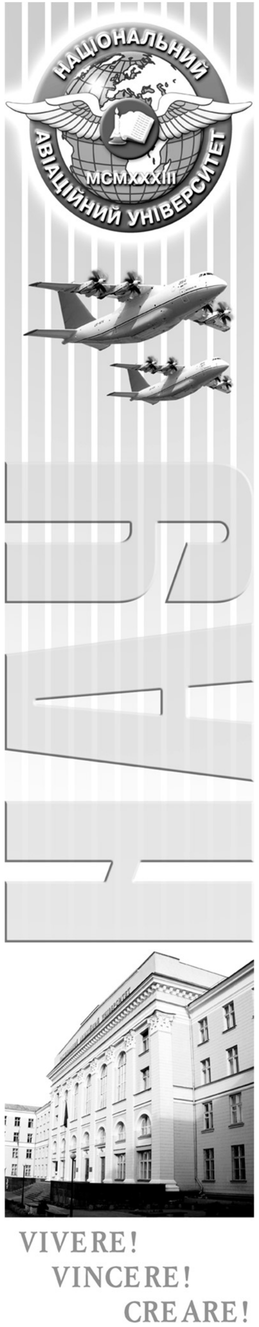

MINISTRY OF EDUCATION AND SCIENCE OF UKRAINE

National Aviation University

Manufacture and Repair of Gas Turbine Plants and Compressors

Guide to Laboratory works

For students of major

6.050604 «Power engineering»

Kyiv 2015

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Розглянуто основні технологічні процеси що застосовуються при виробництві та ремонті газотурбінних установок. Подано короткі теоретичні відомості і порядок виконання робіт.

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The main processes used in the manufacture and repair of gas turbines. A brief theoretical information and the order of the work performance.

Designed for students of major 6.050604 «Power engineering».

Contents

INTRODUCTION

The development of the gas compressor industry needs a constant replenishment of the enterprises with qualified engineering personnel.

The purpose of this guide that meets the curriculum of "Manufacture and repair of gas turbine plants and compressors" course - is consolidation and deepening of knowledge of the lectures, acquiring skills of independent experiments necessary to meet the objectives and future mechanics and engineers in the production, repair and maintenance of gas turbine units.

Before each laboratory work the students are tested. A student with poor knowledge of the topic is not allowed to perform laboratory work, but he should perform these tasks with another group after appropriate training.

Each completed task should be made in the form of a report.

Only after the approval of the report the teacher allows the student perform the next laboratory work. The students which do not pass the laboratory work according to the curriculum are not allowed to perform the module tests.

Laboratory work 1

DEVELOPMENT OF MANUFACTURING PROCESS OF A GAS TURBINE DETAIL WITH THE “RAPID PROTOTYPING” TECHNOLOGY

Purpose of the work - considering the principles of technological processes of manufacture gas turbine parts; learn the terms and definitions of the basic concepts of the unified system of technological documentation.

Task

1. Acquire the basic theoretical principles based on materials of the lectures and recommended literature.
2. Learn the basic terms and definitions of the basic concepts used in the system of technological documentation.
3. Learn the basic principles of the technological process design of an individual detail.
4. Develop the model of the technological process of the details (the drawing of the detail is given by the teacher).

Brief theoretical information

The traditional analog technology is unable to sufficiently respond quickly to the market demands. The work processes of manufacture for analog manufacture technology are based on the traditional layer-by-layer removal of the workpiece material to get a specified size, shape and quality for the detail. Prototyping of the products, their model also requires a lot of time.

Time to create product (TCP) – is the time between the emergence of the idea and the implementation of the product to the market, and it significantly affects the competitiveness of enterprises. The analysis indicates that often more than 25% of TCP falls on the production of prototypes and samples, making 60% of prototypes and prototype lasts several months, so rapid production of prototypes has a great potential of TCP decreasing.

The analysis cycle of product creating (CPC) shows that in all its phases - from the idea to the product until its implementation to the market – is a needed prototype. For manufactured goods the CPC can be divided into six phases. The prototypes used in separate phases of creation have different factors as to a number of the copies, the properties of the material used and geometric, aesthetic and functional requirements (Fig. 1.1).

In the **before development phase** the design of the models and geometric prototypes is repeatedly worked out, which, as a rule, are usually made in a single copy. Functional requirements in this phase are of secondary importance, these models are conducted many times with different materials. They are used to study the design and ergonomics, as well as the first stages of marketing.

In contrast to the first group, the **geometrical prototypes** already possess aesthetic properties, and they must meet higher requirements for size and shape accuracy. Functional properties are also of secondary importance. The material for geometrical prototypes does not necessarily correspond to the material of serial parts. For this purpose the material for modeling is set. Typical applications of this method - is production planning of manufacture, retesting of the manufacture and assembly, and rough planning of manufacture and assembly, where the prototypes are necessary as a means of communication.

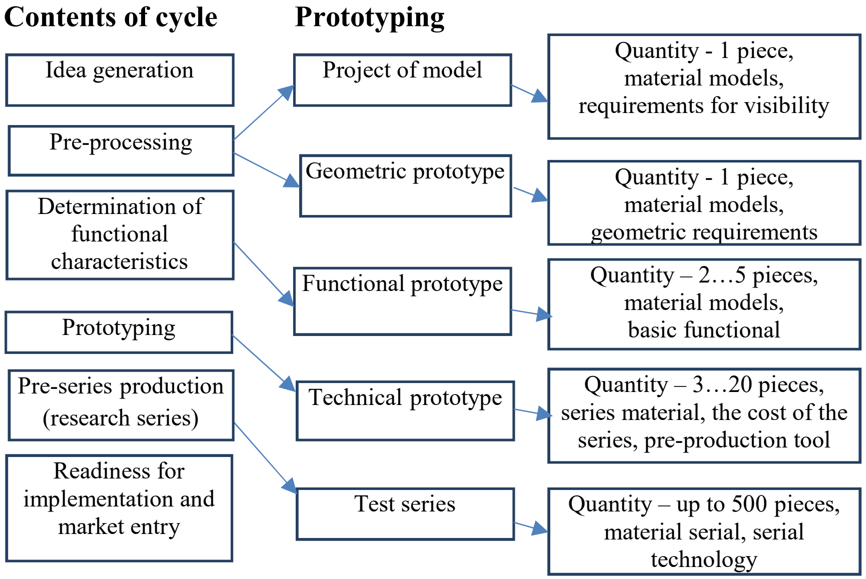


Figure 1.1. The stages of prototyping the products (traditional)

In the **phase of creating of a functional sample** from 2 to 5 prototypes are made to test a product idea at the principle of operation and, if needed, to optimize them. The main question at this stage of creation is the analysis of the function of individual components of the product and its structural parts. During the planning process the functional prototypes will be attracted to the planning of the production, its order, assembly and the production tools, excluding the outline and the dimensions limit. All other properties are of secondary importance, as they do not damage the functioning.

In the next **phase of the creation the technical prototypes** are made in a large number of copies (depending on specific conditions - from 3 to 20) that possibly are identical to the final product in terms of material and the established technology used. In the manufacture of the parts by stamping, high-pressure diecasting, test analyzes are appointed for the product functioning, the duration of the production loading, technological and consumer reaction to the test (experienced) lot, and accordingly test tools are selected. The results of these first tests can be used to optimize the design.

Introduction of the product on the market is carried out **in the pre-production phase** depending on the field up to 500 pieces (samples). Some structural elements are made of the material of the series when using the later stage of tools and technologies. Pre-production is necessary for planning the product for intensive testing and its market. In this phase, the acceleration of production is carried to determine the parameters of production and its optimization. The optimization makes some changes to improve the final products (feedback).

Making models and prototypes required for making the product is usually carried out by conventional technologies, if necessary, in combination with a foundry. In particular, NC milling machines are used as well as copy machines, turning machines and others. In addition, these models are manually assembled, glued or soldered.

New stages of development of science, IT, technology CNC, laser technology, etc. have led to integrated generative methods of accelerated formation at the macro level, it allowed to get rid of several phases of prototyping.

The ideology of accelerated formation of the product (model, prototype) is based on: the possibilities of automated computer design of the product (based on photographs, drawings, or depending on the analytical results of measurements), computer optimization of its design, based on the requirements of the design, shape, functional properties (CAD); transformation of a three coordinate model in a set of layered models; possibilities to reproduce this set of layered patterns (Fig. 1.2), that is to materialize the model as a whole, as a solid-state product, or its prototype (CAM).

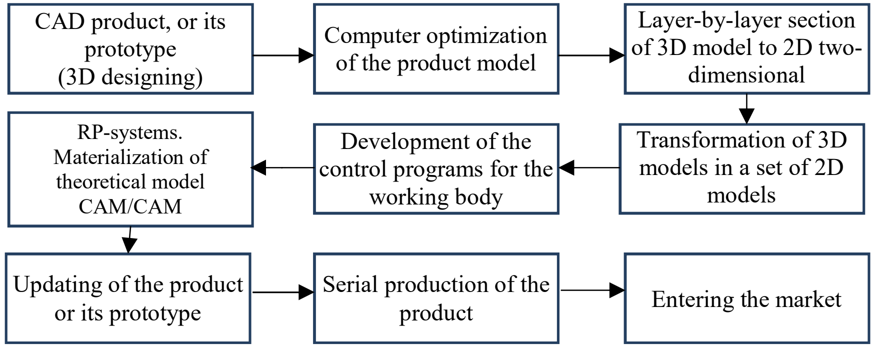


Figure 1.2. The structure of the integrated workflow of the accelerated formation - Rapid Prototyping

Thus, the functional structure of the integrated workflow of the accelerated formation of the product can be represented as follows:

1. Receiving the three-dimensional mathematical model of the product. It is created according to the drawings, a private analytical dependence. If the product is reproduced, then the model is obtained on the three-coordinate measuring machine by scanning the original surface layer-by-layer or by point machining (Fig. 1.3).

2. Computer optimization of the design is carried out by the programs, based on its functionality, design, etc. requirements to the product being developed. The importance of this stage is determined by the fact that the computer optimization does not need a solid-state model or product, so it reduces the time to designing.

3. Layer-by-layer representation of theoretical model as a set of two-dimensional relatively simple models (Fig. 1.3).

4. Creating the programs of computer control of the working body movement, the "tool" by which the theoretical model of the product or its prototype will be materialized layer-by-layer according to a set of 2D models.

5. Layer-by-layer (Fig. 1.3) obtaining the whole solid model or product (or series of products). These stages of accelerated formation are illustrated in Fig. 1.4.

6. The final product or model is obtained by further improvement of properties. For this purpose on the first stage are identified the difference of properties of the expected prototype and necessary product by the geometrical shape, physical, mechanical, chemical and other properties.

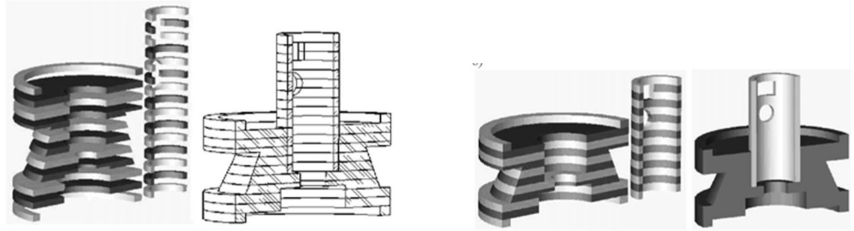


Figure 1.3. Basic transitions of RP method

On the second stage some of these differences are removed due to the parameters of the process of materialization of the theoretical model.

On the third final stage there is a "ennoblement" of the product, that is, maximum possible approaching its functional properties to those that are required: wear resistance, durability, conductivity, metallization, finishing to etc.

It allows design the whole chain of prototyping and manufacture of the product in another way, fully based on the ideology of the generic layer-by-layer making (Fig 1.4). Comparing it to traditional approaches shows (Fig. 1.3) that generic technology is effective on the stages of prototyping and it allows shorten the number of these stages.

But the main advantage consists is that the idea of the method of the generic (layer-by-layer) making is unifying, integrating the processes of the design, creation of the instrumental providing and making.

It allows present the conceptual structure of the integrated technologies which are based on the idea of the generic manufacture as follows: computer creation of conceptual models, generic creation of functional prototypes, generic creation of the instrumental providing, generic serial production, entering the market.

Generally accepted the following classification of the realized generic technologies (symbolic representations respond the abbreviations created from the initial letters of English words for the names of methods of RP (Rapid Prototyping) and presented in alphabetical order):

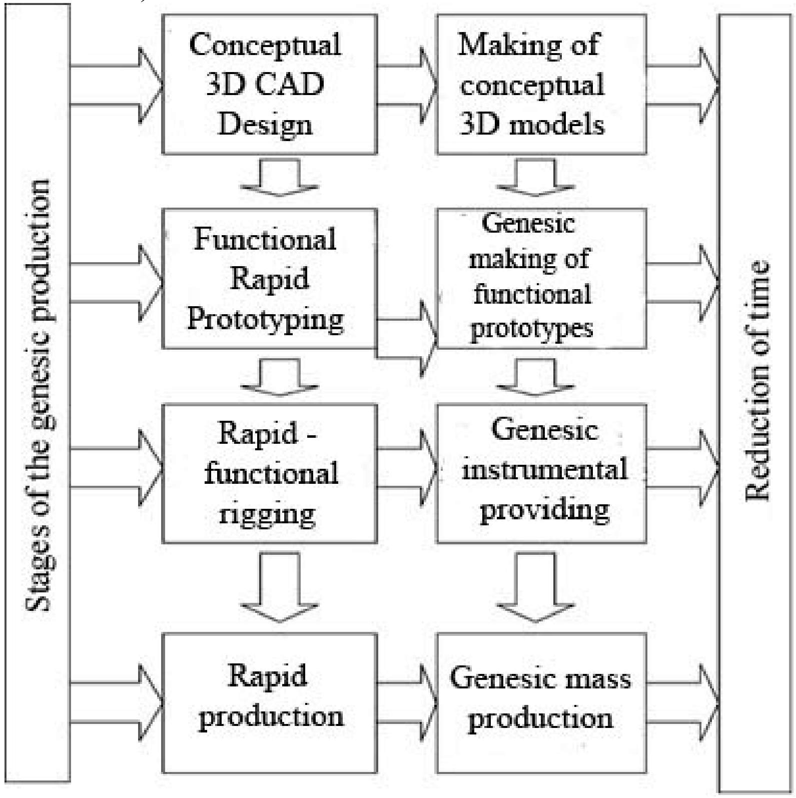


Figure 1.4 Stages of the generic creation of prototypes and products

- 3DW - Three Dimensional Welding ;
- BPM - Ballistic Particle Manufacture ;
- DMD - Direct Metal Deposition ;
- FDM - Fused Deposition Modeling ;
- GPD - Gas Phase Deposition ;
- HIS - Holographic Interference Solidification ;
- LENS - Laser Engineering Net Shaping ;
- LOM - Laminated Object Manufacture ;
- MJM - Multi Jet Modeling ;
- MJS - Multiphase Jet Solidification ;
- RMPD - Rapid Micro Product Development ;

- SGC - Solid Ground Curing ;
- SLA - Stereo Lithographics Apparatus ;
- SLS - Selective Laser Sintering ;
- TDP - Three Dimensional Printing ;
- The last point is a revision of wares as-grown are post-processes (PP), to them it is also possible to take verification of products:
- PP - Post Process

During these systematization of the generic technologies the record of post-process for determination of method of RP is recommended to perform as the following method: PP (abbreviation of the method), for example, PP (SLA).

Order of the work performance

1. Get the draft of GTU detail from the teacher.
2. Work out the technological process of making of the GTU detail.
3. Make a report.

Report

The report must contain the sketch of the product, a layout of the technological process of making of the GTU detail, names of basic elements of the technological process, the list of equipment that is used for making and control of the details.

Laboratory work 2

INFLUENCE OF TECHNOLOGICAL BASES ON ACCURACY OF DETAILS MAKING

Purpose of the work - is to learn the dependence of accuracy of the details making on the chart of the technological process and a choice of bases that are used for setting the details on the machine-tool or on the device.

Task

1. Design the chart of the technological process of making the bush

on the vertical drill.

2. Choose the variant of the conductor chart that provides the minimal loss of accuracy of transference of the size at drilling of three openings in the bush. These openings are 3 mm in size and are from one setting.

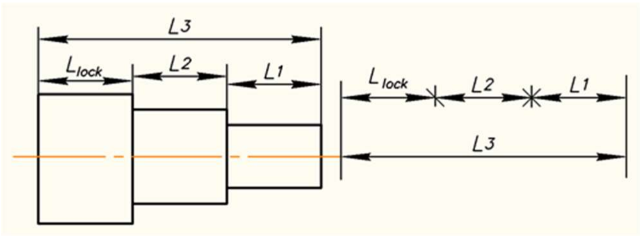
3. Make a bush.

Brief theoretical information

Bases of the products and their role in providing of the set accuracy. Formations of the products dimensions are described by means of the theory of dimension chains.

Dimension chain is a totality of dimensions that form the closed loop and directly participate in the solvation of the set problem (by ГОСТ 16319-70).

Separate dimensions that make up a dimension chain are called its *links* (Fig. 2.1). L_1, L_2, L_3 – component links, and L_{lock} – locking link. The dimension of the locking link is made automatically as a result of solvation of the set problem. Links L_1 i L_2 are called *decreasing,* because with their increase, the dimension of the locking link is decreasing. Link L_3 is called *increasing*, because the dimension of the locking link increases with her increase.



a *b*

Figure 2.1. Construction of the dimension chain of stepped shaft: *a* – chart of dimensions; *b* – dimensions chain

The nominal dimensions of all links of the dimension chain are described by the equalization:

$$L_{lock} = \sum_{i=1}^{m} L_{increase} - \sum_{k=1}^{n} L_{decrease},$$

where $L_{increase}$ and $L_{decrease}$ – accordingly links that increase and decrease; *m* – total number of links that increase, *n* – links that decrease.

It is basic equalization of the dimension chain. On its basis there are equalizations of errors of dimension chain and equalization of admittances on a locking link. The decision of size chains is taken to the calculation of tolerance on the locking link.

Dimension chains, which allow solve the problems of providing of accuracy of the product in the process of its making are called *technological*. Obviously, the longer is the dimension chain, the greater is the dimension of errors that influence the accuracy of formation of the locking link dimension. On the basis of this rule the *principle of the shortest way* has been defined. This principle is the most important in creation of technological processes of high precision. The essence of this principle lies in the development of such technological process that has the shortest technology dimensional chain. This principle is realized by a proper selection of bases.

Basing is giving to the workpiece or products the required position relative to the selected coordinate system. Basing is carried out at the workpiece, product and processes design, their manufacture and assembly (in accordance with GOST 21395-76).

Base is the surface, axis or point performing the same function, which is a part of the workpiece or product and which is used for basing. The base of the technological process, selected during the product designing, is called the *project basing*.

According to their purpose the bases are divided into designing, technological, measuring etc.

Designing bases are the bases that determine the position of parts or assembly unit in the product.

Technological bases are the bases used to determine the position of the workpiece or product in the manufacture process or repair.

Measuring base is used to determine the relative position of the workpiece or product and measuring tools.

Technological bases exist as real surfaces that are used in the manufacture and assembly of products to determine their position relative to the tool, relative to each other or in the device.

There are mounting, measuring and assembling technological bases (hereinafter simply "base").

Mounting base determines the position of the workpiece in the device relative to the tool.

Assembling base determines the position of one detail relative to other details during the assembly. The totality of assembly parts forms the assembling base of the unit.

The distance between the designing and the technological bases is called the *base dimension.* When combining these bases the base dimension is equal zero.

The production error ΔA of some error A is formed by algebraic summation of errors that occur at various stages of processing Δo and error of base dimension Δδ:

$$\Delta A = \Delta_o + \Delta\delta.$$

Thus, errors of preliminary operations are included into the following errors in the form of error of base dimension.

During multi-operational processes can occur the accumulation error of the base dimension which can be significant.

Combining the designing and technological bases is called the rule of base unity. Due to keeping the rules in the designing of technological processes the dimension chain becomes shorter and the accuracy of the details manufacture is significantly increased (Fig. 2.2).

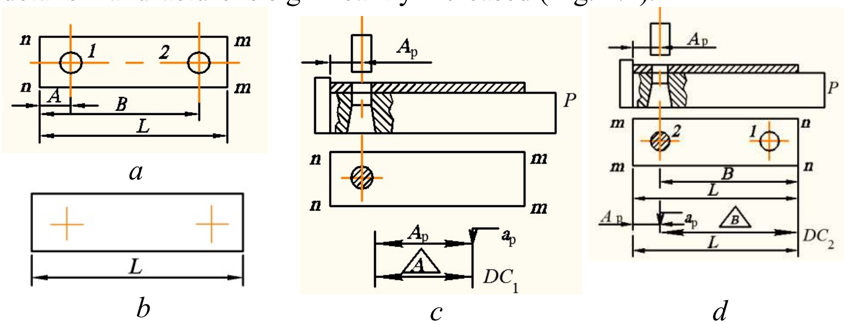


Figure 2.2. Different rules for constructing the process of cutting: *a* - detail; *b* - workpiece; *c* - cutting of the hole 1 according to the rules of unity of the bases; *d* - cutting holes not according to the rules of unity bases; *P* - punch; *1* – cut hole; - *2* – uncut hole; DC_1 and DC_2 - dimension chains that meet the technological processes, built in accordance with the rules of unity of the bases and without them

For example, the detail with holes *1* and *2* (Fig. 2.2, *a*) is made from a strip (Fig. 2.2, *b*). When cutting the hole *1* the constructive base (the surface n - n) is also a technological base. In this case, the reference size is zero. Dimensional chain DC_1 - is the shortest. The accuracy of position of the hole center *1* is defined by the error *a* of the punch

size A_p.

When cutting holes *2* we accept the surface *m - m* as a mounting base. In this case, the constructive base (the surface *n - n*) and the technological base (surface *m-m)* do not match. In this case, the rule of unity of bases is not met. Dimensional chain DC_2 gets the additional link as a basic size *L*.

Production errors, formed at the performance of the process, are divided into systematic and random.

Systematic errors are such errors which are regularly repeated in the performance of the process. The size and sign of these errors can be predicted with a high degree of accuracy.

Systematic errors are constant or variable.

Random errors are such errors, the occurrence of which is unpredictable. In the production of details and assembly of products occur errors in their sizes, shapes and characteristics of the surface layer, weight and so on.

Production error of sizes and shapes arising from the following reasons: malfunctioning equipment, devices, tools; insufficient stiffness of the system “machine - device - tool – detail”; fluctuations in the physical and mechanical properties of the material from which the product is made; temperature deformation; inaccuracies of tuning the equipment.

Selecting the mounting base for the production of devices

Accuracy of the detail usually depends on the accuracy of the machine, stiffness of the system “machine - detail – tool”, precision of adjustment of the device that serves for mounting details, choice of bases used in the production of details. Precision adjustment depends not only on precision of manufacture of some of its elements, but on the chart of adjustment. Therefore, in the design of technological process of manufacture of the parts with the required accuracy for machine tools it is necessary to solve a number of issues: choosing the equipment and mounting base, development of technical specifications for designing special equipment and tools.

Assessment of precision of technological processes enables to implement only such processes that provide accuracy of the detail set in the project. However, to ensure the interchangeability of details it is necessary not only to evaluate the accuracy of processes but also control this accuracy.

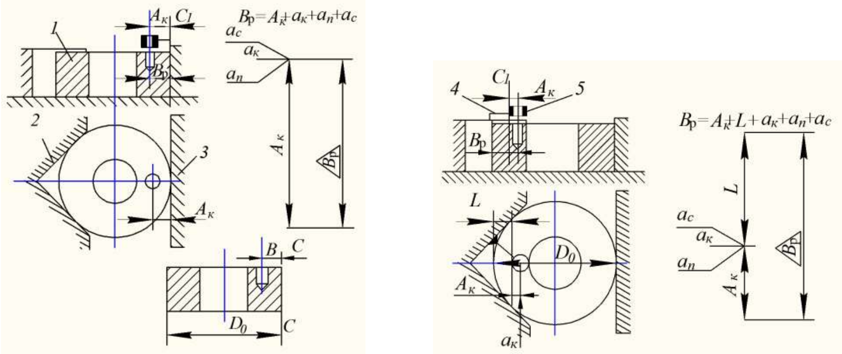
The final size of the detail B_p is formed by the transfer some initial size B to this detail, as given on the chart and made by caliber: machine for adjustment or measuring tool A_k (Fig. 2.3). The longer the path that the initial size of the finished parts travels, the greater number of operational errors are parts of the resulting error, the lower is the accuracy of the process.

Therefore, one of the basic principles of creating a high-precision production process is the principle of the shortest path, the production process should be designed to correspond to the shortest technological dimension chain of the detail. To meet this requirement, it is necessary to choose correctly the technological bases of details.

The shortest path of the size formation is one-step transfer of the caliber size to the detail.

In this case, the final size of the detail is defined by the operating dimension chain (Fig. 2.3, *a*).

A necessary and sufficient condition for the principle of the shortest path in the processing of details is that for the base of the detail (C_1 - C_1) must be used the surfaces that make up the constructing base (C - C) or the surface which is processed (Fig. 2.3, *a*).



a *b*

Figure 2.3. Chart of drilling holes in the bush

a - according to the unity of bases; *b* – not according to unity of bases; 1 - detail (bush); 2 - prism; 3 - flat support; 4 - jig plate 5 - conductor bush; a_k, a_n, a_c – variable of initial size, equal to zero and which are caused by inaccurate mounting respectively: jig bush on the base towards A_k, prisms relative to the axis of jig bush towards A_k and error of the drilling process.

Failure to comply with the rules of unity of the bases in the production of details leads to a violation of the principle of the shortest path. As a result in the structure of technological dimension chain there is an additional link in the chain, which makes the basic size of the detail L. This size determines the distance between the constructive base and setting base of the parts produced (Fig. 2.3, *b*). Thus, violation of rules of unity of bases leads to elongation of the technological dimension chain of the detail on one link - basic size L. Therefore, an error of final size B_u of the detail is increasing on the amount of the error of basic size ΔL.

Fig. 2.3 shows the chart of drilling a hole in the bush and the dimension chain for the case when the rules of unity of bases are not met.

The rule of unity of bases is realized as follows: first of all, such surfaces of the details should be processed which are constructive bases relative to other surfaces (the choice of mounting base is not important), then the rest of surfaces should be processed, mounting the detail on the relevant constructive bases (Fig. 2.3, *a*). Often in practice there are two types of bases: constructive and setting.

Choice of the machine

To ensure the greatest accuracy of transfer the initial size on the detail, the special adjustment is used by which the size is transferred, which must be designed in accordance with the rules of unity of bases. In this case, the error of the final size B_p will not depend on the size of the basic size of the detail L (see Fig.2.4). In practice, this condition is often associated with a significant complication of this adjustment. The rule of unity of bases usually breaks only when to reconstruct the given size the engineer can use accessories which are easier, that can be produced at a lower cost and in a shorter time.

For drilling three holes in the bush (Fig. 2.4) the adjustments as in Fig. 2.5 adjustments could be used.

In Fig. 2.5, *a*, detail 3 is fixed by a self-centering device 2, and 1 tile from the conductor bush 4 moves to guiding 5 to the contact with a cylindrical surface (Fig. 2.4). The chart of Fig. 2.5, *a* is made according to the rules of unity of bases. At other equal conditions of the adjustment, made by the chart *a,* provides higher accuracy compared to

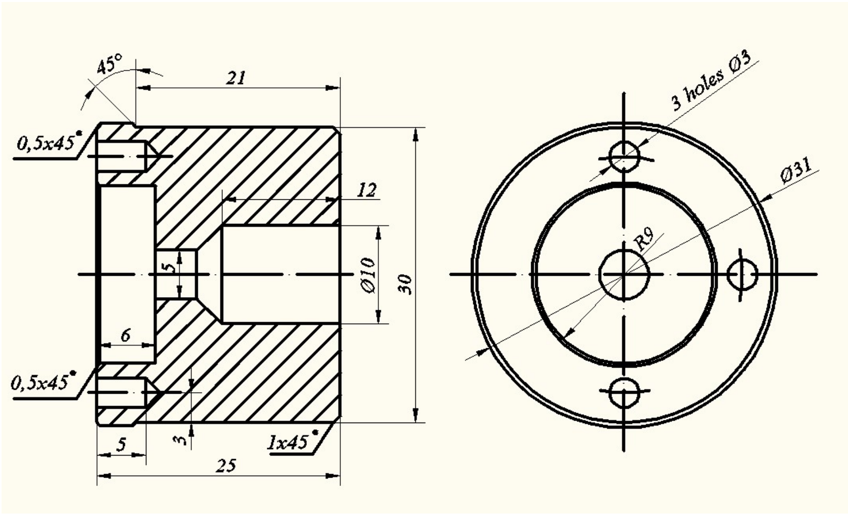
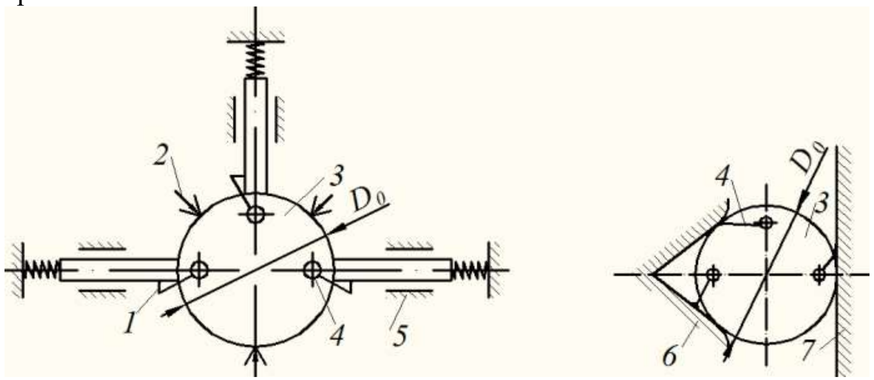


Figure 2.4. Bush

the adjustment, made by the chart *b*. At the same time, the chart would be simpler for its constructive design of adjustment than chart *a*. Therefore, if the chart *b* provides the necessary accuracy, it must be preferred to chart *a*.



a *b*

Figure 2.5. A chart of device for drilling the holes in the bush

Accuracy of drilling holes by the chart *b* depends on the size of errors of size D_0 and variants of fixing of jig bushes 4 to support 7 and clamping 6 of devices (Fig. 2.5, *b*).

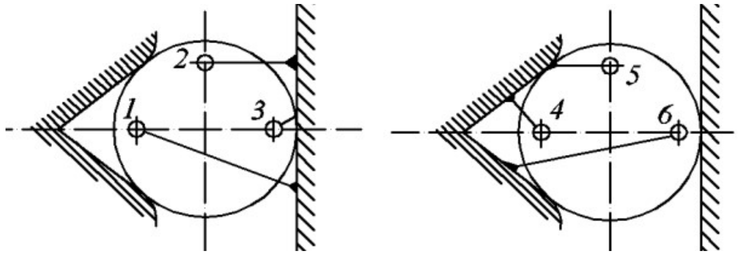


Figure 2.6. Variants of fixing of jig bushes
1, 2, 3, 4, 5, 6 – numbers of bushes

Order of the work performance

1. Draw a sketch of the bush.
2. Make a diagram of the technological manufacture process using turret automatic machine and vertical drilling machine. Make a list of operations and transitions with tools and technological equipment and make it as a card form which will be given by the teacher.
3. Measure the diameter of the surface *F* using micrometer, identify error:

$$\Delta R = \frac{D_1 - D_0}{2}$$

where D_1 – final diameter of surface *F*; D_0 - nominal diameter of surface *F*.

4. Choose a variant of the conductor chart. Draw the chosen chart in the report.
5. Assemble the detail in the auxiliary device, according to the chosen chart, by installing the tiles with conductive bushes on a prism or on a flat support.
6. Determine the resulting error ΔB_{pi} with *a* and *a* (see. Fig. 2.1):

$$\Delta B_{pi} = B_{pi} - B$$

Report

The report must include a sketch of the product, the chart of the manufacture process, the variant of the conductor chart, calculations of errors in the manufacture of bushes, conclusions.

Laboratory work 3

MANUFACTURE OF DETAILS WITH "HIGH SPEED MANUFACTURING" TECHNOLOGY

Purpose of the work – to study the HSM technology at the manufacture of the detail.

Task

1. Learn HSM technology.
2. Select the tool and mode of processing of the GTU detail at the application of HSM technology.
3. Design the manufacture process.

Brief theoretical information

High speed manufacturing (HSM) is not only an innovative technology, that allows to decrease manufacturing time and increase details processing accuracy, but also it is a real strategy for increasing of productivity. Application of this strategy directly influences cycle time and the manufacture costs. The final result is achievement of details of high quality and, more significant, it increases productivity.

In the basis of HSM lies a considerable increase in speeds of spindle and supply, in order to achieve high processing results, which were not possible before. Very thin walls, a smooth surface and a big amount of metal removal – these are examples of processing that can be achieved during HSM usage. HSM can be applied not only to non-ferrous metals, for instance, aluminum, but even to relatively hardened steel and metals that are hard to process. It allows apply HSM in such industries as aircraft manufacturing, production of stamps and molds, miniature production, medical industry.

Benefits of HSM on the world-wide basis:

- Decrease in time of the manufacture cycle on 50% and higher;
- Maximum productivity;
- Surface quality after processing equals to surface quality after polishing;
- Details processing of small sizes, including nanotechnology;
- Complete details processing from the same permanent position.

Theoretical justification of HSM are so called Solomon's curves (Fig.3.1), which show, that after reaching of some cutting speed, a significant decrease in temperature in a cutting zone takes place and, that for definite material there is some cutting speed after which a further cutting processing is impossible.

But the most important factor is heat distribution in a cutting zone. At small section crossings, in a given speed range the main heat is concentrated in shavings, and not getting to the work-piece. This allows process the details made of hardened steel without fearing of tempering the surface layer. This gives the main principle of HSM – a small section crossing, which is removed with high speed, and high rotational speed of spindle (table 3.1.) and high supply per minute (Fig.3.1.)

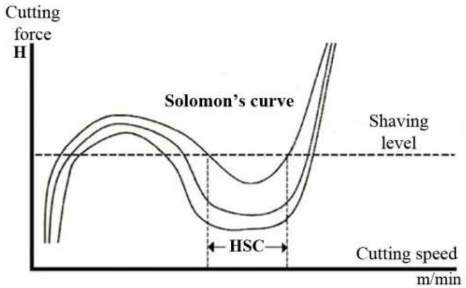


Figure 3.1. Change of cutting force with increase of cutting speed

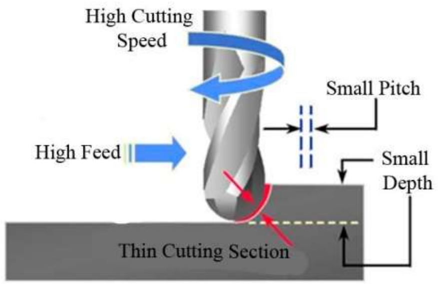


Figure 3.2. Cutting regimes for HSM

The main effect of HSM is not reducing the machine time due to intensification of the cutting; it is the overall simplification of the manufacture process and improving the quality of processing (Fig. 3.2).

There is even a recommendation, that the depth of cut should not exceed 10% of the cutter diameter. The main effect of HSM is not the reduction in machine time due to intensification of the cutting, but the improving the quality of processing and the effective use of modern CNC machine tools.

The success of high-speed processing is the right choice of all factors involved in this process - the machine, CNC system, cutting tools, supporting tool with a system of fixing tools, system programming, a programmer and technologist, a qualified CNC machine operators. Neglecting one of these components may nullify all previous efforts.

Table 3.1.

Cutting speed of various materials depending on the type of processing

Material (due to SMS classification)	Speed of cutting (m/min)			
	Hardness	Usual processing	HSM - roughing	HSM - *finishing*
Steel 01.2	150 HB	< 300	>400	< 900
Steel 02.1/2	330 HB	< 200	>250	< 600
Steel 03.11	300 HB	< 100	>200	< 400
Steel 03.11	39-48 HRC	< 80	>150	< 350
Steel 04	48-58 HRC	< 40	>100	< 250
GCI 08.1	180 HB	< 300	>500	< 3000
Aluminum	60-75 HB	< 1 000	>2000	< 5000
Non-ferrous alloys	100 HB	< 300	>1 000	< 2 000

Modern machine HSM has speed of a spindle 12000-25000 rpm and is equipped with a means of stabilizing the temperature of the spindle. Some companies offer machines with a rotation speed of 40,000 rev / min. The supply rate is 40-60 m /min, the speed of fast movements is up to 90 m / min. The machine performs small displacements from 5 to 20 microns, has high stiffness and temperature compensation. The progress in the field of machine tool building has allowed develop HSM.

Leading tool companies offer today a wide range of cutters for HSM with detailed recommendations on areas of application and cutting conditions. The development of new types of fine alloys, those are capable to operate reliably at high speeds. It is more important to pay attention to the system of auxiliary tools that provide fitting of cutters. Due to reduction in cutting forces at HSM other factors appear - the amount of beats milling, vibration, arising inertial loads and forces, are proportioned to the cutting forces.

Alloys and parameters of cutting tools play a very important role in the process. In view of this, ISCAR has developed fine-grained cemented carbide without coating - IC08, for the treatment of non-ferrous metals at high cutting speeds. Also, ISCAR has developed fine-grained IC903 hard alloy with a cobalt content of 12% and coated with TiAlN PVD with strength and high wear resistance for high-speed HSM machining hardened steel (up to 62 HRC), titanium and nickel alloys, and stainless steel.

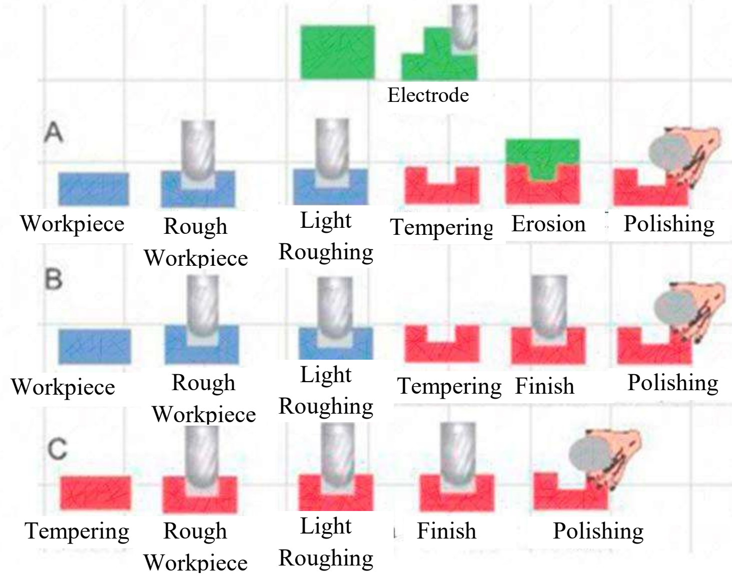


Figure 3.3. Simplification of the manufacture process of the formative elements of tooling (molds, dies) using HSM.

Tools made from these alloys have a special geometry, and specially prepared cutting edges for high-speed processing. Also, they show high impact strength at constant beating load at high frequencies, and provide a reduction in heat and thermal expansion [4].

Order of the work performance

1. Get the drawing of a GTU detail or details from the teacher.
2. Develop a process of manufacture of GTU details.
3. Make a report.

Report

The report should include a sketch of the product, the layout of the technological process of manufacturing parts of GTU, names of the main elements of the process, a list of the equipment used for the manufacturing and control of the details.

Laboratory work 4

TECHNOLOGY OF GAS TURBINE ROTOR ASSEMBLY IN THE MANUFACTURE OF GAS TURBINES

Purpose of the work - to acquaint the students with a typical assembly process of aircraft turbine rotors.

Task

1. Equip fully the rotors discs with turbine blades.
2. Make a distribution of weight moments by the table.
3. Assemble the wheels of all levels of the turbine rotor.
4. Get acquainted with the industrial technology of a joint assembly of the turbine rotor.

Brief theoretical information

Tin order to facilitate the balancing of turbine rotors of aviation GTU one performs a careful selection of blades by weight moment in the assembly of every degree.

Weight moment of blades are defined by a special tool (Fig. 4.1), which is a technical device such scales where the adjustment load is mounted on the left of the balance beam, and the vane 3is mounted on the right of the corresponding stage. To adjust the scale of the corresponding stage it is used its reference blade. The scale is divided in degrees. Deflection of scale hand on one degree corresponds to a change in the moment on 6 g·cm.

After setting the scale, in the place of the reference one mounts a serial blade and identifies deviations from its weight moment to the weight moment of the reference blade.

The indicators on the left hand to the left from “0” are fixed with the symbol "minus" and to the right - with the "plus" symbol. As a reference blade can be used a serial blade, the weight of which is close to the nominal value for this stage. For example, in the engine RD-3M-500 as a reference for the first stage blade of the turbine blade can be used in a blade of weight of 380 ± 5g, and for the second stage - a blade of weight 360 ± 5g. For the turbine rotor engine AI-20 as a reference, you can use the serial blades with weight:

the first stage 130 ± 1g,

the second stage 180 ± 2 g
the third stage 230 ± 3g.

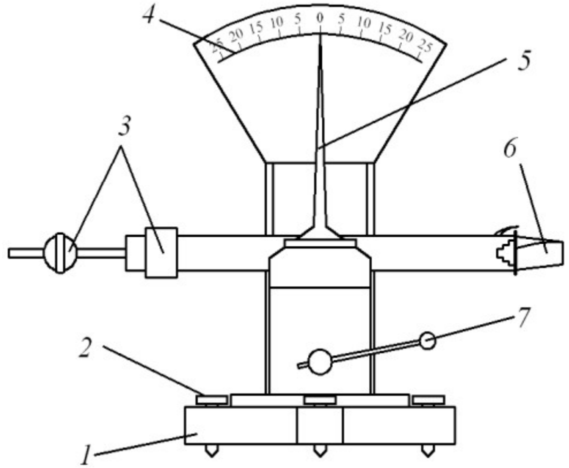


Figure 4.1. The device for determining the weight moment of the blades: 1 - adjusting loads; 2 - scale devices for measuring the weight moment of the blades; 3 - a reference blade, 4 – holder of the zero position of the scale; 5 - base; 6 - the adjusting screw; 7 – the hands is of imbalance of blades

Further work on the definition of weight moments of the blades is similar to work on common technical scale. For convenience, the table usually includes not a complete weight moment of the blade, but its deviation from the weight moment of the reference blade.

The technological process of the stages assembly (blading of discs) we will consider on the example of the rotor of the turbine engine AI-20.

After equipping the turbine discs with blades, they are installed in accordance with the data in table. 4.1.

Table 4.1

Weight moments of 2nd stage of GTU turbine

№ з/п	Number of blades	Weight moment of blades	Number of hole in the turbine disc
1			
2			
3			
…			

The blade with the smallest weight moment in the given set is placed to hole №1 and it is given number №1.

The next vane which by the amount of weight moment is close to blade №1 is placed to the diametrically opposite hole: №36 – for the disc of the 1st stage, №21- for the disc of 2nd stage, №19 – for the disc of 3rd stage.

The blade with the greatest weight moment is placed to hole №2. The next blade, which by the amount of weight moment is close to the blade №2 is placed to the diametrically opposite hole: №37 for the disc of 1st stage, to hole №22- for the disc of the second stage, to hole №20 – for disc of 3rd stage and so on. (a light blade opposite to light and heavy opposite to heavy).

The difference of weight moments of blades, which must be placed to the opposite places of discs, must be within the given range, which depends on the nominal weight of the blades, their values are different for the different engine types. For example for the turbine rotor of the engine РД-3М-500 the difference of weight moments of blades installed in diametrically opposite places must not exceed 120 g/sm. The maximal difference of the weight moments of the given series must not exceed 2500g/sm. For the turbine rotor of engine AI-20 the difference of weight moments of blades in one series for each stage must not exceed 220 g/sm.

After such accurate equipping the mass of blades during mounting is evenly distributed along the disc perimeter (Fig. 4.2), which makes the process of static and dynamic balancing easier.

Then wheels of the I, II i III stages are given for the general assembly of the turbine rotor, which is performed according to the plant technologies, which is available in the laboratory.

Order of the work performance

1. Get acquainted with the description of the laboratory work.
2. Study the setting and operation of device for defining the weight moment of blades.
3. Determine the weight moments of blades of given discs and fix them into the corresponding tables.
4. Mount the blades into the disc holes, using the methodical guidance of the laboratory work.
5. Get acquainted with the plant technology of assembly of I, II or III

stage (according to the teachers order) and assembly of turbine rotor AI-20 engine.

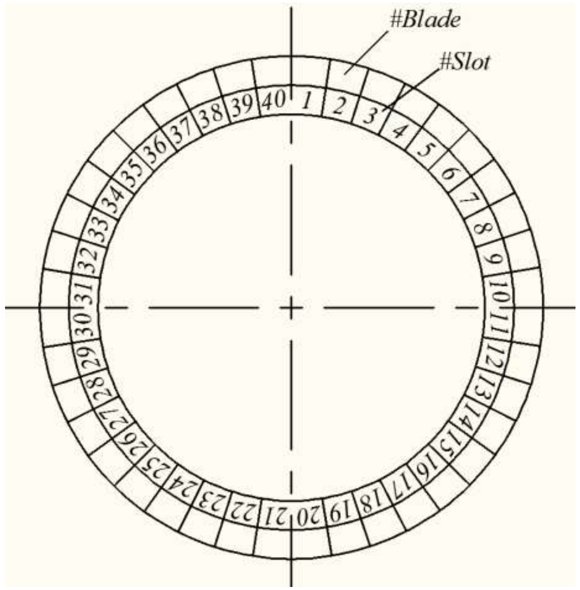


Figure 4.2. Circle table of weight moments of GTU blades

Report

Report must contain the chart of a turbine disc, a table of weight moments of GTU turbine, the placement of GTU turbine blades according to the assembly regulations, conclusions.

Laboratory work 5

WEARING OF THE GTU ELEMENTS IN THE PROCESS OF OPERATION

Purpose of the work – to determine the operation parameters of wearing couples in the process of wearing of main types of GTU wearing and compressors elements.

Task

1. Determine the types of GTU wearing and compressor elements
2. Make the report on the laboratory work

Brief theoretical information

In the process of the increasing of reliability of aviation aggregates and increasing the time of its operation the problems of wear resistance takes a very important place. It is known that in the process of operation the intense wearing of couples of details takes place due to high loads, speeds and temperatures, the influence of aggressive environmental surrounding and vibrations.

The classification of destruction types of surfaces leads to the physical-and-chemical processes which occur in the place of contact of structures. The scheme of the wearing classification is given in fig 5.1.

Corrosion-and- mechanical wearing is characterized by two types: oxidative and fretting corrosion.

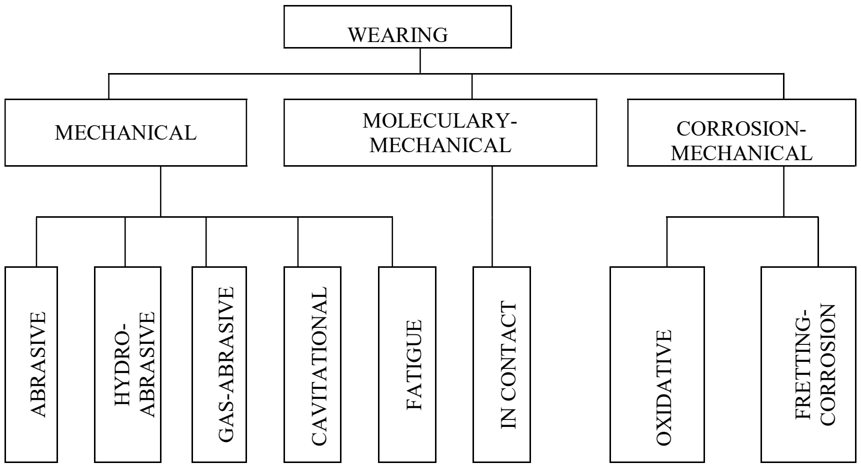


Figure 5.1.Types of wearing in machines

<u>Oxidative wearing</u> – it is the process of destruction of the surface elements or specimens during friction, which is caused by the interaction of active plastically deformed skin metal layers metal with atoms of oxygen, which is contained in the air or in the oil, and is adsorbed in the surfaces. The oxidative wear appears in the chemically adsorbed films, the films of solid solutions and chemical combinations of metal with oxygen and their destruction and removal from the surfaces of friction. This is a stationary process of dynamical balance of destruction and renewal of oxidation films.

Oxidation wear is realized at normal conditions of operation and is characterized by the allowable parameters of friction and provision of reliable operation of friction couples.

<u>Fretting corrosion - </u>it is the corrosion-and-mechanical wear of surfaces, which is pressed at small displacements. The peculiarity of damages of the elements at fretting corrosion allows separate this process into a special type of the surface destruction, the conditions of occurrence and development of which has a number of peculiarities which has three main stages:

1) The process of a mechanical destruction and oxidation of surfaces.
2) Action of a mechanical factor with the following oxidation of particles which have been separated.
3) The accumulation of fatigue damages in metal.

<u>Molecular-and-mechanical wear- is</u> characterized by the wear in coupling. As the result of a deep tearing of metal surfaces and transfer it from one surface to another, and as the result of a molecular compound of parts which are torn.

Depending on the reasons, which cause the wear at the jam we divide: coupling of first and second type.

The coupling of the first type appears during the sliding wear with low speeds of relative displacement and relative pressure which exceed the limit of yield on the point of the contact in the absence of the oil layer and the protection oxidation film. This is the most dangerous and expressive type of elements damages.

The coupling of the second type is the process of unallowable damages of the friction surfaces, which is characterized by the formation of local metal couplings, its deformation and destruction of the particles from the friction surfaces. The intense heating appears during the coupling of the second type, softening and deformation of the surfaces takes place.

Mechanical wear is divided into several types.

<u>Abrasive wear-</u> the wear of the material as the result of cutting or scratching of solid particles, which are the products of wear or other

particles which appear on the friction surfaces.

Abrasive processes can appear in the wide range of external influencing factors. The appearance of mechanical-and-chemical or mechanical form of this type of destruction depends on the relation of mechanical properties of abrasive particles and the skin layers of the wearing metal.

Hydro-and-abrasive wear- is the wear as the result of action of solid bodies or particles which are transferred by a fluid flow.

Gas-and-abrasive wear- is the wear as the result of action of solid bodies or particles which are transferred by a gas or air flow.

Cavitation wear- is the wear of the surface at the relative movement of abrasive particles in the fluid in the condition of cavitation.

Fatigue wear- is the wear of the friction surface or its separate parts as a result of plastic deformation of material of micro volume, which causes the appearance of cracks and removal of details.

The main characteristics and development of fatigue damages is determined by the accumulation of non-reversible phenomenon in the metal structure, which are caused by the metal hardening of the skin layers, the appearance of residual stresses. The destruction of metal at the contact damages from fatigue is characterized by the appearance of micro cracks, the separation of single or group volumes of metal on the friction surface.

Fatigue damage is most distinctive and it often occurs on details of rolling bearings, gear wheels, in pairs of roller-washer and other points of friction others which have contact loads.

Order of the work performance

1. Get some details from the teacher.
2. Determine the type of wear and the cause wear.
3. Make a report.

Report

The report should contain a sketch of the detail, working conditions of the detail, a list of damages and their size, conclusions.

Laboratory work 6

DETERMINATION OF TECHNICAL CONDITION OF THE GAS TURBINE DETAILS

Purpose of the work - to get acquainted with the peculiarities of the process of determination the technical condition of aeronautical engineering (AE) details.

Task

1. Determine the technical condition of details of a separable coupling with by means of technical measuring devices (TMD). The details for determining and TMD are given by the teacher.
2. Fill a card of fault detection (given by the teacher).
3. Determine the method of the detail reconditioning depending on its condition.

Brief theoretical information

Aircraft and aircraft engines are structurally composed of separate units. Modern aircraft units consist of separate parts, which are connected to the nodes, creating separable and non-separable couplings.

All parts of separable couplings have a possibility of mutual movement (sliding or rolling) during the operation of AE wear, changing the size and shape of working surfaces. Wear of the working surfaces of the jointed components ultimately leads to changes in their nominal size (set by the designer). This is reflected in the reduction of the diameter of bolts, axles, rollers and similar details. At the same time the openings in the corresponding parts are enlarged. In addition, during the operation on the working surfaces of the details of separable couplings occur defects: cracks, bullies, scratches, corrosion, thread damage, deformation etc.

Defects on the details of separable couplings are found in the process of determining their technical condition (fault detection). It is performed by external inspection, using technical means of measurement and non-destructive method of testing (NDMT).

Determination of a technical condition (fault detection) is one of the stages of the process.

The purpose of fault detection - is the estimation of the details and components for a further operation and determination the methods and purpose of the defects elimination in the details and nodes.

During fault detection the details are divided into three categories:

- adaptable for further operation without repair (serviceable);
- details to be repaired (renewal);
- details which are not used due to their condition (defect).

Adaptable details without repairing are passed to future assembly of nodes and units; details to be repaired – to the repair station; details, which are not used due to their condition - for disposal.

To estimate adaptability for further use of details, nodes and units (fault detection) are widely used measurements, which determine the compliance of operating parameters that are set by the designer.

Regulating documents for estimating the technical state of aircraft units are special tables of tensions and gaps, albums of joints and repair tolerances and other technical documents which govern when deciding on the adaptability or non-adaptability for further operation. During fault detection the engineers prescribe appropriate technological operations for renewal of the details, determine the causes of the details rejection that went beyond tolerance.

Universal measuring instruments and tools are used widely at AE repairing. By the principle of operation they are divided into several types:

1. Mechanical devices;
2. Optical-and -mechanical;
3. Optical microscopes, projectors;
4. Pneumatic equipment;
5. Electro-mechanical devices;
6. Projectors.

These devices allow to measure linear dimensions of details up to 10 mm. These measurements allow detect some distinguishing defects:

a) nicks, burrs, and other rough surfaces of mechanical damages;

b) cracks, chipping of the material, thread damage, wear, and cold-working on the surfaces of the joint details;

c) warping of the details, changing of the shapes;

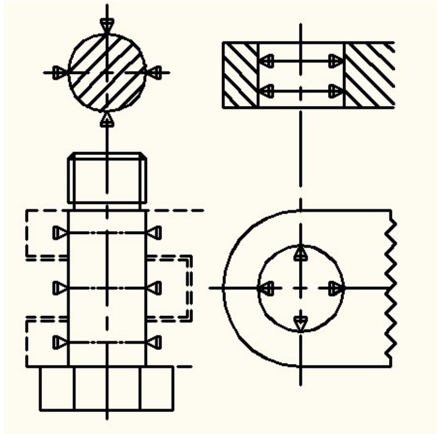
d) corrosion on the details.

The use of technical means of measurements is carried out in order to

verify the geometric dimensions, matching of geometric shapes, details and settings that are set by technical conditions. During the measurements the state of the surfaces is determined. They must be clean and have no scratches, cold working, burrs, corrosion and other damages that could affect the measurement results.

Measurements must be carried out only by serviceable means of technical measurements.

The working surfaces of the details are measured along their length in several sections (at least two) in mutually perpendicular directions with the definition of the maximum and minimum size (Fig.6.1).



a b

Figure 6.1. Chart of measurement of details of a detachable coupling

The card of fault detection and repair of aircraft details or aircraft engines, is made for the detail, which is recommended by the teacher (tab. 6.1).

Table 6.1

Card of fault detection and repair of the detail	Method of detection	Nature of damage or malfunction	Method of elimination
1	2	3	4

When making up tab. 6.1 defects for each separate detail or node is written down. Defects are written down in column 2. A recommended method of determining of a defect is written down in column 3. Elimination - in column 4.

Order of the work performance

1. Determine the size and deviation from the nominal size of the GTU detail.
2. Calculate the deviation from the nominal size of the detail.
3. Make a report.

Report

The report shall contain the sketch of the detail and the chart of the detail measurement, the card of fault detection and repair, calculations of deviation from the nominal size of the details.

Laboratory work 7

METHODS OF RENOVATION OF GAS TURBINE DETAILS AND COMPRESSOR UNITS

Purpose of the work - to develop a technological process of details renovation.

Task

1. Get acquainted with the design of the gas turbine unit details (given by the teacher).
2. Fill in the card of renovation of the GTU details.
3. According to the actual size of the detail determine their "repair size".
4. Determine the technical condition of the details or technical unit by means of technical and optical controls.
5. Make a report on the laboratory work.

Brief theoretical information

Defects of individual parts, nodes, assemblies of AE are divided on 2 types: acceptable and unacceptable. The parts with acceptable defects are subject to renovation of their efficiency. And those that have unacceptable defects - must be rejected.

Renovation of the parts is defined by a corresponding technological

process. Depending on the defect some certain processes of renovation are used.

The most common method of renovation of worn parts is machining of the parts to restore the shape and size of the parts. This method is mostly used in renovation of pairs of separable couplings "shaft-hole." This method restores the shape, size and surface quality of the mating detail.

Depending on the size and geometry of the surface of the wear parts there are two types of renovation. The first type is to provide the details the so-called “repair sizes”. The second includes providing the details of the initial dimensions (nominal), which are set by the designer. In the first case, the parts must be machined (grinding, honing, lapping, polishing). At the same time the working surfaces of the parts receive regular geometric shape and a new size (repair), which is different from the nominal size. Renovation the original dimensions of the parts is performed by applying coatings on the worn surfaces by various methods: electroplated, gas-thermal, electrical and etc. Repair sizes of the parts are obtained by changing the minimum size of the part, which gives the possibility to use it many times. Changing the size of each this part is determined by the so-called "tolerance of repair", which is defined by the designer. For details of the basic separable couplings of AE "Repair tolerance" has a value of Δ = 0,2 - 1 mm. The chart of the received first and second holes of repair size is shown in Figure 7.1.

To increase the overall service life of parts separable couplings at each following repair the metal layer is being removed as little as possible, which is called (allowance for processing (δ_2). The allowance size for processing (δ_2) must take into account the amount of wear and the surface shape (oval, taper, corrosion, etc.). According to Figure 1 the value of the repair tolerance to size of the hole is equal: $\Delta = d_{\max} - d$, where Δ– repair tolerance, $d_{\max}$ Δ–the maximum size of the hole, d– the nominal size of the hole (defined by the designer). The first repair size of the hole:

$d_t = d + 2(\delta_1 + \delta_2)$, where δ_1 the wear, δ_2 allowance for processing. Size $2(\delta_1 + \delta_2)$ called the repair interval, which can determine the number of repairs.

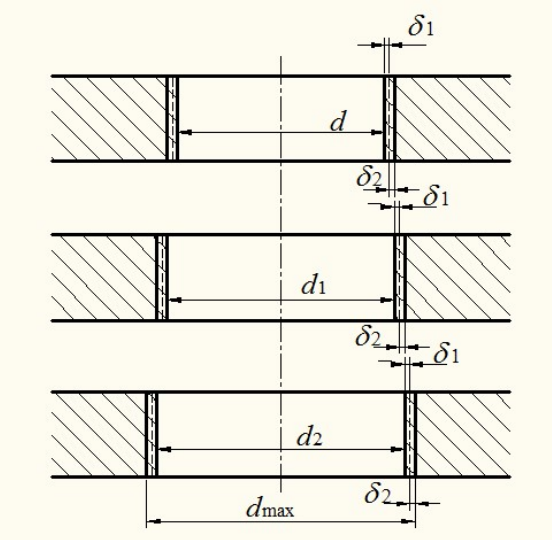


Figure 7.1. Determination the repair size of the parts

Renovation of strength properties of the details in each case has an individual character and depends on the detail condition and objectivity of results of the control. Characteristic methods of elimination and the prevention of defects of the strength is their renovation by welding and polishing, is superficial-plastic deformation, chemical-and-thermic and laser strengthening of the surface, etc. During the operation the physical-and-chemical characteristics of the material of the parts change due to environmental stress, thermal damage from the contact interaction of the joint pairs. Physical-and-mechanical nature of the external factors impact on the performance of the components is complex and requires knowledge of the physical laws of the processes and their consequences. Their deep understanding allows you to properly estimate the extent of the damage, to determine the loss of working capacity and suitability for a further use. A correct estimation of the possibility of a further use of parts, or the necessity of their rejection affects the economic viability and effectiveness of the repair.

Renovation of the surface roughness and quality of the surface layer. On the parts, operating in the air path and which are being subjected to severe shock of abrasive particles, appear defects in the form of thread nicks, scratches, local deepening, which can reduce quality of the

surface. Violation of roughness and changes in the surface layers reduce the strength of the parts. The removal of these defects will restore the surface roughness and the surface layer. This is achieved by removal of the surface layers of a certain thickness in accordance with the requirements to the shape and size of the surfaces.

Renovation of protective coatings. For protection of the parts from corrosion some special metals, plastics, paints and oxidizing coatings are put. In the process of operation they are gradually destroyed, and it results in corrosion. The coating renovation is performed by applying various means: chemical, etching, electrochemical methods, as well as applying protective coatings.

Renovation by cut processing. The processing is carried out manually (bench-work) or the metal-cutting (grinding, polishing) machines (mechanical processing).

Renovation by metal coating. When the parts repair is mainly used electroplating, gas-thermal and electrical methods that provide the renovation of sizes of the worn surfaces, corrosion and decorative coatings. To restore the size of the worn surfaces of steel parts chromium and copper plating are widely used which prevent adhesion of the surfaces in contact. To protect the parts from corrosion cadmium plating and galvanizing are used. Thermal spray coating methods (flame, plasma, detonation, electric, induction) are also used. The advantage of these methods in comparison with electrical is that they allow to vary widely the coating composition, its thickness and physical and mechanical properties.

Renovation of sizes and shapes by plastic working. When repairing the engine system is used cold straightening of thin-walled components and structures (in particular the exhaust pipe). During flattening the strengthening of the metal takes place by applying and work hardening. Residual stresses occur. So flattening can be used on only those parts that do not carry large variable loads and are therefore not subjected to fatigue cracks. There are two kinds of flattening: static bending and blows.

Renovation by welding. This process is used mainly for restoration of working capacity of welded seams in which cracks from the action of variable loads were formed. For example, welding of welded seams of the combustion chamber can serve. One of types of restoration by welding is restoration by build-up welding. Build-up welding is used for restoration of the sizes and the shapes of surfaces. Build-up welding can be performed with use of gas-flame, arc, plasma and laser methods of metal heat.

Renovation of non-metallic coatings. The parts surfaces made of aluminum and magnesium alloys are subjected to anodising (oxidation) in order to protect against corrosion. After oxidation of some of these parts to improve corrosion protection are coated with paint coatings. In case if these coatings are destroyed they should be restored in accordance with the assigned technology.

Order of the work performance

1. Get acquainted with the description of the laboratory work.
2. Fill a sheet of the GTU detail renovation according to the actual size of the details and to define their "repair size".
3. Make up the report on the laboratory work.

Report

The report should contain the sketch of the detail, a sheet of fault detection, calculations of the repair size, conclusions.

Laboratory work 8

REPAIR OF THREADED COUPLINGS AND REPLACING THE STUD

Purpose of the work - learn the technology of the stud replacement at aeronautical engineering repairing.

Task

1. Perform the studs fault detection.
2. Remove the rejected stud.
3. Choose a new stud.
4. Prepare the hole for the stud that is being replaced.

Brief theoretical information

Stud is a core which has thread on both sides. One side of the stud is

screwed into the body of the main detail, and on the second side a screw is put. Both sides of the stud have the same diameter but with a different thread pitch.

A larger thread pitch is on the side which is screwed into the part. This is due to the fact that most aircraft parts are made of aluminum alloy and the use of fine threads in this case does not provide the necessary strength and density of setting. The need to replace the studs often occurs at the maintenance and repair.

Fault detection. Wear and nicks of the thread studs are detected visually or using technical measuring devices (TMD). The bend and drawing-out of studs are detected using the calibrating device. Weak setting of a stud can be effectively detected by the impedance acoustic control. Rejected studs must be replaced.

Removal of the studs. When you delete a stud there are two possible cases: when the stud is projected above the surface and when it is not projected. In each case, the rejected studs are removed by one of the following methods.

1. Screwing out the stud by two nuts. The nut is wound on the stud, the lock nut, and then by means of the nut wrench, the stud is turned out.
2. Screwing out the stud by notching the sides. The stud is notched with the file and turned out with a wrench. If the use of two sides is uncomfortable, then four sides are notched on the stud.
3. Screwing out the stud by "stud driver" (fig. 8.1). On the deleted stud “stud driver" is fixed using the screw in the end of the stud. Using the wrench corresponding to the size, the "stud driver" is turned out together with the stud.

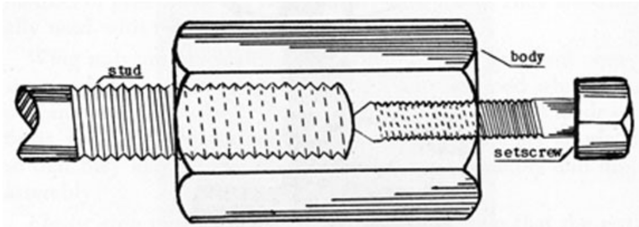


Figure 8.1. Stud driver

4. Screwing out the stud by “eccentric” (fig. 8.2). This method is carried out for the studs with diameters from 6 mm to 12 mm. The eccentric consists of a body, a washer and a head. In the body three holes are drilled for studs of different diameters with the corresponding

size. The washer on the outer surface has a notch and it is hardened. The head is mounted eccentrically relative to the washer, whereby upon the head rotation, the washer cuts into the stud by its notch and clamps it. A special wrench is mounted on the stud. Then the extractor is put into the hole. This extractor has one side with a ribbed conical surface. By rotating the wrench to the left, by friction between the ribbed surface of the extractor and the threaded stud is clamped and turned inside out.

Figure 8.1. Eccentric

5. Screwing out the stud with a clamp device used in easily accessible places. The stud is screwed on the defective device in the head of which a hole is drilled. The hole has a corresponding diameter of thread. The opening in the head of the device allows to create a lot of friction between the head of the device, where the threads and pins, which ensures the stud screwing out.

The studs which are not projected on the detail surface from which it should be removed, using the following methods:

1. Screwing out the stud by the cutting tap with left thread. In this case the cutting tap is screwed into the drilled hole of the stud at 0,5 length of the threaded part of the stud. The stud is screwed out. The cutting tap is made of hard steel and somehow flattened thread that provides high density at screwing.

2. Screwing out the stud with a bolt. Instead of special cutting tap a bolt with left thread is used. For this it is necessary to drill a hole in the stud of 2-3 mm smaller than the diameter of the stud of 0.5 the length of its threaded parts, so as not to damage the thread of the detail by the drill. Then the thread is cut on the stud, completely the bolt with a particular diameter is completely turned out, and continuing to rotate in the same direction a piece of the stud is turned out. The method is rarely used instead of the cutting tap or extractor.

3. Screwing out the stud by a square side of the special wrench. In the broken part of the stud a hole is drilled with the diameter of 2-3 mm smaller of the inner diameter of the thread. Then the square side of the wrench is nailed in the hole and the stud is screwed out, turning the wrench to the left.

4. Removal of the broken studs using the extractor is performed similar to the screwing the stud with a cutting tap with left thread. In the broken part of the stud a hole is drilled with the corresponding diameter and the extractor is put into it. The extractor has a conical left thread and by turning the wrench to the left, the stud is turned out. Size of the extractor must be less than the inner diameter of the stud thread.

5. Removal of the broken stud by etching with nitric acid. This method is applied when the above-mentioned methods are impossible.

A broken part of the stud in the body of the part is removed by etching with an aqueous solution of nitric acid, which dissolves the steel and does not dissolve aluminum alloys.

Note. To determine the concentration of nitric acid in the porcelain cup put a piece of a broken stud (or similar metal) and pour concentrated nitric acid, in which then pour the water. The moment of the start of the metal active dissolution will point to the desired concentration of the solution.

The composition of the solution: chemically pure nitric acid 70-80%, water 20-30%.

Removal of a broken stud is performed in the following order. A hole is drilled in the stud with the diameter of 2-3 mm smaller than the inner diameter of the thread of the stud. To prevent spreading acid and destroying the parts of acid erosion the place around the stud is smeared with technical vaseline.

The prepared solution of nitric acid is taken by a rubber pipette and is filled into the drilled hole of the stud. The eroded products of the stud are removed by a pipette and then the hole is again filled with water and this process is repeated several times for complete removal of the stud. To accelerate the process of etching the studs the solution can be warmed to the temperature of 50-60 C and even up to 70-80 C.

After the process is finished, place of etching must be washed with water several times. Each wound of the thread is checked with the scraper to make sure that there are no un-dissolved residual parts of the stud and then the hole must be calibrated with the cutting tap.

It is not allowed to use nitric acid for etching the parts, made of magnesium alloys.

When the etching process is finished and there is no stud in the body parts, the detail must again be thoroughly rinsed with water, because weak solution of nitric acid can cause corrosion of aluminum alloy and damage other parts.

6. Removal the stud with electro-machining method is performed in the following technological sequence. A hole in the broken stud is cut by the electrode. This hole is in the form of a narrow slot, and then the stud is turned out with the screw-driver. Sometimes the electrode with square section is used to remove the stud which makes cavities in the side of the broken stud, and then square wrench turns out the stud.

If the mentioned methods cannot remove the stud, then its body is perforated with a cylindrical electrode with the diameter smaller than the inner diameter of the stud thread. Then the stud remains are removed by the acute scraper, the hole is blown with compressed air, the diameter of the thread is calibrated with the cutting tap.

Selection of new studs. Selection of the stud is performed at the largest average diameter. Studs are made of predetermined size with average diameters of the thread. A tight fitting of a normal stud of the first group is reached by establishing a stud of the second group, which bigger than the average thread diameter for 0.08 mm. Further, instead of the stud of the second group one takes a stud of the third group, which is bigger than the average diameter for 0.18 mm. Instead of the third group – the stud of the fourth group, which is bigger than the average diameter for 0.8 mm. Groups of studs are labeled with corresponding symbols to its side.

A correctly chosen stud according to tension should be wound into the hole manually in no more than 2-3 turns.

If the average diameter of the stud is unknown one should measure it with the threaded micrometer, or the tool microscope. Measurement of the average diameter on the microscope is performed by clamping the stud 1 in centers 2, setting it parallel to the longitudinal path of the microscope stage. Bending column 3 at the angle equal to the angle of ascent of the stud thread, one of solid lines of the cross hatch is combined with the image of the side thread profile of the detail and if necessary acting with transversal and longitudinal micro-screws. Noting the first count by the cross screw, the cross hatch is moved to the appearance of diametrically opposite parallel side of the thread profile.

Bending the column at the same angle, but in the opposite direction, the dotted line of the cross hatch is again combined mesh with the thread profile and another thread count is performed.

Difference in counts gives the value of the average diameter of the thread, measured on one side of the profile. After that, the second side of the profile of the thread is combined with the dotted line and the measurement is repeated.

The actual value of the average diameter of the thread for this stud is the arithmetic average for the results of measurements on the right and left sides of the profile.

Preparing the thread in the hole of the detail is performed with a calibrating tap with the diameter of 0,02-0,03mm less than the average diameter of the selected stud. To do this the calibrating tap makes hole in the detail, removing any possible damages of the detail thread.

Note. When the thread is damaged, a new one is cut for 2mm in diameter larger than the outer diameter of the stud thread and a stud of the matching average diameter is set.

Mounting of new studs. It is performed with the device "stud driver", previously the stud thread is oiled with transformer oil.

Quality control of the stud mounting is made by means of measuring devices and non-destructive testing. At this process density of mounting, the height of the projected part of the stud, the stud diameter and the thread condition is checked.

It is strictly forbidden to screw out studs to get it desired height. In this case it is necessary to replace the stud.

Order of the work performance

1. Read the description of the laboratory work.
2. Make fault detection of the studs and remove the rejected stud.
3. Select a new stud.
4. Prepare a hole for the stud that is replaced.
5. Make a report on the laboratory work.

Report

The report shall contain brief theoretical information on the studs, calculations for the stud under repair, conclusions.

REFERENCES

1. *Богуслаев В. А.* Технология производства авиационных двигателей: учеб. В.А.Богуслаев, А.Я.Качан, А.И.Долгматов, В.Ф.Мозговой, Е.Я.Корневский. – Запорожье : Мотор Сич, 2005. – 557 с.
2. *Елисеев Ю.С.* Технология производства авиационных газотурбинных двигателей: учеб. Ю.С.Елисеев, А.Г.Бойцов, В.В.Крымов, Л.А.Хворостун – М : Машиностроение, 2003. – 512 с.
3. *Белошапка Н. И.* Производство летательных аппаратов и авиационных двигателей: лабораторные работы. Н. И. Белошапка, Ю.И Луговец.– Киев: КИИГА, 1988. – 60 с.
4. *Сулима А. М.* Основы технологии производства газотурбинных двигателей: учеб. А.М.Сулима, А.А.Носков, Г.З.Серебренников. – М : Машиностроение, 1996. – 480 с.
5. *Богуслаев В. А.* Основы технологии машиностроения: учеб. В.А.Богуслаев, В.И. Цыпак, В.К.Яценко. − Запорожье : Мотор Сич, 2003. – 336 с.
6. *Кудрін А. П.* Ремонт повітряних суден і авіаційних двигунів: підруч. А.П.Кудрін, Г.М.Зайвенко, Г.А.Волосович, В.Д.Хижко – К. : НАУ, 2002. – 492 с.

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