GOST 1435-90, $S = 1.4\text{mm}$
2. Technical Force $P = 330\text{ KN}$
3. Tolerance $H14, h14, \pm IT14/2$

Figure 2.1 - Drawing of the Part

2.1.2 Method of part manufacturing (sheet stamping):

Standard metal plates (blanks) are cut into strips whose width depends on the size of the part. The strip is mounted to the module installed on the lower template. The downward motion of the punch (attached to the upper template) forces the punch to cut the shape of the metal part. The press has a removable upper plate fitted with punches. The nature of death. Finally, the required parts (punches or blanks) are collected and the

rest is disposed of as scrap.

If we are going to choose billet, we must consider efficient utilization, as it further determines the bar nesting pattern. **Analyzing the possibility of low-wasted nesting:**

When we use guillotine cutting, we have to take into account waste. We can compare the tolerance δp of the part size with the tolerance $\delta g.s$ provided by the guillotine shears.

For 13th quality class δp for dimensions between 22 to 50mm (dimension of my part) is: $\delta p = 0.39$

Whereas $\delta g.s$ for the strip with width less than 100 mm and thickness 1.4mm is: $\delta g.s$

$= 0.6$, Since $\delta p < \delta g.s$ so, quality of manufacturing cannot be assured without the use of tabs at lower and upper edges of part. Hence it is necessary to consider tabs.

Deciding the tab dimensions m and n , Vertical distance between parts and strip edge (m) = 2.0 mm horizontal distance between parts (n) = 2.0 mm.

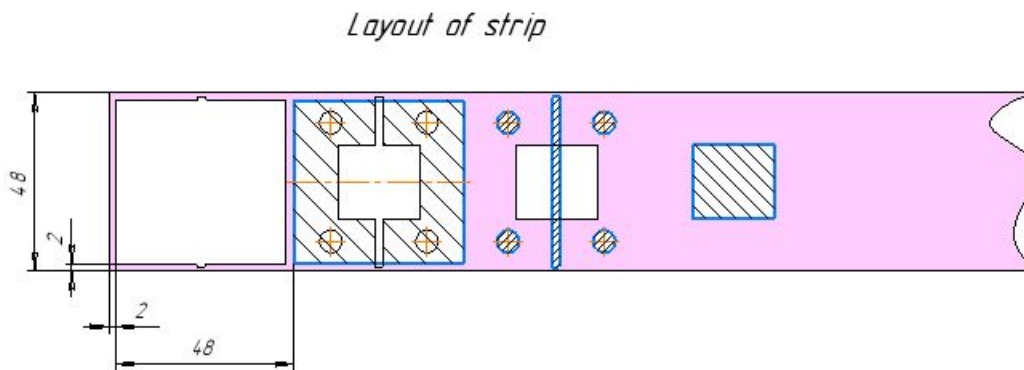


Figure 2.2 - Layout of strip

Let's choose the most rational cutting of a sheet of the standard sizes.

From a number of standard sizes of a sheet for the stamped material Steel 10 of GOST 1435-90 and the set thickness of a sheet we choose the sizes of a sheet: 1000x1000mm. and 1250x1250mm. [4, p.18].

a) sheet 1200x1200mm with a transverse arrangement of strips . 1) Number of lanes: $= 1000/48 = 20.83$. (2.2)

We accept 20

2) The number of parts in the strip: $= 20.83$ pcs (2.3) We accept 20

- 3) The number of parts that fit on the sheet: $20 \times 20 = 400$ 4)
- 4) $KIM (\eta) = 400 \times 2304 / 1000 \times 1000 = 92.16\%$ (2.4)
- b) sheet 1250x1250mm with a longitudinal arrangement of strips
- 1) Number of lanes = 26.04. We accept 26 (2.5)
- 2) The number of parts in the strip: = 26.04 (2.6) We accept = 26 pieces.
- 3) The number of parts that fit on the sheet: $.26 \times 26 = 676$ 4) KIM
- 4) $(\eta) = 676 \times 2304 / 1250 \times 1250 = 99.65\%$.

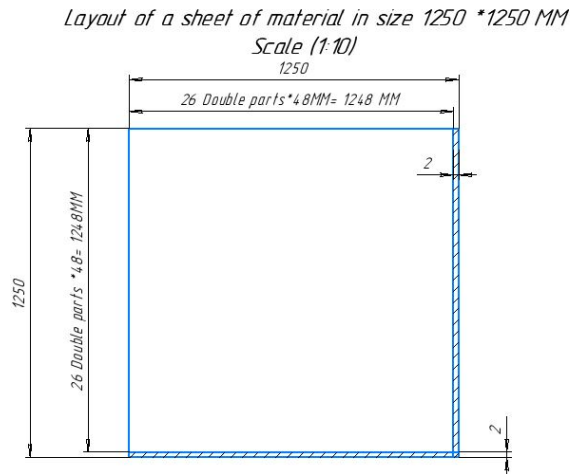


Figure 2.3 - Location of stripes on the sheet 1250x1250 mm.

2.1.3 Selection of technological scheme of stamping and scheme of stamp

Stamping method:

Because the part is not complex. I am choosing the combined stamping method for part manufacturing, this method decreases the labor intensiveness and cost price of parts.

Operating steps order:

Selecting the steps of producing the part, and different technologies . also higher for such stamps. The schematic illustration of such stamp is presented below:

Layout of strip

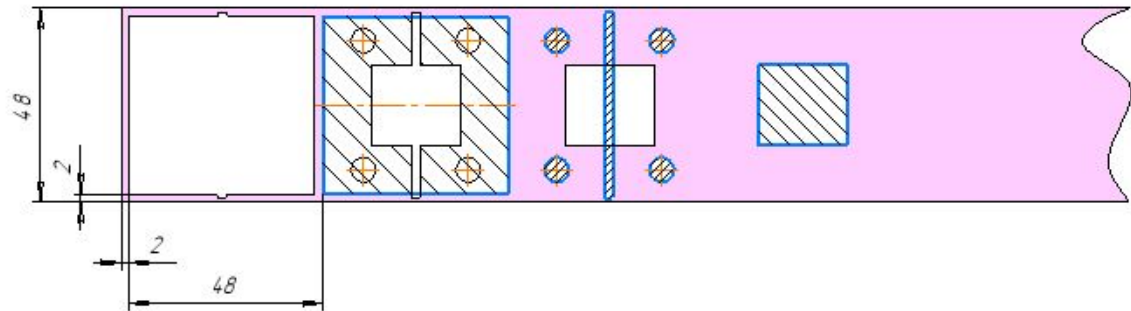


Figure 2.4 - The stamping scheme

Submit manually according to the presentation and installation of the workpiece in the stamp. Fault treatment is carried out through holes in the matrix according to the method of removing scrap and parts. After the first stroke (when the first hole is punched), a part is made in one stroke of the stamping slider.

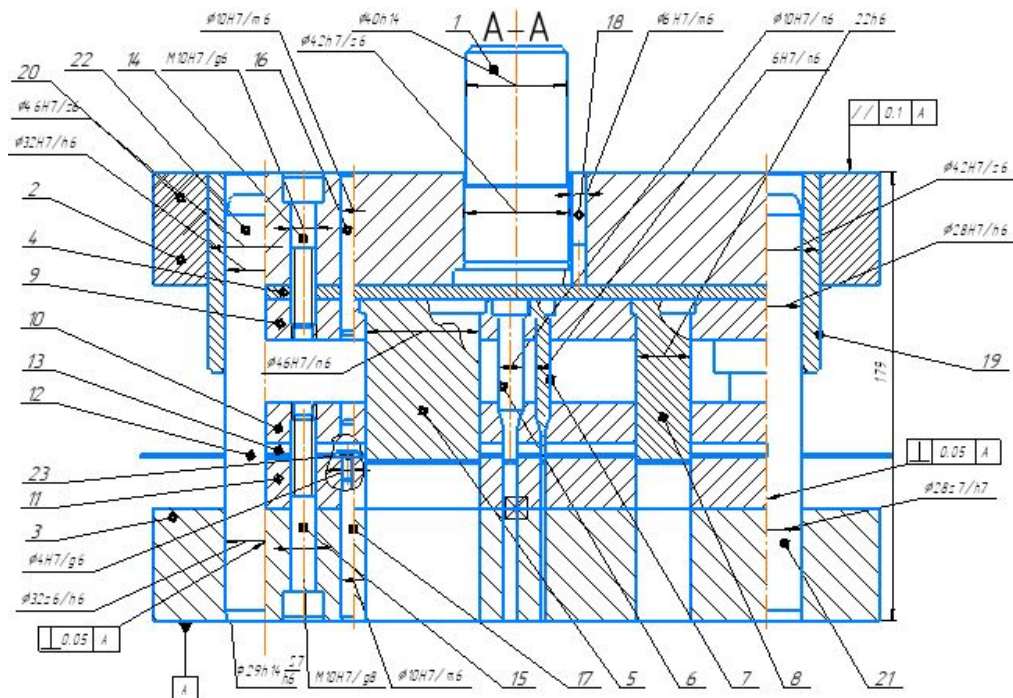


Figure 2.5 - Technological scheme of the stamp

2.1.4 Determination of power parameters of stamping

The power parameters of stamping include the forces of stamping, removal and pushing.

The force P of cutting out of the circuit, if the workpiece or waste freely fall into the hole of the matrix, is determined as follows [5, p.56]:

$$P = k \cdot \tau_p$$

$k = 1.1 \dots 1.3$ - the coefficient takes into account the unevenness of the thickness of the material, its mechanical properties, blunting of the cutting edges, etc
 .;

-resistance of the stamped cut material; L is the perimeter of the contour or hole; $S = 2 \text{ mm}$ - thickness of material.

$$\text{where } k \cdot v_{cu} = \sigma_B < P = \sigma_B \cdot L \cdot S \quad (2.8)$$

- tensile strength for steel 10 = 1110 MPa

The total effort for felling-punching is found by the formula: $P_{sh} = 0.7 \times 1110 \times 350 \times 1.4 \text{ KN} = 380.73 \text{ KN}$ (2.9)

The force of pushing the cut part and the waste for the matrix with a cylindrical belt when working on the failure is determined by the formula [5, p.60]:

Where $P_{\epsilon} = P_{sh} + P_{push} = P_{sh} + 0.05 P_{sh} \times N = 437.84 \text{ KN}$ (2.10) $k = 0,05 \dots 0,08$, for $S = 2 \text{ mm}$, we accept $k = 0,05$;

$h = 6 \text{ mm}$ - height of a cylindrical belt of a matrix;

- felling and punching efforts;

S is the thickness of the sheet material.

Determine the force of the push when punching: $= 0.05M$ Determine the force of pushing when felling: $= 0.05$

Find the total pushing force: 57.11 KN

The removal force is not calculated, because the press effort is not expended on it -

the removal of the strip is carried out on the reverse stroke of the press slider.

2.2 Stamp designing. selection of equipment

2.2.1 Center of pressure of stamp

At this step i need to choose different process, such as blanking, punching and so on.

In order to place a complicated shape dead on center, first the center must be

located.

The method for calculating pressure centers with irregular shapes is illustrated in the sample shown in Figure 2-6.

First, shapes must be broken down into single lines, regardless of the geometric entity they form. The X-Y axis should be located at the corners of the shape to establish the zero position.

To calculate the length of each line, and the distance from its center to the zero on the x and y dimensions. The length of each row should be called L, and its subscript determines the sequence number of the row.

The center of the shape should then be calculated separately along each axis. The formula is as follows:

$$X_{center} = \frac{L_1 X_1 + L_2 X_2 + \dots + L_n X_n}{L_1 + L_2 + \dots + L_n}$$

and

$$Y_{center} = \frac{L_1 Y_1 + L_2 Y_2 + \dots + L_n Y_n}{L_1 + L_2 + \dots + L_n}$$

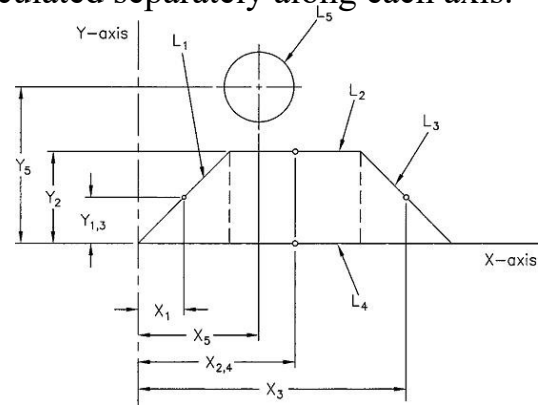


Figure 2.6 - Center of pressure

calculation diagram

The main requirement for normal work procedure (without stamp skewing, irregularity of gaps between punches and the die, deterioration of press slideways, etc.) is: resultant stamping force axis and shank axis must be coincident.

Center of pressure can be determined by equalizing a moment of resultant force and a moment of stamping forces (punching forces) about one axis.

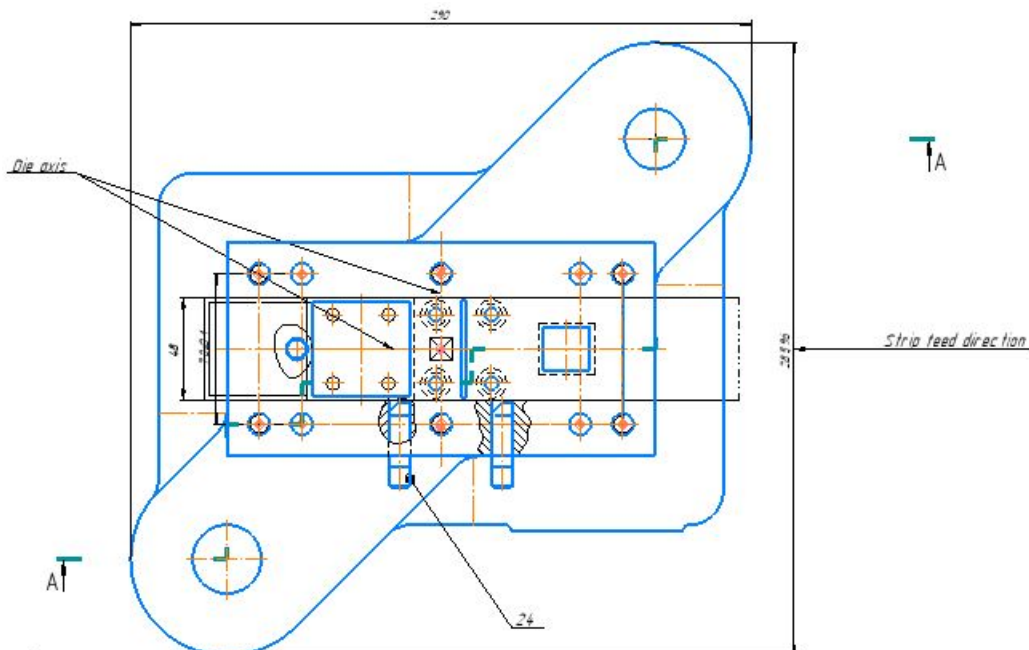


Figure 2.7 - Center of pressure (another method of calculation)

Analytical method of center of pressure calculation gives the following formulas for X center and Ycenter (a', b' and c' not shown on fig. 2.2):

$$X = \frac{P_1 \cdot l_1 + P_2 \cdot l_2 + P_3 \cdot l_3 + P_4 \cdot l_4}{P_1 + P_2 + P_3 + P_4}, \text{ ge } Y = \frac{P_1 \cdot l'_1 + P_2 \cdot l'_2 + P_3 \cdot l'_3 + P_4 \cdot l'_4}{P_1 + P_2 + P_3 + P_4},$$

Ycenter=24 mm, Xcenter=63.0mm

xcenter – distance from *y* axis to the center of pressure; *ycenter* – distance from *x* axis to the center of pressure; *P1, P2, P3* – punching forces;

a, b, c – distances from the center of pressure of respective punches to *y* axis;

a', b', c' – distances from the center of pressure of respective punches to *x* axis.

Instead of forces *P1, P2, P3* one can use the respective perimeters of figures, because $P_{p-i.c} = k \cdot sh \cdot LcS$, and parameters *k, sh* and *S* are the same.

If punches have axial symmetry (e.g. *xc* symmetry on figure 2.1) then one of the distances (*xCP* or *yCP*) shouldn't be calculated (it is equal to zero). E.g., the *xc* axis (figure 2.1) goes through the center of punch plate.

An axis of press shank must go through the die's center of pressure (intersection of *xc* and *yc* axes).

2.2.2 Design of a stamp in CAD "Compass-stamp". Description of the design and procedure

In this work, we design stamps using the Compass-stamp system. Compass Stamp System is an application software product of Automated Stamp Design System. The Compass-Stamp system is implemented in a Windows environment using the drawing and design editor Compass-Graph.

The process of designing a stamp by means of the Compass-stamp system consists of two stages:

- 1) formation of the project of a stamp design;
- 2) design of a stamp and formation of a set of drawings on the design presented in the project.

We create from the stamp's "item tree," so we click the cursor on the green circle near the name of the item, and the "Add to Stamp Item" button opens. In the window that opens,

select the cursor item Stamp, and then click Add to Stamp. From the menu that opens, select Sketch Details, Form Workspace, and click Add.

After deleting the sketch of the part in the menu "Tools" activate the library.

WORKING ZONE, where we select the punch stamp. After that, the command menu (Figure 2.8) will appear on the screen, in which you need to activate the menu bar "Detail (!)" To form the scheme of the strip. The system requests:

- "Enter the thickness of the material" ($S = 2 \text{ mm}$);
- "Choose the brand of material" (choose STEEL10 GOST 1435-90);
- at the request of the system "Blank-strip"? answer in the affirmative;
- in the menu that appears, "Type of jumpers" select both for side and for intermediate jumpers type "Rectangle";
- we answer the question "Stamp combined" in the negative;
- determine the side and inter-bridge jumpers (in our case 2.0 mm (side) and 2.0 mm (inter-part)).

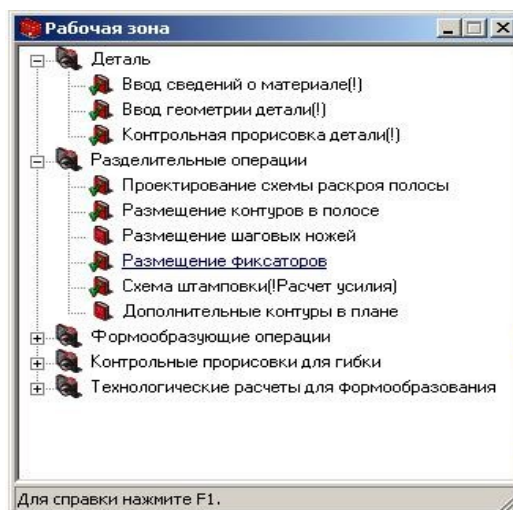


Figure 2.8 - Designing a work area

Next, select the command "Control Part Drawing" from the menu.

The part control chart is to check the correctness of the part chart. This section must have 2 Outlines.

After selecting the Control Part Drawing command, a part sketch model with all numbered Outlines will be displayed on the screen. Let's fix a phantom on the drawing field. The number of numbered Outlines should not be different from the number of crossed out Outlines.

Select the command Design Cut Plan. We assigned a frame profile for stamping. In the slide menu, select the stripe type for single row rotation

Cut. Next, select the command "Cut schema build." A phantom of the stamping appeared on the screen. We fixed a phantom on the image and a similar phantom of

the following detail appeared on the screen. Place it so that the lines touch each other and provide the intermediate jumper value defined earlier. If this is not correct, adjust the location of the phantom in the dialog box that appears. After the cutting scheme is fixed on the drawing, the cutting coefficient calculated from the parameters of the variant is displayed on the screen. Enter cutting parameters into the table using the command Write Table Cutting Parameters. Next, select the command "Place outline in stripe." If necessary, repeat the different types of cuts, and a window with a list of all the cut options will appear on the screen. Select the desired option from the list to fix the Phantom image in the workspace. Next, select the "Placement of clamps" TAB to anchor the workspace. Then the menu item "Stamping scheme (Effort calculation)" is executed. According to the requirements of the system - "Specify the lower left corner of the strip scheme" select a strip scheme using a rectangular box, and exclude elements that fall into the box but do not belong to the stamp working area. Calculate the center of pressure (see the center of pressure shown in Figure 2.7-Envelope). Based on the input data, technical effort and pressure effort are calculated. The data obtained have been given above.

Package design

The Compass-stamp system allows the design of three packaging options: standard, standard and original. In the Diploma project, we will design a standard package, because during the design process, it is at your discretion to change the shape, the relative position of the parts, and the size suggested by the system. The details list remains the same.

Block design

We started designing the unit. To do this, go back to the Project Tree and click Stamp and Add to Stamp. Mark the node "Block" and click "Add". Press the green button "Standard Block", "Add to Standard Block" select "With Sheet Block according to GOST 1435-90". We enter the Compass-schedule and the library "Standard block" has been connected.

To design the bottom floor plan, double-click to activate the bottom (top) of the menu item floor plan. Select the command "Board".

In the parameter that we set the size of the board, the phantom of the board appears on the screen, which we set in the drawing. Select the Columns-bushings command. Mark the center of the stamp axis on the plan. Determine the column types on Slide Menu Smooth GOST 1435-90 and set them at the center of the stamp axis intersection.

We select the plug according to the slide menu - smooth according to GOST 1435-90.

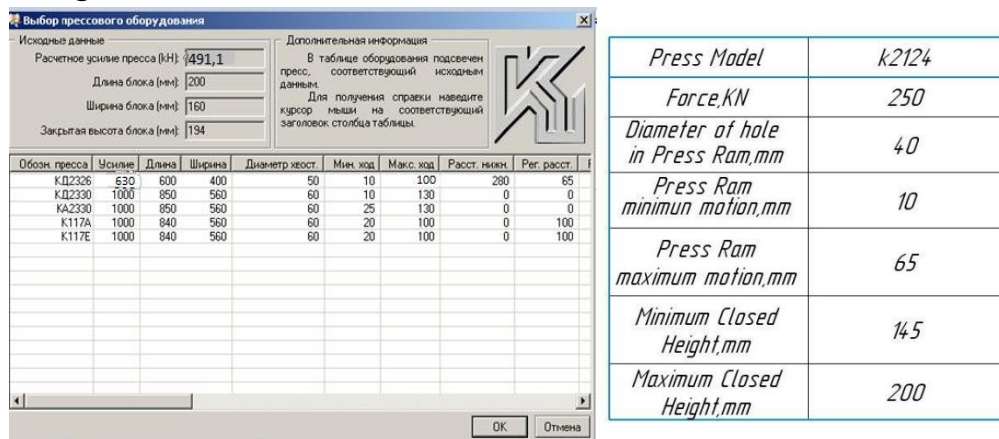
To design a part of the main view, double-click to activate the menu section "Parts of the Main View". Select the command "Board". The phantom of the board

appears on the screen we build on the drawing. Select the command "Column Bushing".

The illusion horn column appears. If the parameters do not fit, you can change them. Install the Column-bushing system in this section.

2.2.3 The choice of the press and its technical characteristics

To select a press, add the "Press Selection" node to the project tree and click the "Design Press Selection" button.



Обозн. пресса	Усилие	Длина	Ширина	Диаметр жест.	Мин. ход	Макс. ход	Расст. нижн.	Рег. расст.
К.Д.2326	630	600	400	50	10	100	280	65
К.Д.2330	1000	850	560	60	10	130	0	0
КА.2330	1000	850	560	60	25	130	0	0
К.117А	1000	840	560	60	20	100	0	100
К.117Е	1000	840	560	60	20	100	0	100

Press Model	k2124
Force,KN	250
Diameter of hole in Press Ram,mm	40
Press Ram minimum motion,mm	10
Press Ram maximum motion,mm	65
Minimum Closed Height,mm	145
Maximum Closed Height,mm	200

Figure 2.9 - The characters of stamping

In the stamped production of relatively small parts, mechanical presses are most often used, due to the large number of strokes of the slider, they are highly productive.

The following basic requirements are made to the chosen press:

-required stamping force should be less than or equal to the nominal force developed by the press:

Since = 328.3 kN, we choose a press that has 330 kN. Technical characteristics of the press

1) For the designed stamp selected mechanical press PB6328M with the following characteristics:

1. **press force P 330 kN;**
2. **maximum closed height 300mm;**
3. **hole in the slider 50 mm;**
4. **minimum press stroke 10mm;**
5. **maximum press stroke 100mm.**

2.2.4 Design of stamp parts

Design of punches

Punches are designed to punch or cut the outline of parts in a variety of configurations and sizes.

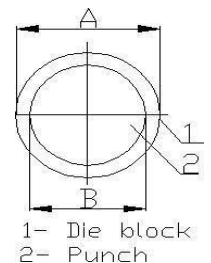
In the Compass-stamp system, two types of punches can be designed: the cutting operation for punch-punch segmentation; For flexible operation, flanging and other shaping operations, punch shaping. In this course project, we will use a punch.

Let's start designing the fist. To do this, click the green button Punch, Add to Stamp in the Project Tree. Label the Punches node and click Add. Then click Punch, Add to Punch. Select "Punctuation Punch" and click "Add." And then another punch. We enter the compass schedule. The Punches library is connected.

Defining the nominal dimensions of inner contours:

$$A = 6.08 \text{ mm}; B = 6 \text{ mm};$$

Where dimension A is of die block and B is of the punch.



Toleranced dimensions of circular punches (dimensions of circular holes in a die) can be calculated by the following formulas:

$$D_d = (D_n - 0.8 \delta) + \delta_d,$$

$$D_p = (D_n + 0.8 \delta) - \delta_p,$$

D_d, D_p – die and punches dimensions; D_n – nominal dimension;

δ – dimensional tolerance of part (for corresponding quality class); recommended table). The results are displayed below in the tabular form

Table 2.1 Circular dimension:

Dimension	Nominal dimension D_n , mm	Tolerance δ , mm	Tool tolerance (δ_p or δ_d), mm	Die (punch) tolerance dimension, mm
A	6	0.2	$\delta_p = 0.009$	$D_p = 6.176 - 0.009$
B	6.08	0.2	$\delta_p = 0.009$	$D_d = 5.904 - 0.009$

Dimensions of non-circular contours can be calculated by the following formulas:

a) decreasing (because of tool deterioration) dimensions – punch dimensions (dimension B and C):

$$P = (P_n + 0.8 \delta) - \delta t;$$

b) increasing (because of tool deterioration) dimensions – die block dimensions (dimension A and D):

$$P = (P_n - 0.8 \delta) + \delta t;$$

P – non-circular dimension;

P_n – nominal dimension;

δ – part dimensional tolerances;

$\delta t = 0.3 \delta$ – tool (die block and punches) dimensional tolerances. The result is mentioned below in the table: Non-circular dimensions.

2.2.5 Formation of drawings

The drawing is formed after the design of the stamp and the system design required for the stamp are fully determined. All design details and systems are drawn on automated detailed drawings. On the drawing, we place a projection of the selected detail.

Drawing formation includes the formation of detailed drawings of the parts of the block and the parts of the package.

The project shows a detailed drawing of the matrix and the second punch. Usage specification

After all detailed drawings of stamps have been created and fully registered, the specification is used. The formation of specifications in the system is performed using all drawings in the project folder, in which the main inscription is filled. If there is a difference, you can edit the specification by selecting "Specification Edit" in the project tree.

2.2.6 Determining the size of the gaps between the punch and the matrix, the executive dimensions of the punch and the matrix

Working details of dies for cutting and punching - a matrix and a punch can be

The design of the designed stamp is shown in Figure 2.12

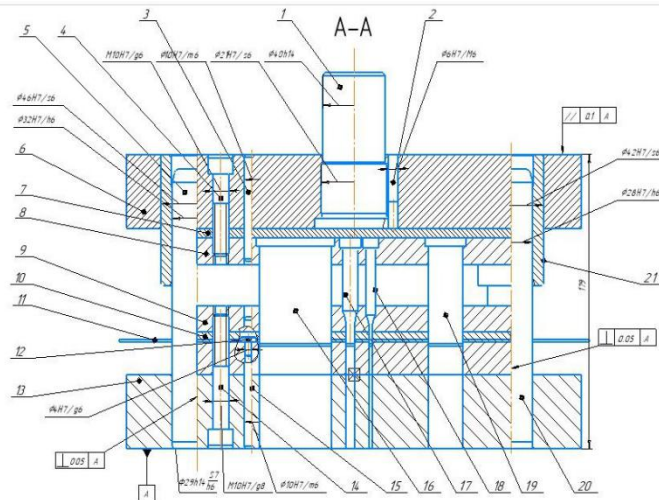


Figure 2.12 - The design of the stamp

1 - shank; 2 - pin; 3 - pin; 4 - screw; 5 - column; 6 - top plate; 7 - laying; 8 - punch holder; 9 - stripper; 10 - guild sheet; 11 - sheet; 12 - stopper; 13 - bottom plate ;14 - pin;15, 16 - punch

2.3 Development of technological materials for fuselage frame No.37

2.3.1 estimation of technological effectiveness of fuselage frame No .37

The technical efficiency of a framework is a set of structural attributes required to optimize the labor and material costs of object manufacturing, as well as the means and conditions in the technical preparation, manufacture, operation, and maintenance of the product to ensure pre-arranged quality under given production and operating conditions. The quality of the aircraft and helicopters that are the objects of production represents a combination of their tactical and technical characteristics and is an indicator of the reliability, longevity and maintainability of the objects. The aircraft or helicopter is evaluated through performance levels and production target levels. The latter depends on the technical perfection of the main production of the continuous plant and the CTE (technical efficiency construction) of the production object. Ctes are structural properties formed at design time that allow the reception of products with high technical and economical specifications at a given quality.

CTE requirements are determined by the following major factors: Product type: component, unit, assembly, airframe, primary functional group of airborne systems, aircraft as a whole; Product output and production type (unit, series, batch). CTE requirements for products manufactured at batch or separate production levels can vary greatly. Mass production must be further advanced in technology. Aircraft frames formed from straight surfaces and their components are easier to manufacture than those made from more complex hyperbolic elements, such as the fuselage, wings, and tail. In its simplest form, the fuselage consists of a series of rotating bodies with long cylindrical sections. Cylindrical and conical surfaces ensure simple rendering of the attic, mathematical modeling of shapes and dimensions, and unity of the extended detailed centralized structure.

2.3.2 analysis of possible variants of assembly methods, schemes of assembling of fuselage and schemes of tooling coordination

An assembly method is a set of rules and recommendations to ensure the accuracy required to close links or dimensional chains during assembly. The assembly method determines not only the accuracy, but also the cost (money) or expense of the assembly and the different cycles. The choice of assembly method depends on the structure of the part or unit. There are different kinds of bases. The lower side is the surface, line, or point (vertex or hole) of one assembly element relative to another. Assembly basis is the basis used to determine the location of parts or assembly units. The main base is the assembly base of the parts or assembly units used to determine their position in the jig. An auxiliary base is a base for a part or assembly unit that is used to locate the product to which it is connected. Assembly bases are divided into primary bases and secondary bases. Basic departments are used for product drawing development and manufacturing processes. This classification is necessary because of the different roles of primary and secondary bases, as well as in product design (part surface structural shape selection, relative position marking, dimensional marking, precision grades) and technical process development and implementation.

A processing datum is a datum used to determine the position of a blank or product during manufacturing or repair. The base of the measuring tool is used to determine the position of the blank or item relative to the measuring tool. The assembly process is fluid because products can often be assembled using different assembly methods or combinations of methods based on drawings and specifications. In order to select specific variants, we need to determine which variants can provide the desired product quality at the lowest manufacturing and preparation (pre-production) cost.

Assembling is the positioning (i.e. locating and fixing) and joining of the assembly components, and also auxiliary assembly operations. Thus,

$$E_{as} = E_{loc} + E_{joint} + E_{other}$$

where E_{as} – the error of product assembling as to required parameter; E_{loc}, E_{joint} – errors of locating and joining; E_{other} – errors of auxiliary operations, and errors caused by locating and joining which are revealed in some period of time

2.3.3 calculation of the tolerance for the frame outline for two variants of coordination

- No machine is 100% accurate; There is only one agreed standard. All machine tools have some degree of free clearance or vibration. Thus, the tolerance specifies the deviation from a known value, expressed as a "+/-" number. Thus, if we have a machine tool that claims a tolerance of "+/-1 mm", this means that the tool may deviate each time it cuts or passes. It may be a millimeter too much, or a millimeter or a fraction too short. Each processing operation creates a component that has some geometric variation compared to its nominal geometry. Designers often give design tolerance specifications for nominal geometries to specify these allowable variations. One needs to estimate the accuracy of various manufacturing processes to verify that a given process plan produces the desired design tolerances. In aircraft manufacturing, a specific method with the desired precision is used. Two main approaches to frame assembly coordination are discussed here:

- Coordinate Template Method (CTM)
- Program Instrumental Method (PrIM)

Tooling coordinate template method is a further improvement of lofting template method. With the advent of large tonnage aircraft, CTM was implemented in the manufacturing industry. CTM features the use of common coordinate measuring equipment (Loft conductor and instrument holder) whose execution ensures coordination of large assembly tools at contour and connection points. The Tool Coordinator Instrument Method (Prim) is a further improvement of CTM. Modern airlines now use Prim to calculate accuracy, etc. The main advantage over CTM is that it reduces time and labor input.

The tolerance equation is calculated as follows:

$$\Delta_{\Sigma} = \sum_{i=1}^n A_i \Delta_i + \sum_{i=1}^n \alpha_i \frac{\delta_i}{2} A_i,$$

$$\frac{\delta_{\Sigma}}{2} = \pm \sqrt{\sum_{i=1}^n A_i^2 \left(\frac{\delta_i}{2}\right)^2} k_i^2,$$

$$\frac{UD_{\Sigma}}{LD_{\Sigma}} = \Delta_{\Sigma} \pm \frac{\delta_{\Sigma}}{2}.$$

There is $\Delta_{\Sigma}, \Delta_i$ - middles the distribution fields for frame and frame assembly components; n- number of steps; A_i - transfer coefficient ($A_i = 1$), α_i, k_i - distribution curve coefficient, ($\alpha_i = 0, k_i = 1$) for nominal distribution case, $\delta_{\Sigma}, \delta_i$ – tolerance for whole object and tolerance for ‘i’ step width of error distribution fields; upper and lower deviation - UD_{Σ}, LD_{Σ} .

Tolerance of frame No 37:

$$\delta_{unit} = \delta_{aggr.TC} - C_{d.aggr.-unit}$$

Where:

$\delta_{aggr.TC}$ - $\pm 2mm$, aggregate tolerance for fuselage and depends on aerodynamics zone of the aircraft.

$C_{d.aggr.-unit}$ - Frame and fuselage jig coordination error

Chains of dimension transferring for assembling and coordination are shown below:

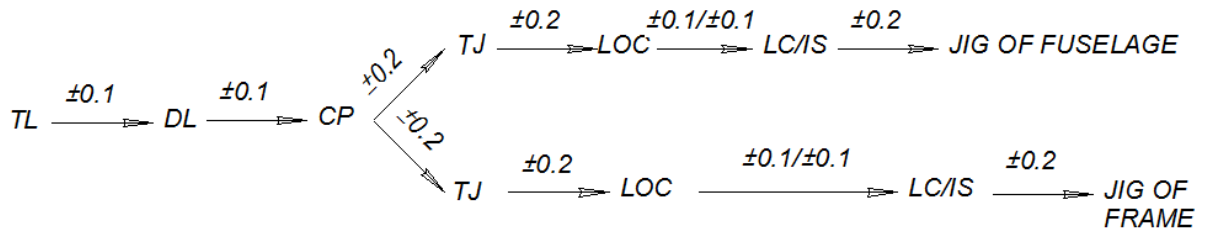


Fig 2.13 Scheme coordination for CTM

(TL- Theoretical Loft; DL- Design Loft; CP- Control print; TJ – Template of jig; LOC- Locator of contour; TJ – Template of jig; LC- Loft-conductor; IS- Instrumental stand)

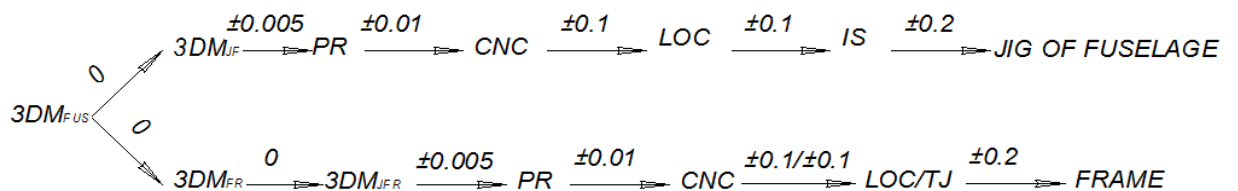


Fig 2.14 Scheme of coordination for PrIM

(PR- Program, 3DM- 3D Model (CAD Model), CNC –machine with numerical control)

Calculation of coordination error for frame and fuselage $C_{d.aggr.-unit}$, coordination error is defined by unconnected dimensions transfer chains.

CTM:

$$C_{d.aggr.-unit} = \pm\sqrt{(0.1)^2 \cdot 4 + (0.2)^2 \cdot 6} = \pm 0.547mm$$

PrIM:

$$\begin{aligned} C_{d.aggr.-unit} &= \pm\sqrt{(0.005)^2 \cdot 2 + (0.01)^2 \cdot 2 + (0.1)^2 \cdot 4 + (0.2)^2 \cdot 2} \\ &= \pm 0.346mm \end{aligned}$$

Calculation of unit tolerance δ_{frame}

- a. CTM: $\delta_{frame} = \pm 2 - (\pm 0.547) = \pm 1.453mm$.
- b. PRIM: $\delta_{frame} = \pm 2 - (\pm 0.346) = \pm 1.654mm$.

2.3.4 calculate the error of assembling for frame no: 36 outline, compare with the unit tolerance and make conclusion

During assembling in assembly jig the errors of incoming parts are compensated, so assembly errors are given as:

$$E_{assembly} = E_{jig} + K_{fix} \cdot C_{outline\ device-part} + E_{other},$$

where,

$E_{assembly}$ - final error of assembly unit,

E_{jig} - assembly jig error,

$C_{outline\ device-part}$ - Outline coordination inaccuracy for the part and the assembling device,

K_{fix} - coefficient which depends on the number of assembling device holder,

E_{other} - other inaccuracies tolerance .

Chains of dimension transferring for the method of coordination are given below.

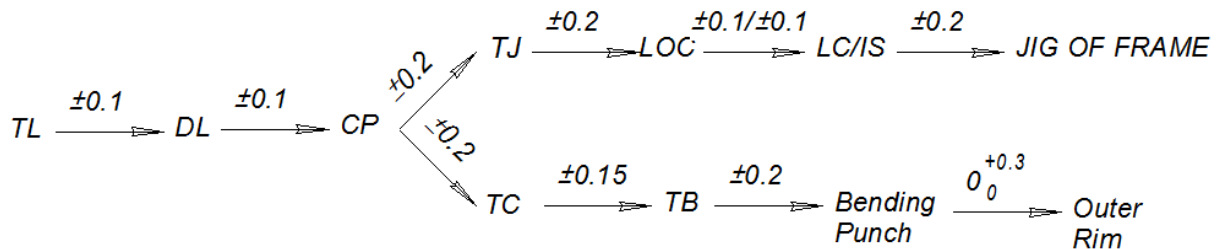


Fig 2.15. Scheme coordination for CTM
(TB – Template of bending)

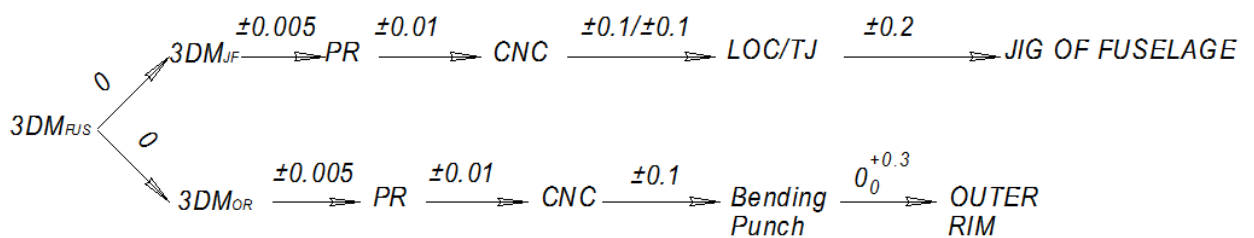


Fig 2.16. Scheme of coordination for PrIM

Calculation of the error of assembling in jig is given below.

CTM:

$$E_{jig} = \sum_{i=1}^n \Delta_i \pm \sqrt{\left(\frac{\delta}{2}\right)^2 \cdot i} \pm \sqrt{\left(\frac{\delta}{2}\right)^2 \cdot i},$$

$$E_{jig} = 0 \pm \sqrt{0.1^2 \cdot 4 + 0.2^2 \cdot 3}$$

$$= \pm 0.4 \text{ mm}$$

$$C_{\text{outline device-part}} = 0.15 \pm \sqrt{0.2^2 \cdot 5 + 0.1^2 \cdot 2 + 0.15^2 + 0.15^2}$$

$$= 0_{-0.36}^{+0.66}$$

$$E_{\text{assembly}} = E_{jig} + K_{fix} \cdot C_{\text{outline device-part}} + E_{\text{other}},$$

$$E_{\text{assembly upper deviation}} = 0.4 + (0.20) \cdot (0.64) = 0.532 \text{ mm},$$

$$E_{\text{assembly lower deviation}} = -0.4 + (0.20) \cdot (-0.34) = -0.472 \text{ mm},$$

$$E_{\text{assembly}} = 0_{-0.67}^{+0.75}.$$

PrIM:

$$E_{jig} = \sum_{i=1}^n \Delta_i \pm \sqrt{\left(\frac{\delta}{2}\right)^2} \cdot i, \pm \sqrt{\left(\frac{\delta}{2}\right)^2} \cdot i,$$

$$E_{jig} = 0 \pm \sqrt{0.1^2 \cdot 2 + 0.2^2 + 0.01^2 + 0.005^2} = \\ = \pm 0.22 \text{ mm.}$$

$$C_{jig-OR} = 0.15 \pm \sqrt{0.005^2 \cdot 2 + 0.01^2 \cdot 2 + 0.1^2 \cdot 2 + 0.15^2 + 0.2^2} = \\ = 0^{+0.43}_{-0.13}.$$

$$E_{assembly} = E_{jig} + K_{fix} \cdot C_{outline\ device-part} + E_{other},$$

$$E_{assembly\ upper\ deviation} = 0.22 + (0.20) \cdot (0.43) = 0.306 \text{ mm,}$$

$$E_{assembly\ lower\ deviation} = -0.22 + (0.20)(0.13) = -0.246 \text{ mm,}$$

$$E_{assembly} = 0^{+0.43}_{-0.35}.$$

Conclusion:

From the comparison of two methods it is clear that PrIM is more accurate than

CTM method. Because, by plotting the graph of tolerance for both methods PrIM shows more wide range of accuracy than CTM.

2.3.5 work out the diagram of assembling and tooling coordination on the ground of accuracy and economic calculation

Coordination is the process of coordinating the geometric parameters of an object (it involves the parts and assembly units of an aircraft, as well as components for manufacturing components, tools, and assembly tools). It provides the possibility to locate the aircraft components in the correct position relationship and change the exploration cycle without adjustment while maintaining mass. The origin of coordinates is the original carrier of geometrical parameters of coordinates of assembly or process tool unit. The coordinate method is the method of passing the coordinate geometric parameters from the origin to the assembly element or technical tool element. A harmony diagram is a graphical representation represented in symbolic terms, in which the contents and process sequence match the geometric parameters of the assembly or process tool elements. The adjustment diagram also shows the adjustment objects and their relationships. Adjustment charts are also used for pre-production financial calculations. We can also use coordination diagrams to estimate time and cost. The diagram includes interchangeability objects, interchangeability and coordination elements, tools, devices, coordination means, coordination sources, and information objects. According to the results of precision calculation, program method is chosen as the best manufacturing method for NO37 frame. Assembly and fitting drawings of blanking and assembling tools used to manufacture No. 37 fuselage frame.

2.3.6 workout locating chart of assembly components for fuselage frame No.37

A location map is an arrangement of anchor points on the base. The amount of white space or product projection in the map should be sufficient to clearly understand the location of anchor points. Positioning refers to the correct positioning of the blank or product with respect to the selected coordinate system. A base is a surface, shaft, or point of a blank or product used for positioning. Select project locations during product design, manufacturing, or maintenance. According to theoretical mechanics, the correct position of entities with respect to the selected coordinate system can be achieved by applying geometric constraints. An anchor point is one of the points representing the blank or product constraints in the selected coordinate system. Positioning is necessary for all stages of production -- designing, manufacturing, measuring, and handling the product as a whole. This means sorting the bases by purpose: assembly, processing and measurement.

The PrIM location diagram is developed, as shown in Figure 2.17.

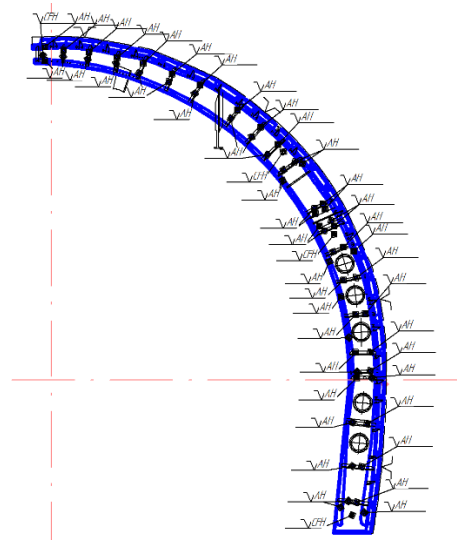


Fig.2.17. Locating Chart for Fuselage Frame No.37

2.3.7 development of enlarged technological process for fuselage frame No.37

The initial information of process development is divided into basic information, guidance information and reference information. Basic information is information about the product (given in the design document) and the output program and volume (quantity). The standards include technical requirements (specifications), process and manufacturing instructions, instructional technical documents (materials), cost standards (such as time and materials), labor protection standards, technical classification, typical process guidance materials, etc.

The working principle of assembly is given in the instructional technical data. Their composition is not specified, but they are usually preceded by a disassembly drawing (dividing the product into assembly parts) and an assembly drawing (the order in which parts are assembled during the assembly process and additional information about assembly tools and techniques). In a disassembly diagram, the product and its assembled parts (components and parts) and their positions with respect to each other are represented at arbitrary angles.

The process flow text for mass production is given in the operational decomposition description that it has an operational content structure such as:

1) Keyword – description of the action (technological operation, or technological step) for either processing or assembling, written by verb in the infinitive form ("locate", "clump", "mark", "drill", "rivet", etc.);

- 2) Information about the amount and type of processed surface elements (such as "drill 3 holes") of products or assembly components (such as "rivet 3 rivets");
- 3) Information about the dimensions of the processed surface elements ("holes with 4,5") or with various components of the product ("rivet 4–10 by OCT 1.34043–85 ");
- 4) Additional information, such as "by the making," "by GH", "by AH", "by CFH", "by template", "by stoppers", "according to sketch, to the drawing", "with providing adjacency".

The technological process of fuselage frame NO 37 is shown in table 1

Table 2.2 – The integrated process of assembly

No	Operation	Tooling
1	2	3
01	Prepare the work area	Work bench
02	Gather the manufacturing kits of part	
03	Open all Assembly jig clamps and fixtures if closed.	Assembly Jig
04	Locate the top rim to the jig by locator of contour and clamp it	Clamps
05	Locate the bottom rim to the jig by locator of contour and clamp it	Clamps
06	Locate the web in the jig on 4 CFH of $\varnothing 8H9$ and fix the web by technological screws (t/s)	Technological screws and nuts
07	Locate the top cap to the web by 4AH of $\varnothing 6$ and fix it with t/s	Technological screws and nuts
08	Locate bottom cap to the web by 4AH of $\varnothing 6.5$ and fix it with t/s	Technological screws and nuts
09	Drill 10 holes of $\varnothing 3.75$ in top cap and web by GH in top cap and clamp it with t/s	Technological screws and nuts, Drilling Gun, Drill bit of $\varnothing 3.75$ mm
10	Drill 10 holes of $\varnothing 3.75$ in the bottom cap and web and clamp it with t/s	Technological screws and nuts, Drilling Gun, Drill bit of $\varnothing 3.75$
11	Locate the first stiffener position no 18 to the web by 2 AH of $\varnothing 3.75$ and fix the stiffeners to the web by 2 t/s	Technological screws and nuts
12	Repeat step 10 to the second stiffener with position no 19	Technological screws and nuts

13	Repeat the step 11 for remaining stiffeners with position no 20-38	
14	Drill 6 holes of $\varnothing 3.75$ inside stiffener in position 18-20 and fix it with t/s	Technological screws and nuts, Drilling Gun, Drill bit of $\varnothing 3.75$ mm

15	Drill 5 holes of $\varnothing 3.75$ inside stiffener in position 21-24 and fix it with t/s	Technological screws and nuts, Drilling Gun, Drill bit size $\varnothing 3.75$
16	Drill 4 holes of $\varnothing 3.75$ inside stiffeners in position 26-39 and fix it with t/s	
17	Locate the T-knee position to the top profile and clamp it with C-clamp.	C- clamp
18	Repeat step 17 for the rest of the T-knee parts	C-clamp
19	Drill 2 holes of $\varnothing 3.75$ through top cap, web and knee	Drilling Gun, Drill bit of $\varnothing 3.75$ mm
20	Drill 61 holes of $\varnothing 3.75$ through top cap and web	Drilling Gun, Drill bit of $\varnothing 3.75$ mm
21	Drill 80 holes of $\varnothing 3.75$ through bottom cap and web	Drilling Gun, Drill bit of $\varnothing 4.1$ mm

22	Dismantle all elements except the top rim and bottom rim and clean the elements by metal brush	Metal Brush
23	Locate the Web into the Jig by, locate the top profile to the jig by contour locator, locate the T-knee to the top profile, locate the top cap to the web, locate the stiffeners to the web.	
24	Clamp each stiffener to the web by 3 holes, Clamp the top cap by 3 t/s, top profile to T-knee, T-knee to stiffeners and rims to web by t/s	Technological screws and nuts
25	Unclamp the Jig and Transfer the frame to the Riveting Press.	Riveting Press, Rivets
26	Coat rivet heads with paint, AK-069 OCT 6-10-401-76	Paint, brush
27	Rivet the holes according to Instruction ТИ 36-53-93	Riveting Press, Rivets
28	Process Holes for bolts up to $\varnothing 6H7$	Work bench, Drilling Gun, Drill bit of $\varnothing 6$
29	Remove Grease from the bolts	Work bench, Bolt
30	Press the bolt, fix washer and nut and slightly tighten	Work bench, Bolt,

	the nut and set the bolt	Nut, Washer, Spanner
31	Repeat step 40, 41, 42 for other bolts	Work bench, Bolt, Nut, Washer, Spanner
32	Replace the ready frame to the storage	

2.3.8 workout technical requirements of assembly components supply for assembling according to fuselage frame n0 37 technological process.

Table 2.3- Technical Requirements for the Frame No.37 Assembly Components Supply for Assembling

Assembly component	Amount	Condition of assembly components supply
Web	1	Without allowance by contour, 4CHF of Ø8H9, 4 AH Ø3.75, 4 AH Ø3.75.
Outer Rim	2	Without allowance by contour, 115 GH Ø3.
Cap	2	Without allowance by contour, 6 AH Ø3.75, 115 GHØ3.0.
Stiffener 1	18	Without allowance by contour 2AH Ø3.75mm, 108GH Ø2.0mm.
Stiffener 2	2	Without allowance by contour 2AH Ø3.75mm, 12GH Ø2.0mm.
Double plate	2	Without allowance by contour 2AH Ø3.75mm, 16GH Ø2.6mm.
Knee	25	Without allowance by contour 1AH Ø3.75mm, 16GH Ø2.6mm.

2.4 Developing of the assembly jig design.

Designing of assembly jig is fulfilled by requirements and demands of the jig. Some of the steps for designing jig as follows:

1. Development of layout diagram of assembly jig.
2. Selecting the main basic axes of assembly tooling.
3. Drawing of the structure in the view should be placed in the assembly jig.
4. Placing of locators of contours and holes with respect to assembly title of contours to picture.
5. Developing the scheme of carcass, frame type or beam type .immovable locators are convenient for designing but in case it should be movable locators.

The main advantage of the assembly method in the fixture is to ensure the identity and interchangeability of the sub-parts. The disadvantage of fixture assembly is the high cost of assembly. The different designs of the assembly units result in significant tooling costs, so that each individual unit can only be assembled in a special (unique) fixture with the desired precision. The average coefficient of use (in time) of special fixtures in batch (large) aircraft production is 0.3... 0.5, they are discontinued when they wear out or when the aircraft design changes (every 3 to 5 years). Therefore, we can use reconfigurable assembly fixtures as one of the ways to reduce cost. Each of these fixtures can be used to produce a set of units of a similar design. Structurally, it consists of a generic substrate on which the positioner is positioned using a planar fixture template (TJ). After assembling a batch of units of the same type, the fixture positioner is repositioned (reconfigured) by another TJ to assemble another unit in that group.

2.4.1 work out the technical requirements for assembly jig designing procedure

Table 2.4.-Technical Requirements to Assembly Jig Design Procedure Or assembling the fuselage frame No.37

1.	Purpose	Assembly jig for frame No.37 of aircraft AN-72 for locating, clamping, drilling the elements of parts or joining.
2.	Position of assembly unit in assembly jig.	The frame is located in vertical position in the assembly jig.

3.	Order of assembly	The order of assembly for assembly unit in the assembly jig is, rim, web, top cap, bottom cap, stiffeners, knee, double plate.
4.	Bases	Bases are shown in locating chart.
5.	Elements of interchangeability and their accuracy.	Outer contour of rim ± 1.654 , CFH $\varnothing 8H9$
6.	Tooling of second order.	Template of jig is used in tooling of second order.
7.	Way/direction of placing/taking out.	The frame parts are placed from the technician vertically towards the jig. After assembly it is taken out from the jig by the technician.
8.	Means of automation of jig and process.	Due to the unit simplicity and its relatively small overall dimensions, manual drilling gun is used and riveting outside the jig on press.

2.4.2 Selection of the scheme of the assembly jig and design assembly jig layout

According to the requirements, the scheme for the jig is selected. It includes

Locator of contour, coordinate fixing holes and clamps. Assembly jig for frame No.37 of aircraft AN-72 is designed for locating, clamping, drilling the elements

Of parts or joining. The jig located in vertical position in the assembly jig. The technician place the frame parts vertically towards the jig and after the assembly it

is taken out by the technician. The layout of assembly jig for fuselage frame No 37 is given in Figure.2.18.

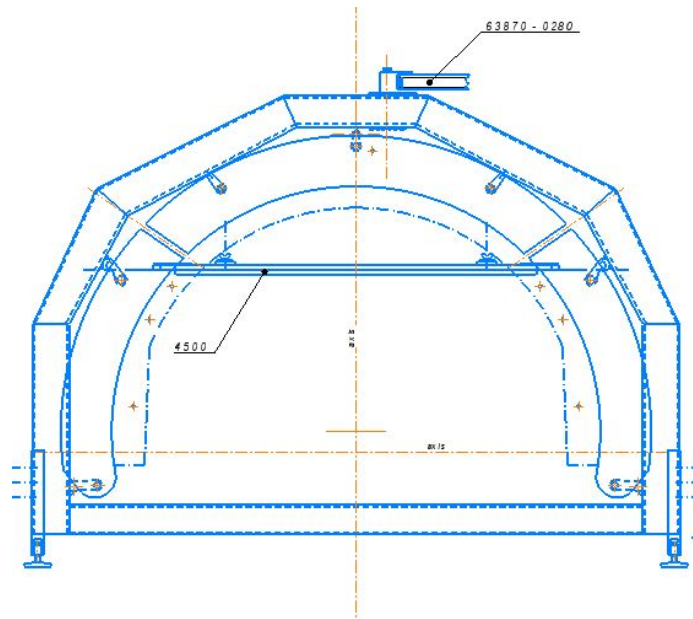


Figure .2.18. Assembly jig layout

2.5 Aircraft structures alignment with distance sensors and CCD cameras

CCD camera has the advantages of high acquisition rate and wide field of view. Generally used for high speed scanning and high precision detection system. The relative pose of the CCD camera and the detected object will not only affect the scanning range of the camera, but also affect the scanning accuracy. In turn, CCD cameras need to be adjusted. Perform baseline positioning. At present, CCD camera calibration methods include traditional camera calibration method, camera self-calibration method and active visual camera calibration method. Traditional camera calibration methods need to be realized by calibrating objects. Limitations, must use two or more images for calibration, use complex; The camera self-calibration method can be directly calibrated only by the relationship between the corresponding points of multiple perspectives, but the motion constraint is too strong and it is not practical in practice. The camera calibration method of active vision is more robust, but it needs a high precision camera platform to realize and costs more.

In aerospace field, linear CCD image sensor is widely used to complete the image acquisition task. In order to complete the image shooting task, the prerequisite is that the linear CCD image sensor must be properly exposed to obtain clear images. Under exposure and over exposure can not obtain clear images. This is usually achieved by controlling the brightness of the target light and the exposure time of the linear CCD image sensor. But in most cases, the target illumination brightness is not

controllable, can only control the linear array CCD image sensor integration time..

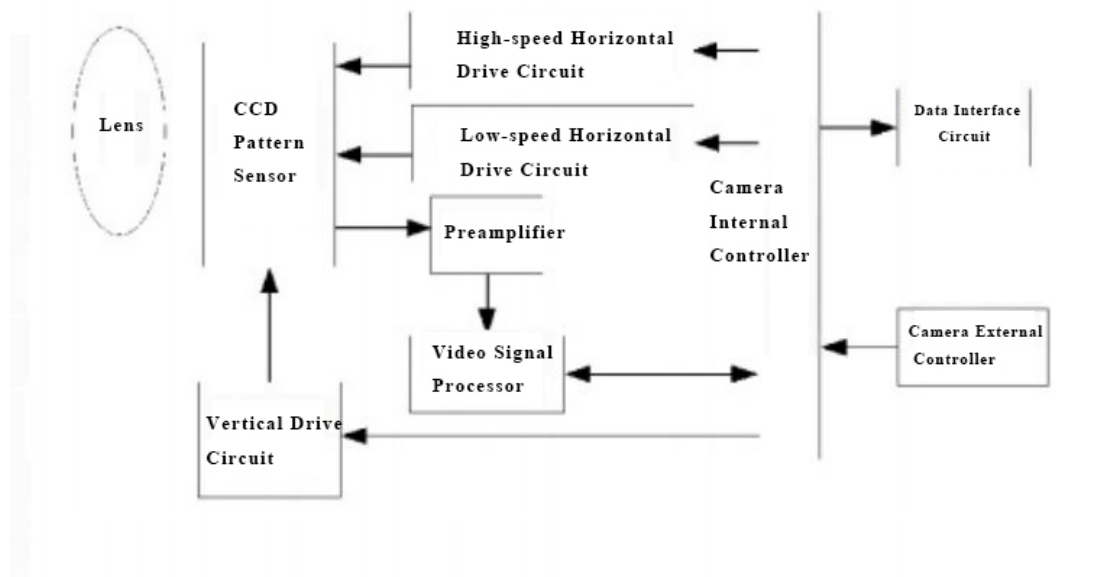


Figure 2.19. CCD camera working process diagram

Since the linear array CCD camera system is always in motion relative to the ground, image motion occurs, and the line cycle must also be controlled in order to obtain a clear image. As shown in Figure 2.20, with the pixel size a of the linear array CCD image sensor and the focal length f of the lens, when the aircraft is flying in the air at a speed V and a height H , the ground scene point A moves backward relative to the aircraft to A' , and is imaged through the optical system at point a , the image point a on the target surface becomes a short line aa' , that is, the movement of the image is generated, and the image movement speed V' on the target surface is:

$$V' = \frac{V \times f}{H};$$

Then the row period of the camera system is:

$$t_H = \frac{H \times a}{V \times f};$$

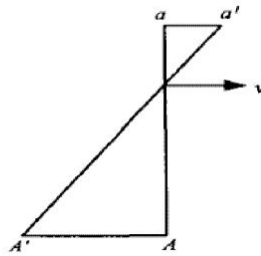


Figure .2.20. CCD working principle

Some linear array CCD image sensors do not have electronic shutters, and some linear array CCD image sensors use electronic shutters to degrade the imaging quality. Many journal articles, dissertations, and patents reflect people's research on exposure time adjustment methods. In these research results, the adjustment methods for the exposure time are: keep the driving signal frequency unchanged in all line periods during the entire working process, adjust the number of empty drives behind the effective drive signal in the line period; or adjust the number of empty drives behind the effective drive signal in the line period. The number of empty drives changes the drive signal frequency at the same time, but all use the same set of horizontal drive systems. When two groups of different horizontal transfer clock frequencies differ greatly, if the same group of horizontal drive system is used, either the driving ability will be insufficient, which will affect the charge transfer efficiency, or overshoot will occur, which will easily generate clock-induced charges, and may even damage the CCD device in severe cases. cause damage.

Based on a linear array CCD camera system with adjustable integration time for aerospace applications, the system includes a linear array CCD image sensor, a high-speed horizontal drive circuit, a low-speed horizontal drive circuit, a preamplifier, a video signal processor, a camera internal controller, and a camera external Controller, data interface circuit and vertical drive circuit, the image plane of the lens is coupled to the focal plane of the linear array CCD image sensor, the external controller of the camera sends commands to the internal controller of the camera through the serial port; the internal controller of the camera is controlled according to the Generate the vertical transfer timing signals required for the work of the line array CCD image sensor, two sets of horizontal transfer timing signals that work alternately at different stages, the control signals required for the video processor to work, and other control signals according to the commands received by the controller; The vertical transfer timing signal generated by the camera's internal controller is transformed into a

vertical transfer driving signal after being passed through the vertical drive circuit; two sets of horizontal transfer timing signals generated by the camera's internal controller are respectively sent to the high-speed horizontal drive circuit and the low-speed horizontal drive circuit. The circuit is controlled by the camera's internal controller and works alternately. One group is in the output enable state, and the other group is in the output high-impedance state, which together generate horizontal transfer drive signals; the target in the field of view of the lens will be imaged on the focal point of the linear array CCD image sensor. On the plane, the amount of induced charge generated in the photosensitive area of the line array CCD image sensor is linearly related to the input light energy; the charge in the photosensitive area of the line array CCD image sensor is controlled by the vertical transfer drive signal and the horizontal transfer drive signal, and the analog image is output. The signal is sent to the video signal processor for video processing after the preamplifier, and then sent to the internal controller of the camera as a digital image signal for data integration, and finally the data is output through the data interface circuit.

The high-speed horizontal drive circuit and the low-speed horizontal drive circuit described in this embodiment work alternately in the same row period, and the switching process of generating the horizontal transfer drive signal is divided into switching from the low-speed horizontal drive circuit to the high-speed horizontal drive circuit and from the high-speed horizontal drive circuit Switch to the working process of the low-speed horizontal drive circuit.

The working process of changing from the low-speed horizontal driving circuit to the high-speed horizontal driving circuit is as follows: 1. The low-speed horizontal driving circuit changes the signal of output high and low level into a fixed level signal in the output blanking stage; 2. High-speed horizontal driving The circuit enables the output, and changes from output high impedance to a fixed level signal in the output blanking stage, and its output level value is the same as that of the low-speed horizontal drive circuit; 3. The low-speed horizontal drive circuit is set to output high-impedance state; 4. High-speed The horizontal drive circuit changes from a fixed-level signal in the output blanking stage to a signal that outputs high and low levels.

The working process of switching from the high-speed horizontal drive circuit to the low-speed horizontal drive circuit is as follows: 1. The high-speed horizontal drive circuit changes the signal of output high and low level into a fixed level signal in the output blanking stage; 2. Low-speed horizontal drive The circuit enables the output, and changes from output high impedance to a fixed level signal in the output

blanking stage, and its output level value is the same as that of the high-speed horizontal drive circuit; 3. The high-speed horizontal drive circuit is set to output high-impedance state; 4. Low-speed The horizontal drive circuit changes from a fixed level signal in the output blanking stage to a signal that outputs high and low levels.

2.5.1 The working process and principle of CCD camera

The high-speed horizontal drive circuit and the low-speed horizontal drive circuit described in this embodiment work alternately in the same row period to generate a horizontal transfer drive signal. Specifically, the integration time control in a row period goes through three stages:

- The empty scan stage before the exposure of the linear array CCD image sensor, the empty scan time before the exposure:

$$t_{\text{pre_idle}} = t_H - t_{\text{exp_ose}} - t_{\text{read}}$$

At this stage, the horizontal transfer signal with the frequency of $f_{\text{read_low}}$ is used, the minimum value of the number of clocks can be 0, and its value is $n_{\text{pre_idle}}$.

$$n_{\text{pre_idle}} = f_{\text{read_low}} \times t_{\text{pre_idle}}$$

Among them, t_H is the current line cycle, which is determined by the pixel size a of the linear array CCD image sensor, the focal length f of the lens, the current speed V and the height H of the aircraft, and may need to be changed in real time. According to the actual application, the line cycle can be set at the minimum line The period $t_{H\text{min}}$ and the maximum row period $t_{H\text{max}}$ change;

$$t_H = \frac{H \times a}{V \times f}$$

- In the exposure stage of the linear array CCD image sensor, t_{expose} is the

current exposure time, which may need to be changed in real time due to the environmental constraints of the aircraft. According to the actual application, the exposure time can be set to change within the minimum exposure time $t_{\text{expose_min}}$ and the maximum exposure time $t_{\text{expose_max}}$; this stage uses For the horizontal transfer signal whose frequency is $f_{\text{read_high}}$, set its maximum value to the maximum horizontal transfer clock allowed by the device, and the minimum value to $f_{\text{read_low}}$,

$$f_{\text{read_high}} = \frac{n_{\text{expose_min}}}{t_{\text{expose_min}} - t_{\text{xiao}}}$$

Among them, $n_{\text{expose_min}}$ is the sum of the horizontal shift register and the number of overscan registers of the linear array CCD image sensor, and t_{xiao} is the fixed vertical transfer time; the number n of the horizontal transfer signal whose frequency is $f_{\text{read_high}}$ during exposure is:

$$n = (t_{\text{expose}} - t_{\text{xiao}}) \times f_{\text{read_high}}$$

The maximum number n_{max} is:

$$n_{\text{max}} = (t_{\text{expose_max}} - t_{\text{xiao}}) \times f_{\text{read_high}};$$

- The useful charge readout stage of the linear array CCD image sensor; t_{read} is the useful charge readout time, which is a fixed value, and a horizontal transfer signal with a frequency of $f_{\text{read_low}}$ is used;

$$t_{\text{read}} = t_{\text{xiao}} + \frac{n_{\text{expose_min}}}{f_{\text{read_low}}}$$

Since horizontal transfer signals of different frequencies are used in different stages of a line cycle, in order to make the linear CCD camera system work in the best state, the low-speed horizontal drive circuit and the high-speed horizontal drive circuit are used to work alternately in a line cycle.

The commands sent by the camera external controller to the camera internal controller described in this embodiment are specifically: the camera external controller sends the camera internal controller to the camera internal controller through the serial port RS232 or RS422 interface. parameters and other commands.

2.5.2 Summary and analysis of CCD camera in this design

The lens in this embodiment is a customized optical lens; Linear CCD image sensor is linear CCD TH7834C of E2V Company. The preamplifier is the operational amplifier THS3061 of American TI Company; Device AD9945; ISL55110 and EL7156C, manufactured by Intersil Corporation, are used as the core devices for high speed and low speed horizontal drive circuits. The vertical drive circuit adopts the DS0026 driver produced by National Semiconductor Company as the core device. The internal controller of the above camera uses the FPGA of Xilinx of America as the core device. The data interface circuit uses the DS90CR287 of National Semiconductor Company as the core device. The camera external controller adopts DSP of TI company as the core device.

Aiming at the exposure time control of linear CCD image sensor in aerospace applications, some linear CCD image sensors do not have an electronic shutter or the image quality deteriorates after using an electronic shutter, the invention adopts a new method to realize the exposure control of linear CCD camera system in each line period is divided into three stages: 1. Two, exposure stage; Third, linear CCD image sensor useful charge reading stage; Low horizontal signals are used in the phase of air sweep and line effective charge reading, and high horizontal transfer signals are used in the phase of exposure. The number of horizontal transmission signals in the air

scanning phase is determined by the current line cycle and exposure time. The frequency of high-low transfer signal in exposure stage is determined by the shortest exposure time, and the quantity is determined by the current exposure time. Flexible control, can adapt to various application requirements.

In order to make the linear array CCD camera system have the best performance under the working frequency of two horizontal transmission signals, the invention adopts two independent horizontal drive circuits to work alternately in one line cycle, and designs two groups of horizontal drive circuits for switching work, ensuring the stability and reliability of the switching process of the two groups of horizontal drive circuits.

2.5.3 AGV System description

The newly designed AGV system is combined with a pose alignment system which makes it more flexible and less demanding on the AGV's docking precision. The main structure of the AGV system consists of an automated guided vehicle, pose measurement system, and pose alignment system as shown in Fig. 2.21.

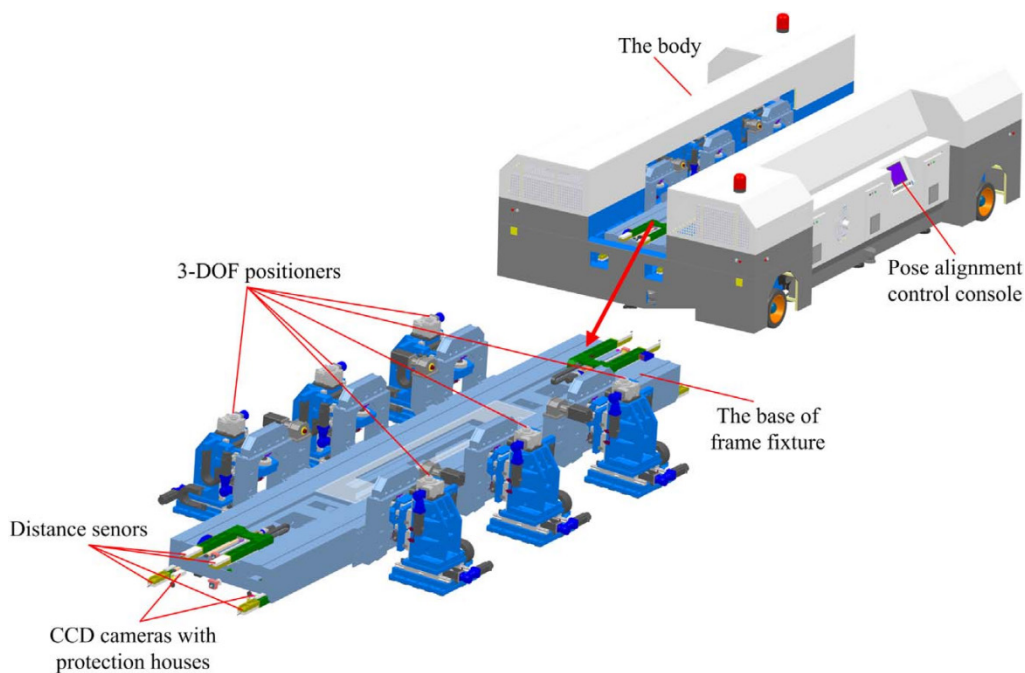


Figure .2.21. Structure of the AGV system.

The AGV is the mounting base for the rest and is driven by four roadwheels; Each is mounted on a rotating suspension system. The control system ensures that the AGV moves autonomously along the planned path by controlling the direction and speed of each wheel, moving forward, backward, sideways, and rotating according to the specified radius. All movements can be easily achieved using the control panel. In addition, you can select preset routes in the control system to move the AGV from one point to another. As the AGV moves forward, it can adjust itself to correct the

direction deviation guided by the magnetic strip, or it can be adjusted manually using the control panel.

The attitude measurement system consists of four distance sensors, two CCD cameras on each side of the vehicle, and four dedicated calibration panels with five circular landmarks. Two distance sensors at the same height are driven by the same spool. Two CCD cameras with LED ring lights are mounted on the same base as the two distance sensors. The four calibration plates are installed on the same reference plane at the bottom of the station.

By driving the two linear axes, the four range sensors will touch the corresponding calibration plate. We can get four current distances (d_1, d_2, d_3, d_4) and compare them with the ideal distance corresponding to the target pose. Then four range deviations ($\Delta d_1, \Delta d_2, \Delta d_3, \Delta d_4$) will come out. Once the range sensor touches the corresponding calibration plate, the two cameras will come out together, and the focal plane has been configured on the calibration plate, which will capture the clearest circle image on the calibration plate. Coordinates of larger circles can be obtained using image processing algorithms. The two cameras can then detect the position deviation of the two larger holes on the calibration plate ($\Delta x_1, \Delta z_1, \Delta x_2, \Delta z_2$). By combining the distance deviation and the hole position error, the pose deviation can be easily obtained by matching the current pose with the target pose. In theory, the 6 degrees of freedom of the frame mounting base is completely covered by a combination of range sensors and cameras.

After the AGV arrives at the docking position, the initial pose is estimated by measuring all the six detected points. If the initial pose is within the error tolerance of the goal pose, no adjustment is needed. Otherwise, plan the trajectory of all the positioners based on the pose deviation and move all the positioners synchronously to their goal position to perform the alignment. Then repeat the whole process until the pose deviation is within the error tolerance, referring to Fig. 2.22.

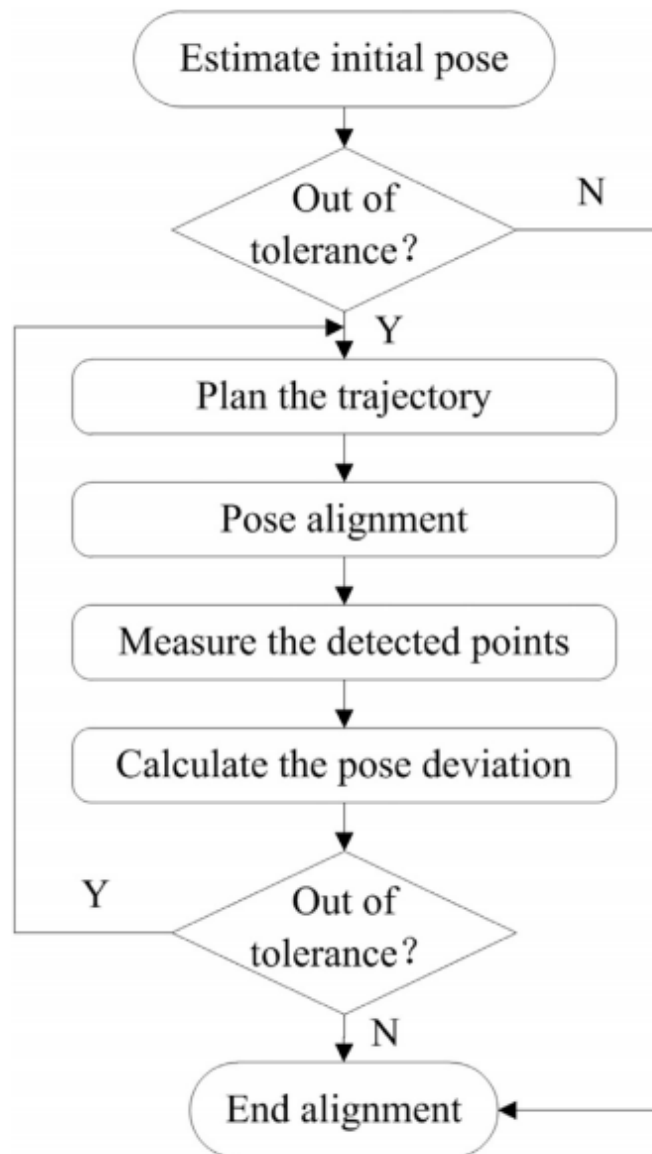


Figure .2.22. The whole pose measurement and alignment process.

The whole procedure of auto-transshipment experiment shown in Fig. 2.22 are as follows:

(1) After calibration, drive away the AGV and adjust the base mounted on AGV used to localize and clamp the frame fixture to an arbitrary pose.

(2) Drive the AGV to the docking position; reach out braces to stabilize tightly the vehicle.

(3) Due to the localization precision of the vehicle there exists a pose deviation more or less; use the pose measurement system to measure the pose of the base mounted on the vehicle, then Calculate the pose deviation with respect to the ideal pose.

(4) Based on the pose deviation and the goal pose, plan the trajectory of all the driving axes.

(5) Actuate all the driving axes to their goal position to adjust the pose of the base. It's necessary to iteratively execute the whole measurement and adjustment procedures till the pose deviation reaches the tolerance limit.

(6) Transfer the transshipment mobile platform between the station and AGV automatically

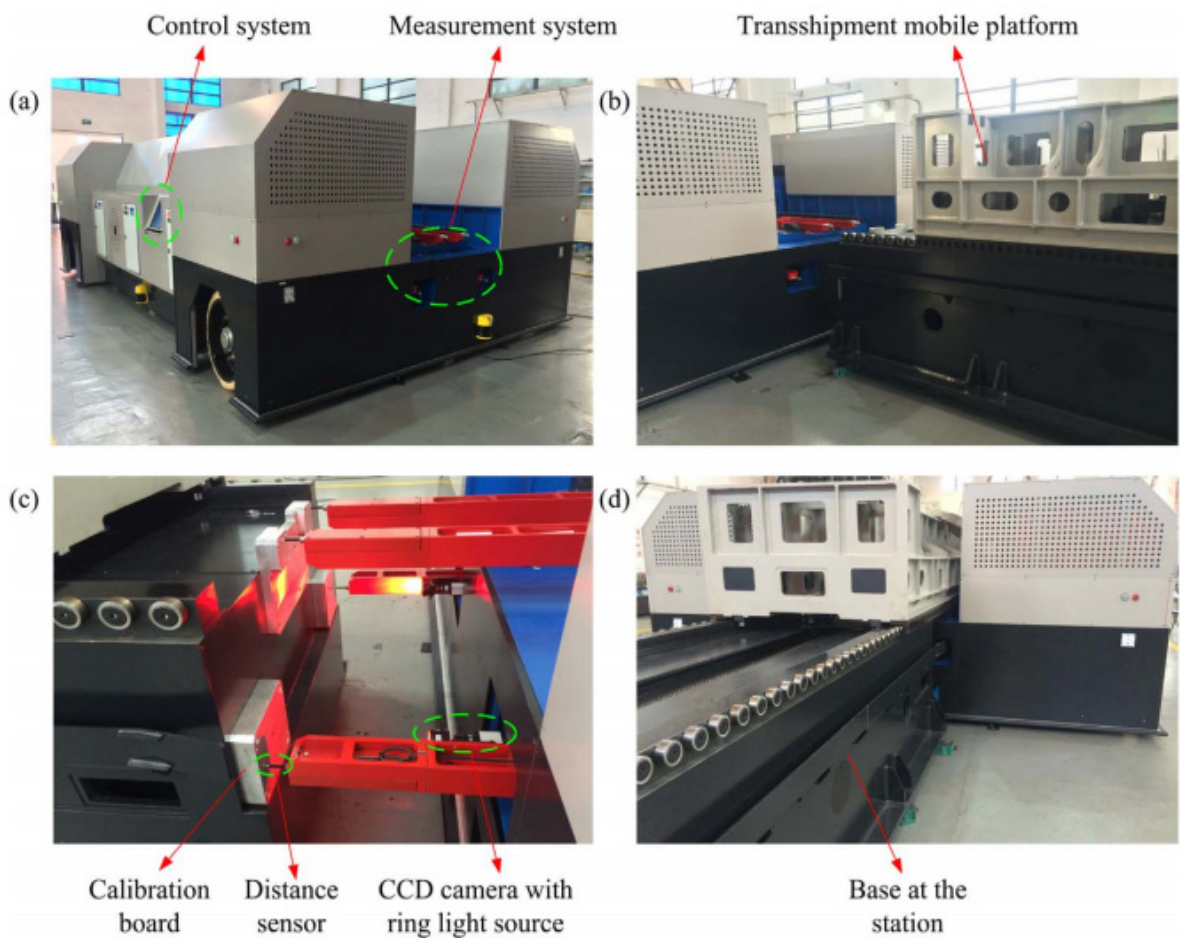


Figure .2.23. The auto-transshipment process.

(a) AGV at the docking place;

(b) Pending transshipment the mobile platform at the station;

(c) Pose measurement and alignment; platform in transit.

ECONOMIC SECTION

3.ECONOMIC SECTION

3.1 Introduction

In this project, we calculated and compared the assembly cost of the top rack of transporter 37 by using assembly holes and assembly fixtures. The goal of the task is to do market research to estimate the product price to estimate the Labor intensity to estimate the cost.

3.2 Description of the product

The product in the Assembly is the top frame of a jet transporter. Frame No. 37 is also used to position control and stabilize the specific relationship between the surface and the lifting surface, which is necessary for aircraft stability and maneuverability.

3.3 Market Research

Predict the cost of producing the aircraft based on the current status of the existing aircraft market, and then conduct reasonable analysis and design.

3.4 Initial data and calculations

3.4.1 Dependence of the tooling specific costs on the assembly method:

Tooling specific cost data C_{tool} .

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

$$C_{\text{tool.A.H}} = 100$$

$$C_{\text{tool.j}} = 500$$

3.4.2 The annual production rate of the considered assembly unit, Pcs/year:

$$N = 56$$

3.4.3 Specific labor input

The values of the specific labor input are taken from annex 5, depending on the weight and type of assembly unit.

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

$$k_{\text{sp.full}} = 2.6$$

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

$$k_{s.p.j} = 2$$

The specific labor input of the assembly by AH approximately must be taken from calculations as:

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

$$\text{Where } k = 0.9.$$

Therefore:

$$k_{sp.AH}(k_{sp.full}) = 0.8 \cdot 2.7$$

$$k_{sp.AH}(k_{sp.full}) = 2.34$$

3.4.4 Actual annual fund of tooling cost productivity

F_t depends on assembly tooling repair complexity (2030 for complex repairs, 2080 for simple ones) hours.

$$F_{t.AH} = 2080$$

$$F_{t.j} = 2035$$

3.4.5 The average number of simultaneous workers in the same work station (P), men

$$P_{AH} = 2$$

$$P_j = 2$$

3.4.6 The average height of the shop (usually 10 – 14m) m,

$$h = 10$$

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

$$S_{AH} = 10$$

$$S_j = 7$$

3.4.8 The weight of the object being assembled, kg:

$$G = 6.583$$

3.4.9 The tariff rate for the assembly workers, UAH/ hour:

$$a_{AH} = 20$$

$$a_j = 15$$

The values are calculated parameters for the production rate.

3.4.10 Wages of assembly workers (W), UAH:

$$W_{AH} = k_{sp.AH}(k_{sp.full}) \cdot G \cdot a_{AH} \quad 3.2.1$$

$$W_{AH} = 2.34 \cdot 30 \cdot 20$$

$$W_{AH} = 1404$$

$$W_{AH} = k_{sp.j}(k_{sp.full}) \cdot G \cdot a_j \quad 3.2.2$$

$$W_{AH} = 2 \cdot 2.6 \cdot 20 \cdot 15$$

$$W_{AH} = 900$$

3.4.11 Estimated amount of similar devices to perform the annual production rate for the compared variants:

$$m_{p-AH}(n) = \frac{k_{sp-AH} \cdot (k_{sp-full}) \cdot G \cdot n}{F_{t-AH} \cdot P_{AH}} \quad 3.3.1$$

$$m_{p-AH}(n) = 0.945$$

$$m_{p-j}(n) = \frac{k_{sp-j} \cdot G \cdot n}{F_{t-j} \cdot P_j} \quad 3.3.2$$

$$m_{p-j}(n) = 0.826$$

Defining the rounding off of the calculations to a whole number:

$$\text{round}(x) = \text{if}(x - \text{floor}(x) < .5, \text{floor}(x), \text{ceil}(x)) \quad 3.4.1$$

$$\text{UpTo1}(x) = \text{if}(x < 1, 1, \text{round}(x)) \quad 3.4.2$$

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

$$m_{j-AH}(n) = \text{UpTo1}(m_{p-AH}(n)) \quad 3.5.1$$

$$m_{j-AH}(n) = 1$$

$$m_{j-j}(n) = \text{UpTo1}(m_{p-j}(n)) \quad 3.5.2$$

$$m_{j-j}(n) = 1$$

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

$$n_j = \frac{m_{p-j}(N)}{m_{j-j}(N)} \quad 3.6.1$$

$$n_j = 0.826$$

$$n_{AH} = \frac{m_{p-AH}(N)}{m_{j-AH}(N)} \quad 3.6.2$$

$$n_{AH} = 0.945$$

3.4.13 Expenditure for tooling for the compared variants(ET), UAH:

$$ET_{AH}(n) = \frac{G C_{toolAH} (N)}{2n} m_{j-AH} \quad 3.7.1$$

$$ET_{AH}(N) = 26.786$$

$$ET_j(n) = \frac{G C_{toolj} (N)}{2n} m_{j-AH} \quad 3.7.2$$

$$ET_j(N) = 133.929$$

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

$$OC_{AH}(n) = 0.625 \frac{h \cdot S_{AH} m_{j-AH}(n) \cdot n_{AH}}{n} \quad 3.8.1$$

$$OC_{AH}(N) = 1.116$$

$$OC_j(n) = 0.625 \frac{h \cdot S_j m_{j-j}(n) \cdot n_j}{n} \quad 3.8.2$$

$$OC_{AH}(N) = 0.781$$

3.4.15 Cost price of assembly(C_{ass}) for the compared variants is calculated using the expression, UAH:

$$C_{ass_AH}(n) = W_{AH} + ET_{AH}(n) + OC_{AH}(n) \quad 3.9.1$$

$$C_{ass_AH}(n) = 1432$$

$$C_{ass_j}(n) = W_j + ET_j(n) + OC_j(n) \quad 3.9.2$$

$$C_{ass_j}(n) = 1539$$

Table 3.1 - Calculated expenses

	Assembly hole (AH) calculation	Assembly jig calculation
Specific cost of tooling, (UAH)	100	500
Annual production rate, (pcs/year)	56	56
Specific labour input, (man- hour/kg)	2.6	2
Actual annual fund of tooling	2080	2035
Average number of simultaneous workers	2	2
Area of the workplace, (m ²)	10	7
Tariff rate of assembly workers, (UAH/hour)	20	15
Wages of the assembly workers, (UAH)	1404	900
Accepted amount of similar devices for the production of the annual program, (pcs)	1	1
Factor of device usage	0.826	0.945
Tooling expenditure for compared variants, (UAH)	26.786	133.929
Operating cost of compared variants, (UAH)	1.116	0.781
Cost price of assembly (C _{ass}), (UAH)	1432	1539

3.5 Building graphs depending on the cost of the assembly of release

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

$$NTto1(x) = \text{if}(x > 60, x - 60, 1) \quad 3.10$$

Detection function of the left boundary of the range of the table, the boundaries and steps of the production rate range for the performed tabular calculations.

$$N_{\min} = NTto1(N) \quad 3.11.1$$

$$N_{\max} = N + 60 \quad 3.11.2$$

Step = 0

$$N_{\min} = N_{\min} + \text{Step} \dots N_{\max} \quad 3.11.3$$

3.5.1 Determining the argument variation range (the production rate).

The table below show the dependence between the amount of jigs and the cost price of assembly from the production rate for the two different assembly methods:

Assembly by AH:

Assembly in jig

$$n = m_{p_AH}(N) = m_{j_AH}(N) = C_{ass_AH}(N) \quad n = m_{p_j}(N) = m_{j_j}(N) = C_{ass_j}(N) =$$

n =	$m_{p_AH}(n) =$	$m_{j_AH}(n) =$	$C_{ass_AH}(n) =$	n =	$m_{p_j}(n) =$	$m_{j_j}(n) =$	$C_{ass_j}(n) =$
1	0.017	1	$2.966 \cdot 10^3$	1	0.015	1	$8.948 \cdot 10^3$
11	0.186	1	$1.546 \cdot 10^3$	11	0.162	1	$2.09 \cdot 10^3$
21	0.354	1	$1.478 \cdot 10^3$	21	0.31	1	$1.763 \cdot 10^3$
31	0.523	1	$1.454 \cdot 10^3$	31	0.457	1	$1.647 \cdot 10^3$
41	0.692	1	$1.442 \cdot 10^3$	41	0.604	1	$1.588 \cdot 10^3$
51	0.861	1	$1.435 \cdot 10^3$	51	0.752	1	$1.552 \cdot 10^3$
61	1.029	1	$1.43 \cdot 10^3$	61	0.899	1	$1.528 \cdot 10^3$
71	1.198	1	$1.426 \cdot 10^3$	71	1.047	1	$1.51 \cdot 10^3$
81	1.367	1	$1.423 \cdot 10^3$	81	1.194	1	$1.497 \cdot 10^3$
91	1.536	2	$1.438 \cdot 10^3$	91	1.342	1	$1.487 \cdot 10^3$
101	1.704	2	$1.435 \cdot 10^3$	101	1.489	1	$1.479 \cdot 10^3$
111	1.873	2	$1.432 \cdot 10^3$	111	1.636	2	$1.54 \cdot 10^3$

3.5.2 Determining the production rate when an increase of the cost price jump

occurs:

Setting the functions for the cost price jump searching for the compared variants of assembly method:

$$FNJ_AH(x) := \begin{cases} i \leftarrow N + 1 \\ \text{while } x \geq m_{j_AH}(i) \\ \quad i \leftarrow i + 1 \\ i \end{cases}$$

$$FNJ_j(x) := \begin{cases} i \leftarrow N + 1 \\ \text{while } x \geq m_{j_j}(i) \\ \quad i \leftarrow i + 1 \\ i \end{cases}$$

$$N_AH_jump := FNJ_AH(m_{j_AH}(N))$$

$$N_j_jump := FNJ_j(m_{j_j}(N))$$

3.12

The nearest cost rise jump occurs when the production rate is as follows, pcs:

$$N_{\text{AH_jump}} = 89 \quad N_{\text{j_jump}} = 102$$

3.5.3 Building the chart of the assembly cost price against the dependence on the production rate

Setting the function to determine the left and right boundary of the production rate range for building the graph:

$$N_{\text{max}} := \text{round} \left[\left[1 + \frac{1.7 \cdot (N_{\text{j_jump}} - N)}{N_{\text{j_jump}} + N} \right] \cdot \text{if}(N_{\text{AH_jump}} > N_{\text{j_jump}}, N_{\text{AH_jump}}, N_{\text{j_jump}}) \right]$$

$$\text{NG to 1}(x) := \text{if} \left[x > N_{\text{max}} - N, x - (N_{\text{max}} - N), 0.9 \cdot N \right]$$

$$N_{\text{min}} := \text{NG to 1}(N)$$

$$n := N_{\text{min}}, N_{\text{min}} + 1 \dots N_{\text{max}}$$

The Left boundary of the production rate range, pcs:

$$N_{\text{min}} = 50.4$$

The right boundary of the production rate range, pcs:

$$N_{\text{max}} = 152$$

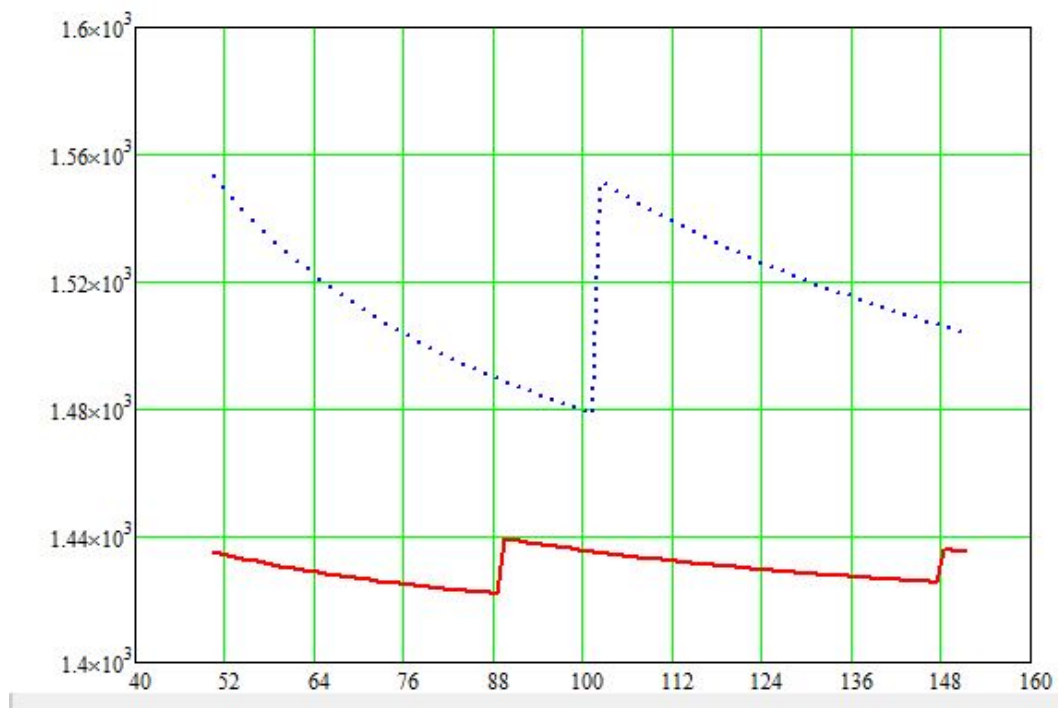


Figure 3.1- Combined graph of the dependence of the cost of assembling using two methods, against the production rate range:

CONCLUSION

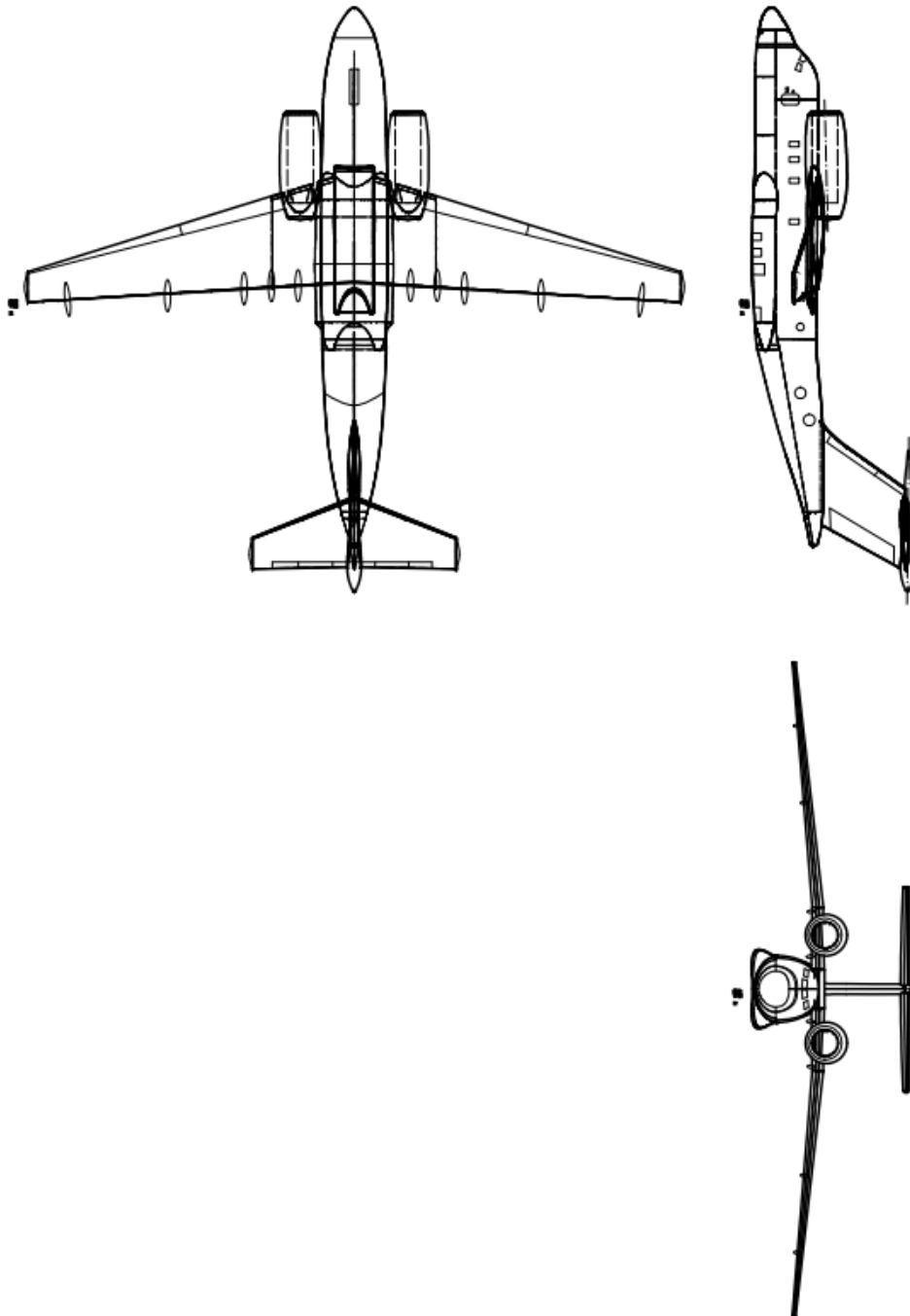
According to the initial data, in the first section, I choose the better material for my top cap. It is more cheaper with higher ultimate.

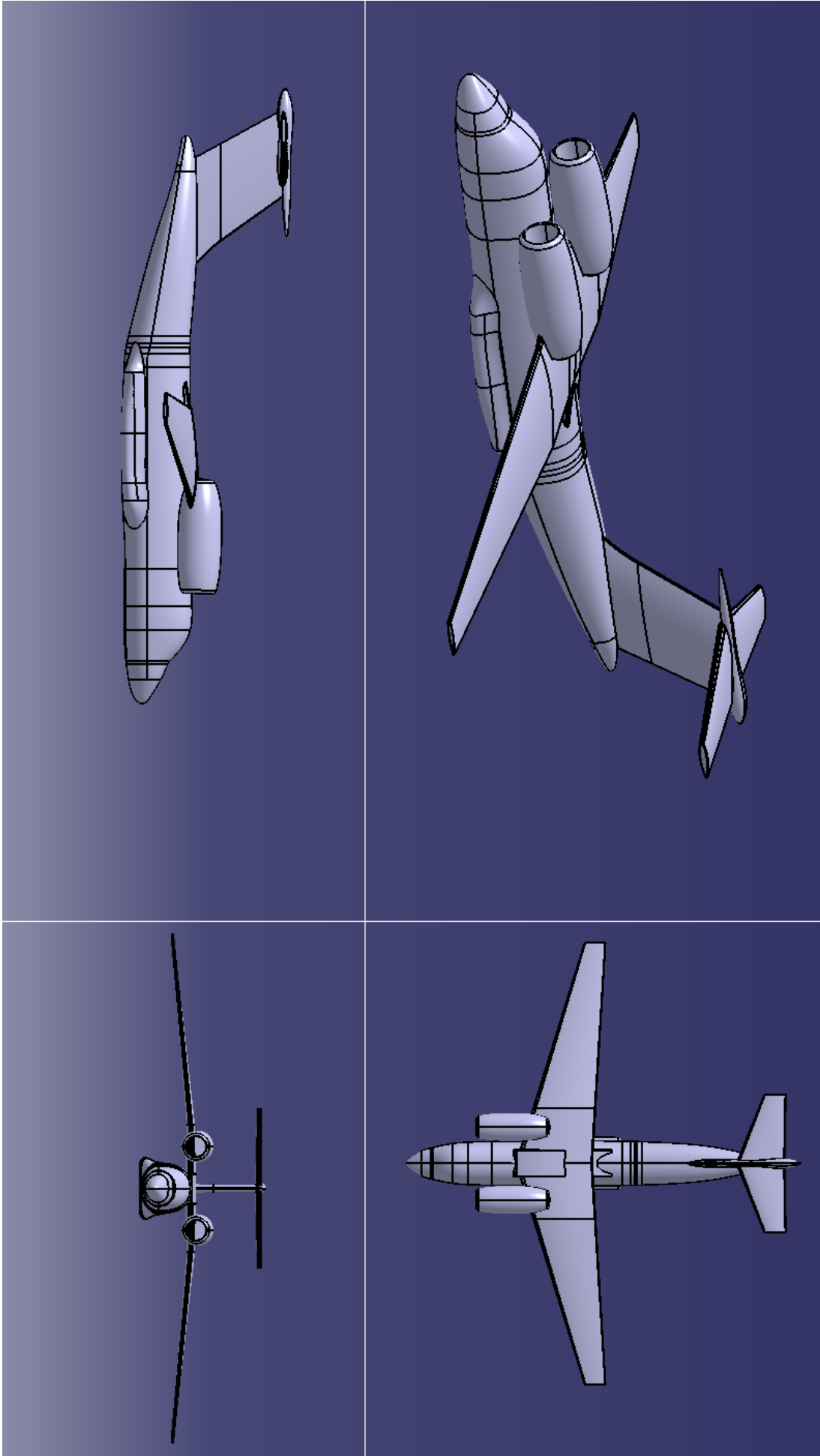
In the second section, I use processing technology to rationally produce my parts, so that the production steps are simpler and the cost is lower.

In the third section, I had compared Assembly Holes and Assembly Jig, finally I chose the assembly jig, because it is more cheaper than assembly holes.

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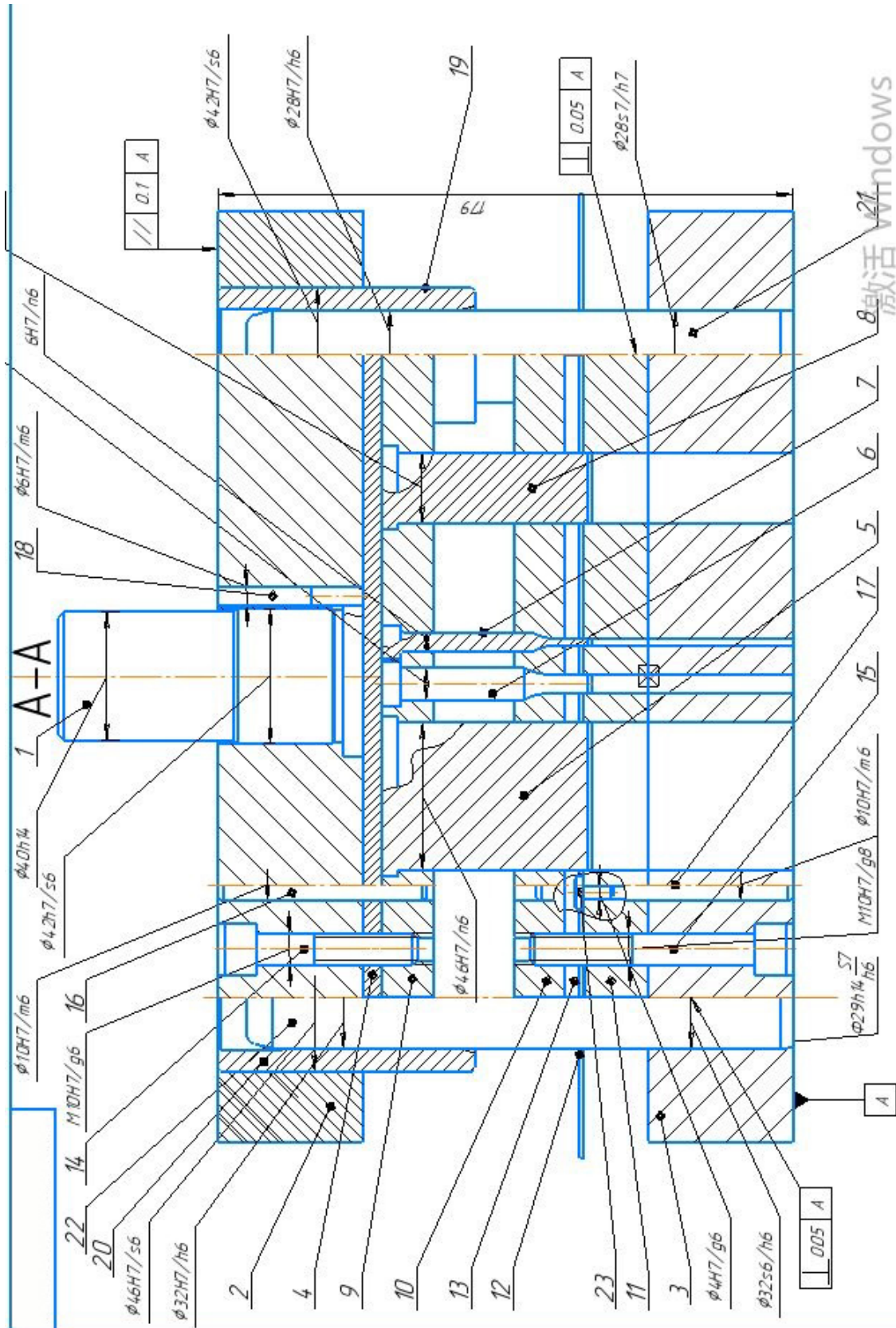
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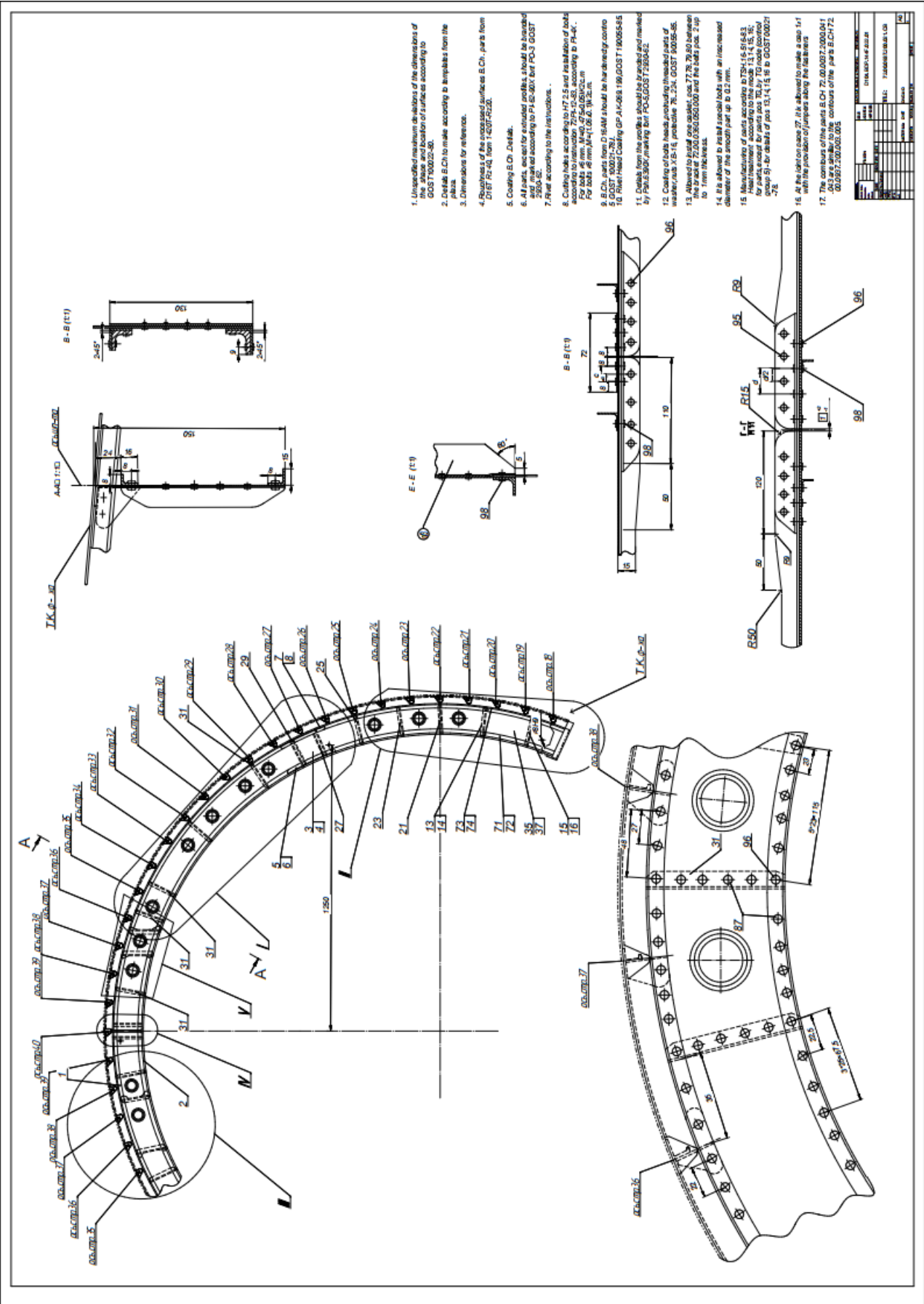
*APPENDIX A***Graphic materials for the design section**



APPENDIX B

Assembly drawings of some parts in Special Section





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