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 case TSF 8.171.137 manufacture including the study of cutting tool geometrical parameters influence on cutting force parameters**

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
2019

Ministry of Education and Science of Ukraine
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Faculty *Engineering of Machines, Structures and Technologies*
Department *Mechanical engineering*
Educational degree *Master of science*
Field of study
(code and title)
Specialism *131 "Applied mechanics"*
(code and title)

APPROVED BY
Head of Department *Doctor of sciences, professor*
Pylypets M.I.

Assignment

FOR DIPLOMA PROJECT (THESIS) FOR STUDENT

Yousif Duhair
(surname, name, patronymic)

1. Project (thesis) theme. **Desing development of machine shop area for the case TSF 8.171.137 manufacture including the study of cutting tool geometrical parameters influence on cutting force parameters**

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 *20 th of December 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 conditions. Rate setting of operations. Designing chapter. Choice and design description of attachments. Tools, materials and appliances for the manufacture of the case. 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)
Case, case (workpiece), caliper gage – A1.
Routing technological process of manufacturing part – A1, A2.
Job setting using the screw-turning and vertical milling operations –2A2.
Dual-stage face mill, dual-stage case – 2A3.
Hop traveler for multi-axis operation – A1.
Fixture for drilling holes of different diameters - A1.
Industrial robot- 3A1.

6. Advisors of design (thesis) chapters

Chapter	Advisor's surname, initials and position	Signature, date	
		assignment given	assignment accepted
Special chapter	*Assis. Prof., Pankiv M.R.*		
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 nd of October 2019*

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 ____________ *Yousif Duhair*
(signature) (surname and initials)

Project (thesis) supervisor ____________ *Danylchenko L.M.*
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ABSTRACT

The diploma project on the theme "Design development of machine shop area for the case TSF-8.171.137 manufacture including the study of cutting tool geometrical parameters influence on cutting force parameters" includes the design of the technological process of mechanical processing of case, technological equipment for its manufacture (adaptations, adjustment, cutting and measuring tools), the development of measures for labor protection and safety engineering, as well as substantiation of the economic efficiency of the adopted design and technological decisions. The analytical chapter 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. In analytic chapter the influence of cutting tool geometrical parameters on cutting force parameters was studied.

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

In the design chapter the choice of equipment, equipment and bases for the design variant of the process of manufacture of the case was substantiated, designing on the basis of technical tasks of technological and control devices and a cutting tool were 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 organization of labor protection at work; ways of elimination of harmful production factors were considered.

CONTENTS

5. SPECIAL CHAPTER

6. PLANNING CHAPTER

7. ECONOMIC BACKGROUND

INTRODUCTION

Technical progress in mechanical engineering is characterized not only by the improvement of product designs, but also by the continuous improvement of the technology of their production. At this time, it is important to produce, with a minimum of costs and at a specified time, a product, using modern high-performance equipment, technological equipment, and means of mechanization and automation of production processes. The adopted production technology depends to a large extent on the durability and reliability of the products manufactured, as well as costs for them.

The decisive means for significantly improving the efficiency of production is automation of the production process, which involves the use of qualitatively new systems of machines, which perform functions of processing, transportation of processed blanks or tools, quality control, regulation and management of the production process.

The solution of this problem is possible due to the wide introduction into the production of flexible automation systems, which represent a qualitatively new stage in the complex automation of the production process, as a result of their creation on the basis of the wide application of software-driven technological devices, automation of design, engineering and manufacturing work.

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 in shape and size to finished products, which contributes to the economy of metal, reducing the work of mechanical processing, reducing the production cycle of parts manufacturing and reducing the cost of production in general.

1. ANALYTIC CHAPTER

1.1. Service purpose and characteristics of the object of production

The Selmichrom-11 type chromatograph is designed to identify the components of the mixture under test and measure their relative or absolute amounts in units of concentration or mass, respectively.

The scope of the chromatograph is the study and control of the composition of powder mixtures, mixtures of chemical compounds, typical for the industries of the machine-building, chemical, gas, petrochemical, pharmaceutical industry, as well as other branches of industrial production.

The chromatograph has a block-modular design, designed for operation under aggressive atmospheres, and consists of the following main units: an analysis block and a control unit. During operation, these blocks are installed next to each other.

The main unit is the analysis block. It consists of a thermostatic chamber in which the chromatographic columns of the detectors, the device for introducing the liquid sample (evaporator) and the gas distributing module. The front panel analysis unit has a control unit: the power supply button, the gas control carrier control, air, hydrogen, pressure gauges for the input pressure in the chromatographic columns, the detector, the gas cocking-batch.

The control unit is a combined electronic device that provides the control of the analytical nodes of the chromatograph with the help of a computer.

Operation of the chromatograph should be carried out in laboratory rooms at an ambient temperature of 10 to 35°C, relative humidity not more than 80% and atmospheric pressure from 84 to 107 kPa. It has increased reliability and is designed for use in an aggressive atmosphere, contaminated with acids, alkali, organic solvents and aerosols.

Power supply is made from AC 220 V with a frequency of 50 ± 1 Hz; power consumption - no more than 2,0 kV.

Gas supply is carried out by carrier gas (nitrogen, argon, helium), hydrogen and air. Required pressure at the inlet to the chromatograph:

- carrier gas - from 0.4 to 0.6 mPa;
- hydrogen - from 0,4 to 0,6 mPa when working from a cylinder with hydrogen; when working with a hydrogen generator - it is not standardized;
- air - from 0.4 to 0.6 mPa.

1.2. Analysis of technical requirements for the part.

The material of the case part is steel 45. The largest diameter is ∅184h10 mm, the length is 160js14 mm.

This part is part of the assembly unit "gas flow meter" of the device for stabilizing two gas flows of the chromatograph. The chromatograph is operated under normal conditions (ambient temperature from 10 to 45 ° C, pressure from 730 mm Hg to 760 mm Hg, humidity from 10% to 90%). Stable flow of gases in the chromatograph is one of the necessary conditions for proper operation of this device. The range of gas flux changes in the chromatograph is in the range of 10 cm^2 / min. to 100 cm^2 / min. every.

The "case" part is the basis for measurement of gas flows. There are two channels ∅8,6 for gas transport through the flow rate sensors in the case of the part. The gas of each stream flows through the inlet of the M24 using a tube with a sealing nozzle and an empty nut screwed into the thread of the inlet. With the same device, the gas is output from the housing of the flow meter.

Flow rate sensors are installed in each of the channels of gas transport, should be blown off by all the gas that enters the flow meter. For this purpose, the sensors are installed through the seals (aluminum washers), which prevent the flow of gas through the temperature gauges.

On the upper surface there are openings ∅24,8 and ∅36 for mounting and fastening of flow sensors.

The bottom surface has openings M24 for the connection of two tubes that divert gases from flow sensors. The projection on this surface is used to correctly install the meter on the basis of the gas flow stabilization device. The fastening of the part to the base is carried out with the help of 4 holes M12.

Larger mesh is used to connect an electronic flow control unit with a gas flow meter unit. The fixation is carried out using two M12 holes. After installing the flow control device in the groove located on the front, the meter measures the temperature of the housing of the gas flow meter. Temperature stabilization of the case is one of the conditions for proper operation of the device.

On the small leaf there are two openings M24 for fastening of pipes, which bring gas streams to sensors of intensity.

1.3. Analysis of the technological design of the part.

The possibility of machining the part with the maximum productivity and minimum cost makes it possible to consider the part as technological. Performance analysis includes qualitative and quantitative indicators.

Qualitative indicators include:

- material parts;
- locating and clamping;
- setting sizes;
- form and location tolerances;
- structural non-technological elements.

The quantitative performance indicators include:

- coefficient of use of workpiece and material;
- coefficient of accuracy;
- coefficient of roughness.

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

The qualitative estimation of the technological detail of the composition and properties are presented in tables 1.1, 1.2.

Table 1.1 - Chemical composition of steel 45,%

C	Si	Mn	Cr	P	N	Cu	S	As
				No more				
0,42-0,5	0,17-0,37	0,5-0,8	0,25	0,035	0,25	0,25	0,04	0,08

Table 1.2 – Mechanical properties of steel 45

HB	$\sigma_{0,2}$	$\sigma_в$	ψ	δ	KCU
	mPa		%		J/cm^2
	No less				
202-234	520-590	730	46-50	40	50-70

The material from which the component is manufactured is well treated with cutting, which means that the processing of the part does not consume additional energy, and therefore reduces its cost.

Convenience of the base. The part is not comfortable to be used for aligning the cylindrical surface and milling the sash and groove. When machining a cylindrical surface, it is difficult to install the workpiece on the machine because the workpiece has a folding pin. The same can be said for a milling operation. When drilling, the part is convenient for the base, because it has a developed base, which is larger than the length of the part and is well installed on the desktop of the drill machine. When drilling holes, you can withstand the placement tolerances shown in the drawing.

Setting sizes. In the drawing, the size 58±0,15 (section A-A, drawing of the part) is not set correctly. It was necessary to measure the depth of the level ∅36 + 0,62 of the step hole. According to the drawing, in order to determine the depth, it is necessary to subtract from the size of 68 ± 0,37 the size of 58 ± 0,15, while these sizes have different qualities of accuracy, therefore the qualification of the received depth is unknown.

Constructive non-technological elements. In the detail, structural non-technological element can be considered baldness because the surface of their surfaces is different and they cannot be processed in one installation. But positive for processing is that they are parallel with one another.

Non-technological ones can be considered openings M12-7H, because they are placed one against another at different angles - this leads to complication markup. Similarly, non-technological openings M16-7H can be considered, they are located at different angles to the axes of the stepped openings.

Step holes - for their production, it is necessary to perform a deep drilling (drill ∅8,6 with a length of the working part more than 160mm). This makes drilling inconvenient, and leads to the need to use different types of conductors. These step openings can be performed only by two institutions.

On this drawing, there are position tolerances (the positional tolerance of the axis of the M12-7H opening equal to 0,07 mm and the positional tolerance of the M16-7H cutting openings equal to 0,05 mm), which are calculated in hundredths of a millimeter, which complicates the base of the part.

Quantitative assessment of technological design.

To calculate the roughness coefficient and the coefficient of accuracy, used surface parameters are presented in table 1.3.

Coefficient of roughness is:

$$K_{ш} = \frac{1}{Б_{ср}}, \qquad (1.1)$$

where - the average roughness of the surfaces, mkm.

$$Б_{ср} = (3,2 \times 34 + 1,6 \times 82) / 42 = 121,6 / 42 = 2,9 \text{ mkm.}$$

Table 1.3 - Parameters of surfaces

Name of surface	Quantity	Class of accurace	Roughness, mkm
Outside:			
1. Cylindrical surface ∅184mm	1	h10	3,2
2. Cylindrical surface ∅116mm	1	d9	3,2
Inside:			
1. Hole M12-7H	6	H7	3,2
2. Hole M16-7H	2	H7	3,2
3.Stepped hole.			
1 - step:			
cylindrical surface ∅36mm	2	H14	3,2
face *l* = 168-58mm	2	H14	1,6
2 - step:			
cylindrical surface ∅24,8mm	2	H12	3,2
face *l* = 58mm	2	js11	1,6
3 - step:			
cylindrical surface ∅12,8mm	2	H12	3,2
4 - step:			
cone 60°	4	H17	1,6
5 - step:			
hole M24-7H	4	h12	3,2
Linery:			
1. Face *l* = 16mm	1	h12	3,2
2. Face *l* = 160mm	2	js14	3,2
3. Face *l* = 124mm	2	js14	3,2
4. Groove *b* = 20mm *h* = 18mm	1	js12	3,2
	38	408	115,2

Sence

$$K_{ш} = \frac{1}{2{,}9} = 0{,}34.$$

The calculated value of the roughness coefficient is less than the permissible (0,34> 0,32), therefore, according to this parameter, the part is non-technological.

Accuracy:

$$K_{тч} = 1 - \frac{1}{A_{ср}}, \qquad (1.2)$$

where $A_{ср}$ - midium accurace of surfaces.

$$A_{ср} = (3\times 11 + 9 + 16 \times 7 + 10 \times 14 + 9 \times 12 + 4 \times 17) / 42 = 10{,}85;$$

$$K_{тч} = 1 - \frac{1}{10{,}85} = 0{,}9.$$

The calculated value of the coefficient of accuracy is greater than necessary (0,90 > 0,8), hence, according to this parameter, the part is technological.

Coefficient of use of workpiece:

$$K_{з} = \frac{m_{д}}{m_{з}}, \qquad (1.3)$$

where $m_{д}$ - weight of part, kg;

$m_{з}$ - weight of workpiece, кg.

The weight of the item is 16,5 kg; the weight of the workpiece obtained by stamping on KGSP - 30 kg.

$$K_{з} = \frac{16{,}5}{30} = 0{,}55 < 0{,}7.$$

Coefficient of material use rate:

$$K_{М} = \frac{m_{Д}}{m_{з} + m_{ВВ}}, \qquad (1.4)$$

where $m_{ВВ}$ - weight of scraps, kg;

$$K_M = \frac{16,5}{30+3} = 0,5 < 0,64,$$

According to this indicator, the item is non-technological.

Based on qualitative and quantitative estimates of the machinability of the part, we can conclude that the part is non-technological, therefore it is difficult to make it.

1.4. Analysis of the basic technological process.

The basic technological process consists of the following operations:

005→Boring.

190 mm, maintaining the size of 180 ± 0.5 mm on the cutting machine 8B72A.∅In this operation, cutting the workpiece from the rolled stock.

010 Control DTC.

The control of the size of the workpiece by the WTC master is controlled, the size is controlled 180 ± 0.5. Measuring tool - calipers SHC-I-125-0,1.

015→Turning-screw 16Б16К.

116d9.∅184h10 (preparation of the finishing base) is partially processed. At the second institution, the other part of the cylindrical surface is treated and the final treatment of the ledge is ∅116d9 and the ends is performed. In this operation, two institutions are used: in the first institution, the cylindrical surface ∅184h10, ∅In this operation, the final treatment of the cylindrical surface

Transitions:

1st institution:

1. Install, fix, and remove.
2. Boring face in size 162±0,5.
3. Cutting cylindrical surface in size ∅ $184^{-0,185}$.

4. Control by the executor.

2^{nd} institution:

1. Install, fix, and remove.
2. Boring face in size 162±0,5.
3. Cutting cylindrical surface in size ∅ $184^{-0,185}$.
4. Cutting face ∅ $116^{-0,120}_{-0,207}$ on length 16 $^{-0,18}$.
5. Control by the executor.

The part is based and fixed in a three-stick cartridge ∅ 250. Basing is carried out at 5 points (the installation base - deprives the detail of three degrees of freedom, the double supporting base - the outer cylindrical surface - deprives the detail of two degrees of freedom). Cutting tool is standard.

020→Control DTC.

Controlling dimensions ∅ $184^{-0,185}$, ∅$116^{-0,120}_{-0,207}$ $16^{-0,180}$ і 160±0,5 by worker of DTK. Measuring tool - calipers ШЦ-I-160-0,05, snap gauge 116 ПР-НЕ, snap gauge 184 ПР-НЕ, ГІ-100.

025→Vertical milling 65.

There are two location on this operation. On the first – treatment of less flat 124js14. On the second - treatment of flat 46,4js14 and 20js12x18js12.

Transitions:

1^{st} institution:

1. Install, fix, and remove.
2. Milling flat in size 127±0,5.
3. Controlled by the performer/executor.

2^{nd} institution:

1. Install, fix, and remove.
2. Milling flat in size 46,4js14.

3. Milling flat in size 20 $_{-0,210}$×18 $_{-0,210}$ i 104±0,345.
4. Controlled by the executor.

The item is installed in a special device. In general, the item is deprived of six degrees of freedom. The baseline deprives the part of three degrees of freedom: moving along Z, rotation around X and Y (taking into account the location of the axes chosen in the sketch). The guide serves as an anterot, which deprives the detail of two degrees of freedom: the movement along Y and the rotation around the Z axis. The supporting part is the forming part, which deprives it of one degree of freedom: moving along the X axis. The cutting tool is standard.

030→Washing.

In this operation, the surface cleaning of the part from the lubricant, lubricating and cooling fluid, which was used in the previous operation, is performed. Sink is carried out in special baths. Operation remains unchanged.

035→Benchwork.

Cleaning the surface of the part from the burrs that formed during the milling process. Appliances - metalwork brushes; tool - file, hammer, emery paper.

040→Control DTC.

In this operation, the control of the resulting milling sizes is carried out:

124js14(±0,5)

46,4js14(±0,125)

20js12($_{-0,210}$)×18js12($_{-0,210}$).

Measurement is carried out by the DTC master. Measuring tool: calipers STC-I-125-0,1, calipers for stamps II-160-0,05.

045→Jig boring 2A430.

In this operation, the treatment of stepped openings and holes under the cutting is performed. The treatment is carried out for 4 institutions.

Steps:

1-step:

1. Install, fix, remove.
2. Center, drill 2 holes $\varnothing\ 12{,}8^{+0{,}18}$ in size $L =\ 82{,}6^{+0{,}35}$.
3. Drill 2 holes $\varnothing\ 24{,}8^{+0{,}21}$ in size $L =\ 68 \pm 0{,}37$.
4. Drill 2 holes $\varnothing\ 39^{+0{,}62}$ in size $L = 17 \pm 0{,}35 - 14{,}5 \pm 0{,}15$.
5. Center and drill 6 holes $\varnothing\ 13{,}6$ for M16-7H.

2-step:

1. Center, drill 2 holes $\varnothing 8{,}8^{+0{,}15}$ for pass in hole $\varnothing 12{,}8^{+0{,}18}$.
2. Drill 2 holes $\varnothing 21{,}2$ for M24-7H with cone $60°^{+3°}$.
3. Center and drill 4 holes $\varnothing 10{,}4$ for M12-7H.
4. Control.

3-step:

1. Install, fix, remove.
2. Center, drill 2 holes $\varnothing 8{,}8^{+0{,}15}$ for pass in hole $\varnothing 24{,}8^{+0{,}21}$.
3. Drill 2 holes $\varnothing 21{,}2$ for M24-7H with cone $60°^{+3°}$.

4-step:

1. Center, drill 2 holes $\varnothing 10{,}4$ for M12-7H.
2. Control.

Cutting tool: center drill ∅ 4 from БРС Р6М5, drills ∅8,8; ∅10,4; ∅12,8; ∅13,6; ∅21,2; ∅24; ∅35,2; core drill ∅12,8; ∅24,8; counter bore ∠ 60° ∅21,2; cylindrical counter bore ∅36.

050→Washing.

In this operation, the surface cleaning of the part from the lubricant, lubricating and cooling fluid, which was used in the previous operation, is performed. Sink is carried out in special baths. Operation remains unchanged.

055 → Radial drilling 2M55.

At this operation, the cleaning of external and internal surfaces from burrs and cutting of a ridge is carried out.

Steps:

1. Install, fix, remove.
2. Counter boring thread holes.
3. Drilling 4 holes M24-7H, 6 holes M16-7H i 6 holes M12-7H.

Tools: taps M24-H3, M16-H3, M12-H3, hammer, file, needle file.

060→Washing.

In this operation, the surface is cleaned of the part from the lubricant, which was used when cutting the cutting. Washing is carried out in special baths. Operation remains unchanged

.

065→Control DTC.

Controlling the dimensions, position tolerances and roughness obtained after coordinate-boring and radial-drilling operations are carried out.

Controlled dimensions:

– M12-7H threaded plug M12-7H ПР-НЕ;
– M16-7H threaded plug M16-7H ПР-НЕ;

– M24-7H threaded plug M24-7H ПР-НЕ;

– ∅12,8H12 plug 12,8H12 ПР-НЕ;

– ∅24,8H12 plug 24,8H12 ПР-НЕ;

– ∅36H12 plug 36H12 ПР-НЕ;

– $\angle 60^{\circ\ +3^{\circ}}$; ∅8,8 provided by the tool;

– $36^{+0,62}$; 68±0,37 ШЦ-I-125-0,1;

– 58±0,15 ИЧ 25-1; tip;

– roughness Ra 1,6 roughness comparison specimen.

070→Electrochemical.

The coating is covered with zinc (Ц18.cr).

An analysis of the basic technological process of manufacturing the part - case TSF 8.171.137 has revealed its shortcomings and made it possible to make the following changes:

1. Machine tools:

– on operation 005 machine tool 8Б72А replace on KGSHP;

– on operation 015 turning screw machine tool 16Б16К replace on 16К40;

– on operation 025 vertical milling machine tool 675 replace on 6Т10;

– jig boring machine 2А430 and radial drilling machine tool 2М55 replace on machine center ИР800ПМФ4.

2. Equipment:

– on operation 015 three-jaw chuck replace on four-jaw chuck;

– for the treatment part on machine center were design special attachment;

– on operation 025 universal face milling cutter replace on special press-fit face milling cutter.

3. Location:

– operation 045 i 055 substitute for one (the workpiece base is changed accordingly).

1.5. Conclusions and problem statement for the diploma project.

The issue of providing high quality case parts and the introduction of numerical control devices are closely interconnected. It is known that products made with the use of CNCs are better due to the use of numerous control and diagnostic devices and machines controlling the process of manufacturing such parts.

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 the shape and size of finished products, which contributes to saving metal, reducing the amount of machining, 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 the manufacture of cases, the development of appropriate equipment and equipment for operations of mechanical processing, assembly and control in order to improve their technological and operational properties.

2. SCIENTIFIC RESEARCH CHAPTER

2.1. Characterization of the cutting tool geometry.

The geometric parameters of the cutting tool significantly affect the cutting force, surface quality and wear of the tool. Eventually, the cutting force and the size of wear of the tool depend on their choice. Cutting of metals is a complex process, because it is influenced by many factors: the properties of the cutting and processed materials, the size of the cut layer, cutting modes, working conditions. In practice, we have to deal with a variety of combinations of these factors. In this regard, the definition of the optimum geometry of the cutter is quite complex task. Each parameter influences the work of the cutter, changing its geometric parameters that are related and other cutting parameters.

Depending on the specific processing conditions, you can find the optimum geometric parameters of the cutting tool. Since it is difficult to establish optimum dimensions of the cutting part of the cutter for all processing cases, it is advisable to investigate the fundamental position on the choice of each of the geometric parameters.

The geometry of the working part of the cutter during cutting characterizes the position of surfaces of the working part relative to the coordinate flatness of the kinematic coordinate system. For example, when segments details the geometry of the blade in the main January plane is characterized by kinematic front and rear angles γ_κ i α_κ (Figure. 2.1):

$$\gamma_\kappa = \gamma_c + \eta\ ; \qquad \alpha_\kappa = \alpha_c - \eta\ ; \qquad tg\ \eta = s/\pi D\ ; \qquad \eta = arctg\ (s/\pi D). \qquad (2.1)$$

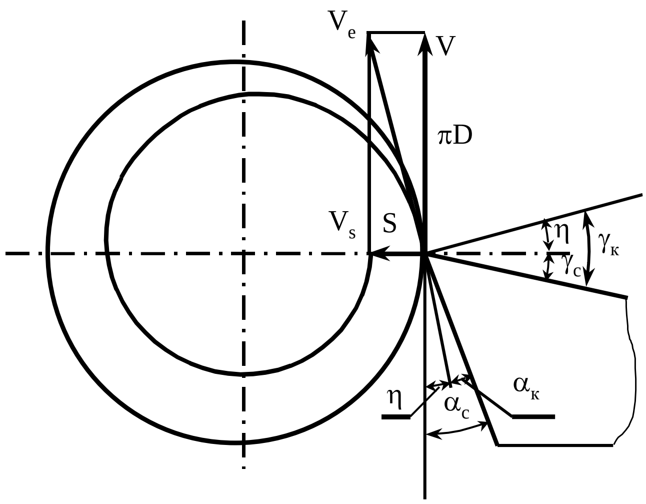


Figure 2.1 – The influence on angles in the main sich
when cutting the workpiece

When the groove or cut off the valid front and rear angles also depend on the error of the installation incase relative to the axis of the workpiece (Figure. 2.2):

$$\gamma_y = \gamma_c - (+)\omega\ ; \qquad \alpha_y = \alpha_c + (-)\omega,$$

where the first character is used if the vertex of the cutter is below the workpiece axis, the sign in brackets – if above.

Ω angle is determined by the formula: $\omega = arcsin\ (2h/D)$.

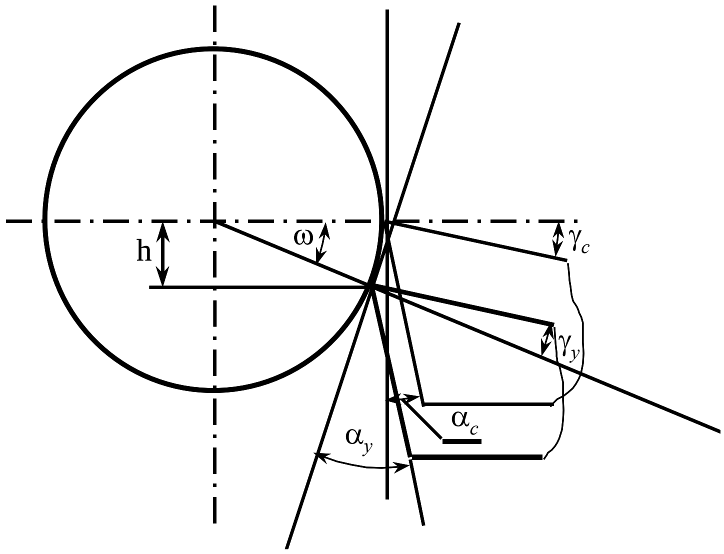


Figure 2.2 – Effect of error setting incutter relative to the workpiece axis
corners in the main such

If the axle is not perpendicular to the axis of the workpiece, then the actual main and auxiliary angles in terms of different from the same static angles on the angle of Δ (Figure. 2.3).

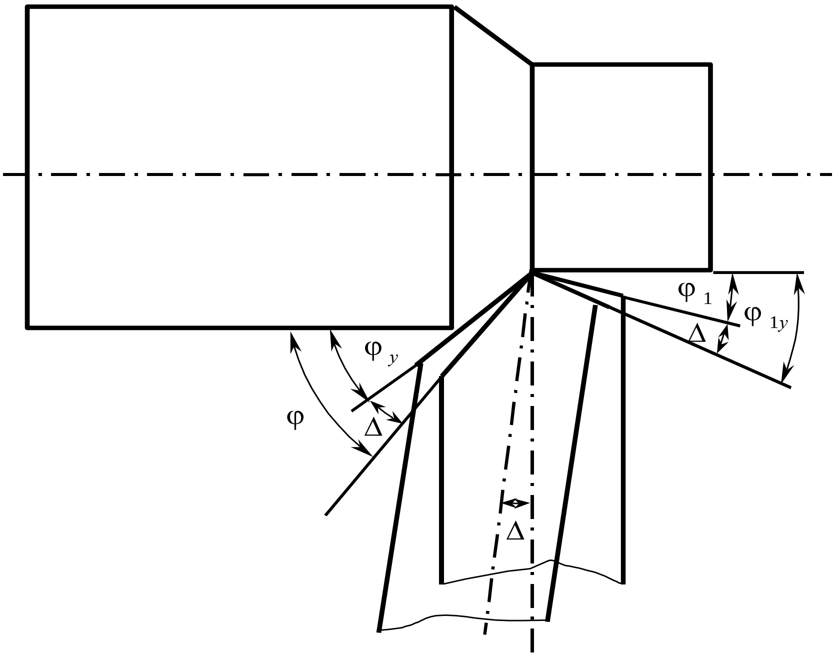


Figure 2.3 – Influence of nonperpendicular axis of the cutter to the workpiece axis angles in terms of

When selecting the values of geometrical tool parameters play a large role to be treated material parts and its physical and mechanical properties, cutting material, its cutting and physical-mechanical properties, the size of the cut layer of metal (thickness, width), designed cutting modes (speed, supply, depth).

So, with the increase in the cutting angle tool is easier to crashes into in the material, reduced cutting force, improves the quality of the surface, but increases the wear tool. The increase in the angle of cutting in terms reduces the force of the friction tool on the cutting surface and its wear, but an excessive increase in the angle weakens the cutting edge, contributing to the destruction of the shock loads.

Force cutting *P* represent the forces that act on the cutting tool in the process of elastic and plastic deformation and destruction of shavings, which is removed during the cutting process.

In the process of processing, the cutting force remains constant due to the change in cross sections of the cut shavings, the allowance for processing, the uneven mechanical properties of the material and the distribution of the cutting force. Change of the cutting force causes attenuation and wear of the cutting tool, accruing and other factors affecting the cutting process.

By the action of the changing cutting force, the elements of the system machine — device — tool — the part is deformed, by changing these cutting conditions.

The purpose of scientific research is to study the influence of the geometry of the cutting tool (cutting angles, the radius of the cutting edge) on such parameters as the cutting force and its components, the quality of the treated surface, the service life of the instrument, the roughness of the treated surface.

During processing, there are high contact tension between the tool and the workpiece, the high temperature, the large values of the cutting force, etc. The cutting temperature that arises during the cutting process, exposes the cutting tool to extreme temperature conditions. The formation of chips during cutting due to friction of the cutting edge and the treated surface with high processing speed is also accompanied by the release of heat, which has an adverse effect on the geometry of the tool and influences the service life.

In the process of continuous cutting, the cutting force is unstable, which causes changes in the microstructure of the tool. Therefore, the material of the cutting tool retractable stringent requirements: high hardness at elevated temperature, high viscosity in destruction, resistance to wear and tear tools high strength [10].

The design of the cutting tool can also be improved by optimizing the macro-geometric parameters (instrument profile, cutting angles, etc.) or microgeometry.

The microgeometry of the cutting tool also influences the roughness of the treated surface, the edge radius.

To prepare the front angle of the cutter before processing apply different ways, based on the principle of sharpening and polishing using abrasive elements (pasta, powder, fiber, magnet, etc.) [18].

The required radius of the rounding cutting edge is formed by combining the speed and duration of the workpiece movement. The purpose of preparation of cutting edge is: formation of the necessary shape and size, increase of strength, decrease of internal tension on the contact surface, decrease the risk of chips at edge edges, increase durability of the instrument.

In Fig. 2.4 the difference between a sharpened tool and a tool with the prepared cutting edge is shown. On the left-sharp cutting edge, which was obtained by grinding the front end surface of the tool.

The cutting edge has the recommended radius, since it is impossible to make a perfectly sharp tool. Roughness on the cutting edge can be higher and the end surface of the tool may have defects. These include microdefects that arise during sharpening, and macrodefects that are caused by different movements and transitions at different stages of the production process.

These defects (shortness of breath) is desirable to detect before coating when preparing the cutting edge, otherwise in the process of cutting the burs can be canceled over the cutting edge, which can lead to the destruction of the cutting tool [10, 25].

The preparation of the cutting edge influences the components of the cutting force, torque, performance and durability of the instrument, forming of shavings, quality of the treated surface, accuracy of processing, etc. In the process of manufacturing the cutting tool it is necessary to observe a clear sequence of all stages, correctly choose the technological method of processing tools, as these factors significantly influence the accuracy of the size of working surfaces and the term operation of the instrument. The process and sequence of manufacturing of the tool is presented in Fig. 2.5 [9].

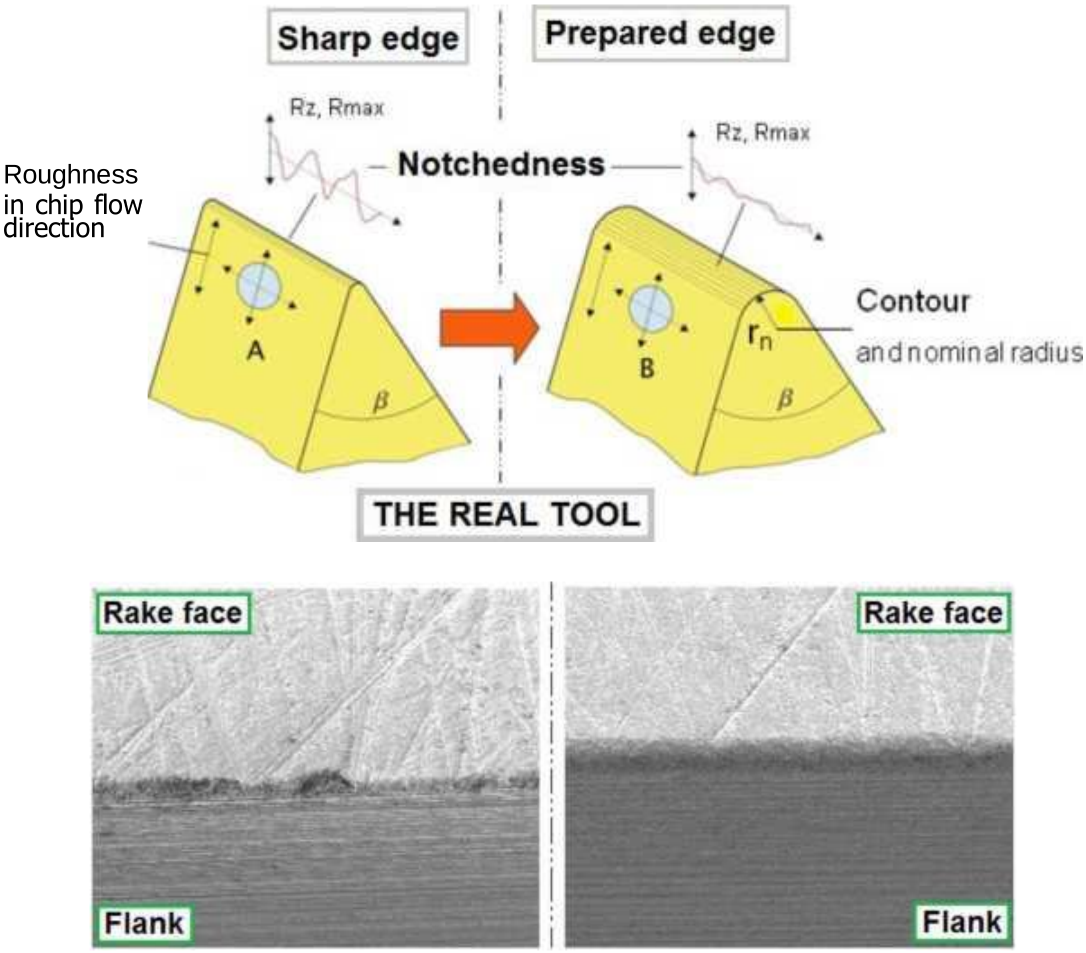


Figure 2.4 - Preparation of cutting edge [26]

Figure 2.5 – Stages of manufacturing process for high-precision tools [9]

To assess the microgeometry of the cutting edge using the following parameters. The cutting edge is characterized by: radius cutting edges r_p, and parameters A_r, S_a, S_y, $K= S_y/S_a$,, presented in Fig. 2.6. The ratio of K determines the symmetry of the contour, which is formed as a result of rounding cutting edge. If K = 1, the microgeometry is symmetrical. If $K > 1$ then the cutting edge is tilted to the front surface, in the case of $K < 1$ – to the rear surface of the cutting tool [9, 10].

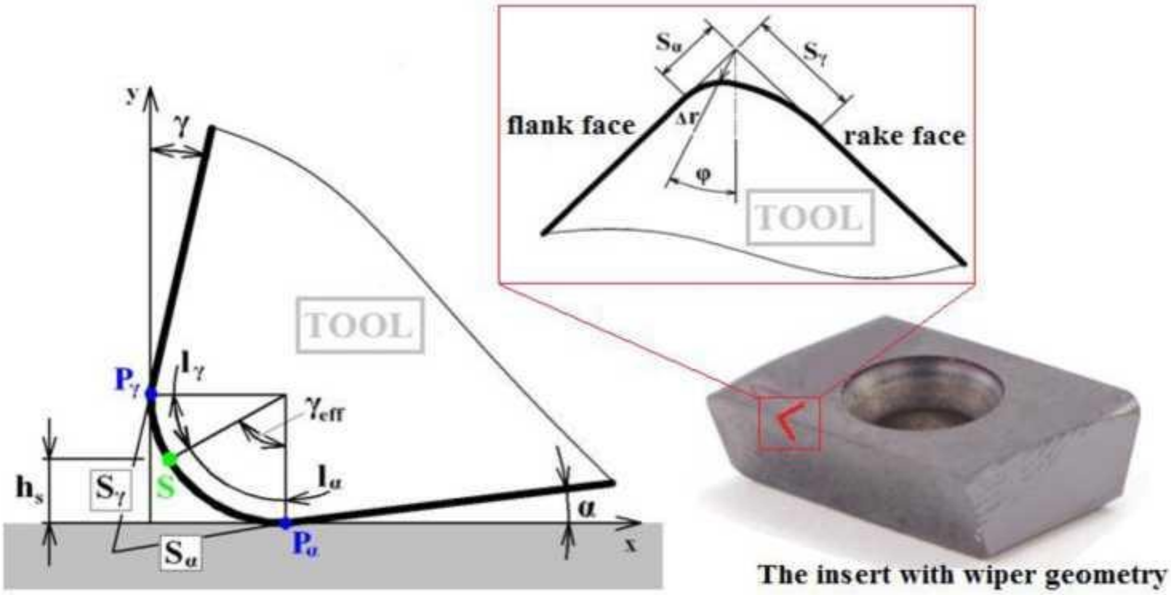


Fig. 2.6 - Parameters of cutting-edge geometry [10]

2.2. Setting up the experimental criterias, technical and cutting conditions.

Experimental researches have been carried out to study the influence of radius cutting edge on the period of operation of the instrument and the main cutting force during milling of the chromium alloy steel, which is used for making casings. The base plane is trimmed with a tool equipped with cutting plate. Scientific researches are based on the real processing process, for which such experimental criteria are determined:

- machining with cutting plate;
- maximum wear of the tool VB_n/KB = 0,15 mm;
- roughness of the treated surface Ra <0,8 pm;
- volume of extracted material B > 60 см^3.

Studies were conducted at the vertical machining center of MCV750. On the desktop of the processing center is fixed detachment, then treated with milling diameter of 80 mm with cooling supply.

The cutter has a cutting carbide plate without a clamp. During processing determined cutting force, the size of the tool wear and roughness of the treated surface. In Table 2.1. are the technical parameters and the cutting conditions.

Table 2.1 - Cutting conditions and technical parameters

Parameter	Value or description
Milling type	Down milling, outer cooling
Axial depth of cut a_p, mm	0,02
Radial width of cut a_e, mm	50
Cutting speed v_c, m/min	200
Feed rate f_z , mm/tooth	4,5
Measurement system	Piezoelectric dynamometer 9255 A. Optical measurement system, surface metrology and form measurement. Device for measuring roughness M300. Microscope PC 500

2.3. Research the experimental results of cutting-edge preparation and cutting-edge radius influences on tool life and cutting forces.

In Figure 2.7 presented cutter, plate, workpiece, machining center, which is mounted dynamometer.

Conditions of experimental researches.

The plates were pre-buffed, polished, and laser treated.

Used plates of radii cutting edge 5, 10 and 15 pm.

The laser beam with radius of the cutting edge 5 pm.

In Figure 2.8 presented cutting edges and plates.

Table 2.2 provides the geometrical parameters of tools that were used in researches.

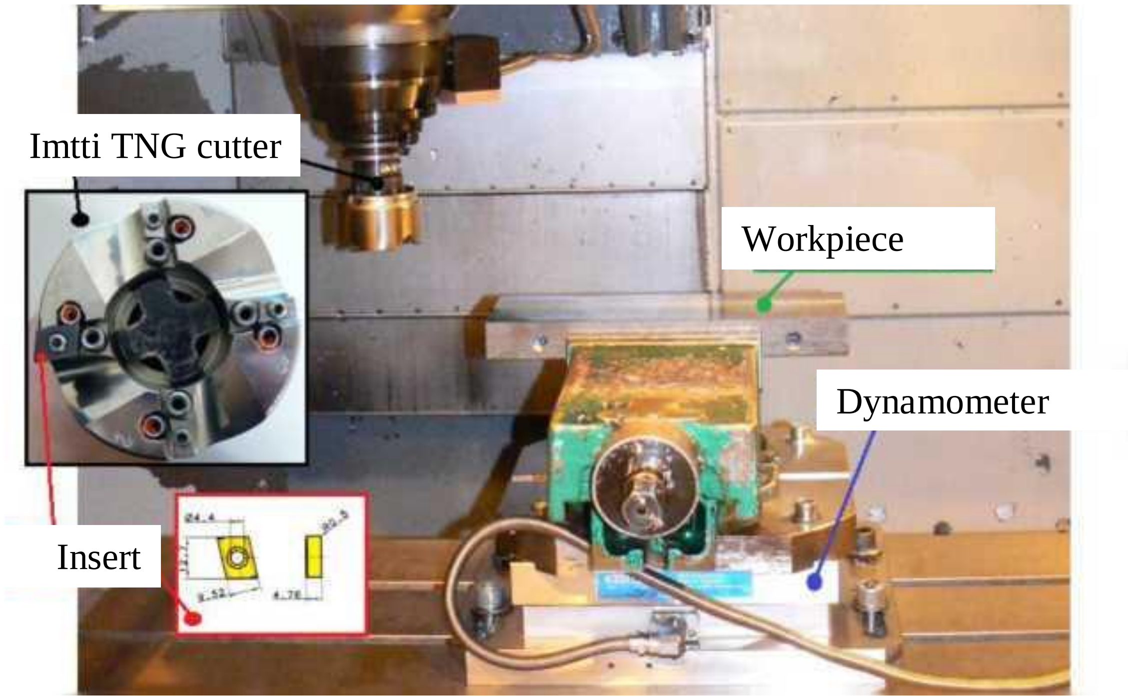


Fig. 2.7 – Workspace of cutting

Fig. 2.8 - Cutting edge received by: a) grinding, b) laser treatment to edge radius 5μm, c) 5 μm, d) 10 μm, e) 15μm [10]

Table 2.2 - Tools geometrical parameters of cutting tools

Test	Rake angle $\gamma,^0$	Flank angle $\alpha,^0$	Edge treatment	Edge radius, μm
1	6	8	Grinded	5
2			Laser	5
3			Drag finished	5
4				10
5				15

In Fig. 2.9 shows the effect of radius cutting edge on the service life of the tool. During experiments, the size of wear determined on the front and back surfaces. Experiments stopped when wear values reached critical values and the volume of the extracted material exceeded 60 cm^3. From the graphs in Fig. 2.9 see that the service life of the tool increases with increasing radius cutting edge. The studies have established that the optimum radius of the cutting edge is within 20-25 microns [10]. Cutting depth is 20 microns, so the radius of the cutting edge should not exceed 20 microns.

Thus, experiments confirmed that the increase in radius cutting edge in the range of 5-15 microns increases the service life of the tool. This is achieved due to the smooth surface of the cutting edge; Its high strength and absence of defects. Wear of the took place tool in the form of a cutting edge for radius edge r_β = 5 and 10 μm and in the form of uniform wear tool for radius edge r_β = 15 μm. Wear of the tool was measured on the faces of the front and rear surfaces. In Fig. 2.6 presented by the magnitude of wear tool on the end surface. The wear tool on the end surface influences the roughness of the treated surface more than the wear tool on the front surface.

Roughness of the treated surface is an important parameter of accuracy, in our case it can not exceed Ra = 0.8 microns. Also, an important parameter is the difference of roughness treated surface at the beginning and end of processing. If the difference of roughness exceeds the given, it is necessary to analyze the causes of its changes, which can be caused by problems with the accuracy of the base parts, its consolidation, damage to the cutting edge, problems with installation and debugging, etc.

The effect of radius cutting edge on the roughness of the treated surface is presented in Fig. 2.10. The lowest roughness of the surface obtained from the radius cutting edge r_β = 15 microns, because the tool is less worn, on its cutting edge there are no defects and roughness of the treated surface is constant both at the beginning and at the end of treatment.

Surface roughness from the radius cutting edge r_β = 5 and 10 μm decreases, and the volume of the removed material - 30 cm^3 - the same. This is due to the formation of cutting edge on a new instrument.

During the experiment, they also measured the components of the cutting forces F_x, F_y and F_z. In Figure 2.10 presents the impact of radius cutting edge on the overall cutting force and the component F_z. Overall force determined with the formula:

$$F = \sqrt{F_x^2 + F_y^2 + F_z^2}.$$

The cutting force increases with the volume of the extracted material and the increase in the size of the tool wear. At the same time the cutting edge radius is reduced, the total cutting power is increasing and its component F_z.

Cutting tool with radius cutting edge 5 μm is sharper compared to the similar, which is the radius of the cutting edge of 15 microns. Theoretically, a sharper tool causes lower cutting force values due to mild entry into the material. Of Fig. 2.10 It is clear that after removing the processed material of 6 cm^3 in the instrument from the radius cutting edge 5 microns is approximately 0.085 mm, and for the tool with a radius of the cutting edge 15 microns the magnitude of its wear is equal to almost 0.035 mm, which means that the wear the tool grows with increasing cutting forces and reducing radius cutting edge.

Preparation of the cutting edge of the tool was in the correct choice of sharpening or cutting method. The tools that were used in the study had the same radii of the cutting edge, but the edges had different values for the aggravation, as they were obtained by different methods. The service life of the tools was higher in the case of their sharpening, and the cutting edge, laser-treated wear faster.

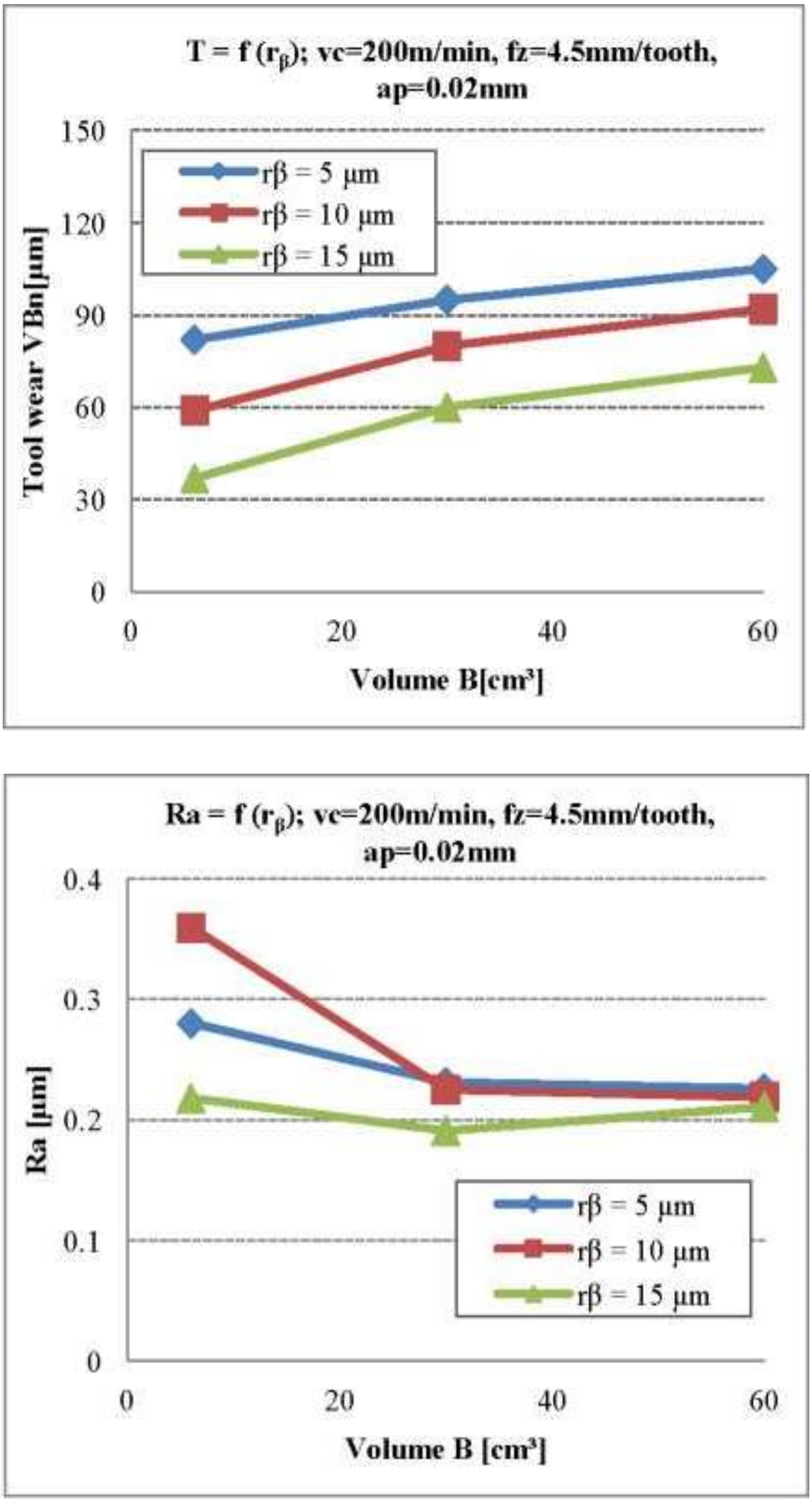
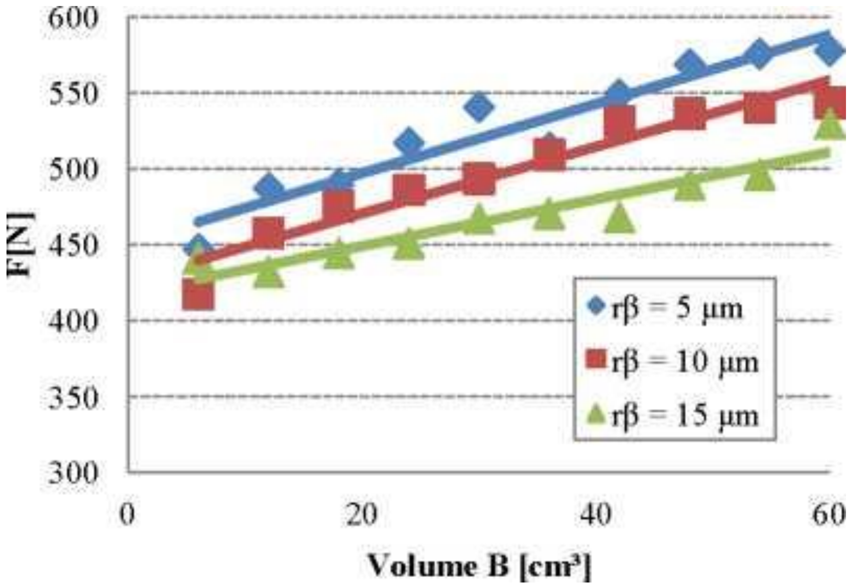


Fig. 2.9 - Effects of edge radius on tool life and roughness of working surface [27, 29]

$F = f(r_\beta)$; v_c=200 m/min, f_z = 4,5 mm/tooth, a_p = 0,02 mm



$F = f(r_\beta)$; v_c = 200 m/min, f_z = 4,5 mm/tooth, a_p = 0,02 mm

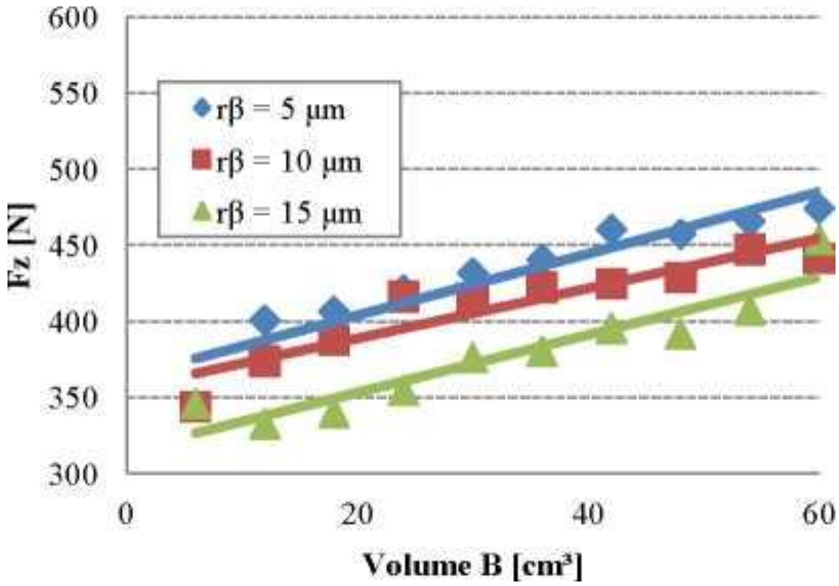


Fig. 2.10 - Effect of edge radius on total force and on cutting force F_z [29]

This may be caused by errors in the designation of the laser processing conditions, sometimes it is difficult to handle the cutting tool due to the presence in carbide plate impurities that have different melting temperature. If you do not correctly assign the modes of laser processing, the cutting edge will be fragile, at first contact with the treated surface it will be destroyed or exposed. In the case of grinding the cutting edge of the tool, it has increased durability compared to a tool, which was processed by laser.

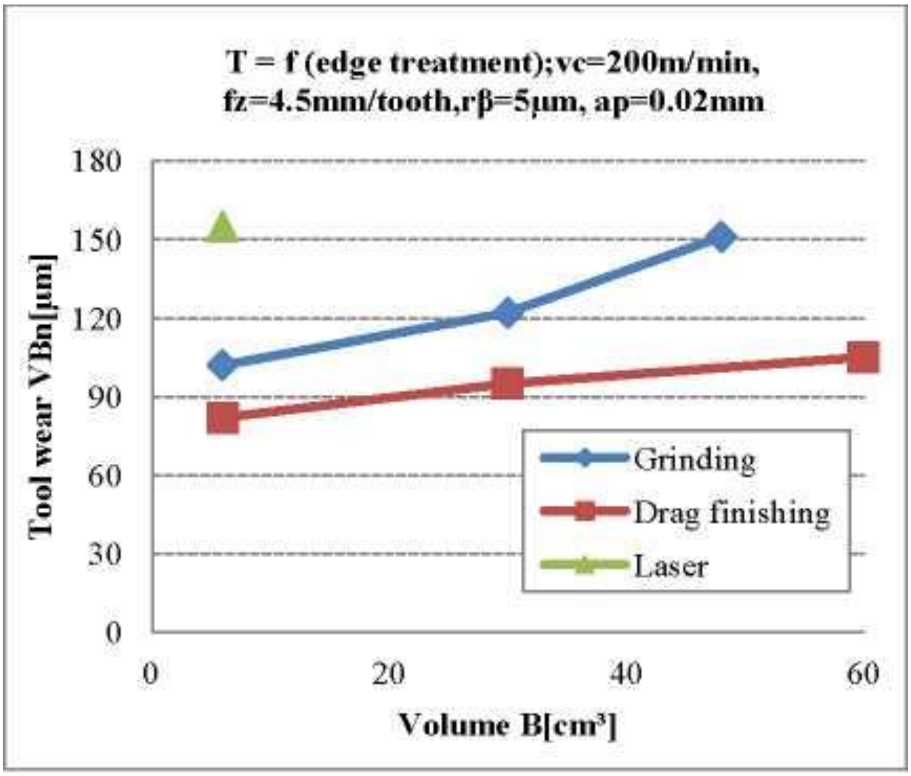


Fig. 2.11 - Effect of edge treatment on tool life [29]

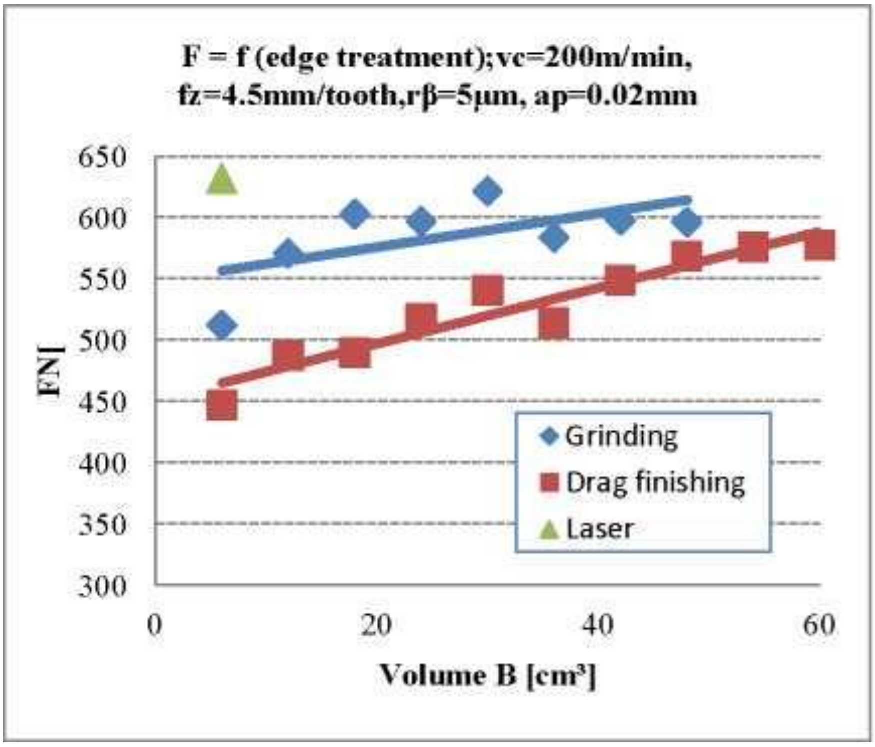
The best wear resistance and service life demonstrate tools in which the cutting edge is obtained polishing, the roughness of Rs is quite low. Such a tool when you remove the required volume of the material does not lose stability, the size of wear does not exceed the limiting values. The service life of tools with cutting edge, treated with polishing, by 60% higher than with instruments in which the cutting edge is treated with grinding or laser tool.

Consequently, the total strength of the cutting effect on the depreciation of the tool. The cutting force increases with the volume of extracted material and depreciation of the instrument.

2.4. Research of edge treatment influence on total force load and component of cutting force F_z.

In Fig. 2.12 provides graphic dependence of wear tool from total cutting force and component cutting F_z.

Conclusions. Theoretical and experimental researches are conducted in order to study the influence of microgeometry tool, preparation of cutting edge on service life of instrument, roughness of the treated surface and force of cutting in chromium processing process steel used for housings manufacturing.



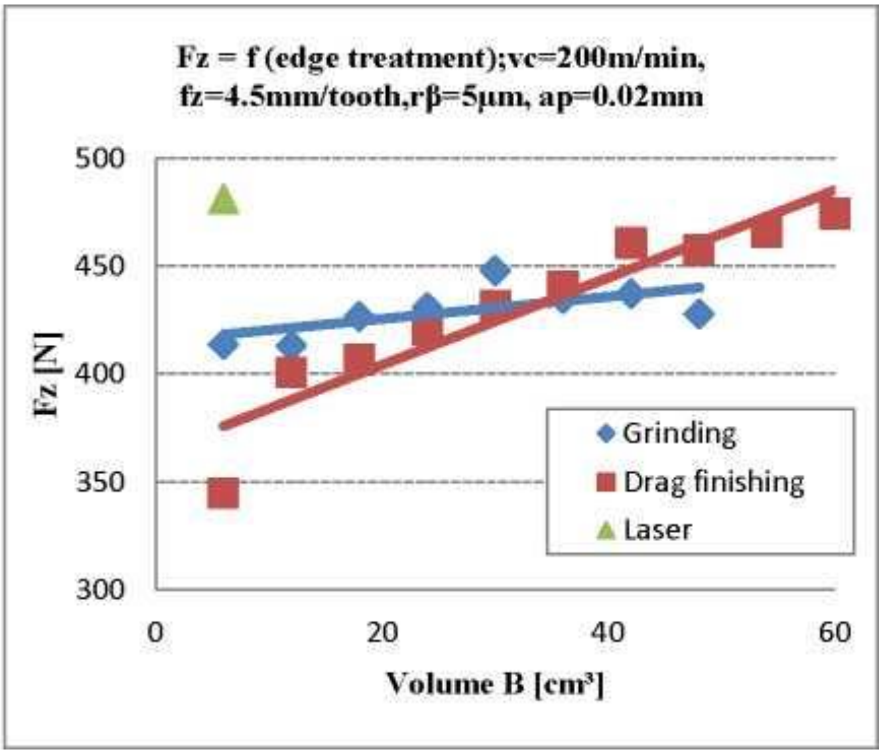


Fig. 2.12 - Effect of edge treatment on total force load and on cutting force F_z [27, 29]

The studies were used for the processing of planes with cutting depth of 0.02 mm and radius cutting edge 20 microns. Carbide plates, treated with sharpening, grinding, laser and polishing were applied. Other cutting modes determined experimentally.

The obtained results indicate that the optimum radius of the cutting edge is 15 microns from the interval of 5 -15 microns. This tool has the highest service life, the lowest roughness of the treated surface and the smallest cutting force compared to the instruments in which the radius of the cutting edge is equal to 5 or 10 microns.

Roughness of the treated surface and the cutting force affects the amount of wear tool. Wear tool radius the cutting edge 15 μm took place evenly. Instruments with other parameters of the cutting edge worn unevenly, especially those in which the cutting surface was processed by laser or grinding.

The optimum parameters of processing and geometric parameters of the tool with using of carbide plate are set experimentally: v_c = 200 m/min, f_z = 4,5 mm/tooth, a_p = 0,02 mm, r_β = 15 microns.

3. TECHNOLOGICAL CHAPTER

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

In the factory conditions, the annual program for the production of the "case" is 30 pieces per year. This release program with a mass of 16.5 kg corresponds to a single production type.

So, as the production capacities of the enterprise are focused on the small-scale type of production, the factory technological process of manufacturing the component involves its production on a universal equipment, which is located on the groups of equipment.

In the developed technological process the given annual program of release of the part is 5000 pieces per year. Medium-batch production is characterized by a limited range of products manufactured by periodically repeating batches and a relatively larger volume of output than in a single type of production.

In serial production automatic and semiautomatic machines, universal machines, equipped with special, as well as universal and universal-assembly devices are used, that allows to reduce the complexity and cost of the product. Also used CNC machines, machining centers, flexible automated systems of CNC machine tools, connected with transporting devices and computer-controlled, located during technical process of the processing part. Used standard, rarely special cutting tools and special measuring instruments.

The average serial production is characterized by a differentiated technological process, that is, divided into separate independent operations, performed on certain machines, located in the rout of the technological process.

Billets, made by exact casting on the forms from the rolled steel, forged and stamped parts, are used.

Along with the workers of high qualification and adjusters, the workers-operators working on adjusted machines.

Depending on the volume of production and features of products, full interchangeability of assembly units is ensure; however in a number of cases, during assembly used compensation of size and fit on the spot.

The main problems of the average serial type of production are:

– increase the quality of manufacturing parts.
– reduction in cost of manufacturing parts.
– improving of working conditions for workers.

These problems are solved when developing the technological process in the diploma project, when their solution is to be guided by the listed principles.

Definition of the production type is carried out on the computer with the help of the corresponding software.

3.2. Choice and justification of workpiece's obtaining method.

In mechanical engineering, the main types of billets are steel and cast iron, castings made of non-ferrous metals and alloys, stamping and various profiles of rolled products.

The method of obtaining the workpiece should be the most economical for a given volume of parts production.

Billets from steel 45 receive by a cut from the rolled stock of the required size. The advantages of this method of obtaining billets include simplicity and cheapness. The disadvantages are greater tolerances for machining, the presence of defects on the surface, which leads to a rapid breakdown of incisors when turning.

Determine the coefficient of the workpiece use and the coefficient of material use. The coefficient of the workpiece use is calculated by the formula (1.3):

$$K_з = \frac{16{,}5}{44} = 0{,}375 \lhd 0{,}7\,.$$

The coefficient of material use is calculated according to the formula (1.4):

$$K_{м} = \frac{16{,}5}{44 + 4{,}4} = 0{,}34 \triangleleft 0{,}64.$$

As a result of calculations of $K_{з}$ and $K_{м}$ coefficients obtained that $K_{з}$<0.7 and $K_{м}$<0.64. From this it follows that this workpiece according to the coefficients is not technological.

During performance of workpiece calculations it need take into account that it must satisfy the requirements of euro standards of technological processes.

3.3. Requirements for the workpiece. Calculation of the workpiece.

In addition to the minimum metal capacity and work capacity for the workpiece, a number of requirements are put forward in view of their subsequent machining. These requirements include:

- minimal allowances for processing - cost reduction due to reduced number of passes and conversions;
- -rational arrangement of foundry and punching slopes;
- increased accuracy of sizes;
- minimization or complete elimination of defective layer, which, on the one hand, leads to increase of allowances, on the other - to decrease the stability of the cutting tool.

We offer for the manufacture of parts to use the workpiece obtained by punching on KGSP (crank and hot-press stamping presses).

The crank and hot stamping press is intended for highly mechanized and automated forgings production, the eccentric arrangement of streams in the die with lower and upper pushes is allowed. KGSP does not allow deformation of the workpiece in one stream in several passes.

When stamping on KGSP, forgings are more similar in shape to the finished part, with more precise dimensions (especially in height) than when stamping on hammers. The more perfect design of the stamps provides a smaller displacement of the half of the die, reducing the tolerances by 20-30%, the permissions and stamping bias 2-3 times and, consequently, increasing the coefficient of metal use.

The productivity of stamping increases by 1.4 times due to the reduction of the number of strokes to 1. The cost of forging decreases by 10-30% due to reduced material costs and operating costs.

Disadvantages: high cost (3-4 times higher than on hammer), less universality, worse filling of deep cavities due to low strain rate, more complex design, regulation and operation of stamps.

Calculation of the workpiece. The amount of allowances and tolerances on the workpiece is determined as follows:

1) accuracy class of forging T4;

2) steel group M2;

3) the coefficient of the estimated mass of forging K_p = 1,5.

Estimated weight of forgings:

$$M_n = m_\partial \times K_p, \tag{3.1}$$

where m_∂ – weight of part (16,5 kg).

$$M_n = 16{,}5 \times 1{,}5 = 24{,}75 \text{ kg};$$

4) the size of the figure describing the fork (cylinder):

– diameter – 184 × 1,05 = 193,2 mm;

– height – 160 × 1,05 = 168 mm.

The mass of the describing figure $M_ф$ = 38,4 kg.

Mass ratio of forging to the mass of the describing figure:

$$M_n / M_ф = 16{,}5 / 38{,}4 = 0{,}43.$$

5) degree of complexity C1;

6) source index 14;

7) additional assumptions:

– displacement along the surface of the connector of the stamp 1,2 mm;

– deviation from the plane of 0.3 mm.

8) The sizes of forging and its permissible deviations:

– diameter 184 + (2,5 + 0,4 + 0,3) × 2 = 190,4 - we accept 190,5 mm;

– length 160 + (2,3 + 0,4 + 0,3) × 2 = 166 mm;

– thickness 124 + (2,3 + 0,4 + 0,3) = 130 mm.

9) assumptions and tolerances (table 3.1).

Table 3.1 - Allowance and tolerances of the workpiece, mm

Name of the surface	Dimen-sions	Allo-wances	Tolerances	Additional tolerances	Workpiece's size
external	∅184h11	2,5	+2,4… -1,2	0,4;… 0,3	190,5
linear	160js14 124js14	2,3 2,3	+2,4… -1,2 +2,1… -1,1	0,4;… 0,3 0,4;… 0,3	166 133

The weight of the workpiece is determined by the formula:

$$M_з = V \times \rho, \qquad (3.2)$$

where V is the volume of workpiece, which is calculated by the formula:

$$V = V_n - V_1 - V_2, \qquad (3.3)$$

where V_n - volume forging, $V_n = 1265,6$ cm^3;

V_1 - volume, which is removed from the smaller fox, $V_1 = 49,6$ cm^3;

V_2 - volume, which is removed from the larger fox, $V_2 = 252,8$ cm^3;

ρ - steel density, $\rho = 0,0078$ kg/cm^3.

$$M_з = (1265,6 - 49,6 - 252,8) \times 0,0078 = 30 \text{ kg};$$

10) coefficient of use of the work, according to the formula (1.3) $K_з$ = 0,55;

11) coefficient of material use, according to the formula (1.4) K_m = 0,5.

When comparing the two methods of obtaining the workpiece, it is obvious that the coefficients of using the workpiece and the material by the proposed method of obtaining the workpiece, although lower than the level of the ETA, are higher than that obtained by obtaining the workpiece from the rolled stock (table 3.2).

Table 3.2 - Comparative characteristics of workpieces

Obtaining method	KGSP	Rolling
$K_з$	0,55	0,375
$K_м$	0,5	0,375

Consequently, obtaining the workpiece by stamping on KGSP is the best and most advantageous.

3.4. Calculations of leakage to the surface of the part in an analytical way.

An external cylindrical surface ∅116d8 has been selected by analytical method for calculation of allowances. The path of surface treatment is given in the table. 3.3.

Table 3.3 - Basic calculation data

Name of operation (step)	Class of accuracy	Roughness, Ra
Wokrpiece	15	12,5
Turning roughing	14	50-6,3
Turning semiroughing	12	25-1,6
Turning finishing	9	3,2

Select permissions for tolerances:

1. Height of profile irregulerities Rz and defects *h*, mkm:

wokrpiece Rz = 200; *h* = 250;

turning roughing Rz = 50; *h* = 50;

turning semiroughing Rz = 25; *h* = 25.

3. The values of interspacesв variations of forms:

$\rho_{зс}$ = 1,4 mm = 1400 mkm - an additional error in the displacement of the figure;

$\rho_{кор}$ = 0,5 m = 500 mkm - size of warping.

$$\rho_{см} = \sqrt{\rho_{зс}^2 + \rho_{кор}^2}\,, \qquad (3.3)$$

$$\rho_{зс} = \sqrt{1400^2 + 500^2} = 1487 \text{ mkm},$$

$$\rho_{чор} = \rho_{заг} \times K_{у\ чор}, \qquad (3.4)$$

where $K_{у\ чор}$ = 0,06 - coefficient of refinement.

$$\rho_{чор} = 1487 \times 0{,}06 = 89{,}22 \text{ mkm};$$

$$\rho_{п|ч} = \rho_{заг} \cdot K_{у\ п/ч}\,, \qquad (3.5)$$

where $K_{ч\ п/ч}$ = 0,05;

$$\rho_{п/ч} = 1487 \times 0{,}05 = 74{,}35 \text{ mkm};$$

$$\rho_{чист} = \rho_{заг} \times K_{у\ чист}\,, \qquad (3.6)$$

where $K_{у\ чист}$ = 0,04;

$$\rho_{чист} = 1487 \times 0{,}04 = 59{,}48 \text{ mkm}.$$

3. Installation error $\sum y$:

workpiece – 0;

roughing - 100 mkm;

semiroughing – 0;

finishing - 80 mkm.

4. Calculation of allowances:

minimum allowances:

$$2Z_{\min} = 2 \cdot (Rz_{(i-1)} + T_{(i-1)} + \sqrt{\rho^2_{(i-1)} + \sum y_i^2}); \qquad (3.7)$$

$$2Z_{\min(чор)} = 2 \cdot (200 + 250 + \sqrt{1487^2 + 100^2} = 3880 \text{ mkm};$$

$$2Z_{\min(п/ч)} = 2 \cdot (50 + 50 + \sqrt{89{,}22^2 + 0} = 378{,}44 \text{ mkm};$$

$$2Z_{\min(чист)} = 2 \cdot (25 + 25 + \sqrt{74{,}35^2 + 80^2} = 318{,}43 \text{ mkm}.$$

5. Calculation of tolerances T_d:

$T_{d\ заг}$ = 3600 mkm $(190^{+2,4}_{-1,2})$;

$T_{d\ чор}$ = 1000 mkm $(\ ^{+0}_{-1000})$;

$T_{d\ п/ч}$ = 400 mkm $(\ ^{+0}_{-400})$;

$T_{d\ чист}$ = 87 mkm $(116^{-0,120}_{-0,207})$.

The results obtained in the previous paragraphs are summarized in table 3.4.

6. Construction of the layout of allowances and tolerances for a given size (figure 3.1) and calculations of interoperative allowances. Calculations of the total allowance for surface treatment $2Z_{н.заг}$:

$$2Z_{н.заг} = \sum 2Z_{м.о.ном.}, \quad (3.8)$$

where $2Z_{м.о.ном.}$ - amount of interoperable allowances (nominal).

Table 3.4 - Output and settlement data

Operations and steps	Elements of allowances, mkm				Calculation of allowances, mm			Calculation of sizes, mm		
	Rz_{i-1}	T_{i-1}	ρ_{i-1}	$\sum i$	$2Z_{min}$	$2Z_{ном}$	$2Z_{max}$	d_{min}	$d_{ном}$	d_{max}
Wokrpiece	-	-	-	-	-	-	-	121,456	123,056	125,456
Turning roughing	200	250	1487	100	3,88	5,08	8,68	116,976	117,976	117,976
Turning semiroughing	50	50	89,22	0	0,378	1,378	1,778	116,198	116,598	116,598
Turning finishing	25	25	74,35	80	0,318	0,598	0,805	115,793	116	115,88

Finishing step:

$$d_{min.ч} = d_{н.ч} + e_{i.ч} \quad (3.9)$$

$$d_{min.ч} = 116 + (-0,207) = 115,793 \text{ mm};$$

$$d_{max.ч} = d_{н.ч} + e_{i\ ч}. \quad (3.10)$$

$$d_{max.ч} = 116 + (-0,120) = 115,88 \text{ m}.$$

By formula (3.5) we define $2Z_{min.ч}$:

$$2Z_{min.ч} = 0,318 \text{ mm};$$

$$2Z_{max.ч} = 2Z_{min.ч} + T_{d\ ч} + e_{i\ ч} + Td_{п/ч} \quad (3.11)$$

$$2Z_{max.ч} = 0,318 + 0,087 + 0,4 = 0,805 \text{ mm};$$

$$2Z_{н.ч} = 2Z_{min.ч} + e_{i\ ч} + T_{d\ п/ч}; \quad (3.12)$$

$$2Z_{н.ч} = 0,318 + (-0,120) + 0,4 = 0,598 \text{ mm}.$$

Semiroughing step:

$$d_{min.п/ч} = d_{max.ч} + 2Z_{min.ч}; \quad (3.13)$$

$$d_{min.п/ч} = 115,88 + 0,318 = 116,198 \text{ mm};$$

$$d_{max.п/ч} = d_{н.п/ч} = d_{min.п/ч} + T_{d\ п/ч}; \quad (3.14)$$

$$d_{max.п/ч} = 116,198 + 0,4 = 116,598 \text{ mm}.$$

By formula (3.6) we define $2Z_{min.п/ч}$:

$$2Z_{min.п/ч} = 0,378 \text{ mm};$$

$$2Z_{max.п/ч} = 2Z_{min.п/ч} + T_{d\ п/ч} + T_{d\ чор}; \quad (3.15)$$

$$2Z_{max.п/ч} = 0,378 + 0,4 + 1,0 = 1,778 \text{ mm};$$

$$2Z_{н.п/ч} = 2Z_{max.п/ч} - T_{d\ п/ч}; \quad (3.16)$$

$$2Z_{н.п/ч} = 1,778 - 0,4 = 1,378 \text{ mm}.$$

Roughing step:

$$d_{min.чорн} = d_{max.п/ч} + 2Z_{min.п/ч}; \quad (3.17)$$

$$d_{min.чорн} = 116,598 + 0,378 = 116,976 \text{ mm};$$

$$d_{max.чорн} = d_{н.чорн} = d_{max.п/ч} + 2Z_{н.п/ч}; \quad (3.18)$$

$$d_{max.чорн} = 116,598 + 1,378 = 117,976 \text{ mm}.$$

By formula (3.7) we define $2Z_{min.чорн}$:

$$2Z_{min.чорн} = 3,88 \text{ mm};$$

$$2Z_{max.чорн} = 2Z_{min.чорн} + T_{d\ чорн} + T_{d\ заг}; \quad (3.19)$$

$$2Z_{max.чорн} = 3,88 + 1,0 + 3,6 = 8,48 \text{ m};$$

$$2Z_{н.чорн} = 2Z_{min.чорн} + e_{i\ заг}; \quad (3.20)$$

$$2Z_{н.чорн} = 3,88 - (-1,2) = 5,08 \text{ m}.$$

Sizes of workpiece:

$$d_{max.заг} = d_{max.чорн} + 2Z_{н.чорн} + e_{i\ заг}; \quad (3.21)$$

$$d_{max.заг} = 117,976 + 5,08 + 2,4 = 125,456 \text{ mm};$$

$$d_{н.заг} = d_{max.чорн} + 2Z_{н.чорн}; \quad (3.22)$$

$$d_{н.заг} = 117,976 + 5,08 = 123,056 \text{ mm};$$

$$d_{min.заг} = d_{max.чорн} + 2Z_{min.чорн}; \quad (3.23)$$

$$d_{min.заг} = 117,976 + 3,88 = 121,856 \text{ mm}.$$

By formula (3.7) we define the total allowance for the surface treatment:

$$2Z_{н.сум} = 5,08 + 1,378 + 0,598 = 7,056 \text{ mm}.$$

Table 3.5 - Final tolerances on the workpiece, mm

Name of surfaces	Value	Allowance	Tolerance	Added allowances	Sizes of workpiece
inner	∅184h11	2,5	+2,4 -1,2	0,4; 0,3	190,5
liniar	160js14 124js14	2,3 2,3	+2,4 -1,2 +2,1 -1,1	0,4; 0,3 0,4; 0,3	166 133

The calculated interoperational allowance yields a significantly smaller table value:

$$2Z_{розр} = 7,056 \text{ мм}; \ 2Z_{табл} = 8,6 \text{ mm}.$$

We construct a layout of allowances and tolerances on size ∅116d8 $\left(^{-0,120}_{-0.207}\right)$ (fig. 3.1).

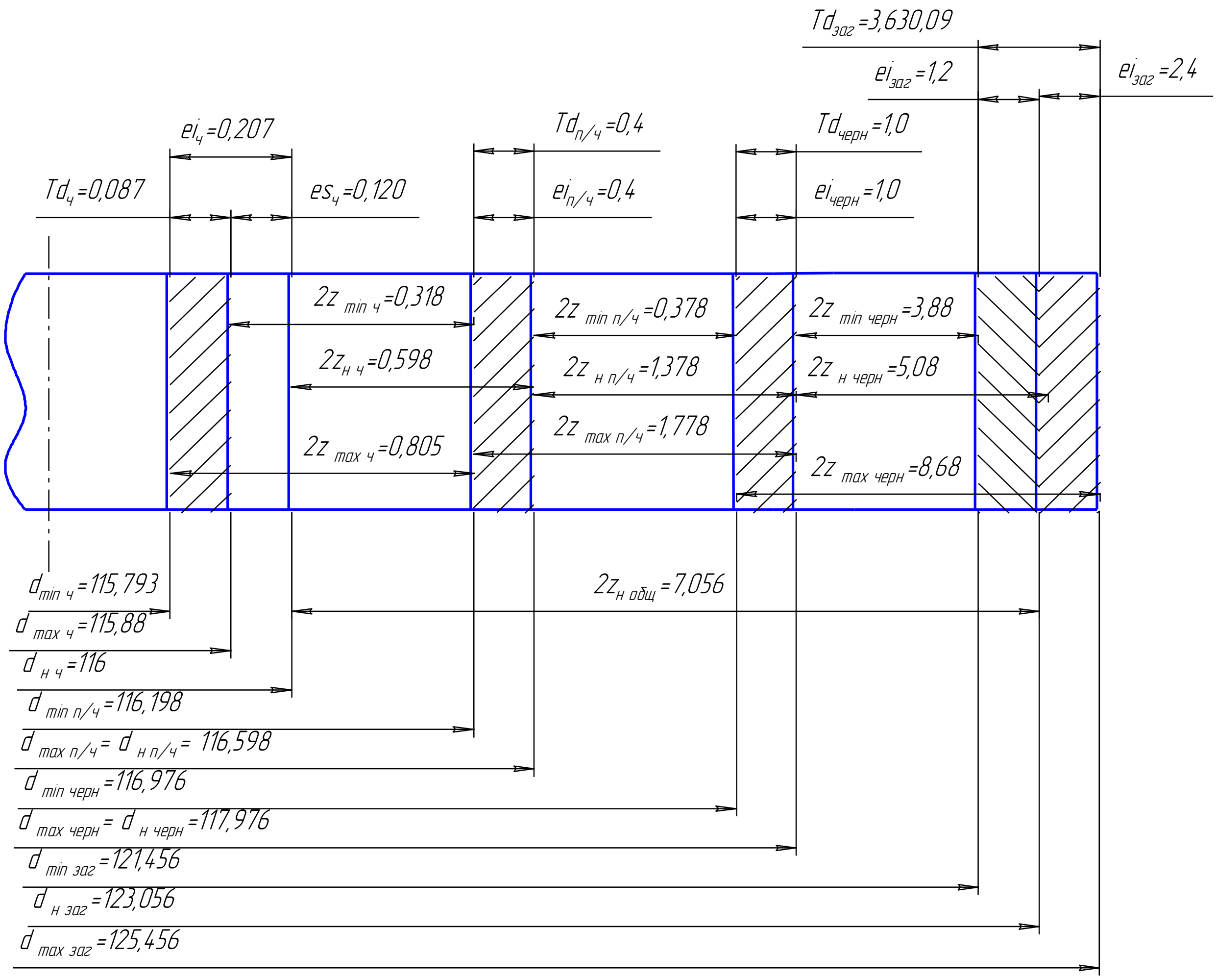


Figure 3.1 - The layout of allowances and tolerances on ∅116d8 ($^{-0,120}_{-0.207}$)

3.5. Development of the routing technological process of mechanical processing of the case TSF 8.171.137 .

In tables 3.6, 3.7 shows the sequence of operations of the basic and design variants of the technological process of processing the part.

Table 3.6 - The basic process of processing the case

№ operation	Operation	Machine tool
1	2	3
005	Slitting	Machine tool 8Б72А
010	Control DTC	Plate DTC
015	Turning-screw	Machine tool 16Б16К

Continue table 3.6

1	2	3
020	Control DTC	Plate DTC
025	Vertical-milling	Machine tool 675
030	Washing	Special bathes
035	Benchwork	Benchworking machine tool
040	Control DTC	Plate DTC
045	Jig boring	Machine tool 2A430
050	Washing	Special bathes
055	Radial-milling	Machine tool 2M55
060	Washing	Special bathes
065	Control DTC	Plate DTC
070	Electrochemical	Galvanizing line

Table 3.7 – Project technological process

№ operation	Operation	Machine tool
1	2	3
005	Slitting	KGSP
010	Control DTC	Plate DTC
015	Turning-screw	Machine tool 16К40
015 К	Control on the working place	
020	Control DTC	Plate DTC
025	Radial-milling	Machine tool 6Т13
030	Washing	Special bathes
035	Benchwork	Benchworking machine tool
040	Control DTC	Plate DTC
045	Jig boring with CNC	Machine tool ИР800ПМФ4
045 К	Control on the working place	
050	Washing	Special bathes
055	Control DTC	Plate DTC
060	Electrochemical	Galvanizing line

3.6. Methods of providing technological requirements in the processing of parts.

The accuracy of surface treatment is determined by four factors:

- compliance with dimensional accuracy;
- compliance with the requirements of surface roughness;
- adhering to the tolerances of the shape and arrangement of the surfaces;
- compliance with the requirements of surface hardness.

The dimensional accuracy of the surfaces is ensured by a sufficient number of stages of processing, selection of equipment and cutting tools, stiffening of the parts, application of the appropriate ZOR.

On the part there are surfaces executed in 14 qualifications, for the given dimensional accuracy of these surfaces is sufficiently one stage of processing:

- end faces of the part (160js14 mm) - roughing;
- two foxes (124js14) - rough milling;
- cone in a stepped hole (60 °) - drilling.

By the sizes of average accuracy are the sizes executed on 11-12 qualifications, for achievement of this accuracy enough two stages of processing: stepped openings ∅12,8; ∅24.8; ∅36 - drilling, sewing.

The exact dimensions of the detail include the sizes performed for grades 9-10, to achieve this accuracy, there are quite three stages of processing: for cylindrical surface ∅184; ∅116 - rough, semi-milled and pure casting.

Compliance with roughness requirements.

According to the requirements of the given roughness, all surfaces can be divided into two groups:

- surfaces with roughness Ra = 3,2 mkm;
- surfaces with roughness Ra = 1,6 mkm.

Roughness of the surfaces Ra = 3,2 microns is achieved at the rough stage of processing. The used tool allows you to get the roughness of a higher class, so these roughing requirements will not affect the choice of cutting modes.

Compliance with the requirements of roughness in stepped openings ∅12,8H12; ∅24,8H12; ∅36H12 is provided primarily by the choice of optimal treatment modes (in particular feed and cutting speed), the correct choice of the cutting tool (material, geometry), as well as the hardness of the technological system VPSI (it is necessary to ensure rigid fastening of the cutting tool, workpieces and tools on the machine).

Adherence to form tolerances and surface arrangement.

The drawing of the parts contains two main requirements for the tolerances of the mutual arrangement of surfaces:

- 1st admission: positional tolerance of 4 cutting openings relative to base B - axis of cylindrical surface ∅116d9 (tolerance is 0,07 mm);
- 2nd tolerance: the positional tolerance of 6 cutting openings relative to the base B - the axis of the hole ∅24, 8H12 (the tolerance is 0,05 mm).

Both of these requirements are ensured by the use of a special high-precision device, as well as compliance with the principle of compatibility and continuity of the bases:

The 1st position tolerance is ensured by the fact that the cylindrical surface ∅184h10 is a technological and measuring base for the treatment of the ledge ∅116d9 and for the treatment of 4 cutting openings.

The 2nd position tolerance is ensured that the processing of the hole ∅24, 8H12 and the cutting openings takes place in one installation.

The mounting surface of the device has tough plane requirements. When installing the device, the indicator is checked to make sure that the installation base is perpendicular to the trajectory of the transfer of the machine support during vertical feeding. Tolerance - within 0,05 mm on a 100 mm stroke.

Requirements for surface hardness.

The design documentation does not provide additional strengthening of the surface of the part. The hardness of the surface of the case is obtained in the buckling operation.

3.7. Description of the route process for operations.

005→Benchwork.

Blanking - stamping, obtained on a crank hot-press stamping press. The advantage of such a workpiece is that it is closest in shape to the part, has small allowances for machining. Coefficient of using the workpiece $K_з$ = 0,55; coefficient of material use $K_м$ = 0,50 (a blank, which is made according to the basic technological process - rent $K_з$ = 0,375 and $K_м$ = 0,375).

010→Control DTC.

The control of the size of the workpiece by the master of the DTC is controlled, the size, length and thickness are controlled. Measuring tool: special templates L = ∅195; L = ∅160; L = ∅124.

015→Turning-screw 16К40.

In this operation, the final treatment of the cylindrical surface ∅184h10, ∅116d9 and the ends is performed. Two institutions are applied: the cylindrical surface ∅184h10 (preparation of the finishing base) is partially processed at the first institution. At the second institution - the treatment of the other part of the cylindrical surface and the final treatment of the ledge ∅116d9.

Steps.

1- Establishments:

1. Install, fix, and remove.
2. Crop the tip while maintaining the size.

3. Fix the cylindrical surface and maintain the size ∅$184_{-0,185}$.
4. Control by the executor.

2- Intstitutions:

1. Install, fix, and remove.
2. Crop the tip while maintaining the size.
3. Fix the cylindrical surface and maintain the size ∅$184^{-0,29}$.
4. Fix the ledge ∅$116^{-0,120}_{-0,207}$ to the length of $16^{-0,180}$.
5. Control by the executor.

Table 3.8 - Depth of cutting in the processing stages

Stage of treatment	Cutting depgth, mm				
	№ of surface				
	1	2	3	4	5
roughing	3	1,5	3	1,5	34,4
semiroughing	-	1	-	1	1,7
finishing	-	0,8	-	0,8	0,9

The detail is based on and fixed in a four-cap cartridge, crankshafts, grounded on ∅190.5 mm and a length of 15 mm; caps are raw, ground on ∅184 mm and 15 mm in length.

1- Institution:

In general, the item is deprived of 5 degrees of freedom. There are two technological bases. The main technological base - the left-hand side - the setup base (points 1,2,3). It deprives part of 3 degrees of freedom: moving along the Z axis, rotation around the axes X and Y. It provides a dimension of 90mm, the perpendicularity of the setup base to the right end. The outer cylindrical surface ∅190,5 mm is a double base (points 4,5). It eliminates the detail of 2 degrees of freedom: displacements along X and Y. The base provides the alignment of the machined cylindrical surface 3 (∅184h10 mm) to the axis of the base surface.

The principle of combining technological and measuring bases is observed at a size of 163 mm.

Cutting tool:

P.I. 1: Cutter straight turning, plate material T5K10; method of fixing the plate - soldering; section of the holder - 16 × 25 mm; angles in the plane φ = 93°, φ_1 = 7°; front angle γ = 10°, rear angle α = 6°; radius of the top of the plate r_v = 1,0 mm; angle of inclination of the main cutting edge λ = 0; chamfer width f = 0.6 mm; period of stability T = 60 min.

P.I. 2: Cutter straight turning, plate material T15K6; method of fixing the plate - soldering; section of the holder - 16 × 25 mm; angles in the plane φ = 93°, φ_1 = 7°; front angle γ = 10°, rear angle α = 6°; radius of the top of the plate r_v = 1,0 mm; angle of inclination of the main cutting edge λ = 0; chamfer width f = 0.6 mm; period of stability T = 60 min.

P.I. 3: Turner turning open right, plate material T5K10; method of fastening - soldering; Section of the holder - 16 × 25 corners in plan φ = 45°, $\varphi 1$ = 45°; front angle γ = 10°, rear angle α = 6°; radius of the top of the plate r_v = 1.0 mm; angle of inclination of the main cutting edge λ = 0; chamfer width f = 0,6 mm; period of stability T = 60 min.

020→Control DTC.

Controlling dimensions ∅ $184^{-0,185}$, $\varnothing 116^{-0,120}_{-0,207}$ $16^{-0,180}$ i 160±0,5 by worker of DTK. Measuring tool - calipers ШЦ-I-160-0,05, snap gauge 116 ПР-НЕ, snap gauge 184 ПР-НЕ, ГI-100.

025→Vertical milling 6T13.

In this operation, there are two institutions. At the first institution, the treatment of a smaller fox 124js14 is performed. On the second one - the treatment of the fox 464js14 and the groove 20h12x18h12.

Steps:

1- Institution:

1. Install, fix, and remove.
2. To mill the sheet while maintaining the size of 127±0,5.
3. Controlled by the executor.

2- Institutions:

1. Install, fix, and remove.
2. To mill the sheet while maintaining the size of $46{,}4 \pm 0{,}125$.
3. Milling the groove, withstanding the dimensions $20_{-0{,}520} * 18_{-0{,}520}$ and$104 \pm 0{,}435$.

4. Controlled by the executor.

The choice of depth of cutting in stages: when milling two flanks, the cutting depth is equal to the pressure for machining and is equal to 3mm; when milling the groove, the required allowance is removed for two passes: t_1 = 10 mm and t_2 = 10 mm.

Basing.

1- Institution:

In general, the item is deprived of six degrees of freedom. There are three technological bases (based on the coordinate angle):

Installation - the base of the part is the main base, depriving the detail of three degrees of freedom: moving Z, rotation around X and Y (taking into account the location of the axes, selected in the sketch). It ensures compliance with the size of 124±0,5 and the parallelism of the fox against the base. The guide is the end, depriving the detail of two degrees of freedom: moving along Y and rotating around the Z axis. The base provides the parallelism of the axis of the fox and the base.

Support - it has the forming parts, deprives one degree of freedom - moving along the X axis. It provides the position of the axis of the lapel in one jumbo plane with the axle of the part.

The part is mounted on the table with one of the end surfaces and the side touches two planes, the fastening is carried out by the capture of the pneumatic action. In our case, we can talk about the combination of bases, the basis of the part at the same time is a measuring and technological base.

Cutting tool:

P.I. 1: Milling end faces ∅200 mm, material of the cutting part T5K10 and T15K6.

P.I. 2: Milling end ∅20 mm, material of the cutting part P6M5; number of teeth cutters z = 6; length of the cutting part l = 32 mm; length of cutter L = 115 mm; shank - cone Morse 2; front angle γ = 15o; rear angle α = 20°; front angle at the end of the cutter γ'= 0; the rear angle at the end face α'= 10°.

Auxiliary tool: cartridge 1-40-2-100.

Correction: 6222-0119.

030→Washing.

In this operation, the surface is cleaned of the part from the lubricant, which was used when cutting the cutting. Washing is carried out in special baths. Operation remains unchanged.

035→Locksmith.

Cleaning the surface of the part from the burrs, that formed during the milling process.

Appliances - metalwork brushes; tool - file, hammer, emery paper.

040→Control DTC.

In this operation, the results of the milling of the sizes 124js14 (± 0,5) are obtained; 46.4js14 (± 0.125) and 20h12 (-0.210) × 18h12.

Measurements are carried out by the WTC master. Measuring tool: special templates: L = 124; L = 46.4; L = 18 × 20.

045→ Boring coordinate with CNC ИР800ПМФ4.

This operation involves the treatment of stepped openings and cutting openings. The treatment is carried out in 4 positions.

Transitions:

1-st position:

1. Center the 6 slots. M16-7H and 2 holes 12.8 0.18.
2. Drill 2 shafts. 12.8 0.18.
3. Drill 6 shaft. M16-7H.
4. Drill 2 shafts. 24.8 0.21.
5. Drill 2 shafts. 36 0.62 and bevels in 6 openings. M16-7H.
6. Zenkerat 2 holes. 12,8 0,18 with bottom trimming.
7. Cut the thread 6 sts. M16-7H.

2-nd position:

1. Center 2 slots. M24-7H.
2. Drill 2 shafts. 8.8 0.15.
3. Drill 2 shafts. M24-7H.
4. Zenkerat 2 holes. M24-7H.
5. Cut the thread in 2 openings. M24-7N.

3-rd position:

1. Center 2 slots. M24-7H and 4 holes M12-7H.
2. Drill 2 shafts. 8.8 0.15.
3. Drill 4 shafts. M12-7H.

4. Drill 2 shafts. M24-7H.

5. Zenkrevate 2 holes. In 2 holes. M24-7N and 4 revs. M12-7H.

6. Drill the chamfers in 2 shafts. M24-7H and 4 отв. M12-7H.

7. Cut the thread in 2 openings. M24-7H.

8. Cut the thread in 4 openings. M12-7H.

4-th position:

1. Center 2 slots. M12-7H.

2. Drill 2 shafts. M12-7H.

3. Drill the chamfers in 2 shafts. M12-7H.

4. Cut the thread in 2 openings. M12-7H.

The part is installed and fixed in a special fitting with a pneumatic clamp.

Cutting and auxiliary tool:

P.I. 1 Drill centering ∅4 with cylindrical shaft, integral; P6M5; *l* = 56 mm.

P.I. 2 Spiral drill with cylindrical shank ∅8,8; P6M5; *L* = 84 mm; *l* = 34 mm.

P.I. 3 Spiral drill with cylindrical shaft ∅10,4; P6M5; *L* = 89 mm; *l* = 43 mm.

P.I. 4 Spiral drill with cylindrical shank ∅12,4; R6M; 5 *L* = 102 mm; *l* = 51 mm.

P.I. 5 Spiral drill with cylindrical shaft ∅13,6; P6M5; *L* = 214 mm; *l* = 140 mm.

P.I. 6 Core drill ∠ 60° with a conical shaft, cone Morse 2, P6M5; *L* = 135 mm, *l* = 40 mm.

P.I.7 Spiral drill with conic shaft, Morse cone 2; ∅21.2; P6M5; *L* = 248 mm; *l* = 150 mm.

P.I.8 Spiral drill with conic shaft, Morse cone 2; ∅24; P6M5; *L* = 281 mm; *l* = 160 mm.

P.I. 9 Machine label for metric cutting cutting M16-H3, *L* = 102mm, *l* = 32mm; P6M5.

P.I. 10 Spiral drill with conic shaft, Morse cone 2; ∅35,2; P6M5; *L* = 349 mm; *l* = 200 mm.

P.I.11 Core drill cylindrical for machining cylindrical surfaces ∅36, Morse cone 2; P6M5; L = 200 mm.

P.I 12 Core drill integral with a conical shaft ∅12.8, cone Morse 2; P6M5; *L* = 220 mm, *l* = 100 mm; with trimming the bottom.

P.I. 13 Core drill integral with a conical shaft ∅24.8, Morse cone 2; P6M5; *L* = 220 mm, *l* = 100 mm; with trimming the bottom.

P.I. 14 Machine label for metric cutting cutting M12-H3, *L* = 89mm, *l* = 29mm; P6M5.

P.I. 15 Machine label for metric carving M24-H3, *L* = 130mm, *l* = 45mm; P6M5.

Auxiliary tool: sleeve 50-2, sleeve 50-3, holder 50-80-231,8; drill cartridge, shaft cone 2, type 191111 - 016; cartridge variegated, type 191221-030; cartridge thread-cutting, type 191221-140.

Measuring tool: special templates: *L* = 82,2; *L* = 68; *L* = 10; calibrator-stopper PR-NO 12,8H12, caliber-stopper ПР-НЕ 24,8H12, caliber-plug ПР-НЕ 36H12, caliber-stopper of cutting ПР-НЕ M12-7H, plug ПР-НЕ M16-7H, cut-off cut-off cutter ПР-НЕ M24-7H.

050→Washing.

In this operation, the surface is cleaned of the part from the lubricant, which was used when cutting the cutting. Washing is carried out in special baths.

055→Control DTC.

Controlling the dimensions, position tolerances and roughness obtained after coordinate-boring and radial-drilling operations are carried out.

Controlled dimension:

– M12-7H threaded plug M12-7H ПР-НЕ;

– M16-7H threaded plug M16-7H ПР-НЕ;

– M24-7H threaded plug M24-7H ПР-НЕ;

– ∅12,8H12 plug 12,8H12 ПР-НЕ;

– ∅24,8H12 plug 24,8H12 ПР-НЕ;

– ∅36H12 plug 36H12 ПР-НЕ;

– $36^{+0,62}$; 68±0,37 special tampleters: *L*=36; *L*=68;

– 58±0,15 ИЧ 25 – 1;

– roughness Ra 1,6 roughness comparison specimen.

070→Elecnrochemical.

The coating is covered with zink (C18. crom).

3.8. Development of operational process.

3.8.1 Description of the trajectories of the motion of the cutting tool on operations performed on CNC machines.

In this section, a brief description of the trajectories of the motion of the cutting tool on the coordinate and boring of the CNC operation 045 is considered. The machining of the part is carried out on the multipurpose machine model of the IR800PMF4.

Device numerical control software.

PDC device - combined with linear and circular interpolation. The machine can be equipped with various CNC devices, this depends on the discreteness of the assignment of displacements, but on average it is 0.002 mm. On this machine the CNC system "Bosh" is used. The number of control coordinates is 6/5, of which at the same time 3/2. There are 79 proofreaders (this number varies in various CNC devices). Introduction of the program from the computer; readout from the tape - photoelectric, automatic cycles according to ISO are triggered. Some CNC machines working with the machine tool have diagnostics of mechanical, electrical, electronic and hydraulic systems of the machine.

For machining surfaces, the parts used in this operation are 15 tools:

P.I. 1 Drill centering ∅4.

P.I. 2 Spiral drill ∅8.

P.I. 3 Spiral drill ∅10,4.

P.I. 4 Spiral drill ∅12,4.

P.I. 5 Spiral drill ∅13,6.

P.I. 6 Core drill ∠ 60°.

P.I. 7 Spiral drill ∅21,2.

P.I. 8 Spiral drill ∅24.

P.I. 9 Machine tag M 16-H3.

P.I. 10 Spiral drill ∅35,2.

P.I. 11 Core drill cylindrical ∅36.

P.I 12 Core drill ∅12,8 with trimming the bottom.

P.I. 13 Core drill ∅24,8 with trimming the bottom.

P.I. 14 Machine tag M 12-H3.

P.I. 15 Machine tag M 14-H3.

So, as in this operation mainly drilling of holes is carried out, then we will consider the trajectory of the motion of the cutting instrument №4, and the trajectory of other cutting tools will be similar.

Trajectory of movement, R.I. 4. For reasons of safety, the starting point is selected so that the part is not damaged when the tool is changed.

From the starting point of the accelerated feed, the drill moves to point 1 (fig. 3.2), the movement occurs simultaneously with two coordinates Z and X. From point 1 along the Y axis, the drill moves on an accelerated feed to the surface of the part, without reaching 3 mm (point 2). From point 2, the drill moves to point 3 (direct drill hole) on the same feedstock on the working feed. Then - return to point 2 on an accelerated feed. From point 2 to point 4, the drill moves accelerated along the Z axis. After that, the next opening, similar to the first, is performed, the drill movement from point 4 to 5 occurs on the working feed.

The output of the drill and the detachment from the part - moving from point 5 to 6 along the Y axis is at the accelerated feed. From point 6, the cutting tool is taken to the starting point for change.

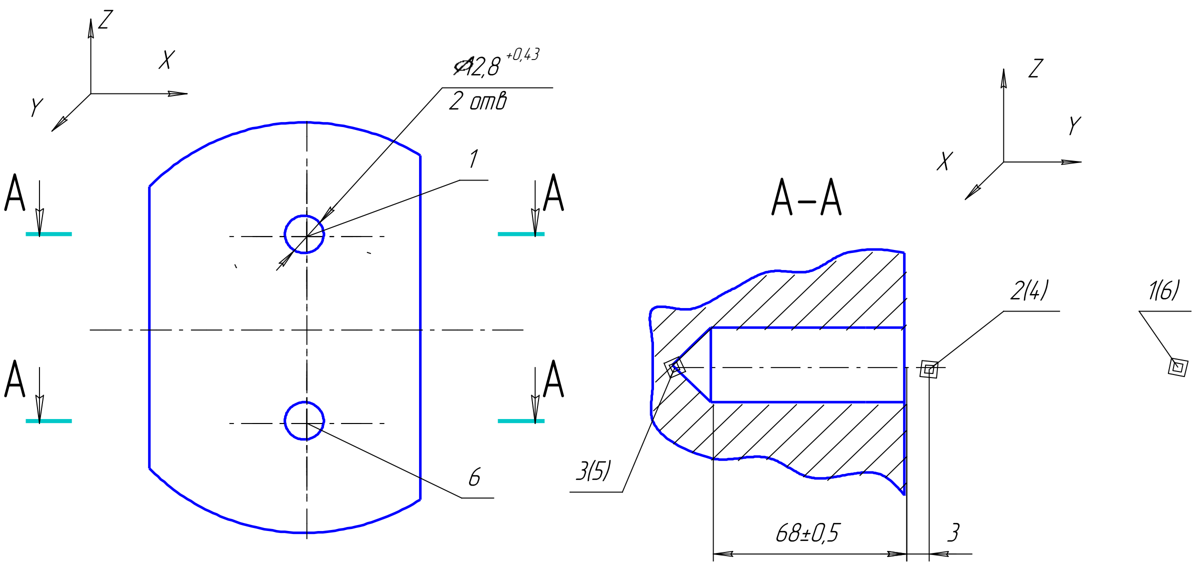


Figure 3.2 - Trajectory of the motion of the cutting tool №4

3.8.2. Selection of cutting and normalization of operations of the technological process.

3.8.2.1. Calculations of cutting and normalization modes of turning-threading operation 015.

The turning-guided operation 015 is designed for the machining of an outer cylindrical surface ∅184h10, ∅116d9 and two ends, performed on a machine model 16K40.

1. Passport data of the 16K40 model machine:

- range of spindle rotational speeds, r / min:

12,5; 16; 20; 25; 31,5; 40; 50; 63; 80; 100; 125; 160; 200; 250; 315; 400; 500; 630; 800; 1000; 1250; 1600;

- row of values of longitudinal feed, mm / rev:

0,05; 0,06; 0,075; 0,09; 0,1; 0,125; 0,15; 0,175; 0,2; 0,25; 0,3; 0,35; 0,4; 0,5; 0,6; 0,7; 0,8; 1; 1,2; 1,4; 1,6; 2; 2,4; 2,8;

- a number of values of the transverse feed, mm / min:

0,025; 0,03; 0,0375; 0,045; 0,05; 0,0625; 0,075; 0,0875; 0,1; 0,125; 0,15; 0,175; 0,2; 0,25; 0,3; 0,35; 0,4; 0,5; 0,6; 0,7; 0,8; 1; 1,2; 1,4;

- power of the electric motor: 10 kW, coefficient of efficiency verst-th within 0,8-0,85;

- frequency of rotation of the electric motor shaft, 1460 rpm;

- the greatest force allowed by the mechanism of longitudinal feed -6000 N.

1. Development of an operating sketch of detail processing (fig. 3.2).

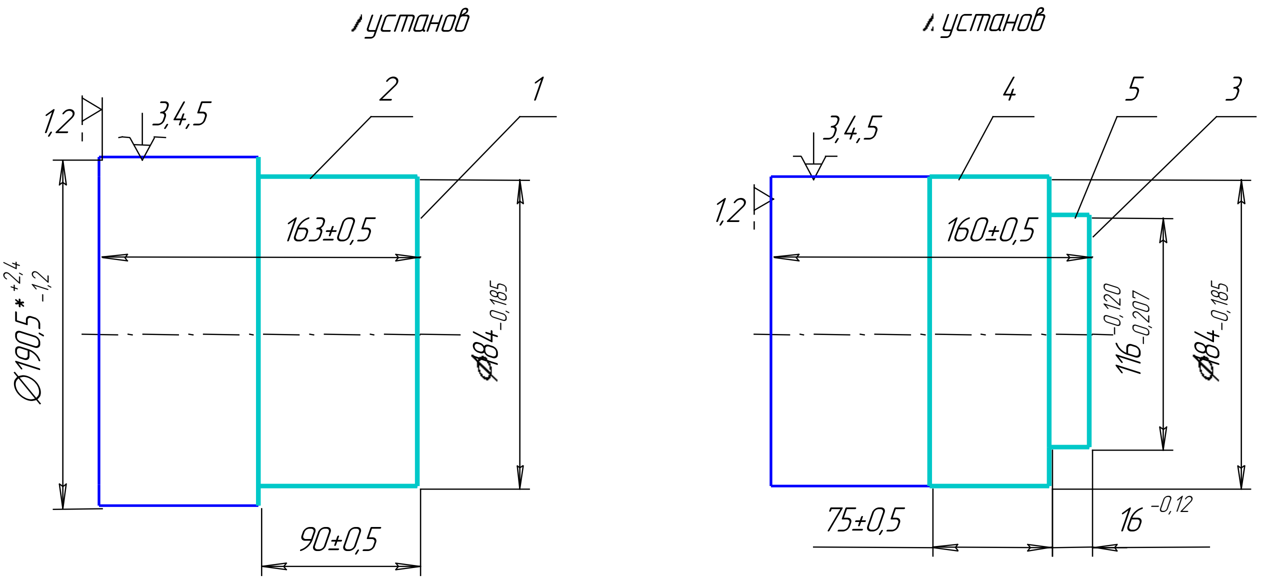


Figure 3.3 - Operational detail thumbnail processing

2. Cutting tools:

R.I. 1: Cutter straight turning; plate material T5K10; method of fixing the plate - soldering; section of the holder - 16 × 25 mm; angles in the plane φ = 93°, φ_1 = 7°; front angle γ = 10°, rear angle α = 6°; radius of the top of the plate r_v = 1,0 mm; angle of inclination of the main cutting edge λ = 0; chamfer width f = 0.6 mm; period of stability T = 60 min.

R.I. 2: Cutter straight turning, plate material T15K6; method of fixing the plate - soldering; section of the holder - 16 × 25 mm; angles in the plane φ = 93°, φ_1 = 7°; front angle γ = 10°, rear angle α = 6°; radius of the top of the plate r_v = 1,0 mm; angle of inclination of the main cutting edge λ = 0; chamfer width f = 0.6 mm; period of stability T = 60 min.

R.I. 3: Turner turning open right, plate material T5K10; method of fastening - soldering; section of the holder - 16 × 25 corners in plan φ = 45°, φ_1 = 45°; front angle γ = 10°, rear angle α = 6°; radius of the top of the plate r_v = 1.0 mm; angle of inclination of the main cutting edge λ = 0; chamfer width f = 0.6 mm; period of stability T = 60 min.

4. Depth of cutting in stages (table 3.9).

Table 3.9 - Depth of cutting in the stages of processing

Stage of treatment	Depth of cutting, mm				
	№ of surface				
	1	2	3	4	5
roughing	3	1,5	3	1,5	34,4
semiroughing	-	1	-	1	1,7
finishing	-	0,8	-	0,8	0,9

5. The choice of feed for roughing surfaces according to [6], map 3:

$$S_{om\,2} = S_{om\,4} = 0{,}83 \text{ mm/rev.};$$
$$S_{om\,1} = S_{om\,3} = S_{om\,5} = 0{,}73 \text{ mm/rev.}$$

Coeficients $K_{si} = 1{,}15$ i $K_{sp} = 1{,}1$.

Correction factors according to [6], map 5 for all surfaces though:

$$K_{sd} = 0{,}95;\ K_{sh} = -\ ;\ K_{sм} = 1{,}0;\ K_{sy} = 1{,}2;\ K_{sn} = 1{,}0;\ K_{s\varphi} = 1{,}0;\ K_{sl} = 0{,}75.$$

Adjusted feed is:

$$S_o = S_{om} \times K_{si} \times K_{sp} \times K_{sd} \times K_{sh} \times K_{sм} \times K_{sy} \times$$
$$\times K_{sn} \times K_{s\varphi} \times K_{sl};\ \text{mm/rev}; \qquad (3.24)$$
$$S_{o\,2} = S_{o\,4} = 0{,}83 \times 1{,}15 \times 0{,}95 \times 1{,}0 \times 1{,}2 \times 1{,}0 \times 1{,}0 \times$$
$$\times 0{,}75 = 0{,}82 \text{ mm/rev};$$
$$S_{o\,1} = S_{o\,3} = S_{o\,5} = 0{,}73 \times 1{,}15 \times 0{,}95 \times 1{,}0 \times 1{,}2 \times 1{,}0 \times$$
$$\times 1{,}0 \times 0{,}75 = 0{,}72 \text{ mm/rev.}$$

Adjust the filing according to the machine's passport:

$$S_{o\,2} = S_{o\,4} = 0{,}8 \text{ mm/rev};$$
$$S_{o1} = S_{o\,3} = S_{o5} = 0{,}7 \text{ mm/rev.}$$

Power check validation.

Tabular force of cutting according to [6], map 32:

Surfaces 2,4:

$$P_{XT} = 900 \text{ H};\ P_{YT} = 360 \text{ N}.$$

Surfaces 1,3,5:

$$P_{XT} = 1360 \text{ H};\ P_{YT} = 530 \text{ N}.$$

Correction factors on both components of force in accordance with [6], map 33 for all surfaces are the same:

$$K_{рм} = 1{,}0;\ K_{p\varphi} = 1{,}0;\ K_{p\gamma} = 0{,}9;\ K_{p\lambda} = 1{,}0.$$

Actual power of cutting:

$$P_X = P_{XT} \times K_{рм} \times K_{p\varphi} \times K_{p\gamma} \times K_{p\lambda},\ \text{N}; \quad (3.25)$$

$$P_Y = P_{YT} \times K_{рм} \times K_{p\varphi} \times K_{p\gamma} \times K_{p\lambda},\ \text{N}. \quad (3.26)$$

Surfaces 2,4:

$$P_X = 900 \times 1{,}0 \times 1{,}0 \times 0{,}9 \times 1{,}0 = 810\ \text{N};$$

$$P_Y = 360 \times 1{,}0 \times 1{,}0 \times 0{,}9 \times 1{,}0 = 324\ \text{N}.$$

Surfaces 1,3,5:

$$P_X = 1360 \times 1{,}0 \times 1{,}0 \times 0{,}9 \times 1{,}0 = 1224\ \text{N};$$

$$P_Y = 530 \times 1{,}0 \times 1{,}0 \times 0{,}9 \times 1{,}0 = 477\ \text{N}.$$

The components of the cutting forces P_X and P_Y are significantly less than the permissible machine tool (P_X = 6000N and P_Y = 10000N, respectively), so the power supply fully meets the necessary requirements.

1. The choice of feed for semi-processing in accordance with [6], map 3:

$$S_{o\,2} = S_{o\,4} = 0{,}49\ \text{mm/rev};$$

$$S_{o\,1} = S_{o\,3} = S_{o\,5} = 0{,}43\ \text{mm/rev}.$$

The correction factors for the semi-stage stage are equal to the correction factors of the draft stage. By formula (3.24) we define the actual feed:

$$S_{o\,2} = S_{o\,4} = 0{,}49 \times 1{,}15 \times 0{,}95 \times 1{,}0 \times 1{,}2 \times 1{,}0 \times 1{,}0 \times 0{,}75 = 0{,}48\ (\text{mm/rev});$$

$$S_{o\,5} = 0{,}43 \times 1{,}15 \times 0{,}95 \times 1{,}0 \times 1{,}2 \times 1{,}0 \times 1{,}0 \times 0{,}75 = 0{,}42\ (\text{mm/rev}).$$

Adjust the filing according to the machine's passport:

$$S_{o\,2} = S_{o4} = 0{,}4 \text{ mm/rev};$$
$$S_{o\,1} = S_{o\,3} = S_{o\,5} = 0{,}4 \text{ mm/rev}.$$

1. Select the feed for the finishing stage of processing in accordance with [6], map 6:

$$S_{om\,2} = S_{om\,4} = 0{,}22 \text{ mm/rev}; \; S_{om\,5} = 0{,}22 \text{ mm/rev}.$$

Correction factors are determined according to [6], map 8:

$$K_{sм} = 1{,}0; K_{sy} = 1{,}2;\; K_{sr} = 1{,}0; K_{sk\,2,4} = 1{,}0; K_{sk\,5} = 0{,}9;\; K_{s\varphi} = \text{-}\,.$$

Adjusted feed is:

$$S_o = S_{om} \times K_{sм} \times K_{sy} \times K_{sr} \times K_{sk} \times K_{s\varphi}; \qquad (3.27)$$
$$S_{o\,2} = S_{o\,4} = 0{,}22 \times 1{,}0 \times 1{,}2 \times 1{,}0 \times 1{,}0 = 0{,}264 \text{ mm/rev};$$
$$S_{o\,5} = 0{,}22 \times 1{,}0 \times 1{,}2 \times 1{,}0 \times 0{,}9 = 0{,}238 \text{ mm/rev}.$$

Adjust the filing according to the machine's passport:

$$S_{o\,2} = S_{o\,4} = 0{,}25 \text{ mm/rev};$$
$$S_{o\,5} = 0{,}25 \text{ mm/rev}.$$

8. Choice of cutting speed for the roughing stage of surface treatment.

The table velocity of cutting Vabl is chosen according to [6], map 21, correction coefficients for [6] on the map 23.

Surfaces 2,4:

$$V_{табл} = 153 \text{ m/min}.$$

Surfaces 1,3,5:

$$V_{табл} = 153 \text{ m/min}.$$
$$K_{vc} = 1{,}0; K_{vi} = 0{,}85; K_{vo} = 1{,}0; K_{vj} = 0{,}7;$$

$$K_{vм} = 1{,}0;\ K_{v\varphi} = 1{,}0;\ K_{vt} = 0{,}8;\ K_{vw} = 1{,}0.$$

Estimated cutting speed:

$$V_p = V_{табл} \times K_{vc} \times K_{vi} \times K_{vo} \times K_{vj} \times K_{vм} \times K_{vt} \times K_{vw} \times K_{v\varphi} \text{ m/min.} \quad (3.28)$$

Surfaces 2,4:

$$V_P = 153 \times 1{,}0 \times 0{,}85 \times 1{,}0 \times 0{,}7 \times 1{,}0 \times 1{,}0 \times 0{,}8 \times 1{,}0 = 72{,}8 \text{ m/min.}$$

Surfaces 1,3,5:

$$V_P = 153 \times 1{,}0 \times 0{,}85 \times 1{,}0 \times 0{,}7 \times 1{,}0 \times 1{,}0 \times 0{,}8 \times 1{,}0 = 72{,}8 \text{ m/min.}$$

9. The choice of cutting speed for the half-stage processing of surfaces.

Table velocity of cutting $V_{табл}$ is chosen according to [6], map 21, correction factors according to [6], map 22.

Cutting speed for surfaces 2,4,5 is the same: $V_{табл}$ = 203 m / min.

By formula (1.33) determine the design speed of cutting:

$$V_P = 203 \times 1{,}0 \times 0{,}85 \times 1{,}0 \times 0{,}7 \times 1{,}0 \times 1{,}0 \times 0{,}8 \times 1{,}0 = 96{,}6 \text{ m/min.}$$

10. Choice of cutting speed for the finishing stage of surface treatment.

The table velocity of cutting $V_{табл}$ is chosen according to [6], map 22, and correction factors according to [6], map 23.

Surfaces 2,4:

$$V_{табл} = 265 \text{ m/min.}$$

Surfaces 5:

$$V_{табл} = 265 \text{ m/min.}$$

The correction factors for all three stages of processing are the same.

Calculate the cutting speed using formula (3.28).

Surfaces 2,4:

$$V_P = 265 \times 1{,}0 \times 0{,}85 \times 1{,}0 \times 0{,}7 \times 1{,}0 \times 1{,}0 \times 0{,}8 \times 1{,}0 = 126{,}1 \text{ m/min.}$$

Surfaces 5:

$$V_P = 265 \times 1{,}0 \times 0{,}85 \times 1{,}0 \times 0{,}7 \times 1{,}0 \times 1{,}0 \times 0{,}8 \times 1{,}0 = 126{,}1 \text{ m/min.}$$

11. Choice of spindle rotational speed for roughing:

Determination of spindle rotational speed in stages:

$$n_P = \frac{1000 V_P}{\pi \cdot D}, \text{ rev/min,} \qquad (3.29)$$

where D is the diameter of the treated surface.

Surfaces 2,4:

$$n_P = \frac{1000 \cdot 72{,}8}{3{,}14 \cdot 187{,}4} = 123{,}5 \text{ rev/min,}$$

Adjust for the machine n_P = 125 rev/min.

Surfaces 1,3:

$$n_P = \frac{1000 \cdot 72{,}8}{3{,}14 \cdot 190{,}5} = 121{,}7 \text{ rev/min,}$$

Adjust for the machine n_P = 125 rev/min.

Surfaces 5:

$$n_P = \frac{1000 \cdot 72{,}8}{3{,}14 \cdot 186{,}4} = 124{,}4 \text{ rev/min,}$$

Adjust for the machine n_P = 125 rev/min.

12. The choice of the spindle rotational frequencies for semi-spotting is carried out using formula (3.29):

Surfaces 2,4:

$$n_P = \frac{1000 \cdot 96{,}6}{3{,}14 \cdot 185{,}6} = 165 \text{ rev/min},$$

Adjust for the machine n_P = 140 rev/min.

Surfaces 5:

$$n_P = \frac{1000 \cdot 96{,}6}{3{,}14 \cdot 121{,}2} = 253 \text{ rev/min},$$

Adjust for the machine n_P = 250 rev/min.

13. We calculate the choice of spindle rotation speeds at the finishing point using formula (3.29):

Surfaces 2,4:

$$n_P = \frac{1000 \cdot 126{,}1}{3{,}14 \cdot 184} = 331 \text{ rev/min}.$$

Adjust for the machine n_P = 315 rev/min.

Surfaces 5:

$$n_P = \frac{1000 \cdot 126{,}1}{3{,}14 \cdot 116} = 346 \text{ rev/min},$$

Adjust for the machine n_P = 315 rev/min.

14. Determination of the actual speed of cutting at roughing precision:

$$V_\Phi = \frac{\pi \cdot D \cdot n_\Phi}{1000}, \text{ m/min.} \quad (3.30)$$

Surfaces 2,3:

$$V_\Phi = \frac{3{,}14 \cdot 125 \cdot 187{,}4}{1000} = 73{,}6 \text{ m/min}.$$

Surfaces 1,3:

$$V_{\Phi} = \frac{3{,}14 \cdot 190{,}5 \cdot 125}{1000} = 74{,}7 \text{ m/min.}$$

Surfaces 5:

$$V_{\Phi} = \frac{3{,}14 \cdot 186{,}4 \cdot 125}{1000} = 73{,}1 \text{ m/min.}$$

15. Determine the actual speed of cutting at semi-precision, using formula (3.30):

Surfaces 2,4:

$$V_{\Phi} = \frac{3{,}14 \cdot 140 \cdot 185{,}6}{1000} = 81{,}5 \text{ m/min.}$$

Surfaces 5:

$$V_{\Phi} = \frac{3{,}14 \cdot 121{,}2 \cdot 250}{1000} = 95{,}1 \text{ m/min.}$$

16. Determine the actual cutting speed for finishing, using formula (3.30):

Surfaces 2,4:

$$V_{\Phi} = \frac{3{,}14 \cdot 315 \cdot 184}{1000} = 182 \text{ m/min.}$$

Surfaces 5:

$$V_{\Phi} = \frac{3{,}14 \cdot 116 \cdot 315}{1000} = 114 \text{ m/min.}$$

17. Checking the speed of cutting on the power of the drive of the main movement. Calculations are carried out at the black stage for [6], map 21.

Surfaces 2,4:

$$N_p = 10 \text{ kW.}$$

Surfaces 1,3,5:

$$N_p = 12 \text{ kW}.$$

Correction factors are determined according to [6], map 24:

$$K_{NM} = 0{,}67;$$

$$N_p = N_T \times K_{NM}, \text{ kW}. \quad (3.31)$$

Surfaces 1,2,3,4,5:

$$N_p = 10 \times 0{,}7 = 7 \text{ kW}.$$

The power of the machine is determined by the formula:

$$N_{max} = N_{ed} \cdot \eta, \text{ kW}; \quad (3.32)$$

where N_{ed} · - power of the electric motor on the main movement of the machine;
η - Coefficient of efficiency of the machine (0,8-0,85);

$$N_{max} = 10 \cdot \times 0{,}85 = 8{,}5 \text{ kW}.$$

$N_p < N_{max}$ – consequently, the cutting speed is acceptable.

18. Definition of the minute feed during the rooting stage of processing:

$$S_{xв} = S_o \times n_P \text{ (mm/min)}. \quad (3.33)$$

Surfaces 2,4:

$$S_{xв} = 0{,}8 \times 125 = 100 \text{ mm/min}.$$

Surfaces 1,3,5:

$$S_{xв} = 0{,}7 \times 125 = 87{,}5 \text{ mm/min}.$$

19. Define a minute feed at the half-stage processing stage, using formula (3.33).

Surfaces 2,4:

$$S_{хв} = 0,4 \times 140 = 126 \text{ mm/min.}$$

Surfaces 5:

$$S_{хв} = 0,4 \times 25 = 200 \text{ mm/min.}$$

20. A minute feed is given at the finishing stage of processing using formula (3.33):

Surfaces 2,4:

$$S_{хв} = 0,25 \times 315 = 78,75 \text{ mm/min.}$$

Surfaces 1,3,5:

$$S_{хв} = 0,25 \times 315 = 78,75 \text{ mm/min.}$$

Calculated cutting modes are presented in Table 3.10.

21. Definition of the basic time.

The basic time on turning-turning operation is determined by the formula:

$$T_o = \frac{L}{S_o \cdot n} \cdot i \text{, min,} \quad (3.34)$$

where L - length of the working tool, mm;

S_o - reverse flow, mm / rev;

n - spindle speed, rpm;

i - number of passes;

$$L = l_o + l_{вр} + l_{пер} \text{, mm,} \quad (3.35)$$

where l_o - length of the treated surface, mm;

$l_{вр} + l_{пер}$ - length of cutting and flow, mm.

Table 3.10 - Cutting modes for operation 015

Elements of cutting modes	State of ttreatment										
	roughing					semiroughing			finishing		
	№ of surface										
	1	2	3	4	5	2	4	5	2	4	5
Tabular feed, $S_{o\ табл}$, mm/rev.	0,73	0,83	0,73	0,83	0,73	0,49	0,49	0,43	0,22	0,22	0,22
Accepted feed S_o, mm/rev.	0,7	0,8	0,7	0,8	0,7	0,4	0,4	0,4	0,25	0,25	0,25
Tabular speed of cutting $V_{табл}$, m/min.	153	153	153	153	153	203	203	203	265	265	265
Actual spindle speed $n_ф$, rev/min.	125	125	125	125	125	140	140	250	315	315	315
Actual cutting speed $V_ф$, m/min.	74,7	73,6	74,7	73,6	73,1	81,5	81,5	95,1	182	182	114
Tabular power of cutting $N_{табл}$, kW	10	10	10	10	10	-	-	-	-	-	-
Actual cutting power, $N_ф$ kW	7	7	7	7	7	-	-	-	-	-	-
Minute feed $S_{хв}$, mm/rev	87.,5	100	87,5	100	87,5	126	126	200	78,8	78,8	78,8

Rough rolling:

1) $l_{o\ 1,3}$ = 95,25 mm; $l_{вр\ 1,3} + l_{пер\ 1,3}$ = 5 mm; $L_{1,3}$ = 95,25 + 5 + 0 = 100,25 mm; i=1;

$$T_{o1,3} = \frac{100,25}{0,7 \cdot 125} \cdot 1 = 1,15 \text{ min};$$

2) $l_{o\ 2}$ = 90 mm; $l_{вр\ 2} + l_{пер\ 2}$ = 5 mm; L_2 = 90 + 5 + 0 = 95 mm; i = 1;

$$T_{o2} = \frac{95}{0,8 \cdot 125} \cdot 1 = 0,95 \text{ min};$$

3) $l_{o\ 4}$ = 75 mm; $l_{вр\ 4}$ = 3 mm; L_4 = 75 + 3 = 78 mm; i = 1;

$$T_{o4} = \frac{78}{0,8 \cdot 125} \cdot 1 = 0,78 \text{ min};$$

4) $l_{o\,5}$ = 16 mm; $l_{вр\,5}$ = 3 mm; L_5 = 16 + 5 = 19 mm; i = 11 ;

$$T_{o5} = \frac{19}{0{,}7 \cdot 125} \cdot 11 = 2{,}39 \text{ min.}$$

Semi-dry toasting:

1) $l_{o\,2}$ = 90 мм; $l_{вр\,2} + l_{пер\,2}$ = 5 mm; L_2 = 90 + 5 = 95 mm; i = 1;

$$T_{o2} = \frac{95}{0{,}4 \cdot 125} \cdot 1 = 1{,}17 \text{ min;}$$

2) $l_{o\,4}$ = 75 mm; $l_{вр\,4} + l_{пер\,4}$ = 5 mm; L_4 = 75 + 5 = 80 mm; i = 1;

$$T_{o4} = \frac{80}{0{,}4 \cdot 140} \cdot 1 = 1{,}43 \text{ min;}$$

3) $l_{o\,5}$ = 16 mm; $l_{вр\,5}$ = 3 mm; L_2 = 16 + 3 = 19 mm; i = 1;

$$T_{o5} = \frac{19}{0{,}4 \cdot 250} \cdot 1 = 0{,}19 \text{ min.}$$

Rough rolling:

1) $l_{o\,2}$ = 90 mm; $l_{вр\,2} + l_{пер\,2}$ = 5 mm; L_2 = 90 + 5 = 95 mm; i = 1;

$$T_{o2} = \frac{95}{0{,}25 \cdot 315} \cdot 1 = 1{,}2 \text{ min;}$$

2) $l_{o\,4}$ = 75 mm; $l_{вр\,4} + l_{пер\,4}$ = 5 mm; L_4 = 75 + 5 = 80 mm; i = 1;

$$T_{o4} = \frac{80}{0{,}25 \cdot 315} \cdot 1 = 1{,}01 \text{ min;}$$

3) $l_{o\,5}$ = 16 mm; $l_{вр\,5}$ = 3 mm; L_2 = 16 + 3 = 19 mm; i = 1;

$$T_{o5} = \frac{19}{0{,}25 \cdot 315} \cdot 1 = 0{,}24 \text{ min.}$$

The total basic time is the sum of time in all stages:

$$\Sigma T_o = T_{o1} + T_{o2} + T_{o3} + T_o 4 + T_{o5}, \text{ min;} \quad (3.36)$$

ΣT_o = 1,15+1,15+0,95+0,78+2,39+1,17+1,43+0,19+1,2+1,01+0,24 = 11,66 min.

22. Determination of auxiliary time for operation.

Auxiliary time:

- on installation-removal of a part $T_{в\ уз}$= 1,2 хв.; ([7], map 18);
- to change the modes of cutting $T_{в\ р/р}$ = 0,43 хв.; ([7], map 3);
- to measure $T_{в\ вим}$ = 0,21 min; ([7], map 86);
- associated with the transition: $T_{в\ пер}$ = 0,10 + 0,43 =0,53 min; ([7], map 18).

Total auxiliary time is:

$$\Sigma T_в = T_{в\ ус} + T_{в\ р/р} + T_{в\ вим} + T_{в\ пер}, \text{ min}; \quad (3.37)$$

$$\Sigma T_в = 1{,}2 + 0{,}43 + 0{,}21 + 0{,}53 = 2{,}37 \text{ min}.$$

The operating time is determined by the formula:

$$T_{оп} = \Sigma T_о + \Sigma T_в, \text{ хв.}; \quad (3.38)$$

$$T_{оп} = 11{,}66 + 2{,}37 = 14{,}03 \text{ хв.}$$

23. Determination of the preparatory and final time for the party.

Preparatory and final time is spent according to [7], map 19:

- on the adjustment of the machine tool and the tool,

$$T_{пз\ 1} = 20 \text{ min};$$

- for additional receptions $T_{пз\ 2}$ = 5 min;
- for reception-delivery of the tool and devices $T_{пз\ 3}$ = 10 min.

Total preparatory and final time is:

$$T_{пз} = T_{пз\ 1} + T_{пз\ 2} + T_{пз\ 3}, \quad (3.39)$$

$$T_{пз} = 20 + 5 + 10 = 35 \text{ min}.$$

24. Determination of artificial and artificial calculation time.

Artificial time is determined by the formula:

$$T_{шт} = T_{оп} + T_{обсл} + T_{ЛН}, \text{ min}; \quad (3.40)$$

where $T_{обсл}$ - the standard time for servicing the workplace, which is 3,5% від $T_{оп}$, $T_{обсл}$ = 0,42 min.

$T_{вοп}$ - the standard of time for rest and personal needs that make up 2% від $T_{оп}$,. $T_{вοп}$ = 0,23 min;

$$T_{шт} = 14{,}03 + 0{,}43 + 0{,}23 = 14{,}65 \text{ min.}$$

Artificially-estimated time is determined according to the formula:

$$T_{ш.к} = T_{шт} + \frac{T_{пз}}{n}, \text{ min;} \qquad (3.41)$$

where n - number of parts in the batch variable;

$$n = \frac{T_{м} - T_{пз}}{T_{шт}}, \qquad (3.42)$$

where $T_{зм}$ - time of change, $T_{зм}$ = 480 min;

$$n = \frac{480 - 35}{14{,}65} = 30{,}3, \text{ accept 31.}$$

$$T_{ш.к} = 14{,}65 + \frac{35}{31} = 15{,}78 \text{ min.}$$

The values calculated above are shown in table 3.11.

Table 3.11 - Summary table of calculation results of normalized time for operations 015

$T_о$	$T_в$	$T_{оп}$	$T_{пз}$	$T_{шт}$	$T_{ш.к}$
11,66	2,37	14,03	35	14,65	15,78

3.8.2.2. Calculations of cutting and verifying modes of vertical milling operation 025.

Vertical milling operation 025 is designed for the final treatment of two woodchips 124js14 and a groove of 20h12 × 18h12 on a machine 6T13.

1. Passport data of the machine, [5]:

The table surface area is 200x800. Engine power N_d = 11 kW; k.k.d. machine tool η = 0.85. Speed of spindle rotation, rpm: 16; 20; 25; 31.5; 40; 50; 63; 80; 100; 125; 160; 200; 250; 315; 400; 500; 630; 800; 1000; 1250; 1600. The velocity of the longitudinal and transverse motion of the table, mm / min: 12.5; 16; 20; 25; 31.5; 40; 50; 63; 80; 100; 125; 160; 200; 250; 315; 400; 500; 630; 800; 1000; 1250. The speed of the vertical motion of the table, mm / min: 4.1; 5.3; 6.6; 8; 10.5; 13.3; 16.6; 21; 26.6; 33.3; 41.6; 53.5; 66.6; 83.3; 105; 133.3; 166.6; 210; 266.6; 333.3; 400. Maximum cutting force, permissible by the mechanism of flow of feed, N: longitudinal - 20,000, transverse - 12000, vertical - 8000.

2. Cutting tool.

P.I. 1: Milling end faces ∅200 mm, material of the cutting part T5K10 i T15K6.

P.I. 2: Milling end ∅20 mm, material of the cutting part P6M5; number of teeth z = 6; length of the cutting part l = 32 mm; length of cutter L = 115 mm; shank - cone Morse 2; front angle γ = 15o; rear angle α = 20o; front angle at the end of the cutter γ '= 0; the rear angle at the end face α '= 10 °.

3. Operational sketch of detail processing on vertical milling operation 025 is shown in fig. 3.4.

4. Depth of cutting:

When milling a two-leaf cut-off depth is equal to leaching on machining.

When milling a two-leaf cut-off depth is equal to leaching on machining and is equal to 3 mm; when milling the groove, the required allowance is removed for two passes: t_1 = 10 mm and t_2 = 10 mm.

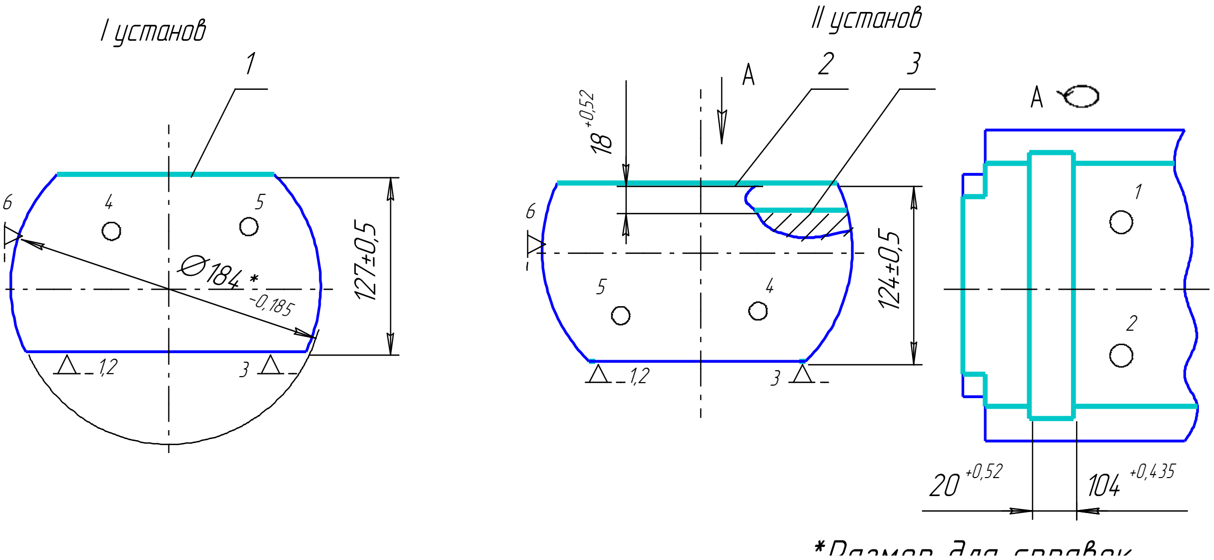


Figure 3.4 - Operational detail thumbnail

7. The choice of innings.

Surfaces 1,2 according to [6], map 56, sheet 1:

$$S_{Z\,табл}\ 0{,}12\ \text{mm/tooth}.$$

Correction factors are determined according to [6], map 56, sheet 2-3:

$$K_{sм} = 1{,}0;\ K_{si} = 1{,}25;\ K_{s\varphi} = 1{,}0;\ K_{sp} = 1{,}1;\ K_{sc} = 1{,}0;\ K_{sb} = 1{,}1;$$

$$S_Z = S_{Zтабл} \times K_{sм} \times K_{si} \times K_{s\varphi} \times K_{sp} \times K_{sc} \times K_{sb},\cdot\text{mm/tooth}; \quad (3.43)$$

$$S_Z = 0{,}12 \times 1{,}0 \times 1{,}25 \times 1{,}0 \times 1{,}1 \times 1{,}0 \times 1{,}1 = 0{,}18\ \text{mm/tooth}.$$

Surface 3 according to [6], map 81:

1-th cutting stroke: S_{Zt} = 0,03 mm/tooth;

2-nd cutting stroke: S_{Zt} = 0,03 mm/tooth.

Correction factors are determined by map 82, [6]:

$$K_{sм} = 1{,}0;\ K_{si} = 1{,}0;\ K_{sz} = 0{,}6;\ K_{sl} = 1{,}0;$$

$$S_Z = S_{Zтабл} \times K_{sм} \times K_{si} \times K_{sz} \times K_{sl}, \text{ мм/зуб mm/tooth.} \quad (3.44)$$

1 pass: $S_Z = 0{,}03 \times 1{,}0 \times 1{,}0 \times 0{,}6 \times 1{,}0 = 0{,}018$ mm/tooth;

2 pass: $S_Z = 0{,}03 \times 1{,}0 \times 1{,}0 \times 0{,}6 \times 1{,}0 = 0{,}018$ mm/tooth.

6. Choice of cutting speed:

Surfaces 1,2, according to [6] card 65, sheet 1:

$$V_{табл} = 242 \text{ m/min.}$$

Correction factors are determined by [6], map 65, sheet 4:

$$K_{vм} = 1{,}0;\ K_{vi} = 0{,}8;\ K_{vn} = 1{,}0;\ K_{v\varphi} = 1{,}0;$$
$$K_{vb} = 1{,}0;\ K_{vt} = 1{,}0;\ K_{vp} = 1{,}15;\ K_{vw} = 1{,}0.$$

$$V = V_{табл} \times K_{vм} \times K_{vi}; \times K_{vn} \times K_{v\varphi} \times$$
$$\times K_{vb} \times K_{vt} \times K_{vp} \times K_{vw}, \text{ m/min.}; \quad (3.45)$$

$V = 242 \times 1{,}0 \times 0{,}8 \times 1{,}0 \times 1{,}0 \times 1{,}0 \times 1{,}0 \times 1{,}15 \times 1{,}0 = 222{,}6$ m/min.

Surface 3, [6] map 87, sheet 1

1 pass: $V_{табл} = 21$ m/min.;

2 pass: $V_{табл} = 21$ m/min.

For this treatment correction factors are not indicated, therefore,

$$V_{табл} = V = 21 \text{ m/min.}$$

7. Determination of the spindle rotational speed using (3.29).

Surface 1:

$$n = \frac{1000 \cdot 222{,}6}{3{,}14 \cdot 125} = 567 \text{ rev/min,}$$

Adjust for the machine $n_ф$ = 500 rev/min.

Surface 2:

$$n = \frac{1000 \cdot 222{,}6}{3{,}14 \cdot 200} = 354{,}5 \text{ rev/min,}$$

Adjust for the machine $n_ф$ = 315 rev/min.

Surface 3 (1 and 2 passes):

$$n = \frac{1000 \cdot 21}{3{,}14 \cdot 20} = 334{,}4 \text{ rev/min.}$$

Adjust for the machine $n_ф$ = 315 rev/min.

8. Determine the actual cutting speed using (3.30):

Surface 1:

$$V_Ф = \frac{3{,}14 \cdot 125 \cdot 500}{1000} = 196{,}3 \text{ m/min.}$$

Surface 2:

$$V_Ф = \frac{3{,}14 \cdot 200 \cdot 315}{1000} = 197{,}8 \text{ m/min.}$$

Surface 3 (1 and 2 passes):

$$V_Ф = \frac{3{,}14 \cdot 20 \cdot 315}{1000} = 19{,}8 \text{ m/min.}$$

9. Definition of minute feed:

Minute feed is determined by the formula:

$$S_{хв} = S_Z \times z \times n_ф \text{, m/min.} \qquad (3.46)$$

Surface 1:

$$S_{хв} = 0{,}18 \times 8 \times 500 = 720 \text{ mm/min},$$

Adjust for the machine $S_{хв}$= 630 mm/min.

Surface 2:

$$S_{хв} = 0{,}18 \times 12 \times 315 = 680 \text{ mm/min},$$

Adjust for the machine $S_{хв}$ = 630 mm/min.

Surface 3 (1 and 2 passes):

$$S_{хв} = 0{,}018 \times 6 \times 315 = 34 \text{ mm/min},$$

Adjust for the machine S_M = 31,5 mm/min.

10. Determination of cutting power:

Surface 1,2 за [6], map 65, list 1:

$$N_{табл} = 16 \text{ kW}.$$

Correction factors are determined according to [6], map 65, sheet 4:

$$K_{NM} = 0{,}8;\ K_{NП} = 0{,}8;\ K_{N\varphi} = 1{,}0;\ K_{NB} = 1{,}0;$$

$$N_{Ф} = N_{табл} \times K_{NM} \times K_{NП} \times K_{N\varphi} \times K_{NB}, \text{ kW}; \quad (3.47)$$

$$N = 16 \times 0{,}8 \times 0{,}8 \times 1{,}0 = 10{,}24 \text{ kW}.$$

Surface 3 за [6], map 87, list 1:

$$N_{табл} = 1{,}24 \text{ kW};$$

1-pass: $N_{табл}$ = 1,24 kW;

2-pass: $N_{табл}$ = 1,24 kW.

For machining operation 025, correction factors are not indicated, therefore, $N_{табл} = N$ = 1.24 m / min.

Actual cutting power is:

$$N_Ф = N \cdot \frac{V_Ф}{V} = 1{,}24 \cdot \frac{19{,}8}{21} = 1{,}17 \text{ kW.}$$

11. Check, which is sufficient power drive machine. It is necessary to fulfill the condition of the cut ≤ $N_{табл}$. The power on the spindle of the machine is determined by the formula (3.31) and is equal to $N_{табл}$ = 0.85 × 14 = 11.9 kW. It is permissible to exceed the cutting power no more than at 5%.

Based on the results obtained, we can conclude that the processing is possible.

Calculated cutting modes are shown in the table 3.12.

Table 3.12 - Cutting modes for operations 025

Elements of cutting modes	Stages of processing		
	Коughing		
	1	2	3
Tabular feed $S_{Zтабл}$, mm/tooth	0,12	0,12	0,03
Accepted feed S_Z, mm/tooth	0,18	0,18	0,018
Tabular speed of cutting $V_{табл}$, m/min.	242	242	21
Actual spindle turns $n_Ф$,rev/min.	500	315	315
Actual cutting speed $V_Ф$, m/min.	196,3	197,8	19,8
Tabular cutting power $N_{табл}$, kW	16	16	1,24
Actual cutting power $N_{табл}$, kW	10,24	10,24	1,17
Minute feed $S_{хв}$, mm/min.	630	630	31,5

12. Definition of basic time.

The basic time for the vertical milling operation is determined by the formula:

$$T_o = \frac{L}{S_{хв}} \cdot i \text{, min.;} \quad (3.48)$$

where L - The length of the workpiece of the instrument is determined by (1.40), mm;

$S_{хв}$ - minute feed, mm / min.;

i - number of passes.

Surface 1:

l_o = 160 mm; $l_{вр}$ = 0,3 × 125 = 37,5 mm; $l_{пер}$ = 3 mm; L= 160 + 37,5 + 3 = 200,5 mm;

$$T_o = \frac{200,5}{630} = 0,32 \text{ min.}$$

Surface 2:

lo = 160 mm; $l_{вр}$ = 0,3 × 200 = 60 mm; $l_{пер}$ = 3 mm; L= 160+60+3=223 mm; i =1;

$$T_o = \frac{223}{630} = 0,35 \text{ min.}$$

Surface 3:

l_o = 180 mm; $l_{вр}$ = 0,3 × 20 = 6 mm; $l_{пер}$ = 3 mm; L=180+6+3=189 mm; i =2;

$$T_o = \frac{189}{31,5} \cdot 2 = 12 \text{ min.}$$

The total basic time is determined by the formula (3.36):

$$\Sigma T_o = 0,32 + 0,35 + 12 = 12,67 \text{ min.}$$

13. Determination of auxiliary time for operation:

Auxiliary time includes the following components:

- installation-removal of a part $T_{в\ ус}$ = 0,21 min, ([7], map 16);

- to change the modes of cutting $T_{в\ р/р}$ = 0,25 min.; ([7], addition 8);

- to measure $T_{в\ вим}$ = 0,63 min; ([7], map 86);

- associated with the transition $T_{в\ пер}$ =0,24 +0,24+0,24 =0,72 min; ([7], map 31).

The total auxiliary time, determined by the formula (3.37), is equal to:

$$\Sigma T_{в} = 0,21 + 0,25 + 0,63 + 0,72 = 1,81 \text{ min.}$$

The operating time using formula (3.38) is equal to:

$$T_{оп} = 12,67 + 1,81 = 14,48 \text{ min.}$$

14. Definition of preparatory, and final time for the party.

Preparatory and final time is consistent with [7], map 31, and has the following components:

- to adjust the machine tool and tool $T_{пз\ 1}$ =17 min;
- for additional receptions $T_{пз\ 2}$ = 5 min.;
- for reception-delivery of the tool and devices $T_{пз\ 3}$ = 7 min.

The total preparation time is determined by the formula (3.39):

$$T_{пз} = 17 + 5 + 7 = 29 \text{ min.}$$

15. Determination of artificial calculation of time.

Artificial time is determined by the formula (3.40):

where $T_{обс}$ - the standard time for servicing the workplace, which is 3,5% from $T_{оп}$, in accordance $T_{обс}$ = 0,51 min;

$T_{вол}$ - the standard of time for rest and personal needs that make up 2% from $T_{оп,}$ in accordance, $T_{вол}$ = 0,29 min.

$$T_{шт} = 14,48 + 0,51 + 0,29 = 15,28 \text{ min.}$$

Artificially-estimated time is determined by the formula (3.41), but first we determine the number of parts in the party according to the formula (3.42):

$$n = \frac{480 - 29}{15,28} = 29\,.$$

Determine the artificial-costing time:

$$T_{ш.к} = 15{,}28 + \frac{29}{29} = 16{,}28 \text{ min.}$$

Calculated time values $T_{ш.к}$ for operation 025 are given in table 3.13.

Table 3.1 - Time components for the operation

$T_о$	$T_в$	$T_{оп}$	$T_{пз}$	$T_{шт}$	$T_{ш.к}$
12,67	1,81	14,48	29	15,28	16,28

3.8.2.3. Calculation of the cutting and normalization modes of coordinate-boring operation 045 with CNC.

The cutting and time modes for coordinate-boring operation 045, calculated similarly, are given in table 3.1.4.

Table 3.14 - Cutting and time modes

№ P.I	Position	Calculation of cutting and time modes								
		D, mm	t, mm	$S_ф$, mm/rev	n, rev/min	$V_ф$, mm/min	$N_ф$, kW	$S_{хв}$, mm/min	L_{PX}, mm	ΣTo, min
1	1, 2, 3, 4	4	2	0,1	2000	25,1	0,19	200	270	0,69
2	2, 3	8,8	4,4	0,15	1000	27,6	0,44	125	371,2	2,8
3	3, 4	10,4	5,2	0,28	710	22,7	0,9	200	240	0,9
4	1	12,4	6,2	0,23	710	27,6	0,75	160	185,6	1,6
5	1	13,6	6,8	0,43	355	15,2	1,04	125	180	1,44
6	2, 3	21,2	6,2	0,2	125	8,32	0,21	25	184	7,36
7	2, 3	21,2	10,6	0,46	250	16,6	1,1	100	160	1,6
8	1	24	12	0,46	250	18,84	2,5	100	156	1,56
9	1	16	1,2	1,5	31,5	1,58	0,53	40	148,5	3,6
10	1, 2, 3, 4	35,2	17,6	0,58	125	13,8	2,5	63	328	2,2
11	1	36	0,4	0,21	125	14,3	0,48	25	40	1,54
12	1	12,8	0,2	0,21	250	10,1	1,08	50	185,6	3,6
13	1	24,8	0,4	0,36	125	9,7	1,28	40	156	3,8
14	3, 4	12	0,8	1,5	31,5	1,19	0,43	40	165,8	2,04
15	3, 4	24	1,4	1,5	31,5	2,37	0,57	40	131	3,24

3.9. Determination of errors of the base of the workpiece.

In order to obtain the required precision of the machined part, it is necessary that the condition is fulfilled:

$$\varepsilon_{б} \le \varepsilon_{доп}; \tag{3.49}$$

$$\varepsilon_{доп} = \delta \times \omega, \text{ mm}, \tag{3.50}$$

where δ - admission of the resulting size to the part;

ω - the accuracy of the machining of the part that is achieved when performing this operation.

$\varepsilon_{б}$ - baseline error.

The part is installed by an external cylindrical surface ∅184h10 on a cone. In such a installation, the error of baseline is equal to half the field of tolerance for the manufacture of a cylindrical surface:

$$\varepsilon_{б} = T_d/2 = 0{,}185/2 = 0{,}0925 \text{ mm}.$$

The tolerance of the diameter of the machined hole is equal δ =0,29 mm, the hole processing error is equal to ω = 0,15 mm. The permissible error of baseline is equal to:

$$\varepsilon_{доп} = 0{,}290 - 0{,}150 = 0{,}140 \text{ mm}.$$

Compare the results: 0,0925 <0,140. Condition 1 is fulfilled, so the required accuracy will be achieved when processing.

3.10. Calculations of the forces of fastening the workpiece.

Determine the required workforce effort and the main dimensions of the power drive, taking into account the following output data:

1. Drawings of the workpiece – case (fig. 3.6).

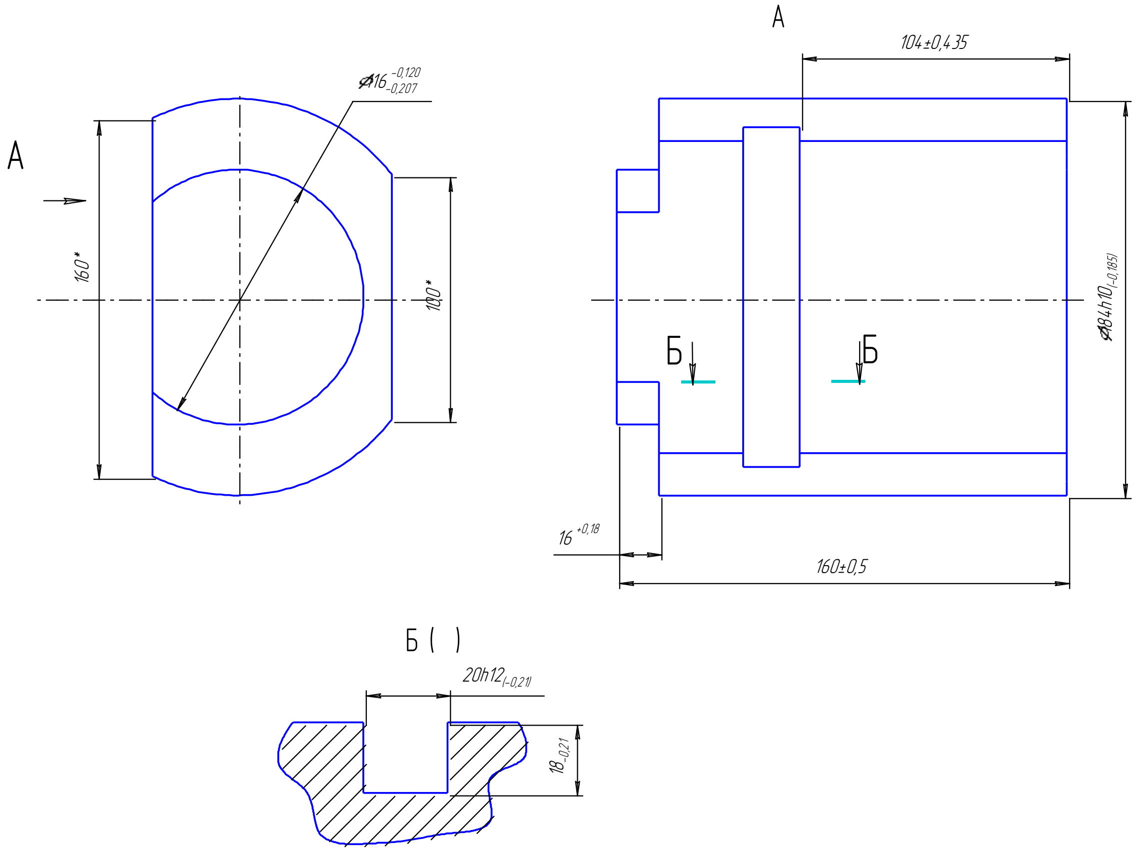


Figure 3.6 - Drawings of the workpiece

– material of the workpiece - steel 45;
– name of operation - coordinate boring with CNC (drilling hole ∅ 24 mm);
– tool - drill ∅ 24 mm, material - Р6М5;
– machine - multipurpose machine ИР800ПМФ4;
– number of simultaneously processed parts - 1.

Passport data of the machine ИР800ПМФ4, [9] p. 48:

1.	The size of the working surface of the table	800 × 800 mm
2.	Moving the table, mm:	
–	Longitudinal	500
–	Transverse	1000
3.	Moving the spindle shaft, vertical, mm	900
4.	Spindle cone	50

5. Spindle rotational speed, min. $^{-1}$ 21,2 - 3000

6. Spindle drive power, kW 22,0

7. Longitudinal, transverse and vertical feed, mm / min. 1 - 2000

8. Accelerated feed, mm / min. 8000 - 10000

9. The largest feed force allowed by the strength of the machine mechanism, N 10000

10. Time of the tool change, c 10,2 - 21,2

11. The largest mass of workpiece, kg 1500

12. Total power of all electric motors, kW 35,0

13. Dimensions, mm:

   – Length 4450

   – Width 4665

   – Height 3100

14. Weight of machine tool, kg 15000

15. The system of numerical control is

16. Number of coordinates coordinated 3

17. Discreteness of the reference on the axes *X*, *Y*, *Z*, мм 0,002

We construct a scheme of forces acting on the workpiece (fig. 3.7).

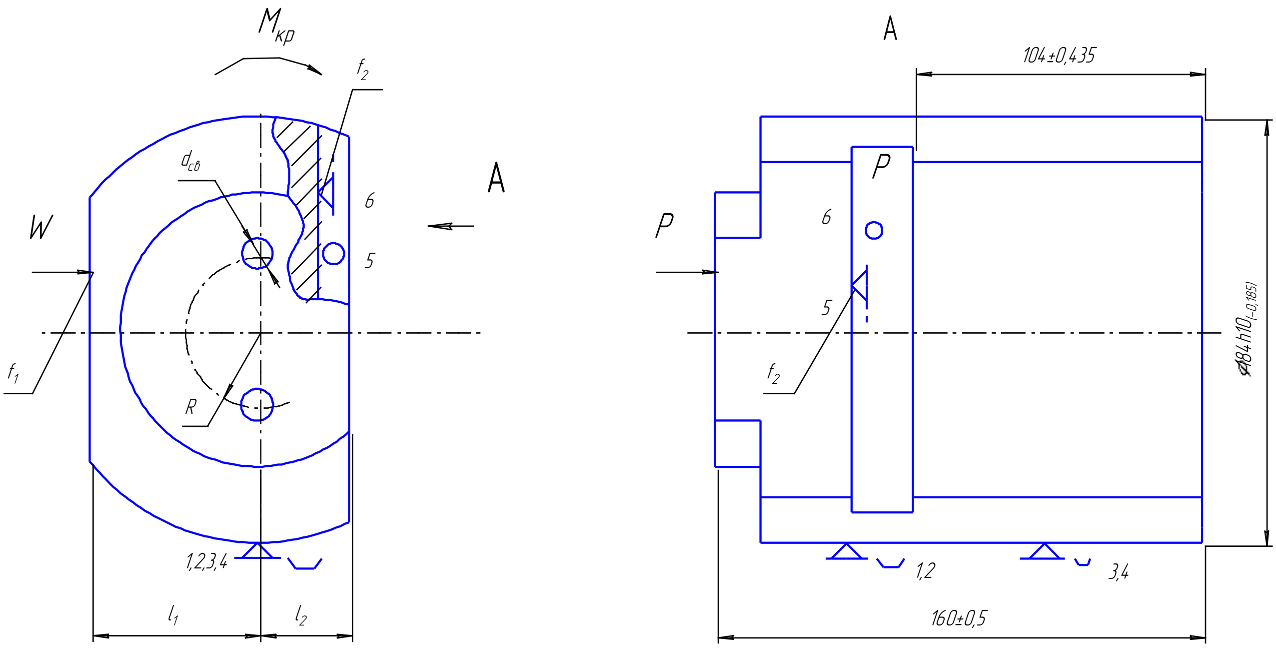


Figure 3.7 - Scheme of forces acting on the workpiece

Cutting modes: cutting depth t = 5.8 mm, feed S = 0.476 mm / rev, drill speed n = 250 rpm, cutting speed V = 18.84 m / min, axial drilling power P_o = 4100 N.

Determine the required force of clamping of the workpiece, [10], p. 208.

In fig. 1.7 it is evident that the displacement moment M_{kp} and axial force P_o are valid for the component. Proceeding from this, we make the equation:

$$K \cdot M_{кр} = f_1 \times l_1 \times W + f_2 \times l_2 \times W + f_2 \times l_1 \times P_o; \qquad (3.51)$$

where M_{kp} is the sliding moment that acts on the workpiece, and is determined by the formulas:

$$M_{кр} = \frac{2 \cdot M_{св}}{d_{СВ}} \cdot (R + \frac{d_{св}}{2}); \qquad (3.52)$$

M_{cb} - the moment that occurs when drilling a hole, M_{cb} = 96.4 N; ·

d_{cb} - diameter of drilling, dsv = 24 mm;

R - the distance from the center of the part to the center of the working hole,

R = 40 mm.

$$M_{кр} = \frac{2 \cdot 96{,}4}{24} \cdot (40 + \frac{24}{2}) = 450 \text{ N·m};$$

f_1 and f_2 - coefficients of friction between the part and the mounting clamping devices; $f_1 = f_2 = 0.15$;

l_1 - distance from the center of the treated hole to the small fox, l_1 = 77,4 mm;

l_2 - distance from the center of the treated hole to the larger fox, l_2 = 46.4 mm;

W – the force of fastening.

So,

$$W = \frac{K \cdot M_{кр} + f_2 \cdot l_1 \cdot P}{f_1 \cdot l_1 + f_2 \cdot l_2}; \qquad (3.53)$$

$$W = \frac{2{,}5 \cdot 450 - 4100 \cdot 0{,}15 \cdot 46{,}4}{0{,}15 \cdot 77{,}4 + 0{,}15 \cdot 46{,}4} = 1459 \text{ N}.$$

The required force of clamping of the workpiece W = 1459 N is calculated.

3.11. Calculate the parts for durability.

We count on the strength of the part at the bend of the axis on which the clamping cam is installed. Material of the axis is - steel 40.

The axle has a flexing force P = 1459 N.

It is necessary to determine the diameter of the axis in order to withstand the load, for this we use the formula:

$$d \geq \sqrt[3]{\frac{M_{зг}}{0{,}1[\sigma]}}, \quad (3.54)$$

where $M_{зг}$ - bending moment acting on the shaft (taken from the curve of bending moments, fig 1.9);

σ - is the yield strength, for steel 40 equals σ = 300 mPa.

We make the equation of equilibrium of a given system without taking into account frictional forces:

$$\Sigma У_i = 0;\ R_A - P + R_B = 0; \quad (3.55)$$

$$\Sigma M_A = 0;\ 39 \times P - 39 \times 2 \times R_B = 0,$$

So,

$$R_B = 0{,}5 \times P = 1459 \times 0{,}5 = 729{,}5 \text{ N};$$

$$R_A = \text{P} - 0{,}5 \times P = 1459 - 0{,}5 \times 1459 = 729{,}5 \text{ N}.$$

We build a diagram of forces acting on the axis and the diagram of bending moments (Fig. 3.8). By formula (3.54) determine the required diameter of the axis:

$$d \geq \sqrt[3]{\frac{131310}{0{,}1 \cdot 300}} = 16{,}2 \text{ mm}.$$

The resulting diameter allows the axis to not deform with the bending force P = 1459 N on it, but in this case we accept a valid diameter of 20 mm.

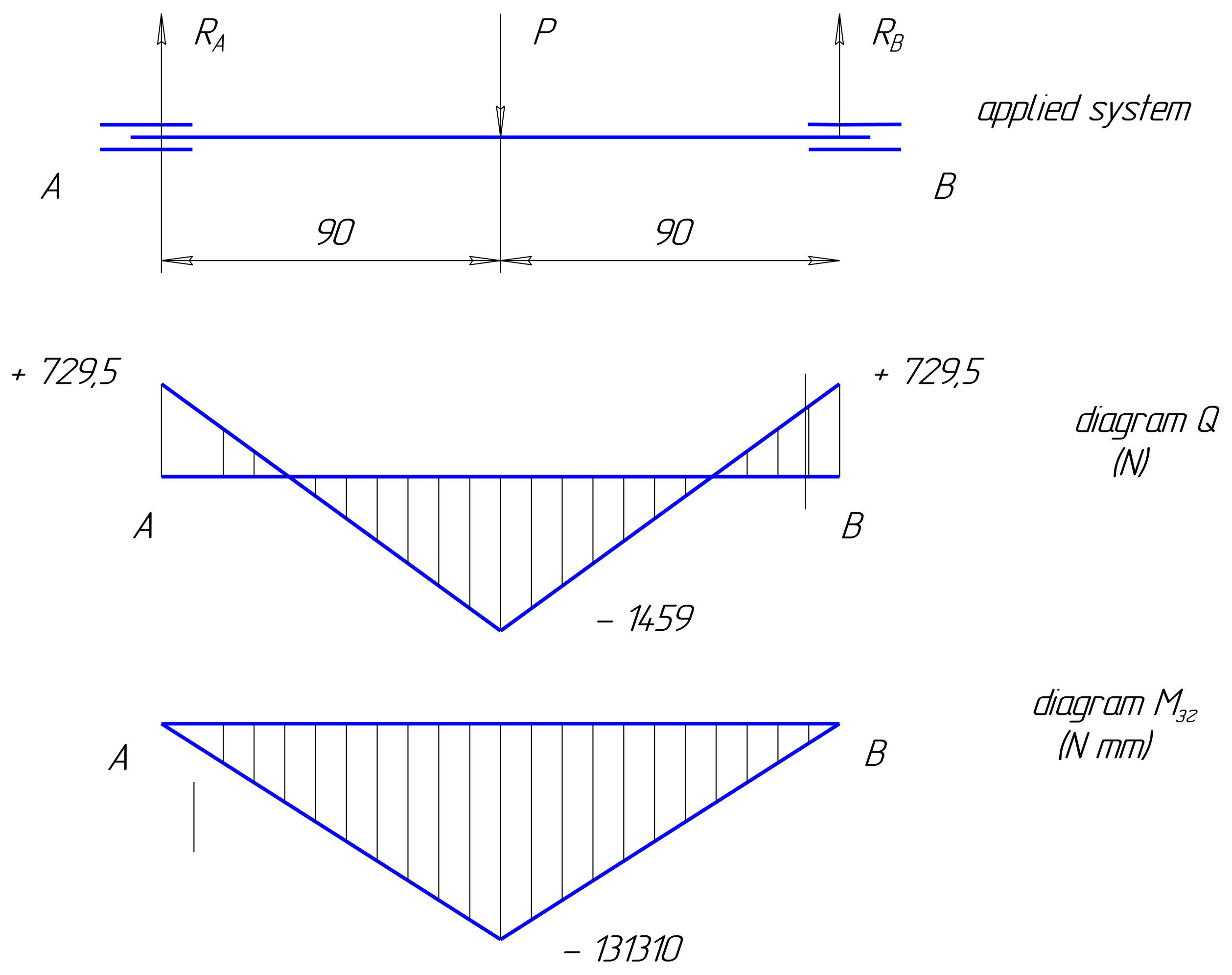


Figure 3.8 - Force curves and bending moments

4. DESIGNING CHAPTER

4.1. The choice of equipment, equipment and bases for the design version of the case.

Due to the need to improve the basic technology in the design process of manufacturing the case, the following changes are introduced, which will significantly improve the technical and economic performance:

By the equipment:

– on operation 005, the cutting machine 8B72A is replaced by KGSP;

– on operation 015, turning-turning machine 16B16K is replaced by a machine 16K40;

– on operation 025, the vertical milling machine 675 is replaced by 6T10;

– The coordinate boring machine 2A430 and radial-drilling machine 2M55 are replaced at the processing center ИР800ПМФ4.

By equipment:

– on operation 015 replace the three-neck patch with a four-bulb;

– a special device for the processing of the part at the processing center has been developed;

– on the operation 025, instead of the universal end cutter, a special cassette cutter mill is used.

Based on:

– the operation 045 and 055 will be replaced by one, accordingly the workpiece base will change.

4.2. Design of machine tool adaptation.

The purpose of the thesis is to create a design of the device, which will provide the necessary accuracy, efficiency and cost-effectiveness of the operation. The adaptation should be simple and cheap in production, convenient at work and high-speed, to satisfy safety engineering and to be reliable in operation.

4.2.1. Description of the design and principle of the selected devices.

It is necessary to design a device for the coordinate-boring operation 045 with CNC. In factory conditions, the part is processed on a versatile machine of model 2A430 in a universal assembly device. The worker in this operation has a 4th level. The use of a special device with a pneumatic actuator creates convenience in operation, increases the stability of the exact parameters.

This device is used for mounting and fixing only case parts, similar to those considered in the thesis.

The item is deprived of six degrees of freedom. There are three technological bases. The double guide - cylindrical surface ∅184h11 relieves the part of 4 degrees of freedom (Fig. 4.1, points 1, 2, 3, 4), the guide base - the groove 20h14 × 18h14, deprives the detail of two degrees of freedom (points 5, 6). The forces of P1 and P2 are applied for fixing the part, oriented perpendicularly to two piles.

Technical characteristics of the device:

The device works at working pressure in the pneumatic network p = 0.4 mPa, the diameter of the rod is 30 mm, the diameter of the diaphragm inside the pneumatic chamber D = 280 mm, the diameter of the reference disk of the diaphragm - d = 196 mm.

Materials of parts: case - СЧ18, a rod - a steel 40, a screw of pressure - steel 45, a capture of a cam - a steel 45.

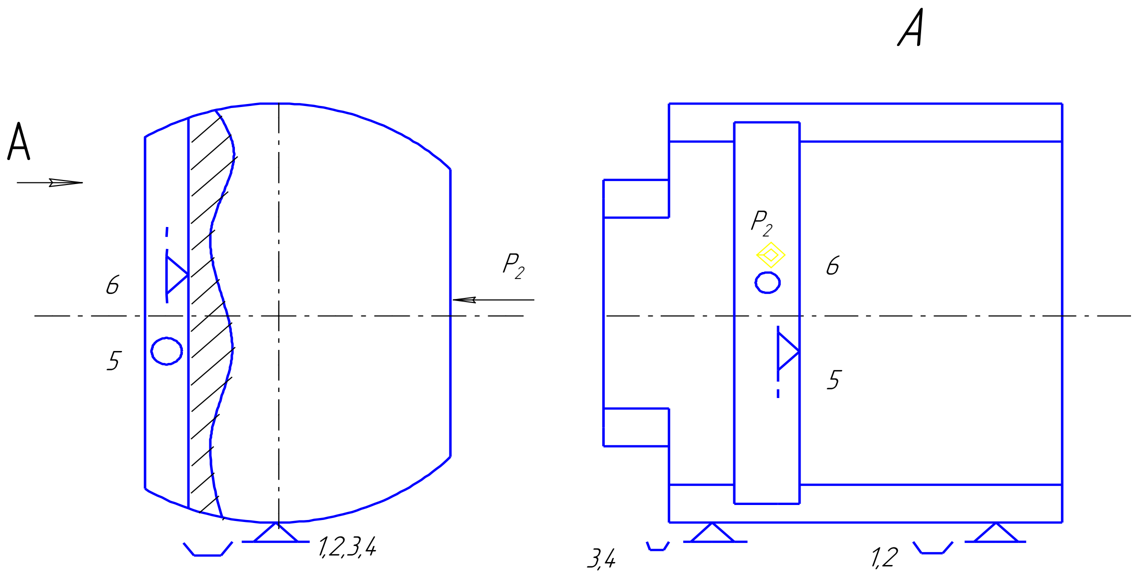


Figure 4.1 - Basing the workpiece in the toolbox

The basic model of the installation and clamping devices of the device is taken from [8], p.107. The main dimensions of the device are listed in the appendix. A large number of other devices that can be used for operation 045 have been suggested as special because it is suitable for the size of the work piece and the strength of the work piece clamping.

4.2.2. Assembly and operation of the device.

The fitting in the assembly must satisfy the technical requirements of the drawing of the general type and ensure the quality processing of the workpiece with specified dimensions.

Preparation of the device.

All parts and components of the device should be subject to visual inspection, defects found to be eliminated.

1. To the case 5 (case stamped) with the help of bolts is attached pneumatic chamber 1.
2. Install axle 8 in housing 5.
3. Put on balancer 7 on axle 8.
4. Insert pusher 12 in sleeve 3.

5. Put the spring 22 on the pusher 12 and fix it with the cover 6 using bolts 15.

6. Attach the camshaft 2 to the housing 5.

7. Use the sleeves to connect the pneumatic motor with the camshaft 10.

8. Prism 11 to install on the case 5, make a precise check, fix with pins 21 and screws 16.

9. Insert the clamping cam 10 into prism 11 and fix its axis 9.

10. Attach the slot 11 to the prism 11 using screws 17.

11. In the clamping cam, insert the pressure screw and secure it with a nut 23.

12. Make verification.

Operation of the device.

1. Install and fix the device on the table of the machine tool, the installation is carried out using the sleeve bushing 4 and the finger 22.

2. Prepare the base surfaces prior to installing the workpiece.

3. Install the workpiece on a cone 11, taking into account that the slot 13, which is fixed to the cone, will enter into the groove on the preform. The cone is a dual guide base, and the slot is the reference base

4. Turn the camshaft handle 2 to fasten the workpiece with the clamping pin 10.

5. Process the workpiece (the workpiece is processed on four sides).

6. Turn the handle of the camshaft 10 in the opposite direction to unpack the workpiece.

7. Prepare the base surfaces of the adjustment before installing the next workpiece.

8. During the operation of the device, comply with p. 2.1 - 2.7 of the technical requirements. The store is stored on a wooden base. Effect of atmosphia precipitation and aggressive environments is inadmissible.

4.2.3. Choice and calculation of power drive.

The main purpose of the power drive in the adaptation is to create the output force necessary for the clamping of the workpiece by the force of *R*.

The power unit of the drive is a converter of the output energy in the mechanical, necessary for the operation of clamping mechanisms. The output energy in pneumatic actuators is the energy of compressed air. The pneumatic actuator is widely used in adaptations due to its speed (operation speed - fraction of a second), simplicity of design, simplicity of management, reliability and stability in work.

The pneumatic actuator consists of the following parts: a compressed air source - an ordinary cement or factory compressor; power unit - pneumatic engine (pneumatic chamber), which converts the energy of compressed air into force on the stock.

In one design with a device, a pneumatic engine is assembled. Other devices are placed outside the device, with the help of air ducts they connect to the device.

By the source of the energy of reverse - a one-way drive, in which the working course is made by compressed air, and the idle - by the force of the spring. Drives of a one-sided action are used when there is no need for a large stroke of the rod and in the reverse process does not require large force to remove the clamping elements in the original position [11] p. 57.

Determine the actual force on the stock of the pneumatic chamber. Consider the lever mechanism of the device and the forces acting on fig. 4.2.

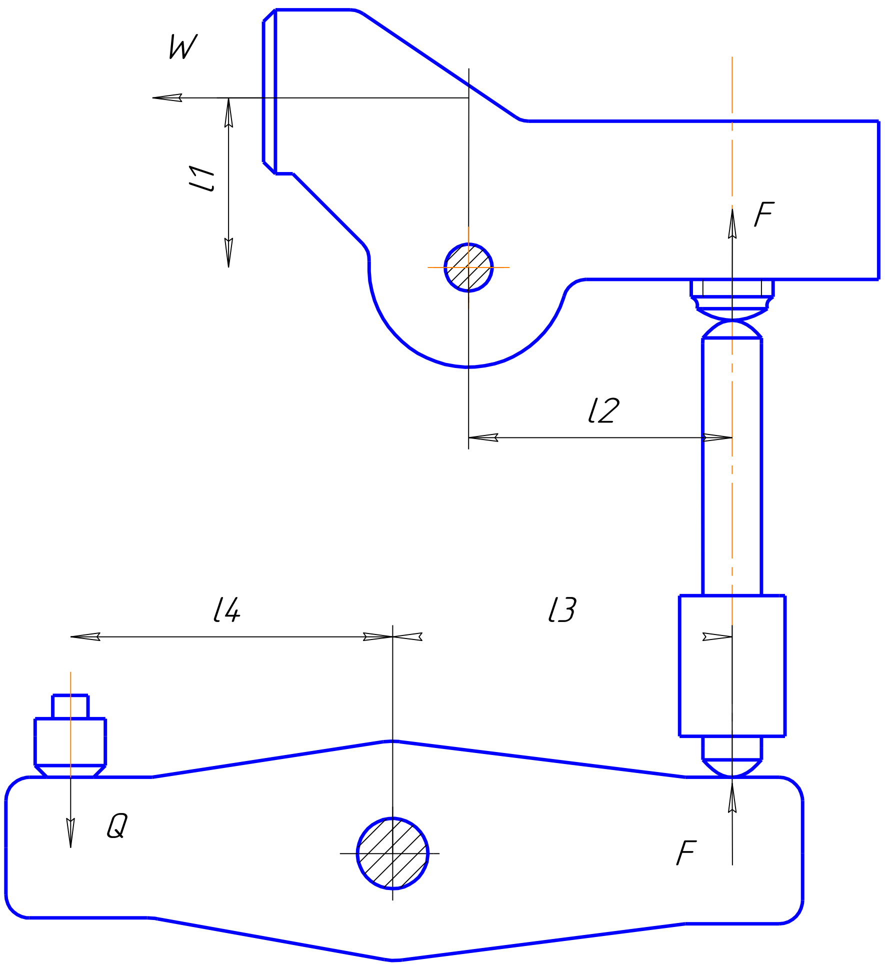


Figure 4.2 - Lever mechanism of adjustment

We break the lever mechanism into two parts. We form an equilibrium equation for the first part:

$$\Sigma M_o = 0;\ Q \times l_4 + F \times l_3 = 0; \tag{4.1}$$

and

$$F = -Q\frac{l_4}{l_3}, \tag{4.2}$$

where F – force acting on the pusher, N;

l_4 - distance between the axle of the rod and the axle of the ramp, l_4 = 53 mm;

l_3 - distance between the axle of the pusher and the axle of the ramp, l_3 = 53 mm.

Construct the equation for the second part of the lever mechanism:

$$\Sigma M_o = 0;\ W \times l_1 + F \times l_2 = 0; \tag{4.3}$$

where W - required force of clamping of workpiece, W = 1459 N;

l_1 - distance between the axis of the clamping cam and the clamping force,

l_1 = 60 mm;

l_2 - distance between the axis of the clamping cam and the pusher axle, l_2 = 90 mm.

Comparing equations (4.2) and (4.3), we obtain the formula for calculating the actual force on the stroke of the pneumatic chamber:

$$Q = W\frac{l_2 \cdot l_4}{l_1 \cdot l_3}; \quad (4.4)$$

$$Q = 1459\frac{90 \cdot 60}{60 \cdot 53} = 2478 \text{ N.}$$

Determine the diameter of the diaphragm inside the pneumatic chamber, using the formula [11], p. 94:

$$W = \frac{\pi}{3}(D - d)^2 p - Q_1; \quad (4.5)$$

where D - diaphragm diameter inside the pneumatic chamber, mm;

d - diameter of the diaphragm support disk; d = 0,7D, mm;

p - compressed air pressure, p = 0,4 mPa;

Q_1 - resistance of the return spring at the final position of the spring, Q_1 = 200 N.

The diameter of the diaphragm inside the pneumatic chamber, based on formula (4.5), is equal to:

$$D = \sqrt{\frac{(Q + q_1) \cdot 3}{\pi \cdot p \cdot 0{,}09}}, \text{ mm}; \quad (4.6)$$

$$D = \sqrt{\frac{(2478 + 200) \cdot 3}{3{,}14 \cdot 0{,}4 \cdot 0{,}09}} = 266 \text{ mm.}$$

Accordingly, the diameter of the aperture taken 280 mm, therefore the diameter of the support disc of the diaphragm is equal to 196 mm.

The determined force exceeds the required force of clamping of the work piece; therefore, the device provides a fixed position of the part during machining.

In the proposed adaptation, a standard pneumatic actuator was used, in which the diameter of the diaphragm inside the pneumatic chamber is 280 mm, the diameter of the reference disk of the diaphragm is 196 mm, the diameter of the rod is 30 mm. The maximum force occurring on the drive rod is 2477 N, and the force of the clamping blade, which provides the device, is 1459 N.

4.3. Design of cutting and measuring tools.

4.3.1. Design of cutting tool.

For the milling of two fingers on the vertical milling operation 025 on the machine 6T13 there is a need for designing a cutting tool. To reduce the basic processing time, choose a two-stage cutter fitted with solid alloy inserts. The first stage of the inserts - from the solid alloy T5K10, the second - T15K6.

Output: Material - steel 45, hardness - 1900-1930. The milling width is 160 mm. Processing tolerance h = 3 mm. The treatment is carried out on a vertical milling machine 6T13 with an electric motor of 11 kW. The work piece is fastened in the device of increased rigidity.

Cutting modes: t = 3 mm; Sz = 0,18 mm/tooth, V = 197,8 m/min., T = 30 min.

Diameter of the hole for the mandrel will be determined by the formula:

$$d = \sqrt[3]{\frac{M_{сум}}{0{,}1\sigma_{з.д}}}, \qquad (4.7)$$

where $M_{сум}$ - total moment when bending and twisting the mandrel, N·m;

$\sigma_{з.д}$ - permissible pressure to bend the material of the mandrel, we accept $\sigma_{з.д}$= 250 mPa.

Total moment equals:

$$M_{сум} = \sqrt{M_{зг}^2 + M_{кр}^2}; \qquad (4.8)$$

where $M_{зг}$ - the bending moment acting on the cutter mill is calculated by the formula:

$$M_{зг} \frac{3}{16} Pl, \qquad (4.9)$$

where P- equivalent forces during milling, calculated by the formula:

$$P = 1{,}411 \times P_z; \qquad (4.10)$$

l - shoulder force action;

$M_{кр}$ - the torque acting on the aperture under the milling cutter, is determined by the formula:

$$M_{кр} = \frac{P_z \cdot D}{2}; \qquad (4.11)$$

where D - milling cutter diameter;

P_z - the main component of cutting power during milling, is determined by the formula:

$$P_z = \frac{9{,}81 \cdot C_p \cdot t^{xð} \cdot S_z^{yð} \cdot B \cdot z}{D^{qð}}, \qquad (4.12)$$

where C_P - coefficient of specific processing conditions (C_P = 68,2; table 41, [4]);

x, y, q - scores of stamps (*x*= 0,86; *y* = 0,72; *q* = 0,86).

By formula (4.12) we define P_z:

$$P_z = \frac{9{,}81 \cdot 68{,}2 \cdot 3^{0{,}86} \cdot 0{,}18^{0{,}72} \cdot 160 \cdot 16}{200^{0{,}86}} = 13456{,}4 \text{ N}.$$

By formula (4.11) determine the torque acting on the hole under the milling cutter:

$$M_{кр} = \frac{13456{,}4 \cdot 200}{2} = 1345{,}6 \text{ N·m.}$$

By formula (4.10) we define the one-way forces:

$$P = 13456{,}4 \times 1{,}411 = 18986{,}9 \text{ N.}$$

By formula (4.9) determine the bending moment acting on the hole under the mandrel:

$$M_{изг} = \frac{3}{16} \cdot 18986{,}9 \cdot 41 = 146 \text{ N·m.}$$

The total moment is determined according to the formula (4.8):

$$M_{сум} = \sqrt{1345{,}6^2 + |146^2} = 1353{,}5 \text{ N·m.}$$

The diameter of the mill cutter will be determined by the formula (1.67):

$$d = \sqrt[3]{\frac{1353{,}5}{0{,}1 \cdot 250 \cdot 10^6}} = 0{,}038 \text{ m.}$$

The required diameter of the hole for the mandrel, which is equal to 38mm, is calculated, but we accept the diameter of the hole at the mandrel of 50 mm in accordance with the State Standard 27066 -96.

4.3.2. Calculations of the measuring instrument.

In the proposed technological process for calculations adopted a smooth one-sided two-limit plug gage to control the size of the part 116d9 ($^{-0{,}120}_{-0{,}207}$) (external cylindrical surface), [12], p. 31.

Limit calibers are used to check the size of smooth cylindrical, tapered, threaded and slotted parts, the height of the protrusions and the depth of the cavities, if the checked size is set to tolerance, not precise IT6. The advantages of calibers are durability, as well as simplicity and fairly high performance control. Despite a number of shortcomings (the complexity of manufacturing and adjusting the caliber, etc.), the limit caliber is used in mass, large-scale and individual production. Often, limiting calibers are used to control cylindrical shafts and openings.

Scheme of calculations of working and control calibers are selected for [12]. The same standard gives tolerances for the manufacture of calibers, µm (mm):

$$Z_1 = 15\ (0{,}015),\ H_1 = 10\ (0{,}01),\ H_P = 4\ (0{,}004).$$

Boundary shaft dimensions:

$$d_{min} = d_{ном} + e_i; \qquad (4.13)$$

where e_i - lower deviation;

$$d_{min} = 116 + (-0{,}120) = 115{,}793 \text{ mm};$$

$$d_{max} = d_{ном} + e_s; \qquad (4.14)$$

where e_s - lower deviation;

$$d_{max} = 116 + (-0{,}207) = 115{,}880 \text{ mm}.$$

The dimensions of the new working caliber stacplug gage:

$$P - ПP_{max} = d_{max} - Z_1 + H_{1/2}; \qquad (4.15)$$

$$P - ПP_{max} = 115{,}880 - 0{,}015 + 0{,}005 = 115{,}870 \text{ mm};$$

$$P - ПP_{min} = d_{max} - Z_1 - H_{1/2}; \qquad (4.16)$$

$$P - ПP_{min} = 115{,}880 - 0{,}015 - 0{,}005 = 115{,}860 \text{ mm}.$$

The smallest size of the worn working plug gage:

$$P – ПР_{зн} = d_{max} - H_p /2; \quad (4.17)$$

$$P – ПР_{зн} = 115,880 - 0.002 = 115,878 \text{ mm.}$$

The dimensions of the new plug gage:

$$НЕ_{max} = d_{min} + H_{1/2;} \quad (4.18)$$

$$НЕ_{max} = 115,793 + 0,005 = 115,798 \text{ mm;}$$

$$НЕ_{min} = d_{min} - H_{1/2}; \quad (4.19)$$

$$НЕ_{min} = 115,793 - 0.005 = 115,788 \text{ mm.}$$

The dimensions of the control plug gage are equal:

$$К - ПР_{max} = d_{max} - Z_1 + H_P/2; \quad (4.20)$$

$$К - ПР_{max} = 115,880 - 0,015 + 0,002 = 115,867 \text{ mm;}$$

$$К - ПР_{min} = d_{min} - Z_1 - H_P/2; \quad (4.21)$$

$$К - ПР_{min} = 115,880 - 0,015 - 0,002 = 115,863 \text{ mm.}$$

Dimensions of control passage of worn-out plug gage:

$$К\text{-}ПР_{зн\ max} = d_{max} + H_P/2; \quad (4.22)$$

$$К\text{-}ПР_{зн\ max} = 115,880 + 0,002 = 115,882 \text{ mm.}$$

The minimum control length of the gauge-bracket coincides with the least passable wear dimension, is equal to $К\text{-}ПР_{зн\ min}$ = 115,878 mm.

The dimensions of the control impenetrable plug gage are:

$$К - НЕ_{max} = d_{min} + H_P/2; \quad (4.23)$$

$$К - НЕ_{max} = 115,793 + 0,002 = 115,795 \text{ mm;}$$

$$К - НЕ_{min} = d_{min} - H_P/2; \quad (4.24)$$

$$К - НЕ_{min} = 115,793 - 0.002 = 115,791 \text{ mm.}$$

Scheme of tolerance fields of the calculated plug gage is shown on fig.4.3.

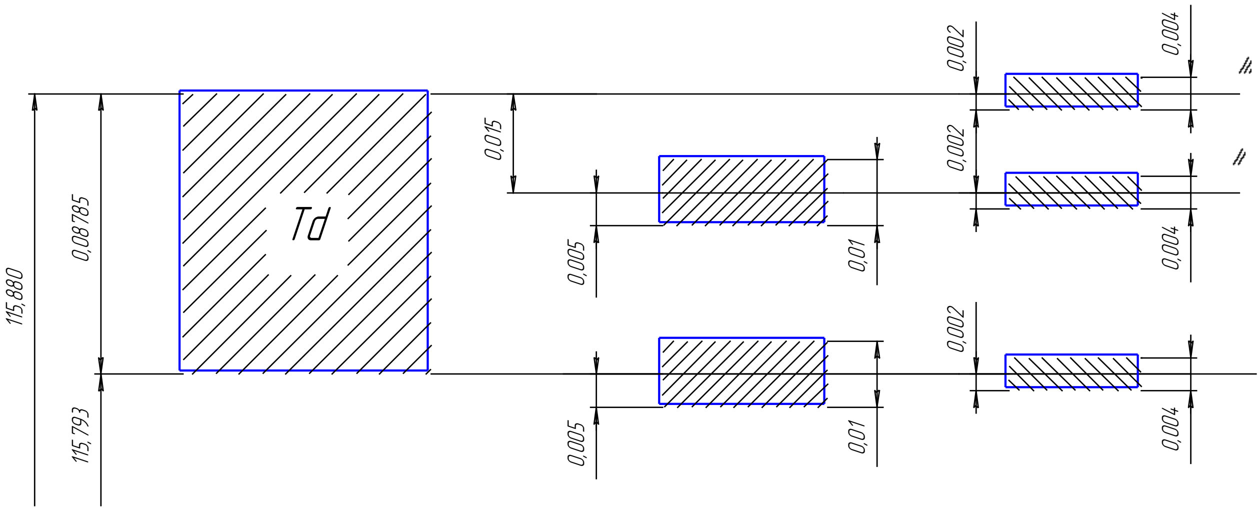


Figure 4.3 - Scheme of tolerance fields of the calculated plug gage

4.4. Means of increasing the technological indicators of coordinate-boring operation 045 with CNC.

The choice of the lubricating and cooling technological environment for the coordinate-boring operation 045 with CNC is based on the fact that this operation is carried out the processing of openings on all sides of the part. Perform a selection of coolant for drilling holes in steel 45 drills made of high speed steel P6M5.

The purpose of coolant application is to reduce the wear of the cutting tool, to improve the quality of the surface to be treated and to increase productivity. It is possible to achieve this by directing the influence on elementary physical, mechanical and chemical processes when cutting metal by appropriately selecting the basis of coolant (water, mineral oils, etc.), the introduction of additives in coolant with the necessary complex of chemical and mechanical and chemical properties, the regulation of conditions for the supply of coolant to the cutting zone etc.

Cooling effect. In most cases, cooling reduces the wear of the cutting tool and improves the quality of the treated surface. This pure effect is used in those technological processes where cold air or carbon dioxide is used as a cooling agent.

The direct cooling characteristics of the coolant are influenced not only by the heat and thermal conductivity, but also by the ability of the coolant to wet the metal surfaces and the vaporization, since at high cutting speeds and temperatures the liquid may not come into direct contact with the surface of the tool due to low wettability or the formation of a steam cushion. For this reason, there is no direct correlation between the thermo physical properties of coolant and its cooling capacity.

However, cooling is not always conducive to a positive effect. For example, when using coolant on the basis of mineral oil and water emulsion, it turned out that the number of openings that can be drilled by this drill until it dies in the first case is an order of magnitude greater than that of the second coolant, although the temperature was thus 280 ° and 101 ° C respectively. Sometimes In order to create conditions for hot metal processing, the temperature in the cutting zone is specially enhanced with the help of external heat sources.

But in most cases, the improvement of the cooling characteristics of the coolant is desirable. An obvious way to increase the cooling capacity of the coolant is to transfer it to the water base, that is, the creation of coolant in the form of real water solutions - synthetic coolant [13], p. 171.

The basics of the choice of coolant should be based on the fact that, on the one hand, the goals to be achieved as a result of the application of coolant are formulated, and, on the other hand, the conditions for carrying out cutting operations are taken into account.

The main purposes of application the coolant:

1. Improving the technological performance of cutting operations.

2. Improvement of economic performance of operations: increasing the stability of the tool and reducing its costs by reducing the intensity of wear, the coefficient of stability variation; increase in labor productivity in operation as a result of increased feed and cutting speed.

3. Improvement of working conditions by reducing the content of metal dust in the premises of the workshop area; lowering the temperature of the processed workpiece, improving the chip formation and chips.

When drilling steel 45 the impact of coolant on wear and the stability of the drill is generally the same as in the 40X steel treatment. The distinguishing feature is that at high cutting speeds, water-borne coolant provide a ten-fold increase in drill stability than oil, which can increase the cutting speed (while maintaining the stability of the tools) in 1, 5 times (fig. 4.4).

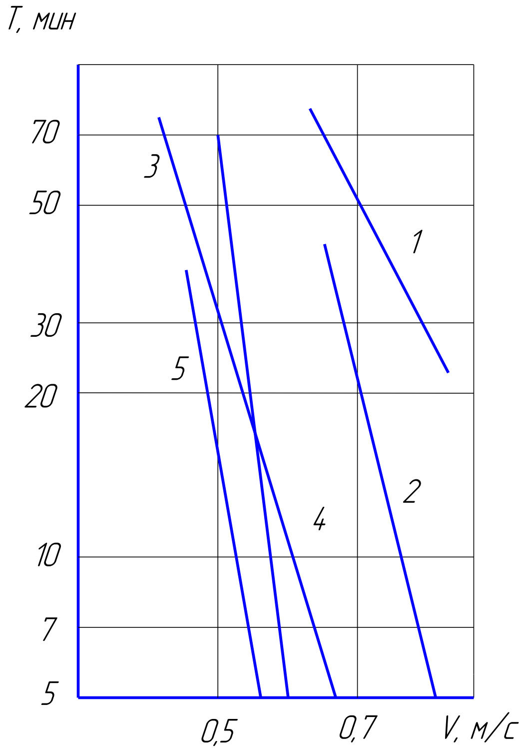


Figure 4.4 - Dependence of the stability of the drill *T* on the steel P6M5 on the cutting speed *V* for machining steel 45
1 – Akvol -2, Akvol -10; 2 – ET-2; 3 – MP-1; 4 – И-12A; 5 – on air without coolant

The greatest stability was obtained when working with synthetic coolant Akvol-10 (3%) and emulsions Akvol-2 (5%) and Akvol-6 (5%). In this case, the stability is 2.5-5 times higher than when working with emulsions ET-2 (5%) and Ukrinol-1 (3%). Tested oil samples MR-1v, OSM-3 and sulfofresol have approximately the same technological properties in the range of cutting speeds of 0.5-0.7 m / s.

I-12 A lubricant without additives, providing cutting speeds 0,5-0,6 m / s the same stability of the drill with other lubricating liquids at accelerated speeds (more than 0,6 m / s), causes a decrease in stability in 3 times. In these regimes, coolant is effective, which consists of a mixture of 5% MP-99 + I-12A and 5% MP-8 + I-12A, which significantly increases the durability of drills compared with MP -1 in 1, 5-2 times. For the steel grade 45, when drilling holes, it is recommended to use synthetic ZOR Akvol-10 (3%) or emulsion Aquvil-2 (5%) and Akvol-6 (5%).

5. SPECIAL CHAPTER

5.1. Subsystems of optimization in CAD.

In the modern production, computer-aided design (CAD, computer aided design) systems have been widespread that allow designing technological processes with less time and money, with increased accuracy of designed processes and processing programs, which reduces the cost of materials and processing time, due to the fact that Processing modes are also calculated and optimized using a computer.

Technical support for CAD is based on the use of computing networks and telecommunication technologies, personal computers and workstations.

Mathematical support of CAD is characterized by a variety of methods of computational mathematics, statistics, mathematical programming, discrete mathematics, artificial intelligence.

Software complexes CAD are among the most sophisticated modern software systems based on operating systems Unix, Windows, programming languages Java and other, modern CASE technologies, relational and object-oriented database management systems (DBMS) , standards for open systems and data exchange in computer environments.

Design, in which all design decisions or their part are obtained by the interaction of a person and a computer, are called automated, in contrast to manual (without the use of a computer) or automatic (without the participation of the person at intermediate stages).

A system that implements automated design, is a system of automated design (in English-language CAD system - Computer Descriptor System).

CAD (or CAD) is commonly used in conjunction with automation systems for engineering calculations and analysis of CAE (Computer-Aided Engines). Data from CAD systems is transmitted to CAM (Computer-Aided Manufacturing) - an automated software development program for machine tools.

CAE - automated design, the use of special software for engineering strength analysis and other technical characteristics of components made in automated design systems. The programs of automated design allow to carry out dynamic modeling, checking and optimization of products and their means of production.

CAM - automated production. The term is used to designate software whose primary purpose is to create programs for controlling CNC machines (numerical control). The input data of the CAM-system is a geometric model of the product, developed in the system of automated design. In the process of interactive work with a three-dimensional model in the CAM system, the engineer determines the trajectories of the motion of the cutting tool for the preparation of the product, which are then automatically verified, visualized (for visual verification of the correctness) and processed by the postprocessor to obtain a program management specific machine.

CAD structure: CAD consists of a design and service subsystem. Projecting subsystems directly execute design procedures. Examples of designing subsystems can be subsystems of geometric three-dimensional modeling of mechanical objects, manufacturing design documentation, circuit design analysis, tracing connections in printed circuit boards.

Servicing subsystems ensure the functioning of designing subsystems, their collection is often referred to as the system environment (or shell) CAD. Typical maintenance subsystems are PDM (Product Data Management), Design Process Management (DesPM - Design Process Management), User Interface for Developers with Computer, CASE (Computer Aiftware Software Engeneering) for software development and maintenance CAD, training subsystems for the development of users of technologies implemented in CAD.

To date, a large number of software and methodical complexes for CAD have been created with varying degrees of specialization and applied orientation. As a result, automation of design has become a necessary part of the training of engineers of various specialties; an engineer, who does not have the knowledge and does not know how to work in CAD, can not be considered a full-fledged specialist.

5.2. Review of the most common CAD of world manufacturers.

AutoCAD is the most famous product of Autodesk, a universal automated design system that combines the functions of a two-dimensional drawing and three-dimensional modeling. Appeared in 1982 and was one of the first CAD designed for PC. It quickly gained popularity among designers, engineers, and designers of various industries. Thanks to democratic prices.

AutoCAD accelerates daily work on creating drawings and increases the speed and accuracy of their execution. The environment of conceptual designing provides easy and intuitive creation and editing of solids and surfaces. AutoCAD allows you to quickly and easily create drawings and projections based on the model of the model, effectively create and manage the sets of drawings: group them by sections of the project and other logical categories, create lists of sheets, manage the types of drawings, archive project design kits and organize joint work of specialists. Available in AutoCAD visualization tools, such as animation and realistic toning, help to identify any faults in the early stages of design.

The DWG format used in AutoCAD is the standard among designers of various industries, besides, it has the ability to export and import other widely used file formats, such as pdf, to effectively organize the data exchange between experts.

The program is constantly evolving, among the possibilities that have appeared in recent times; one can name parametric interconnections between objects, create and edit free-form objects, etc.

There are specialized industry varieties of AutoCAD for architecture, road construction and land management, electrical engineering, mechanical engineering, etc. For professionals who do not need 3D graphics functionality, there is the lightweight version of AutoCAD designed for creating two-dimensional drawings - AutoCAD LT.

Autodesk solutions for industrial production and machine building are based on the technology of digital prototypes, that is, give designers, engineers, designers and technologists the opportunity to fully explore the product at the design stage. With the help of this technology, manufacturers create digital models and designs, construct, test, optimize and manage them at all stages - from idea to real implementation.

AutoCAD Mechanic is AutoCAD's product for industrial production, part of Autodesk's digital prototype technology. It helps to accelerate the design process, while at the same time letting you use the experience and projects you've accumulated when working in AutoCAD. With its DSTU libraries, standard parts and functions for automation of typical tasks, it provides a significant performance gain in design.

AutoCAD Electrical is AutoCAD for designing electric control systems, an integral part of Autodesk's digital prototype technology, and allows you to work quickly, efficiently and with significantly lower costs in a familiar design environment. Specialized functions and large libraries of conditional notations can increase productivity, eliminate the risk of errors and ensure the accuracy of information transmitted to production.

AutoCAD Inventor Suite is a balanced suite of Autodesk solutions for design and engineering in industrial production. The solutions combine the intuitive environment of 3D modeling of parts and products with tools, allowing designers to focus on the functional requirements of the project. These tools include the automatic creation of intelligent components, such as plastic parts, steel frames and rotary mechanisms.

CATIA is an automated design system for the French company Dassault Systems. CATIA V1 was announced in 1981. At the moment, the world uses two versions - V4 and V5, which vary considerably among themselves. CATIA V4 was announced in 1993 and was created for Unix-like operating systems, CATIA V5 was announced in 1998, and it's the first version that can run under Microsoft. According to Dassault Systems, CATIA V5 was written "from scratch" and embodies advanced CAD technologies. At first CATIA V5 was not particularly popular on the market and to stimulate its use, Dassault Systems introduced the concept of PLM (Product Lifecycle Management). The idea of PLM was successful and picked up almost the entire CAD industry. In February 2008, Dassault Systems announced a new version of the CATIA V6 system. The V6 will support simulation programs for all engineering disciplines and collaborative business processes throughout the product lifecycle. The new concept of the company was named "PLM 2.0 on the platform V6". The essence of the concept - three-dimensional simulation and teamwork in real time, for communication between people located in different parts of the world, provided means of easy connection to the Web. PLM 2.0 is a new approach that opens up the ability to use intelligent online interactions. Each user can invent, develop products and share information in a universal 3D language. Users will be able to visualize both virtual and real objects at the same time.

Pro / Engineer - CAD system of high level. Contains all the necessary modules for solid-state modeling of parts and drawing drawing documentation. Has built-in capabilities for designing welded structures.

SolidWorks is a product of SolidWorks Corporation, an automated design system in three dimensions, run by Microsoft Windows. It was developed as an alternative for two-dimensional CAD programs. It gained popularity with a simple interface. The main product SolidWorks includes tools for 3D modeling, drawing drawings, sheet metal work, welded structures and surfaces of arbitrary shape. It is possible to import a large number of 2D and 3D CAD files. There are APIs for programming in the Visual Basec and C environment. Also included is a CosmosXpress entry-level endpoint analysis program.

ADEM (Automated Designe Engeneering Manufacturing) - Russian integrated CAD / CAM / CAPP system designed for automation of design and technological preparation of production (CTI). ADEM was created as the only product that includes tools for designers and designers (CAD), technologists (CAPP) and computer software processors (CPP). Therefore, it contains several different subject-oriented CADs under a single logic of management and a single information base. ADEM allows you to automate the following types of work:

3D and 2D modeling and design registration of design and technological documentation; design of technological processes; analysis of the technological and project valuation hardware programming. ADEM is used in various fields: aerospace, atomic, aerospace, machine-building, metallurgical, machine tool and others.

BCAD - 2- and 3-dimensional automated design system, developed by the Russian company "PROPRO Group". BCAD is an integrated package for two-dimensional drawing, 3D modeling and realistic visualization. The system has become widespread in machine building and interior design. Despite the very advanced design tools, the industry is practically not used.

T-FLEX CAD - a computer-aided design system developed by Top Systems, with the capability of parametric modeling and the availability of design documentation to meet the standards of the ESKD series (Unified Design Documentation System). T-FLEX CAD is the core of the T-FLEX CAD / CAM / CAE / CAPP / PDM complex - a set of tools for solving technical training tasks in various industries. The complex combines systems for design and technological design, modules for training programs for machine tools and engineering calculations. All programs of the complex function on a single information platform of the system of technical document management and warehousing of products.

KOMPAS is an automated design system developed by the Russian company ASKON with the possibility of designing design and engineering documentation in accordance with the standards of the series ESKD and SPDB (System design documentation for construction). There are two versions: Compass-Graph and COMPASS-3D, respectively designed for flat drawings and 3D design.

MechanicCS is an application to AutoCAD or Autodesk Inventor, designed for drawing drawings according to ESKD, design of systems of hydro-pneumatic elements, gears, shafts, engineering analysis, calculation of dimensional chains, creation of user libraries.

MechanCC provides a specialist with all the necessary engineering design objects: more than 1500 standards (including DSTU, OST, DI and ISO) and unified components, the ability to create their own intellectual objects, perform engineering calculations to display results on the model, draw projection drawings on ESKD and much more.

Mechanic CS gives designers the opportunity to apply not only geometric parameters of standard elements, but also their mechanical properties. For objects in assembly drawings (when using AutoCAD) geometric and parametric dependencies can be imposed; use of predefined dependencies when placed on the drawing.

5.3. Methods of designing technological processes for manufacturing parts using the package of applied programs "CCI CAD".

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 of manufacturing parts.

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 may include descriptions of technological equipment, devices, control and measuring instruments, as well as devices used in assembly operations.

The technological process, as an element of the CAD information provision, is a sequential description of operations made up of permanent parts.

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 processes 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.

For forming the route of machining the part, a complete description of the part (coding) is required with the means of any formalized language. 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 a simple part of a technologist, it's easier and faster 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.

The following output information is required for the development of the technological process of mechanical processing using the "TechnoPro" PPP:

1. Working drawing parts, technical specifications for the manufacture.
2. Basic process of manufacturing parts.
3. Typical technological process, executed on the forms of route technological cards.
4. Variable information, executed in the form of tables 5.1, 5.2.

Table 5.1 – General details of the item

Name of manufacturing process	Part		
	Marking	Name	Weigth
TSF 8.171.137	TSF 8.171.137	Case	16,5
Material	Заготовка		
	Type	Profile	Weigth
Steel 45	Rolled stock	Complex profile	30

Table 5.2 - Output information for automated design manufacturing process of the case

Name of surface	Quantity	Class of accurace	Roughness, mkm
Outside:			
1. Cylindrical surface ∅184mm	1	h10	3,2
2. Cylindrical surface ∅116mm	1	d9	3,2
Inside:			
1. Hole M12-7H	6	H7	3,2
2. Hole M16-7H	2	H7	3,2
3.Stepped hole.			
1 - step:			
cylindrical surface ∅36mm	2	H14	3,2
face *l* = 168-58mm	2	H14	1,6
2 - step:			
cylindrical surface ∅24,8mm	2	H12	3,2
face *l* = 58mm	2	js11	1,6
3 - step:			
cylindrical surface ∅12,8mm	2	H12	3,2
4 - step:			
cone 60°	4	H17	1,6
5 - step:			
hole M24-7H	4	h12	3,2
Linery:			
1. Face *l* = 16mm	1	h12	3,2
2. Face *l* = 160mm	2	js14	3,2
3. Face *l* = 124mm	2	js14	3,2
4. Groove *b* = 20mm *h* = 18mm	1	js12	3,2
	38	408	115,2

5.3.2. Block diagram of the algorithm for automated design of the process of manufacturing the case.

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.

The 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 to the end of the document takes place.

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

After analyzing the technological process of mechanical processing of the "case of the TsF 8.171.137", obtained with the help of CAD TP, we conclude that the construction of operations and the choice of technological bases are carried out correctly. In this technological process, the part is processed in one operation, during which there is a sharpening of the external and internal surfaces, as well as drilling holes. In the future, they carry out control of its surfaces, and then rinse it and transport this item to the assembly site.

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.

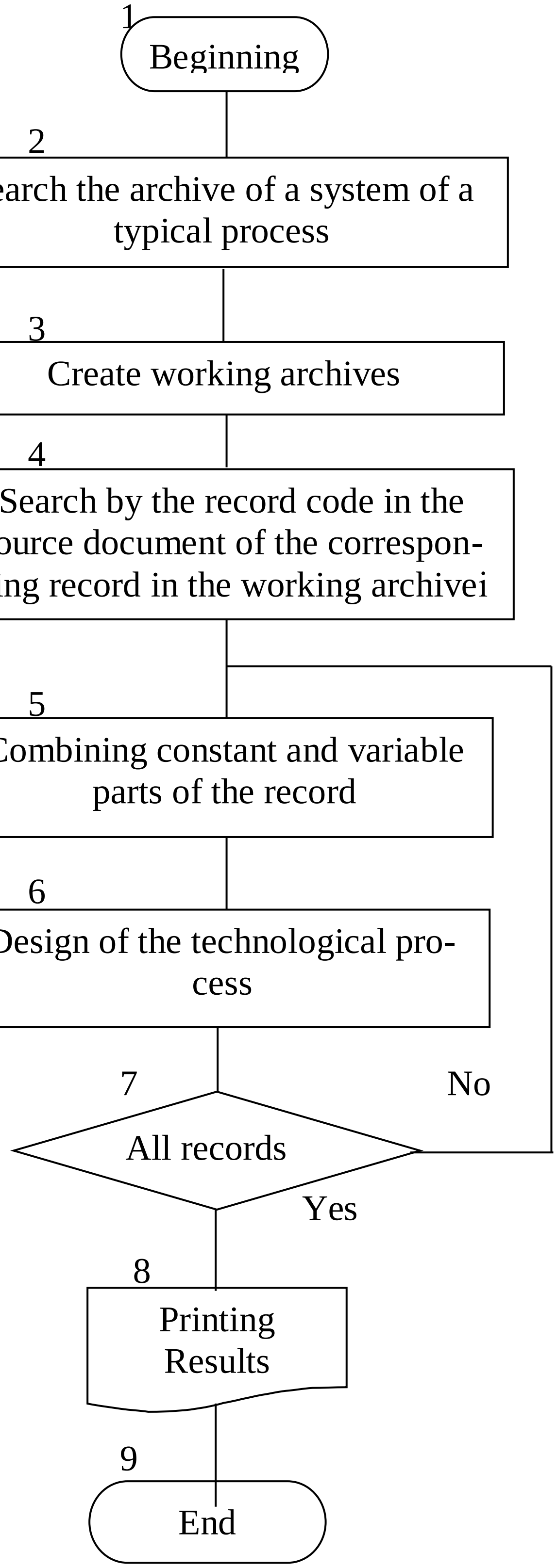


Figure 5.1 - Block diagram of the algorithm of the design subsystem of CCI CAD

6. PLANNING CHAPTER

6.1. Determination of annual needs in technological equipment. Build summary hardware.

In the middle of average production the number of equipment and equipment required is calculated by the types of equipment:

$$n_p = \frac{T_p}{\Phi_{\partial o} \cdot K_{\textit{в}}},$$

where T_p – annual labor work capacity of this type of machine tools, h.;

$\Phi_{\partial o}$ – current year fund time foundation unit uptime.;

$K_{\textit{в}}$ - coefficient that takes into account overfulfillment of norms ($K_{\textit{в}}$ = 1,1).

$$\Phi_{\partial o} = Д_p \cdot T_{\textit{ом}} \cdot n\left(1 - \frac{j}{100}\right),$$

where $Д_p$ – number of working days per year;

$T_{\textit{ом}}$ - duration of changes;

n – number of changes;

j - simple equipment in ППР (accept j = 3%).

$\Phi_{\partial o}$ = 255·× 8·× 2(1-3/100)= 3958 hours.

Determine the equipment load factor:

$$K_з = \frac{n_p}{n_{пр}},$$

where n_p – estimated quantity of equipment;

$n_{пр}$ – accepted quantity of equipment.

Since the estimated utilization rate of the equipment for handling examined details is the housing less recommended, it is conditionally accepting it at the regulatory level by loading the cylinder detail and defining the job capacity of the production program (Table. 6.1).

Table 6.1 - Calculation of annual labor capacity of production program

Name of parts	Employer's capacity 1 pc., min.	Annual release program parts, pieces	Annual capacity of parts, norm-n.
Case	60,72	140	142
Cylinder	548	5000	45667
Total:			45809

The labor capacity of the annual program of parts for machine models:				
16 ДО20Ф3	3 ДО2227А	2204ВМФ4	6Р13Ф3	2А450Ф2
258,4	148,5	217,3	174,3	145,1
3600,7	3236,8	3447,4	3406,3	3125,9
3859,1	3385,3	3664,7	3580,6	3271

Amount of equipment and loading factor	16 ДО20Ф3	3ДО227А	2204ВМФ4	6Р13Ф3	2А450Ф2
n_p	0,84	0,8	0,76	0,74	0,73
$n_{пр}$	1	1	1	1	1
$K_з$	0,84	0,8	0,76	0,74	0,73

The schedule of loading machine tools is presented in Fig.6.1.

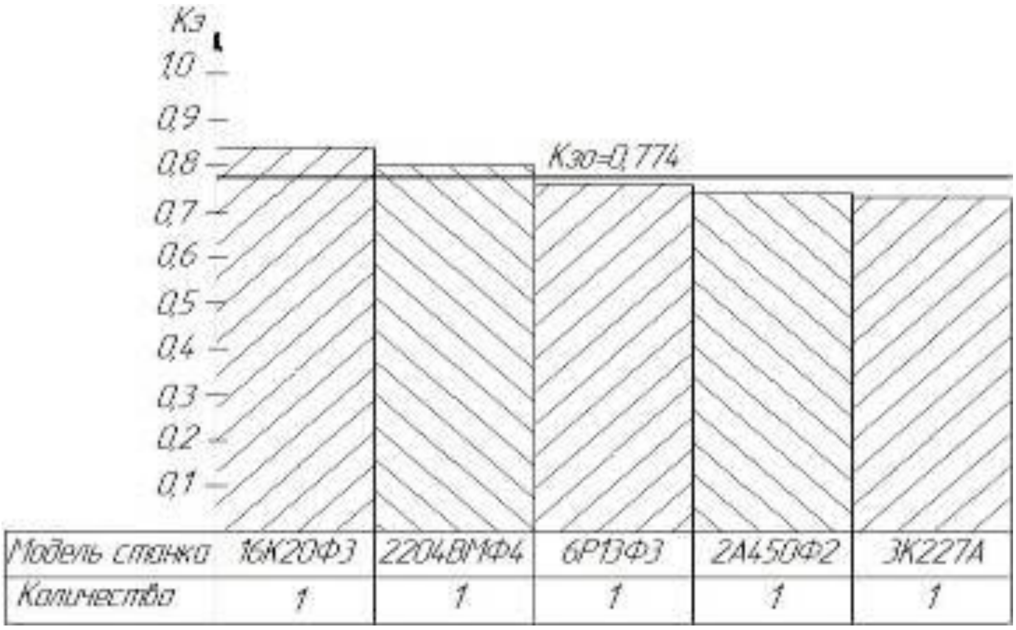


Figure 6.1 - Schedule of loading of metal-cutting machines

6.2. Selection of the type and calculation of the number of lifting and transport vehicles.

The results of calculations of the required number of main, auxiliary and hoisting-and-transport equipment are put into a summary (table 6.2), which calculates the cost of equipment, the power of electric motors in K_w and category of repair complexity.

The cost of equipment is calculated at prices that are available in the company.. The cost of transporting and assembling equipment is the largest, we accept in the amount of 10-15% of its value by price list.

6.3. Calculation of the number of industrial and production personnel.

6.3.1. Monthly time fund estimates.

A valid annual fund of time equals:

$$Ф_д = Ф_н \cdot \left(1 - \frac{j}{100}\right),$$

where $Ф_н$ – nominal annual fund of time, hours;

j – the planned nedimoves to work,% (accept 10%).

Then

$$Ф_д = \times 55 \cdot Ф_д \times 8 \cdot \times 2 \ (1- 10/100)=3672 \text{ hours}.$$

Table 6.2 - Summary statement of the required amount of equipment and its cost

The smallest	Model	Number	The cost of the unit according to tables, thsd. UAH.	The cost of the required amount of equipment, thous. UAH.			Installed power, KW		Category repair complexity	
				Accor-ding to tables	TRANSP-Mounting and assembly	Total	Quan-tity	Total	Quan-tity	Total
Main product	16 ДО20Ф	1	56	56	5,6	61,6	10	10	40	40
	3 ДО227А	1	46	46	4,6	50,6	4	40	30	30
	2204ВМФ 4	1	62	62	6,2	68,2	6,3	6,3	55	55
	6Р13Ф3	1	53	53	5,3	58,3	7,5	7,5	40	40
	2А450Ф2	1	96,5	96,5	9,7	106,2	11	11	40	40
Total		5	313,5	313,5	31,4	345	38,8	38,8	205	205
Lifting and transport equip-ment	Bridge crane	1	42	42	4,2	46,2	20	20	40	40
	Exact trolley	1	2,5	2,5	0,25	2,75	-	-	-	-
Total	-	7	358	358	35,9	394	58,8	58,8	245	245

6.3.2. Calculations of the number of production workers.

At the polling stations of technological specialization, the number of production workers is determined based on the availability of jobs and is calculated for each profession and discharge by the formula:

$$R_{яв} = \frac{T_p}{Ф_д \cdot K_в \cdot K_{бо}},$$

where T_p – annual labor work in the profession and category, год.;

$Ф_д$ – full annual worker time fund, год.;

$K_в$ – coefficient of timing factor, ($К_в$=1,1);

$K_{бо}$ – coefficient of multimachine working, ($K_{бо}$=1).

$R_{яв}$ turner = 3859,1/(3672·1,1·1) = 0,96;

accept $R_{яв}$ turner = 1 person.

$R_{яв}$ drill = (3664,7+3271)/(3672·1,1·1) = 1,72;

accept $R_{яв}$ drill =2 persons.

$R_{яв}$ grinder = 3385,3/(3672·1,1·1) = 0,84;

accept $R_{яв}$ grinder =1 person.

$R_{яв}$ milling machine = 3580,6/(3672·1,1·1) = 0,87;

accept $R_{яв}$ milling machine = 1 person.

Calculate the average tariff factor of production workers in the mechanical shop:

$$K_0 = \frac{\sum K \cdot R_{яв}}{\sum R_{яв}},$$

where K – tariff rates of corresponding discharges;

$R_{яв}$ – number of working digits.

$$K_0 = \frac{1{,}62 \cdot 4 + 1{,}458 \cdot 2}{5} = 1{,}59.$$

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Table 6.3 - Summary of the number of production workers.

Name profession	Dis-charge	The number of workers	Accounting quantity production workers
Turner with CNC	4	1	2
Drill with CNC	4	2	4
Milling machine with CNC	4	1	2
Grinder	3	1	2
Total:	-	5	10

Table 6.4 - Tariff grid

Discharge	I	II	III	IV	V	VI
Tariff rate	1,0	1,1	1,35	1,5	1,7	2,0
- machine worker, kop./hour	1,08	1,188	1,458	1,62	1,836	2,16
- not machine worker, kop./hour	1,02	1,122	1,377	1,53	1,734	2,04

6.3.3. Settlements of the number of auxiliary workers.

Compile a summary of the site auxiliary workers. The number of auxiliary workers is determined by their consolidation by the workers in places or according to established norms of service.

Table 6.5 - Summary statement of the site auxiliary workers.

Name profession	Disc harge	Service norm	Quantity of auxiliary workers
Chevy	3	1 person. on the machine	1
Serviceman	5	1 person on 8-12 machine tools	1
Mechanic-Repairman	4	1 person on 200 machine tools	1
Controller	4	1 person on 10-20 prod. workes	1
Total			4

6.3.4. Calculations of the number of engineering workers and junior service staff.

The number of ITP and employees is determined according to the established norms on the basis of the developed control scheme of the district, as well as taking into account the practical data of the plant, provided that the number of ITP should not exceed 10-15% and the ILO 2-3% of the total Number of workers of polling station.

Summary of the number of ITP and ILO (for each category separately) is presented in table. 6.6.

Table 6.6-Statement of the number of ITP and employees.

Job title	Number of workers	Monthly salary, UAH.
Senior master	1	2500
Interchangeable master	2	2300
Industrial cleaner Premises	1	1800
Total	4	-

6.4. Calculation of necessary production area and construction of site planning scheme.

Area is:

$$S_{діл} = n \cdot S_{пит},$$

where n – Number of equipment;

$S_{пит}$ – area, the unit of the equipment occupied, ($S_{пит}$ = 20-30 m^2).

$$S_{діл} = 5 \cdot \times 25 = 125 \text{ m}^2.$$

Production capacity is:

$$V = S_{діл} \cdot h,$$

where h – fly by height, (h=8,2 m).

$$V = 125 \cdot \times 8{,}2 = 1025 \text{ m}^3.$$

The district planning scheme is presented in the graphics part.

7. ECONOMIC BACKGROUND

7.1. Determination of the technological cost of manufacturing the case.

7.1.1. Feasibility study of the method of obtaining the workpiece.

The cost of the main materials is determined on the basis of the cost of procurement (taking into account transport and procurement costs) with the exception of invoiced amounts for realized waste by the formula:

$$M = C_з - C_o, \text{ UAH}, \quad (7.1)$$

where Cz - the cost of the workpiece (taking into account transport and procurement costs), UAH.

Co - cost of waste, UAH

$$C_з = g_з \times Ц_з \times K_{тз}, \text{ UAH}; \quad (7.2)$$

$$C_o = g_o \times Ц_o, \text{ UAH}, \quad (7.3)$$

where $g_з$, g_o - respectively, the weight of the workpiece and the mass of waste for 1 piece, kg;

$Ц_з$, $Ц_o$ - accordingly, the price of 1 kg of billets and 1 kg of waste, UAH.;

$K_{тз}$ - coefficient taking into account transportation costs (1,03 - 1,05 is accepted).

$$C_з = 30 \times 1{,}7 \times 1{,}04 = 54{,}04 \text{ UAH};$$

$$C_o = 13{,}5 \times 0{,}04 = 0{,}54 \text{ UAH};$$

$$M = 54{,}04 - 0{,}54 = 52{,}5 \text{ UAH}.$$

Calculations of the cost of basic materials are presented in table. 7.1.

Table 7.1 - Calculations of the cost of basic materials

Characteritics	Dimentions
1. Brand of material	Steel 45
2. Weight of the workpiece	30
3. Price of material 1 kg of workpiece	1,7
4. Cost of the workpiece	54,04
5. Weight of part	16,5
6. Weight of wastes	13,5
7. Price 1 kg of wastes	0,04
8. Cost of wastes	0,54
9. Cost of basic materials	52,5

7.1.2. Determination of the wage fund of production workers and the magnitude of their average monthly earnings.

The full wage fund of production workers consists of the basic and additional wages:

$$З_г = З_{ор} + З_{доп.р} + З_{догр}; \text{ UAH,} \tag{7.4}$$

where $З_{ор}$ - annual fund of basic wages of production workers, UAH; is determined by the formula:

$$З_{ор} = З_о \times N_{пр}, \text{ UAH;} \tag{7.5}$$

where $З_о$ - the basic salary of production workers per item is determined by the formula:

$$З_о = \sum_{i=1}^{n} (Р_{сд} \cdot \times К_{мн}), \text{ UAH,} \tag{7.6}$$

where $К_{мн}$ - multi-service ratio.

Calculations of the basic salary for the manufacture of parts are presented in Table. 7.2.

Table 7.2 - Calculations of the basic salary for the item

№ of operation	The cost is unit, UAH	Coeficient of multiplier machines	The basic salary fund for the 1 part
015	0,45	1	0,45
025	0,45	1	0,45
045	1,68	1	1,68
разом			2,56

So, $З_о$ = 2,56 UAH.

By formula (7.4) we define the annual fund of the basic salary of production workers:

$$З_{ор} = 2,56 \times 3400 = 8704 \text{ UAH}.$$

The additional wage of the main worker for the item is determined by the formula:

$$З_{доп} = З_о \times К_{доп}, \text{ UAH}, \quad (7.7)$$

where $К_{доп}$ - the coefficient, which takes into account the payment of leave, the performance of official duties and other payments provided by the legislation on labor for unproductive production time, accept $К_{доп}$ = 0,17 (according to the base enterprise);

$$З_{доп} = 2,56 \times 0,17 = 0,44 \text{ UAH}$$

The annual supplementary salary fund is:

$$З_{доп.р} = З_{доп} \times N_{пр}, \text{ UAH}; \quad (7.8)$$

$$З_{доп.р} = 0,26 \times 3400 = 1496 \text{ UAH},$$

where $З_{догр}$ - wages of workers for the loading of machine tools from other polling stations,

$$З_{догр} = \Sigma Q_{догр} \cdot Сч \times К_{догр}, \text{ UAH}, \quad (7.9)$$

where $K_{догр}$ - loading ratio, $K_{догр}$ = 1,17;

$Q_{догр}$ - labor capacity, $Q_{догр}$ = 4710,2 n-hours;

$$З_{догр} = 4710{,}2 \times 1{,}63 \times 1{,}17 = 8982{,}8 \text{ UAH.}$$

Determine the full wage fund of production workers by the formula (7.3):

$$З_p = 8704 + 1496 + 8982{,}8 = 19182{,}8 \text{ UAH.}$$

The average monthly salary of production workers is determined by the formula:

$$З_{cp} = \frac{З_Г \cdot K_{м.з}}{\sum P_{ПР} \cdot 12}, \text{ UAH;} \qquad (7.10)$$

where $K_{м.з}$ – coefficient, taking into account payments from the fund of material incentives.

$$З_{cp} = \frac{19182{,}8 \cdot 1{,}05}{6 \cdot 12} = 279{,}7 \text{ UAH.}$$

Deductions for social measures (in the pension fund to the fund for assistance and employment, social insurance, labor protection fund) are determined in accordance with the rates approved by the established norms of taxation to the consumption fund for the item.

The amount of deductions in the listed funds per unit is equal to:

$$O_{соц} = \frac{(З_О + З_{ДОП}) \cdot \%O_{соц}}{100}, \text{ UAH;} \qquad (7.11)$$

where $\%O_{соц}$ - the percentage of deductions for social measures, $\%O_{соц}$ = 37,5%;

$$O_{соц} = \frac{(2{,}65 + 0{,}44) \cdot 37{,}5}{100} = 1{,}16 \text{ UAH.}$$

7.1.3. Overhead billing.

7.1.3.1. Calculation of total production costs.

These costs include depreciation of equipment, vehicles and valuables; expenses for support materials; cost of power electric power, compressed air; salaries of installers with deductions to the social insurance fund; costs for the ongoing repair of equipment, vehicles and expensive tools, tool costs and other costs.

Also, they include the costs of managing and organizing production, namely, the cost of maintaining buildings and constructions; expenses for conducting tests, experiments and various researches, expenses for nature protection and other expenses.

The cost of maintaining and operating the equipment is determined by a detailed calculation for each component or, in the case of enlarged calculations, take 170% of the basic salary of the production workers:

$$P_{on} = \frac{З_o \cdot 170}{100}, \text{ UAH;} \qquad (7.12)$$

$$P_{on} = \frac{2,65 \cdot 170}{100} = 4,51 \text{ UAH.}$$

These costs are mainly divided into variables that vary in volume, and are constant.

The amount of costs related to the variables is:

$$P_{on}^{пер} = \frac{З_o \cdot 43}{100}, \text{ UAH;} \qquad (7.13)$$

$$P_{on}^{пер} = \frac{2,65 \cdot 43}{100} = 1,14 \text{ UAH.}$$

The amount of expenses related to the permanent is equal to:

$$P_{on}^{noc} = \frac{З_o \cdot 127}{100}, \text{ UAH}; \quad (7.14)$$

$$P_{on}^{noc} = \frac{2{,}65 \cdot 127}{100} = 3{,}67 \text{ UAH.}$$

7.1.3.2. Calculation of administrative expenses.

This article includes the costs associated with the operation of the enterprise as a whole: the cost of servicing production processes; expenses related to the management of the enterprise as a whole; depreciation of buildings, buildings of general economic purpose and other expenses.

The size of these costs in the enlarged calculations is taken from the data of the base enterprise - 244% to *C*:

$$P_{адм} = \frac{З_o \cdot 244}{100}, \text{ UAH}; \quad (7.15)$$

$$P_{адм} = \frac{1{,}51 \cdot 244}{100} = 3{,}68 \text{ UAH.}$$

7.1.3.3. Calculations of sales expenses.

Their composition includes expenses related to the sale of products; advertising costs; market research; transportation; finished goods insurance and other expenses related to sales, etc. The cost of the data from the base enterprise 384% to C_o:

$$P_{сб} = \frac{З_o \cdot 384}{100}, \text{ UAH}; \quad (7.16)$$

$$Р_{сб} = \frac{2,65 \cdot 384}{100} = 10,18 \text{ UAH.}$$

7.1.4. Calculations of full cost and price details.

The full cost of the "case" is:

$$З = М + З_о + З_{доп} + О_{соц} + Р_{оп} + Р_{адм} + Р_{сб}, \text{ UAH;} \qquad (7.17)$$

$$З = 52,5 + 2,65 + 0,44 + 1,16 + 4,51 + 3,68 + 10,18 = 75,12 \text{ UAH.}$$

The price of the item is:

$$Ц = З + П_н, \text{ UAH;} \qquad (7.18)$$

where $П_н$ - normative profit is calculated by the formula:

$$П_н = \frac{С \cdot Р_Н}{100}, \text{ UAH;} \qquad (7.19)$$

where $Р_н$ - the planned profitability standard is taken as 25%;

$$П_н = \frac{75,12 \cdot 25}{100} = 18,78 \text{ UAH.} \qquad (7.20)$$

By formula (7.17) determine the price of the part.

$$Ц = 75,12 + 18,78 = 93,5 \text{ UAH.}$$

The data of preliminary calculations are summarized in Table 7.3.

Table 7.3 - Planned calculation of the details

Cost item	Sum , UAH
1 Cost of materials (excluding wastes)	52,5
2. Basic salary of production workers for the item	2,65
3. Additional salary of production workers for the item	0,44
4. Deductions in social funds per unit	1,16
5. The size of total production costs	4,51
6. The size of total production costs (permanent)	1,14
7. Total production costs (variables)	3,67
8. Administrative expenses	3,68
9. Sales expenses	10,18
10. Normative profit	18,78
11. Full cost	75,12
15. Price	93,5

7.2. Determination of economic efficiency of the design variant of the technological process of manufacturing the case with the use of CNC machines.

The economic efficiency of the designed technological process is determined by the economic comparison of the chosen variant of the technological process with the basic (factory) version.

When comparing options, the most economical option is the one with the smallest amount of reduced costs. These costs represent the sum of cost and standard profit and are determined by each option by the formula:

$$З = C + E_н \times K, \text{ UAH}, \qquad (7.21)$$

where C - technological cost of annual output in this variant, UAH.;

K - capital investments on the same variant, UAH;

$E_н$ - normative coefficient of efficiency of capital investments, $E_н$ = 0,15.

The annual economic effect of ER is determined by the difference in the cost of the two options [16], p. 156:

$$E_p = (C_1 + E_н \times K_1) - (C_2 + E_н \times K_2), \text{ UAH,} \quad (7.22)$$

If the new version of the technological process requires a larger amount of capital investments (while being effective, that is, $C_1 > C_2$), then it is necessary to determine the payback period of additional capital investments at the expense of the savings derived from reducing the cost of production by the formula:

$$T_o = \frac{K_2 - K_1}{C_1 - C_2}, \text{ years,} \quad (7.23)$$

where T_o - the normative term for the recapitalization of additional capital investments and should be equal to or less than 7 years.

7.2.1. Determination of output data for economical comparison of the basic and project variants of technology.

In table 7.4 it shows the source data for comparing the technology options.

7.2.2. Determination of capital investments in comparable variants.

1. The capital investments taken into account in determining the effectiveness of CNC machines consist of the following costs:

$$K = K_б + K_{пл} + K_{сл}, \text{ UAH,} \quad (7.24)$$

Table 7.4 - Output data for economical comparison of options

Name of the data	Mar-king	Comparison of variants		
		Operations		
		1 variant (basic)		2 variant (design)
		Jig-boring	Radial milling	Jig-boring with CNC
Partrepresentative		Dase		
Annual output volume, pcs.	$N_{пр}$	3400		
Type and model of the machine		2A430	2M55	6P13PФ3
The norm of the artificially calculated time, min.	$T_{шк}$	123,6	25	60,28
Number of machines, pieces		6	1	1
Area of the machine tool in size, m^2	S	21,42	4,5	25
Wholesale price of the machine tool, UAH	$Ц_{вер}$	20600	10260	305500
Number of workers-machine tool operators, people	P	12	2	1
Breakdown of workers-machine tool operators		4	4	3
Norm maintenance of machines (multi-factor ratio)	$K_{бв}$	1	1	1

where $K_{б}$ - value of the machine tool, UAH;

$K_{пл}$ - cost of production space, UAH;

$K_{сл}$ - the cost of office and living space, UAH

The book value of equipment is determined by the formula:

$$K_{б} = \sum_{1}^{Mi} (Ц_{вер} \times C_{пр}) \times K_{дм}, \qquad (7.25)$$

where Mi - the number of standard machine tools for operations taken into account in the calculation of efficiency, pcs.;

$Ц_{вер}$ - wholesale price of the machine, UAH taking into account the correction factor $K_{пр}$=1,7;

$K_{дм}$ - a coefficient that takes into account the costs of delivery and installation of the machine, including commissioning, $K_{дм}$ = 1,15;

$$K_{б1} = (20600 \times 6 \times 1{,}15 + 10260 \times 1 \times 1{,}15) = 153939 \text{ UAH};$$

$$K_{б2} = 305500 \times 1 \cdot\times 1{,}15 = 351325 \text{ UAH}.$$

1. The cost of the production area is determined by the formula:

$$K_{пл} = Ц_{пл} \sum_{1}^{Mi} (S + S_{y}) \times C_{пр} \cdot \gamma, \text{ UAH}, \qquad (7.26)$$

where $Ц_{пл}$ - the cost of 1 m^2 of the area of the mechanical shop (for machines of normal and increased accuracy is equal to 150-200 UAH, for machines of high and especially high accuracy, heavy and unique - 220 UAH according to the base enterprise);

S - the area occupied by a machine tool in size, $м^2$;

S_{y} - area, occupied by auxiliary equipment (CNC devices, electric racks, hydropower stations, silos for chipping, etc.),

S_{y} =1m^2;

γ - coefficient taking into account the additional area.

The area of the CNC machine can be determined by the overall dimensions (including additional devices) according to the planning provided in the operating instructions of the CNC machine. In this case, instead of (S + S), the planning area is taken, and γ = 1. For universal machine tools with an area з 2,6 to 5m^2 γ = 4,5; a with an area from 20,1 to 40m^2 γ = 2,5.

$$К_{пл1} = 150 \times 21{,}42 \times 6 \times 2{,}5 + 150 \times 4{,}05 \times 1 \times 4{,}5 = 50017{,}5 \text{ UAH;}$$

$$К_{пл2} = 150 \times (25 + 1) \times 1 \times 1 = 3900 \text{ UAH.}$$

2. Capital investment in office space is determined by the formula:

$$К_{сл} = Ц_{пл.сл} \cdot\times S_{сл} \times (\sum_{1}^{Mii} P_{пр} + \sum_{1}^{Mi} P_{дод}), \text{ UAH,} \quad (7.27)$$

where $Ц_{пл.сл}$ - the cost of service-living facilities is 1 м^2, UAH (accept 220 UAH);
$S_{сл}$ - specific area per worker; $S_{сл}$ = 7 м^2;
$P_{дод}$ - additional workforce that falls on one CNC machine and is spent on the preparation of control programs, adjustment of the tool outside the machine tool, manufacturing of the cutting tool beyond the norm, maintenance and repair of CNC machines, people. (With consolidated calculations you can accept $P_{дод}$= 0,5 for 1 machine tool).

$$К_{сл1} = 220 \times 7 \times 12 + 220 \times 7 \times 2 = 13860 \text{ UAH;}$$

$$К_{сл2} = 220 \times 7 \times (1 + 0{,}5) = 2310 \text{ UAH.}$$

Total capital investments:

$$К = К_{б} + К_{пл} + К_{сл}, \text{ UAH;} \quad (7.28)$$

$$К_{1} = 153939 + 50017{,}5 + 13860 = 217816{,}5 \text{ UAH;}$$

$$К_{2} = 351325 + 3900 + 2310 = 357535 \text{ UAH.}$$

7.2.3. Determination of technological cost of annual production of parts in comparable variants.

The technological cost (cost of mechanical treatment) includes costs that depend on the technology used and the size of which is different for the comparable variants. The value of the technological cost of annual production of parts is determined by the formula:

$$C = З_{прр} + A_{ст} + A_{пл} + A_{сл}, \text{ UAH}; \qquad (7.29)$$

where $З_{прр}$ - annual salary of machine operators (basic and additional), including deductions to the social insurance fund, UAH.;

$A_{ст}$ - annual depreciation deductions for complete restoration of machine tools, UAH.,

$A_{пл}$ - annual expenses for depreciation and maintenance of premises occupied by machine tools, UAH.,

$A_{сл}$ - annual expenses for depreciation and maintenance of office-premises, UAH.

1. Annual wages of production workers deducted to the social insurance fund is determined by the formula:

$$З_{прр} = \sum_{1}^{Mi} \left(C_г \cdot \frac{T_{штк}}{60}\right) \cdot N_{пр} \cdot K_{доп} \cdot K_{соц} \cdot K_{бв}, \text{ UAH}, \qquad (7.30)$$

where $C_г$ - hourly tariff rate per transaction, UAH; for the third level $C_г$ = 1,5; for the fourth level $C_г$ = 1,72;

$K_{доп}$ - coefficient taking into account holiday pay; $K_{доп}$ = 1,17;

$K_{соц}$ = 1,375;

$K_{бв}$ - multiplier factor;

$$З_{прг1} = 1{,}72 \times \left(\frac{112{,}6}{60}\right) \times 12600 \times 1{,}17 \times 1{,}375 \times 1 + 1{,}72 \times \left(\frac{20}{60}\right) \times$$

$$\times 12600 \times 1{,}17 \times 1{,}375 \cdot 1 = 77051{,}31 \text{ UAH};$$

$$З_{прг2} = 1{,}5 \cdot \left(\frac{60{,}28}{60}\right) \cdot 12600 \cdot 1{,}17 \cdot 1{,}375 = 30547{,}3 \text{ UAH}.$$

2. Annual depreciation deductions for full restoration of machine tools are determined by the formula:

$$A_{ст} = \frac{\sum_{1}^{Mи} K_{б} \cdot \alpha_{в}}{100}, \text{ UAH,} \qquad (7.31)$$

where $\alpha_{в}$ - the norm of depreciation deductions for the complete restoration of the machine, %; $\alpha_{в}$=15%;

$$A_{ст1} = 153939 \times 0,15 = 23090,85 \text{ UAH;}$$
$$A_{ст2} = 351325 \times 0,15 = 52698,75 \text{ UAH.}$$

3. Annual expenses for depreciation and maintenance of premises occupied by machine tools, are determined by the formula:

$$A_{пл} = H_{пл} \times \sum_{1}^{Mi} (S + S_{y}) \cdot\times C_{пр} \cdot\times \gamma, \text{ UAH,} \qquad (7.32)$$

where $H_{пл}$ - the cost of depreciation and maintenance of 1 m2 of the area of the mechanical shop, UAH; for machine tools of normal and increased accuracy $H_{пл}$ = 15 - 20 UAH, For machine tools of high precision, especially precise, heavy and unique machines $H_{пл}$ =20-25UAH;

$$A_{пл1} = 15 \times (21,42 \times 6 \times 2,5 + 4,05 \times 1 \cdot\times 4,5) = 5001,75 \text{ UAH;}$$
$$A_{пл2} = 15 \times (25 + 1) \times 1 \times 1 = 390 \text{ UAH.}$$

4. Annual expenses for depreciation and maintenance of office-premises are determined by the formula:

$$A_{сл} = H_{пл} \times S_{сл} \cdot\times (\sum_{1}^{Mi} P_{пр} + \sum_{1}^{Mi} P_{доп}), \text{ UAH,} \qquad (7.33)$$

$$A_{сл1} = 15 \times 7 \times 12 + 15 \times 7 \times 2 = 1470 \text{ UAH;}$$
$$A_{сл2} = 15 \times 7 \times (1 + 0,5) = 157,5 \text{ UAH.}$$

5. Determination of the annual economic effect and the payback period of capital investments.

Having determined capital investments and technological cost of processing of annual production in comparable variants, the amount of reduced costs by options is calculated, the annual economic effect and the payback period of additional capital investments by the formulas (7.22) and (7.23). The results obtained are summarized in Table.7.5.

Determine the payback period for additional capital investments at the expense of savings derived from reducing the cost of production by the formula (7.23):

$$T_o = \frac{357535 - 217816{,}5}{106613{,}9} = 6 \text{ years.}$$

So, we accept the payback period of additional capital investments that were invested in the introduction of the multipurpose machine IR800PMF4 for six years.

Table 7.5 - Calculations of the value of reduced costs, annual economic effect and the payback period of additional capital investments

Cost Name	Marking	Sum, UAH	
		1 variant (basic)	2 variant (design)
Capital investment	*K*	217816,5	357535
Technology Cost	*C*	106613,9	83793,55
Priced Cost Annual	*З*	139286	137426,8
Economic Effect	E_p	1859,2	

Applications in a developed technological processes of a multipurpose CNC machine instead of universal equipment. A new or more modern cutting tool, measuring instrument, a special tool and equipment, a reduction in the number of workers and support staff, auxiliary workers, managers, as well as time standards, significantly different from overpriced factory, allowed getting an economic effect. Confirmation is made of calculations that prove the feasibility of using a CNC machine, which allowed getting an annual economic effect of 1859.2 UAH.

7.3. Basic technical and economic indicators of the site.

The main technical and economic indicators of the projected area of mechanical processing of the "case" part are given in Table 7.6.

7.4. Substantiation of economic efficiency of the developed technological process.

In the diploma project the technological process of manufacturing the "case" for a serial production type was developed. The technological process of the underlying enterprise is taken as the basis, but changes were made to it, since it was developed for a single type of production.

First of all, the method of obtaining a workpiece has been changed. The factory steel billet 45 is cut off from the rolled stock of the required size. The coefficient of use of the workpiece K_z = 0,375, and the coefficient of use of the material $K_м$ = 0,34. This proves that for serial production this method is not rational. The production of the workpiece on the crank-hot-press-press is proposed. This allowed reducing the permissions for machining and laboring productivity. Coefficient of using the workpiece of the proposed variant K_z = 0,55, and the coefficient of material use $K_м$ = 0,5. When comparing the two options, it was found that the cost of forging the stamped workpiece decreases by 10-30% due to the reduction of material costs and operating costs.

Table 7.6 - Main technical and economic indicators of the shop

Name of indicators	Units of measurement	Value
1. Annual volume of production of parts:		
– in natural terms;	pcs.	3400
– for work capacity (with due regard to load);	n-hours	10070,4
– at cost.	UAH	255408
2. Annual output of cases.	pcs.	300
5. Quantity of equipment.	pcs.	3
4. Average equipment utilization rate.		0,79
5. Total area of the shop.	m^2	330
6. Average area per unit of equipment.	m^2	100
7. Number of staff at the shop, total, including:		
- main workers;	people	6
- auxiliary;	people	3
- managers;	people	1
- specialists;	people	-
- employees.	people	-
8. Average selary of the main workers.		2079,7
9. . Labor productivity for one main worker:		
- by labor insight;	n-hour	1678,59
- in natural terms;	UAH	566,67
- at cost.	UAH	42568
10. Full cost of the case.	UAH	75,12
11. Material costs for UAH 1 unit cost of	n-hour /pcs	
production.	UAH	0,7
12. Labor capacity of the product unit.	n-hour	2,53
15. The price of the part.	UAH	93,5

Changes in the technological process of processing the part of the "case" have been made. Two universal operations (coordinate boring and radial drilling) are replaced with one using the multipurpose machine IR800PMF4. This allowed to reduce the number of main and auxiliary workers, to reduce the area of the machining area to a minimum (at the developed section installed 3 machines). Due to the changes made, the technological cost of parts was reduced and an economic effect of 1859.2 UAH was obtained. Despite the fact that the size of capital investments in the project version is almost twice as long, their payback period is 6 years.

The vertical milling operation suggested the use of a progressive cutting tool - a two-stage end mill. The first stage - the draft cutters, the second - clean. This allows for one working run of mills to reach 9 qualities of accuracy and roughness Ra = 1,6. At the expense of reducing workflows, the energy costs for cutting the material are reduced twice, artificial time decrease, which leads to a reduction in the cost of the part.

In all operations where geometric surface quality control is required, special templates are used instead of a universal measuring instrument, in particular calipers, which reduce the auxiliary time to control and measure the dimensions. This also leads to a decrease in artificial time.

All innovations that were introduced into the basic technological process of manufacturing the "case" part are aimed at reducing the cost of parts and their competitiveness.

8. HEALTH AND SAFETY MEASURES

8.1. Organization of labor protection at work.

The Law "On Occupational Safety" obliges the employer to create at each workplace, in each structural subdivision, the working conditions in accordance with the regulatory legal acts, as well as to ensure compliance with the requirements of legislation on workers' rights in the field of occupational safety.

To this end, the employer must create and ensure the functioning of the system of management of labor protection, for which he:

- creates appropriate services and appoints officials who provide for the resolution of specific issues of labor protection, approves instructions for their duties, rights and responsibilities for the performance of their functions, and monitors their compliance;
- develops with the parties a collective agreement and implements comprehensive measures to achieve the established norms and increase the existing level of labor protection;
- ensures the necessary preventive measures in accordance with changing circumstances;
- introduces progressive technologies, achievements of science and technology, means of mechanization and automation of production, requirements of ergonomics, positive experience in labor protection, etc .;
- provides proper maintenance of buildings and structures, production equipment and equipment, monitoring of their technical condition;
- provides for the elimination of the causes leading to accidents, occupational diseases, and the implementation of preventive measures determined by the commissions on the basis of the investigation of these reasons;

- organizes an audit of labor protection, laboratory testing of working conditions, an assessment of the technical condition of production equipment and equipment, attestations of workplaces and, on the basis of their results, takes measures to eliminate hazardous and harmful to health factors of production;

- develops and approves normative acts on labor protection, operating within the enterprise, provides free of charge workers with regulations and acts of the enterprise on labor protection;

- carries out control over observance of technological processes by the employee, rules of handling of machines, mechanisms, equipment and other means of production, use of collective and individual protection means, performance of works in accordance with labor protection requirements;

- organizes the promotion of safe working methods and cooperation with workers in the field of occupational safety;

- takes urgent measures to help the victims, involves, if necessary, professional emergency rescue units in the event of accidents and accidents at the enterprise.

The employer is directly responsible for violating these requirements.

8.2. Dangerous production factors at the site and measures to reduce them.

The proposed technological process is intended for the production of the "case" of the TSF 8. 027.012. Annual release program 140 pcs. The weight of the workpiece is 15.25 kg, the weight of the part is 9.8 kg. For the manufacture of parts will be used: turning-bending machines, CNC lathes, boring and milling boring machines, coordinate boring and vertical milling machine with a revolving head. Chip collecting is done manually. Treatment is carried out using ZOR. Technological equipment, basically, universal. The workpiece is delivered to the workplaces by batches in a pallet with the help of a bridge crane with a carrying capacity of 5 tons, shavings from workplaces are removed similarly.

Categories of work to be performed on the section by weight - medium weight, accuracy - medium and high accuracy.

There are a large number of production equipment on the site. Below is a list of the main dangerous manufacturing factors that occur when working on it.

The main traumatic industrial factors that may occur during the processing of the part are:

1. Cutting tools, quick-cut mills, drills. They can cause injury, including severe, accidental contact with them during work, in case of seizure of their clothes, as well as sudden destruction of them. As a rule, factories manufacturers of machines are not fenced, and in the instructions to the machine tools are not given recommendations or proposals for their fencing. Producer plants are forced to "invent" such fences and not always successfully, and more often machines operate without a fence. This sometimes leads to serious injuries. Therefore, it will be expedient to apply and develop fencing.

2. Adjustment for fastening of machined parts, especially cam cartridges. They pose a danger both in case of accidental touch to them, and in case of seizure of garments by protruding parts in the process of work of the machine.

3. Workpiece. With modern cutting modes, the part can break out of the fastening devices. The injury can also be caused by the workpiece when it is removed manually from the machine, without the appropriate fittings.

4. Electric current. In case of damage to the ground, the worker may be affected by electric shock. Damage to current when working on metal cutting machines is relatively rare, however, it is a significant risk, and the enclosure, locking and grounding provided by the machine tool builders must always be in good working order in accordance with the current rules.

5. Drive and gear mechanisms of machines, especially turning lathe screws, belt, chain and gear transmissions, which can cause injury in the process of adjustment, lubrication and repair of machine tools, and running gears and rollers of lathes are a huge danger in the process of operation as well their fencing is not foreseen by the producing factories.

6. Metal chips. The strip (drain) shaving, which is formed when finishing and drilling steels, affects the parts of the machine and, leaning against the floor, winding in the loop, entangled around the cutter, the parts, the support, the back, the control levers and other parts of the machine. Shaving up the chips causes extra time, except that the worker is at risk of injury to the hands and face. The shaving chamber, which is formed during the alignment and milling, as well as the large dust particles, can damage the eyes of the worker.

7. Flying chips and dust of brittle metals. Felting shavings and dust are injured by eye and burns of face and hands. When handling brittle metals and non-metallic materials, the air in the working area is polluted by dust of the treated material, which in many cases has harmful components (lead, beryllium, asbestos, etc.). In these cases, safety glasses and screens on the machine are simply necessary, but they do not solve the problems completely.

8. Moving parts of machine tools. These include: tables of longitudinal-planing, vertical and horizontal milling machines, crawling shifts, etc. All this is a danger, especially in the absence of enclosing barriers.

To eliminate and prevent accidents at the site, strictly follow the rules and measures recommended by the relevant regulations, which include:

1. Transmissions (belt, chain, gear, etc.) located outside the case of the machine should be fenced solid, with blinds or mesh coatings, depending on the need to observe the blocked mechanism. Painting in the signal colors of moving assembly units and enclosures is foreseen.

2. The control units of the machine tools must be equipped with clamps that prevent the accidental inclusion or movement of moving bodies, as well as explanatory inscriptions and symbols.

3. Rotational devices or smooth external surfaces, in the presence of protruding parts or recesses, must have a fence.

4. In order to prevent cuts by means of a belt chip, it is necessary to change its shape during the cutting process by swirling it into a screw spiral or chopping it into separate elements. It is necessary to use protective screens and glasses to

prevent the shredded shaving from getting into the eyes of the worker. The average noise level at the polling station is 73-77 dB, at a maximum allowable level of 80 dB. The level of production vibration on the average on the site is 102 dB at the maximum allowable level for these conditions at 113 dB. This level of vibration is permissible, and any measures to reduce it are not required.

The average dust concentration in the site is 2.6%, as the practice shows, it is slightly overestimated at the welding station and mechanical section, but should not exceed 6.0%.

6.3. Analysis of harmful production factors at the site and measures to eliminate them.

The main harmful factors on the site are:

1. Production noise of machine tools, which weakens the attention of workers. The source of manufacturing noise is mainly technological and production equipment, vehicles, etc. Increased noise from working equipment, vehicles, as a rule, is the result of disturbing the centering of individual units of mechanisms, the lack of lubrication in bearings, gears, and the like. Carrying out repair work is accompanied by additional noise. Its value should not exceed the maximum permissible standards, regulated by safety requirements.

2. Production vibration. Under vibration usually refers to mechanical vibrations of elastic bodies with a frequency exceeding 1Hz. The sources of vibration in the production are separate unbalanced nodes and parts of equipment, mechanized tool, etc. Typically, exceeding the permissible level of vibration is the result of a structural failure of the equipment or the loss of technical characteristics of the interaction of individual units of equipment due to the untimely conduct of its inspection and repair.

3. Air pollution. Some technical processes are accompanied by the release of harmful substances into the working environment air. The working area is considered to be a space up to 2 m high above the floor level or the place where the

permanent or temporary working places are located. The concentration of harmful substances in the working area must not exceed the maximum permissible concentrations established by the normative documents.

4. Fugacity of the air of treated materials. The greatest dustiness is characteristic for those kinds of technological operations, where loading, unloading, crushing, sifting and mixing of various materials, which produce fine particles, takes place. All types of industrial dust are aerosols, in which the dispersed medium is air, and the dispersed phase - solid dust particles of at least 5 microns. Stubbing in the breathing zone of machine tool operators must meet the maximum permissible standards.

5. ZOR. As a result of the evaporation of the ZOR, contamination of the respiratory zone of machine operators, their clothes and open parts of the case occurs. This is the cause of the specific diseases of the workers. ZOR may also exhibit an irritant effect on the mucous membranes of the upper respiratory tract.

6. Insufficient artificial lighting of the working area. This leads to over-strain of the worker's vision and makes him approach the treatment zone, which is associated with the danger of injury. In accordance with the applicable norms for feeding lamps of local lighting with incandescent lamps, the voltage should not exceed 24 V.

7. Temperature and relative humidity of the working zone air. Meteorological conditions in industrial premises are mainly determined by the temperature and relative humidity of the air in the working area. In order for the physiological processes in the human case to flow normally, the case should be exposed to heat in the environment. The correspondence between the amount of this heat and the cooling capacity of the environment characterizes it as comfortable. In conditions of comfort the worker does not have to worry about his thermal sensations - cold or overheating. Thus, in a production environment for a worker's thermal health it is important to have a certain combination of temperature and relative humidity of the air in the working zone.

9. ECOLOGY

9.1. The relevance of environment protection.

At all stages of its development man was closely associated with the world. But since there appeared a high industrial society, dangerous human intervention in nature has increased sharply, expanded the volume of this intervention, it has become host richer and now is threatened to become a global danger for humanity. The most large and significant is the chemical and radioactive pollution of the environment unusual substances, dust, sewage.

Environmental pollution worsens primarily the physical conditions of the existence of people, in addition, causes and direct loss of working time-failure to work due to the deterioration of health and safety of workers, and indirect - the society is forced to distract part of the working prevent or eliminate the effects of contamination.

Protection of the environment-a problem nationwide. But practical concrete measures for its solution lie mainly on the regions. After all, they directly suffer from violation of the normal state of habitat and, moreover, have the necessary information to track the situation and take action.

The problem is solved mainly by means of scientific substantiation of maximum permissible levels of environmental pollution taking into account the peculiarities of separate climatic zones and territory development, environmental assessment and project coordination

The construction of large objects of interregional significance, as well as the development of environmentally friendly technologies for small enterprises.

9.2. Environmental pollution resulting from project implementation.

For industry engineering technology typical types of environmental pollution are air pollution abrasive dust, waste metal shavings and metal, environmental pollution and water ponds, sewage, which Used for technical purposes, contamination by waste oil, zmaŝuvalno and cooling liquids.

On the projected site for the production of screw billets and parts by hot skills with their subsequent mechanical processing allocated a significant amount of dust, operations are accompanied by the release of a large number of heat, and as a consequence, significant Water supply for zmaŝuvalno-cooling liquids.

Screw parts are subjected to mechanical machining, which results in a certain layer of metal – shavings which, when contact with into the environment, pollutes it.

The following measures can be foreseen on the projected district to reduce harmful emissions:

Technical water and its wastes.

To reduce emissions of contaminated waste water into the district should provide for the reuse of water for technical needs, more rational use of the process during the restoration of the parts.

Wastewater treatment at the enterprise, depending on their properties, concentration and fractional composition is carried out by methods of straining, defending, Department of particulate matter in the field of centrifugal forces and filtration. To clean industrial effluent in the production can be recommended the use of the following water purification facilities:

- lubricants;
- farbogatherers;
- a station for neutralization of chemically contaminated water;
- treatment facilities for filtration, chemical purification and defending of water.

Metal and steel waste.

In the course of processing of parts from cast iron and steel waste of these materials (shavings, metal) should provide mandatory collection of waste and transfer it to special points, where they will be sent: partly on a melting point on the Lithuania, and in Mainly for the collection points of secondary raw materials for the metallurgical industry enterprises.

Waste oil.

The company widely used lubricants for lubrication of technological equipment, reduction of friction in moving parts of equipment and much more. As a result of this assumed significant quantities of spent oil. Therefore, the company needs to provide the equipment for processing and regeneration of spent oil. It is recommended to use the installation type УРИМ-100.

Abrasive dust.

The air at the district is mainly polluted by particles of fog in size 0.3-5 microns and solid abrasive particles 0.3-2 microns.

In the process of processing of iron and steel products, a significant amount of dust is released, which contaminates the surrounding atmosphere and can lead to serious diseases of the respiratory system.

Classification of dust-separating equipment is based on the features of process of separation of solid particles from the gas phase, it:

- equipment for dust catching in a dry way, which include cyclones, dust-absorbing chambers, vortex cyclones, louvones and rotary dust, electrofilters, filters;

- equipment for the catching of dust in a wet way, which include scrubbers, atomization scrubbers, foam apparatuses, etc.

To clean air from dust should provide filters in local ventilation in the workplace, which is carried out processing of such parts, as well as necessary to provide the use of special filters in places sharpening tools, grinding Parts and other, where a dust-release is possible.

Exhaust cooling fluids.

For drainage heat during the processing of metals in severe conditions, which include the treatment of cast iron, zmaŝuvalno-cooling liquids are used. In order to reduce the flow of such liquids into the environment the enterprise needs to provide for the use of special equipment for processing and filtration of ЗОР. It is recommended to use the plants for the non-waste decomposition and treatment of waste emulsion by Microflotation technology such as installation ТФС-017.

Noise and vibration.

In the process of performing production process or restoration of details the enterprise will have considerable noise. To reduce noise in the company it is necessary to provide for the use of special sound absorbing and sound insulating pads to reduce noise from working equipment, the use of special vibroinsulating devices that reduce the vibration of severe Presses, hammers, heavy machines. On polling stations, which are characterized by high noise, it is necessary to use special sound screens. Strongly vibrating equipment should be installed on special vibroinsulating supports.

9.3. Measures to reduce the toxicity of exhaust gases, protect the environment and reduce environmental pollution.

When operating the engine in the exhaust gases along with the full combustion products contains a certain amount of toxic substances. These include: oxides of nitrogen, hydrogen, hydrocarbon.

One of the main reasons for CO and CH emissions of engines with spark ignition is the use of enriched fuel-air mixture in most operating modes. Therefore, the main direction of improving gasoline engines is to develop measures to ensure their stability in the zbìdnenih fuel-air mixtures.

Ways to reduce harmful substances in the worked gases:

- recirculation of spent gases;

- neutralization of harmful substances in the inlet and exhaust processes;
- the use of closed crankventilation systems;
- application of pollutants traps;
- application of alcohol fuels.

Pollution, which enters the environment can be valid and anthropogenic origin. The actual sources of environmental pollution include sawing, volcanic eruption, cosmic dust, fire, etc.

The sources of anthropogenic action on the environment include issues of industrial enterprises, transport and energy systems, especially non-ferrous metallurgy, which are thrown into the gaseous form of hydrogen sulfide, chlorine, ammonia, fluorine, etc.

In the production process solid industrial wastes are formed in the form of Scrap, shavings, toxins, scale, ash, slurry from the devices of wet cleaning of technological and ventilation emissions.

Along with this, the environment is: noises, vibrations, heat and radiation pollution, etc.

Environmental protection measures.

The most effective form of environmental protection from the emission of industrial enterprises is the development and implementation of non-waste and low-technology technological processes in all types of industry.

By this time, 4 directions have been identified in the creation of non-cutting technological processes:

- development of non-waste technological systems and water-circulating cycles on the basis of existing and promising ways of wastewater treatment;
- recycling of wastes;
- development and implementation of fundamentally new technological processes, which allow eliminating the creation of the main amount of waste;
- creation of territorially-industrial complexes with closed structure of material flows of raw materials and wastes inside the complex.

GENERAL CONCLUSIONS

The diploma project has developed the technological process of manufacturing the "case" for the serial type of production. The technological process of the underlying enterprise is taken as the basis, but changes were made to it, since it was developed for a single type of production.

The method of obtaining a workpiece has been changed, the preparation of the workpiece on the crank-hot-press-press has been proposed. This allowed reducing the permissions for machining and labor productivity, as well as the cost of stamped workpiece by 10-30% due to reduced material costs and operating costs.

Changes in the basic technological process of processing the part "case" are made. Two universal operations (coordinate boring and radial drilling) are replaced with one using the multipurpose machine IR800PMF4. This allowed to reduce the number of the main and auxiliary workers, as well as reducing the area of the machining section.

The vertical milling operation suggested the use of a progressive cutting tool - a two-stage end mill. At the expense of reducing workflows, the energy costs for cutting the material are reduced twice, artificial time decreases, which lead to a reduction in the cost of the part.

In all operations where geometric surface quality control is required, special templates are used that reduce the auxiliary time to control and measure the dimensions.

Due to the changes made, the technological cost of parts was reduced and an economic effect of 1859.2 UAH was obtained. Despite the fact that the size of capital investments in the project version is almost twice as long, their payback period is 6 years.

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