Ministry of Education and Science of Ukraine
Ternopil Ivan Puluj National Technical University
(full name of higher education institution)
Faculty of Engineering of Machines, Structures and Technologies
(faculty name)
Engineering Technology
(full name of department)

QUALIFYING PAPER

For the degree of

master
(educational level)

topic: Development of the body structure 0520F3-35.00.000 production process and the study of drilling strength characteristics

Submitted by: fourth year student group IMTм-63
Specialism (field of study)
131 Applied mechanics
(code and name of specialism (field of study))

Hussein Omar Ashraf Abdelbaki Salem
(signature) (surname and initials)

Supervisor Pankiv V.R.
(signature) (surname and initials)

Head of Department Okipniy I.B.
(signature (surname and initials)

Standards verified by Dyachun A. Y.
(signature) (surname and initials)

Referee Pulupets O.M
(signature) (surname and initials)

Ternopil
2021

Ministry of Education and Science of Ukraine
Ternopil Ivan Puluj National Technical University
(full name of higher education institution)

Faculty Faculty of Engineering of Machines, Structures and Technologies

Department Engineering Technology
Educational degree master
Field of study
(code and title)
Specialism 131 Applied mechanics
(code and title)

APPROVED BY
Head of Department Okipniy I.B

ASSIGNMENT

for QUALIFYING PAPER

Hussein Omar Ashraf Abdelbaki Salem
(surname, name, patronymic)

1. Project (thesis) theme. Development of the body structure 0520F3-35.00.000 production process and the study of drilling strength characteristics

Project (thesis) supervisor PhD Pankiv V.R.
(**surname, name, patronymic**, scientific degree, academic rank)

1.Approved by university order as of 26.03. 2021 року № 4/7-222
2. Student's project (thesis) submission deadline
3. Project (thesis) design basis 1. Basic TP manufacturing parts. 2. The program is 10000 pieces/ year. 3. Drawing the body parts.

4. Contents of engineering analysis (list of issues to be developed)
1. Analytical part, 2 Research part 3.Technological part.4.Designing part.
5.Safety measures. 6.Drawing.

5. List of graphic material (with exact number of required drawings, slides)
Technological cards adjustments, assembly drawings of devices, drawing of the control device, schemes to the scientific part

6. Advisors of design (thesis) chapters

Chapter	Advisor's surname, initials and position	Signature, date	
		assignment was given by	assignment was received by
Safety measures	*Baranovsky V. PhD. Prof*		
	Klepchik V.		

7. Date of receiving the assignment *29 March 2021*

PROJECT TIME SCHEDULE

LN	Diploma project (thesis) stages	Project (thesis) stages deadlines	Notes
1	*Analytical part,*	1.04.2021	
2	*Research part*	15.04.2021	
2	*Technological part*	1.05. 2021	
3	*Designing part*	15.05.2021	
6	*Safety measures*	1.06.2021	
7	*Drawings*	15.06.2021	

Student ______________ Hussein Omar Ashraf Abdelbaki Salem
(signature) (surname and initials)

Project (thesis) supervisor ______________ Pankiv V.R.
(signature) (surname and initials)

ABSTRACT

Actuality of theme. Drilling is the most common method of obtaining holes in a solid material. Drilling produces through and non-through (deaf) holes and process previously obtained holes in order to increase their size, increase accuracy and reduce surface roughness.

Drilling is carried out by combining the rotational movement of the tool around the axis - the main cutting movement and its translational movement along the axis - the feed movement. Both movements on the drilling machine inform the tool.

The cutting process during drilling takes place in more difficult conditions than during turning. In the process of cutting it is difficult to drain the chips and supply coolant to the cutting edges of the tool. When removing the chips is rubbing it against the surface of the grooves of the drill and the drill against the surface of the hole. As a result, the deformation of chips and heat increase. The increase in chip deformation is influenced by the change in the speed of the main cutting motion along the cutting edge from the maximum value at the periphery of the drill to zero value in the center.

The purpose of the study is to improve the manufacturing process of the the case 0520Ф3-35.00.000 with the study of the power characteristics of the drilling process

The object of study - the technological process of manufacturing the case 0520Ф3-35.00.000.

The subject of research - technological parameters of the drilling process.

Research methods. The work was performed using modern provisions of mechanical engineering technology, as well as new technological equipment.

Scientific novelty: The optimal modes of drilling process for this part are determined, cutting modes, time norms and operational machining are determined for the new TP, the existing ones are modernized and new technological equipment is designed.

Practical significance. The technology of manufacturing of the case 0520Ф3-35.00.000 with research of power characteristics of process of drilling is developed and economically substantiated

Approbation of the results of the master's qualification work. Material of the IV International student scientific and technical conference NATURAL AND HUMANITIES. CURRENT ISSUES April 28-29, 2021р.

The structure and scope of the master's qualification work. The work consists of an introduction, four sections, a list of used sources and appendices. The full volume of the master's qualification work is 79 pages, including 24 figures, 11 tables, bibliographies from 20 sources to two pages.

CONTENT

INTRODUCTION

Production efficiency, its technological progress, quality of manufactured products depend to a large extent on the advance development of the production of new equipment, machines, machines and apparatus, on the broadest implementation of technical and economic analysis methods, which ensures the solution of technical problems and the economic efficiency of technological and design developments.

The importance of answering all these questions in the training of skilled personnel of production specialists who have fully mastered the engineering methods of designing production processes is obvious. And the diploma work consolidates, deepens and generalizes the knowledge gained by the student during the lectures and practical classes in the course "Mechanical Engineering". In the course of the diploma design the student performs a complex task of analyzing the design of the part, its manufacturability, the design of the technological process of its manufacture, the choice of technological equipment for its manufacture, the calculation of the economic efficiency of the decisions made. Life safety issues are also addressed. All this is in preparation for the duties of a production engineer.

In diploma design, special attention is paid to the independent work of the graduate to develop his initiative in solving technical and organizational problems, as well as a detailed and creative analysis of existing technological processes. The main task is to make proposals for the improvement of existing technology, equipment, organization and economy of production, which are significantly ahead of the modern production process of manufacturing parts for which the task was issued.

Therefore, it is necessary to study the progressive directions of the development of technological methods and tools, and on the basis of the analysis and establishment of qualitative indicators to give their suggestions and recommendations for the optimum process of manufacturing this part. Considerable attention should be paid to the economic feasibility of blanks, the choice of process options in order to be offered and used the best option.

ANALYTICAL PART

1.1. Analysis of the state of the issue according to literary and other sources. Relevance of the topic of work

Modern directions of drilling intensification are associated with new research of the technological process, including the development of new special designs of drills from high-speed and carbide materials; expansion of the size range of small and large diameters with different lengths of the working part and angles of inclination of the helical grooves ω = 28, 29, 31, 45, 600; special forms of sharpening of the cutting part of drills with concave, convex and wavy cutting blades; development of tools with various types of wear-resistant coatings; the supply of coolant under high pressure and its increased consumption through the working part of the drill directly into the cutting zone, etc. However, the technical literature and catalogs do not sufficiently highlight the problems associated directly with cutting processes during drilling; optimization of the cutting part, rigidity characteristics of drills and oscillatory processes accompanying drilling with tools with long working part lengths; the accuracy of the holes obtained and the quality of the surfaces obtained.

Groups of general principles (1-4) are chip crushing in the cutting area (1); providing low-frequency (300 ... 350) Hz oscillations of the cutting blades (2); screw removal of chips from the cutting zone (3); selection of criteria for optimizing the cutting process when drilling (4). General principles 1 and 2 include the principles of designing special twist drills (5), realizing the possibility of dividing the working part of the drill into cutting and transporting (6) with subsequent optimization of the shape and parameters of the cutting part of the drill (7), optimization of the transporting part (volumes, profiles, angles slope of helical grooves), coolant supply

(8), introduction of structural elements or equipment to ensure oscillation of cutting blades with a given frequency (9).

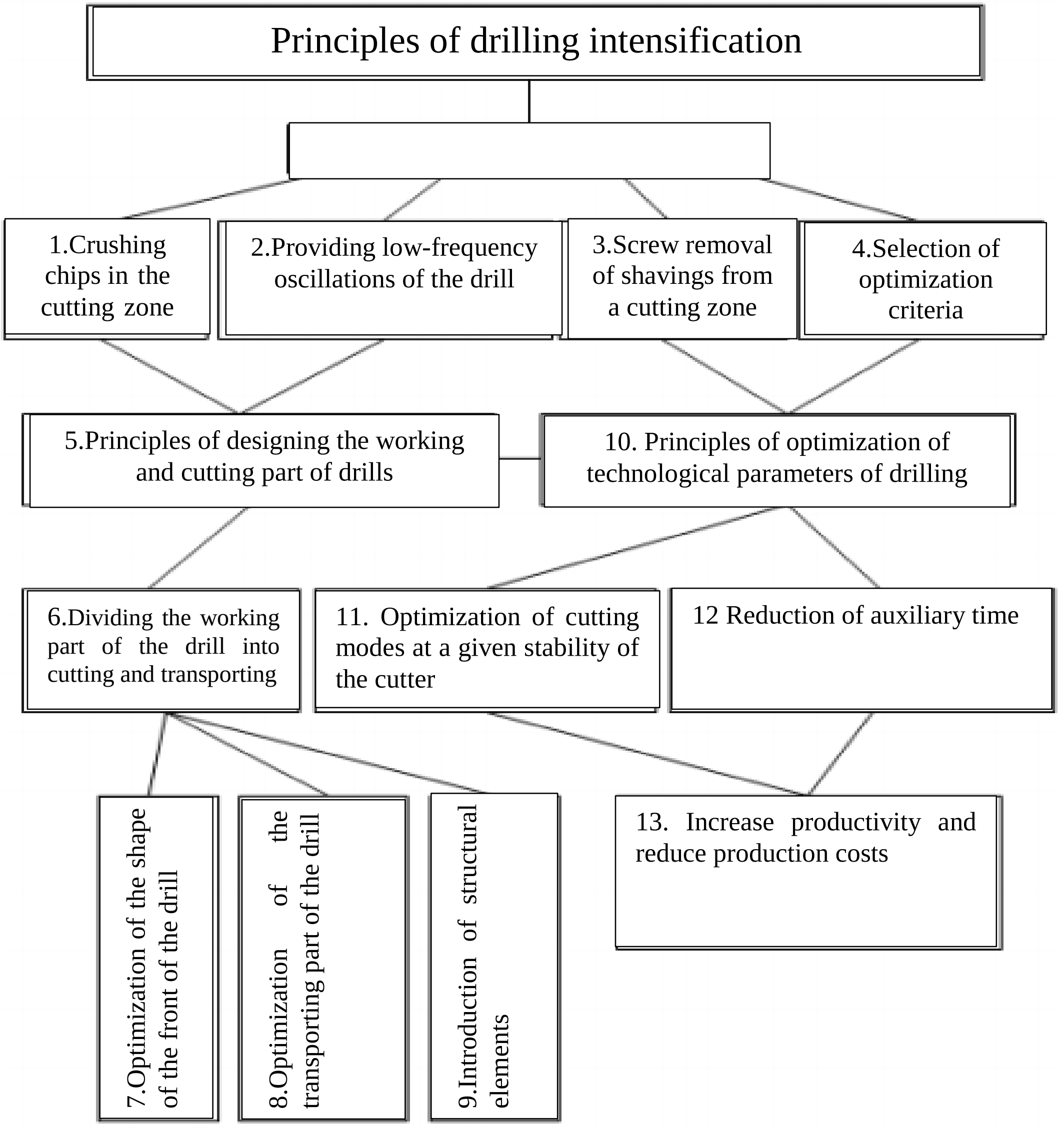
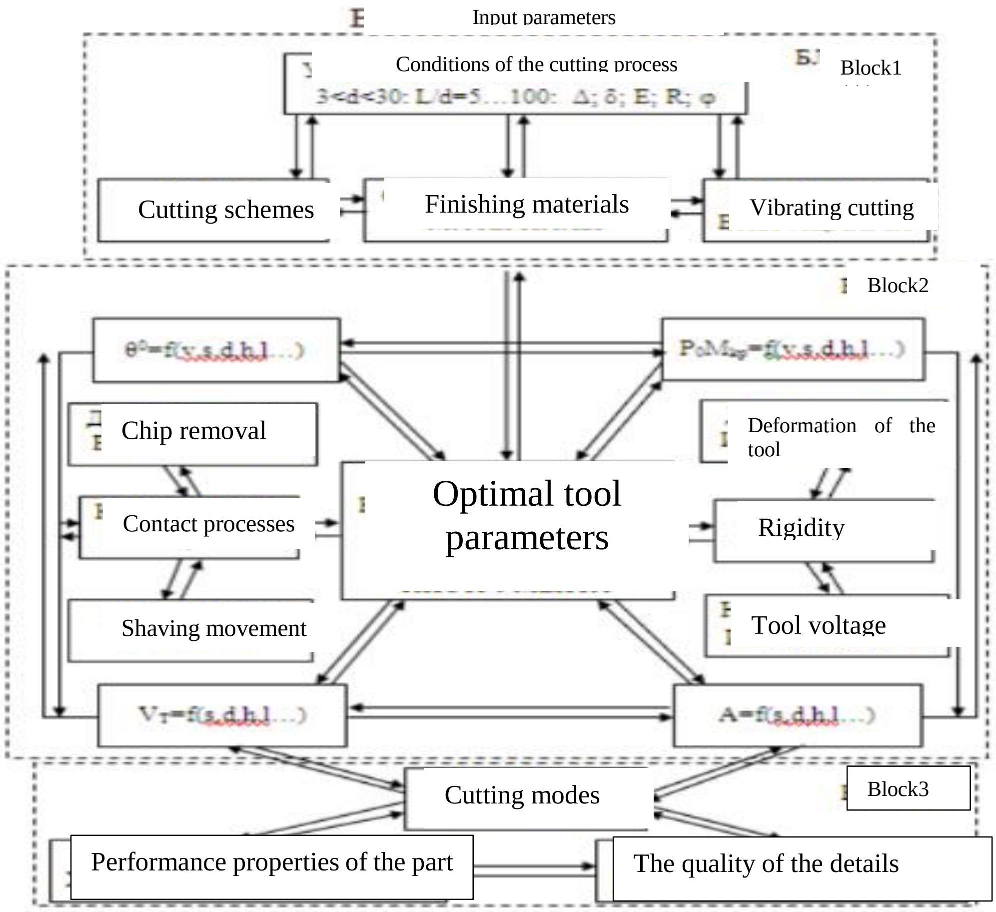


Figure 1.1 - Principles of intensification of the drilling process

General principles 3 and 4 include the principles of optimization of technological parameters of the drilling process (10), optimization of cutting conditions for a given durability and precision parameters of processing (11), reduction of auxiliary times due to stable removal of crushed chips (12). Ultimately, the implementation of these principles makes it possible to increase productivity and reduce the cost of drilling deep holes in plastic materials. In the works of N.N. Zorev, G.I. Granovsky, M.I. Klushina, V.N. Poduraeva, V.F. Bobrova, E.G. Konovalova, A.M. Guskova, S.A. Voronova, H. Paris, G. Moraru and others reflect different approaches to the description, analysis of systems, models and cutting schemes [1-3]. Professor NN Zorev, for example, developed a scheme of interaction of the main factors accompanying the process of rectangular free cutting, in which the following assumptions were made: a) shear deformations are concentrated along the conditional shear plane; b) the cutting process is carried out without build-up; c) some minor factors accompanying the cutting process are omitted. Professor G.I. Granovsky proposed kinematic cutting schemes, which not only reflect various methods of metal cutting, but also make it possible to develop new processes of mechanical processing by V.N. Poduraev developed general structural schemes of processing with primary parameters set by designers and secondary ones that determine the results of processing.

In the future, the principles of combining kinematic schemes were used as the basis for the development of new metalworking methods. Typical mathematical models and algorithms for calculating optimal modes for single-tool cutting of materials are known. Structural diagrams, systems and models of the cutting process describe the variety of connections between individual elements. These connections can complement or weaken each other, the connection itself can be indirect or direct. The cutting process is accompanied by elastic and plastic deformations of the processed material, destruction in the cutting zone, friction in the contact zones of the tool with the workpiece and chips, thermal processes, adhesion, abrasive, diffusion and other types of interaction between the tool and the processed material. A variant of the cutting system for drilling is shown in Fig. 1.2. A feature of deep drilling processes is that in order to exclude periodic withdrawal of the drill from the hole to remove chips, it is necessary first of all to ensure its crushing in the cutting zone. For auger-type drills, the principles of intensifying the process of deep hole drilling in steels at $l / d \leq 40$ include: dividing the working part of the tool into a cutting and transporting part, a combination of trapezoidal sharpening of the cutting part of a drill for crushing chips with low-frequency oscillations of the cutting edges along a helical line, stable crushing and chip evacuation from the cutting zone due



to the design of the helical grooves of the drill with an angle $\omega \geq 600$.

Figure 2.1 - Diagram of the optimization of the deep hole drilling process.

Output parameters: d-drill diameter; L is the depth of the hole; Δ-offset of the hole axis; δ-hole breakout; E-errors in the shape of the hole in the longitudinal section; R-roughness of the hole surface; Qproductivity; θ-cutting temperature; v-cutting speed; s-feed; h-tool wear; l drill out; A-precision parameters of the hole.

1.2. Methods of solving the problem

An unbalanced radial cutting force is one of the factors that determine hole accuracy when drilling. ΔP_y . It is believed that with perfect sharpening of the drill, the radial cutting forces Py, acting on each of the tool teeth are equal to each other and counterbalance each other.

In real practice, an unbalanced radial cutting force occurs due to asymmetric sharpening of the drill. ΔP_y , causing bending of the tool and leading to additional errors in the longitudinal section of the holes being machined. Currently, there is no generally accepted method for determining strength ΔP_y . The paper attempts to show that this force depends not only on the hardness of the material being processed (which is widely known), but also on the design parameters of the cutting tool and the accepted processing modes.

Analysis of the forces arising during cutting shows that the radial cutting force Py can be determined from Fig. 3.1 dependency [1]:

Analysis of the forces arising during cutting shows that the radial cutting force Py can be determined from Fig. 1 addiction [1]:

$$P_y = P_N \cos(\varphi \pm \Delta) \text{ ,} \tag{1.1}$$

where P_N - the component of the cutting force directed along the normal to the cutting edge of the tool; φ – main angle, Δ – chip deflection angle. Take: plus sign for negative angle φ , and a minus sign for a positive angle φ .

Dependence (1) for determining the radial force does not take into account changes in the geometric parameters of the tool along the cutting edge, which is typical for a drill.

The force P_N is one of the components of the force Pz and can be calculated [1, 2] by the expression

$$P_N = P_Z tg(45^0 - \theta) \text{ ,} \tag{1.2}$$

where Pz – force acting in the direction of the main movement; θ – cleavage angle. When processing plastic materials, you can take in calculations

$$\theta = 25^0 + y_n \text{ ,} \tag{1.3}$$

where y_n – the front angle in the normal secant plane.

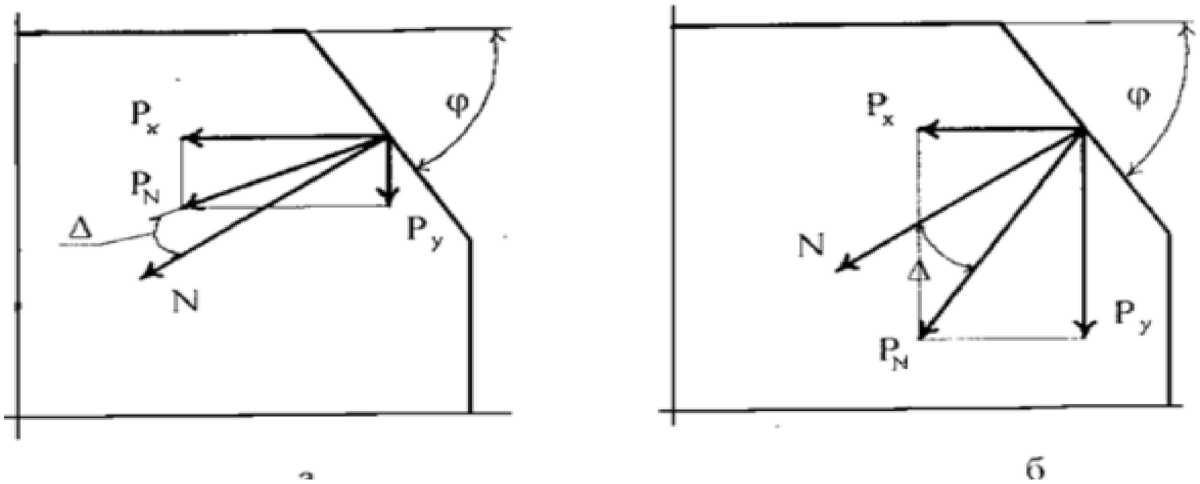


Figure 1.3 – К definition of strength *Py*: a – negative angle Δ ; б – negative angle Δ .

Force *Pz* can be determined from the expression

$$P_z = 0.9\sigma_B S_z t(1 + ctg\theta) \ , \qquad (1.4)$$

where σ_B – tensile strength of the processed material; Sz - feed per tooth of the drill; t - cutting depth.

The depth of cut when drilling [3] is taken equal to the radius of the machined surface: t=0,5D, where *D* – drilling diameter.

Consider the definition of the chip deflection angle φ , which is one of the parameters in determining the radial component of the cutting force *Py*. With a non-free cut and an angle of inclination of the main cutting edge$\lambda \neq 0_v$

$$P_z = 0.9\sigma_B S_z t(1 + ctg\theta) \ , \qquad (1.5)$$

where$\Delta^{\cdot}$ – auxiliary design angle, the value of which is determined by the dependency

$$\Delta^{\cdot} = arctg \frac{S_z sin^2\varphi}{t + S_z sin^2\varphi \cdot ctg(\varphi + \varphi_1)} \ , \qquad (1.6)$$

where φ_1 - auxiliary angle in the plan; when drilling: $\varphi_1 = 0$.

It is known that some parameters characterizing the cutting process are variable depending on the position of an arbitrary point A of the cutting edge of the drill, in which they are measured. Angle size μ determined by dependency

$$sin\mu = r_c/r_x \ , \tag{1.7}$$

where r_c and r_x – respectively, the radius of the core of the drill and the current radius of an arbitrary point of the cutting edge. ω – the angle of inclination of the chip groove.

Calculated dependences of geometric parameters required for subsequent analysis λ ,φ and γ_N determined on the basis of these works [4, 5].

The angle of inclination of the main cutting edge:

$$sin\lambda = [(r_c/r)sin\varphi^{\cdot}]/(r_x/r) \ , \tag{1.8}$$

where $\varphi^{\cdot}$ – drill tip angle.

angles φ and $\varphi^{\cdot}$ related by the relationship:

$$tg\varphi = tg\varphi^{\cdot}\sqrt{1-\left(\frac{r_c/r}{r_x/r}\right)^2} \text{ ; or } tg\varphi = tg\varphi^{\cdot}\sqrt{1-\left(\frac{r_c}{r_x}\right)^2} \ , \tag{1.9}$$

The front angle in the normal secant plane (Fig. 2) is determined from the expression

$$\gamma_N = \gamma_2 - \gamma_3 \ , \tag{1.10}$$

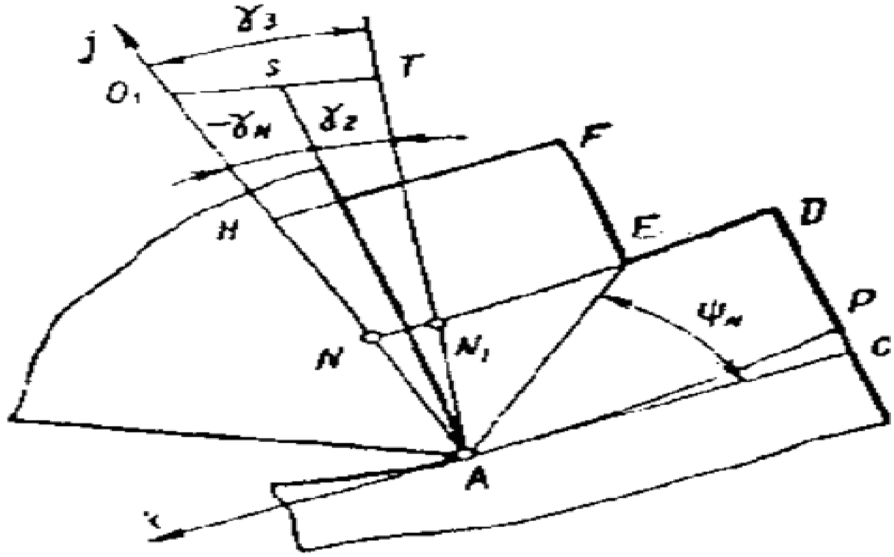
where are the angles γ_2 and γ_3 determined on the basis of some other design parameters of the drill. Angle expression γ_2 depends on the type of the front surface of the drill.

Thus, using the above dependencies, it is possible to determine the radial component of the cutting force Py. With strictly symmetrical sharpening of the drill, these components of the cutting force act among themselves. However, in the practical manufacture of drills, a certain amount of axial runout of the cutting edges of the tool is allowed [6], which leads to the emergence of an unbalanced radial component of the cutting force Py.

One of the parameters affecting the magnitude of the force Pz, and hence the force Py, is the feed to the tooth of the drill Sz, defined as

$$s_z = \alpha/sin\varphi \ , \quad (1.11)$$

Asymmetrical drill sharpening leads to a change in $\Delta\alpha$ the thickness of the cut layer, and, consequently, to a change in *Sz*: feed per tooth of the drill. As a result, vibrations occur ΔPz– tangential component of the cutting force, which ultimately leads to the appearance of an unbalanced radial component of the cutting forceΔPy . Let's find an analytical relationship to determine this component of the cutting force.



To do this, we will use some of the above dependencies, namely, expressions for determining those parameters of the cutting process that change in the presence of asymmetric sharpening of the drill.

Figure 1.4 - Cutting elements in the normal secant plane

Calculations show that the fluctuations of the unbalanced force ΔPy are commensurate with the absolute value Py of the radial component of the cutting force, and sometimes may exceed this force. This significantly affects the position of the tool axis and, consequently, the error of the machined holes.

1.3 Conclusions and setting tasks for qualifying work

The work thesis presents the task to develop the technological process of manufacturing the "Hull", to analyze the possibilities of using multioperational machines, to introduce a more productive way of obtaining the workpiece, to choose the devices that increase the productivity of manufacturing parts.

The task is to develop the technological process of manufacturing parts, to analyze the possibilities of using multi-operational machines, to introduce a more productive way to obtain the workpiece, to choose devices that increase the productivity of parts, to investigate the power characteristics of drilling and reaming and to determine experimental dependences of axial force and torque. parameters of cutting modes, design a production shop

2. RESEARCH PART

2.1. Characteristics of the object or subject of research

Drilling is a common method of making holes in solid material. Through drilling, through and blind holes are obtained and the previously obtained holes are processed in order to increase their dimensions, increase accuracy and reduce surface roughness.

Drilling is carried out with a combination of the rotary movement of the tool around the axis - the main movement and its translational movement along the axis - the movement of the feed. Both movements on the drill press impart to the tool.

The cutting process when drilling takes place in more difficult conditions than when turning. During the cutting process, it is difficult to evacuate chips and supply coolant to the cutting blades of the tool. When the chips are removed, they rub against the surface of the grooves of the drill and drill against the surface of the hole. This results in increased chip deformation and heat generation. The increase in chip deformation is affected by the change in cutting speed along the cutting blade from the maximum value at the periphery of the drill to zero value at the center.

Drilling is a type of machining of materials by cutting, in which, using a special rotating cutting tool (drill), holes of various diameters and depths, or polyhedral holes of various sections and depths are obtained.

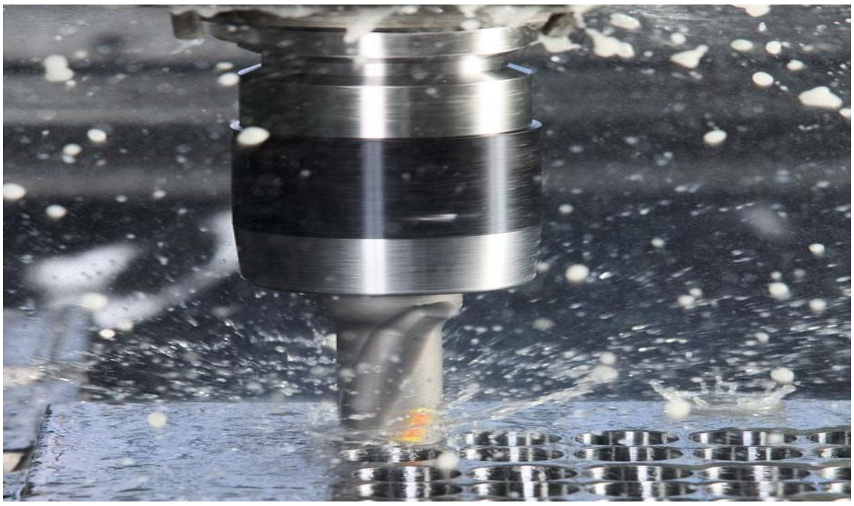


Figure 2.1 - Technological process of drilling

When machining a hole, the drill is inside the workpiece, which makes it impossible to observe the cutting process. Chip control is very important. Unobstructed chip evacuation is important for hole quality, tool life and repeatability.

Drilling depth (l_4) determines the choice of tool by length. For example: max. depth $l_4 = 5 x D_c$

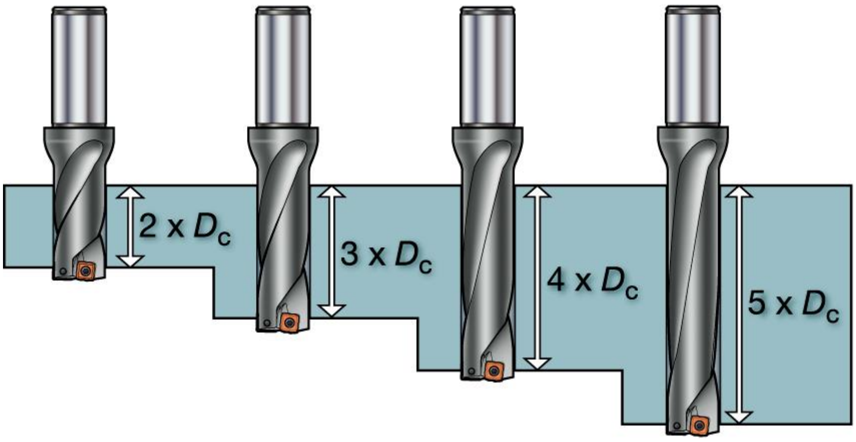


Figure 2.2 - Determination of drilling depth

When analyzing equipment, it is necessary to take into account:

- Rigidity of the machine;
- Rotation frequency;
- Coolant supply;
- Coolant pressure;
- Clamping the workpiece;
- Horizontal or vertical spindle;
- Power and moment;
- Tool store.

Different ways to get a hole:

1. Drilling and boring. Advantages - Simple standard tool, relatively flexible. Disadvantages - two tools, adapter and basic equipment, two tool positions are required.

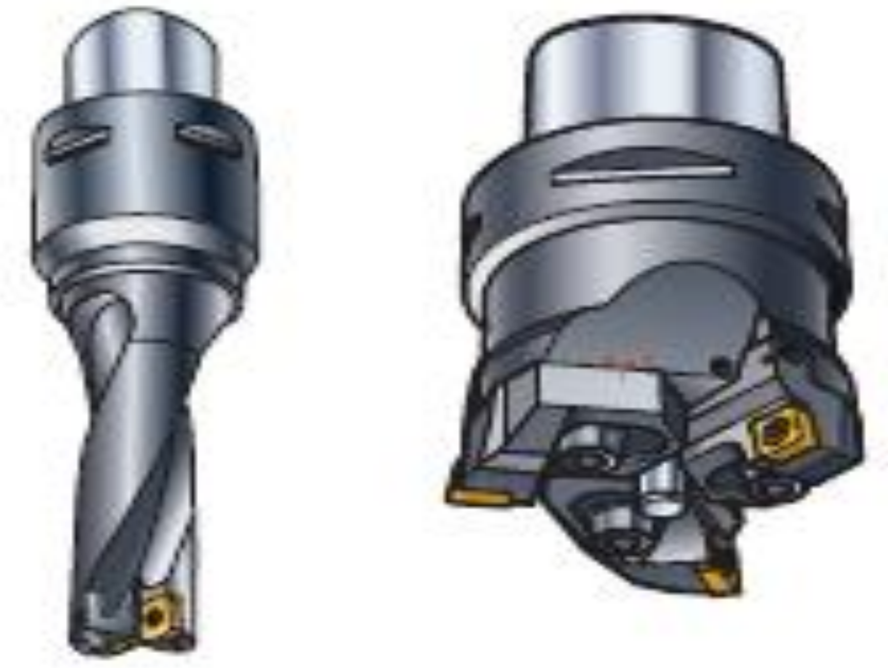
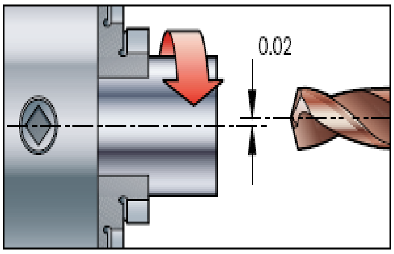
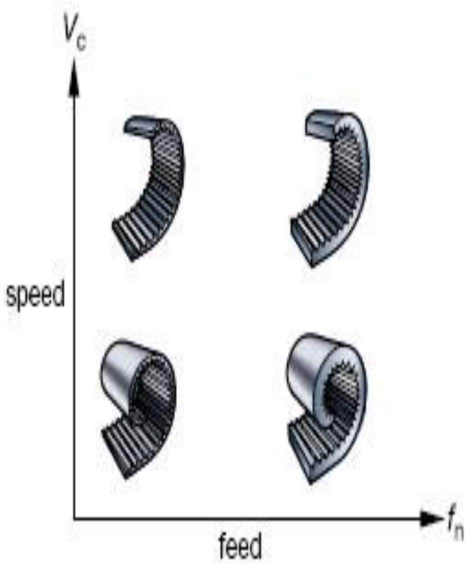


Figure 2.3 - Tools for drilling and boring

2. Step drilling. Benefits - Simple Tailor Made tool, Fast hole making. Disadvantages - Requires high power and rigidity, low flexibility.

Figure2.4 - Tools for step drilling

Table 2.1 - Parameters to be considered during drilling

• Tooling: - Always use the tool with the smallest possible overhang; - For best stability and hole quality, use modular tooling, hydro-mechanical or hydraulic chucks	
• Tool runout : – - Minimal runout - the basis for successful drilling	
• Evacuation of chips and coolant: – - Shaping and chip evacuation is a major factor in drilling and hole quality • Cutting conditions – - Optimum cutting speed and feed - the basis for high productivity and tool life.	

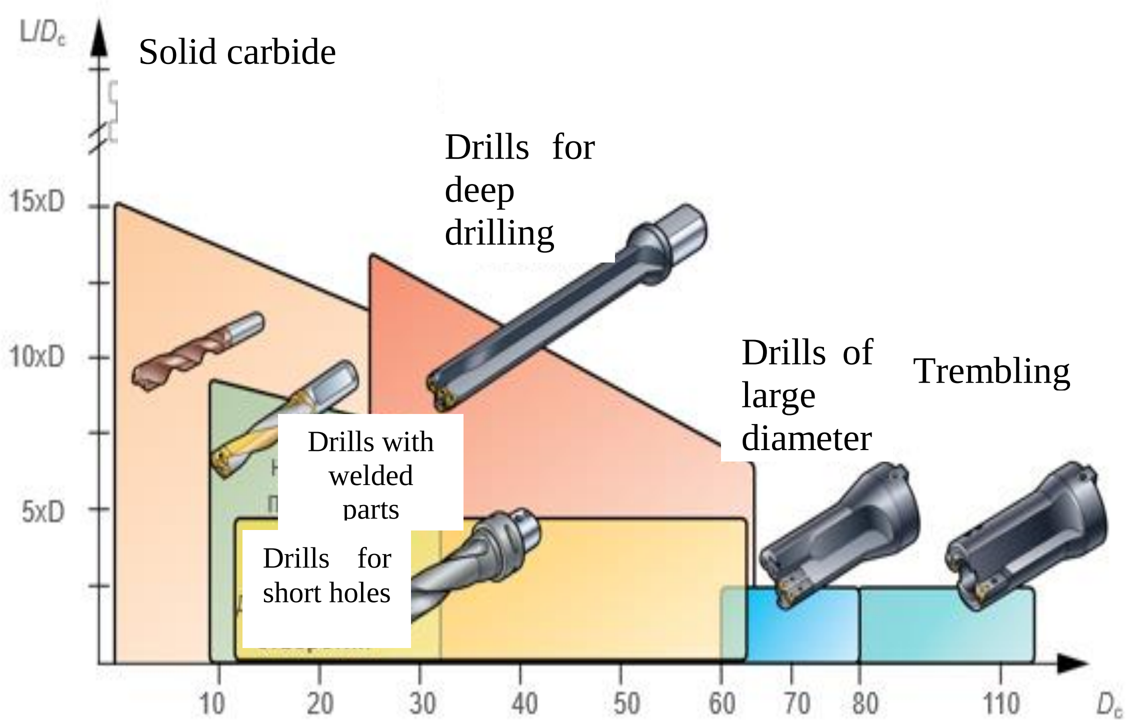


Figure 2.5 - Tool selection

Hole diameter and depth. Positioning of short drills. Indexable drills should always be considered the first choice in order to reduce the cost per hole. This is the most versatile tool.

Figure 2.6 - Drill with a replaceable plate

Solid carbide drills are the first choice for small hole diameters and when there is a tight hole tolerance.

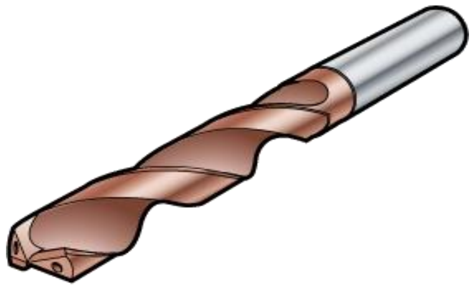


Figure 2.7 - Solid drill

Brazed insert drills are an alternative to solid carbide drills. Also used in case of poor stability during machining (drill body made of hardened steel).

Figure 2.8 - Drill with a soldered plate

Drills with replaceable plates
Types of fasteners

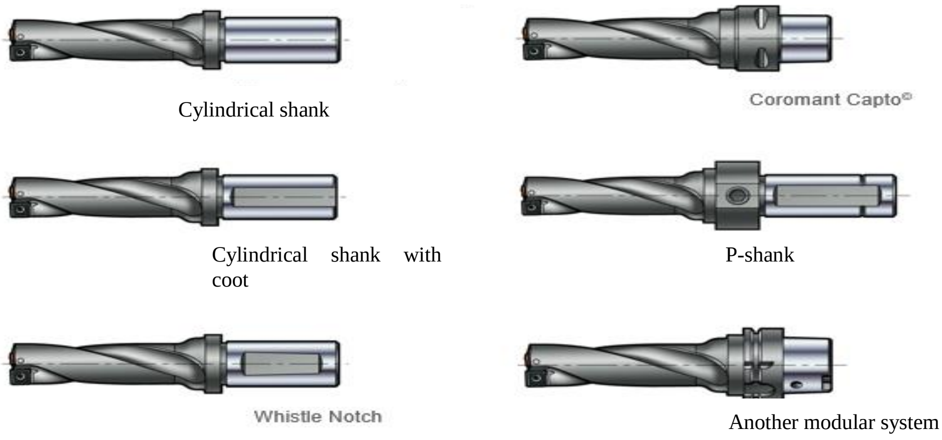


Figure 2.8 – Drills with replaceable plates

The process of obtaining accurate holes of small and medium diameters (3 - 15 mm; 7 - 9 quality; Ra = 0.4 - 3.2 μm) with sufficiently stringent requirements for the geometric shape and location of holes (deviations from roundness, straightness and axis position) associated with certain difficulties.

The most famous technological cycle includes the following sequence of operations: drilling, countersinking, reaming. Sometimes these operations are not enough, and then internal grinding or honing is additionally carried out.

Analysis of the existing production, as well as preliminary studies have shown that when using conventional multi-edge reamers, the process of obtaining accurate holes is ineffective. This is due to the fact that, due to errors in sharpening and resharpening of teeth, installation on the machine, unbalanced lateral forces arise, which cause distortion of the geometric shape, breakdown and drift of the axis of the hole being machined. When machining intermittent holes and holes with oblique entry and exit, these errors increase sharply.

The quality and accuracy of products can be ensured by two methods, which essentially characterize two different technical problems:

1) by improving the accuracy of technological processes;

2) by sorting already manufactured parts or products as a result of postoperative control.

To solve the problem of increasing the efficiency of processing such holes with high precision indicators and subsequent control in the literature, a set of studies aimed at applying the technology of deep vibration drilling, choosing the most effective tool design and choosing or creating the appropriate equipment and tooling.

2.2 Processing of research results

The task of increasing the accuracy, efficiency and reliability of processing can be solved both by using methods based on improving the technological characteristics of machines and tools, designing technological processes with a given accuracy, and by directly controlling cutting conditions, an elastic system, and disturbances acting during processing.

The concept of the quality of holes obtained by drilling includes: the accuracy of the diametrical dimension; accuracy of the geometric shape of the hole in the cross and longitudinal sections; position accuracy and direction of the axis of the drilled hole. The resulting radial components of the cutting force, the appearance of which is associated with the following factors, has a decisive influence on the size of the breakdown of the hole being machined: uneven wear of the cutting blades; tool sharpening errors; the possibility of forming sufficiently strong adhesive bonds between the chips and the processed material and high heat generation; significant spatial unevenness of hardness of many types of processed materials.

According to scientific research, the magnitude of the excess unbalanced radial force, depending on the diameter of the drill and the processing conditions, can fluctuate within 50 ... 200 N. The errors in the shape and drift of the hole axis depend mainly on the static and dynamic errors of the equipment, as well as on the value of the drill overhang , due to a decrease in its rigidity. In this case, the rigidity of the drill sharply decreases with a decrease in its diameter. If, at a given relative drill length, the axial force is greater than the critical value determined from the buckling conditions, deformations of the drill axis inevitably cause its drift. In addition, the beating of the working part of the drill leads to the fact that the axial force applied eccentrically with respect to the axis of the drill, causes its buckling, and, consequently, the axis drift.

To perform the practical part, the application program "Drilling" is used, which is located on the disk, and its main interface is presented in Fig.4.3. Instructions and explanations for working with the application appear on the additional interface when you click the Help button.

The graphic image of the drilling animation is constructed in such a way that when the diameter of the drill is changed, the corresponding changes are displayed in the graphic window, and the drilling depth is displayed at the same scale as the drill. In addition, the increase in feed causes a proportional acceleration of the drill in the animation window. In the process of preparing experimental studies, it is necessary to focus on the following ranges of changes in the parameters of the processing process, which are provided by the program.

Diameter $D_{св}$ drills can be selected from the following series: 5, 10, 15, 20, 25, 30, 35; cutting speed V can vary from 5m / min to 80m / min With a step of 1m / min; supply S-in the range of 0.05 ... 1 mm / rev with a step of 05 mm / rev; drilling length L - in the range of 5 ... 130 mm with a step of 1 mm. The research is performed according to the method of one-factor experiments, and the ranges of parameter changes are selected taking into account the ranges given above, so as to maximize some general trend. The results of measurements are recorded in the table of experimental data, according to which it is necessary to build appropriate graphs of dependencies in each experiment.

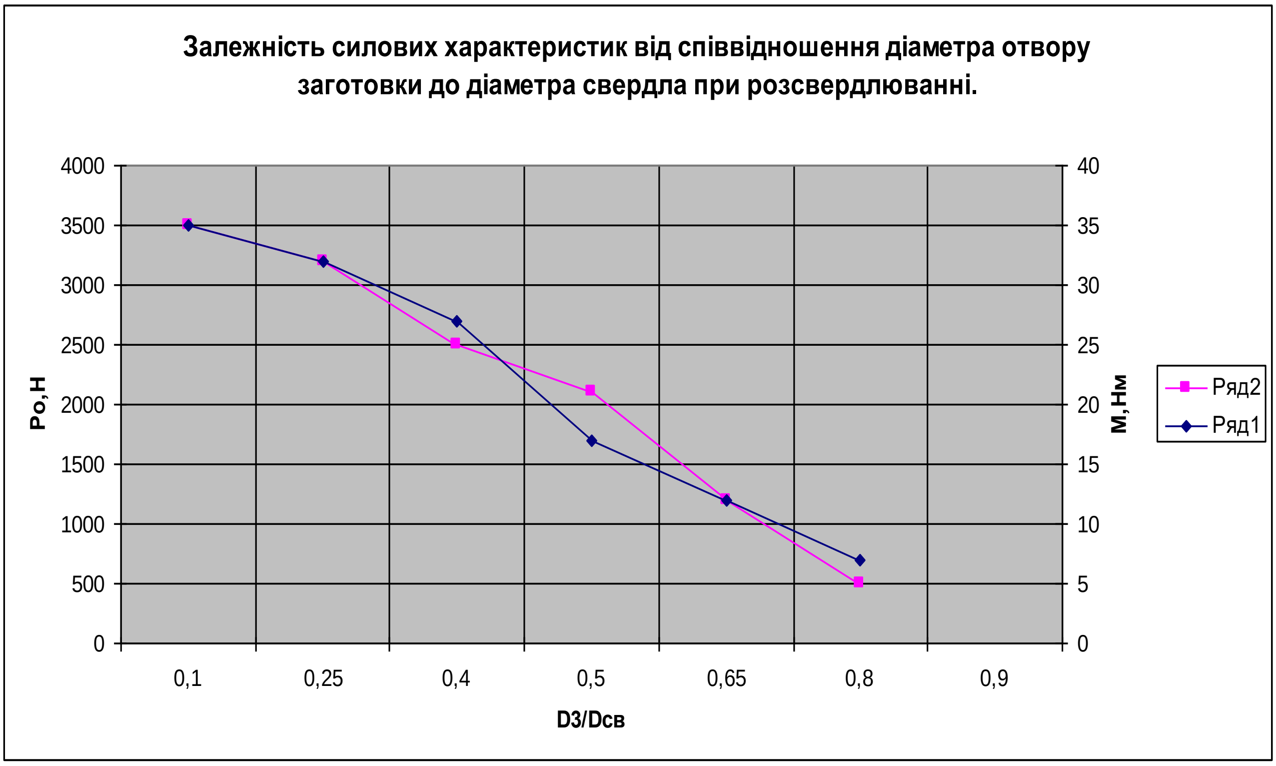


Figure 2.9 - Graphs of experimental dependences of axial force and torque when drilling holes

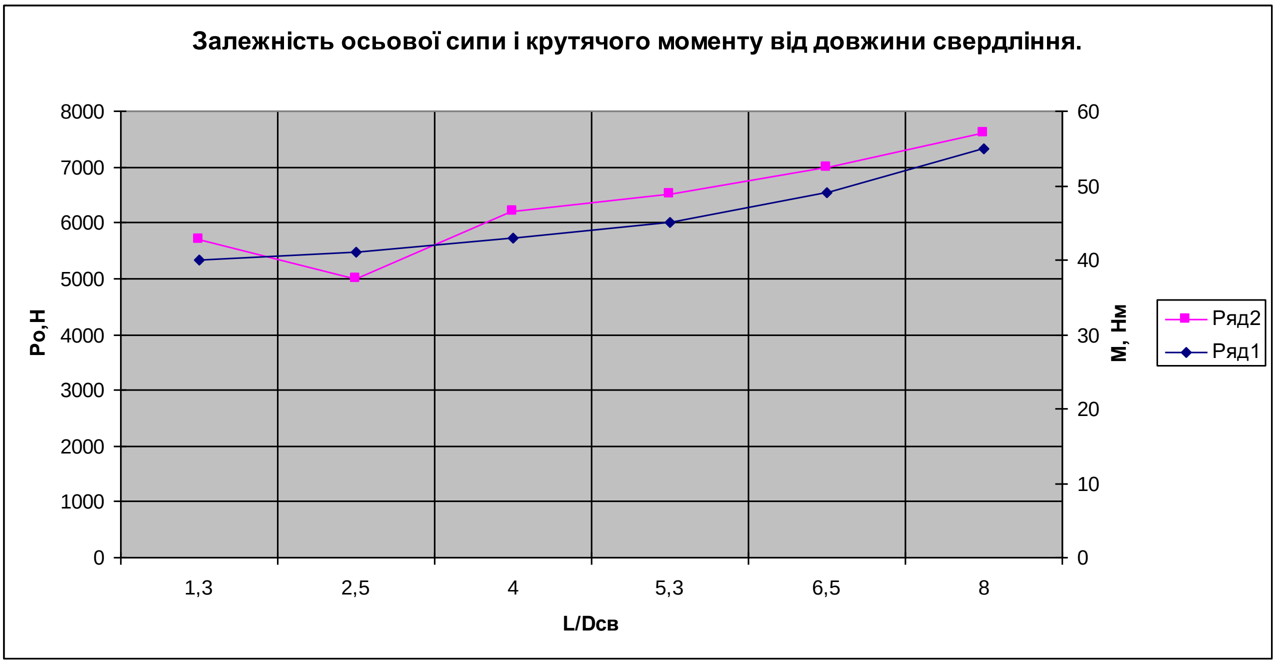


Figure 2.10 - Graphs of experimental dependences of axial force and torque on the length of drilling

2.3 Conclusions and suggestions on the use of research results

Analysis of the obtained experimental dependences allows us to draw the following conclusions that correspond to the investigated range of the mode of drilling and reaming of the specified in the example materials of the tool, workpiece and other invariant parameters of the cutting process:

Experiments to study the drilling process for the initial conditions of the example show that the force characteristics of the process: axial force and torque are almost directly proportional to the ratio $D_З/D_{св}$ moreover, the axial force decreases more slowly than the torque with increasing ratio $D_З/D_{св}$. This nature is explained by the fact that during reaming the diameter of the drill did not change and does not depend on the diameter of the workpiece, while the depth of cut on the contrary depends on the diameter of the workpiece.

4. The dependence of the axial force and torque on the drilling depth is purely nonlinear and the increase in force characteristics increases with increasing drilling

depth. This nature of the ratio coincides with the practice of drilling deep holes with twist drills. Therefore, to reduce the negative impact of drilling depth on the drilling process, various methods are used, among which the most effective should be considered technological - step-by-step drilling, ie with periodic removal of the drill from the hole and tool - drilling drills of special designs for deep drilling.

3.TECHNOLOGICAL AND DESIGN PART

3.1 Purpose and characteristics of the object of production

Detail “Housing” 6520Ф-3.3500011 is the basic detail of the gearbox” 0520Ф3-35.00.000 СК, vertical milling machine with CNC mod. 6520Ф-3.

The gearbox is mounted on the machine frame and is designed to provide the required rotation speed of the machine spindle.

The following requirements are laid down to provide the machine with the necessary technical parameters:

- the tolerance of the axis perpendicularity of the central holes to the main base plane is not more than 0,020 mm;
- the tolerance of the axes axial alignment of the central openings is not more than 0.020 mm;
- the tolerance of the cylindricality and connect of the central openings is not more than 0.008 mm;
- accuracy of the sizes of the central openings I_s 7;
- tolerance on the distance between the centers of the holes - 0,1 mm;
- the roughness of the treated surfaces of the holes R_a 1,25.

Also, in the manufacture of the housing, it is necessary to ensure the parallelism of the upper plane to the plane of the base is not more than 0.030 mm and the tolerance of perpendicularity to the plane of the base of the plane under the cover is not more than 0.05 mm.

The chemical composition of cast iron is given in Table 3.1., And the mechanical properties in the table 3.2.

Table 3.1 - Chemical composition of cast iron С420 ГОСТ 1412-85

Brand of cast iron	C, %	Si, %	Mn, %	P, %	S, %
С420 ГОСТ 1412-85	3,2 – 3,5	2,2 – 2,5	0,5 – 0,8	up to 0,4	up to 0,4

Table 3.2 - Mechanical properties of gray cast iron C420

Brand of cast iron	$\delta_в$, MPa	$\delta_м$, MPa	Hardness HB
C420 ГОСТ 1412-85	200	400	163– 229

Analysis of conformity of mechanical requirements and norms of accuracy of the service appointment of the gearbox.

Output data:

- assembly drawing of the gearbox 6520Ф-3.35.00.000 СК;

- drawing of the corps detail 6520Ф-3.35.00.011.

Based on the analysis of the drawings and the literature data, service appointment can be formulated as follows:

The gearbox is designed to provide the required rotation speed of the machine spindle. The housing is the main part in which all others are based and fixed.

The most important problem to be solved in the manufacturing process is to provide a lateral gap between the gear teeth, which depends on the oscillation of the relative displacement of the wheel dividers.

Determine the actual tolerance of the link

$$TA_\Delta = \sum_{1}^{n} T_{A_i} \tag{3.1}$$

TA_Δ ф = 0,026+0,037+0,007+0,041+0,049+2*0,005+2*0,017+0,1 = 0,289 mm.

This tolerance is much higher than the allowable one.

Let's check the possibility of reaching the radial gap by the method of incomplete interchangeability.

$$TA_\Delta \text{ н.в.} = t \sqrt{\lambda^2 A_i \sum_{i=1}^{n} A_i}; \tag{3.2}$$

$$TA_{\Delta\ н.в.} = 3\sqrt{\frac{1}{9}(0{,}026^2 + 0{,}037^2 + 0{,}007^2 + 0{,}007^2 + 0{,}041^2 + 0{,}049^2 + 0{,}005^2 + 0{,}005^2 + 0{,}017 + 0{,}017^2 + 0{,}1} = 0{,}13 \text{ mm}.$$

Thus the problem is solved by the method of incomplete interchangeability at risk 0,27%.

Analysis of the design part manufacturability (qualitative and quantitative characteristics)

Detail “Housing” 6520Ф-3.35.00.011 included in the node "gearbox” 6520Ф-3.35.00.000 CNC vertical milling machine model 6520Ф-3.

The detail is made by casting with box shaped of gray cast iron. The casting is quite simple in configuration, but requires the use of rods to form holes.

From the point of view of machining, the machined surfaces of the parts do not represent technological complexity and, while providing the required accuracy and roughness of the surfaces, allows for high-throughput machining to pass.

The disadvantage of the workpiece design in terms of manufacturability is the presence of deaf threads M8-7H.

According to ГОСТ 14.204-83 quantitative analysis of the design of the workpiece for the following indicators.

1. The coefficient of unification of structural elements of the workpiece:

$$К_{у.г.} = \frac{Q_{у.г.}}{Q_e}, \tag{3.3}$$

where $Q_{у.г}$ – the number of unified structural elements of the workpiece;

Q_e - the number of all structural elements of the part;

At $К_{у.г.} > 0{,}6$ the design of the part is considered technological.

2. Coefficient of processing accuracy:

$$К_{т..г.} = 1 - \frac{1}{A_{ср}}; \tag{3.4}$$

$$A_{ср} = \frac{1n_1 + 2n_2 + ... + 19n_{19}}{\sum n_i}; \tag{3.5}$$

where $A_{ср}$ - average accuracy: 1;2;...19 – quality of accuracy;

n_i – the number of dimensions of the corresponding accuracy grade.

At $K_{т.г.} > 0{,}8$ the design of the part is considered technological.

3. The roughness factor:

$$K_ш = 1/Б_{ср} ; \qquad (3.6)$$

$$Б_{ср} = \frac{0{,}012n_1 + 0{,}025n_2 + ... + 100n_{14}}{\sum n_i} ; \qquad (3.7)$$

where $Б_{ср}$ – middle class surface roughness;

0,012; 0,025 ...100 – the value of the surface roughness;

n_i – number of surfaces with corresponding roughness.

At $K_ш < 0{,}32$ the design of the part is considered technological.

To perform a quantitative analysis of the manufacturability of the design of the details we compile a table.3.3.

Table 3.3 - Workability analysis of parts

№	The name and number of the surface to be treated	Number of surfaces	Number of unified surfaces	Quality of accuracy	The surface roughness
1.	Ground plane 1	1	-	14	1,25
2.	The upper plane 3	1	-	14	1,25
3.	Side surfaces 2 4	2	-	14	1,25
4.	Cover surface for attachment the cover 5	1	-	14	2,5
5.	Surface 6	1	-	14	6,3
6.	Surface 7	1	-	14	6,3
7.	Hole ∅ 90 9 10	2	-	7	1,25
8.	Hole ∅ 45 8	1	1	8	2,5

9.	Hole ∅ 72 11 16	6	-	7	1,25
10.	Hole ∅ 22 29 30 22 23	4	4	7	1,25
11.	Hole ∅ M8-7H 17 28	12	12	7	1,25
12.	Hole ∅ M8-7H 31 ... 46; 70 ... 87	34	34	7	12,5
13.	Hole ∅ 8 47 48	2	2	8	1,25
14.	Hole ∅ 5 49	2	2	14	12,5
15.	Hole ∅ 13 50 ... 55	6	6	14	12,5
16.	Hole ∅ 26 56 ... 61	6	6	14	12,5
17.	Hole ∅ 10 62 63	2	2	14	12,5
18.	Hole ∅ 12-7H 64 65	2	2	7	12,5
19.	Hole ∅ 17 66 67	2	2	14	12,5
20.	Hole ∅ 88	1	1	7	6,3
21.	Hole	65	65	14	12,5
	TOTAL	153	138	-	-

Based on the data in table. 3.3 carry out a quantitative analysis of the manufacturability of the design of the part.

$$К_{у.с.} = \frac{138}{153} = 0,9 > 0,6 ;$$

$$А_{ср} = \frac{7 \cdot 61 + 8 \cdot 3 + 14 \cdot 89}{153} = 11,09 ;$$

$$К_{т.г.} = 1 - \frac{1}{11,09} = 0,91 > 0,8 ;$$

$$Б_{ср} = \frac{1,25 \cdot 12 + 2,5 \cdot 2 + 6,3 \cdot 3 + 12,5 \cdot 136}{153} = 11,37 ;$$

$$К_ш = \frac{1}{11{,}37} = 0{,}09 < 0{,}32 \quad .$$

Based on the above quantitative analysis of the manufacturability of the workpiece design, we can conclude that the workpiece design is technological.

Analysis of the basic (typical) technological manufacturing process

The factory version of the technological process of production of the "Corpus" consists of the following operations.

005 Foundry (the workpiece is obtained by casting into the ground)

010 Longitudinally milling – Тшт-к = 8,8 min, roughing the plane of the base; machine tool. 6606.

015 Longitudinally milling – Тш-к = 7,6 min, roughing of the upper plane; machine tool 6606.

120 Horizontally boring – Тш-к = 8,5 min, roughing the plane under the lid, the lateral surfaces of the plane of the base, the lateral and lower surfaces of the projection under the hole ∅ 45; machine tool 2622.

125 Horizontally boring – Тш-к = 6,9 min, roughing of the central openings; machine tool 2622.

030 Longitudinally milling – Тш-к = 21,4 min, semi finishing of the base plane and the top plane; machine tool 6606.

135 Horizontally boring – Тш-к = 6,5 min, half-clearing the plane under the lid and the side and bottom surface of the projection under the hole ∅ 45; machine tool 2622.

140 Horizontally boring – Тш-к = 8,3 min, semi-clean processing of the central openings; machine tool. 2622.

145 Flat grinding – Т ш-к = 14,5 min, finishing of the plane of the base, machine tool. 3Б724.

050 Flat grinding – Т ш-к = 13,3 min, finishing of the upper plane, machine tools.3Б724.

055 Horizontal boring with CNC – Тш-к = 46,2 min, machine tool mod. NP-800; finishing and finishing of the central holes and the plane under the cover of the mounting holes.

060 Radial drilling – Тш-к = 14,7 min, cutting threads in the mounting holes in the front plane, the plane of the base, the upper plane; machine tool 2P53.

Also, the factory process after drafting provides heat treatment to relieve internal stresses.

The factory version of the technological process is designed for the conditions of small-scale production

The main disadvantages:

- the use of plane grinding operations for the final processing of planes is not productive as there is a rapid salting of the grinding wheel;
- the use of longitudinal milling machines with three work calipers when processing one.
-

3.2 Development of the technological process of manufacturing the product

Type of production is determined by the factor of consolidation of operations:

$$К_{з.о.} = \frac{Ko}{Kр.м.} ; \qquad (3.8)$$

where $К_о$ – the total number of operations assigned to workplace;

$К_{р.м.}$ – total number of jobs

$$К_{р.м.} = \sum_{i=1}^{r} C_{n.i} , \qquad (3.9)$$

where r – number of operations of technological process;

$C_{n.i}$ – the number of jobs per operation.

Number of jobs $C_{n.i}$ on each operation is obtained after rounding the number of machines required to perform the i-th operation C_{pi} to a larger whole number.

The number of units of process equipment required to perform the i-th operation is determined by the formula.

$$C_{pi} = T_{шт.кi} \cdot N / 60\ F_{д} \cdot \eta_{з.н.}, \qquad (3.10)$$

where N – annual release program: N = 10000 piece;

$T_{шт.кi}$ – artificially calculating time of execution of i-th operation, min.

$F_{д}$ – valid annual equipment operating time fund: $F_{д}$ = 4015h.;

$\eta_{з.н.}$ – standard load factor of equipment: $\eta_{з.н.}$=0,8

The actual load factor of the equipment of the i-th operation is determined by the formula:

$$\eta_{з.н.} = \frac{C_{p.i}}{C_{n.i}}\ ; \qquad (3.11)$$

If $\eta_{з.ф.i}$ will exceed the value previously accepted $\eta_{з.н.}$ increase $C_{p.i.}$ followed by adjustments $\eta_{з.ф.i}$

The number of operations assigned to one workplace is determined:

$$O_i = \frac{\eta_{з.н.}}{\eta_{з.ф.i}}\ ; \qquad (3.12)$$

Determination of the coefficient consolidation of operations:

- accept that $\eta_{з.н.}$=0,8;
- operation 0.05. Longitudinally milling $T_{шт.к}$ = 8,2 min.;

$$C_{pi} = \frac{8,2 \cdot 10000}{60 \cdot 4015 \cdot 0,8} = 0,425;$$

$$C_{ni} = 1;$$

$$\eta_{з.ф.} = \frac{0,425}{1} = 0,425;$$

$$O_i = \frac{0,8}{0,425} = 1,88 = 2.$$

The results of the calculations are recorded in table. 3.4 Similarly, we make calculations for the rest of the operations of the factory technological process and the results are entered in table. 3.4.

Table 3.4 - Route of processing of the case

№	№ of operation	The name of the operation	$T_{шт.к}$ min.	Cp_i, pcs.	Cn_i, pcs.	$\eta_{з.ф.i}$	O_i
1	2	3	4	5	6	7	8
1	005	Longitudinally milling	8,8	0,425	1	0,425	2
2	010	Longitudinally milling	7,6	0,394	1	0,394	2
3	015	Horizontally boring	8,5	0,441	1	0,441	2
4	020	Horizontally boring	6,9	0,358	1	0,358	2
5	025	Longitudinally milling	21,4	1,11	2	0,555	1
6	030	Horizontally boring	6,5	0,337	1	0,337	2
7	035	Horizontally boring	8,3	0,431	1	0,431	2
8	040	Flat grinding	14,5	0,752	1	0,752	1
9	045	Flat grinding	13,3	0,690	1	0,690	1
10	050	Horizontally boring on CNC	46,2	2,397	3	0,799	1
11	055	Radial drilling	14,7	0,763	1	0,763	1
		TOTAL	156,1	-	14	-	17

Based on the calculations, we determine the consolidation of operations.

$$К_{з.о.} = \frac{17}{14} = 1,21 \qquad (3.13)$$

Since 1 < $К_{з.о.}$ <= 10 according to ГОСТ 14.004-83 type of production: multi-serial.

The decision on the feasibility of organization of streaming production is made on the basis of a comparison of the given daily output of parts and the calculated daily productivity of the production line.

Specified daily output of parts:

$$N_g = \frac{N}{Д}, \qquad (3.14)$$

where Д – annual number of working days: Д = 254

$$N_g = \frac{10000}{254} = 39{,}4 \approx 39 \text{ pcs.}$$

Daily production line productivity:

$$Q_g = \frac{F_{\partial}'}{T_{cp}} \eta_{з.н.} \;, \qquad (3.15)$$

where $F_{д}'$ – the daily fund of working time of the equipment: $F_{д}'$ = 952 min;

$\eta_{з.н.}$ – normative load factor of the production line: $\eta_{з.н.}$=0,6;

T_{cp} = average complexity of basic operations, min.

$$T_{cp} = \frac{\sum_{1}^{r} T_{шт.к_i}}{r} \;; \qquad (3.16)$$

where $T_{шт.кі}$ = artificially calculating time of execution of i-th operation, min.;

r – number of operations.

$$T_{cp} = \frac{156{,}1}{11} = 14{,}12 \text{ min.};$$

$$Q_{д} = \frac{952}{14{,}12} \cdot 0{,}6 = 40{,}5 \approx 41 \text{ pcs.}$$

Since $N_{д}$ = 39 < $Q_{д}$ = 41 it is inappropriate to use one nomenclature production line.

We accept a group form of production organization.

The number of parts in a batch for simultaneous start-up is determined by the formula:

$$n = \frac{N \cdot a}{Д} \;, \qquad (3.17)$$

where a – launch frequency in days: a = 3.

Set the estimated number of shifts required to process the entire batch of parts:

$$C = \frac{T_{шт.к.ср.}\, n}{0{,}5 \cdot F_g' \, \eta_{з.н.}} \;; \qquad (3.18)$$

where $\eta_{з.н.}$ – normative factor shifts loading of the equipment in a batch production: $\eta_{з.н.}$ = 0,75.

The estimated number of changes is rounded to the accepted integer $C_{пр}$, and then determine the number of parts in the batch needed to load the equipment during the whole number of changes by the formula:

$$n_{пр} = \frac{0{,}5 F_g^{'} \cdot \eta_{з.н.} \cdot C_{пр}}{T_{шт.к.ср.}} \; ; \qquad (3.19)$$

$$n = \frac{10000 \cdot 3}{254} = 118{,}1 \approx 118 \text{ pcs.};$$

$$C = \frac{14{,}12 \cdot 118}{0{,}5 \cdot 952 \cdot 0{,}75} = 4{,}7$$

We accept $C_{пр} = 5$.

$$n_{пр} = \frac{0{,}5 \cdot 952 \cdot 0{,}75 \cdot 5}{14{,}12} = 126{,}4 = 127 \text{ pcs.}$$

Conclusion: the type of production - multi-serial, the form of production organization - group.

Technological processing methods are selected provided that the "refinement" to the deviations given by the tolerances for the finished part is ensured. To determine it, use a calculation refinement

$$E_p = \frac{T_0}{T_д} \; ; \qquad (3.20)$$

where T_0 , $T_д$ – according to the tolerances for the specified accuracy of the workpiece and details.

Estimated refinement E_p can be provided with different processing methods, each of which gives its own value of refinement. If the first method provides clarification E_1, second E_2 and the last one – E_m , and the workpiece, after going through all the processing methods, will be refined E_n.

$$E_n = E_1 \cdot E_2 \cdot E_3 \cdot \ldots E_m = \prod_{i=1}^{n} E_i \; ; \qquad (3.21)$$

An indication that the required number of surface treatment methods is correctly defined is inequality

$$E_p <= E_n \; ; \qquad (3.22)$$

If the surface needs to achieve an accuracy of not less than sixth grade, then the number of methods of processing m is determined by the formula:

$$m = \frac{\lg E_p}{0{,}46} \; ; \qquad (3.23)$$

Clarification E_i of any processing method is approximately determined by the formula:

$$E_i = \frac{T_{i-1}}{T_i} \; , \qquad (3.24)$$

T_{i-1} , T_i – according to the tolerances provided by the prior and present processing methods.

Processed surface:

- hole ∅ 90 I_s 7 ($\pm$ 0,017), R_a 1,25;
- the tolerance of the perpendicularity of the axis of the hole to the main base plane of 0.020 mm;
- tolerance of ovality and cone-shaped opening of 0,008 mm.

The workpiece tolerance on this surface is T_3 = 1,2 mm, which is more than 14 and less than 15 quality.

$$E_p = \frac{1{,}2}{0{,}034} = 35{,}29 \; ;$$

$$m = \frac{\lg 35{,}29}{0{,}46} = 3{,}36 \; ;$$

We accept m = 4.

Taking into account the tolerance of the form, we accept following the processing methods:

- boring rough;
- semi-pure boring;
- clean boring;
- thin boring.

We define for each method of processing the average economic quality and tolerance.

Rough boring IT12, $T_д^1 = 0{,}35$ mm.

Semi-pure boring IT9, $T_д^2 = 0{,}087$ mm.

Clean boring IT8, $T_д^3 = 0{,}054$ mm.

Thin boring IT7, $T_д^4 = 0{,}035$ mm.

We define the refinement for each processing method:

$$E_1 = \frac{1{,}2}{0{,}35} = 3{,}43\ ;\ E_2 = \frac{0{,}35}{0{,}087} = 4{,}02\ ;\ E_3 = \frac{0{,}087}{0{,}054} = 1{,}61\ ;$$

$$E_4 = \frac{0{,}054}{0{,}034} = 1{,}59$$

Determine the overall refinement of all processing

$$E_n = 3{,}43 \cdot 4{,}02 \cdot 1{,}61 \cdot 1{,}59 = 35{,}30.$$

$$E_n = 35{,}30 > E_p = 35{,}29$$

This means that a sufficient number of processing methods are selected.

Processed surface:

- plane, the resulting size 220 I_s 14 ($\pm$ 0,575), R_a 1,25;
- parallel tolerance to the main base plane 0,030 mm;
- tolerance of ovality and cone-shaped opening of 0,008 mm.

The workpiece tolerance on this surface $T_3 = 1{,}6$ mm.

$$E_p = \frac{1{,}6}{1{,}15} = 1{,}39\ ;$$

$$m = \frac{\lg 1{,}39}{0{,}46} = 0{,}31$$

To ensure admission of the form we accept m = 4.

Taking into account the tolerance of the form, we accept following the processing methods:

The first option

- rough milling IT12 ; $T_1^1 = 0{,}46$ mm.
- semi-pure milling IT9 ; $T_1^2 = 0{,}115$ mm.
- previous milling IT7 ; $T_1^3 = 0{,}046$ mm.
- end milling IT6 ; $T_1^4 = 0{,}029$ mm.

The second option

- rough milling IT12 ; T_2^1 = 0,46 mm.
- semi-pure milling IT9 ; T_2^2 = 0,115 mm.
- previous milling IT7 ; T_2^3 = 0,046 mm.
- end milling IT6 ; T_2^4 = 0,029 mm.

$E_1 = \frac{1,6}{0,46} = 3,48$; $E_2 = \frac{0,46}{0,115} = 4$; $E_3 = \frac{0,115}{0,046} = 2,5$;

$E_4 = \frac{0,046}{0,029} = 1,58$

$E_n = 3,48 \cdot 4 \cdot 2,5 \cdot 1,58 = 54,98$;

$E_n = 54,98 > E_p = 1,38$.

This means that a sufficient number of processing methods are selected.

Similarly, we calculate for other surfaces, the results of the calculations are summarized in table. 3.5.

Table 3.5 - Methods of parts surface treatment

№	The name of the workpiece surface and machining methods	Form tolerance μm.	Roughness R_a	Quality	Tolerance		Specification	
					Marking	Size	Formula	Value
1	2	3	4	5	6	7	8	9
1	Hole ∅ 45 H8	-	2,5	8	$T_д$	39	$E_p = T_i/T_д$	6,41
	I variant							
	Drilling	12,5	12,5	12	T_1^1	250	$E_1^1 = T_3/T_1^1$	-
	Countersinking		3,2	9	T_1^2	62	$E_1^2 = T_1^1/T_1^2$	4,03
	Reaming		2,5	8	T_1^3	39	$E_1^3 = T_1^2/T_1^3$	1,59
	Total		2,5	8	$T_д$	39	E_n	6,42
	II variant							
	Drilling		12,5	12	T_2^1	250	$E_2^1 = T_3/T_2^1$	-
	Semi-pure boring		3,2	9	T_2^2	62	$E_2^2 = T_2^1/T_2^2$	4,03
	Clean boring		2,5	8	T_2^3	39	$E_2^3 = T_2^2/T_2^3$	1,59
	Total		2,5	8	$T_д$	39	$E_n = \prod_{i=1}^{r} E_i$	6,42
2.	Hole ∅ 90 I_s 7	8	1,25	7	$T_д$	34	$E_p = T_3/T_g$	35,29

№	The name of the workpiece surface and machining methods	Form tolerance μm.	Roughness R_a	Quality	Tolerance		Specification	
					Marking	Size	Formula	Value
1	2	3	4	5	6	7	8	9
	The workpiece		20	-	T_3	1200	-	-
	Rough boring		12,5	12	T_1^1	350	$E_1 = T_3/T_1^1$	3,43
	Semi-pure boring		3,2	9	T12	87	E2 = T11/T12	4,02
	Clean boring		2,5	8	T13	54	E3 = T12/T13	1,61
	Thin boring	8	1,25	7	T14	34	E4 = T13/T14	1,59
	Total	8	1,25	7	-	-	En = $\prod_{i=1}^{r} E_i$	35,29
3.	Hole ∅ 72 Is 7	8	1,25	7	Тд	30	Ер = Т3/Тд	40
	The workpiece		20	-	T3	1200	-	-
	Rough boring		12,5	12	T11	300	E1 = T3/T11	4
	Semi-pure boring		3,2	9	T12	74	E2 = T11/T12	4,05
	Clean boring		2,5	8	T13	46	E3 = T12/T13	1,61
	Thin boring	8	1,25	7	T14	30	E4 = T13/T14	1,53
	Total	8	1,25	7	-	-		40,07
4.	Plane 220 + $\frac{IT14}{2}$	30	1,25	14	Тд	1150	Ер = Т3/Тд	1,39
	The workpiece		20	-	T3	1600	-	-
	I- variant							
	Rough milling		12,5	12	T11	460	E1 = T3/T11	3,48
	Semi-pure milling		3,2	9	T12	115	E2 = T11/T12	4,00
	Previous grinding		2,5	7	T13	46	E3 = T12/T13	2,50
	Final grinding	30	1,25	6	T14	29	E4 = T13/T14	1,58
	Total	30	1,25	6	-	-	En = $\prod_{i=1}^{r} E_i$	54,98
	II variant							
	Rough milling		12,5	12	T_2^1	460	$E_1 = T_3/T_2^1$	3,48
	Semi-pure milling		3,2	9	T_2^2	115	$E_2 = T_2^1/T_2^2$	4,00
	Finishing milling		2,5	7	T_2^3	46	$E_3 = T_2^2/T_2^3$	2,50
	Thin milling	30	1,25	6	T_2^4	29	$E_4 = T_2^3/T_2^4$	1,58
	Total	30	1,25	6	-	-	$E_n = \prod_{i=1}^{r} E_i$	54,98

3.3 Selection and estimated justification of bases

Selection of technological bases is the most important stage of technological process development.

It is necessary to distinguish between the choice of technological bases for processing most surfaces of the workpiece and the choice of technological bases on the first operations, when creating bases for the treatment of most surfaces of the workpiece. First of all it is necessary to choose finishing technological bases, for processing of most surfaces of a part, and then rough technological bases, for the first operation.

In order to achieve the required precision of the workpiece in the shortest way, it is necessary to choose the surfaces from which most other surfaces are positioned as finishing bases. Most surfaces of a part are generally positioned according to their intended use with respect to its main bases. Accordingly, as the technological bases for the treatment of most surfaces choose the main base parts, the surfaces on which it is based in the node.

When choosing the rough technological base, you must proceed from the decision by following the tasks.

1. Establishing the necessary connections that determine the distances and turns that we receive as a result of surface treatment relative to the raw free workpiece surfaces.

2. Ensuring uniform distribution of actual allowance on the surfaces to be treated.

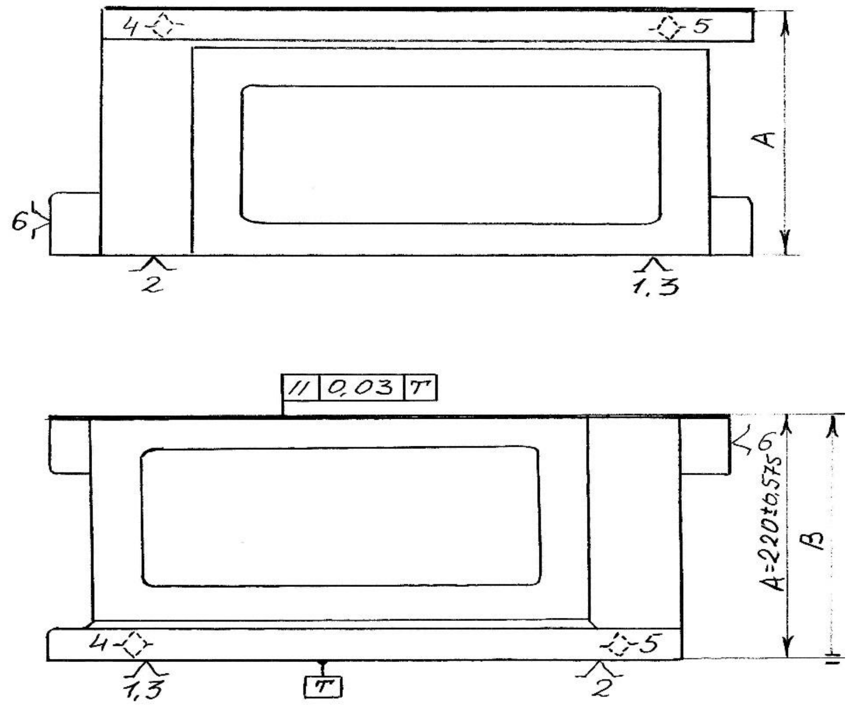
Based on the above for details "Case" we determine the possible variants of finishing technological bases and for each determine the error of the basis by the formula:

$$E_\delta = \sum_{i=1}^{n} \delta_i \;; \qquad (3.25)$$

where E_δ – base error when machining a certain surface, mm;

δ_i – tolerances on the dimensions of the dimensional chain links that connects the founding and measuring bases used respectively for the treatment and control of the surface, mm;

n – number of links in the chain.

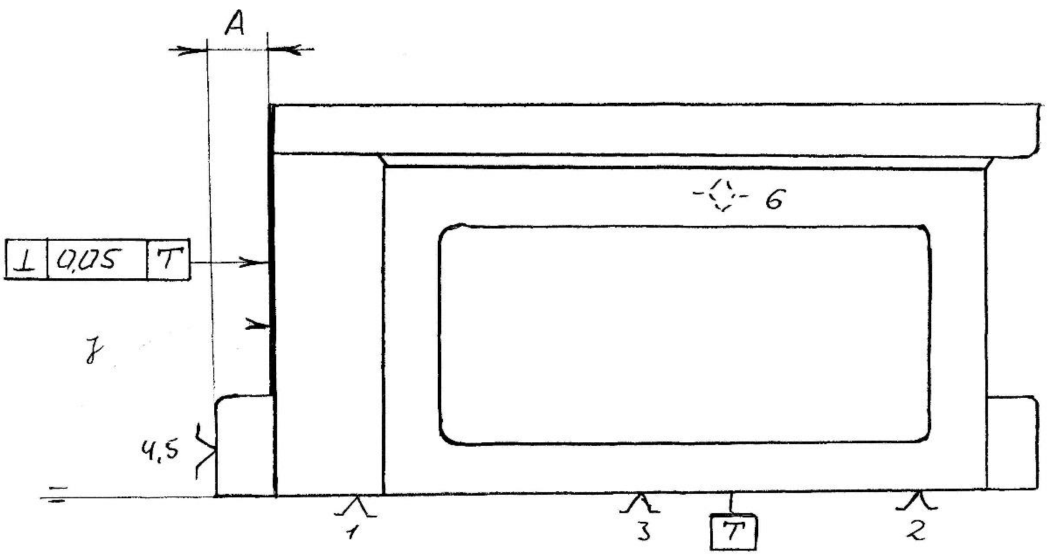


$E_{БА} = 0$

$E_{БА} = 0$

Figure. 3.1 - Clean bases

$E_{БВ} = 0$



$E_{БА} = 0$

$E_{Бу} = 0$

Figure. 3.2 - Clean bases

Clean bases

I option

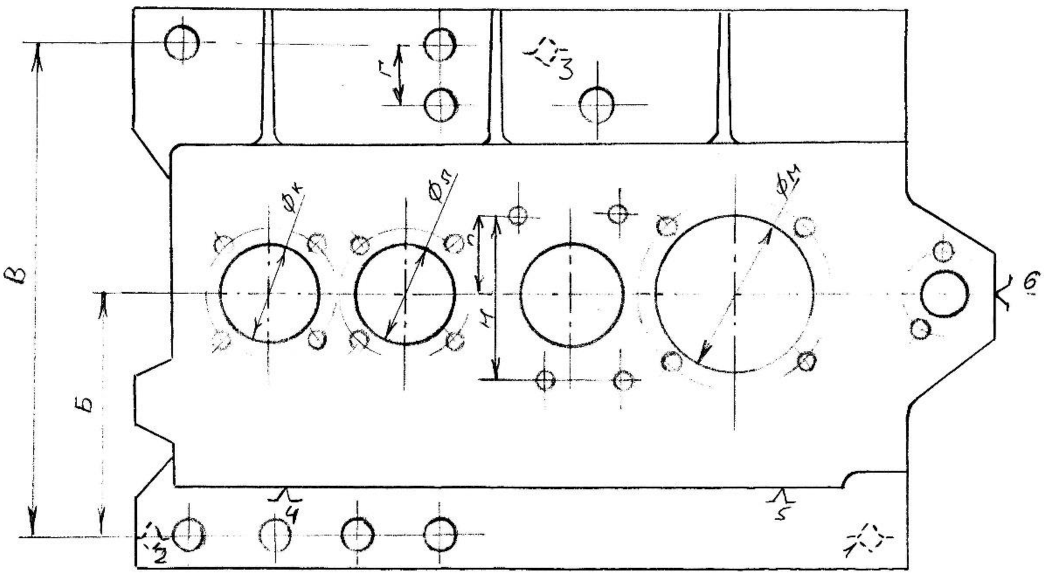


Figure 3.3 - The first version of finishing bases

$Е_{БА} = 0$; $Е_{БВ} = Е_{Бк} = Е_{БА} = Е_{Бн} = Е_{Бм} = ТА$;

$Е_{БВ} = ТА + ТБ$;$Е_{Бт} = ТА + ТБ + ТВ$; $Е_{Бм} = ТА + ТП$.

Clean bases

II option

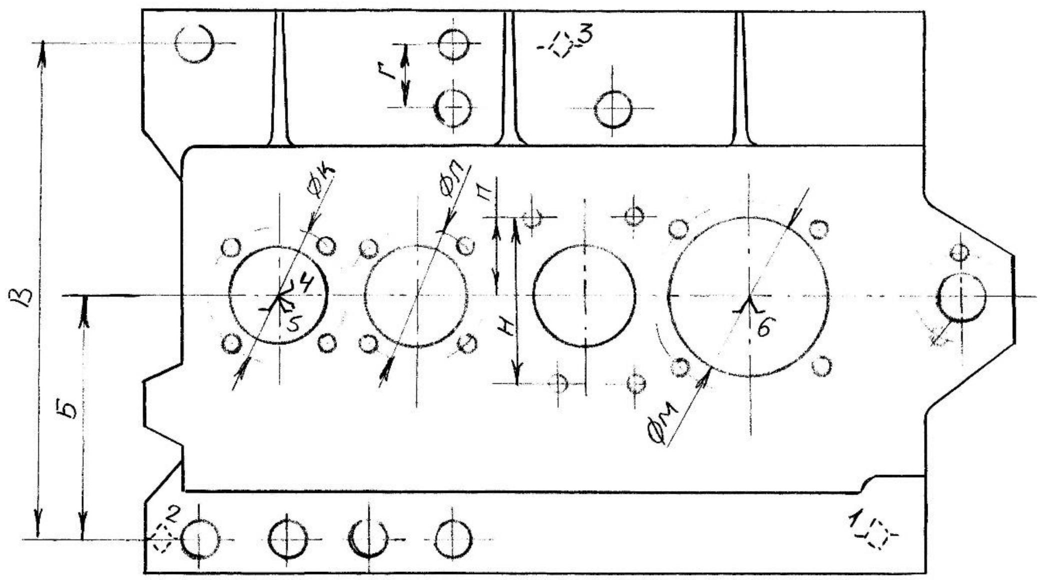


Figure 3.4 - The second version of finishing bases

Figure 3.4 shows a diagram of the workpiece base on the plane and two floating (conical and conical-cut) fingers.

$$E_{Бб} = E_{Бк} = E_{Бл} = E_{Бп} = E_{Бм} = 0 \; ; \; E_{Бм} = ТП \; ; \; E_{Бп} = ТБ \; ;$$

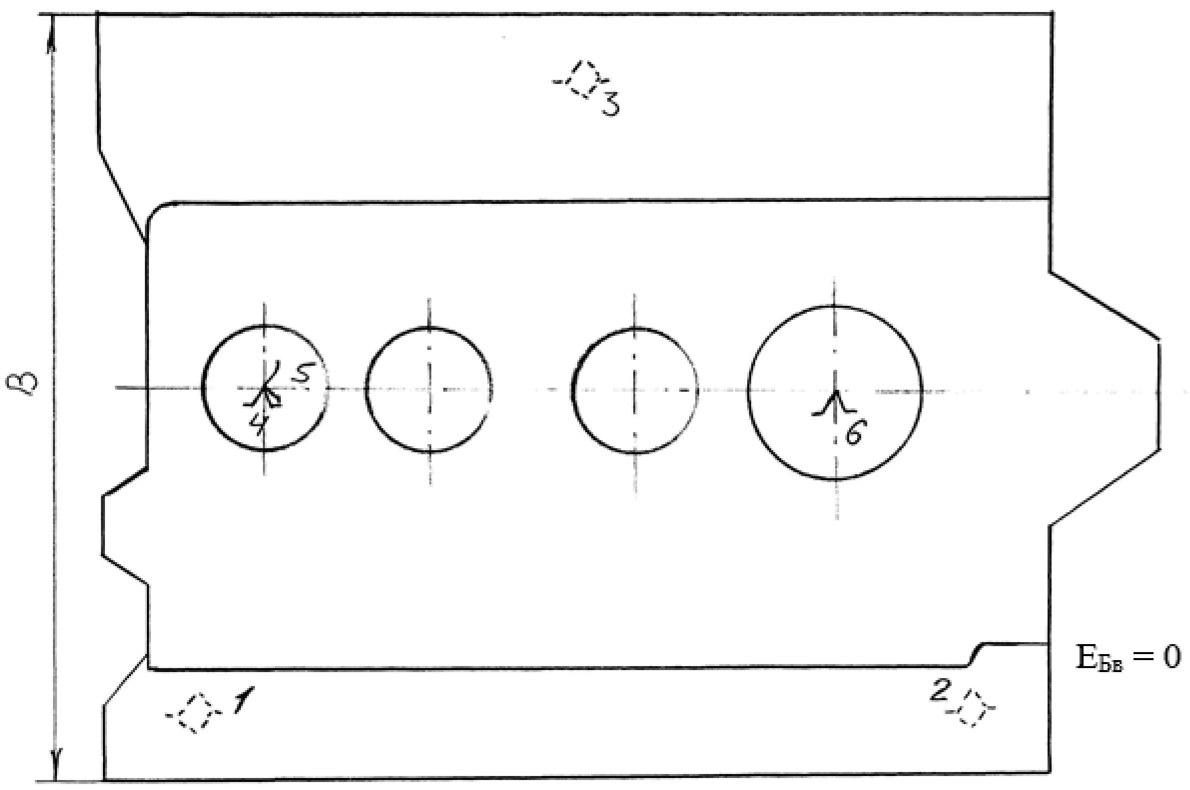
Based on the calculations, we can conclude that when processing the central holes it is advisable to base on the first option, and when processing threaded holes and holes used for mounting higher accuracy is achieved when based on the second variant.

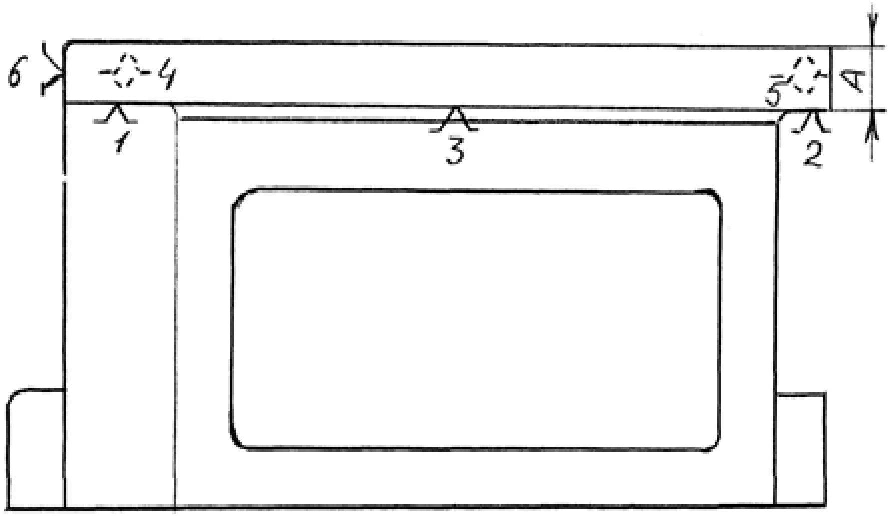
After selecting the clean technological bases, we select the rough technological bases based on the solution of the following problems.

1. Establishing the necessary connections that determine the distances and relative rotations that we receive as a result of machining surfaces relative to the raw free workpiece surfaces.

2. Ensuring uniform distribution of actual allowance on the surfaces to be treated.

Rough bases





$E_{БА} = 0$

$E_{БА} = 0$

Figure 3.5 - Rough bases

Detailed development of the optimal variant of the technological process

Determination of tolerances, allowances and operating sizes.

Calculation of allowances between operating sizes and tolerances is carried out in an analytical and calculated manner.

Processed surface: hole ∅ 72 I_s 7.

Calculation formula for determining the minimum allowance:

$$2\,Z_{i\,min} = 2(R_{Z\,i-1} + T_{i-1} + \sqrt{\rho_{i-1}^{\,2} + E_i^{\,2}}\,, \qquad (3.25)$$

$E_{Бв} = 0$

where R_Z – height of irregularities characterizing surface roughness, microns;

T – depth of the defective surface layer;

ρ - spatial deviations, microns;

E – installation error, microns;

i – technological processing transition number.

To facilitate the calculations we compile a table of allowances and marginal sizes, table. 3.6.

Table 3.6 - Allowances and size limits for technological transitions of hole treatment ∅ 72 I_s 7

Technological transitions of hole processing ∅ 72 I_s 7	Elements of allowance				Estimated allowance $2z_{i\,min}$, microns	Estimated size d_p, мм	Tolerance δ, microns	The maximum size, mm		Limit value of allowance, microns	
	R_Z	T	ρ	E				d_{min}	d_{max}	$2Z_{min}^{гр}$	$2Z_{max}^{гр}$
1	2	3	4	5	6	7	8	9	10	11	12
The workpiece	200	300	830	-		69,515	1200	68,32	69,52		
Rough boring	50	50	40	160	2·920	71,355	740	70,62	71,36	1840	2300
Semi-pure boring	20	-	-	115	2·215	71,785	190	71,60	71,79	430	980
Clean boring	10	-	-	80	2·100	71,985	74	71,91	71,98	200	310
Thin boring	5	-	-	5	2·15	72,015	30	71,98	72,01	30	75
Total					2·1250					2500	3655

We define R_Z and T for the workpiece and technological transitions of machining and recorded in table. 2.5.

The total value of spatial deviations for the workpiece of this type is determined by the formula:

$$\rho_{заг} = \sqrt{\rho_{кор}^2 + \rho_{зм}^2}\ , \qquad (3.26)$$

where $\rho_{кор}$ – spatial deviations arising from the warping of the workpiece;

$\rho_{зм}$ – spatial deviations as a result of possible displacement of the axis of the hole.

$$\rho_{кор} = \sqrt{(\Delta_к d)^2 + (\Delta_к l)^2}\ , \qquad (3.27)$$

where $\Delta_к$ - specific amount of warping: $\Delta_к = 0{,}65$;

d – hole diameter: d = 72 mm;

l – hole length: l = 25 mm;

$$\rho_{кор} = \sqrt{(0{,}65 \cdot 72)^2 + (0{,}65 \cdot 25)^2} = 50 \text{ microns};$$

$$\rho_{зм} = \sqrt{\left(\frac{\delta_А}{2}\right)^2 + \left(\frac{\delta_Б}{2}\right)^2}\ ; \qquad (3.28)$$

where $\delta_А$ and $\delta_Б$ – workpiece size tolerances that determine the spatial location of the hole: $\delta_А$ = 1400 microns; $\delta_Б$ = 400 microns.

$$\rho_{зм} = \sqrt{(700)^2 + (200)^2} = 730 \text{ microns;}$$

$$\rho_{заг} = \sqrt{50^2 + 730^2} \approx 730 \text{ microns.}$$

Spatial deviation after rough boring is 5% $\delta_{заг}$

$$\delta_1 = 0{,}05 \cdot 730 \approx 40 \text{ microns.}$$

There are no spatial deviations after the subsequent technological transitions.

Installation error:

$$E_В = \sqrt{E_Б^2 + E_З^2} \;; \qquad (3.29)$$

where $E_Б$ – base error, for accepted base variant, $E_Б$ = 0;

$E_З$ – fixing error.

Rough boring $E_{В1} = E_З$ = 160 microns;

Semi-pure boring $E_{В2} = E_З$ = 115 microns;

Pure boring $E_{В4} = 0{,}05\ E_З$ = 5 microns;

Based on the obtained values of the allowance elements determine $2Z_{imin}$ for each transition.

$$2Z_{imin1} = 2(200+300+\sqrt{730^2 + 150^2}) \approx 2 \cdot 920 \text{ microns;}$$

$$2Z_{imin2} = 2(50+50+\sqrt{50^2 + 115^2}) \approx 2 \cdot 215 \text{ microns;}$$

$$2Z_{imin3} = 2(20+\sqrt{80^2}) \approx 2 \cdot 100 \text{ microns;}$$

$$2Z_{imin4} = 2(10+\sqrt{5^2}) \approx 2 \cdot 15 \text{ microns;}$$

The Estimated Size column (d_p) fill in from the final size by sequential subtraction of the estimated minimum allowance of each technological transition.

d_{P4} = 72,015 mm;

d_{P3} = 72,015 – 0,030 = 71,985 mm;

d_{P2} = 71,985 – 0,200 = 71,785 mm;

d_{P1} = 71,785 – 0,430 = 71,355 mm;

$d_{Рзаг.}$ = 71,355 – 1,840 = 69,515 mm;

In the Limit Size column, the largest value (d_{max}) is obtained from the estimated dimensions, rounded to the nearest tolerance of the corresponding transition.

The smallest size limit (d_{min}) is determined from the largest threshold sizes by subtracting the tolerances of the corresponding transitions.

d_{min4} = 72,015 – 0,030 = 71,985 mm;

d_{min3} = 71,985 – 0,074 = 71,911 mm;

d_{min2} = 71,79 – 0,190 = 71,60 mm;

d_{min1} = 71,36 – 0,74 = 70,62 mm;

$d_{min\ заг}$ = 69,52 – 1,20 = 68,32 mm.

Minimum allowance limit values $Z_{\min}^{гр}$ equal differences between the maximum limit sizes of the current and previous technological transitions, and the maximum limit values of the allowances $Z_{\max}^{гр}$ - according to the difference of the smallest size limits.

$2\ Z_{\min 4}^{гр}$ = 72,015 – 71,985 = 0,030 mm;

$2\ Z_{\max 4}^{гр}$ = 71,985 – 71,910 = 0,075 mm;

$2\ Z_{\min 3}^{гр}$ = 71,985 – 71,79 = 0,20 mm;

$2\ Z_{\max 3}^{гр}$ = 71,91 – 71,60 = 0,31 mm;

$2\ Z_{\min 2}^{гр}$ = 71,79 – 71,36 = 0,43 мм mm;

$2\ Z_{\max 2}^{гр}$ = 71,60 – 70,62 = 0,98 mm;

$2\ Z_{\min 1}^{гр}$ = 71,36 – 69,52 = 0,84 mm;

$2\ Z_{\max 1}^{гр}$ = 70,62 – 68,32 = 2,30 mm.

The obtained results are recorded in table. 3.7. General allowances Z_{omin} and $Z_{o\ max}$ is determined by summing the intermediate allowances

$Z_{o\ min}$ = 1840 + 430 + 200 + 30 = 2500 microns;

$Z_{o\ max}$ = 2320 + 980 + 310 + 75 = 3685 microns.

The total nominal allowance is determined by the formula:

$Z_{0\ ном} = Z_{omin} + B_3 – B_g$ = 2500 + 600 –15 = 3085 microns.

$d_{3ном} = d_{g\ ном} – Z_{о\ ном}$ = 72 – 3,085 = 68,915 mm.

We carry out a check of correctness of the performed calculations.

$Z^{зр}_{\max 4} - Z^{зр}_{\min 4}$ = 75 – 30 = 45 microns;

$\delta_3 - \delta_4$ = 74 – 30 = 44 microns;

$Z^{зр}_{\max 3} - Z^{зр}_{\min 3}$ = 310 – 200 = 110 microns;

$\delta_2 - \delta_3$ = 100 – 74 = 116 microns;

$Z^{зр}_{\max 2} - Z^{зр}_{\min 2}$ = 980 – 430 = 550 microns;

$\delta_1 - \delta_2$ = 740 – 190 = 330 microns;

$Z^{зр}_{\max 1} - Z^{зр}_{\min 1}$ = 2300 – 1840 = 460 microns;

$\delta_{заг} - \delta_1$ = 1200 – 740 = 460 microns;

On the basis of these calculations, we build a diagram of the graphical arrangement of openings and tolerances for the processing of holes ∅ 72 I_s 7 ± 0,15 mm.

Schematic diagram of the layout of openings and tolerances ∅ 72 I_s 7

The treated surface is the plane, the resulting size 220±0,575; R_a 1,25;

Calculation formula for determining the minimum allowance

$$Z_{i\ min} = R_{Z\ i-1} + T_{i-1} + \rho_{i-1} + E_{y\ i} \quad (3.30)$$

The results of calculations are recorded in the table 3.7.

Table 3.7 - Allowances and size limits for technological transitions of surface treatment in size 220 ± 0,575 mm

Technological transitions of plane processing 220 ± 0,575	Elements of allowance				Estimated allowance $Z_{i\,min}$, microns	Estimated size d_p, mm	Tolerance δ, microns	Limit size, mm		Limit value of allowance, microns	
	R_Z	T	ρ	E				d_{min}	d_{max}	$Z_{min}^{гр}$	$Z_{max}^{гр}$
The workpiece	200	300	800	-		221,393	1600	221,4	223,0		
Rough milling	50	50	40	200	1500	219,895	1150	219,89	221,04	1500	1960
Semi-finished milling	20	-	-	160	300	219,595	1150	219,59	220,74	300	300
Finishing milling	10	-	-	130	150	219,445	1150	219,45	220,60	150	150
Thin milling	5	-	-	10	20	219,425	1150	219,43	220,58	20	20
Total					1970					1970	2430

The treated surface is the plane, the resulting size 157±0,1 mm; R_a 2,5;

Table 3.8 - Allowances and size limits for technological transitions of plane processing in size 157 ± 0,1 mm

Technological transitions of plane processing 157 ± 0,1	Elements of allowance				Estimated allowance $Z_{i\,min}$, microns	Estimated size d_p, mm	Tolerance δ, microns	Limit size, mm		Limit value of allowance, microns	
	R_Z	T	ρ	E				d_{min}	d_{max}	$Z_{min}^{гр}$	$Z_{max}^{гр}$
The workpiece	200	300	800	-		158,64	1400	158,64	160,04		
Rough milling	50	50	40	150	1450	157,19	1000	157,19	158,19	1450	1850
Finishing milling	20	-	-	100	240	156,95	200	156,95	157,15	240	1040
Thin milling	5	-	-	30	50	156,90	200	156,90	157,10	50	50
Total					1740					1740	2940

The allowances are assigned to the rest of the treated surfaces in a tabular manner.

On the basis of the obtained calculations and above, we carry out the workpiece design. Drawings of the workpiece will be given in the graphic part of the project.

3.3 Determining the amount of equipment

Operation 005 Vertical milling.

1. Milling the plane of the base on rough.

Cutting tool:

milling cutter

Д = 500 mm - the diameter of the mill;

Z = 44 – number of teeth of the mill;

ВК6 – the material of the cutting part;

System machine tool tool attachment rigid.

Cutting depth: t = 2 mm;

Feed: S_z = 0,2 mm / tooth

The life of the milling cutter T = 300 min;

Estimated cutting speed:

$$V_p = \frac{C_v Д^q}{T^m t^x S_z^y B^u Z^p} \cdot K_v \quad ; \qquad (3.31)$$

where C_v, q, x, y, u, m, p – coefficients that depend on working conditions: C_v = 445; q = 0,2; x = 0,15; y = 0,35; u = 0,2; m = 0,32; p=0.

B – milling width: B = 451 mm;

Z – number of teeth of the mill: Z = 44;

Д – diameter of the mill: Д = 500 mm;

T - the period of resistance of the mill: T = 300 min;

$К_v$ – speed factor.

$$К_v = К_{Mv} \cdot К_{Пv} \cdot К_{Hv} \; ; \qquad (3.32)$$

where $К_{Mv}$ – coefficient taking into account the quality of the surface to be treated;

$К_{Пv}$ – coefficient taking into account the state of the workpiece surface: $К_{Пv}$ = 0,85;[3] tab. 5. p. 263.

$К_{Hv}$ – coefficient taking into account the material of the cutting part of the tool, $К_{Hv}$ = 1,0;

$$К_{Mv} = \left(\frac{190}{HB}\right)^{n_v} ; \tag{3.33}$$

where HB – the hardness of the workpiece material, HB = 210;

n_v – coefficient taking into account the material of the cutting part of the tool: n_v = 1,25 [3] tab. 2. p. 262.

$$К_{Mv} = \left(\frac{190}{210}\right)^{1,25} \approx 0,9 ;$$

$$К_v = 0,9 \cdot 0,85 \cdot 1,0 = 0,77;$$

$$V_p = \frac{445 \cdot 500^{0,2} \cdot 0,77}{300^{0,32} \cdot 2^{0,15} \cdot 0,2^{0,35} \cdot 451^{0,2} \cdot 44^{0}} \approx 90,5 \text{ m / min.} ;$$

Estimated spindle speed:

$$n_p = \frac{1000V_p}{ПД} = \frac{1000 \cdot 90,5}{3,14 \cdot 500} = 57 \text{ min}^{-1} ;$$

Cutting force:

$$P_z = \frac{10C_p t^x S_z^u \cdot B^n \cdot Z}{Д^q n^w} K_{Mp} ;$$

where C_p, x, y, n, q, w – coefficients that depend on working conditions: C_p=34,5; x = 0,9; y = 0,74; n = 1,0; q = 1,0; w = 0; [3] tab. 41 p. 291.

$К_{Mp}$ – coefficient taking into account surface quality.

$$К_{Mp} = \left(\frac{HB}{190}\right)^{n} ; \tag{3.34}$$

where HB – the hardness of the workpiece material, HB = 210;

n_v – coefficient taking into account the material of the cutting part of the tool: n = 1,25; [3] tab. 9 p. 264.

$$К_{Mp} = \left(\frac{210}{190}\right)^{1,25} \approx 1,1 ;$$

$$P_z = \frac{10 \cdot 34{,}5 \cdot 2^{0,9} \cdot 0{,}2^{0,74} \cdot 451^{1,0} \cdot 44}{500^{1,0} \cdot 57^{0}} 1{,}1 \approx 8493{,}9 \text{ Н.}$$

Estimated cutting power

$$N_p = \frac{P_z \cdot V}{1020 \cdot 60}; \quad (3.35)$$

$$N_p = \frac{8493{,}9 \cdot 90{,}5}{1020 \cdot 60} = 12{,}5 \text{ kW};$$

Engine power required for metal-cutting machine:

$$N_q = N_p / \eta; \quad (3.36)$$

where η - efficiency of machine mechanisms: $\eta = 0{,}8$.

$$N_q = 12{,}5 / 0{,}8 = 13{,}9 \text{ кВт.}$$

In accordance with the required power of the engine of the machine we accept the vertically milling machine mod. 856; N_q= 15 kW.

According to the passport data of the machine, we take a true spindle speed: n_q = 63 min $^{-1}$.

Determine the estimated minute feed:

$$S_{Mp} = S_z \cdot Z \cdot n_q;$$

$$S_{Mp} = 0{,}2 \cdot 44 \cdot 63 = 554{,}4 \text{ mm / min.};$$

We take a real minute feed according to the machine passport data, S_{Mq} = 300 mm / min.;

Determine the true cutting speed:

$$V_q = \frac{\pi Д n_q}{1000};$$

$$V_q = \frac{3{,}14 \cdot 500 \cdot 63}{1000} = 98{,}9 \text{ m / min.}$$

Installation of control auxiliary and transport operations

1. Establishing control operations

1.1. Input control of workpiece details 6520Ф-3.35.00.011

- appearance: inspection for the detection of surface defects (on treated surfaces a depth of not more than 0,5 actual allowance for machining is allowed)

- control of material hardness: HB170-240
- control of the geometric dimensions of the casting

The sample size for the input control of blanks batch:

- external inspection - 100% control;
- control of material hardness - 2÷5 blanks from the batch;
- control of geometric dimensions - 2÷5 blanks from the batch.

1.2. Operational control (on the example of operation 045 vertically milling; milling the surface 3 thinly):

а) final dimensions and parameters of the work surface:

- the resulting size 20$\pm$0,575 mm;
- roughness of the treated surface R_a 1,25;
- tolerance of the machined surface parallel to the plane T = 0.03 mm.

б) the maximum permissible measurement error of the control means is determined by the dependence:

$$[\Delta] = A_{мет} \cdot T; \quad (3.37)$$

where $A_{мет}$ – the accuracy factor of the measurement method:

$A_{мет} = 0,2$

T – a controlled size tolerance: T = 1,15 mm.

When controlling the size 220$\pm$0,575 mm.

$$[\Delta] = 0,2 \cdot 1,15 = 0,23 \text{ mm.}$$

When controlling for the parallelism tolerance.

$$[\Delta] = 0,2 \cdot 0,03 = 0,006 \text{ mm.}$$

For surface roughness, we accept tolerances for the parameter R_a $\pm$ 20%

в) choice of control parameters:

- for size control2 20$\pm$0,575 – template;
- for surface roughness control - standard samples are made according to ГОСТ 9378-70 (control by comparison).

г) frequency of parameters control:

- size control 220$\pm$0,575 –100%, control is exercised by the worker;

- control of surface roughness - selective (5% of the lot), carried out by the worker.

1.3. Final (receiving) control, carried out by the controller at the control operation, the controls are subject:

- appearance (presence of all treated surfaces: chamfers, absence of faces, sinks);
- geometric dimensions;
- surface roughness (control by comparison with roughness specimens);
- tolerances of relative positioning of surfaces.

2. Installation of transport operations.

In the technological process it is necessary to provide transport operations for:

- transportation of blanks from the workroom to the machining section;
- transportation of workpieces between workplaces;
- transportation of workpieces to the heat shop and back to the machining section;
- transportation of blanks for cleaning;
- transportation of finished parts to the paint shop and back to the assembly site.

3. Installation of auxiliary operations.

The following operations should be provided as ancillary to the technological process under development:

- thermal (for removal of internal stresses after roughing);
- control (for final control after machining);
- coloring (to improve the appearance and increase the corrosion resistance of the part).

Normalization of technological process, specification of production type

Technical standards of time in the conditions of mass production are determined by the analytical method.

In batch production, the rate of artificial calculation time is determined by the formula:

$$T_{ш\text{-}к} = T_о + T_g К + T_{тех} + T_{орг} + T_{від} + \frac{T_{п.з.}}{n}\ , \qquad (3.38)$$

where $T_о$ – main time, min.; T_g – auxiliary time;

$T_{тех}$ – time for mechanical maintenance of the workplace;

$T_{орг}$ – time for organizational workplace maintenance, min.;

$T_{від}$ – time for breaks and rest, min.;

$T_{п.з.}$ – preparatory-final time, min.;

n – the number of parts in batches: n = 127 pcs.

The main operating time:

$$T_о = \sum_{i=1}^{n} \frac{l_1 + l + l_2}{S_m} i\ ; \qquad (3.39)$$

where n – he number of transitions of the operation;

l_1 – cutting value of the tool, mm;

l – length of the treated surface, mm;

l_2 – the magnitude of the tool flow, mm

S_m – minute feed at transition, mm / min.;

i – number of transitions.

Auxiliary time consists of the cost of time for individual receptions:

$$T_g = (T_{у.з.} + T_{з.д.} + T_{уп.} + T_{вим})\ К; \qquad (3.40)$$

where $T_{у.з.}$ – time to install and remove parts;

$T_{з.д.}$ – part fixing time, min.;

$T_{уп}$ – machine control time, min.;

$T_{вим}$ – measurement time, min.;

К – coefficient of production type, for batch production, К=1,5.

The time for maintenance of a workplace and rest in a large-scale production is determined by the formula:

$$T_{об.від} = \frac{T_{о.п} \cdot П_{об.від}}{100}; \qquad (3.40)$$

where $T_{о.п}$ – operational time: $T_{о.п} = T_о + T_g$;

$П_{об.від}$ – percentage of time for maintenance and rest.

Operation 005 Vertical milling.

1. Milling the plane of the base on rough

l = 600 mm is the length of the surface to be treated;

Д = 500 mm - the diameter of the mill;

$S_{хв}$ = 300 mm / min - minute feed;

i = 1 – number of passes;

l_1 = 200 mm is the value of mills incision

l_2 = 200 mm is the value mills course

$$T_о = \frac{200 + 500 + 200}{300} = 3{,}0 \text{ хв.}$$

Composition of final time preparation:

- installation of the device on the machine - 19 minutes.;
- installation of the mill - 4 minutes.;
- receipt of the tool and equipment before the start of work and delivery at the end - 7 minutes. [1]
-

$$T_{п.з.} = 19 + 4 + 7 = 30 \text{ min.}$$

It takes 3 minutes to install and remove the workpiece and its clamp. [1]

Time for machine control techniques:

- to turn the machine on and off - 0.01 min.;
- bring the item into working mode - 0.03 min.;
- move table back to length 1000 mm - 0.18 min.; [1].
-

$$T_{уп.} = 0{,}01 + 0{,}03 + 0{,}019 = 0{,}023 \text{ min.};$$

The time spent on measuring the part is 0.21 min. [1] annex 5, with control of 10% of the machined parts we get:

$$T_{шт} = \frac{0{,}21 \cdot 10}{100} = 0{,}02 \text{ min.};$$

Correction factor for batch production К=1,5.

Work time and rest time is 10% of operational time.

$$T_g = (3 + 0{,}023 + 0{,}02)\ 1{,}5 = 4{,}6 \text{ min.};$$

$$T_{оп} = 3+4{,}6 = 7{,}6 \text{ min.};$$

$$T_{об.від} = \frac{7{,}6 \cdot 6}{100} = 0{,}46 \text{ min.};$$

artificially calculating rate of time

$$T_{шт.к} = 3+ (3 + 0{,}023 + 0{,}02)1{,}5 + 0{,}46 + \frac{30}{127} = 8{,}4 \text{ min.}$$

On the basis of the calculated technical standards of the time, we clarify the type and organizational form of production.

Table 3.9 - Characteristics of TP

№ of operation	The name of the operation	$T_{шт.к}$ min.	C_{pi}, pcs.	$C_{пi}$, pcs.	$\eta_{з\ фi}$	Q_i
005	Vertically milling	8,4	0,44	1	0,44	2
010	Longitudinally milling	15,2	0,79	1	0,79	1
015	Horizontally boring	9,8	0,5	1	0,5	2
020	Horizontally boring	7,6	0,39	1	0,39	2
025	Вертикально-фрезерна	19,6/2	0,51	1	0,51	2
030	Horizontal boring with CNC	7,5	0,38	1	0,38	2
035	Horizontal boring with CNC	8,6	0,45	1	0,45	2
040	Vertically milling	10,3	0,53	1	0,53	2
045	Vertically milling	9,6	0,49	1	0,49	2
050	Horizontal boring with CNC	16,3	0,84	1	0,84	1
055	Horizontal boring with CNC	17,5	0,9	1	0,9	1
060	CNC Vertical Drilling	15,8	0,82	1	0,82	1
	Total	136,4	-	12	-	20

Similarly, we calculate for other operations, the results are summarized in the table 3.10.

Table 3.10 -Technical standards of time

Number and name of operations	T_o, min.	T_g, min.			K	$T_{оп.}$, min.	$T_{оз.в.}$, min.	$T_{шт.}$, min.	$T_{п.з.}$, min.	n	$T_{ш.к}$
		$T_{у.з.}+T_{з.в.}$, min.	$T_{у.п.}$	$T_Б$							
1	2	3	4	5	6	7	8	9	10	11	12
005	3,0	3	0,023	0,02	1,5	7,6	0,46	8,06	30	127	8,4

Vertically milling											
010 Longitudinally milling	5,8	3,5	0,032	0,09	1,5	13,6	1,3	14,96	32	127	15,2
015 Horizontally boring	3,7	3,5	0,06	0,04	1,5	8,76	0,8	9,56	30	127	9,8
020 Horizontally boring	3,4	3	0,084	0,06	1,5	6,76	0,6	7,36	30	127	7,6
025 Vertically milling	8,5	6	0,047	0,02	1,5	17,56	1,8	19,36	30	127	19,6
030 Horizontal boring with CNC	2,1	3,5	0,36	0,07	1,5	6,66	0,6	7,26	35	127	7,5
035 Horizontal boring with CNC	2,9	3	0,52	0,08	1,5	7,62	0,7	8,32	35	127	8,6
040 Vertically milling	4,5	3	0,07	0,04	1,5	9,16	0,9	10,06	30	127	10,3
045 Vertically milling	3,9	3	0,07	0,04	1,5	8,56	0,8	9,36	30	127	9,6
050 Horizontal boring with CNC	8,5	3,5	0,43	0,08	1,5	14,52	1,5	16,02	35	127	16,3
055 Horizontal boring with CNC	10,1	3	0,59	0,12	1,5	15,62	1,6	17,22	35	127	17,5
060 CNC Vertical Drilling	8,3	3,5	0,93	0,07	1,5	14,2	1,32	15,52	35	127	15,8

$$К_{з.о} = \frac{20}{12} \approx 1{,}67$$

Since $К_{з.о}$ = 1,67 according to ГОСТ 14.004-83 at $1 \le К_{з.о} \le 10$ type of production serial.

$$N_g = \frac{10000}{254} = 39 \text{ pcs;}$$

$$T_{cp} = \frac{136{,}4}{12} = 11{,}37 \text{ min.;}$$

$$Q_g = \frac{952}{11{,}37} \cdot 0{,}6 = 50 \text{ pcs.}$$

Since $N_g = 39 < Q_g = 50$ it is inappropriate to use one nomenclature production line. We accept a group form of production organization.

$$n = \frac{10000 \cdot 3}{254} = 118\,; \qquad C = \frac{11{,}37 \cdot 118}{0{,}5 \cdot 952 \cdot 0{,}75} = 3{,}8\,;$$

We accept $C_{пр} = 4$; $\eta_{пр} = \frac{0{,}5 \cdot 952 \cdot 0{,}75 \cdot 4}{11{,}37} = 125$ pcs.

Conclusion: type of production: multi-serial, form of production organization - group.

Control devices:

Devices for controlling the perpendicularity tolerance need to be developed: the plane of attachment of the cover to the plane of the base (perpendicularity tolerance δ = 0,050 mm) the axis of the holes ∅22 H7 to the plane of the base (perpendicular tolerance δ = 0,020 mm).

3.4 Design of special equipment and tools

Choice of technological equipment. Selection and justification of operation principle of the device, block diagram

Output data:

- type of production - serial;
- release program - N = 10,000 pcs.;
- basing schemes - according to the section 2.;
- cutting forces - according to section 2.

1. The milling device.

The device is used on a vertical milling machine mod. 656 for roughing the plane of the base of the body part. When designing the device, it is necessary to ensure the rigidity of the structure with large dimensions of the parts, the uniformity of the allowance to be removed, a relatively large clamping force.

2. Boring device.

The device is used on a horizontal boring machine mod. 2A620 for roughing holes ∅45H8; ∅72 I_s 7; ∅90 I_s 7. When designing the device, it is necessary to ensure horizontal placement of the axes of the holes, use as the mounting base of the plane perpendicular to the axis of the holes, providing for the tool to be set to the desired size.

3.1.2 Power calculation of drive parameters

a) milling device

Calculation formula for determining the clamping force.

$$P_z < 2Q + T \qquad (3.41)$$

where P_z – tangential component of cutting force: P_z = 849H;

Q – clamping force; T – the friction force between the surfaces of the support and the workpiece.

Taking into account the factor of safety of fixing.

$$K = K_1 \cdot K_2 \cdot K_3 \cdot K_4 \cdot K_5 \cdot K_6\ ; \qquad (3.42)$$

where K_1 – warranty ratio: K_1 =1,5;

K_2 – coefficient depending on the condition of the surface to be treated: K_2=1,3;

K_3 – coefficient taking into account the increase in clamping force when blunting the tool: K_3 = 1,5;

K_4 – coefficient depending on the constancy of the clamping force: K_4=1,0;

K_5 – a factor that takes into account the type of drive: K_5 = 1,0;

K_6 – coefficient depending on working conditions: K_6 =1,2. [3] p. 85.

$$K = 1{,}5 \cdot 1{,}3 \cdot 1{,}5 \cdot 1{,}0 \cdot 1{,}0 \cdot 1{,}2 \approx 3{,}5$$

$$к\, P_z < 2Q + T \qquad (3.43)$$

From the calculation scheme:

$$T = (Q + P_y)\, f = (Q + 0{,}5P_z)\, f \qquad (3.44)$$

where f – coefficient of friction: f = 0,2

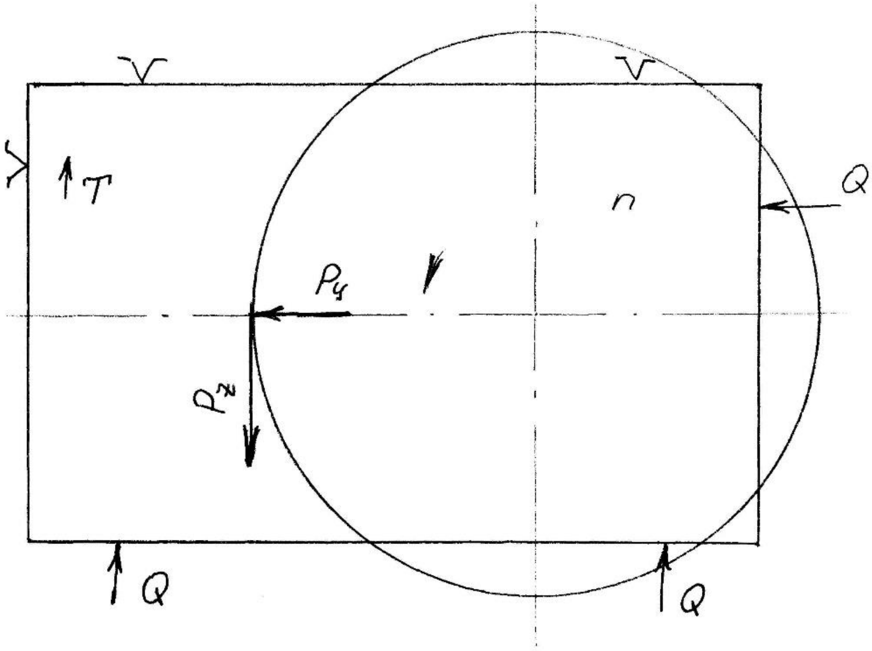


Figure 3.6 - Calculation scheme

$$\text{к } P_z = 2Q + (Q + 0{,}5P_z)\, f \qquad (3.45)$$

$$Q = \frac{кP_z - 0{,}5P_z \cdot f}{2 + f} \qquad (3.46)$$

$$Q = \frac{3{,}5 \cdot 8494 - 0{,}5 \cdot 8494 \cdot 0{,}2}{2{,}2} = 13127{,}1H$$

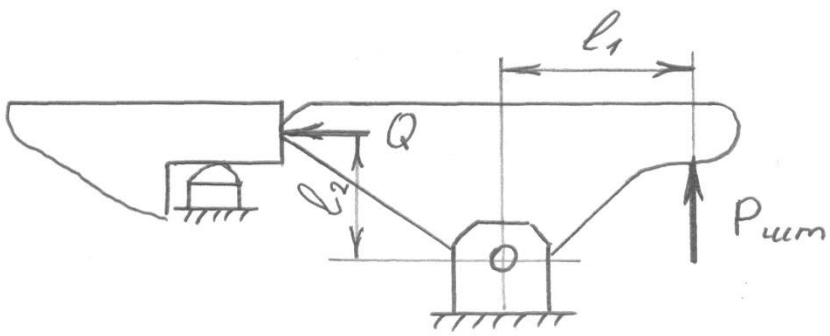


Figure 3.7 - The design scheme for determining the force on the drive shaft

l_1 =80 mm; l_2 =60 mm

$$Q\, l_2 = P_{шт}\, l_1; \qquad (3.47)$$

$$P_{шт} = \frac{Ql_2}{l_1} = \frac{13127 \cdot 60}{80} = 9845H \,.$$

To secure the workpiece in the milling device, we take a hydraulic cylinder with a working pressure of 10 MPa, force on the rod $P_{шт}$=9845H.

Hydraulic cylinder

Accuracy calculation

Since the device is a link of the system, the accuracy of the workpiece depends largely on the accuracy of its manufacture, installation on the machine, the wear resistance of the mounting elements.

The total error of the device during the operation is determined by the formula:

$$E_{\Sigma} = \kappa \cdot \sqrt{E_{в}^2 - E_{р.п.}^2 + E_{р.у}^2 + E_{б}^2 + E_{з}^2 + E_{рн.е.}^2 + E_{п.д.}^2 + E_{н.}^2 + 3E_{р.з.}^2 + 3E_{t}^2 + E_{зн}^2} \qquad (3.48)$$

where $E_в$ – machine error in unloaded condition;

$E_{р.п.}$ - ocation of the device on the machine table;

$E_{р.у}$ - device error due to inaccuracy of the mounting elements;

$E_б$ – base error;

$E_з$ – fixing error;

$E_{р.н.е}$ – error of device guides;

$E_{п.д.}$ error of elastic deformations;

$E_н$ – device setup error on this machine;

$E_{р.з.}$ – error in cutting tool wear;

E_t – error of temperature deformations;

$E_{зн.}$ – wear error;

к - coefficient of distribution of random variables. Depending on the number of applications к = 1,2 at n = 3 ÷ 5; к = 1,1 at n = 6 ÷ 8; к = 1 at n = 8 ÷ 11

[4]

a) milling device.

$E_в$ - tolerance for the parallelism of the surface of the table on which the device 020/1800 mm is mounted, listed for the length of the workpiece L = 600 mm. is.

$$E_в = \frac{0,20 \cdot 600}{1800} \approx 0,07mm \; ;$$

$E_{р.п.}$ – the device is centered on the machine using keyholes that fit into the groove of the table with a gap 18 $\frac{H10}{H9}\left(\frac{+0{,}027}{-0{,}018}\right)$. Then,

$$E_{р.п.} = \frac{S_{\max}}{L} = \frac{0{,}045}{740} = 0{,}00006\ mm;$$

$E_{р.у}$ = 0,25 mm. (see assembly drawing).

$E_б$ = 0

$E_з$ – we assume zero.

Other errors are taken into account by entering the coefficient of distribution of random variables к = 1,2. Then the total error of the device will be:

$$E_{\Sigma} = 1{,}2\sqrt{0{,}07^2 + 0{,}00006^2 + 0{,}25^2} = 0{,}315\ \text{mm.};$$

Since the total error E_{Σ} = 0,315 mm: significantly smaller size tolerance 20, T_{20} = 0,52 mm .; we conclude that this device provides the necessary processing accuracy.

б) device for boring.

The tool (drill) is exposed to the size of the bushing.

$$E_{р.н.е} = E_1 + E_2 + E_{пр}, \qquad (3.49)$$

where E_1 - an error equal to the maximum clearance between the sleeve and the finger at the base of the bar with the guide sleeve, when landing H8/g7 E_1 = 0,025 mm;

E_2 – error of beating the outer and inner diameter of the bushing. E_2 = 0,005 mm [4]

$E_{пр}$ – the error of the tool being skewed in the bushing.

$$E_{пр} = \frac{S_{\max}}{2L}(L + 2a), \qquad (3.50)$$

where S_{max} – maximum clearance between the outer diameter of the axial tool and the inner diameter of the bushing (connection F8/h9, S_{max} = 0,04 mm);

L – height of the bushing; L = 30 mm;

a – the gap between the bushing and the part, a = 9 mm;

Then: $E_{пр} = \dfrac{0{,}04}{2 \cdot 30}(30 + 2 \cdot 9) = 0{,}039 mm$;

$E_{р.н.е} = 0{,}025 + 0{,}005 + 0{,}039 = 0{,}069$ mm.

$E_б$ - base error $E_б = 0$;

$E_з$ – fixing error $E_з = 0$;

$E_{р.п.}$ – the device is centered on the machine using keyholes that fit into the groove of the table with a gap $18\dfrac{H10}{h9}\left(\dfrac{+0{,}027}{-0{,}018}\right)$. Then

$$E_{р.п.} = \frac{S_{max}}{L} = \frac{0{,}045}{440} = 0{,}00001\ mm.$$

Other errors are accounted for by the random variable distribution к = 1,1. Then the total error of the device will be:

$$E_{\Sigma} = 1{,}1\sqrt{0{,}025^2 + 0{,}005^2 + 0{,}039^2 + 0{,}0001^2} = 0{,}105 mm.$$

Because the total error of the device is less than the tolerance on the size 28. T_{28} = 0.210 mm, which determines the position of the axis of the hole can be considered that the designed device provides the necessary precision machining.

в) calculation of the control device for accuracy.

The tolerance of the perpendicularity of the hole axis to the plane of the base, which shall be not more than 0,020 mm, is controlled.

- The measurement error depends on:
- - error of the indicator - 0,005 mm;
- - the maximum clearance in the transmission links of device - 0,003 mm;
- - tolerance of the alignment of the mandrel ends, which is 0.004 mm;
- - the gap between the bushing and the mandrel is 0.003 mm.
- - the gap between the bushing and the part.

All these requirements are shown in the drawing of the detail.

Other errors are taken into account by entering the coefficient of distribution of random variables к = 1,2.

$$E_{\Sigma} = 1{,}2\sqrt{0{,}005^2 + 0{,}003^2 + 0{,}004^2 + 0{,}003^2} = 0{,}00 mm.$$

Since the total error of the device is less than the tolerance of the perpendicularity of the axis of the hole to the plane of the base, it can be assumed that the designed device provides the necessary measurement accuracy.

To determine cost effectiveness, compare the two values of the technological cost of processing the workpiece on this operation when using old and new devices.

$$С_с = З_с \left(1 + \frac{Z}{100}\right) + \frac{S_c}{N}\left(\frac{1}{i} + \frac{q}{100}\right) ; \qquad (3.51)$$

$$С_н = З_н \left(1 + \frac{Z}{100}\right) + \frac{S_н}{N}\left(\frac{1}{i} + \frac{q}{100}\right) ; \qquad (3.52)$$

where $З_с$, $З_н$ – respectively, the basic salary when performing an operation using old and new devices;

z – shop overheads; (we accept 200%);

q – device operating factor: q = 0,2 [4] ;

i - device life: i = 3 years, [4] ;

N = 10 000 pcs.;

$S_с$, $S_н$ – respectively the cost of running the old and new devices.

Determine the technological cost of the milling operation.

- when using an old device design.

$$С_с = 0{,}021 \left(1 + \frac{200}{100}\right) + \frac{480}{10000}\left(\frac{1}{3} + \frac{20}{100}\right) = 0{,}103 ;$$

- when using a new device design.

$$С_н = 0{,}011 \left(1 + \frac{200}{100}\right) + \frac{560}{10000}\left(\frac{1}{3} + \frac{20}{100}\right) = 0{,}08 ;$$

The cost of manufacturing an old device $S_с$ = 480 UAH.; new $S_н = n\ С_н$, where n = 28 det.; $С_н$ = 20 UAH. (device is simple) then $S_н$ = 28 * 20 = 560 UAH.

The economic impact of using a new device based on an annual release program:

$$E = (С_с – С_н) * N = (0{,}103 – 0{,}08) * 10000 = 2300 \text{ UAH.}$$

Description of the design of the accessories:

a) milling device.

The device consists of a molded housing on which the supports for the base of the workpiece are mounted. Three hydraulic cylinders are mounted in the housing, which by means of the rocker arms fix the workpiece in the required position. To place the milling cutter on the required size of the housing is installed institutions. On the table of the machine tool body is based with the help of two keyholes and fastened through the grooves with four bolts.

б) device for boring.

The device consists of a welded housing on which supports are mounted to base the workpiece. In the case are mounted two hydraulic cylinders, which with the help of two wedges, rocker arms and four 2-shaped grips secure the workpiece in the desired position. For insertion of the tool on the necessary size in the device the folding guide bushing is provided. The machine tool table is supported by two keyholes on the table and fastened through the grooves with bolts.

For the automatic collection of chips on the machines, local removal of cast iron chips and dust is installed.

4 PROJECT PART

4.1 Determination of the main and auxiliary areas of the shop

Mechanical shops consist of main and auxiliary sections. The main sections are not manufactured at the auxiliary sections, but they are necessary for the normal operation of the main ones. These include:

- sharpening section;
- section for setting up tools for CNC machines;
- shop repair base.

1. The sharpening section is used for sharpening of the cutting tool. The required number of sharpening machines is determined as a percentage of the metal-cutting equipment of the shop – 5% [4] table. 14.3., Which is: 150. 0.05 = 8 machines.

2. Section for setting up tools CNC machines.

The typical composition of the equipment and equipment of the site is based on data [5]

- the device for adjustment of tools to lathes group machines;
- table under the device of the BV-2026 model;
- the device for adjustment of tools to machines of drilling-milling and boring group;
- rack for tools;
- rack for mandrels;
- metalwork workbench;
- tool cabinet;
- table for the controller;
- control plate;
- table under the control plate;
- the device for check of details on beating;
- rack for devices;

- production table.

3. Shop repair base (CRB) is used for maintenance of production equipment. The number of machines is accepted depending on the number of basic equipment.

Let's make an approximate calculation of the area of the shop:Виробничої для механічних дільниць:

$$F_{вир} = C_р \cdot F_{верст} ; \quad (4.1)$$

where $C_р$ – accepted quantity in the shop: $C_р$ = 150 pcs.;

$F_{верст}$ – the area is necessary for one machine at its average dimensions: $F_{верст} = 15 \div 25$ m^2 ;

$$F_{верст} = 150 \cdot 20 = 3000 \text{ m}^2 .$$

Auxiliary offices:

а) tool sharpening.

Normative value of the area allotted for one machine $F^{н}_{зат.вер}=10$m^2[8].

Area required for 8 machines:

$$F_{зат.\,8} = F^{н}_{зат.вер} \cdot 8 = 10 \cdot 8 = 80 \text{ m}^2 ;$$

б) repair base (CRB)

The specific area under one machine is: $F^{н}_{црб.вер}$ = 25 m^2[8]. The area is required for 4 CRB machines:

$$F_{црб} = F^{н}_{црб.вер.} \cdot 4 = 25 \cdot 4 = 100 \text{ m}^2 ;$$

в) adjustment of tools of CNC machines.

$$F_{н.і} = 96 \text{ m}^2 ;$$

г) control department.

Selected from the calculation $F_н$ = 5-6 m^2 per controller with a factor $K_н$ = 1,75, taking into account the increase in area for the location of control equipment [8].

The number of controllers is determined as a percentage of the number of machine operators and is 5-7% [8].

At two-shift work we accept p = 8

Then

$$F_{к.в.} = p \cdot F_k \cdot K_k = 8 \cdot 5 \cdot 1{,}75 = 70 \text{ m}^2 ;$$

e) compositions of metal, blanks, parts.

The area of the warehouses of parts and assemblies is calculated by the formula:

$$S_1 = \frac{A_1 \cdot Q_1}{q \cdot k \cdot m}, \quad (4.2)$$

where A_1 – storage time of details, knots, semi-finished products: A1 = 4 days [8] table. 20 p.189;

Q_1– mass of parts passing through the warehouse for the year, tone;

q – allowable load area of the warehouse: q = 1.5 t / m ^{2} [8]p. 187;

κ – the utilization factor of the warehouse area, taking into account the aisles and passages: κ = 0,6 [4] p. 173;

m– number of working days per year: m = 254.

$$Q = m_в N, \quad (4.3)$$

where $m_в$ - node mass; m = 125 kg (based on factory data);

N – annual program; N = 10 000.

$$Q_1 = 125 \cdot 10\,000 = 1250 \text{ t.}$$

$$S_1 = \frac{4 \cdot 1250}{1{,}5 \cdot 0{,}6 \cdot 254} = 22 \text{ m}^2 .$$

The area of metal compositions and workpieces is determined by a similar formula:

$$S_2 = \frac{A_2 \cdot Q_2}{q \cdot k \cdot m} \quad (4.4)$$

where A_2 – time of storage of preparations in a warehouse; A_2 = 4 days [8];

Q_2 – mass of blanks;

$$Q_2 = \frac{Q_1}{K_{в.м}}; \quad (4.5)$$

where Q_1 - the mass of parts passing through the warehouse: Q_1= 1250 t.;

$К_{в.м}$– material utilization factor: $К_{в.м}$= 0,65

$$Q_2 = \frac{1250}{0{,}65} = 1923 \text{ t.}$$

$$S_2 = \frac{4 \cdot 1923}{1{,}5 \cdot 0{,}6 \cdot 254} = 34 \text{ m}^2 .$$

Total area:

$$S = S_1 + S_2 = 22+34\ 56 \text{ m}^2 ;$$

ж) premises ZOR and chip processing. This area is determined based on the consumption of lubricants by the formula:

$$Q_м = \frac{q_м \cdot C_п \cdot 254}{1000} = \frac{0{,}2 \cdot 150 \cdot 254}{1000} = 7{,}62 \text{ t.}$$

Emulsion costs:

$$Q_e = \frac{q_e \cdot C_п \cdot 254}{1000} = \frac{2{,}0 \cdot 150 \cdot 254}{1000} = 76{,}2 \text{ t.}$$

Where $q_м$, q_e – consumption of lubricants and emulsions per machine per day, kg;

$C_п$ – number of machines in the shop, pcs.;

254 – number of working days per year.

The area of the chip processing room is set from the condition 1m^2 area per unit of technological equipment of the mechanical shop.

$$F_{зор.стр} = C_п \cdot 1м^2 = 150 \cdot 1 = 150 \text{ m}^2 \quad ;$$

з) total area of auxiliary offices.

$$F_{заг}^{доп} = F_{зат.д} + F_{црб} + F_{м.і} + F_{к.п} + F_{скл} + F_{зор.стр} \qquad (4.6)$$

$$F_{заг}^{доп} = 80 + 100 + 96 + 70 + 56 + 150 = 552 \text{ m}^2 .$$

е) office and domestic premises.

The area of administrative and office premises is calculated 4 m^2 per ITR, and their number is taken within 7-10% of the number of key workers, the number of ILO is 1 … 2% of the number of ITR.

At 300 people. Main number of ITR workers will be 24 people., and the ILO – 3 people.

The total area of the premises will be

$$F_{с.п.п} = p\ F_{пит} = 27 \cdot 4 = 108 \text{ m}^2 .$$

The area under the vacationer is a corner 0,9 m^2 per employee.

$$F_{в.к} = 324 \cdot 0{,}9 = 292 \text{ m}^2 .$$

The area under the dining room and buffet is selected at the rate 1 m^2 area per employee per shift, then:

$$F_{ст.в} = 150 \cdot 1{,}0 = 150 \text{ m}^2 .$$

The area of sanitary facilities (medical centers, locker rooms, showers, toilets) is selected from 0,9 m^2 per employee, when the shop employs more than 100 people.

$$F_{с.т.п} = 177 \cdot 0{,}9 = 159 \text{ m}^2 .$$

j) the total area of the mechanical shop.

The total area of the mechanical shop is equal to the sum of production and auxiliary departments without taking into account the area of office space:

$$F_{цех.р} = F_{вир} + F_{заг.}^{доп.} ; \quad (4.7)$$

$$F_{цех.р} = 3000 + 800 + 552 = 4352 \text{ m}^2 .$$

4.2 Development of plans for the layout of the shop and placement of equipment on the site

The choice of the grid of columns and setting the dimensions of the shop is based on the total estimated area of the shop based on the use of unified standard sections of the frame of the building in accordance with the recommendations [8]. In our case for a faceless shop the grid of columns happens the sizes 12 x 18 m and width and length of shop will be equal: 12. 4 = 48m and 18. 5 = 72m respectively.

Then the area of shop is accepted:

$$F_ц = а \cdot в = 48 \cdot 90 = 4320 \text{ m}^2 ,$$

which corresponds to the calculated value.

The building of the shop is taken in a rectangular shape, a grid of columns 12.18 m, the height of the shop 7,2 m[8] p. 399.

Number of passages – one main and two transverse. Auxiliary compartments will be located along the span of the wall columns. The warehouses are located perpendicular to the wall columns on the end side of the shop.

The layout of the production departments of the shop.

For this production with a group organizational form of work, the location scheme is performed in accordance with the developed route of the technological process of machining.

Diagram of the relative position of vehicles.

Associated with the type of production according to the manufacturing process of the product.

Due to the fact that for the manufacture of parts «Housing» 6520Ф-3.35.00.011 8 units of metal-cutting equipment are needed, namely machines:

vertical milling mod. 656;

vertical milling mod. 654;

horizontal boring mod. 2620Г-1;

horizontal boring with CNC mod. 2А620Ф2;

longitudinal milling mod. 6606

horizontal boring with CNC mod. 2М614Ф2;

milling-drilling-boring with CNC mod. 6906 ВМФ-2;

vertically drilling with CNC mod. 2Р135Ф2.

All equipment is located in two rows.

Transportation of blanks from the warehouse to the site and parts to the warehouse is carried out in the container by forklift. For transportation of details between machines we use the crane beam.

5.OCCUPATIONAL HEALTH AND SAFETY IN EMERGENCIES

5. 1 Microclimate of the production room

Clean air of the required chemical composition, optimum temperature, humidity and speed of its movement is essential for the normal functioning of the worker. Creation in the working zone of metal-cutting machines of the necessary meteorological conditions has a good effect on an organism, promotes well-being, considerably increases safety of work, provides a high degree of working capacity.

Therefore, meteorological conditions in the working areas of machine tools must meet regulatory requirements. As for the air temperature, it should be: in the cold period of the year - 18 - 20^0; in the warm period of the year - 21 -23^0. Regarding the relative humidity, regardless of the period of the year, its value should not exceed 75%. Exceeding the relative humidity relative to the established norms has a negative impact on the health of workers. Regarding the speed of air movement: it should be in the range of 0.2 - 0.3 m / s. Exceeding or reducing the speed of air movement in accordance with the established norms also has a negative impact on the health of workers. In accordance with regulations, the values of temperature, relative humidity and air velocity are set for the working area of production facilities depending on the category of severity of work performed, the amount of excess heat released in the room and the period of the year.

The category of work is the distribution of work based on the total energy expenditure of the body, which is measured in joules per second. For our case, the given normative values correspond to the average severity of the category of works. Regarding the thermal regime, depending on it, there are rooms with insignificant and significant excesses of obvious heat. Explicit heat means heat that enters the room from equipment, heaters, heated materials and other sources, which affects the temperature in the room. So, in our case, according to [2], a room with a slight excess of heat is used, for which the above normative values are set.

5.2 Calculation of protective earthing of the horizontal boring machine of the model 2620

Protective grounding of the horizontal boring machine model 2620 is performed to determine the required number of vertical electrodes, which would provide the required resistance of the grounding mechanism to the spread of current or contact voltage when closing the phase to grounded parts of the machine, not exceeding the permissible values.

For grounding of metal-cutting machines the most widespread are artificial group grounding conductors placed in the homogeneous earth on a certain depth. They are a system of vertical electrodes connected in parallel by a horizontal guide. For our case we choose the scheme of placement of electrodes in a row (fig. 1).

Determine the size of the electrodes.

According to [2] we use steel rods with a diameter of d = 12 mm, length l = 4 m. The distance a between adjacent electrodes:

$$a = 2\,l = 2\times 4 = 8 \text{ m.} \qquad (5.1)$$

Estimated distance t:

$$t = t_0 + l\ /\ 2 = 0{,}7 + 4 / 2 = 2{,}7 \text{ m.} \qquad (5.2)$$

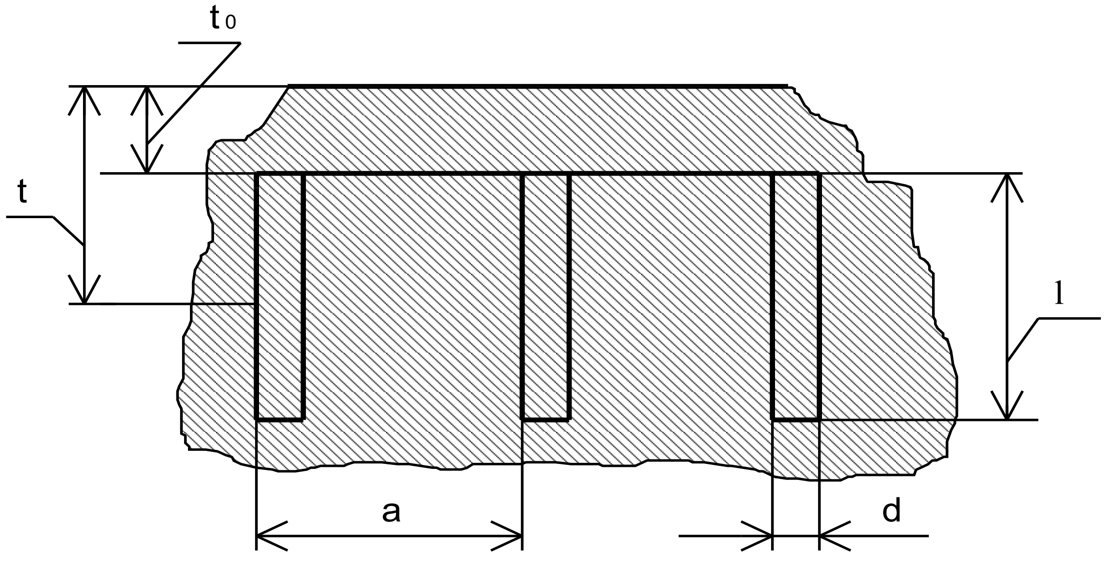


Figure 5.1-Scheme of electrode placement

Determine the resistance of a single vertical electrode [2]:

$$R_b = r_1 / 2п\, l\ (\ln\ 2l / d + 0{,}5\ \ln 4t + l\ /\ 4t - l), \qquad (5.3)$$

where r_1 - soil resistance, Ohm / m;

l, d, t - electrode characteristics, m

$$r_1 = r_{табл} \times\ z;$$

$$r_{табл} = 50\ Ohm / m.$$

At the size z = 1,3.

Тоді: $r_1 = 50 \times\ 1{,}3 = 65$ Ohm / m**.**

So:

$R_b = 65 / 2\times 3{,}14 \times 4\ (\ln 2 \times 4 / 0{,}012 + 0{,}5 \ln 4\times 2{,}7 + 4 / 4 \times 2{,}7 - 4) = 5{,}2$ Ohm.

According to [2] the number of vertical electrodes *n* is defined as follows. Preliminarily determine the product of the utilization factor of vertical electrodes u_b on their number *n*:

$$ub \times n\ = R\,b\ /\ R_{доп1}, \qquad (5.4)$$

where $R_{доп1}$ - the maximum allowable resistance of an artificial grounding conductor, Ohm / m.

According to the table. 8.16 [2] determine the number of vertical electrodes n.

Given that natural grounding in this case is not used, according to the recommendations [2] we accept: $R_{доп1} = R_{доп}$, that is, the maximum allowable resistance of the artificial ground is assumed to be equal to the allowable value of the resistance of the grounding structure according to the PEU.

So: $R_{доп} = 4$ *Ohm.*

Then: $u \times n = 6 / 4 = 1{,}5$.

According to the table. 8.16 [2] for a certain value of the product u x n, using the method of interpolation and rounding the value to the smaller integer, we find the required number of vertical electrodes for grounding the machine: n = 2.

Determine the resistance of the horizontal conductor, which is a steel strip with a width of b, connecting the upper ends of the vertical electrodes:

$$R_1 = \frac{r_2}{2\pi L}\ln\frac{2L^2}{bt_0} \qquad (5.5)$$

where $r_2 = r_1$ = 65 Ohm / m, в = 0,02 m;

L - length of horizontal conductor, m.

When placing the electrodes in a row [2]:

$$L = 1{,}05\ (n - 1) \times a. \qquad (5.6)$$

Тобто L = 1,05 (2 - 1) × 8 = 10,5 m**.**

Then:

$$R_1 = \frac{65}{2\cdot 3{,}14\cdot 10{,}5}\ln\frac{2\cdot 10{,}5^2}{0{,}02\cdot 0{,}7} = 0{,}8\,Ом$$

The resulting resistance of the artificial group grounding [2]:

$$R_i = R_b \times R_1 / (R_b \times u_г + R_1 \times u_b \times n), \qquad (5.7)$$

where $u_г$ and u_b - coefficients of use of horizontal and vertical electrodes. According to [2]:

$u_г = 0{,}94$; $u_b = 0{,}91$

Then:

$$Ri = 5{,}2 \times 0{,}8 / (5{,}2 \times 0{,}94 + 0{,}8 \times 0{,}91 \times 2) = 2{,}35\ Ohm.$$

Because R_i<$R_{доп}$ (2,35 Ohm <4 Ohm), the calculation of the grounding of the machine is performed correctly.

5.3 Characteristics of natural disasters, accidents (catastrophes) and their consequences

Natural disasters - a natural phenomenon (earthquake, flood, avalanches, hurricanes, cyclones, typhoons, fires, volcanic eruptions and others), which are extraordinary and which lead to disruption of normal population, death, destruction and destruction of property.

Natural disasters can occur both independently of each other and in a relationship: one of them can lead to another. Some of them often arise as a result of not always reasonable activity (forest and peat fires, industrial explosions in mountainous areas, etc.).

Regardless of the source, natural disasters are characterized by significant scales and varying lengths - from a few seconds and minutes (earthquakes, avalanches) to several hours, days (landslides) and months (floods).

Earthquakes are strong vibrations of the earth's crust that are caused by tectonic or volcanic causes and that lead to the destruction of buildings, premises, fires and human losses.

The main characteristics are: depth of fire, magnitude and intensity of energy on the earth's surface.

The depth of an earthquake fire is usually in the range of 10 to 30 km, in some cases it can be much greater.

Earthquakes cause other natural disasters, such as landslides, avalanches, tsunamis, floods (due to breakthroughs of rafts), fires (damage to oil storage and rupture of gas pipelines), damage to communications, power lines, water supply and sewerage, chemical accidents. productions with leakage (spill) SDOR, and also on automatic telephone exchanges with leakage (emission) of mercury substances in the atmosphere and others.

To protect against earthquakes, seismically dangerous zones are detected in different regions, so-called seismic zoning is carried out. Such zones provide for various measures of protection, from compliance with the requirements and rules for the construction and reconstruction of buildings and other facilities to the suspension of hazardous industries (chemical plants, automatic telephone exchanges, etc.).

Floods are significant flooded areas as a result of rising water levels in rivers, lakes, reservoirs, which are caused by various reasons (precipitation, dam collapses, etc.). Floods cause great material damage and lead to human casualties.

Immediate material damage from floods is damage to and destruction of houses, highways, power lines, damage to agricultural land, etc.

Floods can be accompanied by fires due to breaks and short circuits of electrical cables and wires, as well as ruptures of water and sewer pipes, electrical, television and telegraph cables that are in the ground, due to subsequent uneven soil precipitation.

The main directions of flood control are to reduce the maximum flow of water in the river by redistribution of runoff (planting of forest protection strips, orc of land across the slopes, etc.).

In addition, to protect against floods widely used method -dam. To eliminate dangerous formations of congestion are directed, clearing and deepening of certain sections of the riverbed, as well as the destruction of ice by explosions.

Nuthatches are a sliding mixture of rocks down the slope, which occur due to imbalance, which is caused by various reasons (washing the rock with water, weakening their strength due to precipitation, systematic shocks, unreasonable agricultural activities, etc.).

Nuthatches can be on all slopes with a slope of 20º or more at any time of year. They differ not only in the speed of displacement of the rock (slow, medium and fast), but also in their scale. The speed of slow displacements of the rock is several tens of centimeters per year, medium - a few meters per hour or per day and fast - tens of kilometers per hour or more.

Rapid displacements include creeping streams, when solid material mixes with water, as well as snow and snow avalanches. It should be emphasized that only rapid landslides can cause catastrophes with human losses.

Nuthatches can destroy settlements, destroy agricultural land, be dangerous in the operation of quarries and mining, damage communications, tunnels, pipelines, telephone and electrical networks, dams.

The most effective protection against crawlers is to prevent them. From a complex of preventive actions it is necessary to note collecting and removal of surface waters, artificial transformation of a relief (in a zone of possible separation of the earth reduce loadings on slopes), fixing of a slope by means of building basic walls.

Avalanches are creeps and occur as well as other displacements. The forces of adhesion of snow exceed a certain limit, and gravity causes the displacement of snow masses on the slope. An avalanche is a mixture of snow crystals and air. Dimensional avalanches occur on slopes of 25º-60 °. Smooth grassy slopes are the most avalanche-prone. Bushes, large rocks and other obstacles hold back the avalanches that have occurred. Avalanches are very rare in the forest.

Avalanches cause material damage and are accompanied by death. Avalanche protection can be passive and active. With passive protection, avoid the use of avalanche-prone slopes or place barrier shields on them. With active protection, avalanche-prone slopes are shelled, causing the displacement of small dangerous avalanches, thus preventing the accumulation of critical masses of snow.

Storms are winds with a force of 12 points on the Beaufort scale, ie winds whose speed exceeds 32.6 m / s (117.3 km / h).

Storms are also called tropical cyclones, which occur in the Pacific Ocean off the coast of Central America; in the Far East and in the Indian Ocean storms are called typhoons. During tropical cyclones, wind speeds often reach 50 m / s. Cyclones and typhoons are usually accompanied by heavy torrential rains.

Storms on land destroy buildings, communication lines and power lines, damage communications and bridges, break and uproot trees; when propagating over the sea, they cause large waves 10-12 m or more high, damage or even destroy ships.

Storms and stormy winds (their speed on the Beaufort scale from 20.8 to 32.6 m / s) in winter can lift large masses of snow into the air and cause snowstorms, which leads to blizzards, traffic and rail traffic, disruption of water systems -, gas -, power supply and communication.

Modern methods of weather forecasting allow to warn the population about the approach of storms (storms) in a few hours and even days, and the Central Election Commission can provide the necessary information about the possible situation and necessary actions in situations that have arisen.

The most reliable protection of the population from storms is the use of protective buildings (metro, storage, underground passages, basements, etc.). at the same time it is necessary to consider possible flooding of sites and to choose protective storages on the raised sites of district.

GENERAL CONCLUSIONS

In this work the analysis of the current technological process of mechanical processing of the part "Corp" 6520Ф-3.35.00.011 is carried out and the main directions of its improvement are highlighted, the design of the workpiece for manufacturability is worked out. The economic justification of the workpiece choice and the allowances for the submitted machining are provided. The optimum variant of technological process which is selected by the method of sorting and comparison with the minimum technological cost of machining operations is developed. For the obtained variant, the calculation of cutting and rationing modes of machining operations was carried out.

REFERENCES

1. Руденко П.О. Проектування технологічних процесів умашинобудуванні: Навчальний посібник. – К.: Вища школа, 1993. – 414с.
2. Гжиров Р.И., Серебреницкий П.П. Программирование обработки настанках с ЧПУ. – Л.: Машиностроение, 1990. – 588 с.
3. Когут М.С. Механоскладальні цехи та дільниці у машинобудуванні:Підручник. – Львів: Видавництво державного університету „Львівськаполітехніка”, 2000. – 352с.
4. Охрана труда в машиностроении / Под ред. Е.Я. Юдина. Учебник для вузов. – М.: Машиностроение, 1976. – 335 с.
5. П.Т.Эгоров, И.А.Шляхов, н.и. Алабин. Гражданская оборона. Учебник для вузов. Изд. 3-е перераб. М., Высшая школа, 1977-303с.
6. Боженко Л.І. Технологія машинобудування. Проектування тавиробництво заготованок: Підручник – Львів: Світ, 1996. – 368 с.
7. Ю.В.Боровский, Г.Н.Жаворонков, Н.Д. Сердюков, Е.П.Шубин. Гражданская оборона: Учеб. Для студентов. Под ред.. Е.П. Шубина. – М.:Просвещение, 1991. – 223с.
8. А.С. Проников, Н.И. Хамышний, Л.И. Волчкович, М.М. Кузнецов и др. Металлорежущие станки и автоматы: Учебник для машиностроительных вузов. Под ред. А.С. Проникова. – М.: Машиностроение, 1981. – 479с.
9. Мягков В.Д. и др. Допуски и посадки: Справочник. В 2т. – Л.:Машиностроение, 1982. – 543 с.
10. Справочниктехнолога-машиностроителя. В 2-х т. Т.1 / Под ред. А.Г.Косиловой и Р.К.Мещерякова. – М: Машиностроение, 1985. – 656 с.
11. Pankiv V., Хуссейн Омар Ашраф Абдельбаки Салем. Дослідження технологічного процесу свердління Зб. Тез Матеріали IV міжнародної студентської науково-технічної конференції «Природничі та гуманітарні науки. Актуальні задачі ».– Тернопіль 28-29 квітня 2021.: ТНТУ, 2021. С.55.

12.Губанова А.А. Повышение эффективности фрезерования концевыми фрезами за счет управления динамикой процесса/ А.А. Губанова // Вестник Дон. гос. техн. ун-та, 2017. №4 (7). С. 23–38.25

13. Заковоротный В.Л. Определение оптимальных координат переключения циклов обработки в эволюционной динамической системе резания/ В.Л. Заковоротный, В.П. Лапшин, А.А. Губанова // Изв. вузов. Сев.-Кавк. регион. Техн. науки, 2014. № 4 (179). С. 59–63.

14. Заковоротный В.Л. Особенности формирования притягивающих многооообразий в окрестности стационарных траекторий попутного фрезерования концевыми фрезами / В.Л. Заковоротный, А.А. Губанова, А.Д. Лукьянов // Вестник Дон. гос. техн. ун-та, 2016. № 3 (86). С. 23–38.

15. Губанова А.А. Виброакустическая диагностика фрезерования концевыми фрезами / А.А. Губанова, Н.Н. Черненко // Юбилейная конференция студентов и молодых ученых, посвященная 85-летию ДГТУ. [Электронный ресурс]. Сб. трудов. науч.-техн. конф. Ростов-наДону, 2015. С. 5089–5091.

16.Automated fixture configuration for rapid manufacturing planning / S.Nelaturi, A. Rangarajan, C. Fritz, T. Kurtoglu // Computer-Aided Design. – 2014. – Vol. 46. – P. 160–169. 102

17.Finite element modelling and analysis of workpiece-fixture system / N. M. Kumbhar, G. S. Patil, S. S. Mohite, M. A. Sutar // International Journal of Applied Research in Mechanical Engineering. – 2012. – Vol. 2. – P. 60–65.

18. Asante J. N. A combined contact elasticity and finite element-based model for contact load and pressure distribution calculation in a frictional workpiece-fixture system / J. N. Asante // International Journal of Advanced Manufacturing Technology. – 2008. – Vol. 39. – P. 578–588.

19. Multi-objective optimization design of a fixture layout considering locator displacement and force–deformation / Z.Liu, M. Wang, K. Wang, X. Mei // International Journal of Advanced Manufacturing Technology. – 2012. – Vol. 67. – P. 1267–1279

20. Papastathis T. N. Modelling and Design Methodology for Fully-Active Fixtures : PhD Thesis. – The University of Nottingham, Great Britain, 2010.