МІНІСТЕРСТВО ОСВІТИ І НАУКИ УКРАЇНИ

НАЦІОНАЛЬНИЙ АВІАЦІЙНИЙ УНІВЕРСИТЕТ

АЕРОКОСМІЧНИЙ ФАКУЛЬТЕТ

КАФЕДРА ПІДТРИМАННЯ ЛЬОТНОЇ ПРИДАТНОСТІ ПОВІТРЯНИХ СУДЕН

ДОПУСТИТИ ДО ЗАХИСТУ
Завідувач кафедри
к.т.н., доцент
____________ Попов О.В.
«____» __________ 2022

КВАЛІФІКАЦІЙНА РОБОТА

(ПОЯСНЮВАЛЬНА ЗАПИСКА)

ЗДОБУВАЧА ОСВІТНЬОГО СТУПЕНЯ МАГІСТРА

ЗА ОСВІТНЬО-ПРОФЕСІЙНОЮ ПРОГРАМОЮ
«ТЕХНІЧНЕ ОБСЛУГОВУВАННЯ ТА РЕМОНТ ПОВІТРЯНИХ СУДЕН І АВІАДВИГУНІВ»

Тема: " Дослідження технологічного процесу ремонту висотної системи. "

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Київ 2022

MINISTRY OF EDUCATION AND SCIENCE OF UKRAINE

NATIONAL AVIATION UNIVERSITY

AIRCRAFT AIRWORTHINESS CONTINUING DEPARTMENT

PERMISSION TO DEFEND

Head of the Department

Ph.D., Assoc. Professor

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«____» __________ 2022

MASTER DEGREE THESIS

(EXPLANATORY NOTE)

APPLICANT FOR ACADEMIC DEGREE OF MASTER

FOR EDUCATIONAL PROFESSIONAL PROGRAM

«MAINTENANCE AND REPAIR OF AIRCRAFT AND AIRCRAFT ENGINES»

Topic: " The study of the technological process of the repair of the high-rise system."

Performed by: __________ Heichenko D.V

Supervisor:

Ph.D., assoc. prof. __________ Smirnov Y.I

Consultants from separate sections of the explanatory note:

Labour precaution advisor:

Ph.D., assoc. prof. __________ Kajan K.I.

Environmental protection advisor:

Ph.D., assoc. prof. __________ Pavlyukh L.I.

Standards Inspector: __________

Kyiv 2022

NATIONAL AVIATION UNIVERSITY
Faculty: Aerospace faculty
Aircraft Continuing Airworthiness Department
Educational level: «Master Degree»
The specialty: 272 «Aviation transport»
Educational-professional program «Maintenance and Repair of Aircraft and Engines»

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GRADUATE STUDENT'S DEGREE WORK ASSIGNMENT

Heichenko Dmytro

1. The Work topic: «**The study of the technological process of the repair of the high-rise system**» approved by the Rector's order of September 29, 2022 No. 1786/st.
2. The work fulfillment terms: since September 26, 2022 till November 30, 2022.
3. Initial data for the project: searching for data and identifying faults that occur in the hydraulic system and reducing them to maintain the safety of the aircraft.
4. The content of the explanatory note: introduction, analytical part, structural design and description of hydraulic system units project part, scientific part, occupational safety and health, environmental protection, conclusions.
5. The list of mandatory graphic materials: shows the work of the hydraulic system, aircraft scheme and landing gear parts

6. Time and Work Schedule

#	Stages of Graduation Project Completion	Stage Completion Dates	Remarks
1	Task receiving, selection of material	30.09.22 - 5.10.22	
2	Analytical part, detailed analysis of negative factors influencing on aircraft operational reliability, serviceability	6.10.22 - 8.10.22	
3	Project part	9.10.22 - 15.10.22	
4	Scientific part	16.10.22 - 22.10.22	
5	Labor precautions	23.10.22 - 28.10.22	
6	Ecology	28.10.22 - 4.11.22	
7	Arrangement of explanatory note	4.11.22 - 10.11.22	
8	Preparing for project defend	11.11.22 - 15.11.22	

7. Advisers on individual sections of the project:

Section	Adviser	Date, Signature	
		Assignment Delivered	Assignment Accepted
Labor precaution	Ph.D., associate professor K.I. Kajan		
Environmental protection	Ph.D., associate professor Pavlyukh L.I.		

8. Assignment issue date 26.09.2022.

Degree work supervisor: __________ Smirnov Y.I

(signature)

Assignment is accepted for fulfillment __________ Heichenko D.V

(signature)

CONTENT

РЕФЕРАТ

Пояснювальна записка до дипломної роботи «   » містить ____ сторінок, ___ рисунків, __ таблиці, ___ використаних джерел.

Ключові слова: ЛІТАК, ВІДНОВЛЕННЯ, ТЕХНОЛОГІЧНИЙ ПРОЦЕС, СИСТЕМА КОНДИЦІОНУВАННЯ, ЛАЗЕР, ДЕФЕКТАЦІЯ, АГРЕГАТ.

Предмет проектування – дослідження технологічного процесу ремонту висотної системи.

Мета дипломної роботи – вдосконалення технологічного процесу ремонту висотної системи і впровадження його при ремонті сучасних літаків.

Технічні та програмні засоби проектування – ПК, Microsoft Word, AutoCAD, Microsoft PowerPoint.

У процесі виконання дипломної роботи було проаналізовано характеристику видів, організації та вдосконалення ремонту АТ. При цьому, головну увагу було приділено аналізу технологічного процесу ремонту агрегатів висотної системи. Розглянуто питання вдосконалення процесу ремонту за допомогою механізації та автоматизації. Було вдосконалено технологічний процес балансування ротора турбохолодильної установки за допомогою лазерного балансувального стенда і провадження комплексу для перевірки агрегатів висотної системи.

Також у роботі розглянуті питання охорони праці та охорони навколишнього середовища.

Матеріали дипломної роботи рекомендується використовувати на авіаремонтних підприємствах, наприклад, на ДП "ЗАВОД 410 ЦА".

ABSTRACT

The explanatory note to the thesis " " contains ____ pages, ___ figures, __ tables, ___ used sources.

Keywords: AIRCRAFT, RESTORATION, TECHNOLOGICAL PROCESS, AIR-CONDITIONING SYSTEM, LASER, DEFECATION, UNIT.

The subject of the design is the study of the technological process of the repair of the high-rise system.

The aim of the thesis is to improve the technological process of repairing the altitude system and its implementation in the repair of modern aircraft.

Technical and software design tools – PC, Microsoft Word, AutoCAD, Microsoft PowerPoint.

In the process of completing the thesis, the characteristics of the types, organization, and improvement of JSC repair were analyzed. At the same time, the main attention was paid to the analysis of the technological process of repairing units of the high-altitude system. The issue of improving the repair process with the help of mechanization and automation was considered. The technological process of balancing the rotor of the turbo-cooling unit using a laser balancing stand and the implementation of a complex for checking the units of the high-altitude system were improved.

Also, issues of labor protection and environmental protection are considered in the work.

The materials of the thesis are recommended to be used at aircraft repair enterprises, for example, at the ДП "ЗАВОД 410 ЦА".

Conventional abbreviations

AQ -aviation equipment

AAR- air-air radiator

APU- auxiliary power unit

ACS- air conditioning system

TCU- turbo cooling unit

CA- civil aviation

IECD-industrial electronic computing devices

ECM - electronic computing machine

MOM-means of measurement

CAVE-control and verification equipment

ARP - aircraft repair plant

FS-flight safety

ATB-aviation technical base

ROOT- rules of operation technique

SR- safety rules

MAR- maintenance and repair

Introduction

Equipping civil aviation with new equipment sets the repair company the task of carrying out timely and high-quality repairs to the aircraft and engine park.

In this diploma project, the main technical and economic indicators are calculated, the issues of economic calculation and improvement of a typical technological process are presented.

The major part of the diploma project is devoted to the equipment used in the typical technological process of repairing the equipment of the high-altitude system of the An-type aircraft (on the example of the An-32).

The improved technological process of repair, thanks to the use of automation and mechanization means, allows to significantly increase labor productivity, reduce the cost price, and improve the organization and culture of production. Solving the tasks of the planned organization of the production process, modern repair enterprises are working towards further improvement of the current-bench method of repair.

The continuous growth of production, the constant improvement of repair equipment and technologies, the introduction of the latest scientific achievements in the field of production processes dictates the need to use the most advanced repair methods in the technological process.

SECTION 1

MAIN PART

1.1. Analysis of defects in the high-altitude equipment of the An-type aircraft

In the process of operation and defecting, important data on the nature, size and location of defect points are accumulated. These data are used to solve tasks aimed at improving flight safety, reducing aircraft maintenance costs, and reducing downtime. Let us indicate the main goals of the statistical analysis of defects during repair:

- identification of "weak points" of the design and submission of claims to the aviation industry

- forecasting the appearance of defects

- calculation of the need for spare parts and units

- analyse of reliability of AT

- division of major repairs into regulated stages

- detection of the possibility of switching to a repair system based on the technical condition

- analysis of repair quality

- calculation of repair tolerances and its value

- establishing the terms of preventive inspections and maintenance.

The stage of defect data analysis depends to some extent on the set goal. However, it is possible to single out a sequence of stages that is common when solving any of the listed tasks.

The general sequence of defect data analysis during repair consists of the following stages:

- classification of data on defects by the location of the defect, the nature of the defect, and the performance of the units

- identifying the cause of the defect

- development of measures to eliminate the causes of defects, malfunctions and failures

- construction of a mathematical model of the appearance of a defect

- calculation of the parameters of the mathematical model

- making a decision.

Analysis of defect data can be useful and important only in conditions where information about defects is objective and reliable.

Table 1.1 gives a list of aggregates and nodes that are repaired in the workshop of high-altitude equipment.

№ п/п	Names of aggregates	TYPE
1	Item number Name of units Type	Item number Name of units Type
2	1 Pressure regulator 2077AT	1 Pressure regulator 2077AT
3	2 Absolute pressure regulator 1314P	2 Absolute pressure regulator 1314P
4	3 Damper 24-7602-605	3 Damper 24-7602-605
5	4 Damper 24-7602-305	4 Damper 24-7602-305
6	5 Check valve 24-7601-100-11	5 Check valve 24-7601-100-11
7	6 Air distributor 514B	6 Air distributor 514B
8	7 Air supply regulator 1408	7 Air supply regulator 1408
9	8 Air pressure regulator 469	8 Air pressure regulator 469
10	9 Excess pressure regulator 6198	9 Excess pressure regulator 6198
11	10 Excess pressure regulator 6198	10 Excess pressure regulator 6198

12	11 Solenoid valve 772	11 Solenoid valve 772
13	12 Filter 11VF-12	12 Filter 11VF-12
14	13 Ground conditioning start-up fitting 11VF-12	13 Ground conditioning start-up fitting 11VF-12
15	14 Blowing nozzle 11VF-12	14 Blowing nozzle 11VF-12
16	15 Damper of the output channel VVR 11VF-12	15 Damper of the output channel VVR 11VF-12
17	16 Outlet valve 2176T	16 Outlet valve 2176T
18	17 Turbocooler 3263	17 Turbocooler 3263
19	18 Pipeline 26-7602-177	18 Pipeline 26-7602-177
20	19 Damper 513B	19 Damper 513B

The most common defects are:

- the appearance of a burning smell in the passenger compartment and the crew cabin. The defect is detected due to the ingress of oil from the power plant or APU of the high-altitude system main line. The defect is eliminated by burning the pipelines of the high-altitude system;

- a through hole from rocking when lifting the sideboard cover into the pipe. The defect is the result of a structural defect. To eliminate the defect, it is necessary to increase the depth of the technological dent to ensure the free movement of the buffet lid lifting swing;

- pipeline cracks along welding seams. The number of pipes with cracks is 10% of the total number of pipes being checked. The use of argon welding did not reduce the number of cracks, so we suggest replacing some pipes with reinforced ones;

- non-parallelism of the corrugations of the compensator and the surface dent. Operational defect;

- complete destruction of the rubber ring of the seal. The defect appears from temperature effects on the non-return valve 24-7601-100-11 during operation due to structural defects. To eliminate defects, replace rubber seals;

- cracks and cracking of the outlet part of the nozzles from vibration loads created by the air environment. To eliminate the defect at the outlet and inlet of the pipe, it is suggested to weld belts made of stronger material;

- clamp 12OH.340.00.21 – cracks on the seat, due to insufficient strength of the clamp material.

- cracks on the seat of the filter 11VF-12, due to insufficient strength, as well as aging of the glass material. We suggest replacing plexiglass with a stronger material;

- breakage of the heads of the screws attaching the pads of the air pressure regulator 2077AT. The size of the strength of the sleeves under the ring and the outer diameter under the key are not the same. Increase the size of the groove under the keys;

- the disc of the turbine of the 3263T turbo-cooling unit leaves traces of what concerns the blades on the cover - the defect is a manifestation of a design flaw. During repair, non-reinforced axles are replaced with reinforced ones;

- displacement of the exhaust valve petal 2176. the defect is the result of a design flaw. It is proposed to change the design of the petal valve;

- bending of the axis 2134T 058 of the command device 2134, caused by an unacceptably large pressure difference in cavities 2 and 1 due to a violation of the tightness of the pressure supply pipeline to the first cavity. Operational defect;

- breakage of more than one turn of the thread on the 2355AT-010 valve body 2355. The breakage of the thread is a consequence of improper installation of the product. Operational defect;

1.2. Defects in pipelines and TCU

To reduce the number of cracks in the pipeline, it is suggested to replace some elements with reinforced (thicker) ones. In this THU 3263 turbo cooler, the labyrinth seals are arranged vertically and hot air enters through these seals into the oil cavities and onto the bearings, the oil burns out and the bearing is destroyed, and, as a result, the rotor jams. It is proposed to change the design of the seal so as to exclude the possibility of hot air entering the oil cavities. Based on the analysis, the weakest points in the altitude system of the An-32 aircraft were identified. They are the following units:

- damper 5145, the defect is found in the form of a section of the axis 514B-004, the defect is structural. In this diploma project, it is proposed to replace the damper axis with a reinforced one. This is justified by the given calculations, the body is also reinforced on this damper to eliminate dents and temperature stress.

- Non-return valve 24-7601-100-11 - the defect appears in the form of plaque on the flap and its jamming. The design of the valve has been changed. Instead of the previously used two semi-axes, one single axis is installed, and the valve body is strengthened to exclude the influence of temperature stress.

1.3. Calculation of the elements of the overhead valve 514B

Determine the diameter of the axis of the damper, knowing the dimensions of the cross section of the air channel where the damper is installed, 0.18m - 0.29m (see Fig. 1.1).

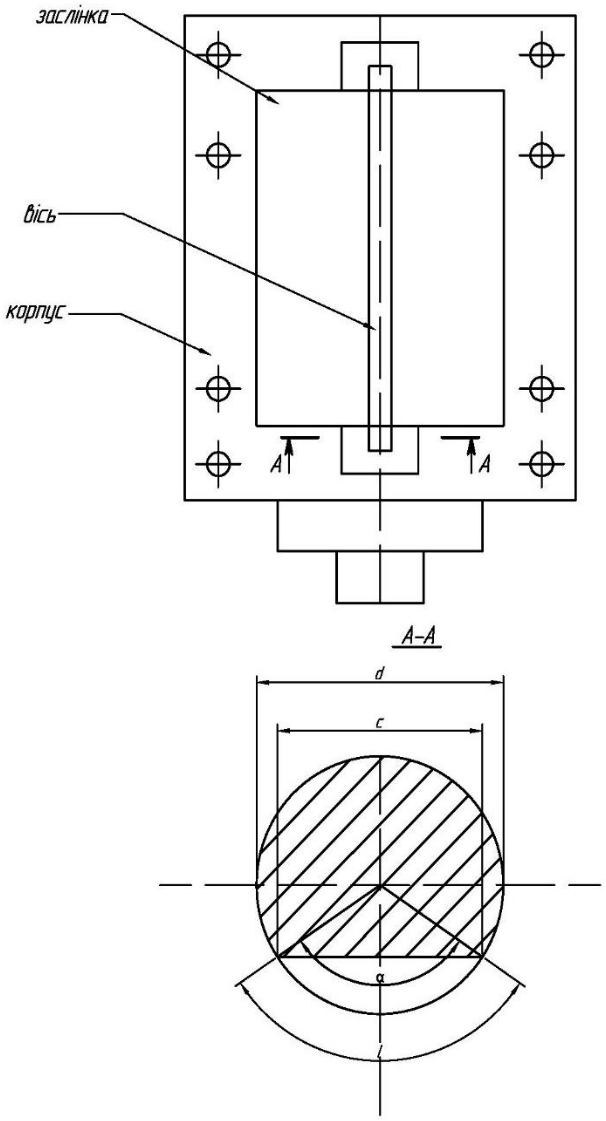


Fig. 1.1. Scheme for calculating the overhead valve 514B

Excessive pressure in the air channel

$$\text{P}_{\text{изб}} = 3 \cdot 10^5 \text{Па}$$

We choose the material for the damper axis

$$\sigma_{\text{в}} = 160 \cdot 10^5 \text{Па}$$

$$[\tau]_{\text{ср}} = 40 \cdot 10^5 \text{Па}$$

The shear strength condition for the damper axis has the form:

$$\tau_{\text{ср}} = \frac{f \cdot Q}{2F_{ch}} \leq [\tau]_{ch}$$

Де f=2 – коефіцієнт безпеки для деталей, що працюють під тиском

Q – сила, що діє на площину заслінки.

$$Q = P_{\text{изб}} \cdot F_3$$

$P_{\text{изб}} = 3 \cdot 10^5$ - excessive pressure inside the air channel of the system

$F_{\text{ср}} = \frac{\Pi d^2}{4}$- cross-sectional area of the damper axis

n is the number of cutting planes

$F_3 = 0.18 \cdot 0.29 = 0.0522\text{м}^2$- area of the system channel, then:

$$\tau_{\text{ср}} = \frac{f \cdot P_{\text{изб}} \cdot F_3}{2\frac{\Pi \cdot d^2}{4}} \leq [\tau]_{cp}$$

$$d \geq \sqrt{\frac{2f \cdot P_{изб} \cdot F_3}{\Pi[\tau]_{cp}}}$$

$$d \geq 0{,}16 \cdot 10^{-2}$$

$$d \geq \sqrt{\frac{2 \cdot 2 \cdot 3 \cdot 522}{3.14 \cdot 4000}}$$

If d=16мм

We determine the tangential stress at the intersection of the damper axis. We accept for calculation (see Fig. 1.1)

$$l = 0{,}01745\frac{d}{2}\alpha \qquad h = 6\cdot10^{-3}\,м$$

$$\alpha = 130^{\circ} \qquad c = 14\cdot10^{-3}\,м$$

Effective cross-sectional area of the damper axis

$$F_g = \frac{\Pi\cdot d^2}{4} - F_1 \text{ де } F_1 = \frac{1}{2}\left(\frac{d}{2}l - c\left(\frac{d^2}{2} - h\right)\right) -$$

when $$F_g = \frac{3{,}14\left(6\cdot10^{-3}\right)^2}{4} - \frac{1}{2}\left(\frac{6\cdot10^{-3}}{2}\cdot0{,}01745\frac{6\cdot10^{-3}\cdot2{,}27}{2} - 1{,}4\cdot10^{-6}\left(\frac{16}{2} - 6\right)\right)$$

$$F_g = 1{,}42\cdot10^{-4}\,м^2 \qquad \text{і} \qquad \tau_{cp} = 21{,}03\cdot10^5\,Па$$

$$21{,}03\cdot10^5 < 40\cdot10^5$$

$$[\tau] > \tau_{cp}$$

Therefore, the strength condition is fulfilled, the strength margin factor

1.4. Analysis of the technological process of repairing units of the altitude system of the An-type aircraft

The technological process of repair is a part of the production process, which includes actions to determine and further change the condition of the subject of repair.

The manufacturing process of repair includes:

- preparation of repair tools;

- organization of workplace maintenance;

- obtaining and storing the repair fund for spare parts and materials

semi-finished products;

– all stages of machine repair;

– assembly of units and the machine as a whole;

– machine testing;

– transportation of parts, spare parts, materials, and assembly units;

- conservation and packaging of the repaired machine and all other actions related to the repair of the aircraft.

The general diagram of the technological process of repair is shown in fig. 1.2. As can be seen from the scheme, the repair begins with a preliminary inspection (acceptance for repair) to identify the feasibility of repairing the machine, check its assembly, and identify defects that are visible without disassembling the machine. To increase labor productivity and the quality of subsequent repairs, external contamination is removed by preliminary washing. These systems are subjected to performance testing, and control with the help of special devices to detect the technical condition of their parts, after which the scope of further dismantling and repair work is determined.

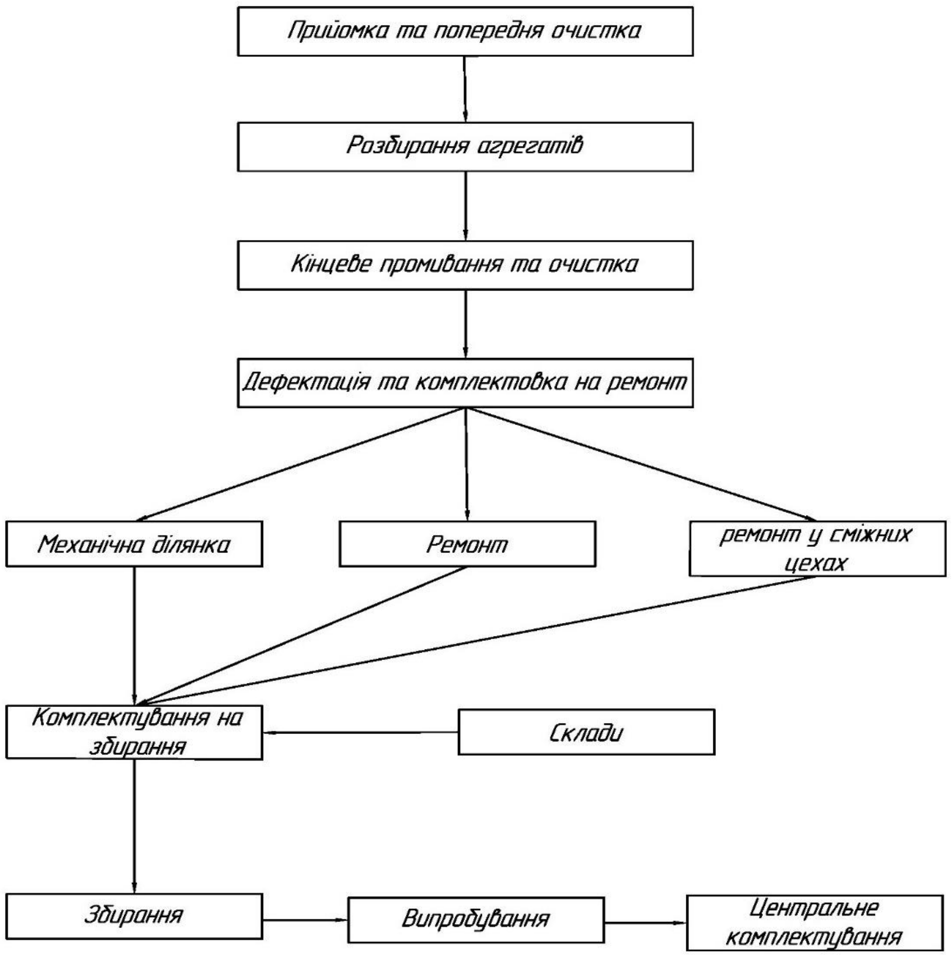


Fig. 1.2. Scheme of technological process of repair

1.4.1. The process of disassembling repair objects

Disassembly refers to the category of mandatory work performed during a repair. It greatly affects the productivity of aircraft repair work and the overall technical level of aircraft repair work. Dismantling sites should have exemplary work organization, advanced technology, and complex mechanization of production processes. The use of a faulty tool during disassembly and deviation from the working technology can cause great damage to the repaired product, more than operation in the most favorable conditions, and will also cause the need to carry out a significant amount of additional repair work.

During disassembly, the following basic conditions must be met:

– installation of the object of disassembly should exclude the possibility of distortion of its geometric parameters;

- the installation of the disassembled product must ensure the maximum front of work, the possibility of using mechanized tools and equipment, and minimal time spent on auxiliary operations;

- disassembly must be carried out strictly in accordance with the existing technology, without loss of parts and with the mandatory preservation of completeness of nodes;

- after disassembly, temporary preservation of the product must be carried out to protect unprotected surfaces from corrosion. It is also necessary to take measures to prevent dirt and foreign objects from getting into the parts and units of the equipment.

Before starting disassembly, it is necessary to familiarize yourself with the safety rules and take measures to prevent damage to parts and units.

1.4.2. The process of cleaning repair objects

The process of cleaning repair objects consists in removing all types of contamination from their surface with the help of a solid and liquid or gaseous medium. The labor intensity of cleaning parts is 7-9% of the total labor intensity of the repair.

Pollution that must be removed in a mandatory manner are:

- products of high-temperature transformations of oils, fuels, and working fluids, carbon deposits, varnish deposits, resin, and sedimentation;

– destructive (old) paint and special non-metallic coatings that preserve the coating;

– accidental and extraneous particles of various origins. The first two groups of contaminants are the most difficult to remove. Contamination can be removed both by washing, and dissolving with the help of chemical reactions and mechanical action. The most effective is a combination of these two methods. The choice of one or another method is determined by the type of contamination, shape, and material, the part to be cleaned, technical requirements for repair, economic considerations, and requirements for safety and environmental protection.

To remove impurities, such methods of washing and cleaning are used as mechanical (thermoforming, hydroforming), electrolytic, physicochemical, and cleaning by immersion in a solution (squeezing). The promising ultrasonic cleaning method has become the most widespread.

1.4.3. Decontamination of repair objects and their assembly in the shop

After washing and cleaning, the parts are subjected to defects and sent to the workshop for assembly. The purpose of the first assembly, or assembly for repair, is the grouping of parts and units by nodes for transfer to the appropriate repair shop. During defecting, parts containing unacceptable defects are rejected. Instead of rejected parts, new or repaired parts from the working capital obtained at the intermediate stage, which is part of the production preparation, are used during assembly. Completed in groups, the parts are transferred to the repair site together with forms and parameter maps. The principle of assembly for repair is determined by the method of organization of the technological process adopted at the enterprise. In the case of applying the progressive group method, the parts must be assembled in accordance with their structural and technological features. In this case, the same high-performance repair methods can be used for each group of homogeneous products.

In the process of defecting, in addition to visual and metrological methods, non-destructive testing methods are currently widely used. Non-destructive testing methods include:

- Acoustic (past radiation, reflected radiation, resonant, free oscillations).
- Magnetic (magnetic powder, magnetographic, ferroprobe).
- Optical (visual-optical, holographic, interference).
- Penetrating substances (capillary colored, fluorescent colored).
- Vacuum.
- Eddy currents.

The use of technical diagnostic methods allows you to obtain a quantitative criterion for evaluating the quality of products, and ultimately their operational reliability and durability.

Parts are rejected during repair for the following reasons:

- resource production;

– exhaustion of existing permits for repairs;

– operational destruction of parts exceeding permissible standards;

– lack of objective methods for determining the technical condition of parts and units;

- lack of appropriate technological methods for repairing parts.

1.4.4. Defects caused by operation

When designing and manufacturing parts, combinations of parts, and aggregates of aircraft, they are provided with the necessary properties. These include material properties, shape, dimensions, surface roughness, manufacturing accuracy, and others. When designing, all these properties, as well as all the necessary fitting of connections, are provided by the detailed drawings. In the process of operation, parts are rubbed, subject to changes associated with various types of damage, for example, various fatigue defects, wear of friction surfaces, corrosion, deformation, and others.

Most parts with such defects are restored during the repair process. The goals of restoring parts can be:

- the restoration of strength;
- the restoration of the shape and dimensions of the part;
- the restoration of surface roughness and surface layer quality;
- the restoration of protective coatings.

Restoration of parts is carried out by processing, cutting, proofing, riveting, welding, and gluing. At the present stage, the method of gas sputtering of coatings has become the most widespread.

The method of restoration of parts by the electrolytic method is also widely used. When choosing the most rational technological method of restoring the aircraft, one should take into account the dimensions, shape, and accuracy of the part's manufacture, its material, heat treatment, working conditions, the appearance and nature of the defect, and the production capabilities of the aircraft repair enterprise.

1.4.5. The process of assembling repair objects

The assembly process is carried out only with serviceable tools and equipment in accordance with the assembly technology. For this, technological maps are specially developed with an indication of the sequence of assembly, the tools, and the materials used. The qualifications of the performers must correspond to the level of work. During assembly, the following conditions must be met:

– installation of the object should exclude the possibility of distortion of its geometric shape

- the installation of the assembled product should ensure the maximum front of work, the possibility of using mechanized equipment and tools, and minimal time spent on auxiliary operations;

- assembly must be carried out strictly in accordance with the technology in force;

- after assembly, conservation should be carried out and measures should be taken to prevent dirt and foreign objects from getting into the parts and units of the equipment.

1.4.6. Testing the repaired product

The final phase of repair is testing. Testing of the repaired product is carried out on special machines that create conditions as close as possible to the operating conditions of the product on an aircraft. The tests allow you to determine the quality of product repair, as well as to determine the possibility of operating the product on an aircraft.

1.4.7. Analysis of shortcomings in the organization of the repair process

Analyzing existing technologies, the process of repairing high-altitude equipment at SE “Facility 410 TSA", as well as the organization of production, the following shortcomings can be noted:

– the existence of individual technologies for aggregates and individual equipment units of the same design and functions on the aircraft, in particular, test stands;

- the technological process of repair involves the complete disassembly of the unit and its components when repairing the product without taking into account its technical condition;

– the equipment, its location, and planning of production premises do not correspond to the general technological cycle of the movement of units;

– does not meet the requirements of the regulatory and technical documentation of the developer of the premises for the repair and assembly of units;

– insufficient level of production culture;

– insufficient equipment for the repair process with means of transportation (sorters, special equipment, universal lifting, and transport devices);

– a large percentage of the use of manual labor during repairs, lack of means of small mechanization of the technical process;

- placement of highly sensitive stands and installations (a machine for dynamic balancing of shafts) in the production premises of the workshop near the sources of large vibrations;

- in the area of washing parts and assemblies, the process of cleaning parts is carried out manually using a brush and a rag. In this diploma project, the following measures are proposed to eliminate the shortcomings identified during the analysis of the existing technological process:

– the creation of typical technological processes for groups of repaired units with the simultaneous design of equipment for the repair flow line;

- the creation of universal units of test equipment - test stands;

– design and wide application of means of small mechanization of the technological process of repairing units of the high-altitude system;

– wide introduction into the technological process of repair of the principles of repair of units of the height system - according to the technical condition with the design of means of diagnosing the technical condition of the products without their disassembly;

- in order to reduce manual labor and improve the culture of production in repair shops of high-altitude equipment, we suggest applying ultrasonic washing of parts.

Despite the seeming simplicity, the existing process (washing with a brush and rag) is very complicated and time-consuming. The use of ultrasonic washing allows you to significantly reduce labor costs, reduce washing time, increase production culture, improve the quality of washing and, ultimately, increase labor productivity. This method is used to wash small parts from greasy and mechanical contamination. Parts are loaded into a bath with B-70 gasoline, at the bottom of which are placed magnetostrictive transducers of ultrasonic vibrations (usually 20-30 kHz). As a result of the absorption of ultrasound, high energy density gradients are created, which causes the appearance of general and local hydrodynamic flows and acoustic currents. If the pressure in some parts of the flow drops to the pressure of saturated vapor, the liquid begins to boil - cavitation occurs. Due to the presence of so-called cavitation nuclei in the washing liquid - air bubbles, solid particles and other particles of pollution, disruption of integrity - the rupture does not occur at a calculated negative pressure of up to 1000 MPa (for water), but at a pressure an order of magnitude lower. Cumulative jets upon meeting the surface cause its destruction from micro- to macro-scale depending on the power. In addition to high impact pressure, cavitation bubbles disrupt the entire liquid, increase the contact area between the liquid and contamination, and increase physical adsorption processes. Equipment for ultrasonic cleaning is usually a series of chambers (baths) designed for multi-position cleaning - degreasing, ultrasonic cleaning, rinsing, drying.

In order to bring it into line with the planning of production premises and the technological cycle of movement of units in repair, we offer the following scheme of production organization (see Fig. 1.3). This scheme of the flow-bench method of production organization.

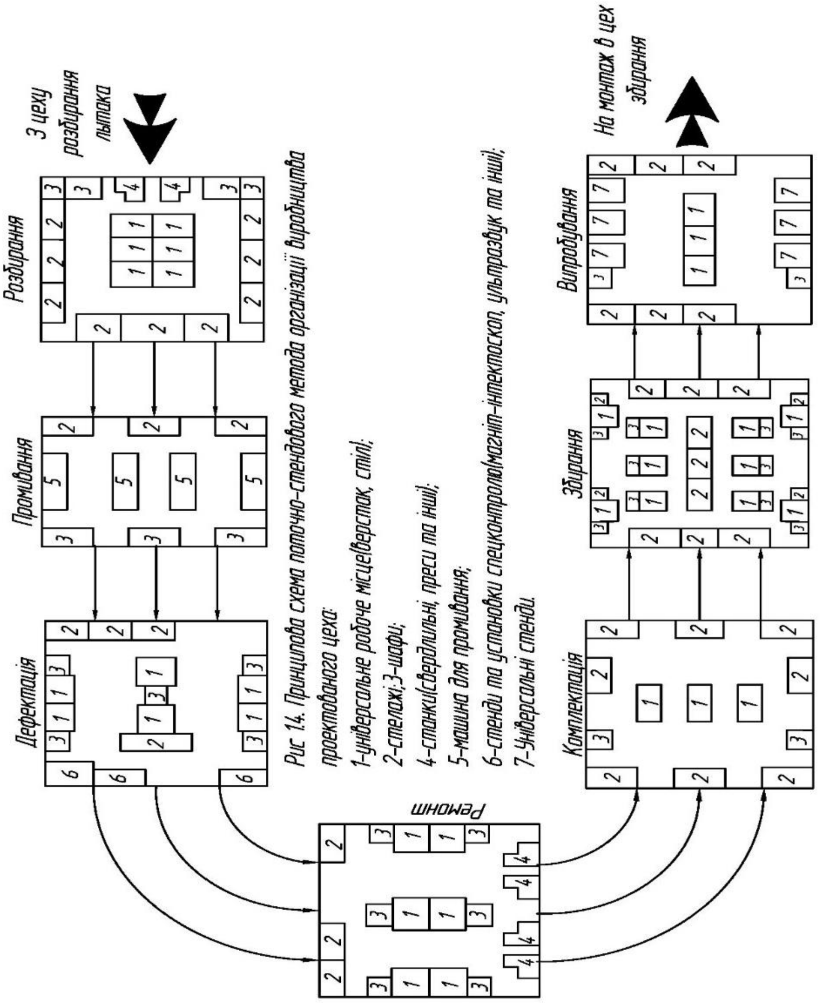


Fig. 1.3. Schematic diagram of the current-bench method of organizing the production of the designed workshop

1.5. Selection and justification of the repair method

One of the most important factors that ensure the rhythm of work is the transition of production to the flow method. The transition of production to flow means the introduction of the most advanced and progressive method of work, which allows, thanks to the better use of production areas and equipment, to achieve the maximum production output, to work rhythmically and according to the schedule.

The use of the flow method gives the following advantages:

- the duration of the production cycle is sharply reduced;

- the labor intensity of repairs is reduced due to the improvement of technology, reduction of transportation, use of high-performance equipment, increase of labor productivity;

- specialization of workers and equipment on the flow enables workers to quickly master the entire volume of work assigned to him and master the most productive work methods;

- production areas are better used;

- favorable conditions are created for quick and clear management of complex repair processes.

Given the specificity of the repair, namely:

a) inconstancy of the volume and nature of work at each facility;

b) availability of dismantling and finishing works;

c) lack of complete interchangeability;

d) the form of the flow is somewhat different from that used in mechanical engineering.

In the conditions of repair, the most favorable form of flow should be a pulsating flow with a forced rhythm.

At CA enterprises that repair aviation equipment. This form was called the flow-bench method of repair.

The flow-bench method of repair is characterized not only by the technological sequence, but also by the continuity of the repair of units and parts. With this method, the entire volume of assembly and preparatory work is divided into separate operations, which are carried out synchronously at the corresponding workplaces of the flow line. The production line includes a certain number of stands, individual workplaces. The consistency of the work of the entire line is ensured mainly by the correct planning of the beginning and end of the operation at each workplace. The flow-bench method provides a wide range of applications in the technological process of repairing network graphs. Taking into account all the advantages of the flow-bench method, we accept this method in this technological process of repairing high-altitude equipment.

1.6. Details of the equipment used

Equipment Purpose Technical characteristics	Equipment Purpose Technical characteristics	Equipment Purpose Technical characteristics
1	2	3
IR stand	Valve testing	Working pressure
Leakage test stand	For testing and processing command devices for tightness and vibration resistance	Working pressure Пр=40-100 kPa
Balancing machine	To check the tightness and processing of units 3263	Balancing accuracy 0.05-0.3 The length of the balanced part is 50-500 mm Maximum engine revolutions 24s-1 Operating voltage 220/380V
Leakage testing stand	For quick and accurate determination of the value of the location of the imbalance on the rotor of the product	The capacity of the working tank is 30 liters Max. spin 7s-1 The power is 0.6 kW Operating voltage 220/380V

Installation for testing units of the high-altitude system	For performance tests of high-altitude system units in conditions as close as possible to operating conditions on the aircraft. Dampers TCU 3263	Consumed power N=820 kW Operating voltage 220/380V Air consumption 0.06-1.4 kg*s-1 Maximum excess pressure P=800 kPa is 10 m
Leakage test stand	For testing pipes for strength and tightness	The length of the bath is 10 m

1.7. Stand for testing units of the high-altitude system of the An-type aircraft

The stand includes:

– control panel with control and measuring devices;

– pressure chamber;

– vacuum pump RMK-4;

– drive electric motor (N=7.5 kW);

- electric panel.

Control panel

Control devices with taps, a fitting for connecting a pressure regulator 2077, "Start" and "Stop" buttons for the pump, a rotameter tap are mounted on the control panel. The rotameter is placed on the stand, and there is also a pressure gauge from the venturi tube, a pressure gauge for measuring the "cabin-atmosphere" difference.

Baro chamber

The pressure chamber is divided into two chambers: a small one that simulates an airplane cabin, and a large one that simulates the atmosphere. The "cabin" has two flanges for installing valves, a stand for installing a control device, a fitting for connecting to the "atmosphere" with a rotameter, an altimeter, a variometer, and a manometer (for measuring the "cabin-atmosphere" difference). If the command device is not installed in the "cabin", but on the control panel, it is connected to the "cabin" by two pipelines to the exhaust valve and the pressure in the "cabin". Supercharging in the "cabin" is created from the workshop air system. The "cabin" has a safety valve adjusted to an overpressure of 39,227 Pa. The height in the "atmosphere" is created by the RMK-4 vacuum pump. "Atmosphere" has fittings for connection with command device 2077, an altimeter (for measuring the "cabin-atmosphere" difference).

Vacuum pump RMK-4

The vacuum pump is installed on the first floor. Liquid-ring type pump. The working fluid is water. The pump drive is an electric motor connected to the pump through an elastic coupling. Buttons for turning on the pump on the first floor and on the control panel (second floor). The maximum vacuum created by the pump is 98%.

Supercharging system

Air from the workshop air network passes through the sump and can be directed to the "cabin" or "atmosphere". The consumption is regulated by the valve. According to the readings of the mercury manometer from the Venturi tube and the monovacuum meter, the flow rate can be calculated using the formula:

$$G = 3{,}01 \cdot \varepsilon \sqrt{\frac{\mathrm{P_T} \cdot \mathrm{P}}{\mathrm{T}}}$$

where: G – air consumption (t/h)

h – drop across the Venturi tube (Pa)

P is the absolute static pressure in front of the Venturi tube according to the monovacuum meter (Pa)

T is the air temperature in front of the Venturi tube (absolute)

ε - air jet expansion coefficient.

Parameters to be checked:

According to the pressure regulator 2077

– checking the specified excessive pressure of the supported 2077 and 4870T;

- checking the operation of the "start of sealing" unit;

– checking the set rate of pressure change.

On exhaust valves

– verification of the specified excessive pressure supported by 2077 and 4870T;

– checking the hydraulic resistance of the valves in a straight line;

– checking air leakage through the valve in ground conditions;

– checking the excess pressure maintained in the cabin by the valve limiter.

Preparation of the installation for work. Before starting work, do the following:

Prepare the pump for operation:

- open the latches;

- turn off the circuit breaker;

- open the valve on the pipeline that supplies water to the pump, taking into account that there is water in the pipeline. Water should flow from the gas tank into the sewer;

– the valve on the pipeline connecting the gas collector to the pump must be open, and the drain valve from the gas collector to the sewer must be closed;

- turn on the circuit breaker, start the pump for a short time. Make sure that there are no constant knocks inside the cylinders;

– drain the condensate from the water-oil separators. To do this, open the tap at the bottom of the water-oil separator for 3.5 minutes;

– check installation leaks.

While working

- taps, valves should be opened and closed in the sequence indicated in the method. Make sure there is no sudden change in height to avoid:

a) spilling of mercury from the manometer;

b) destruction of devices on the front panel of the remote control.

– when starting and stopping the pump, the valves must be open;

– the cover of the pressure chamber must fit tightly to the gasket, it must be constantly pulled diagonally;

- when installing the product on the stand, the tightness of the joints must be complete.

After the work is finished

- open the latches;

– close the valve on the pipeline that supplies water to the pump;

- turn off the switch.

Electric air heater

It is intended for heating the air to a given temperature. The "start" and "stop" buttons for controlling the electric air heater are installed in the operator's control panel. The electric air heater has 6 independent electric heating elements with a capacity of 140 kW each. The air passing through the heater successively blows all the elements that are uniformly connected to the air circuit of the turbocooler 3263. In order to prevent the operation of the heater without flowing air and when the air pressure drops to 29400 Pa or less, in order to protect the heating elements from destruction, the design provides a device that automatically turns off the heater. This function is performed by a pressure alarm installed in the air line of the stand.

Measuring washers

Two washers are installed in the air line to measure air flow. A washer with a hole diameter of 15 mm is installed to measure the air leakage at the connection of the turbocooler. To remove the technical characteristics, a washer with a hole diameter of 30 mm is installed. The pressure drop on the washers is measured by a differential manometer in mmHg. Air consumption in kg/h is determined by graphs built according to the dependence, where the drop is measured in mmHg, and the density in .

Air pipeline installation system

The air system of the installation is made of metal pipes with a diameter of 100 mm, 50 mm, 25 mm, 12 mm. In order to prevent possible burns and contact with the pipes, and to reduce heat losses, the hot section of the pipelines inside the installation is covered with asbestos. The connection point of the air system to the turbocooler is made by a straight section with two hermetic spherical joints, on which there are places for measuring the temperature and air pressure at the entrance to the tested product. Such a connection excludes the possibility of damage to the pipes when testing the turbocooler for vibration resistance. An oil-water separator is installed in the area of air supply to the installation, which ensures the supply of dry and clean air.

Vibration installation

The vibration installation is a machine, in the upper part of which a plate with a vibration sensor is installed on four paired springs. On the axis of the vibration sensor, two oppositely located rotating loads are installed, the amplitude of oscillations depends on their mutual location. The shaft of the vibration sensor receives rotation from the D-400 direct current electric motor, which comes from the power unit. The magnitude of the vibration amplitude of the vibration plate is adjusted by changing the position of the loads fixed on the shaft of the vibration sensor.

The vibration installation is mounted on a flat cement floor and fixed with four anchor bolts.

1.8. Installation for testing TCU 3263 for performance

The installation is designed to test the performance of the turbo cooler 3263 in conditions as close as possible to the conditions of its operation on an airplane. The main elements of the proposed installation are:

– main pipelines designed to supply cold and hot air with specified parameters (pressure P, flow rate Q, and temperature t) to the tested product;

- compensators designed to ensure one degree of freedom in the adapters during assembly and disassembly of the tested products. In addition, compensators serve to compensate for temperature expansions occurring in the system;

– overhead valves for regulating the airflow of main pipelines of the installation, as well as for emergency opening and closing of the pipeline;

– impulse pipelines for supplying pressure to the control and measuring equipment of the installation (manometers, flowmeters, thermometers).

Structurally, the installation for testing TCU 3263 for operability can be made and placed in a separate test box or in the general complex of the test bench, designed to check all repaired units of the high-altitude system for operability.

The structure of the installation is mounted on a frame, which is rigidly fixed to the foundation of the building.

The turbo-cooling unit is fixed on the stand with the help of standard fasteners on the connection points of the unit's attachment to the aircraft. The pipelines are connected to the inlet and outlet nozzles of the unit with the help of flexible rubber adapters, with the help of clamps for fastening pipelines and nozzles. The geometry and shapes of the supply pipelines and nozzles to the tested product are selected from the conditions specified by the developer's manual TCU 3263.

Power elements of the installation, their dimensions, purpose based on strength calculations, and from the condition of uniform strength (see the section "Verification calculations") data are presented. The main pipelines of the installation are made by welding from standard pipes. The nozzles at the entrance to the TCU fan are made of aluminum alloys by welding. To reduce heat loss, the hot air supply pipelines have a heat-insulating jacket.

The principle of operation of the installation is as follows: air with the parameters specified by the tests (pressure, flow rate, temperature) flows from the pipeline to the inlet of the tested unit, where energy is redistributed on the TCU turbine, then the cooled air flows to the outlet of the turbo cooler, from where it is discharged into the general cold line through the damper.

During inspection and acceptance tests and running-in of the turbo cooler, the parameters of the unit are set and controlled according to the requirements of the repair technician. In this diploma project, we propose an increase in the number of seats for tested products with the introduction of multi-channel measurements of parameters, as well as their recording. This will allow simultaneous testing of several units of products, which in turn will significantly increase labor productivity, as well as lead to energy savings, as a result of reducing test time.

1.8.1. Checking the airflow through the valve on the pressure regulator

Checking the airflow through the valve on the pressure regulator is carried out on the installation assembled according to the diagram (see Fig. 1.4) as follows:

– place the output flange of the product in a tank with alcohol, give maximum pressure at the inlet;

- close the valve in front of the rotameter and raise the absolute pressure in the pressure chamber to 0.85;

- hold the pressure regulator for 5 minutes.

Airflow through the valve is not allowed, which is determined by the absence of bubbles in the tank. The characteristics of the pressure regulator should be measured at air temperature on the installation assembled according to the diagram (see Fig. 1.4) as follows:

- provide the maximum pressure at the inlet and, having established the required airflow, check the pressure at the outlet of the regulator;

– then smoothly changing the value of the input pressure, from the maximum to the minimum value at the required flow rate;

– check the output pressure value.

The parameters of the pressure regulator must correspond to the values specified in the technical conditions for the pressure regulator.

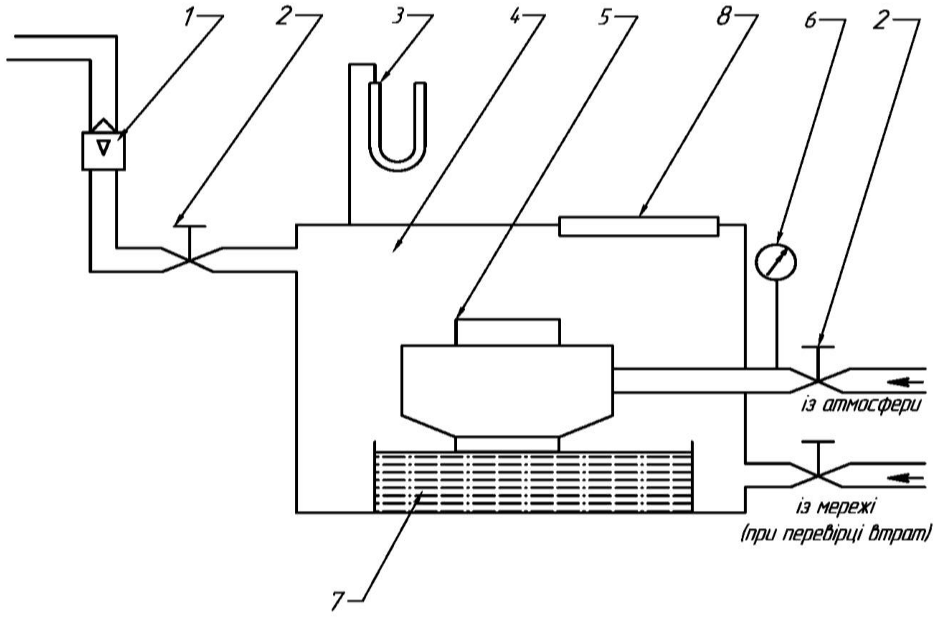


Рис 1.4. Схема установки для випробувань регуляторів тиску на перетікання та втрати повітря, зняття характиристик

1. Регулятор
2. Вентиль
3. Дифманометр
4. Барокамера
5. Регулятор тиску
6. Манометр
7. Бак зі спиртом
8. Скло

1.8.2. Description of the installation for dynamic balancing of the rotor of the product TCU 3263

The dynamic balancing machine consists of a mechanical and electrical part. The mechanical part consists of a bed, housing, drive, support rack. The bed is placed on a special massive foundation, on four support posts. The racks are adjustable in height, which allows you to install the machine at the required height. The landing part of the rotor consists of two supports - front and rear. The front support is the spindle for attaching the front part of the rotor. Spindle rotation is driven by an electric motor using a V-belt transmission. The front and rear supports are located on support swings that are fixed. The front and rear supports are supported by shock absorbers on the frame with the help of support swings. Amortization packages serve to reduce the influence of extraneous disturbances on the accuracy of measurements.

In addition to the electric motor with the throttle block, the electrical part includes a control panel and electrical commutative equipment. The electric motor is equipped with a belt tensioning mechanism. The measuring part of the installation includes capacitive sensors, converter blocks, an amplifier and a control device, and a control panel. In the process of repairing the product, 3263 is subject to disassembly, mechanical processing, restoration of surfaces and coatings. In addition, transportation, cleaning and rinsing. All these operations in the event of the influence of any objective reasons, or violation of the technology can lead to a violation of the geometric shapes of the rotor. The latter, in turn, lead to an imbalance of rotor masses. Installation of such a rotor on a turbocharger causes vibration of the rotor, increased loads on the bearings, their overheating and destruction. In order to improve the quality of repairs, increase the reliability of the product, and, ultimately, increase flight safety and their regularity, in this diploma project we offer a device for dynamic balancing of the rotor of product 3263. When performing work on checking and balancing the rotor of product 3263, it is necessary to strictly observe the technique safety and installation instructions.

1.9. Verification calculations

1.9.1. Selection of the hot air main pipeline to the product under test

Let's consider a segment of the pipeline with length l and outer diameter D. Let's select an element (square) with side Dl on its surface. The voltage acting in this element can be seen from Figure 1.5. Since the thickness S of the pipeline is small compared to its diameter, we believe that only normal stress occurs in the walls of the pipe (which is stretched, because the inside of the pipeline is, by convention, air under excessive pressure).

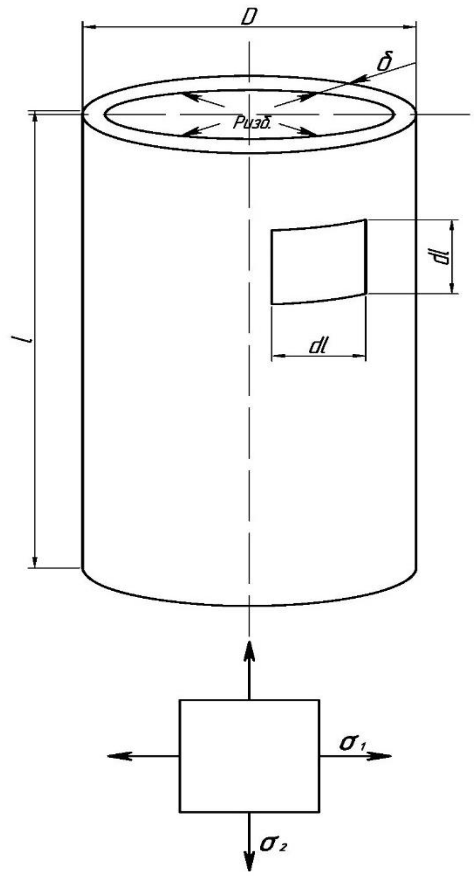


Fig. 1.5. Selection of main pipeline

The outer diameter of the pipeline D = 90 mm is specified by the technical conditions for abrasion of the THU. The material of the pipe is steel 20.

$$\tau_{в} = 120MPa$$

$$[\sigma] = 200MPa$$

The main normal stress arising in the pipe wall:

$$\sigma_1 = \frac{FD}{2\delta}; \qquad \sigma_1 = \frac{FD}{4\delta};$$

The strength condition for the III strength category looks like this:

$$\sigma_1 = f\frac{P_{изб} \cdot D}{2\delta} \leq [\sigma] \text{де f=2,5}$$

– safety factor for pressure vessels.

$$\delta \geq \frac{\text{P}_{изб} \cdot D}{2[\tau]}$$

$$\delta \geq \frac{2.5 \cdot 7 \cdot 10^5 \cdot 90 \cdot 10^{-2}}{2 \cdot 20 \cdot 10^6} = 0.0394m$$

We accept standard steel seamless pipe.

Pipe 90x5x1 - Article 20 of ГОСТ 8734-76

We check the strength of the selected standard pipe according to the IV theory of strength:

$$\delta\sqrt{\delta_1^2 + \delta_2^2 - \delta_1\delta_2[\delta]_{max}}$$

$$\delta_1 = \frac{PD}{2\delta_2} = \frac{7 \cdot 10^5 \cdot 90 \cdot 10^{-2}}{2 \cdot 5 \cdot 10^{-3}} = 6{,}3 \cdot 10^6 Pa$$

$$\delta_2 = \frac{1}{2}\delta_1 = 3{,}15 \cdot 10^6 Pa$$

$$\delta\sqrt{(6{,}3 \cdot 10^6)^2 + \frac{(6{,}3 \cdot 10^6)^2}{4} - \frac{6{,}3 \cdot 10^6 \cdot 6{,}3 \cdot 10^6}{2}}_{max}$$

$$\delta_{\max} = 54{,}6 МПа < [\delta] = 200 МПа$$

that is, the strength condition is fulfilled

Safety factor:

$$n_в = \frac{[\delta]}{f\delta_{\max}} = \frac{200}{2{,}5 \cdot 54{,}6} = 1{,}46$$

1.9.2. Calculation of the mounting frame of the main pipeline at the entrance to the TCU

The calculation scheme of the mounting frame is shown in fig. 1.6. The pipeline fastening frame is welded from a corner steel 40 KhVN angular, equilateral.

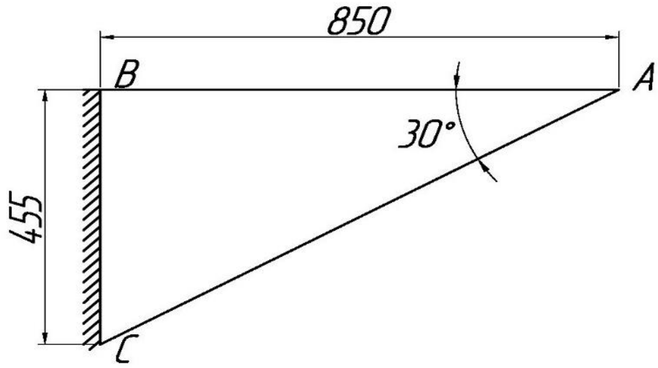


Fig. 1.6. Calculation scheme of the mounting frame

Profile number 4, 5 see Fig. 1.6.

$$B = 45мм = 45 \cdot 10^{-3}m$$

$$R = 5mm = 5 \cdot 10^{-3}m$$

$$S_{кр} = 3{,}48sm^2 = 3{,}48 \cdot 10^{-4}m^2$$

$$I_x = 6{,}63sm^3 = 6{,}63 \cdot 10^{-9}m^3$$

$$d = 4mm = 4 \cdot 10^{-3}m$$

$$z_0 = 12{,}6mm = 12{,}6 \cdot 10^{-3}m$$

I_x - the moment of inertia about the x-x axis (Fig. 1.7).

$E = 2 \cdot \frac{10^6 kg}{sm^2}$ - - modulus of elasticity (from the table)

$\sigma = 172 \cdot 10^7 Pa$ – voltage

We will calculate the strength of the frame elements. The frame is loaded with a vertical force P=1000n. The system is three times statically indeterminate. Let's calculate the reactions of the supports using canonical equations using the force method. We select the main calculation scheme (see Fig. 1.8). Let's replace the connections (reactions) of the rigid construction of B t. C with unknown force factors.

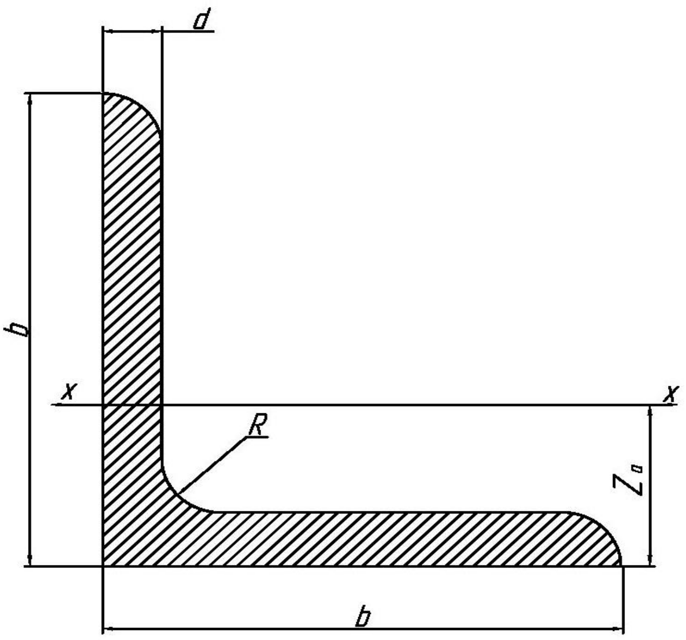


Fig. 1.7. Scheme for calculating the moment of inertia

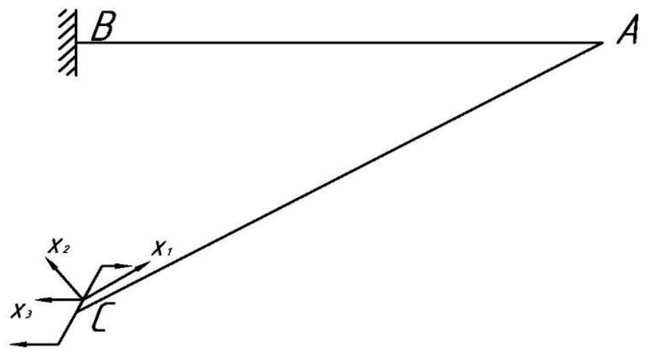


Fig. 1.8. Calculation diagram of the system of forces of the fastening frame

We replace the canonical equations (from the condition of equality of zero displacements when replacing the unknown forces and and also by the moment)

$$\begin{Bmatrix} \delta_{11}X_1 + \delta_{12}X_2 + \delta_{13}X_3 = -\delta_1 P \\ \delta_{21}X_1 + \delta_{22}X_2 + \delta_{23}X_3 = -\delta_2 P \\ \delta_{31}X_1 + \delta_{32}X_2 + \delta_{33}X_3 = -\delta_3 P \end{Bmatrix}$$

Where δ_{12}- displacement due to force

$x_2 = 1$- direction of force

x_1, x_2- unknown reactions

x_3- unknown moment

We define the canonical equations. We assume that the rods work for bending, the stiffness (EJ) of all sections of the frame is constant. The value is determined by multiplying plot 1 (Fig. 1.9) by itself (for each section, the area of the plot is taken and multiplied by the ordinate of the same plot that passes through its center of gravity).

We apply unit forces "1" and "2" to the frame at point C and construct curves of bending moments from the action of these forces (Fig. 1.9). Epure M on stretched fibers.

$$\mathrm{M}_{.B2} = 1 \cdot l \cdot sin\,3\,0° = 0{,}5l = 0{,}5 \cdot 8{,}5 = 4{,}25(\mathrm{H} \cdot m)$$

$$\mathrm{M}_{.A1} = 1 \cdot \frac{l}{cos\,3\,0°} = \frac{8{,}5}{0{,}866} = 10(\mathrm{H} \cdot m)$$

$$\mathrm{M}_{.B1} = 1 \cdot \frac{l}{cos\,3\,0°} - 1 \cdot 4{,}55\, sin\,3\,0° = 10 - 2{,}275 = 7{,}725(\mathrm{H} \cdot m)$$

We apply a single moment at point C (see Fig. 1.9). We determine the values of the coefficients:

$$\delta_{11} = -\frac{1}{EJ} \cdot \left(\frac{2}{3} \cdot l \cdot \frac{l^2}{4}\right) = -\frac{l^3}{6EJ} = -\frac{6141263}{6EJ}$$

$$\delta_{21} = -\frac{1}{EJ}\left[\left(\frac{M_{A2} + M_{B2}}{2}\right) \cdot l \cdot \frac{2}{3} \cdot \frac{l}{2}\right] = -\frac{1}{EJ}\left[\frac{1000 + 772{,}5}{2} \cdot 850 \cdot \frac{2}{3} \cdot \frac{850}{2}\right]$$
$$= -\frac{2136793700}{EJ}$$

$$\delta_{12} = \frac{1}{EJ}\left[\frac{l^2}{4}\left(M_{A2} - \frac{2}{3} \cdot l \cdot \frac{1}{cos\,3\,0°}\right)\right] = \frac{1}{EJ}\left[\frac{l^2}{4} \cdot \left(\frac{l}{cos\,3\,0°} - \frac{2}{3} \cdot \frac{l}{cos\,3\,0°}\right)\right]$$
$$= \frac{602084500}{EJ}$$

$$\delta_{22} = \frac{1}{EJ}\left[\frac{2}{3} \cdot M_A \cdot \frac{l}{0{,}86} \cdot \frac{M_{A2}}{2} + \frac{M_A + M_B}{2} \cdot l \cdot \left[M_B + \frac{2}{3} \cdot (M_A - M_B)\right]\right] =$$
$$= \frac{1}{EJ}\left[\frac{10^5 \cdot 850}{3 \cdot 0{,}86} + \frac{10^3 + 772{,}5}{2} \cdot 850 \cdot \left(\frac{1}{3} \cdot 772{,}5 + \frac{2000}{3}\right)\right]$$
$$= \frac{17257055000}{9} EJ$$

$$\delta_{33} = \frac{1}{EJ}\left(\frac{1 \cdot l}{0{,}86} + l \cdot 1\right) = \frac{18500}{EJ}$$

$$\delta_{23} = \frac{1}{EJ}\left[l \cdot \frac{M_A + M_B}{2} \cdot 1 + \frac{M_A}{2} \cdot \frac{l}{0{,}86} \cdot 1\right]$$

$$= \frac{1}{EJ}\left[850 \cdot \frac{1000 + 772{,}5}{2} + \frac{1000}{2} \cdot \frac{850}{0{,}86}\right] =$$

$$= \frac{125331250}{3{,}44} EJ$$

$$\delta_{13} = \frac{1}{EJ}\left(\frac{l^2}{4} \cdot 1 + 0\right) = \frac{180625}{EJ}$$

$$\delta_{31} = -\frac{1}{EJ} \cdot \left(l \cdot \frac{l}{4}\right) = -\frac{1}{EJ} \cdot \frac{850^2}{4} = -\frac{180625}{EJ}$$

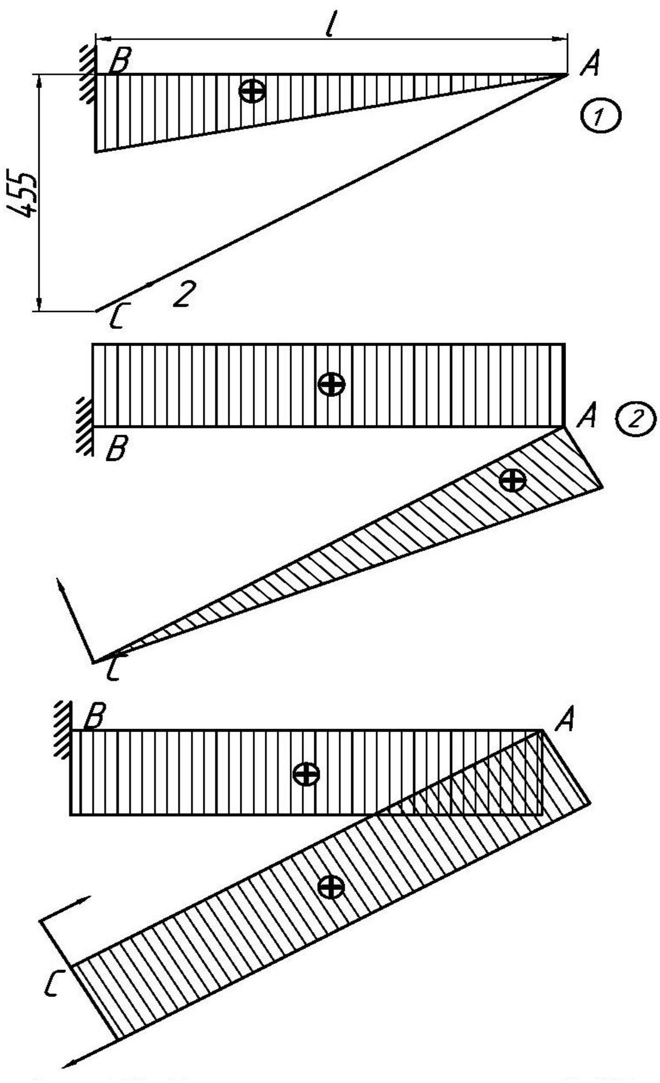


Fig. 1.9. Plots of bending moments from unit forces "1", "2" and unit moment "1" at point C

We take the condition into account $P = 10^3 H$

$$\delta_{1P} = \frac{1}{EJ}\left(\frac{l^2}{4}\cdot\frac{2\cdot P\cdot l}{3}\right) = \frac{1}{EJ}\cdot\frac{850^2\cdot 2\cdot 10^3\cdot 850}{4\cdot 3} = \frac{6424712200}{12}EJ$$

$$\delta_{2P} = \frac{1}{EJ}\left[\left(\frac{M_A + M_B}{2}\right)\cdot l\cdot\frac{P\cdot l^2}{3}\right] = \frac{1}{EJ}\left[\frac{10^3 + 772,5}{2}\cdot\frac{10^3\cdot 850^2}{3}\right] = \frac{135708780}{EJ}$$

$$\delta_{3P} = \frac{1}{EJ}\left(l\cdot\frac{P\cdot l}{2}\right) = \frac{38292,5}{EJ}$$

Moreover, the dimension of the numerator in the expressions of the coefficients is given in

Let's write the canonical equations, translating the coefficients in advance

$\delta_{11} - \delta_{13}$ in $H\cdot m^3$

$$\delta_{11} = -\frac{1023543}{EJ} \qquad \delta_{12} = \frac{602084,5}{EJ} \qquad \delta_{13} = \frac{18062515}{EJ}$$

$$\delta_{21} = -\frac{2136793,7}{EJ} \qquad \delta_{22} = \frac{17257055}{EJ} \qquad \delta_{23} = \frac{12533,125}{EJ}$$

$$\delta_{31} = -\frac{18062,515}{EJ} \qquad \delta_{32} = \frac{80331,25}{EJ} \qquad \delta_{33} = \frac{185}{EJ}$$

Canonical equations take the form:

$$\begin{cases} -\dfrac{1023543}{EJ}x_1 + \dfrac{602084,5}{EJ}x_2 + \dfrac{18062,515}{EJ}x_3 = -\dfrac{64247122}{EJ} \\ -\dfrac{2136793,7}{EJ}x_1 + \dfrac{172570055}{EJ}x_2 + \dfrac{12533,125}{EJ}x_3 = \dfrac{135708780}{EJ} \\ -\dfrac{18062,515}{EJ}x_1 + \dfrac{80331,25}{EJ}x_2 + \dfrac{185}{EJ}x_3 = \dfrac{38292,547}{EJ} \end{cases}$$

Solving the system of equations we find:

$$x_1 = \frac{490{,}62 \cdot 10^6}{2 \cdot 6{,}67 \cdot 10^6} = 370H$$

$$x_2 = \frac{769{,}08 \cdot 10^6}{2 \cdot 6{,}67 \cdot 10^6} = 580H$$

$$x_3 = -\frac{51376{,}02 \cdot 10^6}{2 \cdot 6{,}67 \cdot 10^6} = -432{,}7H$$

We apply the found forces to the main calculation scheme and find the voltage at points B and C (see Fig. 1.10):

$$\mathrm{M}_{\text{изг.C}} = \mathrm{x}_3 = -432{,}7\mathrm{H} \cdot m$$

$$\mathrm{M}_{\text{изг.A}} = \mathrm{x}_2 \frac{l}{cos\, 3\, 0°} - x_3 = 58\frac{85}{0{,}86} - 422{,}7 = 147{,}3\mathrm{H} \cdot m$$

$$\mathrm{M}_{\text{изг.B}} = \mathrm{M}_{\text{изг.A}} + P \cdot l = 147{,}3 + 100 \cdot 85 = 1047{,}8\mathrm{H} \cdot m$$

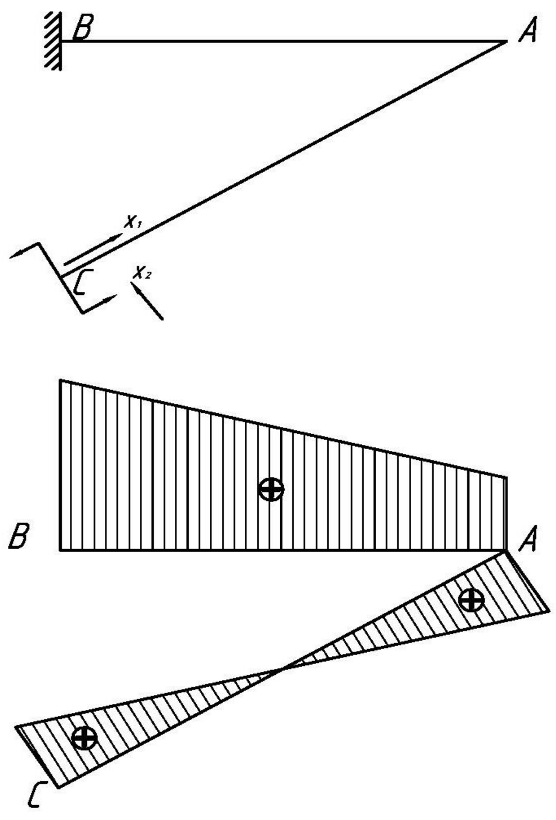


Fig. 1.10. Epures of bending moments

As can be seen from the calculation, the cross section of the frame at point B is the most loaded. The strength condition for point B looks like this:

$$\sigma_В = \frac{М_{изг.В}}{W_x} \le [\sigma_В],$$

$\sigma_в = 1{,}72 \cdot 10^7 Pa$- strength limit for the material of the frame profile

$W_x = \frac{J_x}{J_{max}} = \frac{6{,}63}{3{,}24} = 2{,}046 см^3 = 2{,}046 \cdot 10^{-6} м^3$ - moment of resistance of the frame profile in relation to the x-x axis

$$5122{,}9 \cdot 10^5 Pa < \sigma_B = 172 \cdot 10^7 Pa.$$

That is, the strength condition is fulfilled.

Safety factor:

$$n_\sigma = \frac{172 \cdot 10^7}{5122{,}9 \cdot 10^5} = 3{,}3$$

Check the "main" section according to the III strength theory

$$\sigma_{max}^{III} = \sqrt{\sigma^2 + 4\tau^2} \le \sigma_в$$

not necessary, since the safety factor for the selected frame profile is large enough and the forces acting on the frame are negligible $\mathrm{P} = 10^4$H.

1.9.3. Calculation of the electric heater

The thickness of the wall of the cylindrical part of the vessel is determined by the formula:

$S = \frac{P \cdot D_В}{230 \cdot \phi \cdot \sigma_{доп} - \rho} + l$, where

$P = 25 \cdot 10^5 Pa$ – internal pressure drop

$t = 400°C$ – vessel temperature

$D_В = 700 \cdot 10^{-3} m$ – inner diameter of the vessel

$\phi = 0,7$ – coefficient of strength of welds

l=1mm – corrosion allowance.

Allowable voltage $\sigma_{доп} = \eta \cdot \sigma^{*}_{доп}$

$\eta = 0,9$ - correction factor for structural features of the vessel

$\sigma^{*}_{доп} = 10^7 Pa$ - nominal allowable stress for steel 1X18N9T at

$t = 500°C$ _

$\sigma^{*}_{доп} = 0,9 \cdot 10^7 = 9 \cdot 10^6 Pa$,

$S = \frac{25\cdot700}{230\cdot0,7\cdot9-25} + 1 = \frac{17500}{1460-25} + 1 = 13,3mm = 13,3 \cdot 10^{-3} m.$

Thickness is adopted in the design $14 \cdot 10^{-3} m$.

1.9.4. Calculation of hole reinforcement

The largest diameter of unreinforced holes in cylinder elements should not exceed the value determined by the following formula:

$$d_{пред} = 8,1 \cdot \sqrt[3]{D_в \cdot (S - l)(1 - K)}$$

$$S - l = (14 - 1) \cdot 10^{-3} = 13 \cdot 10^{-3}$$

The "K" coefficient can be calculated using the formula

$$K = \frac{\rho \cdot D_в}{(230\sigma_{доп} - \rho)(S - l)}$$

$$K = \frac{25 \cdot 700}{(230 \cdot 9 - 25) \cdot 13} = 0,658$$

$$1 - K = 1 - 0,658 = 0,392$$

$$d_{пред} = 8,1\sqrt[3]{700 \cdot 13 \cdot 0,392} = 8,1\sqrt[3]{3110} = 118 \cdot 10^{-3} м$$

In our case, the hole diameter is d=488mm

Reinforcement of six holes is carried out with a common overlay. We will cut out the reinforcement of one hole and calculate it (see Fig. 1.11).

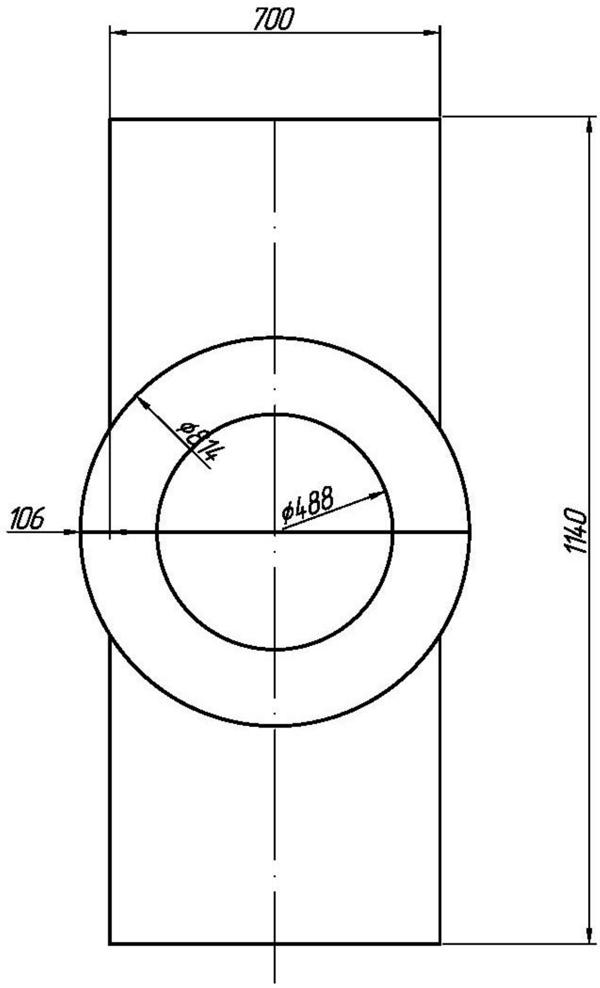


Fig. 1.11. Scheme for the calculation of holes

We believe that the diameter of the lining is equal to the average size

$$\text{В}_1 = 814 \cdot 10^{-3} m.$$

Let's determine the necessary dimensions of reinforcement from the inequality:

$$S_{\text{н}}(B - d) \geq S(d - d_{\text{пред}})$$

$S_{\text{н}} = S = 14 \cdot 10^{-3} m$ - товщина накладки

$$B - d \geq d - d_{\text{пред}} \Rightarrow B \geq 2 \cdot 488 - 118 \Rightarrow B \geq 858 \cdot 10^{-3}\text{м}$$

$$B \geq B_1$$

1.9.5. Bottom calculation

The thickness of the bottom wall with an opening is determined by the formula:

$$S = \frac{P \cdot D_в}{400 \cdot z \cdot \sigma_{доп} - P} \cdot \frac{D_в}{2 \cdot h \cdot b} + l_1 \ ,$$

Where $h_в = 175mm = 175 \cdot 10^{-3}m$ - the height of the convex part of the bottom

$D_в = 700 \cdot 10^{-3}m$ - inner diameter of the bottom

$l_1 = 2 \cdot 10^{-3}m$ - corrosion allowance.

The coefficient z is determined by the formula:

$z = 1 - \frac{d}{D_в}$ where $d = 180 \cdot 10^{-3}m$ - hole diameter.

$z = 1 - \frac{180}{700} = 0{,}743.$

Z – coefficient that takes into account the weakening of the bottom by the hole.

Allowable voltage:

$$\sigma_{доп} = \eta \cdot \sigma^*_{доп} = 0{,}95 \cdot 10 = 9{,}5kg/mm^2 = 95MPa$$

$$S = \frac{25 \cdot 700}{400 \cdot 0{,}743 \cdot 9{,}5 - 25} \cdot \frac{700}{2 \cdot 175} + 2 = 14{,}5 \cdot 10^{-3}m$$

We accept the thickness of the bottom $h = 14 \cdot 10^{-3}m$.

1.9.6. Calculation of the plug

The thickness of the plug is determined by the formula (see also Fig. 1.12):

$$S = 0{,}1d\sqrt{\frac{K_p}{R}} + l,$$

where R – permissible voltage

$R = \eta \cdot \sigma_{доп}$, $\eta = 1$ - for a plug

$\sigma_{доп} = 940MPa$ - nominal allowable stress for steel 3 at $t = 300°$

R=940MPa

l – corrosion allowance.

$K = 0{,}3 + \frac{1{,}4 \cdot Q \cdot h}{H \cdot d}$,

where H – the total hydrostatic load on the surface, limited by the outer diameter of the resistance

$$H = \frac{П \cdot P \cdot D_н^2}{4} = 358000H$$

$Q = P_б$ - load on the bolt

$$Q = P_б = 82240Н$$

$$К = 0{,}3 + \frac{1{,}4 \cdot 82240 \cdot 5{,}775}{55800 \cdot 50{,}45} = 0{,}537$$

$$S = 0{,}1 \cdot 504{,}5\sqrt{\frac{0{,}537 \cdot 25}{9{,}4}} + 1 = 61, mm = 61{,}4 \cdot 10^{-3}m$$

We accept $S = 70 \cdot 10^{-3}m$.

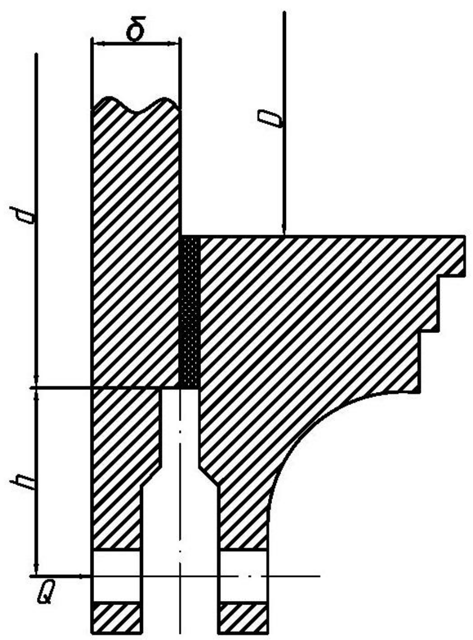


Fig. 1.12. Scheme for calculating the thickness of the plug

1.9.7. Calculation of resistances

Determination of stress from the weight of the structure (see Fig. 1.13).

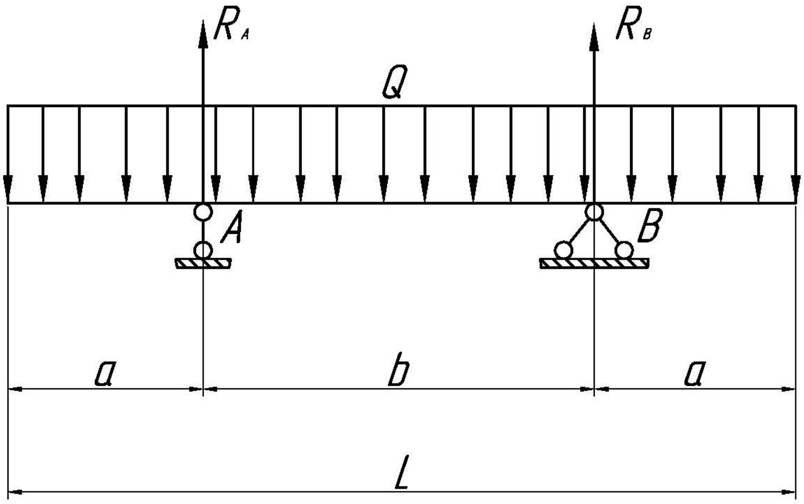


Fig. 1.13. Scheme for the calculation of resistances

The reaction of the supports $R_A = R_B = \frac{Q}{2} = \frac{40000}{2} = 20000H$.

Bending moment at the cross section A i B

$$M_A = M_B = \frac{Q}{L} \cdot a \cdot \frac{a}{2} = \frac{40000 \cdot 130^2}{5,4 \cdot 2} = 6260H \cdot m.$$

Bending moment inside the beam:

$$M = \frac{Q}{8}(2a - 1) = \frac{40000}{8}(2 \cdot 1,3 - 2,8) = -1000H \cdot m.$$

The moment of resistance of the pipe section:

$$W = \frac{\Pi D_{cp}^2}{4} \cdot \delta = 0,785 \cdot 71,4^2 \cdot 1,4 = 0,0056m^2.$$

Stress from bending forces:

$$\sigma_u = \frac{M_A}{W} = \frac{6260}{0,0056} = 11,2 \cdot 10^5 Pa.$$

Tension in the cylinder shell from the internal pressure drop (along the fibers):

$\sigma_1 = \frac{P \cdot D}{4S} = \frac{25 \cdot 70}{4 \cdot 1,4} = 313 \cdot 10^5 P$a.

Because $\sigma_1 > \sigma_u$, hen there are no compressed fibers in the vessel and the loss of stability does not occur.

Let's check the strength of the vessel lining against the action of the support reaction. Bending moment under support:

$M = R_A \cdot R \cdot K,$

where $R_A = 20000H$ - support reaction

$R = 864 \cdot 10^{-3} m$ - the outer radius of the device body

К=0,04 – coefficient that takes into account design features

$M_1 = 20000 \cdot 864 \cdot 10^{-3} \cdot 0,04 = 291H \cdot m.$

The moment of resistance of the cross section of the sheet without taking into account the substrate:

$W = \frac{(b + 2 \cdot 4S) \cdot S^2}{6},$

where $S = 13 \cdot 10^{-3} m$ – the thickness of the sleeve without an allowance for corrosion

$b = 250 \cdot 10^{-3} m$ – the width of the support along the axis of the device

$W = \frac{(25 \cdot 10^{-2} + 8 \cdot 1,3 \cdot 10^{-2})(1,3 \cdot 10^{-2})^2}{6} = 9,97 \cdot 10^{-6} m^3.$

Stress from bending in the wall of the vessel under the support:

$\sigma = \frac{M_1}{W_1} = \frac{291}{9,97 \cdot 10^{-6}} = 29,2MP$a.

$\sigma < \sigma_{доп}$ 29,2<100.

1.9.8. Calculation of the flange connection for a pipe with a diameter of 0.7 m

In advance, we accept the dimensions of the flange according to fig. 1.14.

The total force in the bolts at an ambient temperature of 400 °C is determined by the formula:

$$P_б = Q_2 + Q_{пр} + Q_{гт} + Q_1,$$

where Q_2 - the force acting on the hydrostatic pressure of the external environment $Q_2 = F \cdot P$;

P - робочий тиск середовища $P = 25 \cdot 10^5 Pa$;

F - площа по внутрішньому діаметру прокладки:

$$F = \frac{\pi \cdot D^2}{4} = 0.785 \cdot 0.755^2 = 0.447 m^2;$$

$$Q = 0.447 \cdot 25 \cdot 10^5 = 1120 кН;$$

$Q_{пр}$ - gasket pressure force required to create joint density.

$$Q = F_{пр} \cdot q.$$

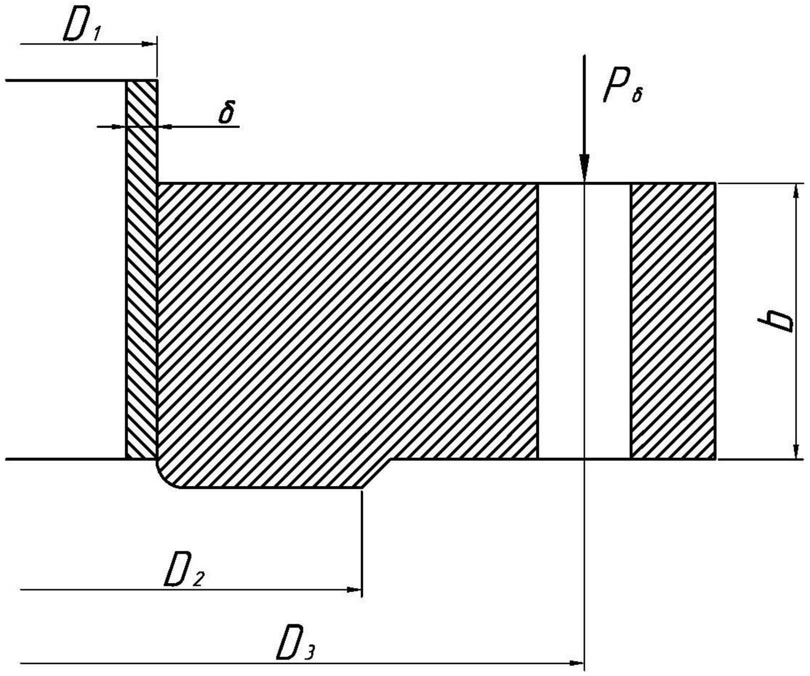


Fig. 1.14. Scheme for the calculation of the flange connection

For soft pads $q = 2.5P$.

F_{sl}- laying area:

$F_{sl} = \frac{\pi(D_2^2 - D_1^2)}{4} = 0.785 \cdot (0.84^2 - 0.755^2) = 0.1065m^2.$

$Q_{sl} = 0.1065 \cdot 2.5 \cdot 25 \cdot 10^5 = 666$кН.

Q_{hp} - we take the additional force that occurs in the presence of hydrostatic pressure of the external environment:

$Q_{hp} = 0.2Q_2 = 0.2 \cdot 1120$кН $= 224$кН.

Q_t - the force arising from the temperature difference of the flange and the bolts. For steel bolts, Qt is determined by the formula:

$$Q_t = \frac{\Delta t_{\text{р}} \cdot L \cdot \alpha}{\frac{L}{E \cdot f \cdot s} + \frac{\sigma}{E_{\text{пр}} \cdot F_{\text{пр}}}}$$

де Δt_p=58°C - temperature difference between the flange and the bolts at the ambient temperature t=400°C during start-up;

$L=210 \cdot 10^{-3}$m the length of the bolt between the head and the nut;

α - coefficient of thermal linear expansion of the flange and bolt material;

δ - the thickness of the gasket (δ=3mm.);

$E=1.9 \cdot 10^5$MPa - modulus of elasticity of bolts;

$E=3 \cdot 10^5$MPa - modulus of elasticity of the gasket;

$F_{п}$=0.1065 m^2 - laying area;

$F_{б}$=0.0302 m^2 - the total cross-sectional area of the bolts.

The diameter of the pins - 40 mm.

$f_{б} = 24\frac{\pi d^2}{4} = 24 \cdot 0.785 \cdot 0.04^2 = 0.0302m^2.$

$$Q_t = \frac{58 \cdot 0.21 \cdot 1.2 \cdot 10^5}{\frac{0.21}{1.9 \cdot 10^6 \cdot 0.0302} + \frac{0.003}{3 \cdot 10^4 \cdot 0.1065}} = \frac{5821 \cdot 1.2}{0.0046} = 3180 \text{кН}.$$

The total force on the bolts of the flange connection:

$$P_б = 112 \cdot 10^3 + 666 \cdot 10^3 + 224 \cdot 10^3 + 318 \cdot 10^4 = 5190 \text{кН}.$$

The diameter of the studs is taken according to the flange of the corresponding size given in GOST 1240-54 for the working pressure P=2.8MPa and t=400°C.

Determine the bending stress in the flange.

Maximum bending moment for the flange $M = P_б \cdot 0.5(D_3 - D_1)$.

$$M = 519 \cdot 10^4 \cdot 0.5 \cdot (0.9 - 0.755) = 3.76 \cdot 10^5 \text{Н} \cdot m.$$

Moment of resistance of the flange section:

$$W = \frac{\pi D_1 b^2}{6} = \frac{3.14 \cdot 0.755 \cdot 0.085}{6} = 2.86 \cdot 10^{-3} m^3.$$

Stresses on the flange from bending:

$$\sigma = \frac{M}{W} = \frac{3.76 \cdot 10^5}{2.86 \cdot 10^{-3}} = 1315 \cdot 10^5 Pa.$$

Permissible stress on boiler supervision

$$R_z = \frac{\sigma_3^*}{1.4} = \frac{1910 \cdot 10^5}{1.4} = 1360 Pa.$$

Bending moment for a welded joint:

$$M = P_б \cdot 0.5(D_3 - D_1) = 519 \cdot 10^4 \cdot 0.5 \cdot (0.9 - 0.755) = 3.89 \cdot 10^5 \text{Н} \cdot m.$$

The moment of resistance of the section along the welded joint:

$$W = \frac{\pi D (H^3 - h)}{6H} = \frac{3.14 \cdot 75 \cdot (0.11^3 - 0.058^3)}{6 \cdot 0.11} = 4.05 \cdot 10^{-3} m^3.$$

Bending stress in the welded joint:

$$\sigma_и = \frac{M_1}{W_1} = \frac{3.89 \cdot 10^5}{4.05 \cdot 10^{-3}} 960 \cdot 10^5 Pa.$$

Stress in the weld from the environment:

$$\sigma_{\text{ср}} = \frac{\text{Р}_{\text{б}}}{1.4\pi D_c} = \frac{519 \cdot 10^4}{1.4 \cdot 3.14 \cdot 0.75 \cdot 2.6} = 605 \cdot 10^5 Pa.$$

Reduced stress in the weld:

$$\sigma_{\text{пр}} = \sqrt{\sigma_{\text{и}}^2 + \sigma_{\text{гр}}^2} = \sqrt{(960 \cdot 10^5)^2 + (605 \cdot 10^5)^2} = 1175 \cdot 10^5 Pa.$$

Permissible stress for the weld:

$$R_{\text{св}} = 0.8 \cdot R_z = 0.8 \cdot 1360 \cdot 10^5 = 1090 \cdot 10^5 Pa.$$

Conclusions

In this section of the diploma project, an analysis of the defects of the high-altitude equipment and air conditioning system of the An-type aircraft (on the example of the An-32), as well as an analysis of the process of repairing the units, was carried out. As a result of the performed work, the shortcomings of the typical repair process were revealed. Based on the received data, we selected and justified the repair process we chose. We also examined the stand for testing units of the high-altitude system and examined its principle of operation and the main components of which it consists. Other stands and installations, which are used to repair units of the altitude system and the air conditioning system of the aircraft, were also illuminated.

In the last point of the section, the calculations of the main elements used to repair the units of the altitude system of the aircraft were carried out.

SECTION 2

2.1. The purpose of diagnosing and identifying defects

The purpose of diagnosing the TCU3263 installation is to determine the technical condition of the rotor bearing unit, the presence of local defects in the outer and inner rings of the bearings, and the ovality of the rolling elements. With positive diagnostic results, the rotors are sent for dynamic balancing and assembly. Determination of local defects on the outer and inner rings of ball bearings and roller bearings, as well as defects of ovality, non-cylindricity (waviness of the profile of the longitudinal section of the rollers) of the rolling elements should be carried out at information frequencies that reflect the kinematics of the bearing and the kinematic connection of various defects with each other (Table 2.1).

Quality control is carried out by comparing the actual value of the measured vibration acceleration from the information frequencies with the corresponding permissible values of the vibration acceleration (Table 2.2).

№	The type of defect and its location	Information frequencies, Hz	
		А346206 Б1 Т2	5А2206 Бт2
1	Ovality (non-cylindrical) of rolling elements	623 ± 20	788 ± 20
2	Fatigue contact damage	604 ± 14 799 ± 18	655 ± 15 743 ± 16
3	Destruction of the raceway on the inner ring	885 ± 20 1079 ± 25	1357 ± 30
4	Fatigue contact failure	577 ± 14 770 ± 18	655 ± 20
5	Destruction of the raceway on the outer ring	842 ± 20 1122 ± 25	504 ± 12 700 ± 16

Information frequencies, Hz	Limit permissible value of vibration acceleration
504 ± 12	2
577 ± 14	0,8
604 ± 14	0,7
657 ± 15	1,5
700 ± 16	2
743 ± 16	2
770 ± 18	2
788 ± 18	2
799 ± 18	2
842 ± 20	0,6
885 ± 20	0,6
1079 ± 25	0,6
1122 ± 25	0,5
1357 ± 30	1,8

2.2. Balancing of the TCU3263 rotor using a laser

According to the definition of ISO (International Organization for Standardization) - ISO 1925 and GOST 19534-74, balancing is "the process of determining the value and angles of imbalances of the rotor and reducing them by adjusting its masses."

Physically, this means that the axis of the rotor bearing (shaft axis) is driven according to the main axis of inertia, with a sufficient degree of accuracy. The accuracy of material removal should be 2-3 orders of magnitude higher than the primary imbalance, i.e. sometimes significantly less than 1 mg.

Balancing of the rotor of the turbo-cooling installation should be carried out at the operating speed of rotation. The spin-up time, using the rotor's drive is very long; braking after balancing due to overheating is not desirable. Thus, one measurement can last up to one hour.

Various metallic and non-metallic materials can be vaporized and sprayed with laser radiation. Continuous or pulsed-periodic lasers can be used to ensure intensive evaporation of the material, but with a high radiation power density. The kinetics of the evaporation process of the material under the influence of laser radiation is largely determined by the properties of the material and the radiation parameters. The evaporation process is affected by thermal conductivity, latent heat of evaporation, and the reflection coefficient of laser radiation. For the vaporization of metals, it is more appropriate to use lasers with a radiation wavelength of λ=1.06 μm, which is better absorbed by metals. For the vaporization of non-metallic materials, CO2 lasers with a long radiation wavelength λ=1.06 μm are more suitable. Laser radiation is absorbed by solid bodies in a thin surface layer with a thickness of a fraction of a micrometer in a very short period. As a result, the surface areas are heated to high temperatures. In this way, atoms are desorbed from the surface of solid bodies during laser irradiation. Optimization of the evaporation process is carried out by adjusting the intensity and duration of the laser radiation pulse.

2.3. Characteristics of the TCU 3263 rotor balancing laser installation

From the assortment of lasers produced by the industry, we choose the LN - 1.2NM - U1 installation. The installation can be used both independently and in combination with other technological equipment in automatic complexes. The installation is designed for heat hardening, alloying, cladding, and surfacing of materials, and can also be used for other technological processes associated with the use of a powerful laser beam. Unlike traditional methods of heat strengthening, the laser provides the following advantages:

– a small heating zone, which excludes distortion of parts;

- increased hardness of the surface layer of the part at a depth of several microns to several millimeters;

– thermosetting can be carried out in hard-to-reach places of parts;

– the configuration of the heat hardening zone depends only on the technological requirements;

– low inertia and easy controllability of the technological process create prerequisites for automating the heat hardening process;

- a significant increase in labor productivity.

A distinctive feature of the installation is that a laser beam acts as a heating device, which provides a number of the above advantages compared to traditional processing methods. Laser treatment is carried out in normal atmosphere, but can be used in vacuum and gas-filled volumes. The installation consists of the following parts:

– laser;

– beam transportation and focusing system;

– balloon ramp;

- rectifier.

The basis of the installation is a laser that generates a laser beam with a radiation power of 1.2-2 kW and a wavelength of 1.06 microns.

To ensure the required energy concentration of the laser beam, its perpendicularity concerning the processed surface, indicating the point of contact of the laser beam with the part, measuring the radiation power and safe work of the service personnel, the beam transportation, and the focusing system is used (Fig. 2.1). A cylinder ramp is designed for storing gas cylinders. The laser refers to gas-discharge multi-beam lasers of continuous action with slow pumping of a working mixture of gases consisting of carbon dioxide CO2, nitrogen N2, and helium He.

When an electric current passes through the gas, CO2 molecules are excited, and at a certain ratio between the gas pressure, the diameter of the pipe, and the amount of current, an inversion of the vibrational levels of the CO2 molecule is formed, which ensures the conversion of the vibrational excitation into laser radiation with the help of an optical resonator formed by two parallel mirrors.

Features of the laser design are:

– output from the resonator of a large number of rays (equal to the number of tubes), which are focused by a special optical system for laser processing of materials;

– the gas mixture is pumped through gas discharge tubes and released into the atmosphere through a vacuum pump, i.e. the mixture circulation circuit is open;

– gas discharge tubes are cooled by oil flowing along the tubes between them.

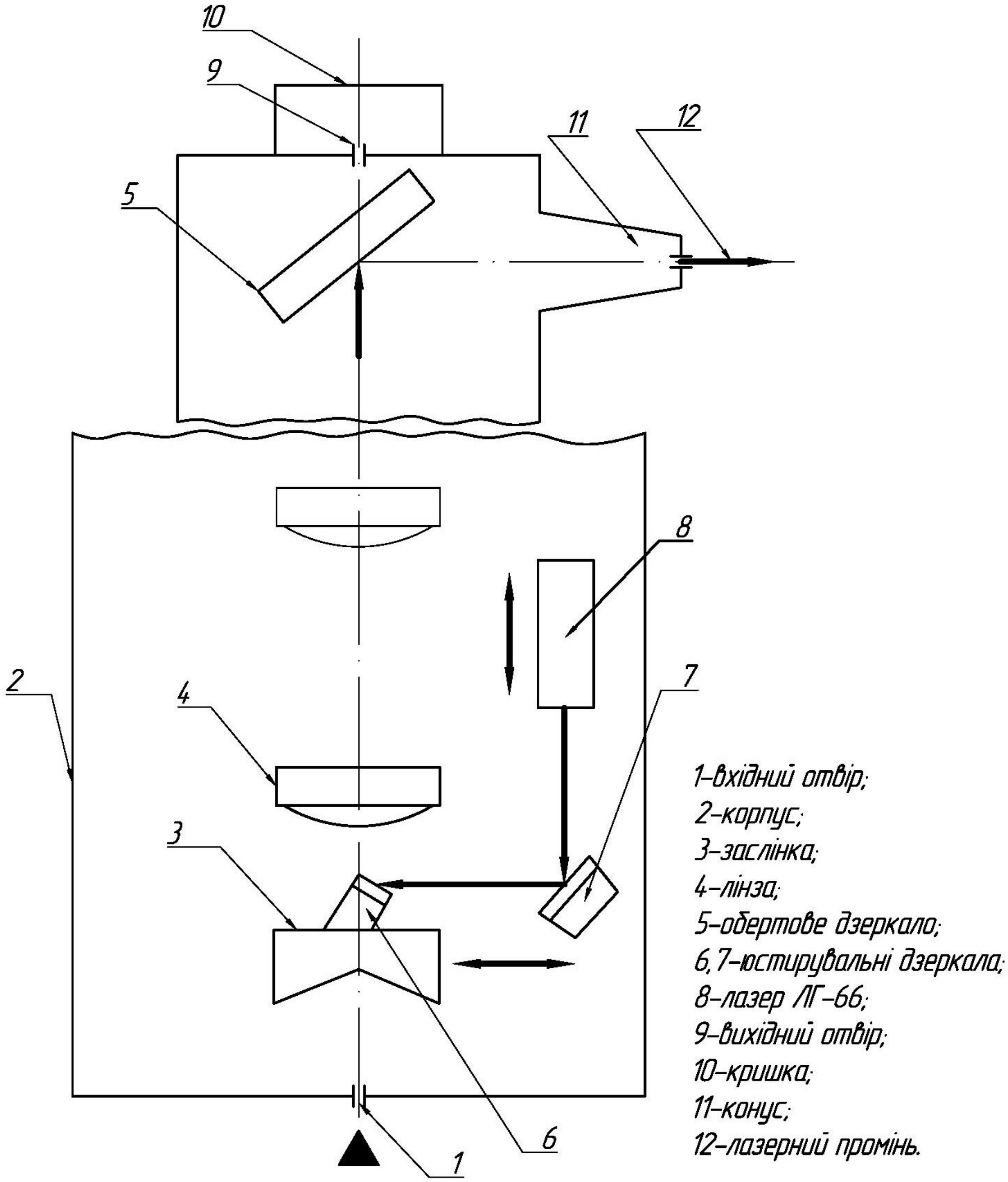


Fig. 2.1. Schematic of the transport and focusing system

The oil circulates in a closed circuit, being cooled in a water-oil radiator (heat exchanger) by running water. Laser sensors are homogeneous laser converters of high Q, able to transfer the image of the object into its electrical function in the coherent region of the spectrum without lensing. At the same time, the linearity of the transformation is preserved. The transformation can be represented as a point transformation in the static position of the initial object and a half-plane transformation in the dynamic mode of the object's movement. The use of two sensors operating on coherent radiation can be used to add and subtract optical signals in phase.

2.4. The technological process of balancing the rotor of the THU3263 turbo-cooling unit using a laser unit

Balancing of the rotor of the turbo-cooling unit is carried out with the help of a laser balancing complex at the operating speed of rotation. The rotor spin-up time is very long, braking after balancing is not recommended due to overheating. Thus, one measurement can last up to one hour. Considering this, balancing the rotor takes a lot of time. During balancing, static and dynamic imbalance is eliminated. The imbalance can be eliminated by either moving the rotor axis or moving the main axis of inertia (Fig. 2.2). This is achieved by adding, removing some mass of material.

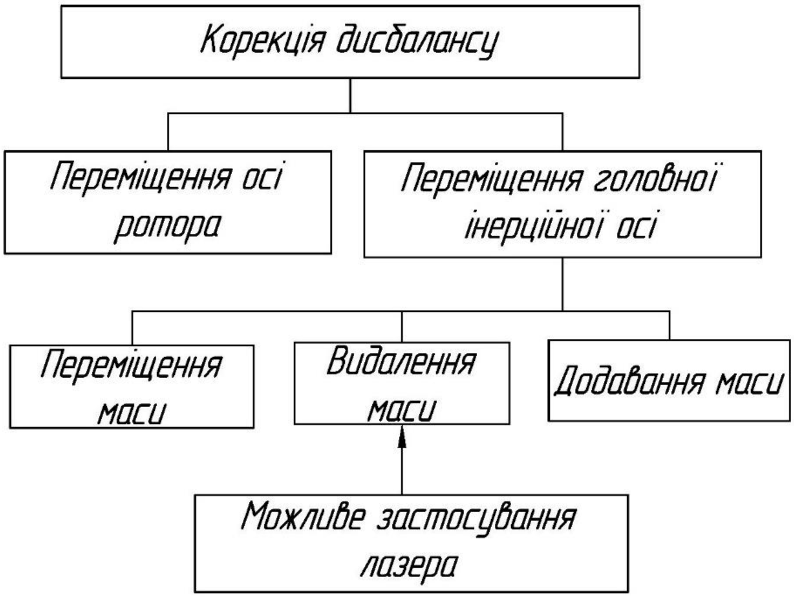


Fig. 2.2. Types of imbalance correction.

Real use of a laser for removing excess weight

The process itself consists of the following operations:

1. Installing the rotor of the TCU3263 turbocooler on the balancing stand and fixing it in the correct position.

2. Installation of strain gauge or piezo sensors on the rotor of the turbo-cooling unit.

3. Starting the stand and bringing the rotor to the working speed of rotation to detect dynamic imbalance.

4. The parameters measured by the sensors are displayed on the oscilloscope screen.

5. According to the obtained parameters, we determine the amount and location of the imbalance.

6. Adjust the power and wavelength of the laser, which will be used to vaporize or weld both metallic and non-metallic materials.

7. Using a laser, we weld additional material to remove the imbalance of the rotor.

8. After laser treatment, we check the accuracy of the rotor repair.

9. Dismantling the repaired rotor and sending it for inspection.

2.5. Solving tasks of automation and mechanization with the help of IECD

The tasks of complex mechanization and automation of technological processes can be successfully solved with the help of industrial electronic computing devices (IECD).

However, for their application, it is necessary to present the technological process in a certain way in the form of an algorithm. At the same time, the algorithm allows you to solve the problem:

1) management of technological equipment for the purpose of implementing a test program or technological operations;

2) measurement and conclusion about the control of product parameters during their testing.

When testing units of the high-altitude equipment of the An-type aircraft, the following control technological actions must be performed:

1) heating of the working medium (gas) for testing using an electric air heater;

2) cooling with running water;

3) maintenance of a given level of gas pressure;

4) creation of conditions simulating the vibration of the TCU using a vibration stand at a certain stage of the test.

In addition, it is necessary to measure the parameters controlled during the test, which include:

– air pressure in the air conditioning system;

– air consumption in the air conditioning system;

- regulation of its temperature.

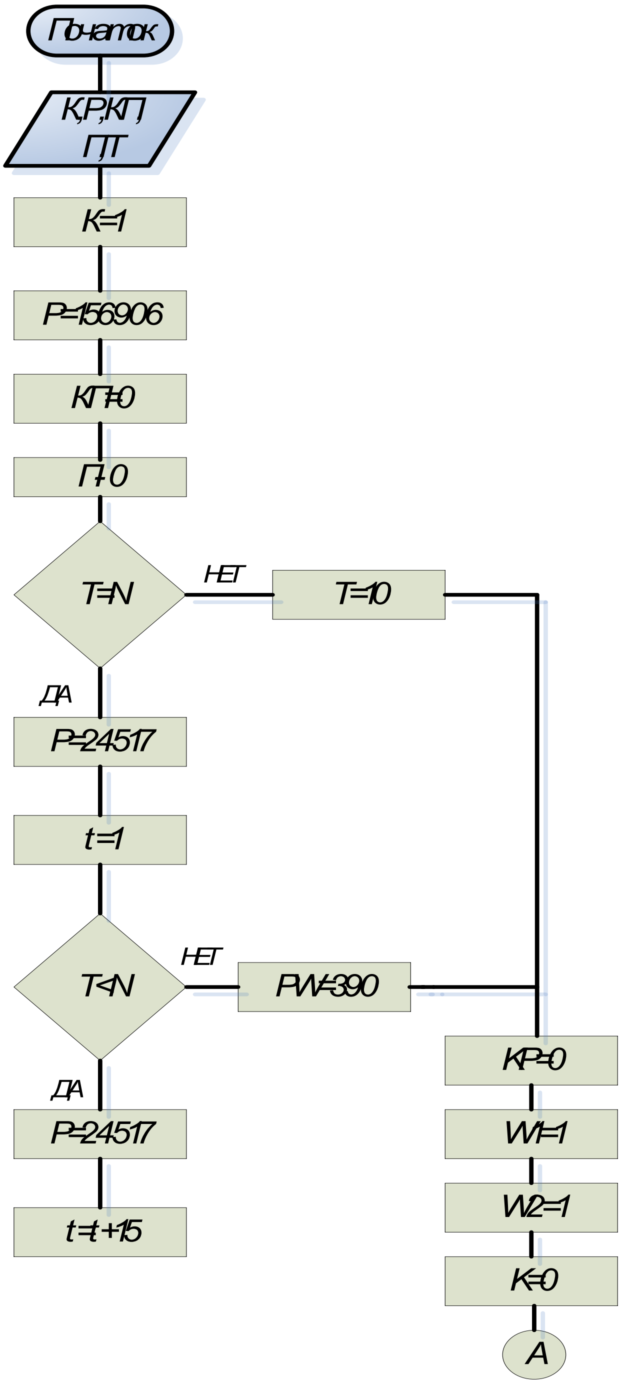
Based on these considerations, an algorithm for testing TCU 3263 was developed, which is presented in fig. 2.3.

The algorithm allows you to control the technological equipment, simulate the test conditions, and print out data based on the results of the tests. To implement the algorithm in bench equipment, a number of refinements were made:

1) installed sensors for control and automatic support of working gas during heating and cooling;

2) airflow, pressure, and temperature control sensors in the air conditioning system.

The implementation of the algorithm may be different depending on the device used. In our case, we implemented the algorithm on a personal computer using the Turbo Basic programming language.



Conclusion

In this section, the process of balancing the rotor of the TCU3263 turbo-refrigerating unit using an industrial laser was illuminated. We considered the design of the balancing machine and familiarized ourselves with the process of laser balancing of the TCU3263 rotor. With the help of such a balancing complex, you can not only balance TCU rotors, but also use it to repair other parts, for example, shafts.

SECTION 3

Improvement of the maintenance process

3.1 Tasks of airlines to improve the maintenance process

Increasing the efficiency of the use of aviation equipment in operation, the level of aircraft flight safety, and reducing the costs of maintenance and repair of aviation equipment and components are the main tasks facing the aviation workers of Ukraine.

The system of maintenance and repair of modern aviation equipment should have a high level of perfection, in which the main goals of maintenance are achieved with a minimum of costs, cost, and downtime of aircraft for repair and maintenance. Extensive experience in the operation of aircraft equipment, units, and assemblies that have undergone repair after the end of the inter-repair resource shows that the planned preventive maintenance and repair system currently used in civil aviation has the following shortcomings:

significant underutilization of the individual capabilities of aggregates, nodes, equipment blocks and aircraft as a whole when replacing them after developing the inter-repair resource or the assigned resource;

establishment of resource limitations for the aircraft system and units (as the experience of operating domestic and foreign aircraft shows, such limitations do not at all exclude the possibility of failures and malfunctions, because for most systems failures are random and cannot be prevented by a repair);

large material costs are required for the production of a replacement fund of spare parts installed on the aircraft after the removal of the units that produced the resource;

technical unsubstantiated checks of the operation of units or systems of the aircraft, including, during preventive and repair work, in themselves introduce violations and changes to the systems of the aircraft, as a result of which the intensity of unit failures immediately after their repair may be higher than before the repair.

In addition to the above-mentioned shortcomings, in some cases there are objective difficulties in establishing technically justified values of the safe resource of units, as a result of which the inevitable occurrence of unforeseen damages and failures within the limits of the permitted operation, which causes a large number of modifications to the entire fleet of aircraft during operation.

Implementation of progressive methods of technical maintenance of aviation equipment by state requires implementation of technical and organizational issues.

At the same time, great attention is paid to the development of measures for the further improvement of aviation equipment, the introduction of new means and methods of diagnosis, means of mechanization, and automation of maintenance processes.

3.2 Requirements for increasing the reliability and economic efficiency of the operation of systems and devices

These requirements are due to the complexity of the design of the high-altitude system and devices and, as a result, the increase in the price of their maintenance. The complexity of the altitude system occurs both due to an increase in the number of operations performed by the altitude system on modern aircraft and due to the fulfillment of the condition of the "principle of safe destruction" of systems, which leads to the creation of backup and duplicate systems.

To ensure high reliability and economic efficiency of operation of the high-altitude system, the system units must meet the following requirements:

- the operational manufacturability of the system units should be such as to ensure the replacement of any unit in a time not exceeding 1 hour;

- the controllability of the hydraulic system units should be such as to provide the ground technical personnel with the information necessary to predict the technical condition of the units and the system for a time no less than the duration of the next flight. The technical condition monitoring system should also provide fault finding up to the block level, which can be independently replaced in the maintenance process in a time not exceeding 1 hour.

Communication devices of the control system should provide the output of the accumulated information to an onboard or ground computer for processing the results of control and forecasting.

Fulfillment of these requirements will ensure the possibility of maintenance of the high-altitude system according to the technical condition in order to prevent unit failures in flight and full use of their individual resources.

Fulfillment of the operational requirements for the reliability of the high-altitude system at the design stage can be achieved if the following basic conditions are met: a clear formulation of the operating conditions and the required level of reliability, tests of units under normal operating conditions, assessment of the degree of reliability during the proving process, factory tests and at the initial stage of operation, analysis of reliability reports in the process of further operation, use of operation experience for timely information of designers and manufacturing plants about all emerging failures and malfunctions.

There is also a need to introduce a maintenance strategy for high-altitude equipment with parameter control. It is advisable to limit the scope of this service strategy to products: failures that do not affect flight safety, which is established by analyzing the reliability of functional systems when choosing and assigning maintenance strategies; for which there is an exponential distribution of the probability of failure-free operation; the reliability of which allows to ensure the fulfillment of the requirements for regularity of flights to the economic efficiency of the aircraft maintenance process; which has high operational technology, including portability, availability, interchangeability; the costs of operating which before failure (when servicing with reliability level control) do not exceed the costs of planned and preventive maintenance; that have an indication of failures by on-board or ground control means, with minimal labor costs at a given time.

Maintenance mechanization is a complex process of improving maintenance processes due to the introduction of the latest technologies in maintenance. Replacing the devices required for the maintenance of the relevant systems with new and improved ones makes it possible to reduce malfunctions and failures during the operation of aircraft equipment.

In a special part of the project, to meet the above-mentioned requirements, it is proposed to develop a stand for technical maintenance of high-altitude equipment.

3.3 Operational requirements to ensure reliability

These requirements are dictated mainly by the importance of the functions performed by the high-altitude system, as well as by large losses due to insufficient reliability of the facilities.

It is known that the reliability of various technical devices of systems is that failures and malfunctions occur periodically. Naturally, the failure of any altitude device leads, of course, to some material damage, in our case, the damage borne by the organization that operates the aircraft.

The amount of damage is determined by the functions performed by the object of interest to us and may manifest itself in different ways. Yes, there may be cases when the damage is a direct consequence of the failure.

In most cases, this is typical for non-renewable objects.

Another case is where the failure leads to downtime, and the damage caused by the downtime may exceed the costs directly related to the failure of the product.

In such cases, when assessing the loss due to failure, it is necessary to assess the loss due to downtime.

Thus, in this case, the dominant factor in assessing the consequences of failure is simple, its duration and associated costs.

A third case is also possible when the task is not completed due to a refusal. In this case, the damage is determined by what stage the task execution process is at. In many cases, the completed part of the task cannot be used and is included in the amount of the loss.

When assessing damage from refusal, the nature of the task and the damage associated with its non-fulfillment are considered first of all. In this case, failure to perform the task is the dominant factor in assessing the consequences of failure.

It is natural that the efficiency of aircraft operation, which is evaluated taking into account the consequences of failures or damage, has a corresponding effect on the choice of quantitative indicators of the reliability of products. These indicators determine the main requirements proposed for aircraft , their systems and devices.

The general requirements for ensuring reliability include the following:

- the system must be designed according to the principle of "safe destruction", which assumes, firstly, that if one or more elements of the system fail, it continues to perform its functions to ensure flight safety, and, secondly, the failure or destruction of any element of the system does not have an emergency effect on the aircraft, that is, it does not cause a fire, destruction of the sealed part of the fuselage and power elements of the structure, as well as damage to elements of other systems.

The development of the principle of safe destruction of the system can lead to the fact that, if these requirements are met, it will be possible to operate individual units until failure and even fly with individual units that have failed to the base airport or destination, until the moment of maintenance at a specified frequency;

- the reliability of the system should ensure a probability of failure no higher than 10-7.

Increasing the reliability of facilities leads to a significant reduction in the costs of operation and maintenance of the high-altitude system, while the costs of aircraft production increase accordingly.

The optimal level of reliability corresponds to the minimum total production and operating costs.

Operational requirements are an integral part of the general requirements proposed for the high-altitude system.

3.4 Development of the stand

During the maintenance of the air conditioning system, they perform technological maps for checking and controlling parameters in the subsystems of the air conditioning system:

- air supply, which is intended for taking air from engines and DSU, limiting its pressure, flow rate, temperature and supply to the turbo-cooling unit and to other consumers;

- distribution, which serves to distribute air in the cabins;

- pressure regulation, which is intended for automatic maintenance of the specified excess pressure in hermetic cabins;

- heating of cargo cabin and underground space;

- air cooling, consisting of two turbo-cooling units designed to cool the air supplied to the cabins of the upper deck.

At the same time, it is necessary to have a constant source of high pressure. This function is performed by the air refueler VZ-20-350, which spends a lot of fuel and lubricants for this work, time for approaching and leaving the aircraft, and human resources for servicing the air refueler. Human resources are also spent on the installation and connection of pipelines and devices, to check and control system parameters.

Therefore, there is a question about the mechanization of the maintenance process.

This diploma work proposes a stand project that will increase the level of mechanization of aircraft maintenance.

3.5 Structure and functions of the stand

The stand can be used in open areas, as well as in hangars. Its movement can be carried out manually (for short distances) or with the help of vehicles.

The stand consists of the following main parts:

- cart;

- frame;

- balloon;

- drummers;

- flexible air pipelines;

- shooting remote, which consists of:
  - manometers;
  - reduction valves.

The stand is mounted on a three-wheeled cart and has a device for its movement both manually and with the help of vehicles. The cylinder is installed on the cart with the help of a housing and fastening clamps. Also, a frame is attached to the cart, on which two drums are installed for winding air hoses. The frame is closed on all sides with panels, on top is a hinged lid. Under the cover there is a panel with a pressure gauge and a reduction valve for controlling the pressure in the cylinder and supplying air to the remote control. The control panel is removable to facilitate work with units and devices of the altitude system on the second deck of the aircraft. A circuit with several pressure gauges, a reducing valve and a switching valve is mounted on the control panel. The remote control is connected to the cylinder by means of a reinforced flexible high-pressure pipeline, and to units and devices by a high-pressure polyethylene tube.

Technological maps such as:

- air flow synchronization check;
- checking the tightness of the task line;

checking the tightness of the reference line;

- checking the tightness of the parameter line;
- checking the tightness of the RNT control line;
- checking of DR flow sensors;
- checking pressure drop sensors on the TCU;
- checking the parameters of CAPT alarm sensors in hermetic cabins;
- checking the tightness of the pipelines for inflating radio units;
- checking the tightness of pipelines after installation and repair.

3.6 Selection of units and devices

For installation on the stand, we choose the following units, devices and materials:

1. Cylinder unified UBSH-25/150.

Ball cylinder made of stainless steel X16H6 consists of two hemispheres connected by welding with welded necks.

Main technical characteristics:

- working environment - air;

- working pressure – 150 kg/cm2 (15 MPa);

- working volume – 2.5 ·10 -2 m3 (25 liters);

- ball diameter – 0.37 m;

- weight - 14 kg.

Operating characteristics:

- atmospheric pressure – without limitation;

- ambient temperature - from -60 to + 80ºC;

- relative humidity of the environment at t=20ºC – up to 98%.

2. Reducing valve U139A.

Principle of operation: control reducer, the output reduction pressure is proportional to the effort of pressing the rod.

Main technical characteristics:

- working environment – compressed air;

- maximum pressure in front of the valve – 70 kgf/cm2 (7MPa);

- range of reduction pressure - from 1 to 12 kgf/cm2 (0.1÷ 1.2 MPa);

- temperature of working and environment - from -50 to +50ºC;

- weight – 0.32 kg;

- overall dimensions - 0.11 × 0.063 × 0.034 m.

To create a very small reduction pressure (from 0 to 0.05 kgf/cm2), we will make a small modification of this valve. Attach a bracket with an adjustment screw to it, so that the screw is opposite the rod.

3. Manometers:

- MKO-0.6 cl.0.5;

- MKO-1.6 kl.0.5;

- MKO-2.0 kl.0.5;

- MKO-5.0 kl.0.5

- MKO-10 class 0.5.

4. Tube made of high-pressure polyethylene PVD 6.0 × 1 mm (TU6-19-272-85).

- working pressure at t = 20ºC – 6 kgf/cm2 (0.6 MPa);

- diameter – 0.006 m;

- wall thickness – 0.001 m.

5. Switch valve 5504.

6. Rubber sleeve with lovsan braid:

Sleeve 6-8-15000-OST1 13527-79 execution according to OST1 03662-74.

Technological process of work at the stand:

When working with the stand, all safety rules should be observed.

1. Before using the stand, make sure that its units are in good condition, the integrity of the hoses, etc.;

2. Fill the cylinder to the required pressure (manometer readings);

3. Roll the stand to the desired place for unit inspection;

4. Unwind the hoses and connect to the required inspection line;

5. Unscrew the reducing valve to the required pressure according to the pressure gauge;

6. To check the units, comparing the displays of the stand devices with the devices on the dashboard.

After checking the units and pipelines, release the pressure from the cylinder, wind up the hose and take the stand to the storage place.

3.7 Requirements for safety measures during maintenance of the high-altitude system

According to the "Occupational Safety Rules for Maintenance and Current Repair of Aviation Equipment", the following safety instructions for high-altitude system maintenance are offered:

1. Persons who have completed a training course on the design and operation of the installation and received permission to work at the installation are allowed to work at the installation.

2. Receivers, high-pressure pipelines must have a stamp (tags) about the inspection of the regular inspection period.

3. Before starting work, make sure that the shut-off valves are closed and the distribution valves are in the neutral position.

4. Use only a serviceable and marked tool for its intended purpose.

5. The system units must be mounted and dismantled with the help of special tools in order to avoid damage to them, as well as injuries to workers.

6. Before turning on the installation, ensure the reliability of the installation's grounding.

7. After installing the unit at the workplace, install the studded pads under the wheels.

8. When working in hard-to-reach and dimly lit places, use only serviceable portable lamps.

9. When using flammable liquids and combustible materials for surface cleaning, special containers, hair brushes and napkins made of natural fabrics and fibers must be used.

10. When removing and installing units on the installation, make sure that there is no pressure in the system, if there is, release the pressure.

11. Pay special attention to vessels that are under pressure.

These works related to the use of flammable liquids, with vessels under pressure, are not allowed to be combined with works related to the use of sources of open fire, with the connection and disconnection of sources of electricity both on the aircraft and in the parking lot, in premises where stands are located.

Resumption of work on the maintenance of the high-altitude system after the use of flammable liquids and combustible substances is allowed after thorough washing and drying, as well as after ventilating the room to remove steam.

Chapter 4. LABOR PROTECTION

4.1. Dangerous and harmful production factors during repair the high-altitude aircraft system of the An type

Dangerous and harmful production factors according to

SSBT "Dangerous and harmful production factors." Classification" by nature of action are divided into the following groups:

- physical;
- chemical;
- biological;
- psychophysiological.

When performing work in the repair shop of units of the height system there is the following physical dangerous and harmful production factors:

1. Special vehicles, self-propelled and manually moved machines,

mechanisms, and unprotected moving elements of production equipment.

2. Working with tools and equipment that have sharp edges, burrs, and rough surfaces.

3. Streams of liquids and gases from pipelines and vessels operating under high pressure

4. Increased noise level at the workplace (more than 85 dB).

5. Dustiness and gassiness of the air in the repair area.

6. Increased or decreased surface temperature of units, equipment, and materials.

7. Increased or decreased temperature, humidity, and air mobility in

the zone of repair of units of the high-altitude system.

8. Dangerous level of voltage in the electrical network, the short circuit of which

can pass through a person. There is a danger of electric shock

9. Insufficient natural lighting in the workshop for the repair of units of the high-altitude system.

Chemical dangerous and harmful production factors include:

- chemical substances (toxic, irritating substances) that are part of the applied materials;

- fuel and lubricant materials, special fluids, the vapors of which enter the human body through the respiratory organs, gastrointestinal tract, skin, and mucous membranes;

- SNB-9 wash, which has a narcotic effect, irritates the skin, the maximum permissible concentration is.

- detergent synthetic MC8 has an irritating effect on the skin with prolonged and direct contact of hands with the concentrate;

- solvents P-4 and P-5, which have a general narcotic effect, strongly degrease the skin and cause dermatitis, the maximum permissible concentration is.

All these substances belong to the IV group of weakly active harmful substances. In addition, solvents P-4 and P-5 are explosive.

There are also psychophysiological dangerous and harmful production factors of labor monotony in the workshop for the repair of units of the high-altitude system: disassembly, assembly, and defective parts.

The following are dangerous and harmful factors when working on the TCU 3263 turbo-refrigerating installation test stand:

- increased temperature of air supply pipelines to the tested product $t = 80°C \ldots 250°C$

- the presence of pressure in the air supply pipelines to the tested product $P = 8 \cdot 10^5$Па

- use of electric current U=220/380V for heating the air in the heat exchanger. Heater power W=1000kW.

4.2 Organizational and technical measures to reduce the impact of dangerous and harmful production factors

To reduce the level of influence on the human body of the dangerous and harmful production factors listed above, the following organizational, constructive, and technological measures are foreseen in the workshop for the repair of units of the high-altitude system.

1. Regarding the provision of electrical and fire safety:

- to prevent electric shock, the devices of electrical installations must comply with the current, in particular, the "Rules for setting up electrical installations", and their operation must be carried out by the "Rules for the technical operation of electrical installations and consumers";
- following , electrical wiring and cables in the workshop are laid in the walls of the housings of electric motors, stands, and machines and are protected for safety. All circuit breakers are mounted on marble shields and secured with metal casings. Fuses and grounding are provided at the wiring terminals;
- there are wooden ladders on the floor at workplaces in the repair area, and rubber mats in the testing area;
- copper tools are used in the shop;
- to remove static electricity, the workshop is equipped with grounding wells;
- the workshop floor is concrete, and the walls up to a height of 1.5 meters are moisture-resistant;
- all planning requirements that do not violate fire safety techniques in accordance with are met: the repair area is separated from the defecting, disassembly, and assembly area by a wall, and the washing and testing areas are placed in separate blocks, to isolate elevated sources of fire and sources of air pollution on the site with a harmless type of production;

- in case of fire, wide passages and passageways are provided in the shop to ensure quick evacuation; areas for washing and testing units have separate doors for exiting the building.
- the workshop is equipped with fire extinguishers, fire hydrants with hoses, and a fire alarm system.

2.Regarding the reduction of dustiness and gassiness of the air:

- fume hoods are used to remove dust and reduce air pollution;
- flow-exhaust ventilation according to, tarpaulin canvas with waterproof impregnation, air conditioners allow to maintain constant humidity and maintain air mobility;
- in the ventilation system of the workshop, circulation of warm dry air is used in winter;
- to eliminate the effect of harmful chemical factors on the body, an automated washing process, a hood, filtering devices, constant monitoring of the concentration of harmful substances, work clothes, ХИОТ-6 paste, and a Г1РШ-2-59 respirator are used.

3. Regarding noise reduction:

- the workshop uses anti-noise shielding partitions: protective fences, nets-shields, casings;
- physioprophylactic measures are used in the fight against noise;
- to reduce the effect of noise from the working electric motor, gearbox, and pump of the installation, the operator's workplace is surrounded by sound insulation.
- headphones are used for the individual protection of shop employees.

To prevent human injury by dangerous factors when working on the TCU 3263 test stand, the following measures are provided: the presence of pressure in the air supply pipelines to the tested product

– the tested product is connected to the hot and cold air pipelines, the heat exchanger, and the control panel are located in different rooms equipped with doors that close reliably and tightly;

– hot air pipelines have thermal insulation;

– the heat exchanger is remotely controlled and has a double enclosure, the first one made of dielectric material, the second one made of metal mesh;

- at the time of inspection, there are no people in the room where the tested product is installed and in the area of the heat exchanger.

The entire test process is carried out remotely from the operator's control panel. It is necessary to undergo industrial training and internship at the workplace to acquire practical skills for working at the stand. Persons who have studied the structure of the stand and who have received instruction on safety techniques when working on the installation for testing units of the high-altitude system have passed the knowledge test at the workplace and are allowed to work on the stand.

The air heating unit is made in accordance with PTE and PTB and is operated by these requirements.

The technical inspection of the installation and maintenance of all units and aggregates is carried out following the operational passport. In the operating passport, a record is made of all types of maintenance and elimination of defects.

4.2.1 Calculation of ventilation of the high-altitude system repair shop

The calculation of ventilation is carried out from the conditions of ensuring the safety of human labor. The maximum permissible vapor concentration is 100 mg/m3.

Let's determine the total evaporation per hour:

Where:

$U = \frac{75\text{г}}{\text{год}} \qquad F = 1\text{м}^2$

evaporation from an area of 1 m2 at t = 20°C;

- approximate area of evaporation

$$W = 1 \cdot 75 = 75г = 75 \cdot 10^3 мг$$

Let's determine the volume of the repair area:

$$V = a \cdot b \cdot h$$

Where:

a=13.7 m – the length of the repair area;

b=6.6 m - width of the repair area;

h=6.7 m - the height of the repair site.

$V = 13.76 \cdot 66.7 \cdot 7 = 6.0м^3$.

Let's determine the concentration of vapors in the repair area:

$$К_{ср} = \frac{W}{V};$$

$$К_{ср} = \frac{7 \cdot 1000}{605.8} = 123.8мг/м^3.$$

as can be seen from the calculation, the concentration of vapors in the repair area exceeds the maximum permissible concentration, while ventilation of the box is necessary.

Let's determine the necessary multiplicity of air exchange in the box:

$$n = \frac{К_{ср}}{К_д};$$

$$n = \frac{123.8}{100} = 1.238.$$

We take n=2.

Let's determine the flow rate of the fan:

$$Q = V \cdot n;$$

$$Q = 605.8 \cdot 2 = 1211.8\,{}^{м^3}/_{год} = 0.337\,{}^{м^3}/_{с}.$$

Let's determine the required fan pressure:

total loss of air pressure in the air intake:

$$H = \sum (k \cdot L + z)$$

where:

H is the required pressure, Pa;

k – loss of air pressure due to friction, Pa;

L – duct length, m;

z – pressure losses due to local resistances, kg/m3.

We assume the speed of air movement in the air duct:

We assume the speed of air movement in the air duct:

$$V_п = 8\,{}^{м}/_{с}$$

$$k = 103\,{}^{кг}/_{м^3} = 0.103\,{}^{Па}/_{м^3}$$

Determine the cross-sectional area of the duct:

$$S_п = {}^{Q}/_{V_п}$$

$$S_п = \frac{0.337}{8} = 0.042 м^3$$

Determine the diameter of the duct:

$$d = \sqrt{4 \times S_n \times \pi/\pi^2} = \frac{2}{\pi} \times \sqrt{S_n \times \pi};$$

$$d = \frac{2}{\pi} \times \sqrt{0{,}042 \times \pi} = 0{,}23\text{м}.$$

Let's determine the value of the air duct pressure:

$$P_т = \frac{\rho \cdot V_п}{2 \cdot g}$$

where:

ρ = 1,225 кг/м^3 - mass density of air.

$$z = \frac{\xi \cdot \rho \cdot V_п}{2g} = \xi \cdot P_т$$

ξ is the coefficient of local pressure, which depends on the length of the duct:

ξ = f (Ln).

From the table of coefficients of local pressures, we select the value of ξ for two sections of the duct:

- for a section outside the shop with a length of L1=2m: ξ=1.5;

- for a section in the workshop with a length of L2=3m: ξ=2.

Then

z1=1.5x4=6Pa,

z2=2x4=8Pa.

Let's determine the pressure in the duct sections:

H=kxL+z,

H1=0.103x2+6=62.06 N/m2,

H2=0.103x3+8=83.09 N/m2.

Let's determine the pressure flow in the bend of the duct:

for: d=0.25 m radius r=85 mm, with a rotation angle of 90o

ξk = 0.35 Pa.

Required fan pressure:

H=H1 +H2 +2xξk,

H=62.06+83.09+2x3.5=152.2 Pa.

Knowing the required pressure and flow rate of the fan, we select the NCV-30 fan with the following characteristics:

Q=2800 m3/h; H=150 Pa; η=0.55.

Selection of an electric motor:

Required power of the electric motor:

$$N = \frac{H \cdot Q \cdot B}{3600 \cdot 102 \cdot \eta}$$

where B = 1.1 is the safety factor.

N = 15x2800x1.1/(3600x102x0.55)=6.23 kW.

We select an AOP 2-51-4 electric motor with rated power:

Nnom = 7.5 kW.

Conclusion

In the "Occupational safety" section, the main safety rules are given

when servicing units of the high-altitude system, as well as measures, with the help of which will be possible to increase labor safety during repair and service.

Conclusion

In this diploma work, an analysis of the existing technology is carried out

of the process of repairing units for the repair of high-altitude equipment. Based on the fee

statistical data, the analysis of defects of high-rise units was carried out

equipment. To improve the technical process, the following are proposed:

– installation for testing units of the high-altitude system with a personal computer;

– installation for balancing the rotor of the TCU 3263 product with

using a laser;

- a device for removing the characteristics and checking for leakage and

pressure regulator leaks.

Proposed measures to improve the technological process.

The proposed measures allow a significantly reduce

labor costs for repairs, reduce transport costs and improve quality

repair, which as a result increases the level of safety and regularity of flights.

In the diploma work, measures on labor protection and protection were developed

environment.

In the "Occupational safety" section, the main safety rules are given

when servicing units of the high-altitude system, as well as measures, with the help of

which will be possible to increase labor safety during repair and

service.

In the "Environmental protection" section, a number are proposed

measures that increase environmental safety. Conducted economic

justification of the proposed measures.

Chapter 5. PROTECTION OF THE ENVIRONMENT

5.1. Environmental protection in aircraft construction

The main physical pollutant of the environment in the airline is noise. Noise means all unpleasant and unwanted sounds and their aggregates, which interfere with normal work, sound perception

signals, and rest. In general, noise is a chaotic accumulation of sounds of different frequencies, strengths, and heights, the duration of which exceeds the limits of sound comfort Sources of noise are all types of transport, industrial enterprises (equipment, tool, technological processes), elevators, televisions, radios, crowds of people. Noise negatively affects human health, reduces work capacity, and leads to cardiovascular, nervous, endocrine systems, and hearing organs [16].

The fight against noise should begin at the stage of enterprise design or its reconstruction. When designing an enterprise, it should be taken into account distance from the residential area, rational placement should be provided for individual buildings and workshops within buildings. For insulation of foundations of buildings with a sound pressure level above 90 dB, so-called acoustic breaks are arranged

- gaps running along the entire perimeter are filled with insulating material.

Between the "noisy workshops" free zones are arranged, which are for a larger efficiency greened because the leaves absorb noise well. When planning shops and areas inside the building, it is necessary to combine machines and equipment according to the degree of their noise. The most effective measure to combat noise should be considered its reduction in the sources of formation, i.e directly in units, machines, mechanisms, and background.

Measures to protect the atmosphere from industrial waste pollution can be conditionally divided into two groups - technical and urban planning. Technical measures provide for the creation of zero-waste and low-waste industries enterprises, gas purification, efficient fuel combustion, construction

high pipes thanks to urban planning measures, it is dispersed location of polluting enterprises are created in the city's sanitary protective zones and tree planting is taking place.

The development of waste-free and low-waste production is the main direction environmental protection, this task is strategic and designed for a long time. The most radical way to eliminate emissions is to change production technology, in which the production process does not produce waste at all or operates in a closed cycle.

Nowadays, the main measures to prevent harmful emissions

development and implementation of effective gas purification systems remain. Dry, wet, and

electrical methods. To neutralize gaseous waste from toxic substances using absorption methods, and thermal methods [18].

Treatment of industrial wastewater. The nature and composition of wastewater dumped by industrial enterprises, are very diverse, therefore. There are also various methods of cleaning them from pollution. Choosing a cleaning method depends on many factors and, above all, on the physical state of pollution,

contained in the effluents. The choice of cleaning method depends on the concentration

pollutant, and the state in which it is dissolved substance.

Currently, they are mainly used for sewage treatment the following methods [4]:

- mechanical methods are used to remove suspended particles

from wastewater (clarification of wastewater), settling in a gravity field (in settling tanks) and in the field of centrifugal forces (in hydrocyclones), filtering,

flotation and filtering;

- chemical methods are used in those cases when allocation of pollutants is possible only as a result of chemical reactions between introduced pollutants and reagents with the formation of new substances which easily removed from wastewater. For this, neutralization is used, coagulation and flocculation;

- physical and chemical methods require the use of a reagent and are based on changes in the physical state of pollutants that facilitate their removal from sewage.

They include flotation, blowing, electrochemical methods;

- biochemical methods are based on the ability of some microorganisms destroy organic and some inorganic compounds (for example, sulfides and salts ammonia), turning them into harmless oxidation products: water, dioxide carbon, nitrate, sulfation, etc.;

- thermal methods consist of complete oxidation at high temperature (during combustion) of pollutants to obtain non-toxic ones combustion products and solid residue. Different application options are possible thermal method, starting from the destruction of waste with a small by the amount of solid residue and a significant reduction (evaporation) of them, after which concentrated solutions can be buried in landfills or used to obtain valuable products.

Most of the details of the interior, internal powertrain, and the aircraft itself after assembly and proofing, it is painted in a paint shop. In almost complete transition occurs during the dyeing and drying process the volatile part of the paint into a vaporous state. Part of this pair is released in the process of applying coatings, and the other - is during drying.

5.2. Environmental safety analysis of the designed object

In the designed technological process of repair of the turbo-cooler installation of TCU 3263, which is part of the high-altitude system, as a source environmental pollution is:

- noises created by the working electric and pneumatic drive of the stand equipment;

- pollution of soils, reservoirs as a result of sewage discharge, created during washing of nodes and parts before and during defecting;

- electricity consumption for equipment operation and shop lighting.

5.3. Measures aimed at increasing environmental safety of the projected object

In order to limit the effect of harmful production factors on humans and environment, the following measures are recommended:

- the use of higher quality and more advanced electric motors with reduced noise values;

- use of special noise absorbers and heat absorbers casings for equipment;

- increase of window openings in order to improve natural lighting;

- cleaning of window openings at least 2 times a year;

- painting the interior surface of the premises in light tones;

- the use of wastewater filtration and the use of a closed cycle use of water resources of the enterprise.

To measures to protect the environment from pollution gas-thermal methods include: reduction of losses of special substances in processing of details; develop devices for utilization and destruction

harmful substances and waste.

Although the implementation of the listed measures is included in the item of expenses

enterprises, but refers to "positive costs", while compliance is not they will lead the company to irreparable costs, costs of means of recovery environment.

All of these measures should be followed to reduce harmful ta negative impacts on the environment. This is especially true for aircraft repair enterprises.

It is compliance with general environmental protection measures the environment will ensure high safety and a production culture.

5.3.1. Determination of damage caused to the environment, as a result of the repair of the TCU 3263.

Calculation of damage caused to the environment at the use of electricity for lighting the repair shop is carried out depending on the total power of lighting devices, the number of hours work taking into account the load factor, losses in the network, and efficiency [15].

The calculation is carried out as follows. Electricity consumption during the operation of the devices during the year

$$W' = \frac{\sum M_Y \cdot \hat{O}_{\ddot{a}} \cdot \hat{E}_{\ddot{a}} \cdot \hat{E}_0}{\eta \cdot \hat{E}_{\ddot{\imath}.\tilde{n}.}}$$

де $\sum M_Y$ - the total power of the lighting devices of the planned repair shop in kW,

without backup equipment ($\sum M_Y = 65 \cdot 48 = 3.12 \hat{e}\hat{A}\grave{o}$);

$\hat{O}_{\ddot{a}}$ - valid equipment time fund ($\hat{O}_{\ddot{a}}$ =2000 hour);

$\hat{E}_{\ddot{a}}$ - equipment load factor ($\hat{E}_{\ddot{a}}$ =0,75);

$К_0$ - refresh rate ($\hat{E}_0$ =0,8);

$\hat{E}_{\ddot{\imath}.\tilde{n}.}$ - network loss ratio ($\hat{E}_{\ddot{\imath}.\tilde{n}.}$ =0,95);

η - coefficient of performance (η =0,5).

$$W = \frac{3.12 \cdot 2000 \cdot 0.75 \cdot 0.8}{0.95 \cdot 0.5} = 7882.11 \ddot{e}\hat{A}\grave{o}$$

$$W_{\hat{i}.\ddot{o}.} = \frac{P_Y \cdot F_{\ddot{o}} \cdot \hat{O}_{\ddot{o}} \cdot \hat{E}}{100}$$

(P_Y =0,01 kW);

$F_{\ddot{o}}$ - workshop area ($F_{\ddot{o}}$ =660 m);

$\hat{O}_{\ddot{o}}$ - the number of hours of operation of lighting devices during an 8-hour working day ($\hat{O}_{\ddot{o}}$ =1300 hours);

K - loss ratio (K=1,06).

$$W_{\hat{i}.\ddot{o}.} = \frac{0.01 \cdot 660 \cdot 1300 \cdot 1.06}{100} = 90.95 \hat{e}\hat{A}\grave{o}$$

Total costs are determined by the formula:

$$W = W' + W_{\hat{i}\ddot{o}} = 7882.11 + 90.95 = 7973.06 \hat{e}\hat{A}\grave{o}$$

Economic costs to the environment:

$$J_{\mathring{a}\ddot{e}} = W \cdot Y_{\mathring{a}\ddot{e}}$$

$Y_{\mathring{a}\ddot{e}}$ - specific economic costs ($Y_{\mathring{a}\ddot{e}}$ =126coins/кW)

$$J_{\text{ел}} = 7973.06 \cdot 1.26 = 10046.06 grn.$$

5.4. Conclusions

Aircraft repair enterprises are a source of environmental pollution environment; their work leads to:

- atmospheric air pollution by harmful substances from the operation of aircraft engines;

- discharge of untreated sewage and harmful water emissions from the territory of the aircraft factory into the soil, rivers, and reservoirs;

- occurrence of industrial noise;

- the appearance of electromagnetic fields and ionizing radiation.

To reduce the impact of the above factors on aircraft repair enterprises need:

- use modern resource- and energy-saving technologies;

- conducting briefings with employees;

- strictly monitor the implementation of all norms and rules regarding the protection environment;

- to increase the area of land plantations;

- financially support environmental protection measures environment

The estimated economic damage to the environment of the environment as a result of the repair of the high-altitude system, is UAH 10,046.06.

General Conclusion

In this diploma work, an analysis of the existing technology is carried out of the process of repairing units for the repair of high-altitude equipment. Based on the fee statistical data, the analysis of defects of high-rise units was carried out for equipment. To improve the technical process, the following are proposed:

– installation for testing units of the high-altitude system with a personal computer;

– installation for balancing the rotor of the TCU 3263 product using a laser;

- a device for removing the characteristics and checking for leakage and

pressure regulator leaks. Proposed measures to improve the technological process.

The proposed measures allow a significant reduce labor costs for repairs, reduce transport costs and improve quality repair, which as a result increases the level of safety and regularity of flights.

In the diploma work, measures on labor protection and protection were developed environment.

In the "Occupational safety" section, the main safety rules are given when servicing units of the high-altitude system, as well as measures, with the help of which will be possible to increase labor safety during repair and service. In the "Environmental protection" section, a number are proposed

measures that increase environmental safety. Conducted economic justification of the proposed measures.

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