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

Engineering of Machines, Structures and Technologies
(faculty name)

Manufacturing Engineering
(full name of department)

EXPLANATORY NOTE

for diploma project (thesis)

master of science
(educational-proficiency level)

topic: **Design development of machine shop area for the cover KS6-57.017 manufacture including the study of the cutter micro geometrical deviations in cutting process by finite elements method**

Submitted by: fourth year student group IMTm-62

Specialism (field of study)

131 «Applied mechanics»
(code and name of specialism (field of study))

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Ternopil
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Ministry of Education and Science of Ukraine
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Faculty *Engineering of Machines, Structures and Technologies*

Department *Mechanical engineering*

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Field of study

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APPROVED BY

Head of Department *Doctor of sciences, professor*

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Assignment

FOR DIPLOMA PROJECT (THESIS) FOR STUDENT

Adusei Ebenezer

(surname, name, patronymic)

1. Project (thesis) theme. **Design development of machine shop area for the cover KS6-57.017 manufacture including the study of the cutter micro geometrical deviations in cutting process by finite elements method**

Project (thesis) supervisor *Assis. Prof., Danylchenko L.M.*

(surname, name, patronymic, scientific degree, academic rank)

1.Approved by university order as *27 th of September 2019 № 4/7-855*

2. Student's project (thesis) submission deadline *2 nd of October 2019*

3. Project (thesis) design basis *Drawing of part. Technical characteristics of part. Basic technological process. Annual production program.*

4. Contents of engineering analysis (list of issues to be developed)

General-technical chapter. Analysis of part design and basic technological process of its manufacture. Technological chapter. The choice of method of manufacture of the workpiece. Development of operational technological process. The calculation of the cutting rates. Rate making of operations. Designing chapter. Choice and design description of attachments. Tools, materials and appliances for the manufacture of the lid. Special chapter. Planning chapter. Economic background. The rationale of economic efficiency. Technical justification of project technology. Health and safety measures. Ecology.

5. List of graphic material (with exact number of required drawings, slides)

Rotating jig – A1.

Adjustment gear on thread-cutting and drilling operations – 1A1.

Fixture for boring internal surfaces – A1.

Fixture for control of radial runout – A1. Designing scheme of the tool – A1.

Calculation of cutting tool – A1. Scheme of the stress state – A1.

Fixture for drilling holes - A1.

6. Advisors of design (thesis) chapters

Chapter	Advisor's surname, initials and position	Signature, date	
		assignment given	assignment accepted
Special chapter	*Assis. Prof., Danylchenko L.M.*		
Economic background	*Assis. Prof., Dyachun A.Y.*		
Health and safety measures	*Assis. Prof., Tkachenko I.G.*		
	Senior Lecture Klepchyk V.M.		
Ecology	*Assis. Prof., Lyasota O.M.*		

7. Date the assignment was given *20 th of December 2019*

8. Project time schedule.

LN	Diploma project (thesis) stages	Project (thesis) stages deadlines	Notes
1	*Analytic chapter*	*22.10.2019*	
2	*Scientific research chapter*	*29.10.2019*	
3	*Technological chapter*	*05.11.2019*	
4	*Designing chapter*	*12.11.2019*	
5	*Special chapter*	*16.11.2019*	
6	*Planning chapter*	*20.11.2019*	
7	*Economic background*	*25.11.2019*	
8	*Health and safety measures*	*02.12.2019*	
9	*Ecology*	*10.12.2019*	
10	*Drawings*	*19.12.2019*	

Student ______________ *Adusei Ebenezer*
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Project (thesis) supervisor ______________ *Danylchenko L.M.*
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ABSTRACT

The master degree diploma project on the theme "Development of project of machine shop section for cover KS6-57.017 manufacturing technology with research microgeometrical deviations of cutting tool in cutting process by finite elements method" involves designing the technological process of machining parts, technological equipment for its manufacturing (adaptations, adjustment, cutting and measuring tools), development of measures for labor protection and technology safety, as well as substantiation of the economic efficiency of the adopted design and technological solutions.

The analytical part of the project includes an analysis of the technical requirements for the component, the analysis of the basic technological process and the formulation of the problem of graduation design.

The technological part includes a description of the type and organizational form of production, the justification of the method of procurement, the manufacturing route of the part, the cutting and normalization of operations of the technological process, calculating the forces of fastening the workpiece.

In the design part the choice of equipment, machines and bases for the design variant of the technological process of manufacture for the cover was substantiated, designing on the basis of technical tasks of technological and control devices and a cutting tool was carried out.

In the special part the block diagram of the algorithm of automated design of the process of manufacturing the case is developed.

Techno-economic substantiation of the design technology was carried out, issues of the ecology and organization of labor protection at work, ways of elimination of harmful production factors were considered.

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INTRODUCTION

The basis of each industrially developed country is to meet the needs of the national economy and the population in high-quality products, provide technical re-equipment and intensify all branches. The qualitative fulfillment of these tasks is impossible without the wide introduction in the manufacturing sector of the latest achievements of domestic and foreign science, technology, production organization, which in turn should ensure the growth of production of industrial products of the required quality to a large extent due to increased productivity. The accelerated pace of scientific and technological progress objectively leads to corresponding changes in the production process, that is, there is a steady growth in the role of machine building products, since this sector itself has a leading role in both the reconstruction and technical re-equipment of the entire national economic complex of the country.

In the process of mechanical machining of machine parts, there are many problems associated with the need to meet the technical requirements and conditions set by the designer before production. The process of machining is associated with the operation of complex equipment -metal-cutting machine tools. The practicality and cost of machining is much greater than at other stages of the manufacture of machines.

The machine-building technology combines the machine tool, the device, the cutting tool and the machined part by constructing the most rational machining processes of the machine parts, requiring the exact selection of equipment. The efficiency of production, its technical progress, the quality of manufactured products largely depends on the development of production of new equipment, machines, machine tools and devices, from the wide introduction of modern methods of technical and economic analysis, which provide the solution of technical issues and the economic efficiency of technological and design developments.

The prevailing trend in the development of technology in automated production is the introduction of low-waste and low-operating technology, the use of precise blanks close to shape and size to finished products, which contributes to the economy of metal, reducing the amount of machining, reducing the production cycle of parts manufacturing and reducing the cost of production in general.

In this regard, the diploma project focuses on an initiative approach to the solution of technical and organizational tasks, as well as a detailed and creative analysis of existing technological and engineering proposals, taking into account current priorities and trends. At the same time, attention is given to the technical substantiation of the decisions taken in order to ultimately find the optimal solution to the problem.

1. ANALYTIC CHAPTER

1.1. Primary objectives and characteristics of object of production. Technical analysis of product specification.

The part - cover refers to the bodies of rotation (such as a hollow cylinder). The cover is produced from aluminum AK7M2 (AL14B) GOST 2685-75 is manufactured by casting method, so the configuration of the outer contour and internal surfaces does not cause significant complications in obtaining the workpiece. Nevertheless, the formation of the workpiece in this case should be made using the rods that form the inner cavity.

The part - cover is included in the assembly unit of the undercarriage of the beet-harvesting combine. Its functional purpose is that it serves as a basic part for the installation of a wheel shaft and tapered bearings.

Table 1.1 presents the technical requirements for the part and methods of their implementation, as well as tools for controlling the sizes of the surfaces to be treated. These data clearly define its configuration and indicate the possible methods for obtaining the workpiece and the processing methods.

On the drawing of part are all the necessary dimensions, tolerances, and roughness parameters of the machining surfaces. Specific technological requirements for roughness, purity of processing are not put forward in part, which allows the use of publicly available equipment, cutting tools, universal jigs and control methods in rate and mass production. The working surfaces of the cover, which are in contact with the working surfaces of other parts during operation, have increased precision, their required sizes and tolerances are obtained as a result of technological measures and sequential machining operations.

Table 1.1 - Specifications and requirements, methods of their implementation

Marking of the surface	Content of technical requirements	Treatment after receipt	Method of control
А	Bore the surface	Rough turning	Caliper ШЦ - III
Б,В,Г	Plunge the ends	Rough turning	Caliper ШЦ - II
	Turn the outer diameter	Finish turning	Caliper ШЦ - II
	Bore the holes	Rough boring	Tap (ø140) 8140-016H8 ГОСТ 9823-89
	Ø139,2 H8	Diamond boring	
П Н	Ø124 P7		Tap (ø120) 8140-0157 GOST 14823-89
К	Ø119,2 H8		Tap (Ø85) 8136-0017 GOST 14816-89
І	Ø85 H8		Tap (Ø124) 8142-0107 GOST 14822-89

1.2. Characteristics of the workpiece material. Analysis of chemical and mechanical properties.

Taking into account the design features of the part, its shape, as well as technical requirements, as a material for its manufacture, an alloy based on AK7M2 (AL14B) is used. Chemical and mechanical properties of the alloy are given in Table. 1.2, 1.3.

Table 1.2 - Chemical composition of aluminum AL14B,%

Cu	Mn	Ti	Fe	Si	Mg	Zn	Mg	Ni	Zr	Others
4-5	-	700,2	1,0	1,2	0,03	0,2	0,1	-	-	2,2

Table 1.3 - Mechanical properties of the material

$\sigma_{в}$, mPa	$\sigma_{т}$, mPa	δ, %	Hardness HB
20	21	6	60

Alloys based on AK7M2 (AL14B) have a high overall corrosion resistance, are not subject to corrosion cracking and intercrystalline corrosion.

Corrosion resistance essentially depends on the technology of making semi-finished products, mainly from annealing temperature. Improvement of corrosion resistance is possible by using annealing at temperatures of 265-285˚C. Satisfactory corrosion resistance can be obtained after annealing at temperature of 310-335 ° C.

Alloys AK7M2 (AL14B) are well treated with cutting, which means that the processing of the part does not consume additional energy, which allows for the use of alternative types of energy to reduce its cost.

1.3. Analysis of part's technological design.

The possibility of machining a part with the maximum productivity and minimum cost allows us to consider the part as a technological one. The main tasks of the solution in the analysis of the machinability of the part are reduced to a possible reduction of labor intensity and material consumption of its processing. Improvement of technological design allows you to reduce the cost of manufacturing parts without compromising on official use.

Replacement of this part in a built-up or welded construction is economically inexpedient, since the cost of manufacturing covers the cost of manufacturing the workpiece.

Performance analysis includes qualitative and quantitative indicators.

Qualitative indicators include:

- material of part;
- basing and fixing;
- setting sizes;
- form and location tolerances;
- structural non-technological elements.

The quantitative performance indicators include:

- coefficient of using of workpiece and material;
- coefficient of accuracy;
- coefficient of roughness;

Technology is considered the construction, which processing is possible with maximum productivity and minimum cost.

Due to the fact that the main machining is done by rough turning and drilling holes, with the simple simplicity of the construction of the detail, it is allowed to use high-performance processing methods. Such as: drill heads, turning multi-tool semiautomated machine, etc.

In the case of internal surfaces, they must be made at the boundary of the specified deviations and the radial beating should not exceed 0,025 mm.

The only method for achieving such precision is the finish boring on diamond cutting machines.

Technological design of the part - cover characterize the following quantitative indicators:

1. The coefficient of precision of the processing is determined by the dependence [5, p.35]:

$$K_{ТЧ} = 1 - 1/T_{ср} = 1 - \frac{\sum n_i}{\sum T_{ni}}, \tag{1.1}$$

Where $T_{ср} = \frac{\sum Tn_i}{\sum n_i} = \frac{n_1 + 2n_2 + 3n_3 + ...}{n_1 + n_2 + n_3 + ...}$ – middle class of precision machining;

n_i – the number of dimensions of the corresponding a precision class;

T – class of precision;

$$T_{ср} = \frac{1 \cdot 4 + 2 \cdot 2 + 3 \cdot 4 + 4 \cdot 10 + 5 \cdot 16}{4 + 2 + 4 + 10 + 16} = 3{,}88;$$

$$K_{ТЧ} = 1\text{-}1/3{,}88 = 0{,}74.$$

2. The technological level of construction on the surface roughness is determined by the formula [5, p. 34] :

$$K_ш = 1 - \frac{1}{Ш_{ср}}, \tag{1.2}$$

Where $Ш_{ср}$ - middle class of roughness [5, p. 34];

$$Ш_{ср} = \frac{n_1 + 2n_2 + ... + 14n_{14}}{n_1 + n_2 + ... + n_{14}}, \tag{1.3}$$

Where n_i - the number of surfaces with the corresponding numerical value of the roughness parameter;

$$Ш_{ср} = (7\times8+5\times3+3\times6+2\times3) / (8+3+6+3) = 4{,}75.$$

Determine the coefficient of roughness by dependence:

$$K_ш = 1 - \frac{1}{4{,}75} = 0{,}79.$$

Consequently, according to the roughness factor, the design of the parts is technological.

3. The coefficient of material use [5, p. 39] is determined by the formula:

$$K_{вм} = M_{д} / M_{з} = 4{,}74 / 4{,}99 = 0{,}94; \quad (1.4)$$

Where $M_{д}$ = 4,74 kg –weight of part;

$M_{з}$ = 4,99 kg – weight of workpiece.

A more detailed analysis of this issue is considered in the organizational and economic chapter of the diploma project.

4. The level of technological capability of the construction design by the labor intensity of the manufacturing is characterized by the coefficient of labor intensity:

$$K_{тр}=T_{пр}/T_{б}=13/17=0{,}77; \quad (1.5)$$

Where $T_{пр}$, $T_{б}$ – accordingly, the calculated and basic labor intensity of the part.

The calculations show that the part is sufficiently technological and allows the use of high-performance cutting modes, has acceptable base surfaces for initial operations and is quite simple in design.

Based on qualitative and quantitative estimates of the technological detail, it can be concluded that the main tasks of improving existing technology are the introduction of low-waste and low-operating technology.

1.4. Analysis of the basic technological process of manufacturing the part.

The technological process of manufacturing the cover KS6-57.017 is characterized by a sufficiently long basic time required for the manufacture of this part. In this regard, we carry out the replacement in the technological process of the main metal-cutting equipment on a more productive one.

In addition, the manufacture of the cover - part on the base machines is carried out with huge economic costs, which is irrational to the modern requirements of the economy.

1.5. Modern achievements in the field of technology, machines and equipment in the manufacture of similar products.

Type design practice of technological processes is one of the most progressive directions of improvement of technology of mechanical engineering. Among the various parts of the machine-building industry, a large number of details of a similar configuration, similar in precision, materials, requirements that are advanced to the quality of processing their main surfaces can be found. Quite often, such parts are manufactured at different plants, factories, in different shops (sometimes in one shop), on various equipment from different workpieces, by various technological methods with varying productivity and cost-effectiveness.

The typing of technological processes for configurations similar to the technological features of the parts involves their manufacturing according to the same technological processes, which are based on the application of the most advanced methods of processing, which ensure the achievement of the highest productivity.

Typing of technological processes can be performed in three directions:

1) processing of individual surfaces;

2) processing of individual (typical) combinations of surfaces;

3) processing of workpieces.

Further typing of technological processes led to the creation of group processing methods, which occupy an important place in the conditions of production.

The main feature for combining blanks into groups for individual technological operations is a set of surfaces to be processed or their combinations.

The group method does not necessarily provide a complete similarity of operations for all the parts that are include in the group. Parts from one group may have differences in the technology route, duration of operations, etc. A characteristic feature is the presence of group operations.

To generalize the features of the shape of the parts that are include in a group and are processed on the same machine tools, drawings of a generalized part, which is called complex. Technological processes are developed for the processing of a complex part. When processing other parts of the group, unnecessary operations are excluded from the technological process.

Group debugging expands the ability to use high-performance technological methods in the rate production of parts, the ability to achieve a higher load of machines and reduce the time for re-debugging.

Group debugging can be used with multi-spindle drill heads on conventional drilling machines. Part of the spindles can be used to drill some parts, another part of the spindles - for drilling holes other parts. Group debugging creates favorable conditions for the implementation of group technological processes.

1.6. Conclusions and problem statement for a diploma project.

From the analysis of the technological design and designation of the parts, the following conclusions can be drawn:

1. The part is technological and the obtaining of the workpiece is not difficult.

2. There is no specific technological requirements to the part - cover for roughness, cleanliness of the processing, which allows the use of publicly available equipment.

3. Operations for the turning process are accompanied by sufficiently large time costs, therefore, there is a need for optimization of the technological process.

Lastly the main task of diploma designing is to improve the basic technological process with the condition of ensuring all technical requirements, maximum efficiency when more efficient using of equipment.

The prevailing trend in the development of technology in automated production, which contributes to the economy of metal, reducing the volume of mechanical is the introduction of low-waste and low-operating technology, the using of precise blanks close to the shape and size of finished products, reducing the production cycle of parts manufacturing and reducing the cost of production in general.

Therefore, the relevance of the diploma project is due to the importance and need to improve the technological processes of manufacturing such parts, the development of appropriate machines and equipment for machining, assembly and control operations in order to increase their technological and operational properties.

2. SCIENTIFIC RESEARCH CHAPTER

2.1. Investigation of the factors that influence the change of the geometrical parameters of the cutting tool during the machining process.

Improving the performance of a cutting tool is a multifaceted problem that involves solving several interrelated problems. These include the formation of optimal geometry and microgeometry of the working elements of the cutting tool, provided that the corresponding reinforcement. Their solution lies in a comprehensive approach to machining processes, in particular, at the final stages of tool making. It is important to take into account the interrelated technological aspects of machining, such as the degree of hardening, the microgeometric parameters of the cutting tool working elements, and especially the thin, sharpened cutting edges. Traditionally, the sharper the cutting edge, the less effort will be made when using the tool.

When performing an instrument of its functions, geometrical parameters may change for subjective or objective reasons. When subjectively affecting the geometry of the tool, it is possible to change the back or front angles by positioning the top of the tool above or below the center of the workpiece (Fig. 2.1).

When the tip of the cutter is moved above the axis of the workpiece, the front angle γ increases and the rear angle α decreases, and for the inner surfaces: the front γ decreases, the rear α increases. When you set the top below the center, the angles are reversed relative to those considered.

Due to the positioning of the cutter, the main angle in the plan φ and the auxiliary φ_1 angles in the plan are changed, changing the position of the main cutting edge relative to the working plane P_S when installing the tool (Fig. 2.2).

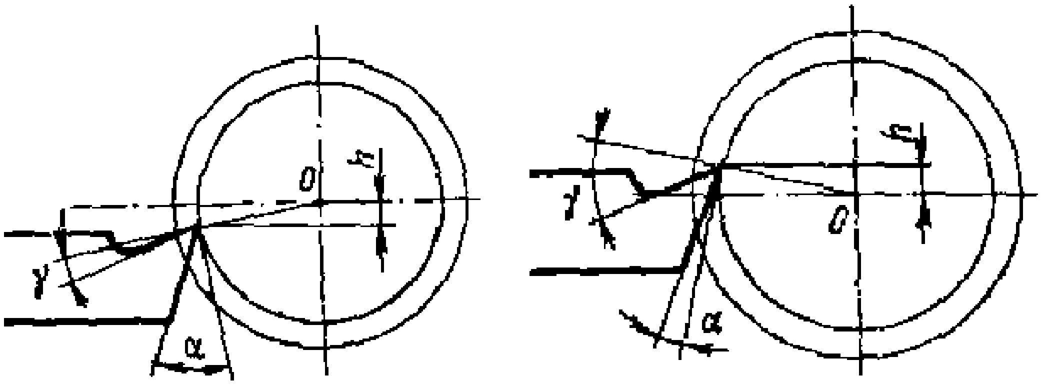


Fig. 2.1 - Effect of displacement of the tip of the cutter on the value of the front and rear corners

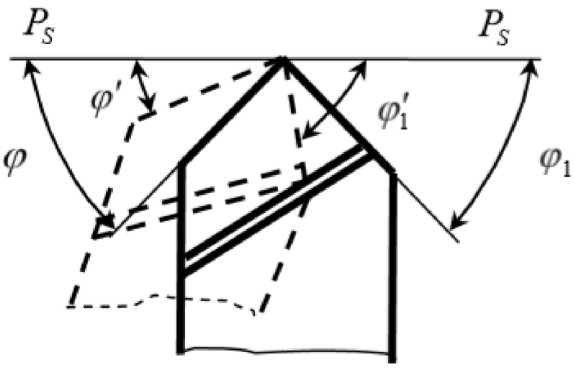


Fig. 2.2 - Change of the main and auxiliary angles in the plan depending on the errors of the position of the cutter relative to the axis of the workpiece

In the same way, by changing the position of the cutting edge when installing the tool, you can change the value of the angle. An objective change in the geometry of the tool occurs in the kinematics (in the cutting process), depending on the change in the cutting speed *V*, the feed rate *S* and the diameter of the workpiece *D*. In this case, the angles in the main cutting plane $P\tau$ are considered in the kinematic coordinate system in which the kinematic cutting plane P_{nk} deviates from the static P_{nc} by the angle η and the values of the rear and front angles accordingly change. The magnitudes of the angles can be determined by the following dependencies:

$$\alpha' = \alpha - \eta;\ \gamma' = \gamma + \eta;\ \eta = \mathrm{arctg}\ S/(\pi D). \qquad (2.1)$$

The reduction of the rear angle is primarily taken into account when working with large feeds *S* (Fig. 2.3).

When machining shaped profiles on CNC machines, depending on the shape of the surface being treated, the tool trajectory changes (Fig. 2.4). This changes the position of the working plane *Ps*. In this case, the angles in the plan φ and φ_1 may be increased or decreased. This situation should be taken into account when machining parts on CNC machines and copy machines, as angles φ and φ_1 close to zero or negative may occur.

It should be borne in mind that in the areas of "lifting" of the workpiece (when the radius of the machined surface r_i increases) the kinematic head angle in the plan φ decreases, and in the areas of "recession" (when the radius of the machined surface r_j decreases) there is an increase in the head angle in the plan φ. In addition, when you change the angles of the plan, the cutting forces also change, which results in machining errors.

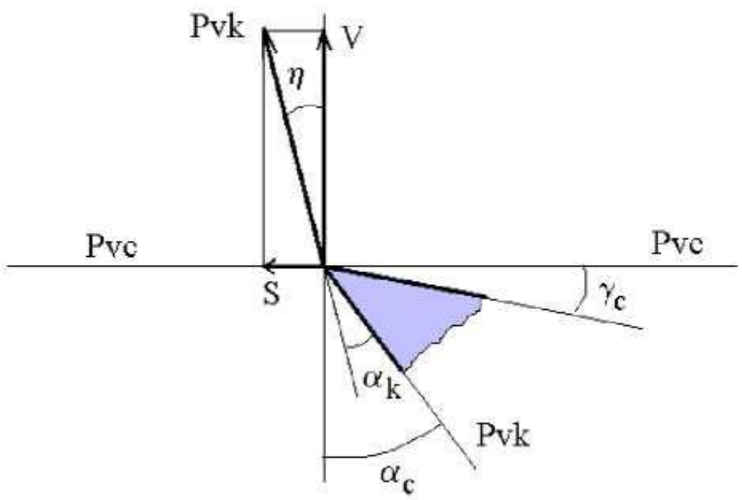


Fig. 2.3 - Diagram of the change of the posterior angle in kinematic coordinate system

The magnitudes of the angles have a significant impact on the chip cutting process. The main rear angle α reduces the friction of the back surface of the cutter about the cutting surface, α = 6-12^{o} for machining steel and cast iron parts, increasing this angle leads to a weakening of the cutting edge.

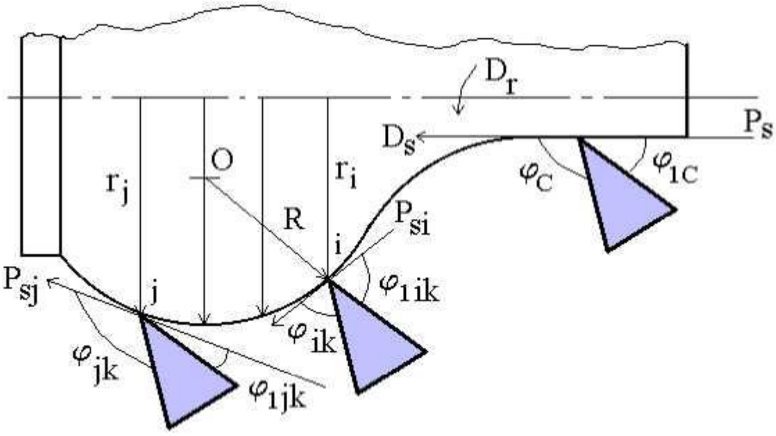


Fig. 2.4 - Scheme of change of angles in plan in the process of processing of shaped surfaces

The leading front angle *γ* influences the process of cutting the cutting edge into the material being machined. Cutters with large positive front angles are better cut into the workpiece, but have a weak cutting part, and therefore are used for processing plastic materials. Thus, when processing low carbon steel *γ* = 8-20 about. The larger this angle, the better the surface cleanliness. Cutters with small positive and even negative angles are used for the processing of solid and brittle materials. Most often, the value of the front angle is taken from -10^o to + 20^o. When machining very hard steels, this angle is *γ* = -5^o-10^o.

The two angles considered are correlated with the acute angle *β* in a directly proportional relationship.

The main angle in the plan *φ* affects the stability of the cutter and the purity of the machined surface, it is assigned within 30-90^o, as this angle determines the relationship between the radial and axial cutting forces. When processing parts of low elasticity, the angle φ take close to or equal to 90^o, since in this case the radial force that causes the bend of the workpiece is minimal. The most common angle φ when machining on universal lathes 45^o.

The auxiliary angle in plan φ_1 affects the friction and the rising of the chip. This angle is in the range 0-45^o. The most common angle φ_1 = 12-15^o.

The angle of inclination of the main cutting edge λ determines the direction of descent of the chips. With a positive value of λ, the shavings descend on the treated surface, and on the negative surface - on the treated surface. The angle λ is often taken equal to 0. In finishing, the angle λ is not recommended to be positive, as chips can reduce the purity of the surface being treated.

The magnitude of the angles is also affected by the placement of the tip of the cutter relative to the center of rotation of the workpiece. When machining the outer surface of the cutter whose top is above the workpiece axis, the front angle γ increases and the rear one decreases with respect to the angles α and γ of the cutter, whose top is exactly on the workpiece axis being machined.

By placing the tip of the cutter below the workpiece axis, the angle γ decreases and the angle α increases. When drilling the hole, the impact of the height cutter on the angle γ and α is reversed. When installing the cutter above the center, the front angle γ decreases and the rear α increases (Fig. 2.5).

When the top of the cutter is placed below the center, the front angle γ increases and the rear α decreases.

When installing the cutter axis perpendicular to the workpiece axis, the main and auxiliary angles in the plan also change accordingly.

Therefore, if you need to change the cutting angles, it is not necessary to sharpen the cutters, just raise or lower the tip of the cutter relative to the center of rotation of the workpiece.

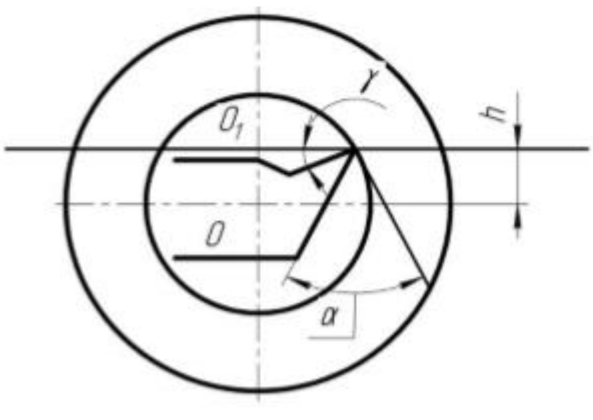


Fig. 2.5 - Placing the top of the cutter above the axis of rotation of the workpiece when boring

2.2. Modeling of microgeometry of cutting tool by finite element method.

The power of modern personal computers and mobile devices, as well as new software technologies allow to improve the output block of calculations, providing design engineers with the means of three-dimensional visualization of results.

To study the change in the geometrical parameters of the cutting tool, we apply the finite element method, which is a powerful tool that allows to model the distributions of displacements, deformations, resizing in the structures of tools for metal cutting.

The basic idea behind this method is that any continuous value (displacement, force, pressure, temperature, etc.) can be approximated by a model made up of individual elements. On each of these elements, the investigated continuous value is approximated by a partially continuous function that is constructed from the values of the investigated continuous value in a finite number of points belonging to the investigated element.

Many different software systems (ANSYS, NX Nastran, SolidWorks Simulation, etc.) have been developed to implement the finite element method, most of which are general purpose systems. The simplest to use when modeling such tasks is the SolidWorks software suite with its Simulation add-on. Regardless of what task is solved in the course of finite element analysis in SolidWorks Simylation, there are three stages of the process: preliminary (preprocessing) - model preparation; applying loads and getting resolved; postprocessor - processing of the obtained results [7].

In the pre-processor preparation stage, a geometric 3D model is constructed, the calculation type is selected, and all the initial conditions necessary for the solution of the problem are specified: the type of coordinate system, the physical and mechanical properties of the material. In the second stage, the finite element grid is built, the necessary actions are performed on its nodes and elements, the loads are applied, the boundary conditions are set and the problem is solved. At the post-processing stage, it is possible to refer to the results obtained and output them as necessary. The most effective method of visual representation of numerical data obtained by the finite element method is the image of the model of the three-dimensional framework of the investigated structure, so the result of the program at the post-processing stage is a graphical and tabular representation of the obtained results, both in individual sections and their distribution throughout the structure.

The practice of operating tools shows that its performance is largely determined by the tool material, the geometrical parameters of the cutting element, cutting modes, as well as the method of mounting and securing the tool.

Analyzing the nature and causes of changes in the microgeometry of cutting tools, they can be divided into the following groups depending on the nature of the destruction [22]:

a) plastic deformation and wear on the back surface occurs at a very high cutting speed;

b) crater wear is the most common type of wear that occurs on the front surface of the tool due to the critically high temperature in the cutting area;

c) the buildup that occurs during the processing of low carbon or stainless steels;

d) cutting of the cutting edge, which may occur due to inconsistency of the axis of the tool and the axis of its rotation;

e) removal of the tool, feed or cutting depth; insufficient rigidity of the tool as a result of improper mounting.

The existing methods aimed at achieving optimal parameters of the initial condition of the tool in order to improve its performance (strength, efficiency, productivity, etc.) can be divided into stages:

- choice - the development and improvement of existing tool materials, the application of surface hardening methods of the cutting part of the tool, which provide increased durability and efficiency;

- design - improvement of design and optimization of geometrical parameters of the cutting part of the tool;
- operation - optimization of cutting modes is carried out in order to increase the durability of the tool.

2.3. The results of the study of the deviations of the microgeometry of the cutter in the cutting process.

The purpose of scientific research is to determine the deviation of the geometrical parameters of the cutting tool that result from the application of cutting forces. The cutting force is determined by the feed, depth, speed, and also by the geometrical parameters of the cutting tool, such as the cutting angle, the planes, the angle of the cutting edge, and the ratio between the angle of inclination and the forward angle of the cutter in the plan.

The use of the finite element method to determine the deviation of the cutting tool in the machining process allowed to obtain the optimum values of the parameters that affect the change in the geometry of the cutter.

Cutting tool deviation studies are important based on accuracy. Cutter deflections cause various types of deformation: axial, tangential, radial and deformation caused by cutting forces that occur during cutting.

Also the accuracy of perfect geometry is affected by cutting depth, cutting speed and feed rate. However, the deviation of the geometrical parameters of the tool under the action of cutting forces may be higher than acceptable, especially when the stability of the tool during machining changes.

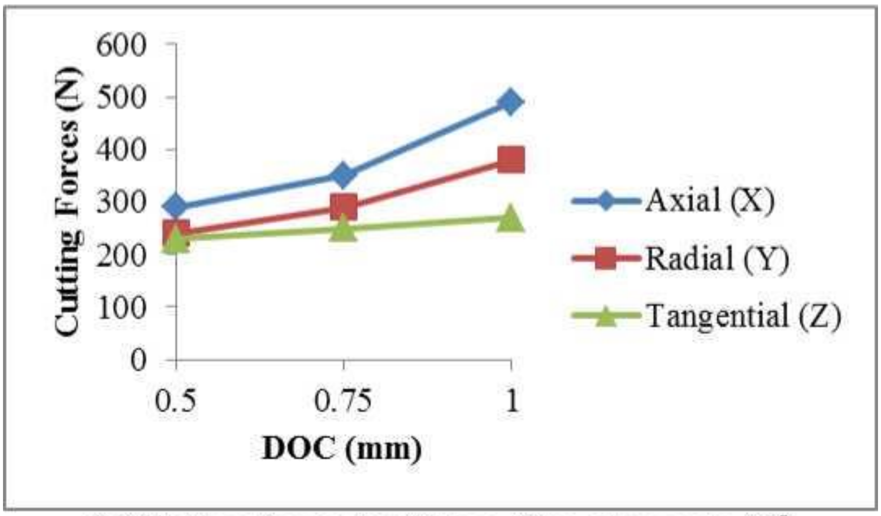
Over the years, many researchers have focused on the compensation of many different factors that have been influenced by cutting forces and changes in tool geometry. Full wear of the cutting tool due to the efforts with different angles of the cutting edge can be calculated using the displacement area during the cutting process. The cutting force varies with cutting conditions such as cutting width, cutting thickness, feed, cutting depth and cutting angle of the tool. Therefore, cutting forces are influenced not only by the cutting conditions, but also by the geometry of the cutting edge and the workpiece material [4].

Cutting parameters (cutting speed, feed rate and cutting depth) affect the tool temperature, tool wear, cutting force and roughness of the cutting surface of the tool. The deviation of the microgeometry of the tool affects its service life, surface roughness and size accuracy. The results of this relationship can be calculated using the finite element method using the CAD model. Such a model predicts finite element-like deviation similar to a finite element. The projected deviations in the axial, radial, tangential directions using the finite element method are compared with the results of the CAD model with different angles of cutting edge and an increase in the cutting angle of the cutter.

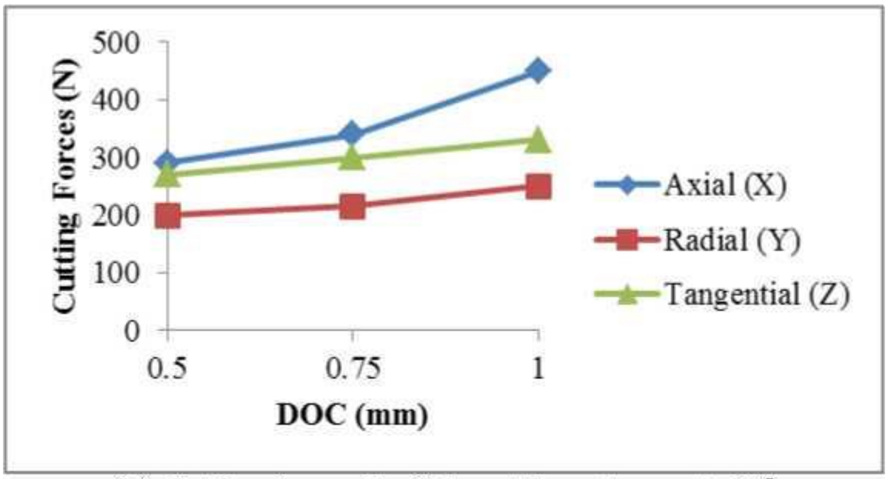
Finite element analysis is performed to study the deviation of the angle of inclination of the cutting tool in three directions, for example, axial, radial and tangential directions due to the simultaneous action of all three cutting forces, namely axial *Fa*, radial *Fr* and tangential force *Ft*. The experimental values of forces were obtained using a dynamometer [22]. To measure the force used a workpiece mounted in the cartridge and a cutter mounted on a dynamometer. The values of axial cutting force acting on the *X*-axis, radial cutting force acting on the *Y*-axis and tangent acting on the *Z*-axis were obtained. The results are presented in Fig. 2.6.

Table 2.1 shows the characteristics of the geometrical parameters of tools with different angles of cutting edge [7].

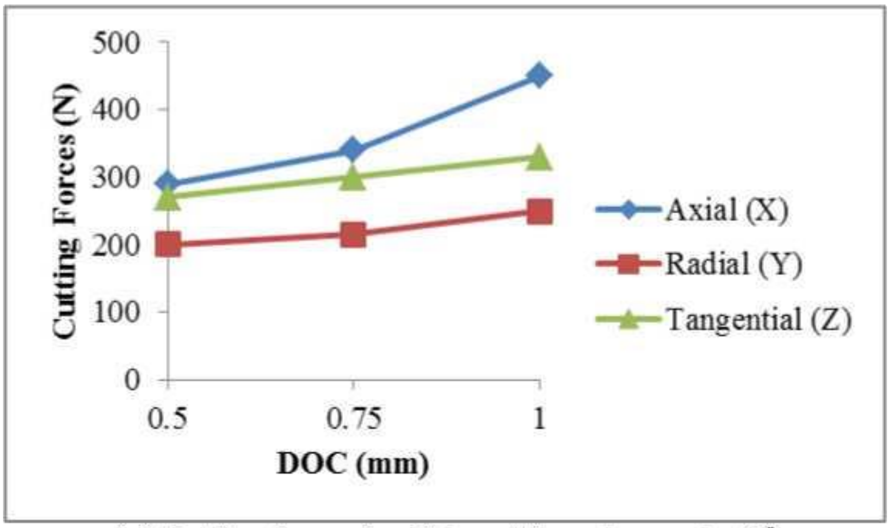
In Fig. 2.7, and shows a CAD model of a single-blade cutting tool. The complete geometry of the cutting tool is represented by tetrahedral elements with a finite element grid (Fig. 2.9b). Axial, radial, tangential forces applied to the cutting edge at different angles are applied with different d = 0.5, 0.75 and 1 mm, constant feed f = 0.3 mm / min and cutting speed N = 160 rev. /min.



(a) Cutting forces for Side cutting edge angle 20°



(b) Cutting forces for Side cutting edge angle 30°



(c) Cutting forces for Side cutting edge angle 40°

Fig.2.6 - Graphs of dependence of cutting forces for different angles of inclination of the cutting edge of a single-tool [20, 22]

Table 2.1

Cutter microgeometry parameters

Total Width	15 mm
Total Height	15 mm
Total Length	70 mm
Flank Length	10 mm
Fixed Shank Length	45 mm
Nose Radius	0.5 mm

Table 2.2

Angle cutter parameters with cutting angle of 20^o

Angle	Tool 1	Tool 2	Tool 3
End Relief Angle	10	10	10
Side Rake Angle	10	20	30
Side Relief Angle	10	10	10
Side Cutting Edge Angle	20	20	20
End Cutting Edge Angle	15	15	15
Back Rake Angle	10	10	10

Table 2.3

Cutter angular parameters with cutting angle of $30\ ^o$

Angle	Tool 1	Tool 2	Tool 3
End Relief Angle	10	10	10
Side Rake Angle	10	20	30
Side Relief Angle	10	10	10
Side Cutting Edge Angle	30	30	30
End Cutting Edge Angle	15	15	15
Back Rake Angle	10	10	10

Table 2.4

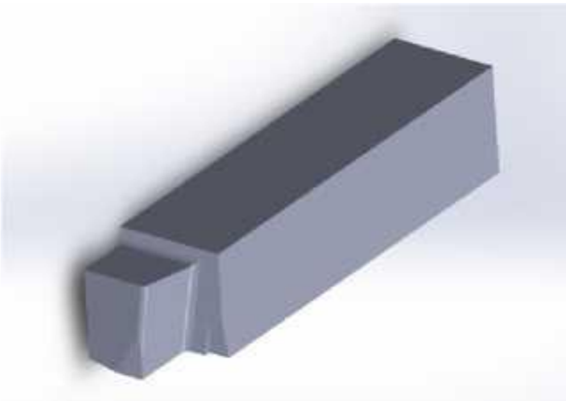
Cutter angular parameters with cutting edge 40^o

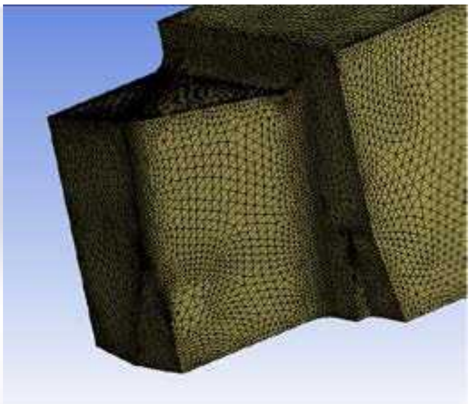
Angle	Tool 1	Tool 2	Tool 3
End Relief Angle	10	10	10
Side Rake Angle	10	20	30
Side Relief Angle	10	10	10
Side Cutting Edge Angle	40	40	40
End Cutting Edge Angle	15	15	15
Back Rake Angle	10	10	10

Deviations of the tool are predicted by the finite element method while changing the angle of inclination of the cutting edge. The average values of the measured forces are used to calculate the deviation of the tool.

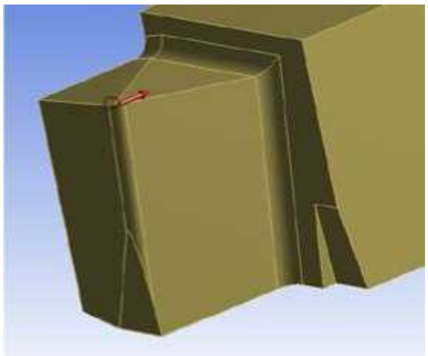
After modeling, the deviations in the axial *δa*, radial *δr* and tangential *δt* directions are taken and compared with the results of the CAD model.

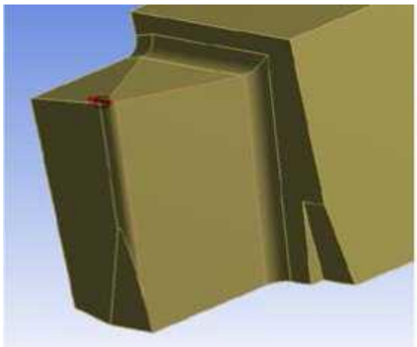
The results obtained experimentally show that the cutting force increases with increasing cutting depth, as does the angle of inclination of the cutting edge.

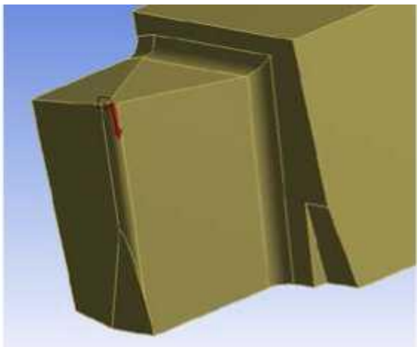




CAD model finite element mesh







axial force radial forces tangential force

Fig. 2.7 - Presentation of the conditions of finite element study of deviations [24,26]

CAD Modelling. Cutting forces are measured on a cutting tool during machining with different cutting depths and are used to predict deviations. The elastic strain energy due to the cutting forces is stored in the tool. The tool is deformed by this elastic energy, and this deformation can be detected using the Castigliano theorem.

The effort-cutting model of the tool has been designed to represent it as a cantilever beam with forces and moments [7].

The total deformation U_a stored in the tool with length L, cross-sectional area A and Young's modulus E due to the axial force F_a is equal to:

$$U_a = \int_0^L \frac{Fa^2}{2AE} dx. \tag{2.2}$$

The total deformation U_m, which is stored in the instrument with the moment of inertia I due to the moment of bending M, is determined by the dependence of:

$$U_m = \int_0^L \frac{F_{r,t}{}^2}{2AG} dx. \tag{2.3}$$

The total deformation stored by U_t in the tool with polar moment of inertia J due to torsion is:

$$U_t = \int_0^L \frac{M^2}{2EI} dx. \tag{2.4}$$

The total deformation stored by U_t in an instrument with polar moment of inertia J due to friction forces is determined by the dependence of:

$$U_t = \int_0^L \frac{T^2}{2GJ} dx. \tag{2.5}$$

The total deformation is calculated:

$$U_a = \int_0^L \frac{Fa^2}{2AE} dx + \int_0^L \frac{F_{r,t}{}^2}{2AG} dx + \int_0^L \frac{M^2}{2EI} dx + \int_0^L \frac{T^2}{2GJ} dx =$$
$$= \frac{Fa^2 L}{2AE} + \frac{F_r{}^2}{2AG} + \frac{F_t{}^2}{2AG} + \frac{F_t{}^2 L^3}{6EI} + \frac{F_t{}^2 L^3}{6EI} + \frac{F_t{}^2 L^3}{6GJ}. \quad (2.6)$$

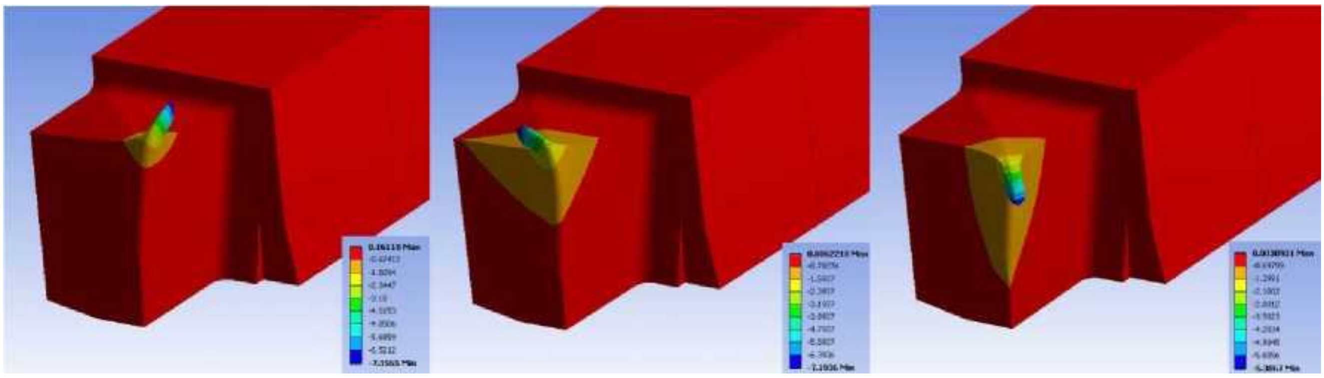
According to Castigliano's theorem, the displacement for the various components of the cutting force is determined by the dependencies [24]:

$$\delta_a = \frac{\partial U}{\partial F_a} = \frac{F_a L}{AE}. \quad (2.7)$$

$$\delta_r = \frac{\partial U}{\partial F_r} = \frac{F_r L}{AG} + \frac{F_r L^3}{3EI}. \quad (2.8)$$

$$\delta_t = \frac{\partial U}{\partial F_t} = \frac{F_r L}{AG} + \frac{F_t L^3}{3EI} + \frac{F_t L^3}{3GJ}. \quad (2.9)$$

The results of the analysis show a decrease in axial deflection, an increase in radial and tangential deflection with an increase in the angle of inclination of the cutting edge. In Fig. 2.8 presents the results of a sample of the predicted deviations predicted by the finite element method.



axial deviation radial deviation tangential deviation

Fig. 2.8 - Sampling of deviations depending on axial, radial and tangential components [24, 26]

Therefore, the condition of the cutting part of the tool largely determines the quality of the cutting. It is characterized by a set of parameters and, first of all, the geometrical parameters of the cutting part. Wearing occurs during processing. This leads to significant changes in the parameters due to the appearance of wear zones on the front and back surfaces, displacements of the cutting edges and changes in their shape.

Lack of control over cutting tools leads to gradual or sudden failures; the destruction of tools and the possibility of machine crashes. Modern metal-cutting machines work with the limited involvement of the operator, which necessitates the creation of automated systems for monitoring these changes in geometric parameters and diagnosing tool states. An important part of this process is the development of new control methods for tools that provide the formation of information parameter sets that reflect their state; mathematical and information support, creation of software complexes of classification - recognition of states of tools and their failures.

3. TECHNOLOGICAL CHAPTER

3.1. Determination of the type and organizational form of production.

The type of production is characterized by the coefficient of consocoveration of operations:

$1<K_{30}<10$ – full-rate production;

$10<K_{30}<20$ – medium-rate production;

$20<K_{30}<40$ – low-rate production.

The coefficient of fixed operations is determined by the formula [7]:

$$K_{зо} = O/P, \tag{3.1}$$

where O – the number of different operations assigned to one workplace;

P – number of working places with different operations.

The total number of operations O on the basic variant of the technological process is determined by the summing up of various operations $O_{p.o}$, fixed at the working place.

Determine the number of operations that are performed on each working place [7, p.35]:

$$O_{p.o}=(60 \cdot F_м \cdot K_в \cdot \eta_m)/(T_{шт.к} \cdot N_м), \tag{3.2}$$

where $F_м$ – monthly working time fund with two-way mode;

$F_м$=4055:12=337,9 hours;

$K_в$ – the average coefficient of execution of works, for machine building is equal - $K_в$=1,3;

η_m - standard load coefficient for two-shift work and low-rate production, is η_m=0,8 - 0,9; for medium-rate η_m=0,75 - 0,85; for full-rate and mass production η_m = 0,65 - 0,75;

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$T_{шт.к}$ - artificially-calculating time of operations on this machine;

$N_м$ – monthly release program $N_м$=1200 pcs**.**

Basic and - component time on operations are summarized in Table 3.1.

Table 3.1 - Processing time (base version)

№ operation	The name of the operation	T_o, min	$T_{шт}$, min
005	Turning-screw	1,0	2,0
010	Turning with CNC	5,3	10,3
015	Turning with CNC	4,93	5,6
020	Turning- screw	1,7	3,1
025	Diamond cutting	2,1	3,6
030	Radial-drilling	1,84	3,1
035	Metalworking	1,1	1,1
040	Radial-drilling	1,8	3,5

We calculate:

Operation 005:

$O_{р.м}$=(60×337,9×1,3×0,70)/(2,0×1200)=7,69.

Operation 010:

$O_{р.м}$=(60×337,9×1,3×0,70)/(10,3×1200)=1,49.

Operation 015:

$O_{р.м}$=(60×337,9×1,3×0,70)/(5,6×1200)=2,75.

Operation 020:

$O_{р.м}$=(60×337,9×1,3×0,70)/(3,1×1200)=4,96.

Operation 025:

$O_{р.м}$=(60×337,9×1,3×0,70)/(3,6×1200)=4,27.

Operation 030:

$O_{р.м}$=(60×337,9×1,3×0,70)/(3,1×1200)=4,96.

Operation 035:

$O_{р.м}$=(60×337,9×1,3×0,70)/(1,1×1200)=13,98.

Operation 040:

$O_{р.м}$=(60×337,9×1,3×0,70)/(3,5×1200)=4,39.

Hence

$$K_{зо}=(7,69+1,49+2,75+4,96+4,27+4,96+13,98+4,39)/5=8,9.$$

Since $K_{зо}>1$, the type of production of the manufacture of the part-cover is full-rate.

3.2. Choosing a method for obtaining of workpiece.

The choice of the method for obtaining a workpiece has an impact: the material of part, its purpose and technical requirements for manufacturing, volume and rate of release, shape and dimensions of the surface of the part.

From an economic point of view, the method of procurement the workpiece should be cheaper. From the technological point of view, the workpiece should have minimal but permissible allowances for machining, since this reduces the labor intensity of machining and increases the coefficient of material use.

The optimal option for obtaining a workpiece must provide the lowest cost of the finished product at a given quality of the product, that is, the cost of the material, the manufacturing of the workpiece and the subsequent machining together with the overhead should be minimal.

The optimal method for obtaining a workpiece is determined on the basis of the analysis of the mentioned factors and the technical and economic calculation of the technological cost of the parts.

To develop rational technology it is necessary to analyze the existing method of obtaining the workpiece in the enterprise. In this case, it is necessary to analyze the positive and negative aspects of the methods, the quality of workpiece, the causes of the shortage and the possibility of reducing it. It is also necessary to calculate the economic indicators for obtaining the workpiece in production: cost, labor intensity, productivity and material consumption.

In modern production calculations of mechanical processing parameters are based on the use of rough blanks with economic structural forms, which provide the possibility of using the most rational and economic methods of their treatment on metal cutting machines, that is, machining with the highest productivity and the smallest waste of metal in the chips.

This direction requires continuous improvement of the precision and class of surface cleanliness of the billets with the approach of their structural shapes and sizes to the finished part, which allows correspondingly to reduce the area of application of cutting machining, limiting it in some cases by ended finishing operations.

It must be understood that the methods of manufacturing the billets also depend on the type of production, since the number of manufactured billets and the frequency of their repetition involves the cost of production, and, accordingly, the level of its equipment.

In this particular case, taking into account the design features of the part, material and other indicators, it is possible to recommend consideration of several basic types for obtaining the billets, namely castings.

In the medium-rate, full-rate and mass productions it is already possible to apply machine molding on wooden or metal models.

For obtaining high precision of casting with simultaneous reduction of allowance on mechanical processing it is possible to achieve casting in shell molds. This method is based on the properties of a thermosetting resin-bonded mixture, which takes the form of a heated metal model and creates a dense and quickly hardening shell. However, this method is more expensive, although in some cases such casting requires a slight mechanical treatment. This method allows us to obtain precision 4-5 grades and Ra 2,5 surface finish.

For progressive methods and more expensive, can be attributed casting in dies (chill molds), which in turn exclude the formation process and the process of processing and transportation of molding ground associated with it, providing good cooling conditions and the simple removal of the workpiece from the mold.

Having considered the above-mentioned methods, taking into account the design features of the part, material, programmer of production of parts, advantages and disadvantages of each method for obtaining the workpieces, we conduct a feasibility study of the choice of method for obtaining the workpiece in two versions:

- investment casting;
- chill casting.

Table 3.2 - Comparative table of methods for obtaining the workpiece in two variants

Name of metrics	Investment casting	Chill casting
Group of rate	1	2
Group of complexity	3	3
Bulk weight, kg	4,69	4,56
Weight of part, kg	3,82	3,82
Cost of 1 tonne of billets, UAH	167430	167430
Cost of 1 tonne of chips $S_{відх}$,UAH	8314	8314

Determine the cost of comparable workpieces:

- the cost of the workpiece obtained by investment casting is found by the formula:

$$S_{заг}=(C_б/1000\times Q\times k_t \times k_c \times k_в \times k_м \times k_п)-(Q-q)\times S_{відх}/1000, \qquad (3.3)$$

where $C_б$ - base cost 1 tonne of billets, UAH;

k_t =1 – coefficient, which depends on the precision class;

$k_м$ =5,1 – coefficient depending on the material;

$k_в$ =0,96 – coefficient, which depends on mass;

k_c =1,0 – coefficient, which depends on the complexity group;

k_n=0,77 – coefficient, which depends on the volume of production;

Q - weight of workpiece, Q = 4,69 kg;

g –weight of part, g = 3,82 kg.

Determine the cost of the workpiece for this variant by the formula (3.3):

$$S_{заг\ I}=(167430/1000\times1{,}0\times5{,}1\times1{,}0\times0{,}96\times0{,}77)-(4{,}69-3{,}82)\ 8314\times/1000= =623{,}97\ \text{UAH};$$

- the cost of the workpiece obtained by chill castinging is equal to:

$$S_{заг}=(C_б/1000\times Q\times k_t\times k_c\times k_{â}\times k_{ì}\times k_{ï})-(Q-q)\times S_{відх}/1000, \qquad (3.4)$$

where $C_б$ - base cost 1 tonne of billets, UAH;

k_t =1 – coefficient depending on the precision class;

$k_м$ =5,1 – coefficient depending on the material;

$k_в$ =0,96 - coefficient, depending on mass;

k_c =1,0 – coefficient depending on the complexity group;

k_n =0,9 - depends on the volume of production;

Q – weight of workpiece, Q = 4,56 kg;

g – weight of part, g = 3,82 kg.

Substituting output and tabular datas into the formula, we get:

$$S_{заг\ II}=(167430/1000\times1{,}0\times5{,}1\times1{,}0\times0{,}96\times0{,}9)-(4{,}56-3{,}82)\times8314/1000= =731{,}6\ \text{UAH}.$$

An economic effect for the ratio of methods for obtaining the workpieces, provided that the technological process of processing does not change, can be found by dependence:

$$E=(S_{заг\ II}-S_{заг\ I})\times N. \qquad (3.5)$$

Determine the economic effect of choosing the workpiece, taking into account the size of the batch of parts:

$$E=(731,6-623,97)\times 14400=15500 \text{ UAH.}$$

Thus, the preform produced by casting according to the first variant is more economical. The annual economic effect is 15500 UAH.

3.3. Development of the technological process of processing the part.

During the analysis of the basic technological process of machining, the details revealed a number of demerits in connection with the proposed two variants of the technological route.

In this case, the choice of the variant of the technological route for the given conditions of processing is made on the basis of comparison of options at cost and labor intensity. According to the provision on the assessment of the effectiveness of the new technology, the more effective variant of the current and reduced costs per unit of product is considered to be the most effective. The sum of these costs, attributed to the operating time of the equipment, is called hourly reduced costs.

The changes made in the process of the technological process:

- in the first variant - on operations 010, 015 boring of holes and grooves, plunging faces, removal of chamfers on a lathe model 1716Ц;

- in the second variant - on operations 010, 015 treatment of holes and grooves, plunging faces, removal of chamfers is carried out on a turning machine with a CNC mod. 16K20.

Table 3.3 - Basic version

№ oper.	Operation name and processing steps	Type of equipment
005	Turning-screw: 1. Cut surface in size (1).	Turning-screw-lathe.16К20
010	Turning: 1. Plunge faces in sizes (1) (2) (3). 2. Bore holes in sizes (7) (10) (5) (11) (15), chamfers in size (9). 3. Bore grooves in sizes (8) (13) (10) (6) (14) (12) (16) (11) (17).	Lathe tool.1716Ц
015	Turning: 1. Plunge faces in size (1). 2. Bore holes in sizes (5) (2) (6) (3), chamfers in size (7) (4). 3. Bore grooves in size (8) (9).	Lathe tool. 1716Ц
020	Turning-screw: 1. Plunge faces in size (4). 2. Bore grooves in sizes (1) (2) (3).	Turning-screw-milling machine.16К20
025	Diamond cutting: 1. Bore two holes in sizes (1) (2) (3) (4). 2. Bore hole in sizes (5) (6).	Machine tool OC 2425
030	Radial Drill: 1. Drill 8 holes in size (1) (2) (3) at a time.	Radial-drilling machine. 2M55
040	Radial Drill: 1. Drill consecutively 2 holes in sizes (3) (4) (5). 2. Counter-drill consecutively 2 chamfers in size (1). 3. Cut thread in 2 holes in sizes (2) (5).	Radial-drilling machine. 2M55

Table 3.4 - Project version

№ п/п Op.	Operation name and processing steps	Type of equipment
005	Turning-screw: 1. Cut the surface in size (1).	Turning-screw-lathe. 16K20
010	CNC Turning: 1. Plunge faces in sizes (1) (2) (3). 2. Cut surface in sizes (4) (3). 3. Bore holes in sizes (7) (10) (5) (11) (15), chamfers in size (9). 4. Bore grooves in sizes (8) (13) (10) (6) (14) (12) (16) (17) (11).	Lathe with CNC tool. 16K20
015	CNC Turning: 1. Plunge face in size (1). 2. Bore hole and chamber in sizes (5) (2) (6) (3) (7) (4). 3. Bore the groove in size (8) (9).	Lathe with CNC tool. 16K20
020	Turning-screw: 1. Plunge face in size (4). 2. Bore grooves in sizes (1) (2) (3).	Turning-screw-lathe.16K20
025	Diamond cutting: 1. Bore two holes in size (1) (2) (3) (4). 2. Bore hole in size (5) (6).	Machine tool OC 2425
030	Radial Drill: 1. Drill 8 holes in size (1) (2) (3) at a time.	Radial-drilling machine. 2M55
040	Radial Drill: 1. Drill consecutively 2 holes in sizes (3) (4) (5). 2. Counter-drill consecutively 2 chamfers in size (1). 3. Cut thread in 2 holes in sizes (2) (5).	Radial-drilling machine. 2M55

The choice of the technological version for the given conditions of processing is made on the basis of comparison of options at cost and labor intensity. According to the provision on the assessment of the effectiveness of the new technology, the more effective variant of the current and reduced costs per unit of output is considered to be minimum. The sum of these costs attributed to the work time of equipment is called the hourly reduced costs $C_{п.з.}$

In order to choose the best of two treatment options, a feasibility study is required. The criterion of optimality is the minimum of reduced costs per unit of a part .

The changes made in the process of the technological process:

- in the first variant - the machining of the part on the turning-screw lathe of the mod. 16A20 on two operations;

- in the second variant - the machining of the part on two operations on the turning multi-tool copier semiautomated machine mod. 1716Ц.

The value of hourly reduced costs is determined by the dependence:

$$C_{п.з.} = \frac{C_з}{M} + C_{г.з} + E_н\left(K_в + K_б\right), \text{ kop./hour,} \tag{3.6}$$

where $C_з$ – the basic and additional wages with accrual, as well as deductibles for social contribution to operator and installer for the physical operating time of servicing machines, kop./hour;

M – multi-machine coefficient, applied at the actual state of the shop;

$C_{г.з}$ – hourly expenses on the operation of the workplace;

$E_н$ – normative coefficient of economic efficiency of capital investments;

$E_н = 0{,}2$;

$K_в$ – per unit hourly capital investments in the machine tool;

$K_б$ – per unit hourly capital investments in the building.

The basic and additional wages with accruals are determined by dependence:

$$C_з = C_{т.ф}\ 1{,}53\ k; \text{ kop./hour,} \tag{3.7}$$

where $C_{т.\ ф}$ – hourly wage rate of machine-tool operator of the corresponding category, kop./hour;

1,53 – total coefficient taking into account the wage of the installer, the implementation of the rules, additional wage, deductions for social insur deductibles for social contribution;

k – coefficient, taking into account the wage of the installer, in conditions of mass or full-rate production, k = 1,1-1,5.

Hourly costs for the operation of the working place are determined by the dependence:

$$C_{ч.\ з} = C^{б.ч}_{г.з}\ k_м, \text{ kop./hour,} \tag{3.8}$$

where $C^{б.ч}_{г.з}$ – practical adjusted time costs at the base working place;

$k_м$ – machine-coefficient, which shows how many times the costs associated with the operation of this machine exceed the similar costs of the base machine; $k_м$ = 1,5;

$C^{б.ч}_{ч.з}$ = 110 kop./hour;

$C_{г.\ з} = 110 \cdot 1{,}5$ = 165 kop./hour.

Capital investments in the machine tool and building are accordingly determined by dependencies:

$$K_в = \frac{Ц \cdot 100}{3200}, \text{ kop./hour,} \tag{3.9}$$

$$K_б = \frac{F \cdot 75 \cdot 100}{3200}, \text{ kop./hour,} \tag{3.10}$$

where $Ц$ – book value of the machine, UAH;

F – production area occupied by the machine with gangways:

$$F = f \cdot k_f, \text{ m}^2, \tag{3.11}$$

where f – the production area occupied by the machine tool;

k_f – coefficient which takes into account the additional production area.

Technological cost of mechanical processing on the considered operation is determined by the dependence:

$$C_o = \frac{C_{п.з} \cdot T_{шт}}{60},\ \text{kop.,} \qquad (3.12)$$

where $T_{шт}$ – component time on operations, min.

We carry out the calculation of the basic version of the manufacturing process of the cover.

In this case, we use the turning-screw lathe of model 16A20 with CNC.

We determine the basic and additional wages, taking into account the hourly wage rate and the coefficient that affects on the wage of the installer:

$$C_з = C_{т.\,ф} \times 1{,}53 \times k = 47{,}9 \times 1{,}53 \times 1 = 73{,}3 \text{ kop./hour.}$$

We determine the hourly expenses for the use of the working place by dependence:

$$C_{г.\,з} = C^{б.ч}_{г.з}\ k_м = 110{,}0 \times 1{,}5 = 132 \text{ kop./hour.}$$

The book value of the machine is: $Ц$=230000 × 1,1=25300 UAH.

The production area is: f= 3,0×1,6 = 4,8 m^2.

The production area F, which is occupied by the machine tool, taking into account gangways, is: F =4,8 × 3,0=14,4 m^2.

Multi-machine coefficient M = 2.

Capital investments for a machine and building for rate production:

$$K_в = Ц \times 100/3200 = 253000 \times 100/3200 = 7906 \text{ kop./hour;}$$

$$K_б = F \times 75 \times 100/3200 = 14{,}4 \times 75 \times 100/3200 = 33{,}75 \text{ kop./hour.}$$

Determine the value of reduced costs:

$$C_{п.з.} = \frac{C_з}{M} + C_{г.з} + E_н\left(K_в + K_б\right) = =73{,}3/2+132+0{,}2(7906+33{,}75)=$$

$$=1756{,}4 \text{ UAH/hour.}$$

The cost of machining for this basic operation

$$C_o = (C_{п.з} \times T_{шт})/60=(1756,4\times10,3)/60=301,5 \text{ UAH}.$$

We calculate the design variant of the manufacturing process of the cover. In this case we use the turning multi-tool copier semiautomated machine model 1716Ц.

We determine the basic and additional wages, taking into account the hourly wage rate and the coefficient that affects on the wage of the installer:

$$C_з = C_{т.ф} \times 1,5 \times k = 47,9 \times 1,5 \times 1=71,85 \text{ kop./hour}.$$

We determine the hourly expenses for the operation of the workplace by dependence:

$$C_{г.з} = C_{г.з}^{б.ч}\ k_м = 110,0\times1,5=132 \text{ kop./hour}.$$

The book value of the machine is: $Ц$=128000×1,1=140800 UAH.

The production area is: f=3,0×1,48=4,44 m^2.

The production area F, which is occupied by the machine, taking into account passageways, is equal: F =4,44 × 3,0=13,32 m^2.

Capital investments for the machine tool and building for serial production

$$K_в = Ц\times100/3200 = 140800\times100/3200 = 4400 \text{ kop./hour};$$

$$K_б = F\times75\times100/3200 = 13,32\times75\times100/3200 = 31,2 \text{ kop./hour}.$$

Determine the value of reduced costs:

$$C_{п.з.} = \frac{C_з}{M} + C_{.з} + E_н\left(K_в + K_б\right) =$$

$$= 71,85/2+132+0,2(4400+31,2)=1054,2 \text{ UAH/hour}.$$

The cost of machining for this basic operation is:

$$C_o = (C_{п.з} \times T_{шт})/60=(1054,2\times10,3)/60=144,1 \text{ UAH}.$$

The economic effect of comparing the basic and design variants of the manufacturing process of the component is:

$$E = (C_{01} - C_{02}) \cdot N, \tag{3.13}$$

where C_{01} – technological cost of the first variant of the technological process of manufacturing parts;

C_{02} – technological cost of the second variant of the technological process of manufacturing parts;

$$E = (301{,}5 - 144{,}1) \cdot 14400 = 22667{,}8 \text{ UAH.}$$

Consequently, the design version of the technological process of manufacturing the cover is more beneficial, since the economic effect of its implementation is 22667,8 UAH.

3.4. Determination of allowances and interoperational sizes.

Calculation of allowances for mechanical processing we carry out the calculation-analytical method and according to the tables. Calculation of allowances and determination of their values by tables can be carried out only after selecting the optimal for the given conditions of the technological route and the choice of method for obtaining the workpiece.

The workpiece is a casting of the 1st grade of precision with a mass of 4.99kg.

The technological route of the treatment of the hole consists of two operations: roughing and finishing.

Calculation of allowances for processing Ø120N8 is carried out by constructing a table. 3.5, in which we enter the technological route of the treatment of the hole and all the values of the elements of the allowance.

Table 3.5 - Calculation of allowances for processing

Processing steps of surface treatment Ø120H8+0,054	Release elements			Estimated allowance $2Z_{min}$	Estimated size d_p, mkm	Tolerance δ, mkm	Limit size, mm		Limit value of allowances	
	Rz	*T*	*S*				d_{min}	d_{max}	$2Z_{min}$ гр	$2Z_{max}$ гр
Work-piece	200	100	226	-	118,518	-	118,518	118,718	-	-
Rough cut	50	50	16	2×696	119,688	200	119,688	119,828	1110	1170
Dia-mond cut	-	-	-	21×12	120,049	80	120,049	120,054	226	361

The total deviation of spatial deviations is determined by the formula:

$$\rho_3 = \sqrt{\rho_{кор}{}^2 + \rho_{зн}}\ , \tag{3.14}$$

where $\rho_{кор}$ – size of the distortion of the hole;

$$\rho_{кор} = \sqrt{(\Delta K01)^2 + (\Delta Kl)^2} = \sqrt{(0{,}9\cdot 12)^2 + (0{,}9\cdot 29)^2} = 350{,}1 \text{ mkm;}$$

where ΔK – specific curvature of the workpiece, ΔK=0,9;

d - diameter of the treated surface;

l – length of the working surface;

$\rho_{зн}$ - total deviation of the hole in the casting according to the external surface;

$$\rho_{зм} = \sqrt{(\frac{\upsilon^0}{2})^2 + (\frac{\delta}{2})^2} = \sqrt{184{,}1^2 + 216^2} = 268 \text{ mkm,}$$

$$\rho_3 = \sqrt{68^2 + 246^2} = 255 \text{ mkm},$$

$$\rho_1 = 0{,}05 \cdot \rho_3 = 12{,}7 \text{ mkm}.$$

The calculation of minimum values of allowances is carried out using the formula [1, ст.68]:

$$2Z_{\min} = 2(K_{21-1} + T_{i-1} + \sqrt{\rho_{im}{}^2 + \varepsilon^2}\,. \tag{3.15}$$

Minimum allowance for boring:

- rough

$$2Z_{\min 2}=2\times(200+100+\sqrt{255^2})=1110 \text{ mkm};$$

- diamond

$$2Z_{\min 3}=2\times(80+50+13)=226 \text{ mkm}.$$

Design diameters:

- rough

$$d_{p2}=d_{з\max}-2Z_{\min 3}=120{,}054-0{,}226=119{,}828 \text{ mm};$$

- workpieces $d_{p1}= d_{p2}-2Z_{\min 2}$=119,828-1,110=118,718 mm.

Minimum diameters:

$$d_{1\min}= d_{p1}-\delta_1=118{,}718-0{,}2=118{,}518 \text{ mm};$$

$$d_{2\min}= d_{p2}-\delta_2=119{,}828-0{,}14=119{,}688 \text{ mm};$$

$$d_{3\min}= d_{3\max}-\delta_3=120{,}054-0{,}05=120{,}049 \text{ mm}.$$

Limit values of allowances:

$$2Z_{\max 3}= d_{3\max}- d_{2\max}=120{,}054-119{,}828=226 \text{ mm};$$

$$2Z_{\max 3}= d_{3\min}- d_{2\min}=120{,}049-119{,}688=361 \text{ mm}.$$

- rough boring:

$$2Z_{\min 2}= d_{2\max}- d_{1\max}=119{,}828-118{,}718=1110 \text{ mm};$$

$$2Z_{\max 2}= d_{2\min}- d_{1\min}=119{,}688-118{,}518=1170 \text{ mm}.$$

General allowances:

$$2Z_{0\min}=2Z_{0\min 2}+2Z_{0\min 3}=1110+226=1336 \text{ mm};$$

$$2Z_{0max}=2Z_{0max2}+2Z_{0max3}=1170+361=1534 \text{ mm.}$$

Total control allowance:

$$2Z_{min}=2Z_{0min}+B_3-B_2=1336+200-19=1517 \text{ mm;}$$

$$d_{заг}=d_{2кон}-2d_{0кон}=120-1{,}517=118{,}843 \text{ mm.}$$

We conduct verification of the correctness of the calculations:

$$Z_{max3}-Z_{min3}=361-226=135 \text{ mkm;}$$

$$Z_{max2}-Z_{min2}=1534-1336=200 \text{ mkm;}$$

$$\delta_3-\delta_2=200-65=135 \text{ mkm;}$$

$$\delta_1-\delta_2=400-200=200 \text{ mkm.}$$

Table 3.6 - Calculation of allowances and boundary sizes for processing the size $l=10^{+0,5}$mm

Processing steps of surface treatment	Release elements			Estimated allowance Z_{min}	Estimated size $l_{p.}$ mkm	Tolerance, δ mkm	Boundary size		Boundary values of allowances	
	Rz	T	ρ				l_{min}	l_{ma}x	$Z_{max\ гр}$	$Z_{min\ гр}$
Work-piece	200	300	52	-	12,008	800	12,008	12,008	-	-
Rough cut	-	-	3	508	11,008	400	11,1	11,1	908	508

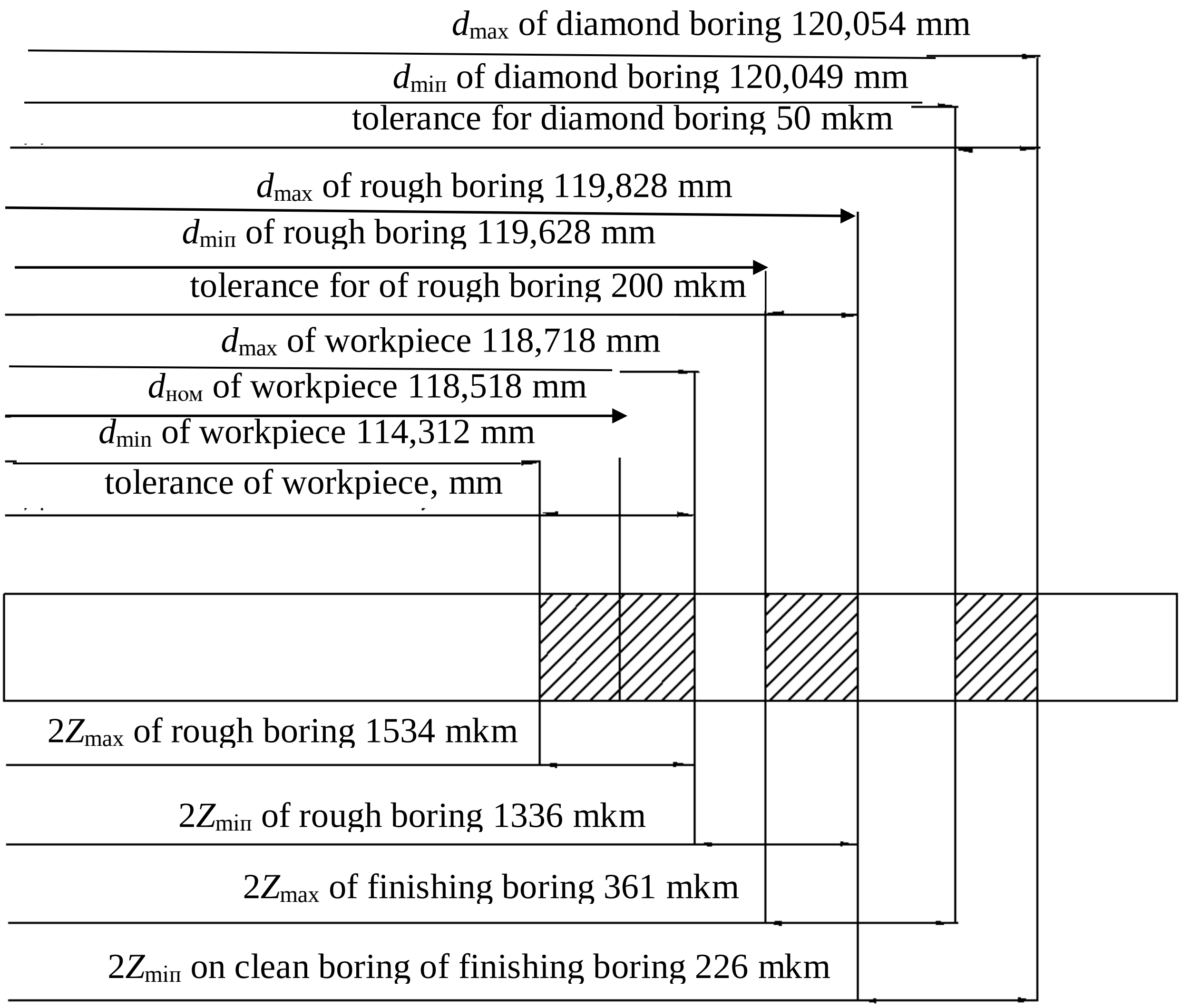

Figure 3.1 - Graphic calculation of allowances

Calculation of minimum values of allowances.

Define a scalar deviation:

$$\rho_3 = \sqrt{\rho_{нор}{}^2 + \rho_{ст}{}^2}\ ; \tag{3.16}$$

where $\rho_{нор}$=ΔK_{∂} = 0,8×10 = 8 mm;

$\rho_{ст}$ = 0;

ρ= 8 mm;

$\rho_3 = \sqrt{8^2}$ =8 mm.

For rough cutting:

$$\rho=0{,}06\times \rho_3=0{,}06\times 8=0{,}48 \text{ mm.}$$

We calculate the minimum values of allowances by the formula:

$$Z_{\min}=\mathrm{Rz}_{i-1}+T_{i-1}+\rho_{i-1};$$

$$Z_{\min}= 200+300+8 = 508 \text{ mm.}$$

We find the estimated sizes:

$$l_{p3}=l_{\max}+Z_{\min} = 10{,}5+0{,}508 = 11{,}008 \text{ mm.}$$

Maximum sizes:

$$l_{2\max}=11{,}008+1{,}0=12{,}008 \text{ mm;}$$

$$l_{1\max}=10{,}5+0{,}6=11{,}1 \text{ mm.}$$

Boundary values of allowances:

$$Z_{\max}=l_{3\max}-l_{1\max}=12{,}008-11{,}1 = 908 \text{ mm;}$$

$$Z_{\min}=l_{3\min}-l_{1\min}=11{,}008-10{,}5=0{,}508 = 508 \text{ mm.}$$

We conduct verification of the correctness of the calculation:

$$Z_{\max}-Z_{\min}=908-508=400 \text{ mkm;}$$

$$\delta_3-\delta_2=1000-600=400 \text{ mkm.}$$

Total nominal allowance:

$$Z_{\text{ном}}=Z_{\min}+H_3+H_{Д}=508+500+0=1008 \text{ mkm;}$$

$$l_{3\,\text{ном}}=l_{d\,пор}+Z_{\text{ном}}=10+1{,}008=11{,}008 \text{ mm.}$$

On other processing surfaces of the cover, we select the allowances and tolerances according to Table. 3.7.

Table 3.7 – Allowances on sizes and tolerances for machining

Surface	Size, mm	Tabular allowance, mkm	Estimated allowance, mkm	Tolerance, mkm
А	Ø275-1	2-4	-	+- 0,63
Б	10+0,5	2	-	+- 0,5
В	34+0,1	2	-	+- 0,9
Г	104*0,4	3	1,008	+- 1,1
Н	Ø124-0,3	2*0,8	-	+- 0,6
П	Ø139+0,01	2*1,5		+- 0,54
К	Ø120$^{+0,059}$	2*1,5	2*1,517	+-0,63
І	Ø85$^{-0,048}$	2*1,5		+- 0,86

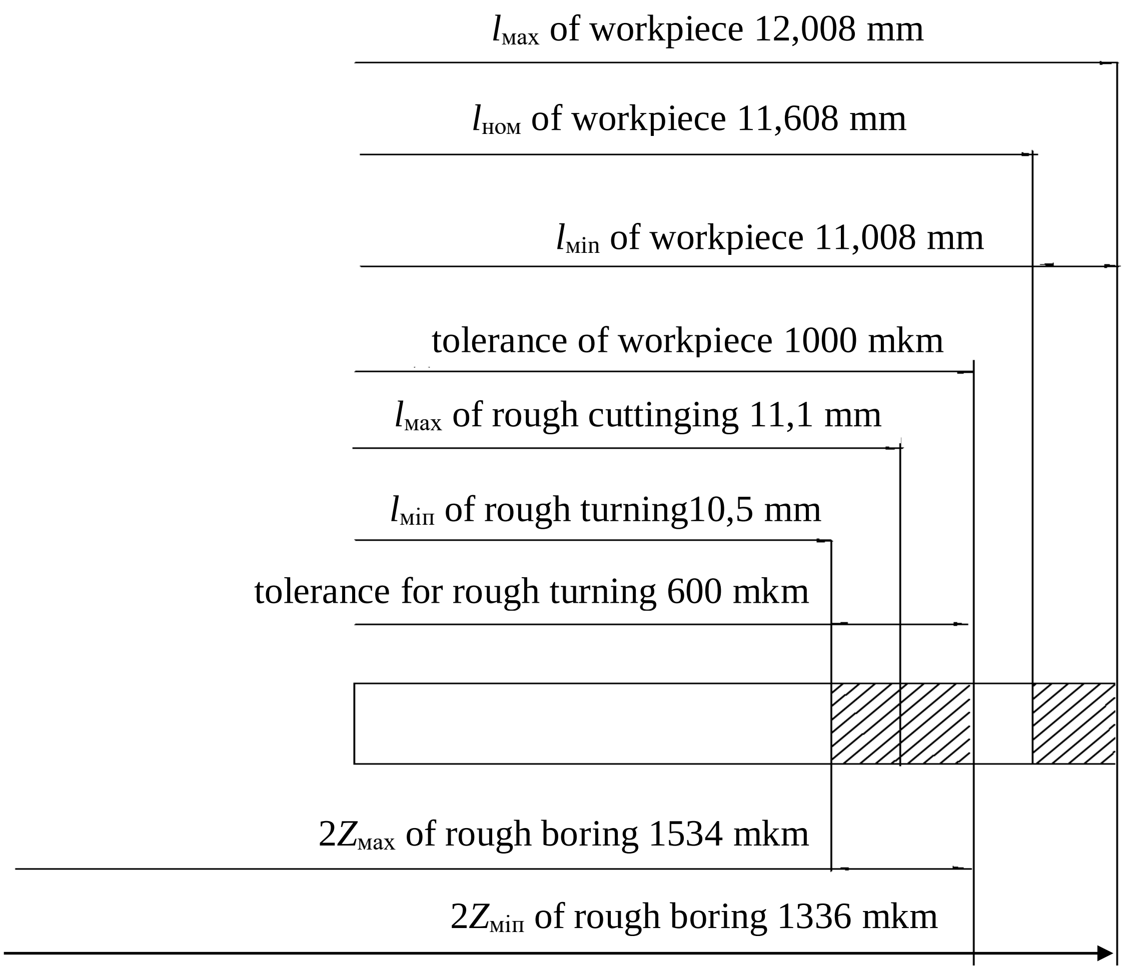

Figure 3.2 - Scheme of graphical placement of allowances and tolerances in the processing of linear size

3.5. Calculation of cutting modes.

3.5.1. Calculation of the cutting modes for the internal cylindrical surface ø120mm, ø130mm, ø140mm.

Boring operation:

1. Depth of cutting - the length of the working stroke of the support is:

$$L_{p\cdot x} = L_{piз} + y + L_{\partial o\partial}, \qquad (3.17)$$

where $L_{piз}$= 41 mm – length of cutting;

y = 1 mm – supply, cut off tool;

$L_{\partial o\partial}$ = 0;

$$L_{p.x} = 41 + 1 = 42 \text{ mm.}$$

2. Assign the feed of the support on the spindle spin S_o, mm/rev.

Cutter for deaf holes.

Material – ВК8.

Depth of cutting t=1,518 mm.

S=0,18 mm/rev.

S=0,12 (for diamond boring).

3. Determine the stability of the tool:

$$T_p = T_м \cdot \lambda\,, \qquad (3.18)$$

where $T_м$ – stability in minutes of machine work, $T_м$ =200.

λ - coefficient of time of cutting;

$$\lambda = \frac{L_{piз}}{L_{p.x}} = \frac{41}{42} = 0{,}97\,. \qquad (3.19)$$

Hence, $T_м$=T_p=200 min.

4. We calculate the cutting speed by predefined cutting parameters:

$$\upsilon = \frac{C}{60T^m t^{X\upsilon} S^{Y\upsilon}} \cdot K\upsilon, \qquad (3.20)$$

where C – coefficient that characterizes the processing material and the conditions of treatment, C=1680;

T – period of stability, min;

t - cutting depth, mm;

S - feed, mm/rev;

Xv, Yv, m - exponents of power; Xv=0,12; Yv=0,5; m=0,29;

Kv – correction factor; $Kv = 1{,}02$,

$$\upsilon = \frac{1680}{200^{0,29} \cdot 2^{0,12} \cdot 0{,}2^{0,5}} \cdot 1{,}2 = 93{,}8 \cdot 1{,}02 = 96 \text{ m/min.}$$

The number of revolutions of spindle is equal to:

$$n = \frac{1000 \cdot \upsilon}{\pi \cdot D} = \frac{1000 \cdot 96}{3{,}14 \cdot 14{,}0} = 218 \text{ rev/min.}$$

Determine axial force and cutting forces:

$$P_z = 10 \cdot C_p \cdot S^y \cdot \upsilon^n \cdot K_p, \qquad (3.22)$$

where C_p=40; x=1; y=0,75; n=0; K_p=0,91;

$$P_z = 10 \cdot 40 \cdot 1{,}5^4 \cdot 0{,}2^{0,75} \cdot 96^0 \cdot 0{,}91 = 218{,}4 \text{ N.}$$

Cutting power is:

$$N_p = \frac{P_z \cdot \upsilon}{1020 \cdot 60} = \frac{218{,}4 \cdot 96}{1020 \cdot 60} = 0{,}34 \text{ kW.}$$

Calculation of the main machine time:

$$t_m = \frac{L_{p \cdot x}}{S_o \cdot n} = 2{,}79 \text{ min.} \qquad (3.23)$$

3.5.2. Calculation of cutting modes for drilling 8 holes ø11mm.

1. Depth of cutting t = 5,5 mm.

The material of the drill is high-speed steel P6M6.

2. Feed S = 0,3 mm / rev.

3. Determination of the stability of the tool in machining with 8 drills: $T_м$=140.

4. We calculate the cutting speed and the number of revolutions of spindle:

$$\upsilon = \frac{C\upsilon \cdot D^q}{T^m \cdot S^y} K^\upsilon, \text{ m/min;} \tag{3.24}$$

where *Cv*=32,6; *q*=025; *y*=0,2; *m*=0,125;

$$\upsilon = \frac{32{,}6 \cdot 11^{0,25}}{140^{0,125} \cdot 0{,}5^{0,2}} = 18{,}7 \text{ m/min.}$$

Hence

$$n_{св} = \frac{1000 \cdot \upsilon}{\pi \cdot D} = \frac{1000 \cdot 18{,}7}{3{,}14 \cdot 11} = 522 \text{ rev/min.}$$

Determine the number of revolutions of spindle of the machine. So, as at the same time the drilling of 8 holes is carried out, then through a drill head with a gearing ratio

$$U = \frac{n_{шп}}{n_{св}} = 1{,}8;$$

$$n_{шп} = 1{,}8 \cdot n_{св} = 1{,}8 \cdot 522 = 939 \text{ rev/min.}$$

5. Determination of rolling torque and axial force:

$$M_{кр} = 10C_м \cdot D^{q_1} \cdot S^{y_2} \cdot K_p ; \text{Nm}, \tag{3.25}$$

$$P_o = 10C_p \cdot D^{q_2} \cdot S^{y_2} \cdot K_p ; \text{N},$$

Where $C_м$=0,005; C_p=9,8; q_1=2,0; q_2=1,0; y_1=0,8; y_2=0,7;

$$K_p = K_{пр} = (\frac{60}{150})^{0,58} = 1,11; \tag{3.26}$$

$$M_{кр} = 10 \cdot 0,005 \cdot 11^2 \cdot 0,5^{0,8} \cdot 1,11 = 3,8 \text{ Nm},$$

$$P_o = 10 \cdot 9,8 \cdot 1,11 \cdot 0,5^{0,7} \cdot 1,11 = 741 \text{ N}.$$

6. Determine the power of cutting:

$$N_c = \frac{M_{кр}}{9750} ; \text{kW},$$

$$N_c = \frac{3,8 \cdot 939}{9750} = 0,36 ; \text{kW}. \tag{3.27}$$

Since simultaneously we drill 8 holes, then, correspondingly, the power increases:

$$N_{c\,заг} = 0,36 \cdot 8 = 2,88 \text{ kW}.$$

Calculate the main machine processing time:

$$T_o = \frac{L_{p \cdot x}}{n_p \cdot S_n S} = \frac{11}{522 \cdot 0,5} = 0,24 \text{ min}.$$

The rest of the cutting modes for other operations of machining of the part are summarized in Table. 3.8.

Table 3.8 - Summary table of the cutting modes

The name of the operation, processing step	t, mm	$\frac{L_{ps}}{L_{p\cdot x}}$, mm	λ	$\frac{T_м}{T_n}$	$\frac{S_p}{S_n}$ mm/rev	$\frac{n_p}{n_n}$ rev/min	$\frac{V_p}{V_n}$, м/min	S_n, mm/min	T_o, min	$N_{кр}$ kW
1	2	3	4	5	6	7	8	9	10	11
005 Turning-screw: 1.Hone the surface in size (1)	2	$\frac{10}{13}$	0,67	$\frac{210}{200}$	$\frac{0,15}{0,15}$	$\frac{100}{140}$	$\frac{85}{94}$	12,5 7	1,0	$\frac{0,86}{10}$
010 Turning: 1. Plunge the ends in size (1)(2)(3)	4	$\frac{70}{16}$	0,81	$\frac{210}{200}$	$\frac{0,78}{0,31}$	$\frac{133}{160}$	$\frac{116}{150}$	32,4 8	2,01	$\frac{0,51}{18,5}$
2. Bore the holes in size (7)(10)(5)(11)(15)	1,5	$\frac{120}{126}$	0,73	$\frac{210}{200}$	$\frac{0,2}{0,2}$	$\frac{218}{160}$	$\frac{96}{126}$	19,2	2,79	$\frac{0,49}{18,5}$
3. Bore the grooves in size (8)(13)(10)(6)(14)(12)	1,5	$\frac{5}{7}$	0,9	$\frac{210}{200}$	$\frac{0,16}{0,2}$	$\frac{109}{140}$	$\frac{49}{57}$	7,84	0,28	$\frac{0,21}{18,5}$
015 Turning: 1. Plunge the end in size (1)	2	$\frac{54}{59}$	0,6	$\frac{210}{200}$	$\frac{0,28}{0,3}$	$\frac{281}{280}$	$\frac{115}{160}$	32,2	0,68	$\frac{0,24}{18,5}$
2. Boring the holes in size (5)(2)(6)(3)	10	$\frac{40}{45}$	0,83	$\frac{210}{200}$	$\frac{0,25}{0,3}$	$\frac{260}{280}$	$\frac{92}{96}$	23	0,69	$\frac{0,3}{18,5}$
3. Bore the groove in size (8)(9)	1,3	$\frac{5}{9}$	0,8	$\frac{210}{200}$	$\frac{0,15}{0,15}$	$\frac{198}{190}$	$\frac{49}{56}$	7,35	0,24	$\frac{0,16}{18,5}$
020 Turning-screw: 1. Plunge the end in size (1)	2	$\frac{70}{16}$	0,81	$\frac{210}{200}$	$\frac{210}{200}$	$\frac{0,78}{0,31}$	$\frac{133}{160}$	32,4 8	2,01	$\frac{0,51}{18,5}$

End of table. 3.8

1	2	3	4	5	6	7	8	9	10	11
2. Hone the groove in size (4)(2)(3)	5	6 9	0,9	210 200	РУЧ	200 190	63 63	hand	0,25	0,1 10
025 Diamond cutting: 1. Bore the holes in size (1)(2)	1	40 44	0,64	180 160	0,08 0,08	650 640	286 270	22,8 8	0,84	0,3 4,5
2. Bore the holes in size (3)(4)	1	15 19	0,46	180 160	0,03 0,035	580 640	256 270	7,68	0,7	0,25 4,5
030 Radial drilling: 1. Drill 8 holes in size (1)(2)	5,5	11 16	0,83	140 140	0,3 0,5	522 560	58 18	5,4	0,24	2,88 5,5
040 Radial drilling: 1. Drill 8 holes in size (5)(4)	2,5	22 26	0,46	140 140	hand	880 820	14 14	hand	0,8	0,96 5,5

3.6. Choice of cutting and measuring tools.

The choice of the cutting tool is carried out taking into account the latest achievements of tool manufacturing, the characteristics of the precision of the machined surfaces of the parts, as well as the size of the product release program. The choice of instrument should be carried out with the maximum possible use of cheaper standard tools.

The choice of a measuring instrument must be carried out with the maximum possible application of modern universal and special technical means of measurement, which allow to carry out qualitative control of the product being processed at minimal expenses of time.

Control and measuring instruments for machining operations are included in the table. 3.9.

Table 3.9 - Summary table of cutting and measuring instruments

№ operations	Name of operations	Cutting tool	Measuring tool
005	Turning-screw	Straight-turning tool GOST 18877-13	Caliper ШЦ-1-125-0,1 (ГОСТ 166-89)
010	Turning	Facing tool 2102-4095 Straight-turning tool 2102-4099 Internal boring tool (2pcs.) 2102-4190 Internal boring tool 2128-430618	T Caliper ШЦ -1-125-0,1 (GOST 166-89) Micrometer MK25-2 Clip GOST 16776-71 Chamfer gauge GOST 10365-16 Templet GOST 2675-78
015	Turning	Facing tool 2102-4095 Internal boring tool GOST 16365-76 (2 pcs.) Internal boring grooving tool GOST 1873 - 79	Templet GOST 1845 - 78 Caliper ШЦ -1-125-0,1 (GOST 166-89) Micrometer MK25-2 Templet GOST 1584 - 89
020	Turning-screw	Facing tool GOST 18877-73 Boring grooving tool GOST 17837 - 78	Caliper ШЦ-1-125-0,1 (ГОСТ166-89)
025	Diamond cutting	Boring tool with diamond insert (4pcs.)	Caliper ШЦ -2-0-320-0,1 (GOST166-89) Stopper (Ø140) GOST 14815 - 89 Stopper (Ø120) GOST 14815 - 89 Stopper (Ø90) Stopper (Ø86)
030	Radial-drilling	Drill (Ø11) GOST 10903 - 71 Drill (Ø6) GOST 1090 - 87	Clearance gage (Ø11) GOST 15875-79

3.7. Characteristics of equipment.

3.7.1. Turning–screw lathe 16K20.

On this lathe, the processing of the base surface for the next turning operation is carried out on a turning multi-tool copier semiautomated machine 1716C, on which the part is fixed on the surface to be machined in the self-centering jaw chuck. This allows you to reduce the margin of error when fixing.

Technical characteristics:

The largest diameter of the workpiece, mm:

- over the bed plate.................................... 400
- over the support................................... 200

The largest length of the workpiece, mm 2000

Height of the cutter installed in the toolholder, mm .... .25

Engine power, kW 10

Spindle rotational speed, rev / min 12,5-1600

Longitudinal feed, rev / min 0.05-2,8

Cross feed, rev / min 0.025-1,4

3.7.2. Lathe multistage semi-automatic model of 1716 TS.

The treatment on a turning multi-tool semiautomated machine is reduced to the principle of simultaneous actions. The treatment is carried out simultaneously by the supply of several cutters, which significantly reduces the processing time, as well as allows you to process both internal (rough boring) and external (facing) of the surface.

Technical characteristics:

The largest sizess of the workpiece, mm:

- over the bed plate....................................... 400

- over the banner 200

Product length 750

Maximum displacement of the support, mm:

- longitudinal or vertical 820

- horizontal 100

Spindle speed, rev/min 100-2000

Working feed, mm / min:

- copier 5-1250

- cross 10-600

Speed of rapid transfer of the support, m / min: 4,5

- copier 4.5

- cross 4

Power of the electric motor 18.5

Overall sizes, mm:

- length .... .3000

- width 1480

- height 2200

Weight, kg 4500

3.7.3. Diamond cutting machine OS2425.

This machine is horizontal two-way, which means that the machining is carried out on both sides at the same time and independently. The diamond cutting machine has independent drives on both spindles, which makes it possible treatment in different cutting modes simultaneously.

Technical characteristics:

Maximum diameter of drilling, mm 150

Maximum force of feed platten, kg 250

Distance from the end of the mandrel to the platen 800

Distance from the end of the mandrel to the plate 100-1250

Number of speeds 12

Cone Morse ....№5

Feed for one table revolution 0,05-2,2

Platen sizes, mm 500 1220

Power of the electric motor, kW 4,5

Overall sizes, mm:

- length 1600

- width 975

Weight, kg 3600

3.7.4. Radial-drilling machine model 2M55.

Technical characteristics:

The largest diameter of the drilling, mm 50

Maximum displacement, mm:

- vertical 750

- horizontal 1225

Morse cone of spindle hole .... No. 5

Number of spindle speeds 21

Spindle speed, rev/min 20-2000

Number of feeds 12

Spindle feed .... 0.56 – 2,5

Maximum feeding force, Nm 20

Power of the electric motor, kW 5,5

Overall sizes, mm:

- length 2665
- width 1020
- height 3430

Weight, kg 4700

3.8. Technical normalization of the developed technological process.

Technical norms of time in production conditions are determined by the calculation and analytical method:

Determine the norm of component time, [1, p. 111]:

$$T_{шт} = T_o + T_в + T_{обсл} + T_{відп}. \quad (3.28)$$

The calculation is given for a turning operation, which is executed on a turning multi-tool semiautomated machine model 1716Ц.

The main time on the boundary position is 2,79 min.

Calculate the duration of added work and time for its implementation.

Installing the workpiece and removing it from the machine at one position is 0.3 minutes, and another loading time is 0.31 minutes. In general, 0,31 + 0,30 = 0,61 min.

Measuring of the part is 0,24 × 2 = 0,48 min.

The time spent on management, advance and removal of the tool we find by the formula:

$$T_и=T_1+T_2+T_3=4,6+1,45=6,05 \text{ c}=0,1 \text{ min.},$$

where T_1 – time for transporting the workpiece from the load to the working position, T_1=4,6 c.;

T_2, T_3 - time of advance and removal of the support.

Values of L_n i L_o (mm) at a speed of 1.5m / min. we find by dependence [7, p. 85]:

$$T_2 + T_3 = 0{,}017(L_n + L_o) = 0{,}017(45+40{,}4) = 1{,}45 \text{ c.}$$

The time for the measurement and replacement of the workpiece is:

$$0{,}61+0{,}48=1{,}09 \text{ min.}$$

overlapping the main time on the boundary position. In this case, the added time is 0,1 min.

The operating time is:

$$T_{on} = T_o + T_\partial = 2{,}79 + 0{,}1 = 2{,}89 \text{ min.}$$

In determining the time of maintenance of the working place, it includes time to replace the blunt instrument, as the time on chip control overlaps with machine time.

The tool kit contains 11 cutters.

Time to replace cutters is 1.03 × 11 = 11.33 min.

The time to replace the grooving tools is 1.5 + 3 = 4.5 minutes.

Then the time to replace the tool kit is:

$$T_{зм} = 11{,}33+4{,}5=15{,}83 \text{ min.}$$

We calculate the stability and basic time of tools:

$$T_{mex} = \frac{T_{зм} \cdot T_o}{T} = \frac{15{,}83 \cdot 2{,}79}{200} = 0{,}22 \text{ min.}$$

The operating time for the maintenance of working place is 2,4% of the operating time:

$$T_{орг} = \frac{2{,}89 \cdot 2{,}4}{100} = 0{,}069 \text{ min.}$$

The time for rest and personal needs is 6% of the operating time:

$$T_{відп} = \frac{2{,}89 \cdot 6}{100} = 0{,}17 \text{ min.}$$

As a result, the component time for an operation is equal to:

$$T_{шт} = T_{оп} + T_{тех} + T_{орг} + T_{відп} = 2{,}89 + 0{,}22 = 0{,}069 + 0{,}17 = 3{,}35 \text{ min.} \quad (3.29)$$

We will conduct technical normalization for an internal cylindrical stepped surface, the processing of which is carried out on a diamond-boring machine model OS2425.

Basic time at boundary position $T_о$=0,84 min.

The added time that goes on installing and removing the part is $T_{доп}$=0,13 min.

Time to control the machine is equal $T_к$=0,25 min.

The time taken to measure the precision of the part is $T_в$=0,22 min.

The operational time will be determined by the formula:

$$T_{оп} = T_в + T_{доп} + T_к + T_о = 0{,}84 + 0{,}13 + 0{,}25 + 0{,}22 = 1{,}44 \text{ min.}$$

The tool kit contains 5 internal boring tools.

Time to replace is $T_{зм}$=1,03×5=5,15 min. Since they work simultaneously, then:

$$T_{мах} = \frac{T_{зм} \cdot T_о}{200} = \frac{5{,}15 \cdot 0{,}84}{200} = 0{,}023 \text{ min.}$$

The operating time for the working place is 2,4% $T_{оп}$:

$$T_{орг} = \frac{1{,}44 \cdot 2{,}4}{100} = 0{,}034 \text{ min.}$$

Time for rest and personal needs we accept 6% from the operational time:

$$T_{відп} = \frac{1{,}44 \cdot 6}{100} = 0{,}086 \text{ min.}$$

Component time for operation is:

$$T_{шт}=0{,}84+0{,}034+0{,}22+0{,}086=1{,}18 \text{ min.}$$

3.9. Choice of equipment and determination of its quantity.

Proper choice of equipment means its rational use in time.

To this end, determine the use of time in line with other technical and economic indicators, the criteria that show the degree of use in time of each individual machine and all together on the developed technological process.

The coefficient of the machine loading will be determined by dependence:

$$\eta_3 = \frac{m_p}{m_n}, \tag{3.30}$$

where m_p – estimated number of machines;

m_n – accepted number of machines:

$$m_p = \frac{T_{шт}}{t_в}. \tag{3.31}$$

The calculations are performed on operations:

- 005 turning-screw:

$$m_p = \frac{2,0}{1,33} = 1,5; \ \eta_3 = \frac{1,5}{2} = 0,75\%,$$

- 010 turning:

$$m_p = \frac{3,35}{1,33} = 2,5; \ \eta_3 = \frac{2,5}{3} = 0,83\%;$$

- 015 turning:

$$m_p = \frac{1,1}{1,33} = 0,82; \ \eta_3 = \frac{0,82}{1} = 0,82\%;$$

- 020 turning-screw:

$$m_p = \frac{0,96}{1,33} = 0,72; \ \eta_3 = \frac{0,72}{1} = 0,72\%;$$

- 025 diamond cutting:

$$m_p = \frac{1{,}18}{1{,}33} = 0{,}88; \ \eta_3 = \frac{0{,}88}{1} = 0{,}88\%;$$

- 030 radial drilling:

$$m_p = \frac{0{,}4}{1{,}33} = 0{,}3; \ \eta_3 = \frac{0{,}3}{1} = 0{,}3\%;$$

- 040 radial drilling:

$$m_p = \frac{3{,}5}{1{,}33} = 2{,}6; \ \eta_3 = \frac{2{,}6}{3} = 0{,}86;$$

The coefficient of use for basic time η_0 indicates the proportion of machine time depending on the total operating time of the machine:

$$\eta_0 = \frac{T_o}{T_{шт}} \tag{3.32}$$

- 005 turning-screw: $\eta_0 = \frac{1{,}0}{2} = 0{,}5;$

- 010 turning: $\eta_0 = \frac{2{,}79}{3{,}35} = 0{,}83;$

- 015 turning: $\eta_0 = \frac{0{,}93}{1{,}48} = 0{,}62;$

- 020 turning-screw: $\eta_0 = \frac{0{,}25}{0{,}96} = 0{,}26;$

- 025 diamond cutting: $\eta_0 = \frac{0{,}84}{1{,}18} = 0{,}71;$

- 030 radial drilling: $\eta_0 = \frac{0{,}24}{0{,}4} = 0{,}6.$

- 040 radial drilling: $\eta_0 = \frac{1{,}4}{3{,}5} = 0{,}4.$

Determine the use of the machine on the power of the drive. This parameter is characterized by the coefficient of equipment usage:

$$n_N = \frac{N_{np}}{N_{\partial в}}, \qquad (3.33)$$

where N_{np} – the power of the machine drive, which is necessary for the cutting process.

$N_{\partial в}$ – power of the electric motor.

Accordingly for each operation:

- 005 turning-screw: $n_N = \frac{0{,}86}{10} = 0{,}086$;

- 010 turning: $n_N = \frac{1{,}21}{18{,}5} = 0{,}06$;

- 015 turning: $n_N = \frac{0{,}7}{18{,}5} = 0{,}03$;

- 020 turning-screw: $n_N = \frac{0{,}61}{10} = 0{,}061$;

- 025 diamond cutting: $n_N = \frac{0{,}55}{4{,}5} = 0{,}12$;

- 030 radial drilling: $n_N = \frac{2{,}88}{5{,}5} = 0{,}52$;

- 040 radial drilling: $n_N = \frac{0{,}96}{5{,}5} = 0{,}17$.

For a more visual presentation of the evaluation of the technical and economic efficiency of the developed technological process, it is advisable to construct the following graphs:

- loading equipment;
- -loading equipment for the main time;
- loading equipment by power.

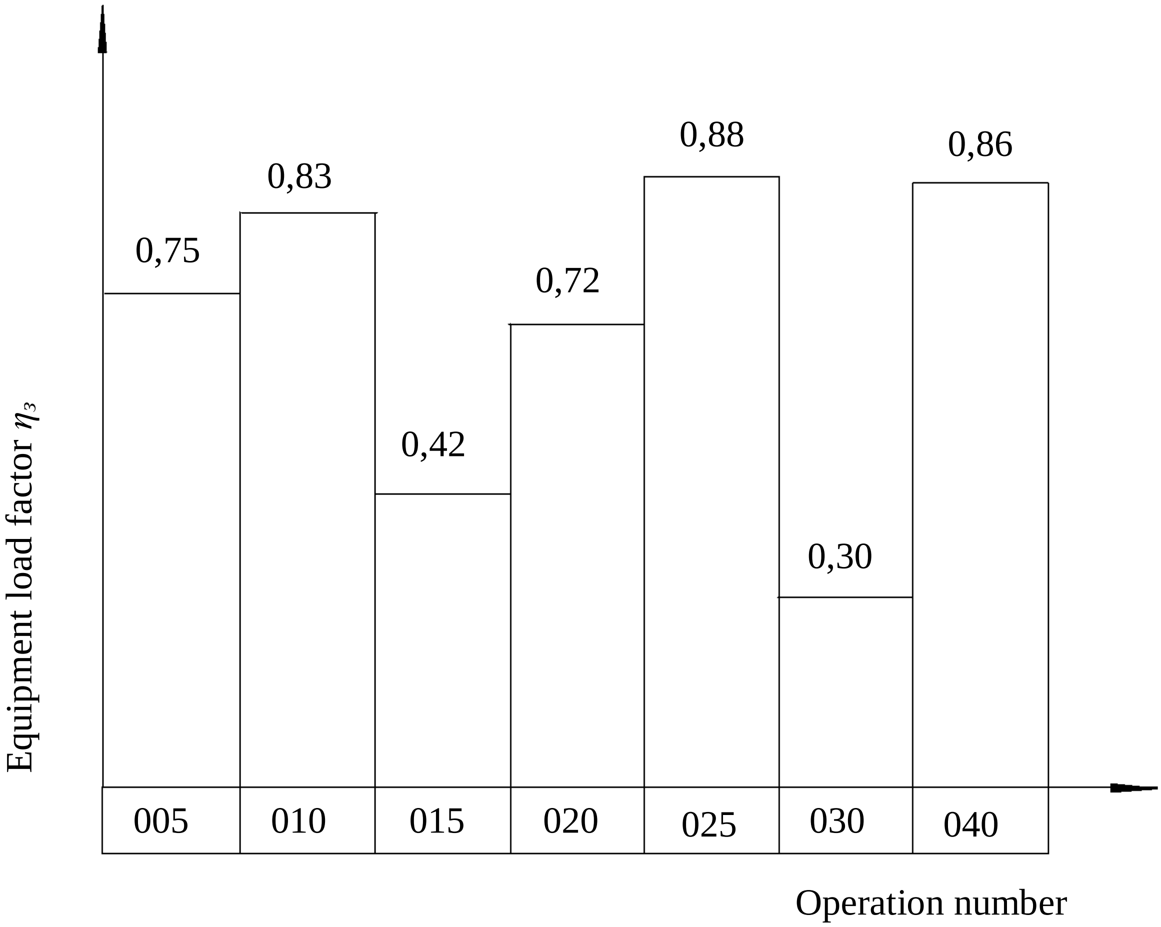

Figure 3.3 - Schedule of equipment load on operations

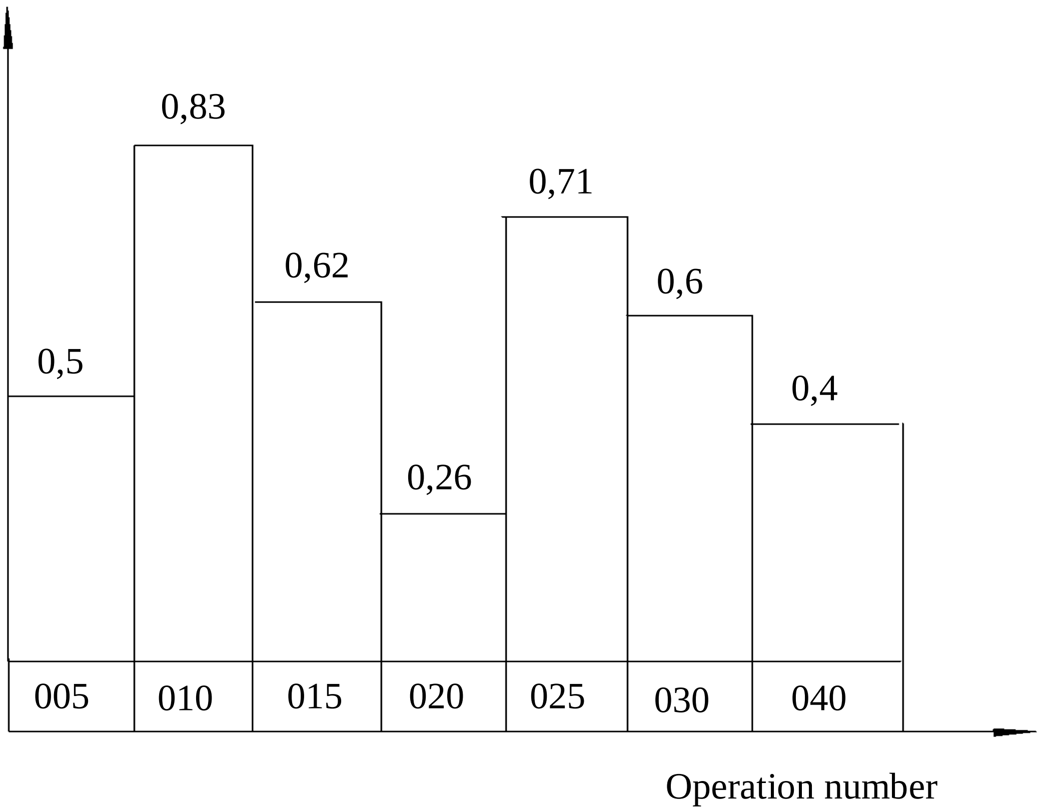

Figure 3.4 - The schedule for loading equipment for the main time

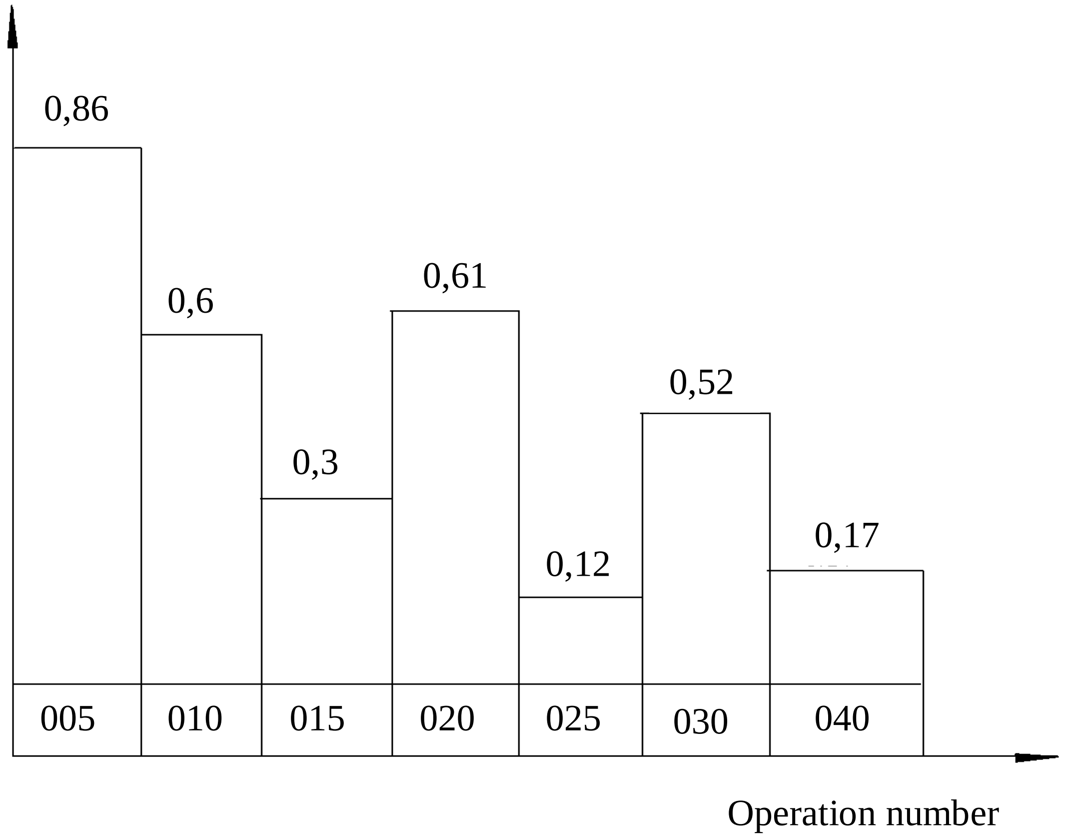

Figure 3.5 - Load schedule for power equipment

4. DESIGNING CHAPTER

4.1. Jig for boring holes ø92H8, ø120H8, ø140H8.

Design description.

The offered diamond-boring jig allows simultaneous fixing of two products, for simultaneous processing on a two-sided diamond-boring machine OS2425. This jig is installed on the platten of the machine tool in longitudinal fixtures using bolts. The jig is equipped with two power cylinders, on which a clamp of products is carried out.

The jig consists of a body 1, to which, with the help of screws 14, a barrel 8 is fixed, in which the workpiece must be based. The finger 3 acts as a pusher, which transfers the moment to the lever 5. After this, the lever presses on the clamp 6, which in turn fastens the workpiece in the barrel.

The lever 5 is located on the axis 7, which is respectively contained in the sleeve 9.

How it works.

The product is installed in a vertical position, so that the product axis is placed horizontally. The power clamp is made by a clamping, which is firmly fixed on the shaft axis. The barrel is installed in such a way that there is no scrolling of the workpiece during the boring process. Calculation of clamping force.

We calculate the condition:

$$Q_{зат} > K \cdot P_o, \tag{4.1}$$

where K – coefficient ratio, K=1,4...2,6 [10, p.32];

P_o – axial force.

$$P_o = 10 \cdot C_p \cdot t^x \cdot s^y \cdot \upsilon^n \cdot K_p, \tag{4.2}$$

where C_p=60; x=1,1; y=0,18; n=0;

$$K_p = K_{np} \cdot K_{\varphi p} \cdot K_{зp} \cdot K_{вp} \cdot K_{\upsilon p}, \tag{4.3}$$

where $K_{np} = (H_в / 150)^n - (60/150) = 0,4$;

when n=1: $K_{\varphi p}$ =1,19; $K_{вp}$=1;

$$K_p=0,4 \cdot 1,19 \cdot 1 \cdot 1 \cdot 1=0,476.$$

Axial force equals:

$$P_o = 10 \cdot 60 \cdot 1,0^{1,1} \cdot 0,2^{0,18} \cdot 98^0 \cdot 0,47 = 211,5 \text{ Nм}.$$

Considering, that $P_{o1}=P_{o2}$ - axial forces do not exist.

We deduce the formula for calculating the clamping force of the part.

In order for the part to be screwed, the cutting moment must be less than or equal to the clamping force of the part $M_{pіз} \le M_{тp}$.

For a greater probability, the coefficient K is introduced:

$$2M_{pіз}=K \cdot M_{тp}.$$

The result is:

$$K_{p_z} \cdot \frac{d_{cp}}{2} = F_{тp} \cdot d, \tag{4.4}$$

where $F_{тp} = Q \cdot f$ - frictional force.

Considering

$$K \cdot M_{різ} = f \cdot Q \cdot d_{cp} \tag{4.5}$$

We receive the formula for determining the clamping force:

$$Q = \frac{K \cdot M_{різ}}{f \cdot d_{cp^2}}, \tag{4.6}$$

where $M_{різ}$ – cutting moment;

f – coefficient of friction.

Determine the moment of cutting:

$$M_{різ} = P_z \cdot \frac{d_{cp}}{z}, \tag{4.7}$$

where d_{cp} – average diameter of boring holes.

The value of the cutting force is determined by the dependence:

$$P_z = 10 \cdot C_p \cdot t^x \cdot s^y \cdot \upsilon^n \cdot K_p, \tag{4.8}$$

where C_p=100; x=1; y=0,75; n=0.

Substituting data gives:

$$P_z = 10 \cdot 100 \cdot 0{,}25^1 \cdot 0{,}15^{0,75} \cdot 98^0 \cdot 1{,}56 = 94 \text{ Nm.}$$

Since, $P_{z_1} = P_{z_2}$ than:

$$M_{різ1} = 0{,}4 \cdot 0{,}0635 = 5 \text{ Nm,}$$

$$M_{різ2} = 0{,}4 \cdot 0{,}055 = 5{,}14 \text{ Nm.}$$

Given that the moments of cutting act in different directions, then:

$$M_{заг} = M_{різ2} - M_{різ1} = 5{,}14 - 5 = 0{,}14 \text{ Nm.}$$

Hence:

$$Q = \frac{2 \cdot 0{,}17}{0{,}25 \cdot 0{,}057} = 54{,}4 \text{ N},$$

$$Q_{заг} = 3 \cdot Q = 16324 \text{ N}.$$

4.2. Conductor rotary for drilling 8 holes ø11M.

Description of the jig.

The designed conductor makes it possible to fasten the product on already treated surfaces. It works in pairs with an 8-spindle head, through which the processing is carried out on all 8 holes simultaneously.

The conductor consists of a body 1, on which the stand 3 is mounted, which, in turn, must be based on the workpiece. On the workpiece from above, the conductive plate 6, which is mounted on the axis 5. In order to have the product centered, a finger 7 is attached to the axis, which is attached to the conducting plate by means of a screw 18 and pins 21. The conductor plate contains 8 sleeves 32, through which are directly carried out and the processing of holes. The plate is fixed with a nut 16. Disk 8, like a finger, serves for the main product base.

Calculation of clamping force.

We calculate the clamping force that is required for installing the part. To do this, we determine the coefficient of safety by the formula:

$$k = k_0 \cdot k_1 \cdot k_2 \cdot k_3 \cdot k_4 \cdot k_5 \cdot k_6, \tag{4.9}$$

where k_0 =1,5;

k_1 – take into account the state of the surface of the workpiece k_1=1,2;

k_2 – take into account an increase in the cutting force from the blunt tool k_2=1,5;

k_3 – take into account an increase in the cutting force during continuous cutting k_3=1,2;

k_4 – take into account the continuity of the clamping force k_4=1,0;

k_5 = 1,0;

k_6 – take into account the method of fixing the drill k_6=1.

So

$$k = 1{,}5 \cdot 1{,}2 \cdot 1{,}5 \cdot 1{,}2 \cdot 1 \cdot 1 \cdot 1 = 3{,}24 .$$

The force of the clamp Q is determined by the formula:

$$Q = \frac{2M \cdot k \cdot R}{d \cdot f \cdot P_o} - P_o , \tag{4.10}$$

where M – torque of the drill 13,403 Nm;

R – distance from center of drill to center of workpiece, R =125 mm;

d – diameter of the drill, d=11 mm;

f – coefficient of friction, f =0,25;

P_o – axial force 747,55 N.

Hence:

$$Q = \frac{2 \cdot 13{,}403 \cdot 3{,}24 \cdot 0{,}125}{0{,}011 \cdot 0{,}25 \cdot 0{,}1157} - 747{,}55 = 3258{,}1 \text{ N.}$$

4.3. Jig for controlling radial beats.

Description of the jig.

The jig for controlling radial beats provides the ability to control radial beats relative to the surface A. The jig consists of a plate 2, to which the indicator 25 is attached. The part is attached to the stopper 3, which consists of a plunger 8 used for clamping the product. The plate is attached to the edge by 4 screws 21 and 12.

Also, the stand 6 is attached to the plate, which in turn is fixed by a movable lever 7 and indicator 25. The indicator is fixed by screw 15. And the lever to the stand is fastened by a pin 19, the indicator 1 is used to control the end beating.

The principle of the operation of the jig.

The part is installed on the stopper 3 and pressed against the walls of the plunger. 8 The part is based on the surface of the stopper. Radial beats are controlled by lever 7. Since the angle of inclination of the edge - 15^0 then when placed on a horizontal surface of the deviation will be clearly visible on the indicators 25. The jig works in such a way that, in the case of a radial beat, the part will, when deviating, push on the levers which will be crushed on the fingers of the indicators.

Determine the permissible radial beating of the surface (Ø140мм).

To calculate we use the dependence:

$$\varepsilon_{пр} \leq \delta - k\sqrt{\varepsilon_{\delta}{}^{2} + \varepsilon_{3}{}^{2} + \varepsilon_{уст}{}^{2} + \varepsilon_{знош}{}^{2} + \varepsilon_{n}{}^{2} + (k+\omega)^{2}} \quad , \qquad (4.11)$$

where δ - deviation to the corresponding size of the processed surfaces of the product; δ=0,12 mm;

k –coefficient that takes into account the possible deviation from the normal distribution of these components; k=0,2;

ε_{δ} - baseline error; ε_{δ}=0;

ε_{3} - bonding error, ε_{3}=0,08 мм [4, p. 40];

$\varepsilon_{уст}$ - installation error; $\varepsilon_{уст}$=0,017 mm;

$\varepsilon_{знош}$ - wear error; $\varepsilon_{знош}$=0;

ε_{n} - transition and offset error; ε_{n}=0;

ω - error value based on economic precision for this method; ω=0,5 mm.

$$\varepsilon_{пр} = 0{,}12 - 0{,}2\sqrt{0^2 + 0{,}08^2 + 0{,}017^2 + 0{,}07^2} = 0{,}043 \text{ mkm.}$$

Therefore, the deviation in radial beating is within the normal range.

5. SPECIAL CHAPTER

5.1. Structure and composition of CAD.

Structural elements CAD, which are rigidly associated with the organizational structure of the design organization are subsystems, which, through the use of specialized sets of measures, is solved a functionally completed sequence of CAD tasks.

As the basic CAD structure, they adopt a design subsystem that has all the properties of a system that is object orientation and implements the design functions.

The second structural part of the CAD is a subsystem of service that has common systems of use and serves to support the design system, as well as the execution of data transmission and output. Each of the subsystems CAD consists of components combined by a common target function, which ensure the functioning of the target system.

The component is a security element that performs a specific function in the subsystem. Depending on the type of security, the following components are distinguished:

- mathematical support: methods, mathematical models, algorithms;
- linguistic support: terminology;
- technical support: computing and office equipment, storage and data transmission devices;
- information support: documents describing standard procedures, typical elements and typical solutions;
- software: documents with program texts, programs on carriers and operational documents;

- methodical support: documents, which reflect the composition, rules of choice and operation of software;

- organizational support: regulations, instructions, orders and other documents regulating the organizational structure of the design organization in the functioning of CAD;

- legal support: documents regulating the legal relations of the parties when creating, implementing and operating CAD.

The structural unity of each of the subsystems is ensured by links between the components of different types of security, and the timely pooling of subsystems in the system is ensured by the links between the components.

To determine the structure of CAD and subsystems, all system-based principles are distinguished, including the principles of compatibility, systemic unity, standardization and development.

The principle of compatibility is that the languages, symbols, codes, information and technical characteristics of the structural links between the components of CAD should be coordinated in such a way as to ensure the interoperability of the system and maintain the open structure of the system as a whole. In addition, when creating a CAD, it is necessary to ensure compatibility of automated and unmanned control of subsystems CAD and CAD with the external environment.

The principle of system unity is that at all stages of the creation and operation of CAD, the development of all types of security should be carried out so that all components form the system.

The principle of standardization is that all components and complexes of devices are brought in line with industry standards, in addition, all elements must be designed so that they can be used without significant changes for any design object.

The principle of development lies in the fact that CAD should function as a system that is improved, allows for renewal and improvement.

In the process of exploitation, CAD should be improved not only by expanding the nomenclature of technological design documentation, but also by improve the quality and automation of design, which is to use multivariate (optimization of technical solutions).

5.2. The main components and types of CAD information support.

Information support CAD - documents that contain descriptions of standard design procedures, typical design decisions, typical elements, component parts, materials and other data, as well as files and units of data on carriers with the recording of these documents.

The basis of information support CAD (CAD) are data that are used by designers in the design process directly to develop a design solution. A database in CAD means a set of interrelated data stored together in the external memory of a computer and is usually used by more than one software component or user of CAD.

These data, given their complexity and the multidimensionality of the CAD itself, can be presented in a variety of ways. These can be program modules (programs), output and intermediate results of calculations (numbers) and various reference normative data, standard solutions, intermediate and final design decisions, etc.

All functions related to organization, maintenance and access to the database are performed using special software called database management system (DBMS).

The set of data used by all components of the CAD is called the CAD information resource.

The purpose of informational provision of CAD is to realize the information needs of all structural elements (subsystems) CAD.

The main function of CAD information provision is to manage an information fund, that is, to provide, support and organize data access. Thus, the information security CAD - a collection of information fund and its means of conducting.

2. Composition of the CAD information fund.

The structure of the information fund CAD includes:

1. Software modules stored in the form of program texts and associated object modules, respectively. Typically, these data vary little during the lifecycle of CAD, they have fixed sizes and appear at the stage of creation of information support CAD. Users of this data have monitors of various CAD subsystems and instrumental software complexes.

2. Output and result data that are needed to execute program modules during the transformation process. These data often change during the design process, but their type is constant and is fully determined by the appropriate software model. Users of these subsystems are program modules of procedural subsystems.

3. Normative reference project documentation (NDPD) - which includes reference data on materials, elements of schemes in unified nodes and designs. These data are usually well structured and can be categorized as factual. The NAP also includes State and industry standards, guidance materials and guidance, typical design decisions (poorly structured documentary data). Users - program modules of projecting subsystems.

4. The content of the display screens, which is a connected set of data that defines the shape of the frame, and accordingly - they allow displaying information on the screen for the purpose of organizing the dialogue interaction during the design. As a rule, these data do not change during the life cycle CAD, have a fixed size and in their characteristics occupy an intermediate position between program modules and output data. Users - CAD system dialogs.

5. Current project documentation - shows the status and progress of the project. Typically, these data are poorly structured, often changing in the design process and placed in the form of text documents. Users

- program modules of projecting subsystems CAD.

Distinguish the following ways of maintaining an information fund CAD:

1) the use of the file system;

2) construction of libraries;

3) use of data banks;

4) creation of information programs - adapters.

The use of the file system and the construction of libraries is widespread in the organization of information support of computing systems, as supported by standard system-wide tools and operating systems. In the appendix to the CAD they are used in the preservation of program modules in symbolic and object codes, dialogue scenarios to maintain the design process, the initial input of large arrays of output data; saving text documents.

But to provide quick access to the reference data; saving of data variables; maintenance of current project documentation; search of necessary text documents; organizing the interaction between multilingual modules, these methods are ineffective.

A file system is a collection of files organized using data management tools that are available in the computing system. A file is a collection of data that consists of logical records pertaining to a single topic, or - is an ordered area of memory on external magnetic storage media (disks) that consists of individual records. To manipulate with records or integer files (viewing, deletion, correction, etc.) you need to create special programs or use only computer systems.

The library is the same set of files, but combined into some group for some functional attributes. For example: a PPP library for designing and constructing drilling machines and auxiliary equipment.

In CAD applications, these two methods are used only to store program modules, output and object codes, content display screens, initial input of large arrays of output data, save text documents, although the use of these methods is excluded in the organization of an information fund for the whole CAD for simple objects. However, it should be noted that these methods are ineffective in order to provide quick access to the reference data, save fast-moving data, enter current project documentation, search for the required text documents, and organize interactions between multilingual software modules.

Method 3: Using Data Banks. It is the basis and the most important form of organization of the information fund, and the data bank, in turn, constitutes the largest part of information support CAD compared with other types of organization and data management. This method allows you to:

- Centralize CAD information resource;
- to structure data in a way that is convenient for the designer;
- provide quick search of normative reference and design documentation;
- Simplify the organization of the intermodule interface by unifying intermediate data.

5.3. Methodology of designing technological processes for manufacturing parts using a package of applied software of the CAD-CAM.

The application package (EPT) of the CCI CAD is used to design the technological processes of manufacturing parts, especially in the conditions of small-series and unit production, when there is no need for detailed design of technological processes.

Description of operations of the technological process in this CAD is divided into two parts: constant and variable. The permanent part of the description is common to all the details of the group. This part of the description includes the names of operations, the description of transitions, for individual transitions in the form of constant information can be recorded cutting and measuring instrument, devices. Actually, it also makes up the content of a typical technological process. The variable part of the description of operations and transitions is formed according to the specific conditions of each detail of this group when developing the working process. This is primarily the executive dimensions, the characteristics of the used cutting tools, machine models. Variable parts can include attributes of technological equipment.

The technological process, as an element of the CAD information provision, is a sequential description of operations made up of transitions and their detailed description.

Work with the package is carried out in dialog mode. The technologist forms the structure of the route operational process, selects operations and transitions, and in memory of the computer introduced only a variable part of the descriptions, which is marked with special icons on the display screen. In addition, typical process that are stored in the information retrieval subsystem CAD are widely used for work.

Despite the small share of tasks that are solved by the computer, the use of CAD of route technological processes on the basis of the standard technology gives the company a significant effect. Terms of manufacturability are reduced on average 3-4 times.

5.3.1. Preparing the source information.

Для формування маршруту механічного оброблення деталі необхідний повний опис деталі (кодування) засобами якої-небудь формалізованої мови.

In a situation where the range of products that are produced is large, coding can be very laborious procedure. Therefore, at a low level of complexity of the part it is expedient to leave behind the technologist the stage of formation of the structure of the route technological process. For downtime, the details of the technologist are easier and quicker to set the computer structure of the route than to describe the design details, all sizes and technical requirements in the formalized language.

With this approach, the technologist himself analyzes the typical technological process, chooses the necessary operations and transitions, and in the computer he introduces only the variable parts of the descriptions, that is, the description of those operations of the project variant of the technological process, which made changes.

1. For the development of the technological process of machining with the help of CIM "CAD CAM" the following output information is required:

2. Basic process of manufacturing parts.

3. Typical technological process, executed on the forms of route technological cards.

4. The variable information is presented in the form of tables 5.1 and 5.2.

Table 5.1 - General details of the item

Marking technological the process	Part		
	Marking	Name	Mass
КС6 57-017	КС6 57-017	Cover	4,74
Material, name and brand	Workpiece		
	Kind	Profile and size	Mass
АК7М2(АЛ14В)	Casting	Foldable profile	4,99

Table 5.2 - Input information for technological design the manufacturing process of the part

Number			Code of operation, transition	Equipment	Technological equipment
Shop	Places	Workers places			
1	01	005	41211X	16К20	Adaptation
1	01	010	0090	1716Ц	Adaptation
1	01	015	4212	1716Ц	Adaptation
1	01	020	4212	16К20	Adaptation
1	01	025	4262	ОЦ 2425	Adaptation
1	01	030	0090	2М55	Adaptation
1	01	040	4214	2М55	Adaptation

5.3.2. Block diagram of the algorithm for automated design of the technological process.

PPP "CCI CAD" contains maintenance subsystems for input and control of source information, documentation, adaptation, information retrieval. Information retrieval subsystem stores the typical technological processes and their search. The source document is a route description of the technological process. The subsystem of CAD adaptation serves to introduce new typical processes into the archive and delete unnecessary ones.

An enlarged block diagram of the algorithm of the subsystem design is shown in Fig. 5.1. To reduce machine-time designing, first search for the typical process and re-write it into the computer memory. In the fourth block, the formation of the transition for the work process is performed. To do this, in the description of the transition or operation (constant part), taken from the archive of operations and transitions, the corresponding information (variable part) from the original document is entered. After designing and processing the first record of the source document, the transition to the next and so on until the end of the document occurs.

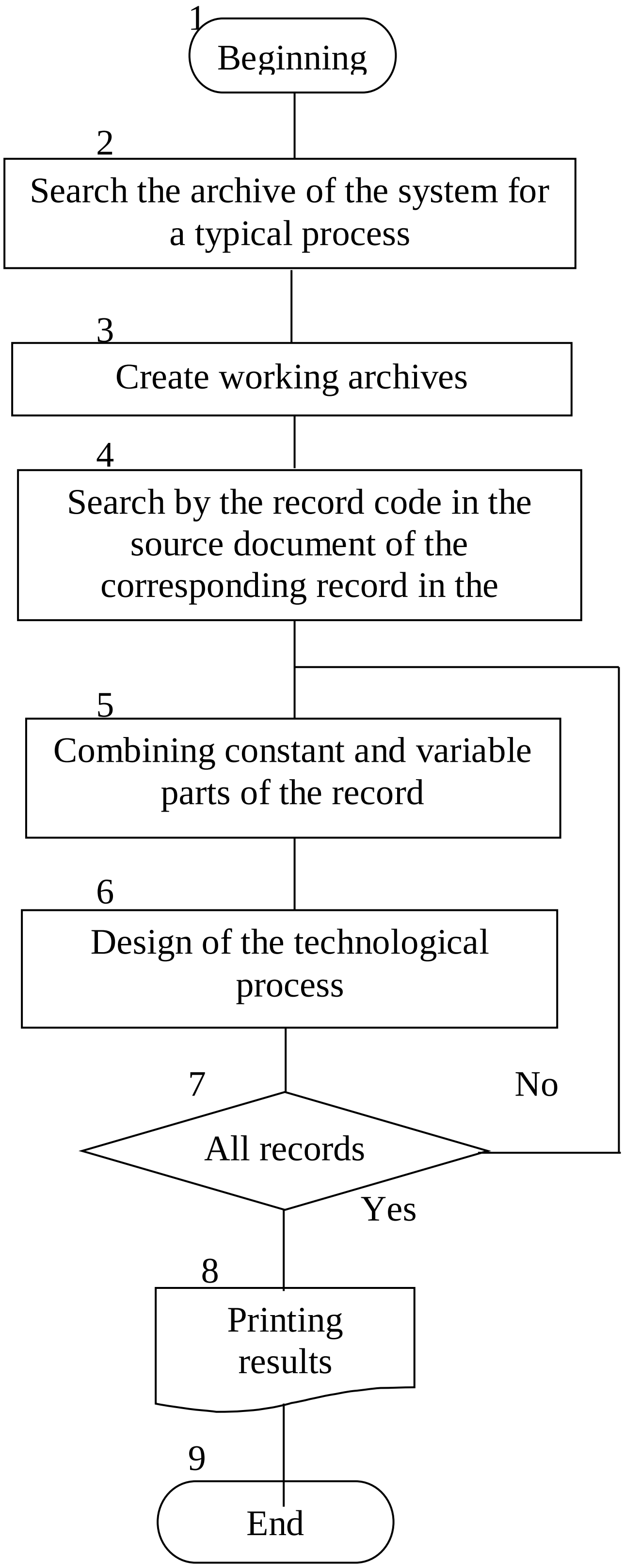

Figure 5.1 - Block diagram of the algorithm of the design subsystem of CCI CAD

5.4. Analysis of the technological process, obtained with the help of CAD of the TP.

After analyzing the technological process for machining the guides, obtained using CAD of the TP, we conclude that the construction of operations and the choice of technological bases are carried out correctly.At the first operation, the preparation of the base surfaces for the next treatment is carried out.

The first operations are cutting the ends, boring of the base surfaces, milling, drilling and cutting, and after that the control of the treated surfaces.

The devices, cutting and measuring tools are selected correctly taking into account the type of production and the provision of minimum operating time.

The tool for processing is chosen to allow the use of high-performance processing methods.

The developed technological process is real, provides the qualitative detail in accordance with the working drawings and technical requirements and can be used in the current production.

6. PLANNING CHAPTER

6.1. Specification of production program.

The main objective of this section is to design a site that would provide the product of this program and the required quality, while achieving the lowest possible cost of production, taking into account all requirements for compliance with occupational safety and fire safety.

The production program of the site is determined based on the production program of the enterprise, taking into account the established percentage of spare parts. It should be kept in mind that often parts and assembly units are manufactured by adjacent factories. Detailed production program at the site is formalized in the form of table 6.1.

Table 6.1 - A detailed annual production program for manufacturing parts

№	№ drawing		Item name	Material Brand	Type of workpiece	Number of parts per item	% on spare parts	Number of parts			Mass, kg		Weight per program, kg	
	node	details						main one	on spare parts	Total	Billets	details	blanks	details
1	KS6-57.017	KS6-57.017	Cover	AK7M2(АЛ14В)	Casting	1	-	12000	2400	14400	4.69	3.82	67536	55008

6.2. Calculation of complexity and machine-tool manufacturing of products on the basis of developed technological processes.

Considering the availability of baseline data and the depth of development of technological solutions, the design of the site is carried out by integrated methods. The main source data in this case will be:

- annual release program;
- weight of the product;
- artificial time of processing of details on each operation.

The complexity of machining in detailed design is determined by the technological process according to the recommendations, as the sum of artificial times for all operations:

$$T_M = \sum T_{um} \ . \qquad (6.1)$$

$$T_M = 2.00 + 3.35 + 1.48 + 0.96 + 1.18 + 0.4 + 3.5 = 12.87 \text{ min.}$$

6.3. Determination of the annual need for technological equipment. Compilation of equipment summary.

The quantity of the main technological equipment of the site is determined by the technological process in accordance with the selected type of production and the form of production organization.

The specification of the basic process equipment of the machine shop section for the manufacture of the cover is given in Table 6.2.

In addition to the main, the station is located auxiliary equipment:

– device for removing the burrs;

– flushing unit;

– control table.

Table 6.2 - Specification of the basic processing equipment of the machine shop section for the manufacture of the cover

№ п/п	The name of the operation	Name and model of equipment	Quantity, items.	Dimensions, mm
005 020	Screw-cutting	Screw-cutting mod 16K20	2	2785×1165
010 015	Lathe	Lathe 1716C	2	3000-1480
025	Diamond-boring	Diamond boring mod. OS2425	1	1600×975
030 040	Radial drilling	Radial-drilling mod.2M55	2	2665×1020
	Total	-	7	-

6.4. Determining the number of staff at the site.

The following categories of workers are involved in the projected section during the production process:

– production workers;

– support workers;

– engineering and technical workers;

– junior support staff;

– office staff.

The number of production workers machine-tools of mechanical department is determined depending on the number of machines by the formula:

$$P_B = \frac{C_{ПР} \cdot F_Д \cdot k_з}{F_{др} \cdot k_б}, \tag{6.2}$$

where $C_{ПР}$ – quantity of equipment accepted;

$F_Д$ – vacover annual equipment operating time fund with accepted operating mode, $F_Д$ = 4015 year.;

$k_з$ – equipment load factor, $k_з$ = 0,12;

$F_{др}$ – vacover annual working time fund of workers, $F_{др}$ =1820 hours;

$k_б$ – multilevel service factor, $k_б$ = 1;

$$P_B = \frac{7 \cdot 4015 \cdot 0{,}73}{2250 \cdot 1{,}3} = 7 \text{ person.}$$

We accept $P_в$ = 7 men.

The number of working other categories is accepted according to the recommendations, the results are recorded in Table 6.3.

Table 6.3 - Statement of the composition of the employees of the site

Working Category	Determination Method	Percentage ratio	Number
1	2	3	4
Workbenches	by the formula (6.2)	—	7
Locksmiths	в % ratio	1...3	—
Auxiliary hardeners	в % ratio	35...50	1
МОП	в % ratio	2...3	—
ІТП	в % ratio	10...13	—
ЛКП	в % ratio	4...5	—
Total			8

The number of controllers VTK is accepted in mass production 8 ... 10% of the number of production workers of the mechanical department. We accept the number of controllers - 1.

6.5. Determining the size of the main and auxiliary areas of the shop.

Determination of the total area of the site of the assembly shop is based on data on the complexity of the work on the technological process of manufacturing the part in the conditions of production of the base enterprise. Output data:

– the total number of machine tools of the shop – 7 pieces;

– number of grinding machines – 2 pieces;

– number of machines of the workshop repair base – 3 pieces;

– number of machines of the equipment repair station – 2 pieces;

– number of control tables – 3 pieces;

– dimensions of all machines – medium.

The production area of the site, which is determined by the specific area per unit of equipment according to technological design standards, is equal to:

$$S_M = N \cdot S_П , \tag{6.3}$$

where N – number of machines, pcs.;

$S_П$ – specific area for one machine, $S_П$ = 18...25 m^2.

$$S_M = 17 \cdot 25 = 425 \text{ m}^2.$$

The area of the assembly and test compartment according to the recommendations is accepted within 30 ... 40% of the area of the mechanical compartment. We accept 30% від 425 m^2 = 127,5 m^2.

The auxiliary area consists of the areas occupied by the subsidiary offices:

1. Tool sharpening department.

Number of grinding machines –2, specific area – 8...10 m^2.

So, the area of the grinding department = 20 m.

2. Workshop repair base.

Number of CRB machines - 3, specific area – 20 m^2.

So the total area = 60 m^2.

3. Control department.

Branch area is determined at the rate of 5 ... 6 m^2 per controller.

Therefore, the area of the control department is 1×6 = 6 m^2.

4. Compositions of materials and blanks.

The area of composition of materials and workpieces is determined by dependence:

$$F_З = \frac{M_{\Sigma} \cdot t}{260 \cdot q \cdot k_B}, \tag{6.4}$$

where M_{Σ} – mass of material and billets of annual output, M_{Σ} = 122.5 ton;

t – number of working days of storage of blanks in storage, t =12;

q – permissible load per 1 m^2 of warehouse floor area, q = 1,4 ton/m^2;

k_B – storage area utilization factor, k_B = 0,3…0,4.

$$F_Ç = \frac{122.5 \cdot 12}{260 \cdot 1{,}4 \cdot 0{,}39} = 11{,}46 \text{ m}^2.$$

5. The intermediate composition.

The intermediate composition is intended for the interoperable accumulation of nodes and parts and its area is determined by the formula (6.4).

$$F_З = \frac{122.5 \cdot 12}{260 \cdot 1{,}4 \cdot 0{,}3} = 13{,}46 \text{ m}^2.$$

6. Department for preparation and distribution of coolants, lubricants composition.

The area of this compartment is determined by the recommendations depending on the number of machines and is assumed to be 30 m^2.

7. Chips collection and processing department.

The area of this compartment is determined similarly to the previous one and is assumed to be 60 m^2.

8. Instrument-distribution pantry.

The rules for calculating the area of this compartment depend on the number of machines of the mechanical compartment. Take an area of 34 m^2.

Office space is assumed to be 25 ... 30% of the area. We accept an area of 25%, and therefore it is 184.3 m^2.

The area of the site depends on the size and weight of the machines and is accepted for light machines within 14 ... 18 m^2, for medium - 18 ... 22 m^2, for heavy - 22 ... 30 m^2.

Table 6.4 - Area of the site for manufacturing parts

Equipment (machine)	Model	Dimensions, mm	Type	Accepted specific area, m^2
1	2	3	4	5
Screw-cutting	16К20	2785×1165	average	6,48
Lathe	1716Ц	3000×1480	average	8,88
Diamond-boring	ОС2425	1600×975	average	1,56
Radial drilling	2М55	2665×1020	average	5,44
Control table	—	2000×1000	—	6
Seats warehouse. blanks and parts	—	—	—	13,46
The total area of the machining section				41,82

Table 6.5 - Area Notices

№ п/п	Branch name	Area, m^2
1	Mechanical	425
2	Assembly	127,5
3	Sharpening	20
4	Workshop Repair Base (CRB)	60
5	Equipment and tools	22
6	Control	60
7	Composition of materials and blanks	11,50
8	The intermediate composition	13,46
9	The composition of lubricating and cooling liquids (MPA)	30
10	Chips processing department	60
11	Instrument Distribution Room (IRC)	34
	Total	864
12	Main thoroughfares (12 ... 15% of the area of all branches of the shop)	130
	Total	994
13	Office premises	184,3
	Total	1178,3

6.6. Determining the basic dimensions and choosing the type and construction of the building.

The basic dimensions are chosen based on the design area based on the use of standard type sections. The production areas of the workshop are housed in a single-storey, non-crane rectangular building with a grid of columns of 18 × 12 m. The height of the span is 7.2 m.

Auxiliary facilities were added to the side of the shop with a width of 12 m, a grid of columns 6 × 6 and the number of floors 2. The height of the floors is assumed to be 4.2 m. Total area - 1152 m^2.

In the frame structure of the building is used precast concrete foundation glass type. It rests on columns and foundation beams. Uniform reinforced concrete columns are accepted dimensions of 500 × 500 × 6900 mm.

Half-timbered columns are also reinforced concrete, as six-meter wall panels use three-layer reinforced concrete. In the standard type sections, only one truss with a span length of 18 m is foreseen for rafters and supporting structures and 12 meters for rafters.

For side windows, window frames made of steel and plastic materials are used to fill them with large-sized sheet glass, using sunscreens.

Scovering gates, wooden with iron frame - 4 × 4,2 m, equipped with air thermal curtains. The doors are 1.5 x 2.4 m in size and are placed at equal distances along the perimeter of the building.

The roof is pitched, made of 3 × 6 m reinforced concrete slabs. The boards are made of wood-fiber boards. Asphalt screed is laid on the insulation boards, on which a waterproofing carpet of 5 layers of rolled materials is glued with the help of mastic, the 3 lower layers are made of tal-skin, the upper 2 - of roofing material.

The floor is made of polymer-cement coating, which allows for technological loading of 3..5 t / m^2, use of water, mineral oils and emulsions and has low cleaning efficiency.

6.7. Development of layout plan.

The purpose of the layout plan is the interconnection of shops, departments and divisions that are part of the building, the choice of optimal directions of the production process, internal transport, cargo and human flows, as well as auxiliary and office premises.

The initial data for drawing up the layout plan are: technological scheme of the master plan and scheme of cargo flows; the composition of the workshops and the size of the areas of all offices and premises; the scheme of the building is accepted; basic building parameters and general layout of the building.

The layout with the help of conventional symbols shows: the main walls; workshop and site boundaries, ancillary equipment and structures; basic lifting and transport vehicles; main aisles and passageways; tunnels, passageways with elevation marks for them relative to the floor of the first floor. A cross-section of the production building span, made on a scale of 1: 100, is added to the layout plan. All departments of the workshop are located in the direction of the total production flow in the following sequence:

a) blanks are located at the beginning of each production line;

b) the sites for storing the finished parts are located at the end of the machine lines after the technical control units;

c) in the composition of the workpieces are located machine compartments;

d) at the end of the machine compartments, a transverse passage of 4 m wide is envisaged;

e) on the way there are offices of technical control;

f) The sharpening compartment, toolbox and other auxiliary compartments shall be located on the side of the stream so as not to interfere with the movement of parts.

Warehouses in the shop (material and billet composition, intermediate warehouse, distribution and toolbox) are separated from the machine compartment by a grid height of 2.5 m, and the control and sharpening compartment - by a glass partition.

6.8. Elaboration of the layout of the equipment.

The layout of the equipment is developed on the basis and in accordance with the layout of the shop and the location of the building elements of the building. Development of the equipment layout plan was performed in an AutoCAD environment using flat templates.

The basic principle in drawing up the layout of equipment at the machining section is to ensure the accuracy of the movement of parts in the process of processing in accordance with the technological process, as well as to establish the optimal distances between the equipment, columns, walls.

As the type of production is a multi-series, the recommended way to place equipment is in the process.

Prior to loading, the equipment is made by processing other parts manufactured in the shop at this site.

The equipment at the site is placed sequentially during the technological process along the span. The coordinate axes of the building on the plan coincide with the designations adopted on the layout plan. The distance between the machines - 900 mm, from the passage to the front of the machine - 1000 mm, from the walls, columns to the back of the machine - 700 mm.

The plan of placement of equipment at the site is accompanied by a cross-section of the span of the industrial building, in which it is located indicating the height of the span, the total height, equipment and vehicles, elevation markings of clean floor and channels for removal of chips, contours of the bases of columns, foundations with the sizes of anchoring equipment to coordinate axes and structural elements of the building.

6.9. Development of technical specification for technological preparation of production.

After designing the product to identify the necessary equipment, equipment and tools, information is collected about their need.

The equipment group is engaged in the technological equipment together with the service of the chief mechanic. They select the equipment from the warehouses available and free in the shops of the enterprise, which meets the technological accuracy requirements of the technological process and carries out, if necessary, control of its repair.

The draft order for the transfer of equipment from the shop to the shop agrees with the chief specialist and is submitted to the chief engineer for approval.

The manufacturer of the new equipment at the plant and beyond is determined, the technological documentation related to the ordering and manufacturing of the equipment is drawn up through the capital construction department, the terms of delivery and testing are determined.

Special equipment, cutting tools, and controls are manufactured according to the tasks provided by the technological services to their design units. These units include design offices for tooling, tooling, casting, hot and cold stamping.

When designing technical equipment, the requirements of ESCD should be sought, striving for structural rationality and perfection of the design at the lowest possible cost of production and operation.

7. ECONOMIC BACKGROUND

7.1. Organization and efficiency of equipment repair at machine shop section.

The organizational and production structure of repair services depends on a number of factors: the type and volume of production, its technological characteristics, the development of co-operation when performing repair work. The repair industry of a large engineering enterprise includes a repair and construction workshop, which performs repairs of buildings and structures, subordinate to the department or the management of capital construction; electric repair shop, which carries out repair of energy equipment and subordinate to the main power engineering; repair and mechanical workshop, which carries out repair of technological and other types of equipment, manufacturing of variable parts and is subordinate to the chief mechanic. Repair base of the chief mechanic, except repair and mechanical shop, includes lubrication and emulsion economy, warehouses of equipment and spare parts. In large workshops there are also repair bases or workshops that are subordinated to the mechanics of the shop.

Modern machine-molding enterprises are equipped with expensive and varied equipment, automated parts. For uninterrupted operation of equipment with specified precission characteristics, systematic maintenance, performance of repairs and measures for technical diagnostics are necessary.

The organization of maintenance and equipment maintenance is based on the system of planned and preventive repairs.

The system of planned and preventive repair of equipment is a set of planned organizational and technical measures for the care, supervision of the equipment, its maintenance and repair.

The main objective of these measures is to prevent progressively deteriorating wear, prevent accidents and maintain equipment in a state of constant readiness for work. This system includes maintenance and planned repairs - current and capital.

Maintenance is a complex operations for maintaining the equipment's performance when used for its intended purpose, while maintaining and transporting. In the process of maintenance, periodic repetitive operations-inspections, flushing, and precission checks are performed according to a pre-designed schedule. In addition, production workers, metalworkers, electricians, lubricants daily monitor the equipment state, adhere to the rules of its operation, and eliminate minor malfunctions. Some regulated maintenance operations may be combined in time, for example, a change in lubrication with overviews.

Current repairs are carried out during the operation of the equipment. In this type of repair are replaced and restored individual parts of the equipment and is regulated its mechanisms. The purpose of such repairs is to ensure the efficiency of the equipment and adjustments to the pre-planned repairs. Major repairs are carried out to restore a full or close to full resource. Usually it is accompanied by the modernization of equipment..

Repairs caused by failures in work and equipment failures are called unplanned or emergency. With a well-organized system of maintenance service and a high culture of operation of the equipment, the need for unplanned repairs, as a rule, does not arise.

The system of repair and maintenance depending on the nature and operating conditions of the equipment can function in various organizational forms: in the form of a post-inspection system, periodic repair systems or a system of standard repairs. In the system of after-care repairs in accordance with the pre-drawn schedule performed inspections of equipment in the process of which evaluates its condition and consists of a roll of defects.

Based on the survey data, the terms and contents of future repairs are determined. The system of periodic repairs and normative part of the basis for a typical system maintenance and repair of metal and woodworking equipment. At this system, the terms and volumes of repair works of all types are planned. However, the actual amount of work is adjusted when viewed. This system is most widely used in machine molding. With the system of standard repairs, the volume and content of them are planned and strictly adhere regardless of the actual condition of the equipment. This system is based on well established standards and apply to equipment, unplanned stops is unacceptable.

The standards of the typical system are differentiated according to the equipment groups. The most important of them are: repair cycles and their structure, repair complexity categories, laboriness and material consumption of repair works, spare parts, units and aggregates. On the basis of calculations of these standards, develop annual schedules of planned and preventive repairs, determine the labor intensity of future work and establish the staff of repair staff.

Repair and maintenance of technological equipment at machine-molding enterprises are carried out by repair-mechanical shops and repair shopsof the enterprise. Depending on the proportion of work performed by the industrial repair and mechanical workshops and guild repair services, there are three forms of organization of repair: centralized, decentralized and mixed. In the centralized form, all types of repairs are performed by the repair and mechanical workshop of the enterprise. When decentralized, they are executed by the workshop repair bases. On these bases, new and reconditioned worn parts are manufactured. In the mixed form, the most labor-intensive works are carried out in the repair and mechanical workshop, and maintenance and repairs - by the workshop repair bases, complex groups of metalworkings, which are fixed at separate sections.

The main directions of improvement of the repair industry are: introduction of advanced methods, technological processes and organizational forms of work, application of modern means of technical diagnostics of the state of equipment, complex mechanization of works, introduction of advanced technological processes, factory certification of works, specialization of repair teams by type of equipment.

In order to carry out repair works in the structure of the machine-assembly workshop it is recommended to install a workshop repair base (WRB).

The WRB area is determined by the specific area, which falls on the unit of installed equipment. The number of WRB machines is determined by the dependence:

$$S = \frac{T_{\Sigma}}{F_{\partial} m \eta}; \tag{7.1}$$

where T_{Σ} – Total time for repair of all equipment, h.;

F_{∂} – vacover annual work time fund;

m – the number of changes;

η - load factor of equipment.

$$\text{therefore, } S = \frac{12848}{4015 \cdot 2 \cdot 0.8} = 2.$$

The volume of repairs per year for the entire number of equipment:

$$Q_E = E_p kN; \tag{7.2}$$

where E_p – number of units of repair complexity;

k – coefficient of cyclical performance of repair work;

N – number of units of equipment.

Hence

Q_E =10 × 1.2 × 104 = 1248 (units of repair complexity).

The quantity of materials necessary for the performance of repair works is determined by the indicators established by the practice.

Detailed design of the shop repair base is considered in the project part.

7.2. Drawing up of network scheduling of works on the machine shop section.

The grid graph is a graphical method for planning technological preparation of production.

Before plotting the schedule, we compile a list of events from the original to the final and put in Table 7.1.

Table7.1 - List of production preparation events

Event numbers		Event content
ordinal	previous	
1	-	The task for designing is accepted
2	1	Approval drawing of the parts for machinability
3	2	Presentation of a drawing for preparation of the part
4	3	Development of a technological route for the manufacture of parts
5	4	Development of production training schedule
6	5	Design of the technological process
7	4	Development of the task for the design of equipment and tools
8	7	Design of equipment and tools
9	8	Manufacturing of equipment and tools
10	4	Development of standards for material dispersion
11	10	Approval of supplies with materials and workpieces
12	4	Development of a task for the supply of equipment
13	12	Planning for equipment installation
14	13	Supply of equipment
15	11	Delivery of billets to the enterprise
16	6	Reproduction and provision of technological documentation of workplaces
17	9	Testing equipment and its refinement
18	14	Installation of equipment and its launch
19	15,16,17, 18	Implementation of the technological process
20	19	Manufacturing of the first industrial party
21	20	Organization of serial production

We evaluate each event according to the schedule with time.

The duration of the events is indicated in weeks (table. 7.2).

Table 7.2 - Event duration (in weeks)

Event numbers		Ways			
the initial one	the final one	1	2	3	4
1	2	3	4	5	6
1	2	0,5	0,5	0,5	0,5
2	3	0,5	0,5	0,5	0,5
3	4	0,5	0,5	0,5	0,5
4	5		0,5		
4	7	0,5			
4	10			0,5	
4	12				0,5
5	6		2		
6	16		1,5		
7	8	2,5			
8	9	4			
9	17	1			
10	11			0,5	
11	15			1,5	
12	13				0,5
13	14				2,5
14	18				1,5
15	19			1	
16	19		1		
17	19	1			
18	19				1
19	20	1	1	1	1
20	21	0,5	0,5	0,5	0,5
Duration		12	10	6,5	9

Summing up the duration of events along the paths, we conclude that the critical way is the first.

Based on these results, we build a network schedule for planning the technological preparation of the product (Fig. 7.1).

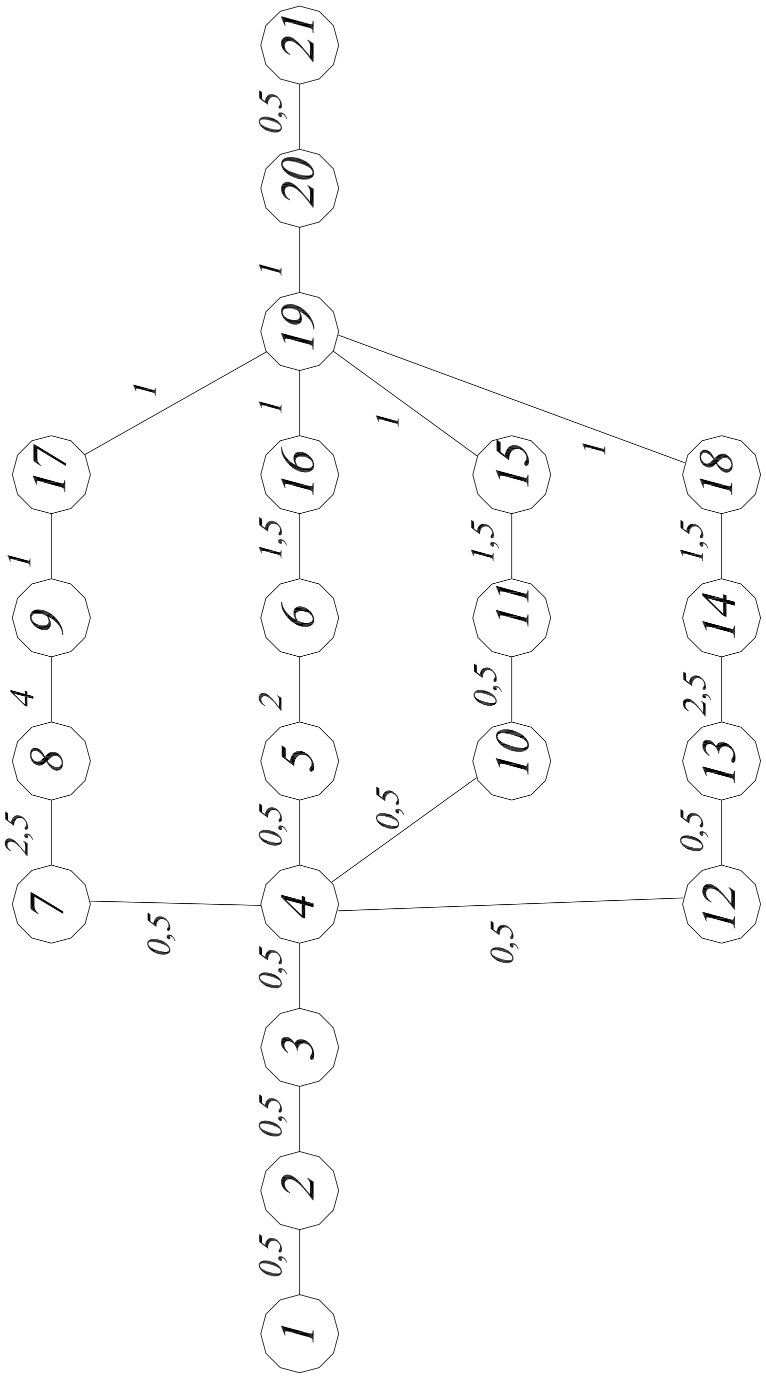

Figure 7.1 - Grid scheduling of technological preparation of production

7.3. Determination of the economic efficiency of the decisions taken in the project.

Organizational and economic planning of production involves the calculation of the number of main technological equipment and the number of employees working in the shop based on the data received in the technological part, the determination of the size of all the cash costs for construction, equipping the workshop (site) and its operation.

Execution calculations allow us to draw conclusions about technical feasibility and cost-effectiveness of developments.

- It determines:
- the magnitude of capital investments;
- production losses;
- cost per unit of production;
- Major normalized working capital;
- technical and economic indicators of the shop.

Output data for calculation are:

- annual release program;
- type of production;
- number of machining operations;
- characteristics of operations: artificial time, power, cost and category of repair equipment, the level of work;
- weight of parts, type of workpiece, cost of material and waste;
- prices for electric power, water, steam, compressed air.

Characteristics of the technological process and the composition of the technological equipment are made in the form of tables 7.1, 7.2.

The estimated number of jobs is determined by the formula:

$$C_p = T / \tau,$$

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where T – laboriness of mechanical processing;

τ – release rate, determined in the technological part.

The resulting estimated value is rounded to the nearest integer and the main data defines the load factor of the equipment.

The number of basic production workers is determined by the formula:

$$P_c = \frac{C_n \cdot F_\partial \cdot k_3}{F_{\partial p} \cdot k_б}; \qquad (7.3)$$

where C_n – accepted amount of equipment;

F_∂ – a vacover annual operating time of equipment;

$k_з$ – load factor of equipment;

$F_{\partial p}$- working time all workers;

$k_б$ – coefficient of multi-level equipment.

The number of auxiliary workers is determined in percentage terms to the main workers and taken 35-50% in large-scale and mass production, 18-25% in rate and unit.

The number of junior staff is 2-3%, engineering staff is 10-13%, accounting staff 4-5% of the total number of employees.

The results of calculations are made as table 7.3.

When conducting economic analysis, the life cycle of technology and technological cost is determined - a set of costs associated with the implementation of technology.

Technological cost of operation of the technological process in the general case is determined by the formula, UAH.:

$$C_{мо} = M_{\partial m} + П_m + E_m + З_{op} + З_{ip} + B_{мо} + \qquad (7.4)$$
$$+ B_{np} + B_{ін} + B_{вим} + B_{пч} + B_{пл} + B_i,$$

where $M_{\partial m}$ – cost of auxiliary materials for technological purposes;

$П_m$ – cost of technological fuel;

E_m – the cost of technological energy;

$З_{ор}$ – wages of the main production workers with deductions;

$З_{ір}$ – wages with deductions from other categories of workers who directly provide the technological process;

$В_{то}$ – cost of maintenance and operation of process equipment;

$В_{до}$ – the cost of maintaining and operating auxiliary equipment that directly provides this process;

$В_{пр}$ – maintenance and operation costs of equipments;

$В_{ін}$ – the cost of the cutting tool;

$В_{вим}$ – the cost of measuring instrument and tools;

$В_{пч}$ – the cost of preparing programs for CNC machines and industrial robots;

$В_{пл}$ – maintenance and operation costs of production areas;

$В_i$ – other cost elements.

Technological production cost of a part is the sum of the technological cost of operation for all workshops and sections, UAH / part.:

$$C_{твд} = \Sigma C_{то}. \tag{7.5}$$

Technological cost of parts, UAH / part.:

$$C_{тд} = M_o + \Sigma C_{то}; \tag{7.6}$$

where M_o – the cost of the main materials with deductions for the cost of waste that is being sold.

In the practical activities of the technological engineer, the ability to correctly estimate the costs associated with the execution of the technological operation is of paramount importance..

Calculation of costs associated with the implementation of technological operations is performed on the basis of the standards of different costs, which account for 1 hour of equipment operation.

For machining operations, the technological cost of operation, UAH.:

$$C_{то} = \Sigma H\ T_{н}/60\ 100, \qquad (7.7)$$

where $T_{н}$ – the standard time for performing the operation, min.;

ΣH – amount of standards, kop. / hour, which includes:

$H_{зв}$ – standard of labor costs of machine tool operator;

$H_{зн}$ – standard of labor costs for the installer;

$H_{се}$ – electricity consumption standard;

$H_{дм}$ – standard of expenses for auxiliary materials;

$H_{пр}$ – equipment cost benchmark;

$H_{вим}$ - the cost standard for a measuring instrument;

$H_{рі}$ – Cutting cost costing standard;

$H_{ао}$ – standard of depreciation of equipment;

$H_{пл}$ – standard cost per square.

For operations with defined features (special equipment or equipment, labor-intensive or machine-tool operations, expensive unique equipment, DHW, RTC, automatic lines, high energy consumption, etc.), the most comprehensible is the detailed calculation of individual elements of technological cost, which allows taking into account all the individual features of this technology. and conditions for its implementation.

7.3.1. Expenditures on basic materials, UAH.:

$$M_{о} = H_{вом} K_{тз} Ц_{м} – B_{відх} Ц_{від};$$

where $H_{вом}$ – the rate of consumption of the main material, kg;

$K_{тз}$ – transport and purchasing cost factor (1,05-1,10);

$Ц_{м}$ – list price 1 kg of material, UAH;

$B_{відх}$ - mass of waste, kg;

$Ц_{від}$ - the price of 1kg of waste, UAH.

The price of waste is determined depending on the nature of their utilization. It is equal:

– the full cost of the initial material, if the waste is used as a conditional raw material;

– the reduced price of the source material when it comes to non-conforming raw materials;

– - prices of scrap, chips, if the waste appears as secondary raw materials.

Prices for materials and waste are taken at the appropriate price list.

7.3.2. Costs for auxiliary materials for technological purposes (alkali, alcohols, inert gases, etc.) are taken into account in all their nomenclature, which is used in the design technological process, UAH.:

$$М_{дт} = ΣН_{вдм}\ Ц_{дм}\ К_{тз};$$

where $Н_{вдм}$ – the amount of material consumption on the process, operation;
$Ц_{дм}$ – the price of the unit of material consumption.

Fuel consumption technological (for heating, melting and other processes), UAH.:

$$П_{т}= Н_{вп}Ц_{п}К_{тз};$$

where $Н_{вп}$ – the rate of fuel consumption on the process, operation;
$Ц_{п}$ – the price list of the corresponding fuel unit, UAH..

7.3.3. Electricity costs for technological purposes (heating, melting, electrophysical and electrochemical processes, testing, etc.), UAH.:

$$Е_{т} = Н_{ве}Ц_{е};$$

where $Н_{ве}$ – amount of electricity consumption, kWh;
$Ц_{е}$ – price (average tariff) of one kWh of electricity for the base enterprise.

7.3.4. Labor costs (with deductions) of the main workers who provide this technological process are determined by dependence, UAH.:

$$З_{ор} = Т_{н}Г_{тс}Ч_{бр}К_{дп}К_{дв}К_{сс}/60Н_{об}\ , \qquad (7.8)$$

where $Т_{н}$ – standard time for process execution, operations (in mass production $Т_{шт}$=

$=T_{штк}$), min.;

$Г_{тс}$ – hourly tariff rate of the corresponding tariff rate of execution of the process, UAH.;

$Ч_{бр}$ – the number of people in the brigade who provide this technological process;

$К_{дп}$ – coefficient of surcharges for the worked time;

$К_{дв}$ – pay-as-you-go coefficient;

$К_{сс}$ – the ratio of deductions for social and health insurance;

$Н_{об}$ – labor costs with deductions from other categories of workers, which directly ensure the performance of the technological process, are determined in accordance with the specific situation:

a) if the regulator pays for each adjusted equipment, then the costs for one operation will be, UAH.:

$$З_{ір} = Т_{нал} Г_{тс} К_{н} К_{дп} К_{дв} К_{с} / Ч_{р}\ , \qquad (7.9)$$

where $Т_{нал}$ – setting time, year;

$Г_{тс}$ – hourly rate of the adjuster, UAH.;

$К_{н}$ – number of adjustments per year;

$Ч_{р}$ – annual volume of transactions.

b) if the operation is performed on a machine, on which the regulator is permanently fixed, UAH.:

$$З_{ір} = Ф_{др} Г_{тс} К_{дп} К_{дв} К_{сс} / Н_{об} Ч_{р}\ , \qquad (7.10)$$

where $Ф_{др}$ – annual fund of work time of the installer, h .;

$Н_{об}$ – the amount of servicing the installer of a group of similar machines.

в) if the operation is carried out on equipment, the work of which is directly provided by several employees, the labor costs are increased (for example, in the case of a processing center, the need for the work of the operator, the installer, the electronics, the metalworker is taken into account).

The calculation of the annual salary fund is made in the form of table 7.5.

7.3.5. The costs for maintenance and operation of process equipment are complex and include the following elements, UAH.:

$$B_{mo} = B_a + B_p + B_e + B_\partial \,, \qquad (7.11)$$

where B_a – depreciation costs of equipment;

B_p – maintenance and repair costs;

B_e – energy costs;

B_∂ – the cost of supporting materials for the maintenance of equipment.

These cost elements refer to the technological cost of performing the operation in different ways:

– - if the operation carried out on a particular detail is performed on a universal equipment, which is also used for other operations carried out on other parts, then the costs of operating the equipment are assigned to the cost of the operation in proportion to the time T_n for its execution;

– if the operation is performed on a specially designed and manufactured equipment, specialized or universal in case of impossibility of loading it with other parts, then all the expenses for such equipment refer only to the cost of this operation.

Amortization deductions for universal equipment for operation, UAH.:

$$B_{ay} = B_б H_{ap} E_н / Ф_{\partial o}\ 60\ 100\ . \qquad (7.12)$$

where $B_б$ – balance cost of equipment (including transport, installation and start-up and adjustment works), UAH.;

H_{ap} – rate of depreciation of equipment for renovation,%;

$Ф_{\partial o}$ – annual fund time of equipment, year.

Amortization deductions on special and equivalent equipment, UAH:

$$B_{ac} = B_б H_{ap} / Ч_p 100\ . \qquad (7.13)$$

Values are adopted by normative documents or according to the data of the base enterprise.

Maintenance and repair costs cover all types of repairs, inter-repair services and inspections. These costs are determined, UAH.:

– for universal equipment

$$B_{ру} = (P_{см}H_{вм} + P_{се}H_{ве} + H_{вп})Tн/Ф_{до}60; \qquad (7.14)$$

– for special equipment

$$B_{рс} = (P_{см}H_{вм} + P_{се}H_{ве} + H_{вп})T_{н}/Ч_{р}; \qquad (7.15)$$

where $P_{см}$ – group (category) repair complexity of the mechanical part of the equipment in repair units;

$P_{се}$ – group of repairing complexity of electrical part of equipment in repair units;

$H_{ве}$ – amount of annual expenses on the one of the repair complexity of the mechanical part, UAH.;

$H_{вп}$ – standard annual maintenance and repair cost of software management unit, UAH.

Values of standards $P_{см}$, $P_{се}$, $H_{вм}$, $H_{вп}$, $H_{ве}$ are accepted according to the normative documents.

Energy costs not included in previous calculations (electricity, steam, gas, compressed air, water for technical needs) depend on the type of energy used.

In particular, the cost of power energy per transaction is determined by dependence, UAH.:

$$B_{ед} = П_{д}T_{н}K_{ч}K_{п}Ц_{е} / K_{д}K_{м}60, . \qquad (7.16)$$

where $П_{д}$ – total power of electric motors of equipment, kW;

$K_{ч}$ і $K_{п}$ – coefficients of the use of engines in time and power;

$K_{д}$ і $K_{м}$ – coefficients of efficiency of electric motors and networks, $K_{д}$ = 0.8 – 0.9, $K_{м}$ = 0,9–0,94.

The power of electric motors is taken according to the passport data of the equipment, the value of the coefficients $K_{ч}$ і $K_{п}$ are accepted from the reference literature or according to the data of the base enterprise.

Costs of compressed air per transaction are UAH:

$$В_{сп} = Н_{впо}Ц_{сп}/1000 = Н_{впг}Т_{н}Ц_{сп}/1000\ 60, \qquad (7.17)$$

where $Н_{впо}$ – air flow rate per transaction,м^3;

$Н_{впг}$ – hourly rate of compressed air consumption, м^3;

$Ц_{сп}$ – the price of 1000 m^3 of compressed air, UAH (accepted for price lists or data of the base enterprise).

Expenditures for support materials for maintenance of equipment (lubricating and rubbing, oils for hydraulic drives, MW, etc.) are determined from the standard of these costs for 1 repair unit, 1 machine, per unit of vehicles.

For universal equipment, UAH:

$$В_{ду} = Н_{вдм}Р_{см}Т_{н} / Ф_{до}\ 60. \qquad (7.18)$$

For special equipment, UAH:

$$В_{дс} = Н_{вдм}Р_{см} / Ч_{р}\ , \qquad (7.19)$$

where $Н_{вдм}$ – standard annual cost per unit of repair complexity.

Calculation of expenses for materials and semi-finished products is made in the form of a table 7.8.

7.3.6. Costs of operation of technological equipment used in the operation, it is advisable to consider only the complex and expensive tools and instrumentss. These costs per transaction are UAH.:

– for universal tools

$$В_{пру} = В_{бпр}К_{вр}Т_{н} / Ф_{до}Т_{а}60, \qquad (7.20)$$

– for special tools:

$$В_{прс} = К_{д}В_{бпр}К_{вр}/Ч_{р}Т_{а}, \qquad (7.21)$$

where $В_{бпр}$ – book value of the tools, UAH;

$К_{вр}$ – the cost factor for maintenance and repair;

T_a – term of depreciation, years;

$K_д$ – number of snap equipment.

The book value of the universal equipment is determined by its price list and transportation and purchase costs, special

- Estimated cost of design, fabrication and adjustment.

The values of the Qur and Ta standards are taken according to the data of the base enterprise. The value of Ta for special tools should not exceed the duration of the life cycle.

In the case of using a universal assembly equipment, the cost of it is determined as the cost of its hire.

If universal equipment is used only in the course of this operation and it is impossible to use it in other technological processes, then the costs for it are defined as for special equipment.

7.3.7. The cost of the cutting tool that is involved in the operation includes the costs of sharpening, repair and restoration. These costs are UAH.:

– on a universal cutting tool:

$$B_{іну} = (Ц_{ін}K_{уб}K_{вр} + B_{пер})T_{маш} / T_{ст}(K_{пер} + 1)60; \tag{7.22}$$

– special cutting tool:

$$B_{інс} = (Ц_{ін}K_{зб}K_{вр} + K_{пер}B_{пер})/Ч_р T_а, \tag{7.23}$$

where $Ц_{ін}$ – cost of the tool (including transport and procurement costs), UAH.;

$K_{зб}$ – accidental loss ratio;

$K_{пер}$ – number of redoings;

$B_{пер}$ – redevelopment costs, UAH.;

$T_{маш}$ - Machine run time, min.;

$T_{ст}$ – Instrument firmness, year.

The prices for the tool are shown in the respective pricelists. Standards

$K_{зб}$, $K_{пер}$, $T_{ст}$ are accepted according to the data of the base enterprise.

Expenses for re-equipment of the instrument, UAH:

$$B_{пер} = T_{пер}Г_{тс}K_{дп}K_{дв}K_{се}K_{нв}, \tag{7.24}$$

where $T_{пер}$ – average rate of time for re-tooling, min.;

$K_{нв}$=1,8-2,2 – coefficient taking into account overhead costs.

When calculating the cost of re-erasing a special instrument, not the maximum possible number of refinements is taken into account, but due to the annual volume of work (operations).

The above formulas focus on a socover tool. For a build-up tool, further interpretation of these formulas is required. If the nature of the use of a universal instrument is similar to the use of a special one, then the costs of its operation are calculated, as for a special tool.

The cost of the measuring instrument is determined by the same method as the cost of the cutting tool. Standards are accepted according to the data of the base enterprise.

7.3.8. The cost of developing and setting programs for CNC machines and industrial robots depends on the complexity of the operation and the way programs are developed. Recommendations on methods of conducting calculations and the required standards are given in the reference books, however, one should strive to use the methodology and standards applied at the base enterprise.

In the general case, these costs per transaction are UAH.:

$$B_{пг} = B_{пр}K_{вдн}/Ч_pT_a, \tag{7.25}$$

where $B_{пр}$ – expenses for development and adjustment of programs, UAH;

$K_{вдн}$ – a coefficient that takes into account the recovery of the program carrier;

T_a – term of depreciation of expenses, years.

7.3.9. Costs of operation of production areas include depreciation, repairs, heating, lighting and cleaning costs, calculated on the area occupied by the workplace (including equipment) where the operation is carried out. For workplaces where special equipment is installed, the cost per square meter per one transaction is UAH,.:

$$В_{плс} = П_{рм}Н_{рпл} / Ч_р, \tag{7.26}$$

for workplaces with a universal type of equipment:

$$В_{плу} = П_{рм}Н_{рпл}Т_н/Ф_{до}60, \tag{7.27}$$

where $П_{рм}$ – work area, м^2;

$Н_{рпл}$ – amounts of annual maintenance costs 1 м^2 Production space, UAH, taken according to the data of the base enterprise.

On the basis of the results, a cost estimate is drawn up, which is executed in the form of table 7.9.

Calculation of costs for production and unit costs is performed separately for each item according to the cost items and is executed in the form of tables 7.10 and 7.11, respectively.

Other elements of expenditure that are directly related to a particular operation are determined based on the specific conditions for the operation to be performed..

The results of all calculations for determining the main technical and economic indicators are made in the form of table 7.12.

Table 7.13 compares the options for basic and project technological processes.

The calculation of the technological cost of the operation (a set of operations, the processing of the part as a whole) on different versions of the technology allows us to give the most reasonable answer to the question which of the options is optimal for specific technical and economic conditions. The best option is to provide the least technological cost.

If technological options require high capital expenditures (the purchase of expensive equipment, reconstruction of sites, etc.) and it is about design variants of technology, and not about existing and design, then the optimal version of technology should be sought on the criterion of minimum costs:

$$C^p_{mi} + Є_н K_i \rightarrow min,$$

where $Є^p_{mi}$ – annual technological cost for the i-th version of the technology, UAH,
$Є_н$ – normative coefficient of efficiency of capital investments;
K_i – capital investments for this option.

Normative coefficient of efficiency of capital investments $Є_н$ reflects the minimum allowable return on 1 UAH of additional capital investments, which, in turn, determines the normative (maximally permissible) term of their return at the expense of them caused by additional profits:

$$T_н = 1/ Є_н.$$

Coefficient $Є_н$ is determined by the scale and nature of the design decisions that are considered. When it comes to measures of the economic level associated with significant capital construction, $Є_н$= 0,12 ($T_н$= 8,3 years).

If there are significant investments in new equipment, then $Є_н$= 0,15 ($T_н$= 6,7 years). For local technological measures at the workshop level, enterprises may set more stringent pay-as-you-go costings (up to 2-3 years).

For technological measures that have a limited duration,

$$T_н \leq T_{жц}.$$

Annual technological cost is UAH:

$$C^p_m = C_m Ч_p,$$

where C_m - technological cost of the operation, processing of parts, UAH,
$Ч_p$ – annual volume of operations (parts).

When it comes to the optimal design option, which is intended to replace the base version of technology and provides less current costs, then the estimated annual savings from cost reduction will be, in UAH:

$$E_{кр}=(C_{mб} - C_{mпр})\ Ч_p,$$

where $C_{тб}$, $C_{тпр}$ – technological cost according to the basic and project variants of operation (parts), UAH.

The expected annual effect from the introduction of a new technology option, UAH, is determined:

$$E_p = E_{кр} – Є_н\, K_{дод},$$

where $K_{дод}$ – additional capital investments related to the implementation of the project option (including losses from the elimination of the underlying), UAH.

The payback period of additional capital expenditures, years

$$T_{ок} = K_{дод} / E_{кр}.$$

Approved payback period of capital expenditures for modernization of technological processes - two or three years. Anyway $T_{ок} \leq T_{жц}$.

Table 7.3.1 - Characteristics of the basic version of the technological process

№ п/п	Program release	$T_{шт}$, min.	Work (n/h)		% execution numbers	Job rank
			On the part	on the program		
1	14400	2,000	0,033	480,00	100	4
2	14400	10,300	0,172	2472,00	100	4
3	14400	5,600	0,093	1344,00	100	4
4	14400	3,100	0,052	744,00	100	4
5	14400	3,100	0,052	744,00	100	4
6	14400	3,600	0,060	864,00	100	4
7	14400	1,100	0,018	264,00	100	4
8	14400	3,500	0,058	840,00	100	4

Table 7.3.2 - Characteristics of the design variant of the technological process

№ п/п	Program release	$T_{шт}$, min.	Work (n/h)		% execution numbers	Job rank
			On the part	on the program		
1	14400	2,000	0,033	480,00	100	4
2	14400	3,350	0,056	804,00	100	4
3	14400	1,100	0,018	264,00	100	4
4	14400	0,960	0,016	230,40	100	4
5	14400	1,180	0,020	283,20	100	4
6	14400	0,400	0,007	96,00	100	4
7	14400	2,060	0,043	624,00	100	4

Table 7.4.1 - The composition of the technological equipment of the basic version the manufacturing process of the cover

№ п/п	Number of seats	Power of the electric motor machines, kW		The cost of machine tools UAH		Costs of transportation and installation, UAH	Category of repair-complexity	Amount of all expenses, UAH
		one	all	one	all			
1	1	10,0	10,0	14000	14000	1400,0	15400,0	16
2	1	12,0	12,0	18000	18000	1800,0	19800,0	21
3	1	12,0	12,0	18000	18000	1800,0	19800,0	21
4	1	10,0	10,0	14000	14000	1400,0	15400,0	16
5	1	10,0	10,0	14000	14000	1400,0	15400,0	16
6	1	4,5	4,5	12000	12000	1200,0	13200,0	4
7	1	5,5	5,5	10000	10000	1000,0	11000,0	16
8	1	5,5	5,5	10000	10000	1000,0	11000,0	16
Σ	7	-	69,5	-	110000,0	11000,0	121000,0	-

Table 7.4.2 - The composition of technological equipment of the design variant of the process of manufacturing the cover

№ п/п	Number of seats	Power of the electric motor machines, kW		The cost of machine tools UAH		Costs of transportation and installation, UAH	Category of repair-complexity	Amount of all expenses, UAH
		one	all	one	all			
1	1	10,0	10,0	14000	14000	1400,0	15400,0	16
2	1	18,5	18,5	21000	21000	2100,0	23100,0	21
3	1	18,5	18,5	21000	21000	2100,0	23100,0	21
4	1	10,0	10,0	14000	14000	1400,0	15400,0	16
5	1	4,5	4,5	12000	12000	1200,0	13200,0	18
6	1	5,5	5,5	10000	10000	1000,0	11000,0	16
7	1	5,5	5,5	10000	10000	1000,0	11000,0	16
Σ	7	-	72,5	-	102000,0	10200,0	112200,0	-

Table 7.5.1 - Summary of the composition of the employees in the basic version of the manufacturing process of the cover

№ п/п	Category of work	Number	%
1	Production workers	13	-
2	Auxiliary workers	5	40
3	Junior Staff	1	2-3
4	Engineering and technical staff	2	10-13
5	Clerical and office staff	1	4-5
Total workers		22	-

Table 7.5.2 - Summary of the composition of the employees in the design version of the manufacturing process of the cover

№ п/п	Category of work	Number	%
1	Production workers	11	-
2	Auxiliary workers	5	40
3	Junior Staff	1	2-3
4	Engineering and technical staff	2	10-13
5	Clerical and office staff	1	4-5
Total workers		20	-

Table 7.6.1 - Capital expenditures on fixed assets of the basic version of the manufacturing process of the cover

№ п/п	Title of the main assets	Cost, UAH	Amortization		Specific gravity in the general fund
			Number	Cost	
1	Buildings:				
	a) production facilities	24,00	2,4	576,00	2,09
	b) auxiliary premises	10,88	2,4	261,12	0,95
	c) administrative-household	9,60	2,4	230,40	0,84
Total:		44,48		1067,52	3,87
2	Buildings and transmitting Rooms	3,11	3,1	96,52	0,35
3	Equipment:				
	a) production	110,00	14,1	15510,00	56,26
	b) energy	2,78	2,7	75,06	0,27
	c) transport	11,00	16,6	1826,00	6,62
	d) control and measuring	5,50	8,5	467,50	1,70
Total		129,28		17878,56	64,85
4	Instrument and devices	27,50	30,0	8250,00	29,93
5	Industrial and economic Inventory	2,20	12,5	275,00	1,00
Total		206,57		27567,60	

Table 7.6.2 - Capital expenditures on fixed assets of the design variant of the technological process of manufacturing the cover

№ п/п	Title of the main assets	Cost, UAH	Amortization		Specific gravity in the general fund
			Number	Cost	
1	Buildings:				
	a) production facilities	21,00	2,4	504,00	1,98
	b) auxiliary premises	9,52	2,4	228,48	0,90
	c) administrative-household	8,40	2,4	201,60	0,79
Total:		38,92		934,08	3,66
2	Buildings and transmitting premises	2,72	3,1	84,46	0,33
3	Equipment:				
	a) production	102,00	14,1	14382,00	56,38
	b) energy	2,90	2,7	78,30	0,31
	c) transport	10,20	16,6	1693,20	6,64
	g) control and measuring	5,10	8,5	433,50	1,70
Total		120,20		16587,00	65,02
4	Instrument and devices	25,50	30,0	7650,00	29,99
5	Industrial and economic Inventory	2,04	12,5	255,00	1,00
Total				25510,54	

Table 7.8.1 - Consocoverated statement of the annual salary fund of the basic variant of the manufacturing process of the cover

Categories of workers	Basic salary, UAH.	Additional w / o UAH.	Total fund / n UAH.	Awards and rewards, UAH.	Total salary, UAH	Average monthly salary, UAH
Workers - the main ones - auxiliary	5,6 4,8	2,0 1,4	7,5 6,3	446,52 482,30	8,0 6,8	511,60 1125,40
ІТП			2,9	1008,00	3888,0	1620,00
ЛКП			1,1	216,00	1296,0	1080,00
МОП			0,8	84,00	924,0	770,00
Total					20841,7	
Deductions on social insurance, in the pension fund, employment funds, etc.					11462,9	
Total					32304,6	

Table 7.8.2 - Summary of the annual salary fund of the design variant of the manufacturing process of the cover

Categories of workers	Basic salary, UAH	Additional w / o UAH.	Total fund / n UAH.	Awards and rewards, UAH.	Total salary, UAH	Average monthly salary, UAH
Workers - the main ones - auxiliary	2,0 4,8	0,7 1,4	2,7 6,3	160,22 482,30	2,9 6,8	21,70 1125,40
ІТП			2,9	1008,00	3888,0	1620,00
ЛКП			1,1	216,00	1296,0	1080,00
МОП			0,8	84,00	924,0	770,00
Total					15724,1	
Deductions on social insurance, in the pension fund, employment funds, etc.					8648,3	
Total					24372,4	

Table 7.8.1 - A statement of the cost of materials for the basic version of the technological process of manufacturing the cover

№ п/п	Material	Part of the item, kg	Annual expenditure, tone	Cost, UAH	General transportation costs, UAH	Total cost of waste, UAH	Total cost of the material, UAH
1	Basic materials	5,10	73	1982880	198288	22766	2158402
2	Auxiliary materials	-	-	-	-	-	32376

Table 7.8.2 - A statement of expenses for materials of a design variant of a technological process of manufacturing the cover

№ п/п	Material	Part of the item, kg	Annual expenditure, tone	Cost, UAH	General transportation costs, UAH.	Total cost of waste, UAH	Total cost of the material, UAH
1	Basic materials	5,10	73	1982880	198288	22766	2158402
2	Auxiliary materials	-	-	-	-	-	32376

Таблиця 7.9.1 - Estimated cost of the basic version of the technological process of manufacturing the cover

№ п/п	Name of cost items	Cost, тис. UAH.
A. The maintenance and operation of equipment		
1	Depreciation of equipment	27,57
2	Operation of equipment a) auxiliary materials	 32,38
	b) electricity c) compressed air d) water for production needs e) steam for production needs	16,02 2,04 6,13 2,19
	e) the salary is basic and additional	4,05
3	Regular repair a) equipment b) a valuable tool	 7,70 4,13
4	Internal movement of goods	14,7
5	Depreciation of a low-value and worn-out tool	44,00
Total in section A		146,22
B. General workshop costs		
1	Maintenance of the shop management machine a) ITP б) employees	 3,89 1,30
2	Retaining the rest of the shop staff a) JSS б) auxiliary workers not listed in section A	 0,92 2,70
3	Depreciation of buildings and equipment	1,07
4	Maintenance of buildings, structures and inventory a) Electricity for lighting b) steam for heating c) water for household needs d) material and other expenses e) inventory	 19,10 6,74 16,66 1,33 1,54
5	Another repair of buildings, structures, inventory	1,33
6	Tests, experiments and research rationalization and Invention	0,66
7	Safety practice	0,44
8	Depreciation of low-value and high-wearing implements	0,44
9	Other witts	2,91
Total section B		61,03
Total workshop (side) costs		207,25

Table 7.9.2 - Estimates of craft costs of the design version of the technological the process of manufacturing the cover

№ п/п	Name of cost items	Cost, thous. UAH.
A. The maintenance and operation of equipment		
1	Depreciation of equipment	25,51
2	Експлуатація обладнання a) costing b) electricity c) compressed air d) water for production needs e) steam for production needs	 32,28 16,02 1,79 5,37 2,19
	f) the salary is basic and additional	4,05
3	Regular repair a) equipment b) a valuable tool	 7,14 3,83
4	Internal movement of goods	14,7
5	Depreciation of a low-value and worn-out tool	40,80
Total in section A		139,08
B. General workshop costs		
1	Maintenance of the shop management machine a) ITP b) employees	 3,89 1,30
2	Retaining the rest of the shop staff a) JSS b) auxiliary workers not listed in section A	 0,92 2,70
3	Depreciation of buildings and equipment	0,93
4	Maintenance of buildings, structures and inventory a) electricity for lighting b) steam for heating c) water for household needs d) material and other expenses e) inventory	 16,71 5,89 15,15 1,17 1,41
5	Another repair of buildings, structures, inventory	1,17
6	Tests, experiments and research rationalization and Invention	0,60
7	Safety practice	0,40
8	Depreciation of low-value and high-wearing implements	0,40
9	Other expenses	2,63
Total section B		55,27
Total workshop (side) costs		194,35

Table 7.10.1 - Cost estimates for the production of the production of the basic version of the manufacturing process of the cover

№ п/п	Name of cost items	Cost, thous. UAH.
1	Basic materials, taking into account transport costs and net waste	1960,11
2	The main salary of the main production workers	5,58
3	Additional salary of the main production workers	1,95
4	Deductions on social insurance from the salaries of the main production workers	3,01
5	Costs of operation and maintenance of equipment	146,22
6	Total business expenses	61,03
Total shop floor costs		2177,92
7	Total production costs	2,79
Total production cost		2180,71
8	Output costs	65,42
Total full cost		2246,13
9	Planned profit	179,69
Total issue in wholesale prices of the enterprise		2425,82

Table 7.10.2 - Estimates of production costs of the design version of the manufacturing process of the cover

№ п/п	Name of cost items	Cost, thous. UAH.
1	Basic materials, taking into account transport costs and net waste	1960,11
2	The main salary of the main production workers	2,00
3	Additional salary of the main production workers	0,70
4	Deductions on social insurance from the salaries of the main production workers	1,98
5	Costs of operation and maintenance of equipment	139,08
6	Total business expenses	55,27
Total shop floor costs		2158,25
7	Total production costs	1,00
Total production cost		2159,25
8	Output costs	64,78
Total full cost		2224,03
9	Estimated profit	177,92
Total issue in wholesale prices of the enterprise		2401,95

Table 7.11.1 - Cost calculation of the unit of production of the basic version of the manufacturing process of the cover

№ п/п	Name of cost items	Amount, UAN
1	Basic materials, taking into account transport costs and net waste	136,12
2	The main salary of the main production workers	0,39
3	Additional salary of the main production workers	0,14
4	Deductions on social insurance from the salaries of the main production workers	0,21
5	Costs for the maintenance and operation of equipment	10,15
6	Total business expenses	4,24
Total shop floor costs		151,24
7	Total production costs	0,19
Total production cost		151,44
8	Output costs	4,54
Total full cost		1555,98
9	Planned profit	12,48
Total issue in wholesale prices of the enterprise		168,46

Table 7.11.2 - Cost calculation of the unit of production of the design variant of the manufacturing process of the cover

№ п/п	Name of cost items	Amount, UAN
1	Basic materials, taking into account transport costs and net waste	136,12
2	The main salary of the main production workers	0,14
3	Additional salary of the main production workers	0,05
4	Deductions on social insurance from the salaries of the main production workers	0,08
5	Costs for the maintenance and operation of equipment	9,66
6	Total shop costs	3,84
Total shop floor costs		149,88
7	Total production costs	0,0149,957
Total production cost		4,5154,450
8	Output costs	12,36
Total full cost		166,80
9	Planned profit	16,21
Total issue in wholesale prices of the enterprise		148,54

7.4. Basic technical and economic indicators of the machine shop section.

Table 7.12.1 - Basic technical and economic indicators of the basic version of the manufacturing process of the cover

№ п/п	Normative indicators	Unit	Cost, UAN
1	Annual output: a) in physical terms b) in value terms	 pc, UAH.	 14400 2425818,05
2	Capital expenditures: a) general b) specific c) total production area d) the number of machines e) power capacity of the equipment	 thousand, UAH. UAH./pc $м^2$ pc. kW.	 207,25 14,39 160 8 69,50
3	Rolled circulating assets	thousand. UAH.	 272,24
4	Total number of employees	people	22
5	Annual salary fund	thousand. UAH.	 32,30
6	Average monthly salary: a) production workers б) ITP	 UAH. UAH.	 51,16 162,00
110,267	Production per one working	т. UAH./г.	 110,26
8	Production output: a) for one UAH, fixed assets b) per square meter of area	 UAH. UAH.	 11,74 15161,36
9	Machine loading	%	20,92
10	Cost of parts	UAH.	155,98
11	Side-effects of the workshop	UAH.	207253,39
12	Percentage of shop expenses	%	9,23
13	The level of profitability of the shop	%	8,25

Table 7.12.2 - Basic technical and economic indicators of the design variant of the manufacturing process of the cover

№ п/п	Normative indicators	Unit	Cost, UAH
1	Annual output: a) in physical terms b) in value terms	 pc. UAH	 14400 2401953,35
2	Capital expenditures: a) general b) specific c) total production area d) the number of machines e) power capacity of the equipment	 thousand UAH. UAH./pc $м^2$ pc, kW	 194,35 13,50 140 7 72,50
3	Rolled circulating assets	thousand UAH.	269,78
4	Total number of employees	чол.	20
5	Annual salary fund	thousand. UAH.	24,37
6	Average monthly salary: a) production workers б) ITP	 UAH. UAH.	 21,70 162,00
7	Production per one working	t. UAH./h.	120,10
8	Production output: a) for one UAH, fixed assets b) per square meter of area	 UAH. UAH.	 12,68 17156,81
9	Machine loading	%	15,54
10	Cost of parts	UAH.	154,45
11	Side-effects of the workshop	UAH.	194353,10
12	Percentage of shop expenses	%	8,74
13	The level of profitability of the shop	%	8,24

Table 7.14 - Determining the effectiveness of design decisions

Indicator	The value of the indicator
Cost reduction,%	9,8
Annual savings, UAH.	22032,0
Annual economic effect, UAH.	31740,0

8. HEALTH AND SAFETY MEASURES

8.1. Measures to ensure safe working conditions of the equipment.

The shops of machine-building plants are equipped with different types of technological equipment. Its use facilitates human labor and increase productivity. However, in some cases, working with this equipment presents an industrial and occupation hazard not forgetting the environmental hazards.

When designing technological equipment in mechanical engineering and during its operation, devices that prevent and protect personnel from dangerous zones and accidents should be considered. These devices are referred to us safety tools.

General requirements for the means of protection are:

- maximum reduction of hazards and harmful effects at workplaces;
- reliability, durability, convenience of service of the machine and mechanisms in general;
- taking into account the individual features of the equipment, tool, adaptations or processes for which they are intended.

Blocking (barrier) devices – this can be used as a means of protection that prevent people from entering a dangerous zone. Blocking devices are used for the isolation of drive systems (moving parts) of machines, the zone of workpiece processing by machines, presses, stamps; barriers to current-carrying parts, zones of intense radiation.

Blocking devices are divided into three main groups:

- stationary (non-removable)
- mobile (removable) and
- portable.

Stationary barriers are only periodically dismantled to perform auxiliary operations (changing the working tool, lubricating, carrying out control measurements of parts). They are executed in such a way that they engage the workpiece, but do not let the hands of the worker. Examples of complete barriers are the barrier of distribution devices of electrical equipment, cases of electric motors, pumps.

Movable (removable) barriers - the device is locked up with the working organs of a mechanism or a machine, as a result of which it closes access to the working area at the onset of a dangerous moment. Such barrier devices are used in machine tools.

Portable barriers are temporary. They are used in repair and operation works to protect against accidental touches to current-carrying parts, as well as from mechanical injuries and burns.

The design and material of blocking devices are determined by the peculiarities of this equipment and the technological process in general. Enclosures are made in the form of welded and cast housings, grids, nets on a rigid housing, as well as in the form of rigid solid shields.

Safety precautions are intended for automatic disabling of machines in the detection of any parameter characterizing the operating mode of the equipment beyond the limits of the permissible values. Thus, in emergency situations (release of pressure, temperature, working speeds) the possibility of explosions, breakdowns, flares is excluded. The compressed air is widely used in various machine tools and equipment for fastening machined parts with clamps. Such a device should be equipped with devices that prevent the unauthorized release of the clamps when the pressure is switched off or with significant power influences from the working units of the tool (cutter, milling cutter, grinding wheel). In intermediate devices to eliminate the possibility of breaking parts, it is necessary to adjust the clamping force in the desired range, depending on the cutting force and the stiffness of the workpiece. For this, the device must be equipped with pressure regulators.

In electromagnetic plates for fixing the workpiece, lifting and transferring various products, provision should be made for a spare wiring for feeding electromagnets from an additional power supply. Which should be switched off automatically when you stop power supply from the main network. This eliminates the possibility of tearing off materials or products from an electromagnet and injuring the worker.

To prevent breakdowns of certain parts of the equipment, which are possible due to their transition to setting the limit, apply “stops”. They are important because, at high speeds of the transfer of the support, the machine tool is not always able to turn off the manual transmission and to exclude the incidence of the cutting edges in the area of rotation of the cartridge cam. One-way, two-way stops, which can be various stops, as well as end switches, are applied.

Technological equipment must be equipped with reliable braking devices that allow you to quickly stop the shafts, spindles and other elements which can be potential sources of danger in emergencies.

One of the safety devices is a weak link, that is, a component or a node that is designed to break or not overload. These parts include: cutting pins and joints, friction clutches, smooth fuses, discontinuous membranes. Activation of the weak link leads to the machine stopping in emergency modes, which eliminates breakdowns, damage and, consequently, injuries.

Blocking devices exclude the possibility of a person entering a dangerous zone or eliminate a dangerous factor for the time of stay of a person in this zone. Widespread use in forging machines and mechanical workshops has acquired photovoltaic blocking, which is based on the principle of protecting the hazardous zone by light beams. The change in the light flux that falls into the photocell is converted into an electrical signal, which, after amplification, is fed to an emitter-command device, which, in turn drives the actuating mechanisms of the protective device. Such lock does not require any mechanical structures. Small in size, reliable and convenient in operation, allows in providing protection of sufficiently extended zones.

The distinguishing signaling is used to isolate certain types of technological equipment, its hazardous zone. To do this, use a system of signal colors and security signs. The alarm system is designed to alert you to danger (switching on equipment or supplying voltage).

The safety of the operation of lifting-transport vehicles requires the enclosure of all moving or rotating parts of the mechanisms. It is necessary to exclude the unpredictable contact with the movement of loads and the mechanisms themselves during their movement, as well as provide reliable strength mechanisms. To ensure safe operation, the machines are equipped with:

- safety devices and remote control systems, end switches that automatically shut off the lifting mechanism of the hook or the crane moving mechanism when approaching the extreme positions; load limiting devices that prevent overload by switching off the lifting mechanism;
- devices preventing the slipping of cables from hooks, sound and light signaling, which warns of the onset of a dangerous moment in the operation of the crane;
- devices for automatically switching off unrestrained trolley wires at the exit of the person on the site, which has the possibility of accidental contact with trolley wires, brakes and holders (catchers).

Exclude the tension and breaking of the rope when lifting the load at an unacceptable height and to ensure the safe operation of riggers using terminal switches. Avoid strikes of lifting vehicles in the walls and collide with each other. The end switches of the movement mechanism must be set in such a way that the drive is switched off at a distance equal to at least half the braking distance of the mechanism. For damping the impact of the support are fitted with elastic elements of rubber and wood.

8.2. Electrical installation safety measures.

Electrical installations protective measures can be divided into two groups: those that provide security during normal operation of electrical installations and those that provide security in emergency mode of operation.

Electrical insulation — This is a dielectric layer or a construction made from an insulator that covers the surface of current-carrying conductors, or which separate current-carrying conductors from each other.

The state of insulation is characterized by its electrical strength, dielectric loss and electrical resistance. Isolation prevents the flow of currents through it due to the large resistance.

In order to ensure reliable insulation work preventive measures are taken. First of all, mechanical damage, moisture, chemical effects, pollution should be excluded. But even under normal conditions, insulation permanently loses its original properties with time. Over time, there are local defects, due to which the insulation resistance begins to drastically decrease, and the current loss increases. In the place of the defect there are partial discharges, the insulation burns out. There is a so-called breakdown of insulation, resulting in a short circuit, which can lead to fire or shock. In order to prevent this, a periodic and continuous control of isolation is carried out. Periodic control of isolation involves measuring the active resistance of insulation in the established terms (once every 3 years), as well as in the detection of defects. Measurement of the insulation resistance is carried out at the offset electrical installation using a megohmmeter.

The norms of isolation resistance of different electrical installations are established. For example, insulation resistance of power and lighting electrical wires should be at least 0.5 mΩ. An effective safeguard is the use of double isolation. In this case, in addition to the working main insulation, additional insulation is used. It is intended for protection against electric shock in the event of damage to the working isolation. Protective double insulation can provide safety when operating any electrical installation. An example can be an electric drill with a plastic case. However, the plastic has a low mechanical strength, an unreliable connection with the metal. Scope of double insulation - small power plants. In the event of damage to the work isolation, the transition of the voltage to the housing and the hit of people under the contact voltage are not possible.

However, double insulation does not exclude the risk of damage by touching the current-carrying parts due to partial damage to the case or repairs. Double insulation, are used in wiring equipment (distribution boxes, switches, sockets, plugs, bulbs), portable fixtures, electrical meters, electrified hand tools (drill, disk saw, plan, etc.) and some household appliances.

Contact with current-carrying parts is always dangerous even in a voltage of up to 1000V with isolated neutral, with good insulation and low capacity, not to mention the networks with grounded neutral and the network with a voltage of more than 1000V. In the latter case, even the approach to the current-carrying parts of an electrical installations up to 1000V, the use of insulated wires provides adequate protection against damage when exposed to them. However, isolated wires that are under 1000 V are no less dangerous than naked ones. In these cases, one of the means of safety is stationary enclosures. They are divided into solid and mesh.

Solid enclosures in the form of casings and covers are used in electrical installations up to 1000 V. The mesh fencing has doors that are closed to the lock. Protecting devices include temporary portable barriers (boards, insulating lining, insulating caps, temporary portable earthing). The enclosures are equipped with lids or doors, which are closed to the lock or equipped with locks.

The location of current-carrying parts at an unattainable height or inaccessible location provides security without fencing and locks. When choosing the height of the hanging, it is necessary to take into account the possibility of unintentional contact with parts that are under voltage, long metal objects. The height of the hanging of the wires of the overhead lines depends on the voltage and the passage of the line.

When working with portable power tools, as well as with a hand-held portable lamp when the insulation is damaged and when the voltage on the case increases, the risk of electric shock is increased. In such cases, small voltages not higher than 42V. When voltage is up to 42V, the current passing through the human body is safe. Small voltages are used to power local lighting on machines, portable lamps, power tools. When working in premises with high danger, electrical installation can be used not only without grounding or demolition, but also without isolating means. When working in especially dangerous premises for feeding portable electric lamps, the voltage is not higher than 12 V.

Sources of low voltage are reducing transformers, batteries, rectifier units, frequency converters, batteries of galvanic elements. The use of autotransformers or rheostats for low voltages is prohibited, since in this case the low voltage network is electrically connected to the higher voltage network. Most often lowering transformers are used (Fig. 8.1).

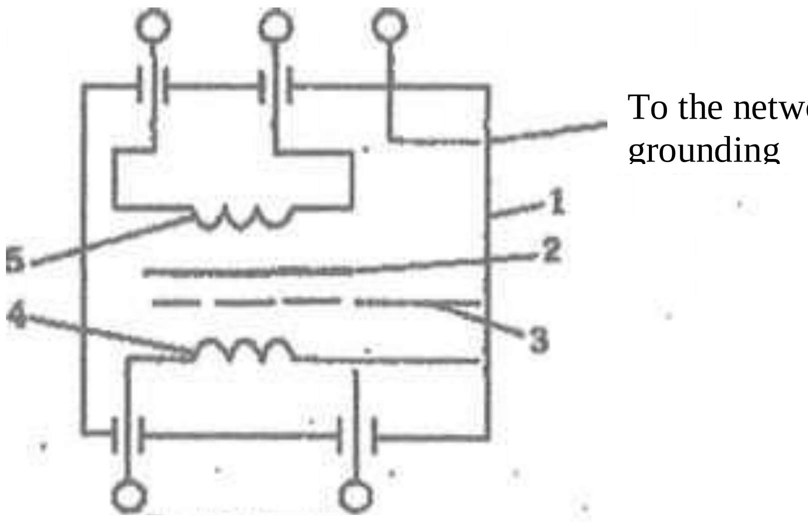

Figure 8.1 - Installing a low voltage with a transformer:

1 - metal casing; 2 - magnet conductor; 3 - screen;

4, 5 - winding of small and higher voltage

Other low voltage sources are rarely used. The only danger of the use of reducing transformers is the possibility of a transition of higher voltage to the side of low voltage. To reduce this danger, the secondary winding and transformer housing are grounded or drowned (one of the terminals or the midpoint of the low voltage winding) or between grounded grounded static screen.

Equalization of potentials — it is a decrease in the stresses of the touch and step between the points of the electrical link, which can be simultaneously touch or on which can simultaneously stand a person. Equilibrium of potentials is achieved by artificially increasing the potential of the supporting surface of the legs to the level of the potential of the current-carrying part, as well as in the contour grounding.

8.3. Safety practice at thermal, electrochemical and electrophysical treatment of parts.

In engineering, thermal, electrochemical and electrophysical metal processing are widely used.

Thermal treatment includes annealing, quenching, nitriding, boring, aluminum, chromium plating, coking, brining, titania, and the like.

Electrochemical and electrophysical - electrospray, electromotive pulse, plasma, electron beam, laser and other methods of processing.

The main hazardous and harmful production factors that arise in the specified methods of treatment to its appearance, the equipment used and working media, can be the following:

- moving machines and mechanisms; moving elements of moving equipment, products, workpieces, materials;
- increased dust and gas pollution of the working zone;
- elevated temperature of surfaces of equipment, materials and air of the working zone, increased level of infra-red (thermal) radiation;
- increased noise and vibration in the workplace;
- elevated level of electromagnetic radiation; dangerous voltage level in the electric circuit, etc. In this case, there is a danger of mechanical injury to workers, poisoning by potent poisons, overheating, burns, electric shock.

In this regard, during the processes of thermal, electrochemical and electrophysical treatment, measures should be provided for the protection of workers from the possible action of hazardous and harmful production factors.

Different enclosures and locks are used to protect against mechanical and thermal hazards, as well as to comply with the relevant safety rules when performing certain operations of the technological process.

Protection against dangerous electric current (range of voltages from 368 to 150 kV) is ensured by the use of protective grounding, grounding and electric protective equipment in accordance with the measures of protection against electric current.

Particular danger to the treatment methods involved are various toxic gases and chemicals used as electrolytes and cleaning solutions.

When thermally treated, the controlled atmosphere and exhaust gases contain toxic gases (carbon monoxide CO2, ammonia NH3, hydrogen sulfide H2S, etc.), the appearance of which (a sharp smell) warns of malfunctions.

Electrolytes used in electrochemical treatment are solutions of strong acids (sulfuric, phosphoric, hydrochloric, hydrofluoric, nitric, etc.), their mixtures in various proportions, as well as solutions and melting of caustic alkalis. The heating of conducting materials is carried out in solutions of caustic alkalis or alkali metal salts. Ultrasonic cleaning is carried out in the environment of various solvents, aqueous solutions of mineral and organic acids, solutions of caustic alkalis and salts (phosphates, carbonates, fluorides, etc.). Some used salts (cyanide silver, potassium cyanide) are strong poisons. In the presence of moisture, acids, and carbon dioxide contained in the air, cyanide salts secrete cyanide hydrogen (strong acid), which causes a rapid breath as a result of paralysis of the tissues of the respiratory organs.

The most important measures that ensure the safety of the service personnel are the following:

- mechanization and automation of processes;
- change in the composition of the electrolyte to reduce its aggressiveness;
- the device of general and local ventilation;
- the use of personal protective equipment and reliable protective devices.

The use of individual means of protection is reliable but as an additional security measure. They need to be used as additional protection or in emergencies.

Personal protective equipment includes: safety glasses, respirators, gas masks, overalls, special footwear, protective pastes and ointments. From clothing wear aprons and protective suits from acid-proof fabrics, as well as acid-resistant gloves. Special protective hydrants in the form of a short hose with a flat tip for water supply from the water supply network, as well as a special hydrant in the form of a fountain of potable water, neutralizing and disinfectants (soda, boric acid, etc.) are also referred to as protective devices. These devices are used to quickly and easily wash sprays and drops of hazardous chemicals that hit the skin or eyes of workers.

The use of reliable barrier devices is an appropriate measure of protection when operating installations with potential sources of chemical hazards. The type, shape and dimensions of the barriers must conform to the design, which is protected.

In order to improve the safety of work with personnel, conduct general instruction, as well as a special familiarization with the properties of all chemicals used, a clear study of the rules of handling and storage of these substances.

In thermal, electrochemical and electrophysical treatment, there may be an explosion and fire hazard. High danger is represented by: dissociation ammonia (containing hydrogen), endothermic gas (containing hydrogen and carbon monoxide), liquefied gases propane and butane, hygroscopic oils - thermal treatments; liquid boundary hydrocarbons (kerosene, solyar and spindle oils, etc.) - electrospray treatment; the condensation of dispersed metal on the walls of the chamber and the formation of deposits, which in some cases have high ability to self-engage in the air - a vacuum electron beam installation.

The main measures of explosion and fire safety are the following: the use of non-combustible liquids or fluids with a higher flash point, maintaining the temperature of the working fluid at a certain level; prohibition to be located near the machine tool in overslept overalls; a device for reliable ventilation; provision of melting furnaces with safety valves and screens of sheet steel; application of automatic fire-prevention devices and systems of suppression of explosions; the presence of adequate means of fire extinguishing, etc.

9. ECOLOGY

9.1. Influence of components of machine-building complex on environment.

9.1.1. Atmospheric pollution.

Emissions of pollutants into the atmospheric air from the activities of the enterprises of the machine-building complex make up about 1-2% of the total volume of industrial pollution - this is mainly the gas emissions of the metallurgical component of the machine-building complex.

1. Foundry. The main sources of air pollution in foundry include:

- melting units of foundries;
- sections of foundries associated with the storage, processing and use of charge and mold materials;
- charge yards;
- mixing plants;
- rod forming and preparation stations, etc..

In the foundry, one ton of castings produces from 1 to 3 tonnes of waste, which contains waste and unused mixture, slag, dust, gases. Although the major part of the waste is waste mixtures and slags, but dust and gases are most at risk of environmental pollution because they are difficult to capture and dispose of.

In closed furnaces-cast iron castings with a production capacity of 5-10 t / h. an average of one ton of castings is emitted into the air: dust - 11.5 kg / t; CO - 193 kg / t; SO2 - 0.4 kg / t; CmHn - 7.7 kg / t. In open-cast furnaces for castings of cast iron with a production capacity of 2-25 t / h. per 1 ton of castings is vented into the atmospheric air:

saw – 17,0-20 kg/t; CO – 185-200 kg/t; SO_2 – 1,3-1,5 kg/t; C_mH_n – 2,1-2,6 kg/t; NO_x – 0,012 kg/t.

The chemical composition of the dust of the cuticle is: SiO_2 – 20-50%; CaO – 2-12%; Al_2O_3 – 0,5-6 %; Fe_2O_3 + FeO – 10-36%; C – 30-45%. The particle size of the dust is 5-150 microns. During casting of one ton of cast iron from the cuttings, about 130 g of CO and 18-22 g of graphite dust are emitted into the atmosphere.

Specific emissions per tonne of finished product pollutants in electric arc furnaces during smelting of one ton of steel are: dust 7,6-9,5 кг/т; CO – 1,5 kg/t; SO_2 – 1,4 kg/t; NO_x – 0,25 kg/t; cyanides – 28,4 kg/t; fluorides – 0,56 kg/t.

In foundry gases emitted into the atmosphere, dust is composed mainly of fine particles, and the free silicon dioxide content reaches 80%. The calculation of pollutant emissions from the melting unit is carried out according to the formula:

$$П = q\,Д \cdot \beta \cdot (1 - \eta),$$

where q – specific allocation of the substance per unit of production, кг/т;

$Д$ – estimated efficiency of the unit, т/год;

β – correction factor for melting conditions;

η – efficiency of emission reductions (in units of units).

At the site of unloading bulk materials (foundry coke, limestone, sand, etc.), an average of 2–2.5 kg / h is allocated to the receiving baths. dust per unit of equipment. 0.2-0.5 kg / h of carbon monoxide, 0.10-0.15 kg / h of sulfur oxide, up to 0.2 kg / h of nitric oxide and other substances such as acromine, formaldehyde, etc. are released from the drying apparatus. . The dust content of gases vented from the drying apparatus is 10-15 g / m^3.

Of the toxic gases, carbon monoxide comes first. The main way to reduce the amount of it entering the environment is through its oxidation to carbon dioxide (IV) - CO_2.

2. Forging and press production. Dust, acids and oil aerosols (fog), carbon monoxide, sulfur dioxide and the like are released in the process of heating and metalworking. Carbon monoxide, sulfur, nitrogen, and other combustion products are emitted into the atmosphere when used in the forging shops to heat the metal of flame furnaces. In order to determine the gross emissions of harmful substances into the atmosphere from heating furnaces, it is advisable to use specific indicators for emissions resulting from the unit of mass (t) or volume (m^3 or thousand m^3) of the fuel burned.

Machining of metals. Machining of metals on machines is accompanied by the release of dust, chips, fogs of oils and emulsions, which are released through ventilation installations into the atmosphere. Table 9.1 provides data on the amount of water vapor, oil mist, and emulsions emitted per hour during the operation of machine tools per 1 kW of power of electric motors.

Table 9.1 - Dust intensity during work on machine tools

Equipment	Маса, мг		
	money water	oil mist	fog, emulsion
Oil-cooled metalworking machines Emulsion-cooled metalworking machines	- 150	200 -	- 6,3
Grinding machines with cooled emulsion and soda solution	150	-	16,5

The dust generated in the process of abrasive machining consists of 30-40% of the material of the abrasive wheel and 60-70% of the material to be treated. The intensity of dust release during grinding of metal parts depends on the diameter of the grinding wheel (Table 9.2).

Table 9.2 - Dependence of dust extraction intensity on grinding wheel diameter

The diameter of the grinding wheel, mm	150	300	350	400	600	750	900
Dust extraction, g / h	117	155	170	180	235	270	310

Metal dust emissions from machining of metal by turning, drilling, grinding and grinding machines are determined by the general formula:

$$M_{МП} = A\ T\ K_1\ У_П, \text{ t/year;}$$

Where A – number of machines, pcs;

T – annual working time fund, h / year;

K_1 – dust extraction efficiency;

$У_П$ – specific emission of metal dust from the machine, kg / h.

The emission of an aerosol emulsion from a lathe or drill is determined by the formula:

$$M_{МП} = A\ T\ У_П\ 10^{-3}, \text{ t/year;}$$

$У_П$ – specific emission of machine-made aerosol emulsion, kg / h;

A – number of machines, pcs;

T – annual working hours of the machine, h / year.

3. Thermal workshops. Significantly pollute the environment thermal enterprises. To give details of certain physical characteristics, they are subjected to heat treatment (such as quenching). The essence of this process is that the metal workpiece is first heated to a high temperature, and there is already enough discussion of environmental pollution due to combustion of fuel or other means of heating.

Heat treatment provides rapid cooling of the hot workpiece. In this case, the hot part is immersed in water or in the oil, which begins to burn (and the water evaporates) with the release of a large amount of harmful gases and metal oxides. After heat treatment, the metal is covered with scale (a thick layer of burnt metal), which is mechanically cleaned. Tumbling drums and sandblasting machines are sources of noise pollution and large amounts of dust.

The sources of atmospheric pollution include: baths, units for heat treatment, heating furnaces running on liquid and gaseous fuels, as well as shot blasting, shot blasting chambers. During the operation of these units and installations, vapors and combustion products of lubricants, ammonia, cyanide hydrogen, dust, etc. are emitted into the atmosphere. The concentration of dust in the air released from the chambers, where the metal is cleaned after heat treatment, reaches 200-700 mg / m^3. Up to 600 mg / h is released during cyanidation of metals. hydrogen cyanide per unit cyanidation unit.

4. Electroplating shops. To give details of certain chemical properties (for example, to avoid rusting), or simply to give details of attractive appearance (nickel plating, chromium plating, zinc coating, etc.) - the details are further chemically treated in electroplating shops. They are immersed in special baths, which are filled with a variety of chemical compounds - acids, alkalis, salts. These liquids are then heated and current is passed through them. The machined parts play the role of the anode or cathode in the galvanic process. Thus, the required surface is created on the workpiece surface. This produces a large amount of very harmful gases and vapors of the solution in the bath. After some time, it becomes unusable for further production and is therefore a very aggressive chemical that needs to be disposed of. Proper chemical measures are required to dispose of it, but it is impossible to completely eliminate it and they become very dangerous environmental pollutants.

The main pollutants released during galvanic processes are dust, fine fog, vapors and gases, especially in the acid and alkali melting process.

9.1.2. Hydrosphere pollution.

About 10 billion m3 of water is consumed annually for the needs of machine-building enterprises of Ukraine, where water is used to cool (heat) raw materials and products, parts and components of technological equipment; preparation of various technological solutions; washing, enrichment and purification of starting materials or products; household and household use.

1. Foundry production. Water in foundries is used for hydraulic knocking out of rods, transportation of forming earth at the regeneration site, as well as for hydrotransportation of waste of burned earth and ventilation system.

The sources of wastewater pollution in foundry shops are mainly installations of hydraulic and electrohydraulic cleaning of castings, wet air purification, hydro-regeneration of waste mold mixtures. Wastewater recycling is of great economic importance for the national economy.

The wastewater generated during these operations is contaminated with clay, sand, ash residues from the burnt part of the core mixture and binder additives of the mold mixture. The concentration of these substances in water reaches 5 kg / m^3.

2. Forging and press production. The main impurities used to cool process equipment, forgings, metal fracturing, and furnishings are dust, scale, and grease particles.

3. Mechanical and thermal production. In mechanical shops, water is used for the preparation of lubricating and cooling liquids, washing of painted products, for hydraulic testing and other work.

The main wastewater pollutants are dust, metal and abrasive particles, baking soda, oils, solvents, paints, etc.

In thermal workshops, water is used to prepare process solutions for quenching, releasing and firing parts, washing parts and baths after throwing out waste solutions, and so on. The main impurities of waste water are dust of mineral origin, metal scale, heavy metals, cyanides, oils and alkalis.

4. Electroplating sites. The water at these sites is used for the preparation of technological solutions intended for etching parts and metals, applying paints to them, as well as for washing parts and baths after the discharge of waste solutions and finishing the premises. The main impurities of the wastewater are dust, metal scale, emulsion, alkalis, acids, heavy metals and cyanides.

The purification of wastewater from solids, depending on their properties, concentration and fractional composition in the engineering plants is carried out by methods of filtering, settling, separation of solids in the field of centrifugal forces and filtration. Sewage treatment of lubricants depending on their composition and concentration is carried out at machine-building enterprises, as a rule, by settling, hydrocyclone treatment, flotation and filtration.

The selection of lubricants in the field of centrifugal forces is carried out in pressure hydrocyclones. The treatment of sewage from oil impurities by flotation is to intensify the process of leakage of lubricants during entrapment of their particles with air bubbles supplied to the sewage. Wastewater treatment of impurities containing oil by filtration - the final stage of purification.

9.2. Rationale for environmental protection measures, selection of equipment for dust, fog, sewage treatment.

Cleaning the air of dust, smoke and fog.

Gas emissions contain solids and various suspended particles and are therefore called aerosols. They are divided into:

- dust (particle size 6-50 microns);
- smoke (particle size 0.1-5 microns);
- fog (0, -5 μm).

In most cases, they are used dry or wet cleaning due to the use of gravity, inertia, centrifugal forces and filtering through devices - porous sections. In wet-cleaning apparatus, gas is contacted with the liquid, causing insoluble particles to increase in size and soluble to disappear. It is also widely used to charge particles and move them to opposite dry filters.

The choice of method and apparatus for trapping aerosols depends primarily on the dispersion composition.

Aerosol cleaning equipment is divided into:

- 0,05-100 Aerosol cleaning equipment is divided into:

- 5-1000 мкм- cyclones up to 1 m - dust chips.

In addition to dispersion, the following properties play a significant role:

a) adhesive, ie the adhesion properties of the individual particles (increased adhesion can disrupt the apparatus) the smaller the size of the particles, the greater their specific surface area and the easier they adhere to the surface of the apparatus. Metallic dust refers to the medium-stick.

b) abrasives that increase the destruction and failure of equipment;

c) wettability - hydrophilic (well lubricated), hydrophobic (not wettable: graphite, coal, sulfur).

For purification from gases and vapors use: absorbers, adsorbers, thermal oxidizers (oxidation in furnaces).

Water purification. Defending.

Periodic (contact) and continuous (flow) settling tanks are used to capture insoluble contaminants from wastewater. Continuous settling tanks have been widely used.

According to the direction of the fluid flow in the structure, the sumps are divided into horizontal and vertical. Sewage wells are widely used for sewage treatment, which is a horizontal variant.

In recent years, thin-layer sedimentation tanks have become widespread. The peculiarity of them lies in the fact that the settling zone is divided by rod sections and tubular elements into shallow layers, where laminar movement of illuminated water is provided.

Depending on the purpose in the technological scheme of the treatment plant, the sump is divided into primary and secondary. Primary sedimentation tanks are used for pre-illumination of sewage that is being advanced for biological or physical or chemical treatment, and secondary ones are for pre-illumination of sewage that has undergone biological or physical or chemical treatment, in some cases it is possible to use clarifiers with an overlying sediment layer.

Compared to urban wastewater treatment plants, local wastewater treatment plants have lower costs - up to thousands of m^3 / day.

In view of this, as well as the cumbersome mechanism of periodic action for scraping and removing sediment of horizontal settling tanks, it is advisable to use vertical sumps and corridors with preliminary coagulation of suspended matter.

9.3. Assessment of environmental performance at the site of the machine shop for the manufacture of the cover.

According to ISO 14001, environmental performance is the measured performance of an enterprise system associated with controlling its level of environmental impact.

Increasing the level of ecological efficiency of the enterprise can be ensured by the effective management of those elements of the activities of its sites, workshops, industrial premises, which have the most significant impact on the environment.

Environmental Performance Assessment is an internal process and management tool designed to provide enterprise management with information on how well an organization's environmental performance meets the set criteria.

Planned and targeted environmental criteria are one of the commonly used indicators for assessing an enterprise's environmental performance. They provide information on efforts made by the organization in management activities that affect or may affect the environmental performance of the organization. Examples of such management activities can be focused on ensuring environmental literacy training, meeting environmental law requirements, regulating environmental management costs, providing environmental resources with the necessary resources and using them effectively, ensuring product sales, product development, documentation, or corrective actions.

Management indicators can be used, for example, the number of environmental targets achieved; the number of units within the organization that have achieved the established environmental target criteria; the degree of implementation of specialized environmental standards in management or operation practices; the number of environmental measures implemented to prevent pollution of production areas and the environment.

The second group of indicators are performance indicators of production functioning. They provide the management of the enterprise with information on the environmental performance of the organization, give an idea of such components of the enterprise as:

- input material streams, such as treated, recovered, reused, or raw materials, natural resources, energy, and services;
- providing supplies for the functioning of the organization.

If the environmental performance of the workshop (site) is related to the materials used in the functioning of the organization, then choose the following indicators:

- quantity of raw materials used for production of unit of production;
- the amount of recycled, recycled or reused materials;
- the number of packaging materials, new or reused, per unit of production.

If the environmental performance of the workshop (site) is related to the total energy consumption or types of energy used, or the energy efficiency of the organization, then the following indicators are usually chosen:

- amount of energy consumed per year or per unit of output;
- the amount of energy consumed in the production of annual volume or provided to the consumer;
- the amount of energy used by each species.

If the environmental performance of the workshop (site) is related to operations that support the functioning of the organization, then choose the following metrics:

- number of cleaning components used in additional work;
- the amount of hazardous materials used in operations.

If the environmental performance of the workshop (site) is related to the material objects and the equipment used, then choose the following indicators:

- the number of structural elements of process equipment that have units designed with ease of disassembly, recycling and reuse;
- the number of hours of operation of a particular equipment per year.

If environmental performance is related to inbound (delivery) and outbound (delivery) flows as a result of the functioning of the organization, then choose the following metrics:

- - average fuel consumption of vehicles in the workshop (at the site);
- - number of cargo transportation by vehicles per day.

When the environmental performance of the plant (site) is related to the main or ancillary products, such as non-core production materials, including reclaimed or reused materials, which are retrieved and stored for further commercial use, then choose the following metrics:

- the number of products released on the market with less dangerous properties;
- the number of products that can be reused or renewed after the end of their service life;
- the percentage of products that can be restored or reused after the end of their service life.

When certain works are performed at the site and the enterprise is interested in the environmental performance of these services, then the following indicators are selected:

- the number of detergents used per square meter of area;
- fuel consumption when providing a unit of transport service.

When the environmental performance of the workshop (site) is associated with the waste generated by the operation of the organization, then choose the following indicators:

- the amount of waste per year that is per unit of output;
- the amount of hazardous, recoverable or reused waste generated at the site during the year;

- the total amount of waste disposed outside the premises of the enterprise shop.

When environmental performance is related to emissions into the atmosphere during production at the site, the following indicators are chosen:

- amount of emissions per year;
- the amount of secondary (thermal) energy released into the atmosphere;
- the amount of emissions per unit of production per year.

GENERAL CONCLUSIONS

In the thesis on the topic "Development of project of machine shop section for cover KS6-57.017 manufacturing technology with research microgeometrical deviations of cutting tool in cutting process by finite elements method" the design of the technological process of machining the part - the cover, technological equipment for its manufacture (adaptations, adjustment, cutting and measuring tools), the substantiation of the economic efficiency of the adopted design and technological solutions.

The scientific researches of the stability of the cutter on the criterion of fatigue failure have been carried out, the influence of the processed material on the process of chip formation has been studied, the energy parameters of grinding and control are determined.

The developed technological process of manufacturing the component - the cover is more advanced and has significant advantages over the basic technological process. Making a workpiece by another method makes it possible to significantly reduce the cost of its production.

The analysis of the technological process obtained with the help of CAD was carried out, as well as the technical and economic calculations of two technological processes were made and economically advantageous. Grouping with the introduction of new gadgets allows you to replace two machines one by one.

With these and other factors, it is possible to reduce the amount of equipment used, thus reducing production areas and the number of employed key workers. The introduction of the new machine allows processing the part for one operation in three establishments, which increases the quality of production, reduces the time for processing, and therefore increases the productivity with reduction in the cost of manufacturing parts.

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