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

EXPLANATORY NOTE

for diploma project (thesis)

Nwaoyibo Donatus Junior
(educational level)

topic: Development of transfer gearbox LPZ 304-15-318 backward motion production process including the study of cutting modes under face milling conditions

Submitted by: fourth year student VI group IMTм-62
Specialism (field of study)
131 Applied mechanics
(code and name of specialism (field of study))
(signature) Nwaoyibo Donatus Junior (surname and initials)

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

Standards verified by (signature) Tkachenko I.G. (surname and initials)

Referee (signature) Okipniy I.B (surname and initials)

Ternopil 2020

Ministry of Education and Science of Ukraine
Ternopil Ivan Puluj National Technical University
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Faculty Faculty of Engineering of Machines, Structures and Technologies

Department Engineering Technology

Educational degree master

Field of study
(code and title)

Specialism 131 Applied mechanics
(code and title)

APPROVED BY
Head of Department Okipniy I.B

Assignment

FOR DIPLOMA PROJECT (THESIS) FOR STUDENT

Nwaoyibo Donatus Junior
(surname, name, patronymic)

1. Project (thesis) theme. Development of transfer gearbox LPZ 304-15-318 backward motion production process including the study of cutting modes under face milling conditions

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

1.Approved by university order as of 28.09. 2020 року № 4/7-686

2. Student's project (thesis) submission deadline

3. Project (thesis) design basis 1. Basic TP manufacturing parts. 2. The program is 50000 pieces/ year. 3. Drawing the body parts.

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

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

6. Advisors of design (thesis) chapters

Chapter	Advisor’s surname, initials and position	Signature, date	
		assignment was given by	assignment was received by
Safety measures	PhD *Assoc. Prof Tkachenko I.G.*		

7. Date of receiving the assignment *12 October 2020*

PROJECT TIME SCHEDULE

LN	Diploma project (thesis) stages	Project (thesis) stages deadlines	Notes
1	*Analytical part,*	21.10.2020	
2	*Research part*	1.11.2020	
3	*Technological part*	15.112020	
4	*Designing part*	1.12.2020	
5	*Safety measures*	4.12.2020	
6	*Drawings*	20.12.2020	

Student ______ Nwaoyibo Donatus Junior
(signature) (surname and initials)

Project (thesis) supervisor ______ Pankiv V.R.

ABSTRACT

Actuality of theme. End milling of flat surfaces of details has become widespread not only as a highly productive way of processing, but also as a finishing technological process. Equipment of face mills superhard materials made it possible to significantly increase the cutting speed and provide the absence of shortcomings inherent in the grinding process.

The purpose of the study is to improve the process of manufacturing the mechanism of the return stroke of the transfer case with the study of cutting modes in face milling.

The object of study - the technological process of manufacturing the return mechanism of the transfer case.

The subject of research - technological parameters of face milling.

Research methods. The work is performed using the basic provisions of mechanical engineering technology, as well as statistical and graphical methods.

Scientific novelty: the influence of cutting modes at face milling on the quality of the machining surface has been studied.

Practical significance. A fundamentally new technological process is proposed, the production of the reverse gear transfer mechanism, which can be introduced into production, and the cutting modes for face milling are investigated.

Approbation of the results of the master's qualification work. Material
VIII scientific and technical conference "Information models, systems and technologies ».

The structure and scope of the master's qualification work. The work consists of an introduction, four sections, a list of used sources and appendices. The full volume of the master's qualification work is 108 pages, including 16 figures, 16 tables, bibliographies from 16 sources to two pages.

ЗМІСТ

ABSTRACT

The billing and explanatory note includes the letters of the printed text. It consists of 5sections. The graphic part contains 8 letters A1.

In the general technical and technological parts of the thesis the value and design of the part is described, the analysis of technological capacity, the chosen type and the organizational form of production are given, the comparison of two choices of the workpiece is given. The design and technological process shows the choice and justification of the base surfaces, the operational process is developed, calculations are made for mechanical processing with analytical and tabular methods, calculation of cutting modes. In the organizational-economic section the comparison of two variants of the technological process: factory and project, the annual savings of the introduction of a new technological process are counted. In the design part there is a power calculation of adjustments for cutting and milling. Writing calculation of a weak link for restoration for a hole. Describing the principle of integrated assimilation for control. Having calculated the spindle node of the longitudinal milling machine. In part, the system of automated design (CAD), described the drawing program COMPASS - 3D LT, which was used for the development of technological documentation. The use of personal protective equipment has been described in the section on the safety of life.

1 ANALYTICAL PART

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

End milling is the most common type of machining by cutting flat surfaces of machine parts. The end mill represents the steel case in which separate cutters - teeth of a mill are fixed. From the practice of face milling it is known that increasing the number of teeth leads to an increase in cutting power. In addition, carbide teeth require a fairly high cutting speed, which also increases the cutting power. Therefore, mills with a small number of teeth are practically used: when milling steels z = (0.04 ... 0.06) Df, when milling cast irons z = (0.08, .. 0.1) D, f. However, keep in mind that this solution increases the unevenness of the cutting process.

Each end mill tooth works similarly to a planing cutter, so the front and rear corners, as well as the cutter, are measured in the main section. When milling steel parts to prevent possible destruction of the cutter blade due to the unevenness of the cutting process (exit from the cutting zone - cutting into the allowance), the front angle is negative -5 °. ..- 15 °. When processing cast iron cutters are made with front angles of 5 ° ... 10 °. The rear angle of the cutter tooth cutter in all cases is chosen in the range of 12 ° ... 15 °.

End mills are designed for processing planes on vertical and horizontal milling machines. End mills, unlike cylindrical cutters, have teeth located on the cylindrical surface and at the end.

End mills are divided into shell cutters with fine teeth and coarse teeth and shell cutters with plug-in knives according.

The main dimensions of end mills are: diameter - D, cutter length - L, hole diameter - d and number of teeth - z.

End mills have a number of advantages over cylindrical mills, the main of which are:

- more rigid attachment to the mandrel or spindle;
- smoother operation due to the large number of simultaneously working teeth.

Therefore, the processing of planes in most cases is advisable to carry out with end mills.

End mills, as well as cylindrical, are divided into right-handed and left-handed.

Right-handed cutters are called such cutters, which during operation should rotate clockwise (Fig. 1.1, a), and left-handed ones - counterclockwise (Fig. 1.1, b), if you look at the cutter or milling head from above (when working on a vertical milling machine).

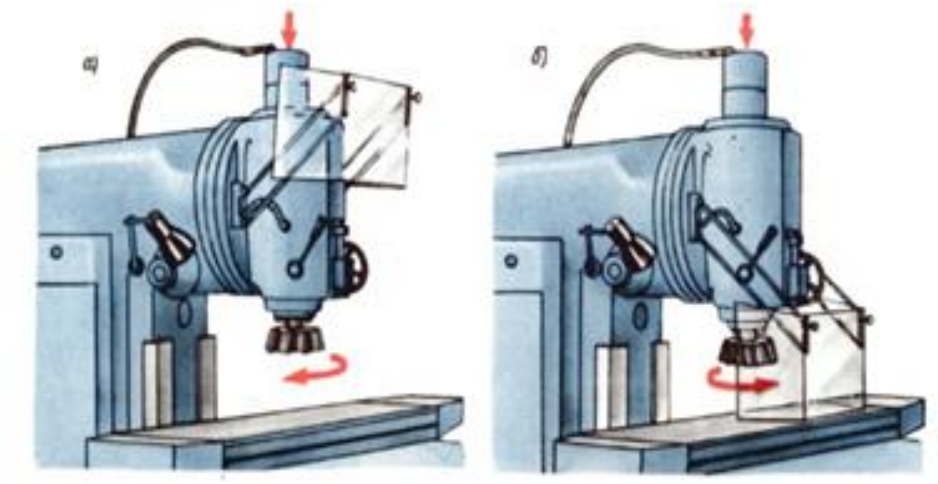


Fig. 1.1 Scheme of cutters rotation.

a) right-handed, b) left-handed

End mills equipped with carbide plates are widely used. Surface milling with solid carbide end mills is more productive than cylindrical milling.

In recent years, face mills with non-regrowth carbide inserts have become widespread.

Adjustment and tuning of the machine for various jobs. When working on vertical and horizontal milling machines with face mills, setup and adjustment are fundamentally no different from setup and adjustment of a horizontal milling machine when working with cylindrical cutters. Therefore, we will dwell only on the distinctive features of setting up and tuning when milling with end mills.

Installation and fixing of end mills on vertical milling machines. Depending on the type of cutter used, its fastening on a vertical milling machine can be done in several ways:

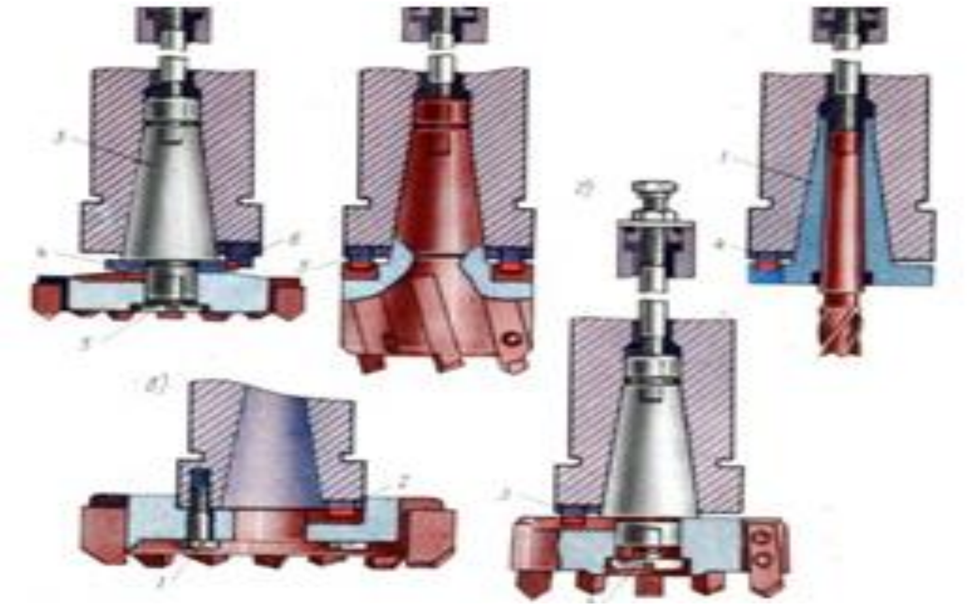


Fig. 1.2 Installation and fixing of end mills on vertical milling machines

End mills with a calibrated through hole are centered on the cylindrical part of the mandrel 3 with the taper part, installed in the tapered hole of the spindle and fixed in it with a ramrod 7 and a nut 2 (Fig. 1.2, a). The base end of the cutter rests on one of the ends of the adapter flange 4, the second end of which rests on the end of the mandrel 3. The spindle pins 6 enter the slots of the adapter flange, and the flange projections into the cutter slots, transmitting the torque from the stud to the cutter. The cutter is attached to the mandrel with a screw 5 using a special key.

End mills with a centering groove (Ø 128.57A) are installed directly on the spindle head and fixed on it with four screws 7 (Fig. 1.2, b). Spindle pins 2 enter the grooves of the cutter body, transmitting torque from the spindle to the cutter.

End mills with a taper shank with a nominal size of the largest diameter of the cone Ø 59.85 mm and a taper of 7:24, made in one piece with the cutter body, are inserted into the taper hole of the spindle, fixed in it with a ramrod 7 and a nut 2 (Fig. 1.2, c) .The torque is transmitted by pins 3, which enter the grooves of the cutter body.

End mills having a through calibrated hole and grooves in the body, in width corresponding to the dimensions of the spindle pins, are mounted on a mandrel fixed in the machine spindle. The cutter is fixed on the mandrel with a screw 7. The torque is transmitted by the spikes 3, which enter the grooves of the cutter body (Fig. 1.2, g).

End mills with a shank with a Morse taper and a threaded hole are centered in the adapter sleeve 7 inserted into the taper bore of the spindle and secured with a ramrod 2 and a nut 3. The spindle pins 4 enter the slots of the adapter sleeve, transmitting torque from the spindle to the cutter (Fig. 1.2, d).

In fine milling of steel and cast iron with carbide cutters to obtain a surface of a higher class, the feed per tooth is reduced, and the cutting speed is accordingly increased, depending on the grade of the processed material, grade of the carbide and other processing conditions.

Setting the end mill to the depth of cut when working on a vertical milling machine is no different from the previously considered case of setting a cylindrical mill to the depth of cut.

When milling with a face mill on a horizontal milling machine (Fig. 1.3), the following procedure for setting the milling depth is used.

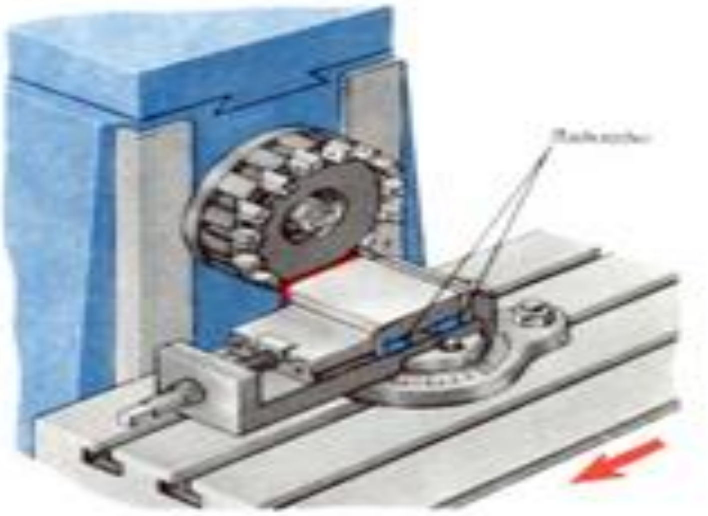


Fig. 1.3 Milling with a face mill on a horizontal milling machine

Switch on the machine and the rotation of the spindle and, using the handles for longitudinal, transverse and vertical feeds, carefully bring the workpiece to the milling cutter until it touches lightly. With the handle of the longitudinal feed, remove the workpiece from under the cutter, turn off the spindle rotation. Use the cross feed knob to move the table in the cross direction by an amount corresponding to a depth of cut of 3 mm. After setting the cutter to the required cutting depth, lock the table console and cross feed slide, install the power feed engaging cams. Then, by smoothly rotating the handle of the longitudinal bend feed, bring the workpiece to the cutter, without touching it, turn on the spindle, turn on the mechanical feed, milling the plane, turn off the machine and measure and measure the processed workpiece.

Milling of inclined planes and bevels. Inclined planes and bevels can be milled with end mills on vertical milling machines, setting workpieces at the required angle, as in processing with cylindrical cutters, using a universal vice (Fig. 1.4, a), rotary tables or special devices (Fig. 1.4, b). Milling of inclined planes 1 and bevels with end mills 2 can also be performed by turning the spindle, and not the workpiece. This is possible on vertical milling machines, in which the milling headstock with a spindle rotates in a vertical plane, for example, as in machines 6P12, 6P13, as well as on universal machines of the 6P82SH type, in which the vertical head has a turn in the vertical and horizontal planes.

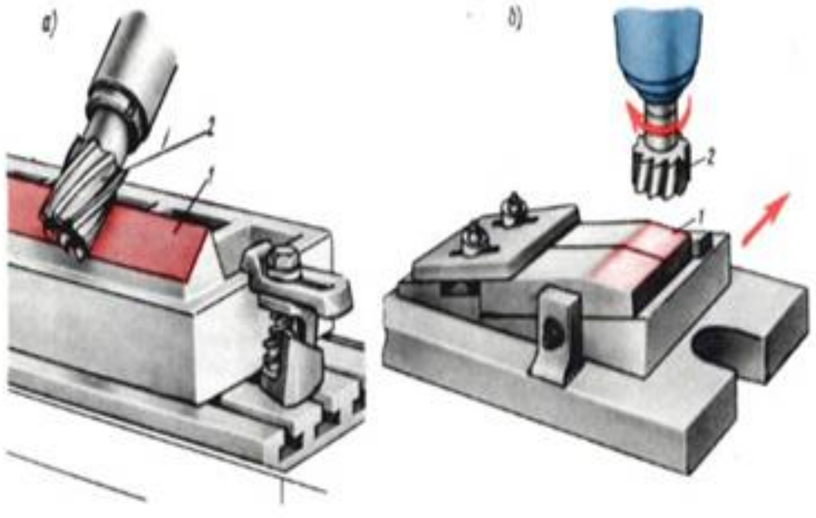


Fig. 1.4 Milling of inclined planes and bevels

Milling of inclined planes and bevels with end mills can be done using a vertical overhead head.

The overhead vertical head is a special accessory for the horizontal milling machine.

In fig. 1.5, a shows one of the designs of the overhead vertical head, and Fig. 1.5, b - different positions of the spindle. The body 2 (Fig. 1.5, a) of the overhead head is installed on the vertical guides of the machine bed and fixed with bolts U. The spindle 5 rotates in the rotary part 6 of the head. By loosening the bolts connecting the rotary part 6 of the head to the body, the spindle can be rotated in the vertical plane and at any angle on the scale 4.

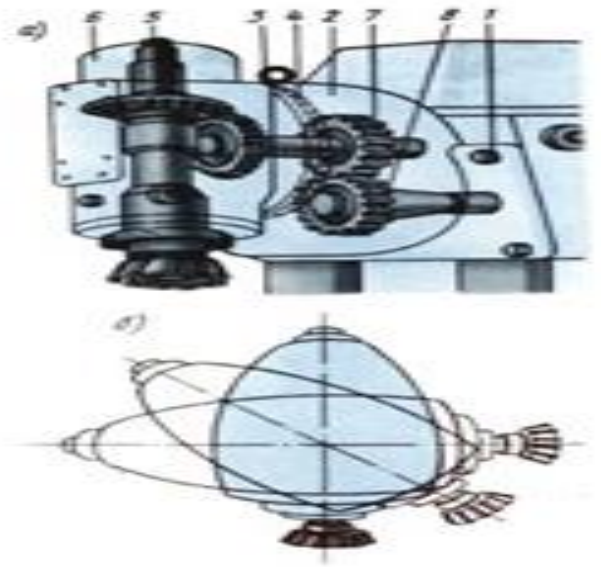


Fig. 1.5 Vertical overhead head

1.2 Methods of solving problems

Ring 3 serves to remove the head. Rotation from the spindle of the machine to the spindle of the head is transmitted using a pair of cylindrical gears 7 and 8. The wheel 8 is fitted with a tapered shank on the spindle of a horizontal milling machine, it transfers rotation from the spindle of the machine to the wheel 7, and then through a pair of bevel gears to the spindle 5 of the overhead vertical head. A cutter is installed in the tapered hole of the spindle 5. With the help of a pair of bevel gears, the spindle of the attachment head can be rotated around the machine spindle by 360 °, and therefore, the cutter can be installed at any angle to the plane of the table (Fig. 1.5, b). The presence of an overhead vertical head significantly expands the technological capabilities of horizontal milling machines.

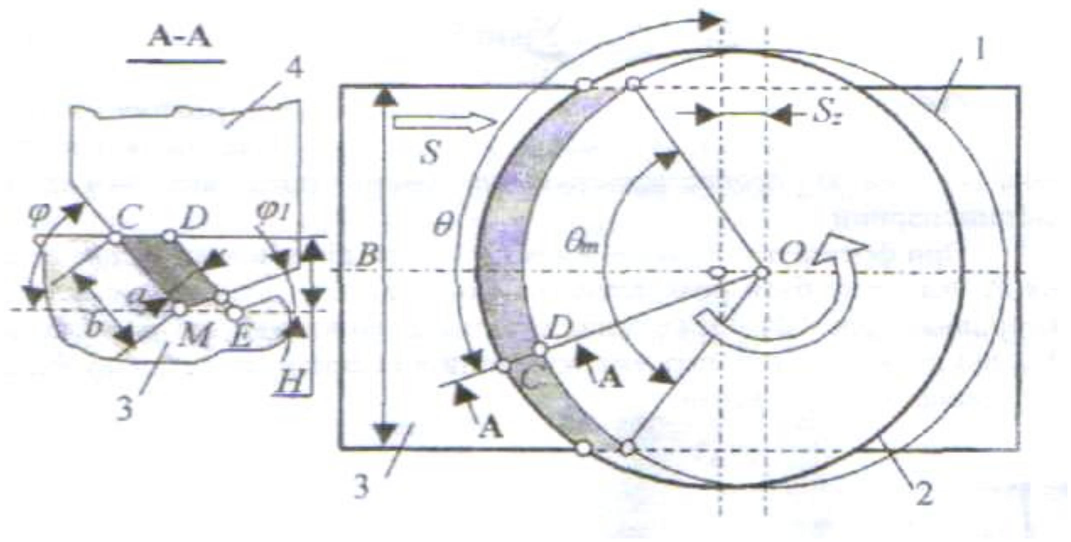


Fig.1.6 - Scheme of calculation of cutting elements

The cutter rotates around a vertical axis, providing the main cutting movement, and the part 3 performs the movement of the longitudinal feed *S*. The position of the CD of the cutting tooth of the cutter is determined by the angular coordinate θ, which is usually measured from the position of the diameter of the cutter, which is perpendicular to the direction of longitudinal feed. Maximum angle θm of contact depends on the width *B* milling and symmetrical milling can be determined from the geometric relations of the scheme by the formula:

$$\theta_m = 2Arc\sin\left(\frac{B}{D_\Phi}\right) \tag{1.1}$$

where D_Φ - diameter of a mill.

The cross-sectional area of the allowance layer, which is cut with one tooth, is marked by a dark background in Fig.1.6 (see section AA). With some approximation, the cross section can be replaced by a parallelogram CDEM. Then, given that, $CD = S_z \sin\theta$ we obtain an approximate formula for calculating the cross-sectional area of the allowance layer, cut with one tooth:

$$F = S_z H \sin\theta \tag{1.2}$$

The number of teeth of the cutter in operation is constantly changing from the maximum $m_{\max} = 1 + \theta_{mz} / 2\pi$ to the minimum. $m_{\min} = \theta_{mz} / 2\pi$ Thus the total cross-sectional area of the cut allowance layer:

$$F_{\Sigma} = S_z H \sum_{i=1}^{m} \sin\theta \tag{1.3}$$

Since the number of teeth of the cutter performing the cutting and their angles are constantly changing, the total cross-sectional area is also not a constant value and the milling process should be represented as quasi-stationary.

Given the non-stationary process of cutting when milling end mills here, as well as in the case of milling with cylindrical mills, try to build a mathematical model that reflects this feature of the process.

The construction of a mathematical model begins with the determination of the specific force p of cutting, which in the case of involuntary cutting, which is the process of milling end mills, is calculated by the formula:

$$p = \frac{C_p}{a^k H^{\mu}} \tag{1.4}$$

where *Cp, к and* μ - coefficient and indicators of degree, which depend on the mechanical properties of the processed material, and - the thickness of the layer of allowance cut by the tooth.

The obtained dependence with certain assumptions for the case when the milling width is equal to the diameter of the cutter and φ=90^0 can be considered adequate to the real cutting process during milling. It reflects the non-stationary nature of the milling process, ie the periodic change of the cutting force, but is approximate and partial due to the accepted assumptions that were previously highlighted in italics in the text. Dependence (1.7) is quite inconvenient for technological calculations at the stage of determining the cutting mode, because it contains such parameters as the angles of the teeth of the cutter and their number in operation.

Similarly to the method adopted for milling with cylindrical cutters, the average value of the cutting force is determined by the average effective cutting work or the effective cutting power. At the same time, as in the case of milling with cylindrical cutters, the reflection of the actual non-stationarity of the process is completely lost, but technological calculations are significantly simplified by the formula containing elements of the cutting mode, which are set and subject to simple definition: feed and milling depth.

The process of milling end mills is characterized by non-uniformity, for the evaluation of which the coefficient of non-uniformity is used, which is determined by the geometric ratios of the parameters of the cutter and the width of milling.

To assess the non-uniformity of the process of milling end mills in experimental studies, it is advisable to use the coefficient, which is determined from the ratio of the maximum $P_{\max}$ minimal $P_{\min}$ values of cutting force:

$$k_p = \frac{P_{\max} - P_{\min}}{P_{\max}} 100\% \qquad (1.5)$$

It is in this form that this coefficient will determine the dynamic instability of the cutting process, which will provoke oscillations in the elastic TOC during milling.

Fig.1.7 - Technological process of milling

1.3 Conclusions and problems for the master's thesis

As a result of the analysis of the technological process for the manufacture of the housing of the return mechanism of the junction box, certain conclusions can be drawn.

Details are technological in both quantitative and qualitative terms.

The basic technological process mainly provides requirements for quality, accuracy, surface roughness of the obtained part, but some operations need to be replaced or combined in order to reduce the main and auxiliary time, savings, improve quality, accuracy, roughness.

Thus, the purpose of the master's work is to develop a technological process on based on the basic, which would be more progressive, economical and productive and the formation of practical skills to determine the dependence of the parameters of the cut layer, milling conditions and the circumferential component of the cutting force from the cutting mode and geometric parameters of the cutter.

2 RESEARCH PART

2.1 Program and methods of theoretical and experimental research

In the figure of the oscilloscope shown below, synchronously with the animation of the milling process in the graphical window 1 of the interface, oscillograms of its characteristics appear: line 2 - circumferential component of cutting force, line 3 - total cutting depth, line 4 - average (per mill cutter) value of circumferential component cutting. Moreover, the average value of the circumferential component is equal to the value that was determined on the previous revolution of the cutter. When modeling the machining is carried out in the feed direction S, and the workpiece has a rectangular initial shape, there is a gradual increase in the circumferential component of the cutting force, the total depth of cut, as the number of cutting teeth increases from one to two. Therefore, the value of the average district component is gradually increasing and for its correct definition it is necessary to wait for the established process. A sign of this process is the stabilization of the average circumferential component of the cutting force for two adjacent rotations of the cutter.

The graphic image of the milling animation is constructed in such a way that when the diameter of the cutter changes in the original data in the image, it remains constant, but the graphic image of the allowance (cutting depth H) changes so that the proportions between them are maintained. The studies are performed according to the method of one-factor experiments, and the ranges of changes in the parameters in the function of which the studies are performed are selected taking into account the ranges given above, so as to demonstrate some general trend. The results of measurements are recorded in the table of experimental data, according to which it is necessary to build appropriate graphs of dependencies in each experiment.

After activating the program, the graphs of restrictions appear. Lines 1 and 2 - maximum and minimum spindle speed, lines 3 and 4 restrictions on the maximum and minimum feed of the machine, line 5 - restrictions on the allowable surface roughness, line 6 - restrictions on the stability of the tool, line 7 - restrictions on the power of the machine , line 8 - limit on the maximum allowable feed force. It should be noted that the maximum and minimum feed limits, which are measured and set on the machine in mm / min on the phase plane S_Z - n turned from direct (in phase coordinates "minute feed speed") into hyperbolas according to the known from the theory of cutting dependence, which connects the "minute" feed and feed to the tooth:$S_Z=S/zn$.

Area D of the allowable values of the spindle speed and feed to the tooth, which corresponds to the output data of the cutting process formed on the interface is formed by the intersection of the following restrictions: maximum speed (line 1), minimum feed (line 4), allowable cutting power (line 7), the maximum allowable feed force (line 8) and the allowable roughness (line 5). However, with the change of the initial process data and, in particular, the depth of cut, the range of permissible values may be formed by other restrictions.

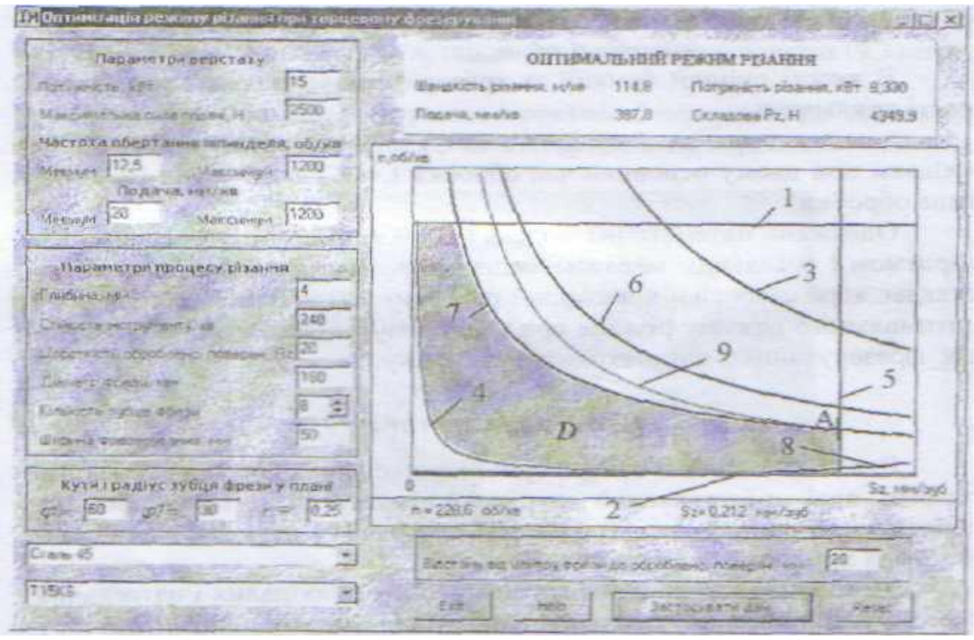


Fig.2.1 -Interface of the optimization application

Line 9 displays the estimated optimization function for maximum performance, and appears on the phase plane when moving the mouse cursor. In accordance with the solution of the optimization problem, the maximum productivity of milling at satisfaction of all restrictions will correspond to the top of area D of admissible values, the furthest from the origin.

Thus, the optimal values of the cutting mode correspond to the coordinates of the vertex A of the range of possible values. Therefore, to determine the coordinates of the range of permissible values, it is necessary to move the mouse so that the line of maximum performance is tangent to the farthest from the origin of the vertex of the range of permissible values, and the mouse intersection coincides with such a vertex.

2.2 Processing of research results

The following components of the cutting mode and its main characteristics are determined: spindle speed (228.6 rpm), cutter feed (0.212 mm / tooth), cutting speed (114.8 m / min), longitudinal feed , 8 mm / min), cutting power (8.33 kW). component Pz of cutting force (4349.9 N).

We draw your attention to the fact that in accordance with the accepted criterion of optimality, the maximum productivity - its value is convenient to estimate directly by the value of the longitudinal (minute) feed.

The developed software product can form the basis of the module "optimization model" of CAD TP in determining the cutting mode, as well as be used to study the influence of various parameters of the processing process on its optimal mode. Moreover, the use of the software product in the SAP for CNC machines does not require any modernization of the machine, and does not complicate the control process. According to preliminary estimates, the productivity gain can range from 20% to 80%, depending on the processing used.

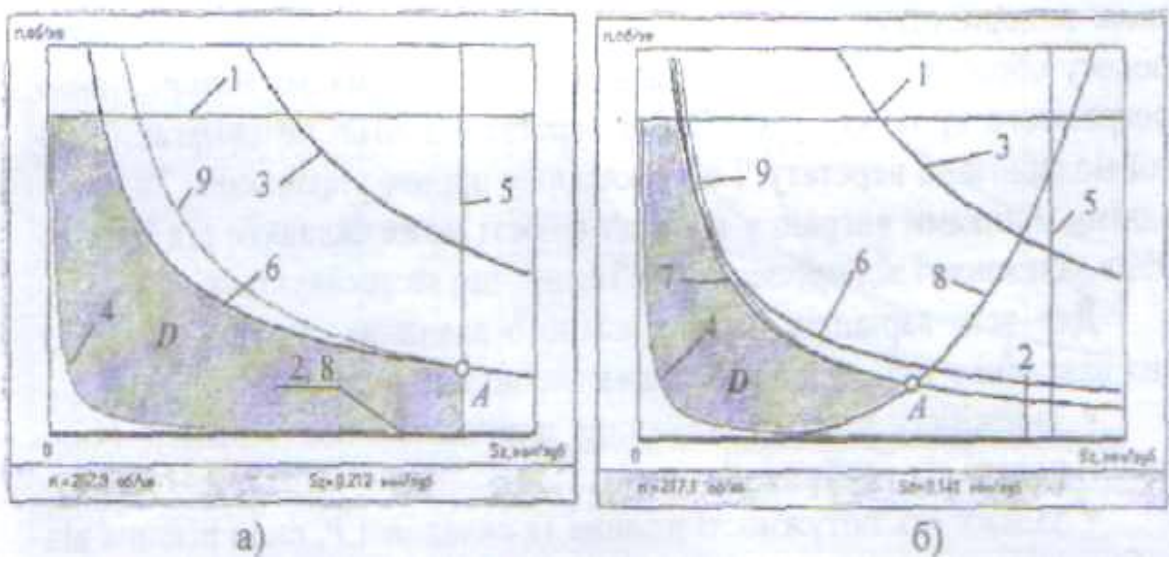
As an example of performance of work below the course of researches for initial data which are specified in windows of the main interface of the program on fig.2.2 is presented.

Since the research on the first two tasks is performed as a function of depth of cut, before activating the application program it is necessary to compile a table of experimental data, determining the range and step of changing the depth of cut (see table 2.1).

Depending on the change in the depth of cut, the vertex A of the range of allowable values, which corresponds to the optimal (in terms of productivity) cutting mode, is formed by the intersection of different constraints.

Figure 2.3 shows the state of the area D of the allowable values of the spindle speed and feed to the tooth of the cutter during experimental studies according to table 2.1.

Here the same designations are accepted as in Fig. 9.3: line 1 and 2-restrictions on the minimum and maximum spindle speed, lines 3 and 4 - restrictions on the minimum and maximum feed, line 5 - feed restrictions on a given surface roughness, line 6 - restrictions on the stability of the tool, line 7 - restrictions on the power of the machine, line 8 - restrictions on the supply of the allowable force of the feed mechanism of the machine drive. Line 9 shows the evaluation function of optimization for maximum productivity. It is seen that with a change in the depth of cut, the vertex A of the range of allowable values, which corresponds to the optimal (in terms of productivity) cutting mode is formed by the intersection of different constraints. Thus, at a cutting depth of 0.5 mm, this vertex is formed by restrictions on the maximum feed and the required surface roughness, and at a depth of 3 mm - restrictions on the cutting power and the required surface roughness.



а) б)

Fig.2.3 - The results of determining the optimal cutting mode:

a) - at a depth of cutting of 1 mm, b) - at a depth of cutting of 8 mm

Since the developed application program allows to determine not only the optimal value of the minute feed, but also the appropriate value of the feed to the tooth of the cutter, in the table of experimental data should enter this important parameter of the cutting distance.

According to experimental data, using the Echell package, graphs of the corresponding dependences are presented, which are presented in Fig.2.4 and Fig.2.6. From the analysis of experimental results it is possible to draw conclusions concerning control laws according to which the optimum mode of cutting at change of depth of cutting is reached.

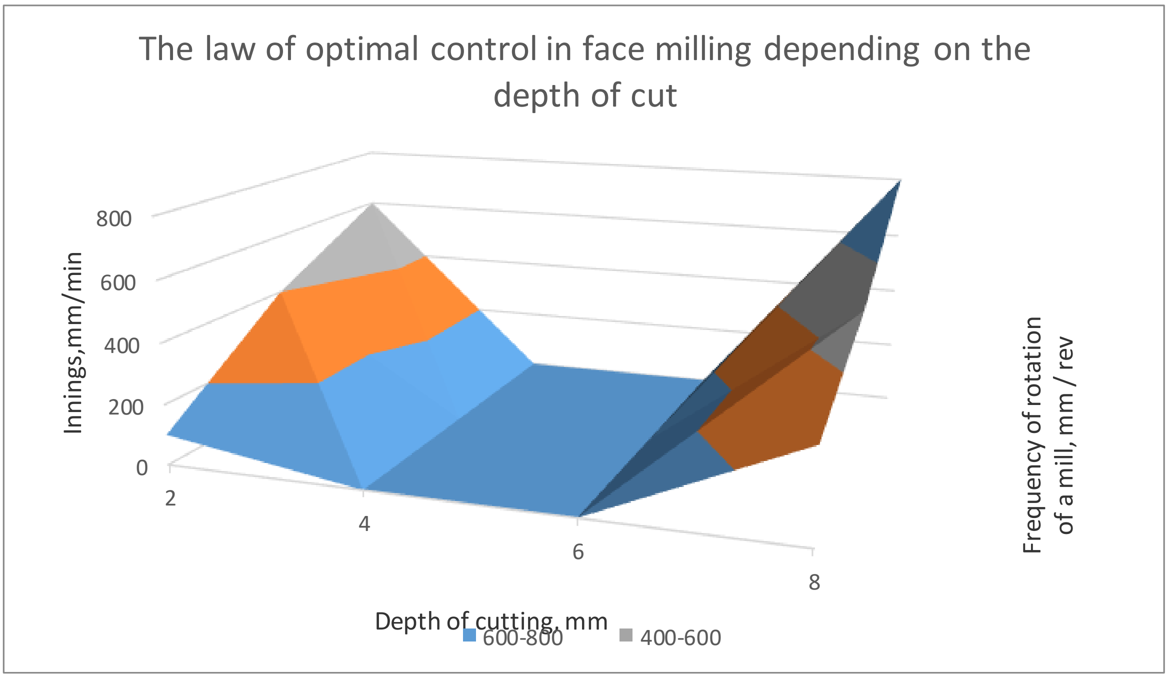


Fig. 2.4 - The law of optimal control in face milling depending on the depth of cut

Based on the results of experimental studies, it is also possible to plot the dependences of the cutting speed and feed on the cutter tooth on the cutting depth for the optimal mode (Fig. 2.6).

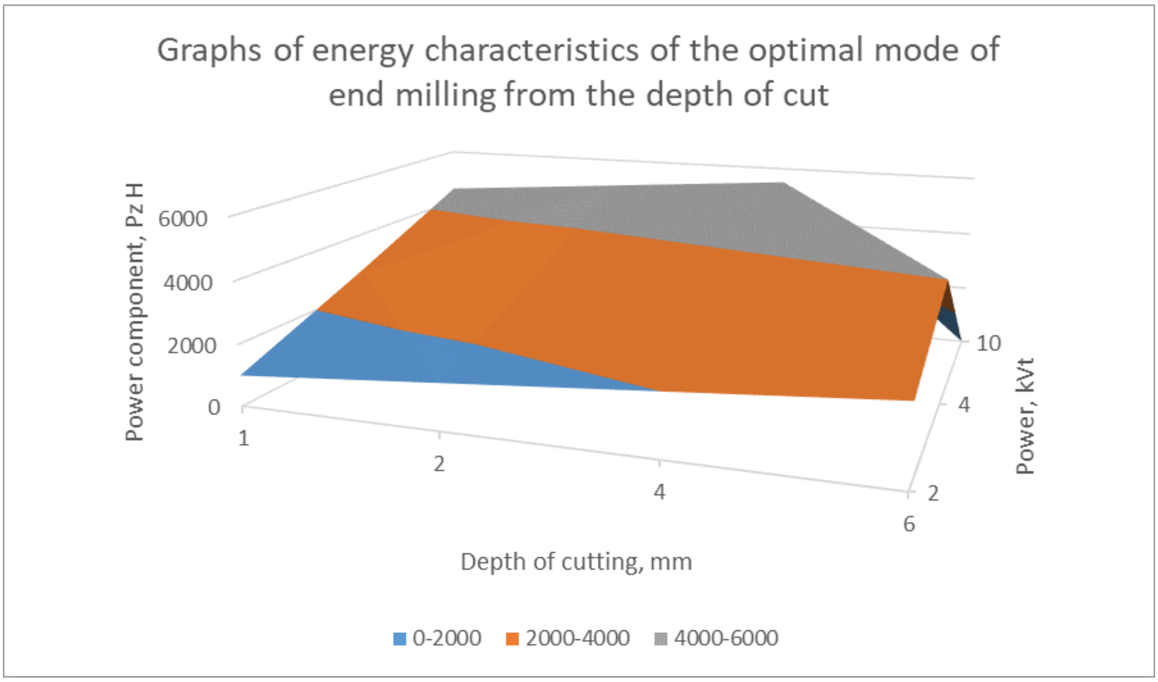


Fig.2.5 - Graphs of energy characteristics of the optimal mode of end milling from the depth of cut

Comparison of such dependences with the optimal control law, presented in Fig.2.4, allows us to draw conclusions about the physical laws of the end milling process, because it is the magnitude of the feed to the cutter tooth is one of the dependences of determining the component PZ cutting force

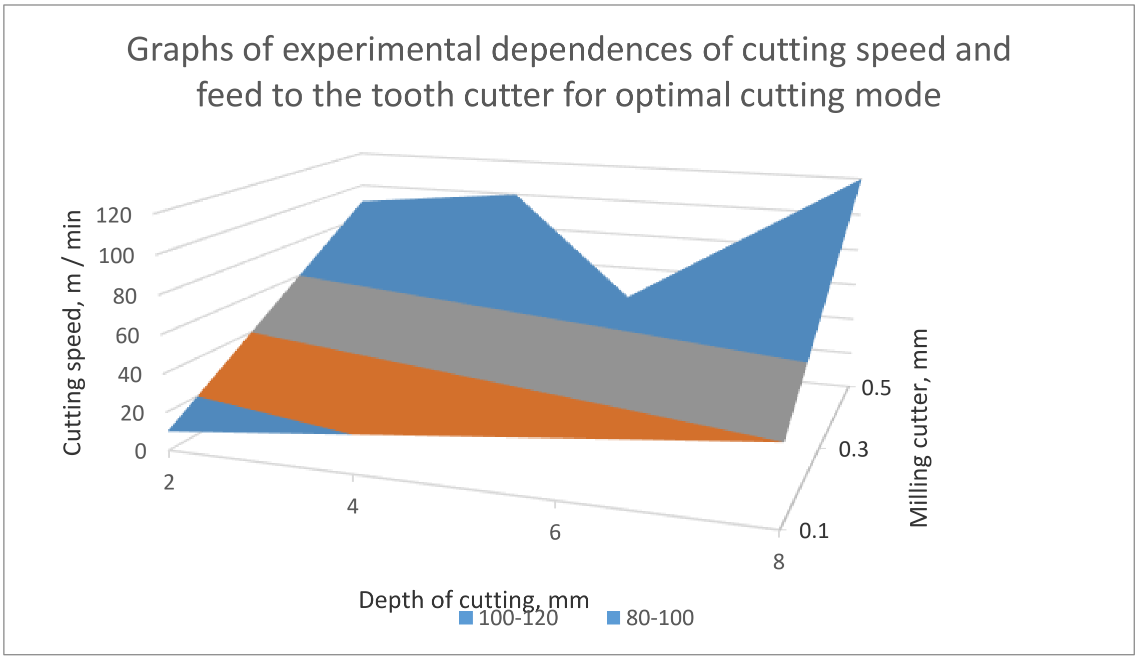


Fig.2.6 - Graphs of experimental dependences of cutting speed and feed to the tooth cutter for optimal cutting mode

To perform experimental research on the last paragraph of the task, it is necessary to prepare an appropriate table in which to record the measured results (Table 2.2). When choosing the step and range of change in the number of teeth, it is desirable to focus on real values.

According to experimental data, also using the Echell package, graphs of the corresponding dependences are presented, which are presented in Fig.2.7. From the analysis of experimental results it is possible to draw conclusions concerning expediency of use of mills with various quantity of teeth.

When milling with a width of 49 mm, the total depth of cut (line 1) varies from 5 to 10 mm at a given depth of 5 mm. This nature indicates that in the process of cutting involved or one or two teeth of the cutter. Corresponding changes occur with the circumferential component of the cutting force (line 2).

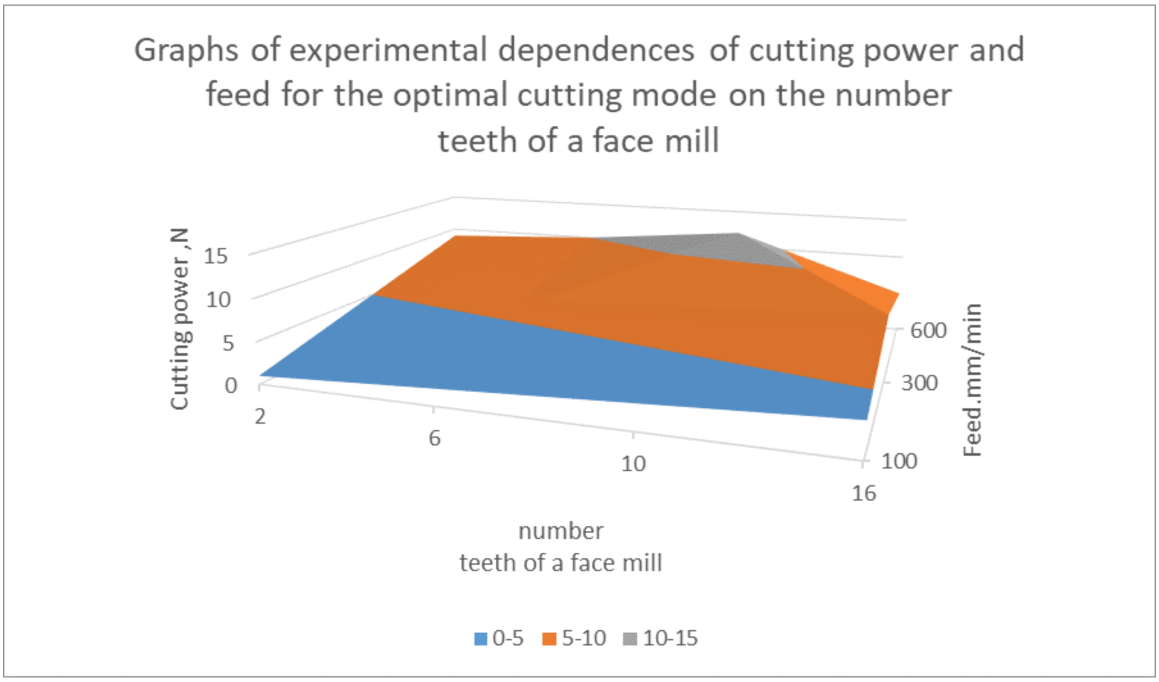


Fig. 2.7 - Graphs of experimental dependences of cutting power and feed for the optimal cutting mode on the number
teeth of a face mill

Increasing the milling width to 51 mm leads to a change in the number of teeth of the cutting cutter. The total depth of cut varies up to 15 mm, so cut at the same time or 2 or 3 teeth of the cutter. With a milling width of 50 mm, there are 2 teeth of the cutter all the time in the cutting - the total depth of cutting is constant and equal to 10 mm. However, even in this case, the circumferential component of the cutting force is not constant (see the increased section of the oscillogram at B = 50 mm in Fig.2.4). However, the unevenness of the process is significantly reduced.

2.3 Conclusions and suggestions on the use of research results

Analysis of the obtained experimental results of the dependences of the parameters and characteristics of the optimal mode of end milling depending on the depth of cut allows us to draw the following conclusions.

1. Comparison of the law of optimal control on minute giving and frequency of rotation of a mill and schedules of power characteristics of optimum process of face milling allows to define two zones on depth of cutting which border makes 5 mm. When milling and cutting depth up to 5 mm, not all possible machine power is used, although the process has a fairly high productivity in terms of processing time of the workpiece surface.
2. Comparison of the law of optimal control and graphs explains the nature of the change in cutting speed and longitudinal feed - for optimal cutting mode, they change so that in the range of changes in cutting depth h <5mm feed to the cutter tooth remains constant.
3. The study of the number of teeth of the cutter allows us to draw an important conclusion about the existence of the optimal number, which for the original experimental data is 10. by machine power.

The presented results of the analysis are not generalized in quantitative terms, because they were obtained for end milling with the initial data given in the example. However, they accurately represent the general trends of the optimal cutting mode in face milling.

The developed program gives the chance of experimental research of dependences of an optimum mode of cutting on parameters of process of face milling. At the stage of technological preparation of production, such studies make it possible to assess the feasibility of using a machine, to determine the limitations that affect the overall optimum and to propose changes to the technological process that will increase the productivity of processing. Such studies are particularly useful in determining the redistribution of the depth of cut when machining in several strokes, for example, roughing and finishing stroke, and so on.

3.TECHNOLOGICAL AND DESIGN PART

3.1 Purpose and characteristics of the object of production

Considered in the thesis, the detail - the mechanism of the return mechanism of the distribution box is a casting of the carton form of gray cast iron СЧ-18. The mechanism, which is in the body, is a six-speed reducer, with the help of which the direct and reverse of the car is carried out. The body is fastened to the machine frame by four M16 bolts.

The knot of the mechanism of the return gear of the distribution box is one of the main components of the machine and operates under difficult operating conditions. However, after analyzing the design and material of the case, we can conclude: the part - is robust and can withstand the working life, which is determined by the technical conditions.

In the hole Ø90 mm the bearing of a drive shaft is installed, in which the gear of direct and returning moves freely on rollers. The second bearing of this shaft is installed in a lid that closes the hole Ø212 mm .

In four openings Ø110 mm also bearings of 2 shafts are installed. In two openings Ø22, 5 mm are sockets with forks to move the gear. In two openings Ø30 and Ø30,1 mm the axle on which the intermediate gear gear is rotated on the rollers.

The case has a rectangular hole in size 424×148 mm, to which 20-bolts M6 fasten the lid. Other holes of the holes are fastened with 8 bolts M8. Overall dimensions of the part 680×570×190 mm Weight of the part - 65 kg.

Let's give a chemical composition and mechanical properties (table 3.1, 3.2).

Table 3.1 - Chemical composition СЧ-18ГОСТ1412-70

C, %	Si, %	Mn, %	Cr, %	S, %	P, %	N, %	Fe
3,1 – 3,4	1,7 – 2,1	0,8 – 1,2	not more				
			0,3	0,15	0,3	0,5	remaind

Table 3.2 - Mechanical properties СЧ-18ГОСТ1412-70

$\sigma_в,\ kgf/mm^2$	$\sigma_з,\ kgf/mm^2$	$f_{600/300}$	HB
18	36	8/2.5	167 - 224

The cast is fairly simple in design, but requires the use of rod forming for the formation of the inner surface (split B-B). In addition, the model should have a complicated connector due to the presence in the detail of 2 protruding side surfaces that are at different altitudes.

From the point of view of mechanical processing, the item has the following disadvantage in relation to the technological design. It is impossible to process the exterior of the rectangular holes with the dimensions mm with a milling cutter. It prevents the bean with a hole Ø11,5 мм., radius of 40 mm, which is on top of the product. It is acceptable to raise this surface by 10 mm, which does not violate the mechanism and does not affect the operation of the machine..

Holes Ø110, Ø90, Ø212 mm admit processing on one side of the casting. Treatment of two holes Ø22,5 mm spend on both sides of the product. The need for processing Ø28 і Ø24 mm and threaded hole to 1/2”. Turning processing carried out on two holes to 1/4” and a hole for a drain plug.

Other surfaces in terms of accuracy and roughness do not present a technological difficulty.

The material details allow the use of a hard alloy tool. The design of the part allows the use of multistep processing.

So the part is technologically enough.

Determine quantitative performance indicators.

Coefficient of unification of structural elements:

$$K_{ye} = \frac{N_{ye}}{N_e} = \frac{160}{169} = 0{,}946; \qquad (3.1)$$

where N_{ye} – number of unified structural elements in the part;

N_e – total number of structural elements in the part.

The level of precision engineering is characterized by the precision coefficient determined by the formula [2], c. 33:

$$K_m = 1 - \frac{1}{T_{cp}} = 1 - \frac{1}{6{,}28} = 0{,}84; \tag{3.2}$$

where T_{cp} – middle class precision product processing:

$$T_{cp} = \frac{\sum T n_i}{\sum n_i} = \frac{6\times 6{,}7 + 6\times 8 + 9\times 4 + 10\times 6{,}9 + 11\times 4 + 12\times 2 + 14\times 15}{169} = 6{,}28; \tag{3.3}$$

where T - class of machining precision;

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

The level of technology on surface roughness is estimated by the coefficient of roughness, determined by the formula [2], c. 33:

$$K_ш = 1 - \frac{1}{Ш_{cp}} = 1 - \frac{1}{7{,}96} = 0{,}875; \tag{3.4}$$

where $Ш_{cp}$ - average roughness parameter:

$$Ш_{cp} = \frac{\sum Ш \times n_i}{\sum n_i} = \frac{12{,}5\times 86 + 6{,}3\times 3 + 3{,}2\times 78 + 0{,}8\times 2}{169} = 7{,}96; \tag{3.5}$$

where $Ш$ - numeric value of the roughness parameter;

n_i – the number of surfaces with the corresponding numerical value of the roughness parameter.

The coefficient of material use is determined by the formula:

$$K_{вм} = \frac{M_{\partial}}{M_{з}} = \frac{65}{68{,}73} = 0{,}94; \qquad (3.6)$$

where M_{∂} = 65 kg - weight of detail;

$M_{З}$ = 68.73 kg - weight of workpiece.

The results of the determined performance indicators are presented in the table 3.3.

Table 3.3 - Combined performance characteristics of the part

№	Name of the indicator of productivity	Marking	Weights	Numerical value
1	2	3	4	5
1	Material usage indicator	$K_{вм}$	1,0	0,94
2	Accuracy	$K_{т}$	0,8	0,84
3	Coefficient of roughness	$K_{ш}$	0,7	0,875
4	Indicator of unification of structural elements	$K_{уе}$	0,7	0,946

Technical requirements for the manufactured case, as well as the methods of providing and its justification is given in Table 3.4.

Table 3.4 - Technical requirements for the manufacture of the case

№	Specifications	Accuracy class	Parameter of roughness	Method of providing and its justification
1.	Deviation from co-axial Ø90 i Ø212; Ø30 i Ø30,1; Ø110 i Ø22,5 not more than 0,04 mm .	7	$Rz20$	When machining on aggregate machines in restraints an alignment of holes in the boundaries of 0,015 mm is achieved. The rigidity of the system provides the requirements of one hole relative to the other
2.	Deviation of the holes axes parallel Ø90; Ø212; Ø30; Ø30,1; 2 отв. Ø110; 2 отв. Ø22,5 not more than 0,04 mm	7	$Rz20$	
3.	Offset axes of the threaded holes relative to the placement is no more 0,15 мм	7	$Rz20$	

The basic technological process of processing the parts allows you to achieve the required precision of the dimensions, surface roughness, that is, to meet all the requirements that apply to this part.

As for databases, they are chosen correctly, observing the principle of unity and continuity of databases. Also, the condition is fulfilled that during the first operation the following surfaces are processed, which in the future serve as the basis for other operations.

But this technological process is characterized by high costs of basic and auxiliary times and time for debugging.

The basic technological process is given in Table 3.5.

Table 3.5 - Basic process of manufacturing the case

№	Title and content of operations	$T_{шт}$, min
1	**2**	**3**
005	Vertical milling: 1. Milling the surface 60×176. 2. Milling the surface 60×176.	8,373
010	Radial drill: 1. Drill two holes Ø17.5 mm. 2. Drill two holes Ø18 mm. 3. Polishing of 4 surfaces Ø36mm. 4. Boring two holes Ø18H9.	3,12
015	Longitudinal milling: 1. Two side milled surface in size 190.	8,14
020	Horizontal milling: 1. Milling the surface (plane to install the cover with size 446×188).	3,74
025	Aggregate-drilling: 1. Drill 20 holes Ø5 mm and 30 holes Ø6,7 mm. 2. Countersink two chamfers. 3. Cut the thread in 20 holes M6-H6, 30 holes M8-H6, 1 hole M10-H6.	0,8
030	Aggregate-boring : 1. Treat the surface Ø212 mm, Ø90 mm, 2 holes Ø110 mm, 4 holes Ø20.5 mm, Ø25.5 mm, Ø30 mm, Ø30.1 mm.	24,5
035	Radial drill : Treat the surface to 1/2”, (to 1/4” 2 holes), $M36\times2$, to 3/4”.	17,8

he type of production is characterized by the coefficient of consolidation of operations. Its value is taken for a scheduled period equal to one month and is determined by the formula [2]:

$$K_{зо} = \frac{O}{P} \qquad (3.7)$$

where O - number of different operations;

P - number of jobs with different operations.

The number of operations assigned to one workplace can be found by the formula [2], p.37:

$$O = \frac{60 \times F_{м} \times K_{в} \times \eta_{н}}{T_{шт} \times N_{м}} \qquad (3.8)$$

where $F_{м}$ – monthly operating time of equipment in two-shift mode, $F_{м} = 4015/2 = 334{,}5$ hours;

$K_{в}$ – average rate of time use, $K_{в} = 1.3$;

$\eta_{н}$ – standard load factor for equipment, $\eta_{н} = 0.9$;

$T_{шт}$ – artificially-estimated time of execution of the projected operation on this machine, min;

$N_{м}$ – monthly release program, $N_{м} = 44000/12 = 3666{,}6$ pcs.

I accept $N_{м} = 3667$ pcs.

1. Vertical milling:

$$O_1 = \frac{60 \times 334{,}5 \times 1{,}3 \times 0{,}9}{8{,}37 \times 3667} = 0{,}765;$$

2. Radial drill:

$$O_2 = \frac{60 \times 334{,}5 \times 1{,}3 \times 0{,}9}{3{,}12 \times 3667} = 2{,}052;$$

3. Longitudinal milling:

$$O_3 = \frac{60 \times 334{,}5 \times 1{,}3 \times 0{,}9}{8{,}14 \times 3667} = 0{,}787;$$

4. Horizontal milling:

$$O_4 = \frac{60 \times 334{,}5 \times 1{,}3 \times 0{,}9}{3{,}74 \times 3667} = 1{,}712;$$

5. Aggregate-drilling:

$$O_5=\frac{60\times334{,}5\times1{,}3\times0{,}9}{0{,}8\times3667}=8{,}004;$$

6. Aggregate-boring:

$$O_6=\frac{60\times334{,}5\times1{,}3\times0{,}9}{24{,}5\times3667}=0{,}261;$$

7. Radial drill:

$$O_7=\frac{60\times334{,}5\times1{,}3\times0{,}9}{17{,}8\times3667}=0{,}340.$$

$$O=\sum_{i=1}^{7}O_i=0{,}765+2{,}052+0{,}787+1{,}712+8{,}004+0{,}261+0{,}346=13{,}927.$$

$$K_{зо}=\frac{O}{P}=\frac{13{,}927}{7}=1{,}989.$$

Hence, the type of production is large-scale, since 1< $K_{зо}$ <10.

According to the recommendations, the machines, located in the technological sequence of equipment, use a special, cutting tool - standard, which is equipped with carbide plates.

Blanking is done in batches. The size of the batch of the part I find for the mill on the most complex operation:

$$n=\frac{T_{n.s.}}{\alpha\times T_{шт.}}=\frac{30}{0{,}20\times8{,}373}=18\text{ pcs;}\qquad(3.9)$$

where $T_{n.s.}-$ preparatory-finishing time, $T_{n.s.}=30$ min;

$T_{шт.}-$ artificial time, $T_{шт.}=8{,}373$ min;

$\alpha-$ allowable time to adjust, $\alpha=5.$ ...30 %;

For large-scale production $\alpha=20$ %.

The size of the batch should be a multiple annual program. We accept n = 20 pcs.

Size of release tact:

$$t_o=\frac{F_{\partial}\times60}{N}=\frac{4015\times60}{44000}=5{,}56\text{ min / pc;}\qquad(3.10)$$

Accept $t_o=6$ min / pc;

where $F_\partial -$ a valid annual operating time fund equipment, $F_\partial = 4015$;

N - annual program for the production of parts, N=44000 pcs.

The choice of the type of workpiece or the establishment of a method for obtaining it is an important step in the development of the technological process of manufacturing the component. The degree of improvement in the method of obtaining the workpiece depends to a large extent on the meta-

Lu, the number of machining operations and complexity, the cost of the process of obtaining the workpiece parts.

In solving this issue it is necessary to go to the fact that the shape and size of the workpiece as close as possible to the shape and size of the part.

One and only way to get this detail - the case is casting. Consider two options for obtaining a workpiece. The first method is molding in sand-clay forms with manual shaping of shapes. The second method is molding in sandy-clay forms with machine-forming molds. This method provides greater productivity. To do this, determine the mass of billets. The comparison results are summarized in Table 3.6.

Table 3.6 - Comparison of procurement methods

Indicator	1 option	2 option
1	2	3
Type of workpiece	Casting in sand-clay forms with:	
	manual molding	machine molding
Bulk weight, kg	68,73	67,59
Cost of workpiece, UAH	392,08	385,88
Weight of the removing layer, kg.	3,73	2,59
The machining operations that are different:	A layer of metal that removes:	
1st operation	under the rectangular cover	
Allowance, mm	3,5	2,5
Volume of removable layer, mm^3	$V = (464\times188-444\times \times168)\times3{,}5 = 44240$	$V = (464\times188-444\times \times168)\times2{,}5 = 31600$

Continuation of table 3.6

1	2	3
2nd operation	from the side surface to the size $190_{-0,05}$	
Allowance, mm	3,5	2,5
Volume of removable layer, mm ^{3}	$V=[3{,}14\times(124^2-106^2)+$ $+3{,}14\times(73^2-55^2)+3{,}14\times$ $\times(82^2-55^2)+3{,}14\times(35^2-$ $-30^2)]\times3{,}5=118615$	$V=[3{,}14\times(124^2-106^2)+$ $+3{,}14\times(73^2-55^2)+3{,}14\times$ $\times(82^2-55^2)+3{,}14\times(35^2-$ $-30^2)]\times2{,}5=82173{,}8$
3rd operation	from the side surface to the size $190_{-0,05}$	
Allowance, mm	3,5	2,5
Volume of removable layer, mm ^{3}	$V=[3{,}14\times(64^2-45^2)+$ $+3{,}14\times(73^2-55^2)+3{,}14\times$ $\times(82^2-55^2)+3{,}14\times(35^2-$ $-30^2)]\times3{,}5=148310{,}1$	$V=[3{,}14\times(64^2-45^2)+$ $+3{,}14\times(73^2-55^2)+3{,}14\times$ $\times(82^2-55^2)+3{,}14\times(35^2-$ $-30^2)]\times2{,}5=105935{,}9$
4th operation	from the hole Ø212 mm	
Allowance, mm	3	2
The volume of the removing layer, mm^3	$V=[3{,}14\times(106^2-103^2)\times$ $\times16]\times3=31500{,}48$	$V=[3{,}14\times(106^2-103^2)\times$ $\times16]\times2=21100{,}8$
5th operation	from the hole Ø30 i Ø30,1 mm	
Allowance, mm	3	2
Volume of removable layer, mm^3	$V=[3{,}14\times(15^2-12^2)\times$ $\times20]\times3=10173{,}6$	$V=[3{,}14\times(15^2-12^2)\times$ $\times20]\times2=7033{,}6$
6th operation	from the hole Ø110 mm	
Allowance, mm	3	2
The volume of the removing layer,	$V=3{,}14\times(55^2-52^2)\times$ $\times(3\times26+20)=98778{,}1$	$V=3{,}14\times(55^2-53^2)\times$ $\times(3\times26+20)=66467{,}5$

Continuation of table 3.6

1	2	3
7th operation	from the hole Ø90 mm	
Allowance, mm	3	2
Volume of removable layer, mm^3	$V=3{,}14\times(45^2-42^2)\times$ $\times 32=26225$	$V=3{,}14\times(45^2-43^2)\times$ $\times 32=17684{,}5$

3.2 Development of the technological process of manufacturing the product

Find the cost of the workpiece, from the section of the feasibility study for the selection of the workpiece.

Determine the coefficient of material use:

$$K_м=\frac{q_{дет}}{Q_{заг}} \qquad (3.11)$$

$$K_{м1}=\frac{65}{68{,}73}=0{,}946, \quad K_{м2}=\frac{65}{67{,}59}=0{,}962\ .$$

So, we take a way of obtaining a workpiece - molding in sandy-clay forms with machine molding.

For the most accurate manufacturing of the case we will go to ensure that the rule of consistency and compatibility of the bases is fulfilled. Or, as far as possible, install and measure the workpiece from the same surface.

Based on these general provisions, we choose the following basic surfaces when handling the case. The results are recorded in the table 3.7.

Table 3.7 - Basic surface of the processing of the case

№ of the operations	The title of the operation	Treated surfaces	Base surfaces
1	2	3	4
005	Vertical milling	Protrusions for fixing in the size 22 mm	Reverse side of the surfaces of the protrusions
010	Aggregate Drilling	Hole Ø18and Ø36 mm	Treated in the previous operation of the surface
015	Longitudinal milling	2 2 sides of the case in the size of 190 mm and the plane under the cover	The same surface and two holes Ø18 mm
020	Aggregate Drilling	All threaded holes under the cover	The same
025	Aggregate-boring	Отв. Ø212, Ø90, Ø110, Ø30, Ø30.1, Ø22.5 mm	The same
030	Aggregate Drilling	Ø11.5 mm, to 3/4”	The same

Analytical calculation of allowances and operational sizes on the surface of the hole $Ø90^{+0,022}_{-0,013}$.

The calculation is carried out according to the formula:

$$2 \times Z_b \geq 2 \times \left[(R_z + T_a) + \sqrt{P_a^2 + \sum y^2} \right] \qquad (3.12)$$

where $R_z, T_a, P_a -$ respectively, the height of the microworldities, the depth of the layer, the total value of the spatial deviations derived from the previous transition; $\sum y -$ deviation of the installation of the workpiece on the metal cutting machine during the transition;

The workpiece - is a casting of the 1st grade of precision with a weight of 65 kg. The technological route of the processing of the hole consists of transitions: roughing and finishing boring and unfastening.

The bases for workpiece are 22 mm planes and holes in them Ø18H7.

Calculation of allowances is reduced to a table, in which the entire technological route and all the values of the allowance elements are sequentially recorded. Total value R_z and Ta is equal to 100 microns. After the first transition T_a for cast iron parts are excluded from the calculations. For rough boring $R_{z2} = 50$ mm, pure boring $R_{z3} = 20$ mm, unfolding $R_{z4} = 10$ mm.

Total value of spatial deviations:

$$P_{\text{З}} = \sqrt{\rho_{\text{нор}}^2 + \rho_{\text{ом}}^2} = \sqrt{23^2 + 721^2} = 724 \text{ microns;} \qquad (3.13)$$

Corrugation is taken into account, both in the diametral and in the axial direction.

$$\rho_{\text{нор}} = \sqrt{(\Delta k \times d)^2 + (\Delta k \times l)^2} = \sqrt{(0{,}7 \times 90)^2 + (0{,}7 \times 32\ )^2} = 23 \text{ microns;} \qquad (3.14)$$

where $\Delta k -$ specific curvature of the workpieces, $\Delta k = 0.7$ mm [2], c.48;
d – diameter of the workpiece hole, d = 90 mm;
l – length of the hole, l = 32 mm.

In determining the ρ_{OM} we take into account the accuracy of the placement of the base surfaces relative to the processed.

The total displacement of the opening in the casting relative to the outer surface is a geometric sum of two mutually perpendicular planes.

$$\rho_{\text{ом}} = \sqrt{\left(\frac{\delta}{2}\right)^2 + \left(\frac{\delta''}{2}\right)^2} = \sqrt{\left(\frac{800}{2}\right)^2 + \left(\frac{1200}{2}\right)^2} = 721 \text{ microns;} \qquad (3.15)$$

where δ, δ''– tolerances on the size of 46 and 147 mm, respectively, of the second class accuracyi, $\delta = 800$ мкм, $\delta'' = 1200$ microns.

Ultimate spatial deviation after rough boring:

$$\rho_1 = 0{,}05 \times P_{з} = 0{,}05 \times 724 = 36{,}2 \text{ microns}; \tag{3.16}$$

After pure boring: $\rho_2 = 0{,}04 \times P_{з} = 0{,}04 \times 724 = 28$.

Installation deviation for rough boring:

$$\varepsilon_1 = \sqrt{\varepsilon_{б}^2 + \varepsilon_{з}^2} = \sqrt{25^2 + 120^2} = 122; \tag{3.17}$$

where $\varepsilon_{б}, \varepsilon_{з}$ – deviation of base and fixing of workpiece;

It occurs due to bias of the workpiece in the horizontal plane when installed on the restoration pin. The deflection is due to gaps between the largest diameter of the installed holes and the smallest diameter of the pins.

$$S_{\max} = \delta_A + \delta_B + \delta_C\ ; \tag{3.16}$$

where $S_{\max}$ – the biggest gap size;

δ_A – tolerance to the hole, $\delta_A = 18$ microns;

δ_B – tolerance to the diameter of the pin, $\delta_B = 18$ microns;

δ_C – minimum clearance between hole diameter and pin, $\delta_C = 16$ microns;

Then, the largest angle of rotation on the pins can be found from the ratio of the largest gap when rotated in one direction from the middle of the position to the distance between the base surfaces.

$$tg\alpha = \frac{0{,}018 + 0{,}018 + 0{,}016}{\sqrt{620^2 + 100^2}} = 0{,}0008 \tag{3.19}$$

Remaining error of the installation during the pure boring:

$$\varepsilon_r = 0{,}05 \times \varepsilon_1 = 0{,}05 \times 122 = 6 \text{ microns}. \tag{3.20}$$

Calculation of allowances and limiting sizes for technological transitions on processing of hole $\varnothing 90^{+0,022}_{-0,013}$ is given in the table 3.8.

Table 3.8 – Calculated tolerances for machining the hole

Technological transitions of processing of hole $\varnothing 90^{+0,022}_{-0,013}$	Elements allowance, microns				Estimated allowance 2Zmin, microns	Estimated size *dp,mm*	Tolerance for accuracy δ, microns	Limit size, mm		Limit tolerance, microns	
	R_z	T	ρ	ε				$d_{\min}$	$d_{\max}$	$2Z^{np}_{\min}$	$2Z^{np}_{\max}$
1	2	3	4	5	6	7	8	9	10	11	12
Workpiece	700	700	724	-	-	86,845	1600	85,24	86,85	-	-
Rough boring	50	-	36	122	$2 \cdot 1434$	89,713	350	89,36	89,71	2870	4120
Pure boring	20	-	28	6	$2 \cdot 86.5$	89,886	140	89,7	89,88	170	380
Unfolding	10	-	-	-	$2 \cdot 48$	90,022	40	89,9	90,02	140	240
									Total	3180	490

$$2 \times Z_{\min} = 2 \times \left(R_{r-1} + T_{i-1} \times \sqrt{\rho_{i-1} + \varepsilon_i^2} \right) \tag{3.21}$$

Minimum allowance for boring:

a) rough boring

$$2 \times Z_{\min 1} = 2 \times \left(700 + \sqrt{724^2 + 122^2} \right) = 2 \times 1434 \text{ microns;}$$

б) pure boring

$$2 \times Z_{\min 2} = 2 \times \left(50 + \sqrt{36^2 + 6^2} \right) = 2 \times 86{,}5 \text{ microns;}$$

в) unfolding

$$2\times Z_{\min 3}=2\times\left(50+\sqrt{28^2}\right)=2\times 48 \text{ microns.}$$

We find the calculation gap:

а) for pure boring: $d_{p1}=90{,}022-2\times 0{,}048=89{,}889\,\text{mm}$;

б) for rough boring: $d_{p2}=89{,}886-2\times 0{,}0865=89{,}713$ microns;

в) for unfolding: $d_{p3}=89{,}713-2\times 1{,}434=86{,}845$ microns.

The smallest size limits:

$d_{\min 3}=90{,}022-0{,}040=89{,}98$ mm;

$d_{\min 2}=89{,}98-0{,}40=89{,}74$ mm;

$d_{\min 1}=89.71-0.35=89.36$ mm;

$d_{\min\, заг.}=86{,}84-1{,}6=85{,}24$ mm.

Minimum limit of allowances:

а) for unfolding: $2\times Z^{пр}_{\min 3}=90{,}02-89{,}88=140$ microns;

б) for pure boring: $2\times Z^{пр}_{\min 2}=89{,}88-89{,}71=170$ microns;

в) for rough boring: $2\times Z^{пр}_{\min 1}=89{,}71-86{,}84=2870$ microns.

Maximum marginal value of allowances:

а) for unfolding: $2\times Z^{пр}_{\max 3}=89{,}91-89{,}74=240$ microns;

б) for pure boring: $2\times Z^{пр}_{\max 2}=89{,}74-89{,}36=380$ microns;

в) for rough boring: $2\times Z^{пр}_{\max 1}=89{,}36-85{,}24=4120$ microns.

General allowances:

$2\times Z_{o\min}=140+170+2870=3180$ microns;

$2\times Z_{o\max}=240+380+4120=4740$ microns.

Verification:

$2\times Z^{пр}_{\max 3}-Z^{пр}_{\min 3}=240-140=100$ microns;

$\delta_2-\delta_3=140-40=100$ microns.

$2\times Z^{np}_{\max 2}-Z^{np}_{\min 2}=380-170=210$ microns;

$\delta_1-\delta_2=350-140=210$ microns.

Analytical calculation of allowances and interoperable sizes on the surface in size $190_{-0.05}$ mm.

The calculation is carried out according to the formula:

$$2\times Z_{в}=2\times\left(R_z+T_a+\rho_a+\varepsilon_y\right)=2\times\left(700+364+122\right)=2\times1186 \qquad (3.22)$$

Base: plane 22 mm and two openings in them Ø18-H7.

Technological process of processing consists of one-time milling of the case on both sides.

$R_z+T_a=700$ microns [2], table 4.3;

For milling $R_{za}=10$ microns [2], table 4.8;

$\rho_a=\rho_{нор}$ [2], table 4.7;

$$\rho_{нор}=\Delta k\times l=0{,}7\times520=364 \text{ microns}; \qquad (3.23)$$

where $\Delta k=0{,}7$ by 1 mm of length [2], table 4,8;

$l-$ the size of the treated surface, $l=520$ mm.

Residual spatial deviation after milling: $\rho=36$ microns.

Installation deviation: $\varepsilon_y=122$ mm.

$d_{р.заг.}=189.5+2\cdot1186=191.87$ mm,

$d_{р.заг.}=189{,}5+21186=191{,}87$ mm.

$2\cdot Z^{np}_{\max}=194.67-190=4670$

$2\cdot Z^{np}_{\min}=191.87-189.5=2370$

Table 3.9 - Calculation of allowances and limit sizes for mechanical surface treatment

Technological transitions of surface treatment $190_{-0,05}$ mm	Elements of allowance, *microns*				Estimated allowance 2Zmin, microns	Estimated size *dp,*mm	Tolerance δ, microns	Limit size, mm		Limit allowance, microns	
	R_z	T	ρ	ε				d_{min}	d_{max}	$2Z^{np}_{\min}$	$2Z^{np}_{\max}$
workpiece	700	700	364	-	-	191,87	2800	191,8	184,67	-	-
Milling	10	-	36	122	$2\cdot1186$	189,5	500	189,5	180	2370	4680

Verification:

$Z^{np}_{\max} - Z^{np}_{\min} = 4670 - 2370 = 2300$ microns;

$\delta_1 - \delta_2 = 2800 - 500 = 2300$ microns.

On other processed surfaces, allowances and tolerances are selected according to tables and recorded in the table 3.10.

Table 3.10 - Tolerances and allowance on other machined surfaces

№	Surface and processing method	Accuracy class	Roughness parameter	The size by the drawing, mm	Allowance, mm	Size with admission
1.	Hole Ø212 mm Boring	7	Rz 20	212	4	208±1.0
2.	Hole Ø110 mm Boring	7	Rz 20	110	4	106±0.08

3.3 Determining the amount of equipment

Since the type of production is large-scale, I use mainly specialized equipment. For convenience, the selected equipment is summarized in Table 3.11.

Table 3.11 - Selection of equipment for operations

№ of operation	The name of the operation	The name and model of the machine
005	Vertical milling	Special 2-spindle vertical milling machine
010	Aggregate-drilling	Special aggregate-drilling 4-positional, 4-way machine
015	Longitudinal milling	Longitudinal milling machine model 6632
020	Aggregate-drilling	Special aggregate and boring machine
025	Aggregate-boring	Aggregate-boring, special 4-axis machine
030	Aggregate-drilling	Special aggregate-drilling 4-way machine

Technical characteristics of the longitudinal milling machine model 6632 [2] p.57:

1. The size of the working surface of the table - 630×2000;
2. The largest mass of processed billets – 2500 kg;

3. Distance to the surface of the table:
- from the horizontal spindle axis – 25-560;
- from the end of the vertical spindle – 25-760;
4. The distance between the ends of the horizontal spindles – 470-870;
5. Number of spindles:
- horizontal – 2;
- vertical – 1;
6. Most movement:
- longitudinal table – 2000;
- sleeves of spindles – 200;
7. Number of spindle speeds – 21;
8. The frequency of spindle – 16-1600 rpm;
9. Feed, mm / min:
- table – 10-3000;
- spindle – 10-1000.

Power of machine tools in operations [15]:

005	20 kW;
010	21 kW;
015	30 kW;
020	30 kW;
025	42 kW;
030	27 kW.

Calculation of cutting modes by empirical formulas.

Operation 010. Aggregate-drilling.

Position 1. Install the part and fix it.

Position 2. Drill two holes Ø17,5 mm and two holes Ø18 mm.

Calculation is carried out on a larger diameter drilling. Depth of cutting:

$$t=\frac{D}{2}=\frac{18}{2}=9 \text{ , mm;} \tag{3.24}$$

$$S_o=S\cdot D^{0.6}=0.058\cdot 18^{0.6}=0.33 \text{ rpm;} \tag{3.25}$$

where D – diameter of the drill, D=18 mm;

S=0,058 [3],

We accept $S_o=0{,}35$ rpm ;

Cutting speed :

$$V=\frac{C\cdot D^z\cdot n_1}{T^m\cdot t^\alpha\cdot S_o^y\cdot HB}=\frac{11400\cdot 18^{0.25}\cdot 1.3}{32^{0.125}\cdot 9^0\cdot 0.35^{0.4}\cdot 200}=37 \text{ m/min;} \tag{3.26}$$

where T – drill stability, T = 32 min [3];

C – coefficient, C = 11400 [3];

n_1 - coefficient, n_1 = 1,3 [3];

Rotation frequency:

$$n=\frac{1000\cdot V}{\pi\cdot D}=\frac{1000\cdot 37}{3.14\cdot 18}=665 \text{ min}^{-1}; \tag{3.27}$$

The power of cutting:

$$P_x=C_1\cdot D^z\cdot S_o^y\cdot HB^n=2.6\cdot 18^1\cdot 0.35^{0.8}\cdot 200^{0.6}=4800\text{H;} \tag{3.28}$$

where C_1=2,6 ;

z = 1; y = 0,8; n = 0,6 [3];

The moment of cutting:

$$M=C_3\cdot D^z\cdot S_o^y\cdot HB^n=1.0\cdot 18^2\cdot 0.35^{0.8}\cdot 200^{0.6}=31.27 \text{ H}\cdot\text{mm}; \tag{3.29}$$

where C_3=1.0 [3], p.230, table 30;

z = 2 ; y = 0.8 ; n = 0.6 .

Since the machine is prepared according to the order, we accept cutting modes, obtaining according to calculation.

Machine time:

$$T_{01} = \frac{L_{p.x.}}{n \times S_o} = \frac{33}{655 \times 0{,}35} = 0{,}128 \text{ min}; \qquad (3.30)$$

where $L_{p.x.}$ – length of the drill path, $L_{p.x.} = y + l + y_1 = 9 + 22 + 2 = 33$ mm. ;

y – length of the cut, y = 9 мм;

l – length, l = 22 мм;

y_1 - length of the drill run, y_1 =2 мм.

Position 3. Unfolding 4 surface Ø36 mm to a depth of 2 mm.

Depth of cutting:

$$t = \frac{D - d}{2} = \frac{36 - 18}{2} = 9 \text{ mm}; \qquad (3.31)$$

Assign feed [3], p.288: $S_o = 0{,}113 \times 36^{0.6} = 0{,}95$ rpm;

where S = 0,113 [3],;

Feed on the tooth:

$$S_z = \frac{S_O}{z} = \frac{0{,}95}{4} = 0{,}24 \text{ mm / tooth}; \qquad (3.32)$$

Cutting speed: $V = \dfrac{979000 \times 36^{0.4}}{30^{0.4} \times 9^{0.1} \times 0{,}95^{0.45} \times 200^{1.5}} = 139$ m/min;

m = 0.4; x = 0.1; y = 0.45; z = 0.4 [3], p.230, table 40;

T = 30 min. [3], p.288;

C_v = 979000 [3], p.234;

n_1 = 1.3 [3], p.230, table 40;

Spindle speed: $n=\frac{1000\times 139}{3{,}14\times 36}=123\ \text{min}^{-1}$;

Machine time: $T_{02}=\frac{2}{123\times 0{,}95}=0{,}017\ \text{min}$;

Position 4. Unfolding 2 holes Ø18H9.

Depth of cutting: $t=\frac{18-17{,}5}{2}=0{,}25\ \text{mm}$;

Assign feed [3], c.288: $S_o=0.15\times 18^{0.7}=1{,}2\ \text{mm / rev}$;

where S = 0,15 [3], c.238, table 46;

Cutting speed: $V=\frac{100000\times 1{,}8^{0.2}}{48^{0.045}\times 1{,}2^{0.5}\times 0{,}95^{0.45}\times 200^{1.5}}=43{,}6\ \text{m/min}$;

m = 0,045;

y = 0,5;

z = 0.2 [3], p.230, table 40;

T = 48 хв. [3], p.288;

C_v = 100000 [3], p.234;

Spindle speed: $n=\frac{1000\times 43{,}6}{3{,}14\times 18}=775\ \text{rpm}$;

Machine time: $T_{03}=\frac{35}{775\times 1{,}2}=0{,}037\ \text{min}$;

where $L_{p.x.}-$ path length of the reamer, $L_{p.x.}=y+l+y_1=9+20+6=35\ \text{mm}$;

On operating machines take into account the cycle time:

$$T_y=T_{p.x.}+T_{x.x.}=0{,}128+0{,}5=0{,}628\ \ \text{min}; \qquad (3.33)$$

where $T_{p.x.}-$ time of working movement, $T_{p.x.}=T_o=0{,}128\ \text{min}$;

$T_{x.x.}-$ time of idling, that is, the time for the pick-up of the tool to the part, the turn of the table, $T_{x.x.}=0{,}5$.

Operation 015. Longitudinal milling.

Milling the surface under the cover and lateral surfaces.

Tool: End mill Ø500 mm, $z=16$ mm, ВК8 – 2 pcs. Mill Ø250, $z=10$, ВК8.

Depth of cutting: $t=2.5$mm.

Feed on the tooth: S_z=0.05 mm / tooth [3], p.249;

Feed per one mill rotation: $S_o=0{,}05\times16=0{,}8$ rpm;

Radial-slip cutting speed:

$$V=\frac{C_v\cdot D^q\cdot k_u\cdot k_\mu\cdot k_\varphi}{T_m\cdot t^k\cdot S_z^y\cdot z^n\cdot B^z}=\frac{306.5\cdot500^{0.25}\cdot1\cdot0.9\cdot1.06}{220^{0.35}\cdot2.5^{0.2}\cdot005^{0.56}\cdot50^{0.15}}=251\text{ m/min;}\tag{3.34}$$

where $C_v=306.5$;

K_u- coefficient of material and instrument, $K_u=1.0$ [3];

$K_\mu-$ coefficient of mechanical properties of the material, $K_\mu=\frac{C_1\times180}{200}=\frac{1\times180}{200}=0{,}9$;

$K_\varphi-$ coefficient of the main angle in the plan, $K_\varphi=1{,}06$, $\varphi=45^\circ$;

T – mill stability, T = 220 min. ;

B – milling width, B = 50 mm;

The exponent: q = 0.25, m = 0.35, k = 0.2, y = 0.56, n = 0, z = 0.15;

Spindle speed: $n=\frac{1000\times251}{3{,}14\times500}=159$ rpm;

Power is required for cutting:

$$N_e=c\cdot t^x\cdot B^z\cdot D^q=376\cdot10^{-2}\cdot2.5^{1.14}\cdot0.05^{0.9}\cdot50^{0.13}=3\text{ kW;}\tag{3.35}$$

where$c$ = $376\cdot10^{-2}$, x = 1.14, y = 0.7, z = 0.9, q = 0.13

;

The power of the selected machine:

$N_{e.\partial.}=3\cdot10$ kW;

$\eta=0.75$;

Taking into account the efficiency of the machine, the power of the drive is one mob:

$$N_n = 10 \cdot 0.75 = 7.5 \text{ kW};$$

$$N_n \geq N_{e.\partial.};$$

Correct the cutting mode under the machine's passport:

$n_{np} = 150 \text{ min}^{-1}$;

$S_{\min} = 118$ mm/min;

The actual cutting speed: $V_{np} = \frac{3{,}14 \times 500 \times 150}{1000} = 235{,}6$ m/min.;

Feed on the tooth: $S_z = \frac{118}{16 \times 150} = 0{,}045$ mm / tooth;

Machine time: $T_o = \frac{830}{118} = 7{,}03$ min;

where $L_{p.\partial.}$ – length of cutting.

It is determined by drawing the details. To do this we will have a circle Ø500 mm, which is equal to the diameter of the cutter, so that it does not come up to 5 mm to the contour of the milling plane. Then, make the second circle so that it leaves 5 mm behind the contour. The distance between the circle centers will be $L_{p.\partial.} = 830$ mm;

Calculation of cutting modes by tabular method

005. Vertical milling.

Mill 2 platforms in size 60×176.

End milling tool Ø125 mm: ВК-8, z = 8, T = 180 min.

Depth of cutting: $t = 2{,}5$ mm;

Feed: $S_z = 0.05$ mm / tooth [4], p.33;

Spindle speed: $n = \frac{1000 \times 158}{3{,}14 \times 125} = 402 \text{ min}^{-1}$;

where V – cutting speed, V=158 m/min [4], p.334;

D – diameter of the end mill, D=125 mm.

Minute feed: $S_{xв} = 0{,}05 \times 8 \times 402 = 160{,}8$ mm/min;

Cutting power: $N_e = 4{,}7$ kW [4], ;

Machine: special, two-spindle, vertical milling.

Machine time: $T_o = \frac{310}{160{,}8} = 1{,}93$ min;

020. Aggregate drilling.

Position 2. Drill 20 holes Ø5 mm and 42 hole Ø6,7 mm on both sides of the details at the same time. The calculation is conducted on a larger number and on a larger diameter of the drill (21 hole Ø6.7 mm).

Tool: drill Ø5 mm ГОСТ10902-77, drill Ø6.7 mm ГОСТ10902-77.

Depth of cutting: $t = \frac{6{,}7}{2} = 3{,}35$ mm ;

Feed: S=0,22 mm / rev [4], p.234;

Cutting speed: V=32 m/min [4], p.244;

Spindle speed: n=1295 rpm [4], p.244;

Axial force: $P_o = 1280$ H [4], p.246;

Torque: $M_o = 3700\ H \cdot mm$ [4], p.246;

Cutting power: $N_e = 0.38$ kW [4], p.286;

Required drive power for 21 drill: $N = \frac{0{,}38 \times 21}{0{,}75} = 5{,}78$ kW;

Machine: special, aggregate-drilling, four-position.

Machine time: $T_O = \frac{27}{1295 \times 0{,}22} = 0{,}08$ min;

where $L_{p.x.}$ – length of the tool path, $L_{p.x.} = 4 + 20 + 3 = 27$ mm.

Position 4. Cut the thread in 20 hole M6- 6H, in 30 hole M8-7H.

Tool: screwing tap M6-7H ГОСТ3266-87, screwing tap M8-H6 ГОСТ3266-81.

Depth of cutting: $t = 3{,}35$ mm;

Feed: S=1,25;

Cutting speed of threading: V=3,1 m/min;

Spindle speed: $n = \frac{1000 \times 3{,}1}{3{,}14 \times 8} = 123{,}4\ \min^{-1}$;

Machine time: $T_o = \frac{25}{123{,}4 \times 1{,}25} = 0{,}161$ min;

where $L_{p.x.}$ – length of the tool path, $L_{p.x.} = 20 + 5 = 25$ mm.

Operation 025. Aggregate-boring.

Position 2.

1. Bore the hole Ø212 mm and Ø90 mm, 2 holes Ø110 mm.

Tools: boring bits 2142-0109 ГОСТ9795-75.

Depth of cutting: $t = 2$ mm;

Feed S=0,25 mm / rev;

Speed: V= 135 m/min [4], p.133;

The machine is custom-made: special aggregate-boring, four-position.

Equation mode is set by law:

a) for hole Ø110 mm $V = \frac{3{,}14 \times 98 \times 205}{1000} = 60{,}1$ m/min;

б) for hole Ø90 mm $V = \frac{3{,}14 \times 92 \times 205}{1000} = 59{,}2$ m/min;

2. Drill 4 holes Ø20,5 mm and 2 holes Ø28,5 mm.

The calculation is carried out through the opening Ø28,5 mm.

Tool: drill Ø20,5 mm ГОСТ10903-77, drill Ø28,5 mm ГОСТ10903-77.

Drilling depth: $t = 2$ mm;

Feed: S=0,8 mm/rev;

Speed: V= 37 m/min [4], p.251;

Spindle speed: $n = \frac{1000 \times 37}{3{,}14 \times 28{,}5} = 440$ rpm;

Machine time for boring: $T_{o1} = \frac{35}{205 \times 0{,}25} = 0{,}682$ min;

where $L_{p.x.}$ – length of the tool path, $L_{p.x.} = 20 + 15 = 35$ mm.

Machine time for drilling: $T_{o2} = \frac{80}{205 \times 0{,}25} = 0{,}606$ min;

where $L_{p.x.}$ – length of the tool path, $L_{p.x.} = 12 + 60 + 8 = 80$ mm.

Position 3.

Unfolding 3 holes Ø90 mm; Ø212 mm; 2 holes Ø110 mm; 2 holes Ø22,5 mm; hole Ø30 mm and Ø30,1 mm.

The calculation is carried out through the opening Ø212 mm.

Tool: reamer Ø22,5 mm 2365-5080; Ø30 mm and Ø30,1 mm 2571-4018; floating reamer Ø90 mm, Ø212 mm, Ø110 mm.

Depth of cutting: $t = 2$ mm;

Feed: S=3,6 mm / rev;

Speed: V= 12 m/min [4], p.261;

Spindle speed: $n = \frac{1000 \times 12}{3{,}14 \times 212} = 18$ rpm;

Machine time: $T_{o4} = \frac{230}{18 \times 3{,}8} = 3{,}36$ min;

where $L_{p.x.}$ – length of the tool path, $L_{p.x.} = 15 + 190 + 25 = 230$ mm.

Operation 030. Aggregate drilling.

Position 1. Drill 3 holes ащк the thread $M36 \times 2$, 1/4”.

The calculation is conducted for the hole Ø36 ьь.

Tool: вrills Ø36 mm, Ø11,5 mm, Ø17,5 mm ГОСТ10903-79.

Depth of cutting: $t = \frac{36}{2} = 18$ mm ;

Feed: S=0,15 mm / rev;

Cutting speed: V=42 m/min [4], p.244;

Spindle speed: $n = \frac{1000 \times 42}{3{,}14 \times 36} = 400$ rpm;

Drive power: N=4,5 kW.

Machine: special aggregate drilling, four-position, two-spindle.

Machine time: $T_{o1} = \frac{56}{400 \times 0{,}15} = 0{,}93$ min;

where $L_{p.x.}$ – length of the tool path, $L_{p.x.} = l + y = 50 + 6 = 56$ mm.

Position 2. Mill the chamfer $1{,}6 \times 45^{\circ}$.

Depth of cutting: $t = 1{,}6$ mm;

Feed: *S*=0,2 mm / rev;

Speed: *V*= 8,2 m/min;

Spindle speed: $n = \frac{1000 \times 8.2}{3{,}14 \times 13} = 200$ rpm;

Machine time: $T_{o2} = \frac{8}{200 \times 0{,}2} = 0{,}2$ min;

where $L_{p.x.}$ – length of the tool path, $L_{p.x.} = 1.6 + 6.4 = 8$ mm.

Position 3. Cut the thread $M36 \times 2$,

Depth of cutting: $t = 2$ mm;

Feed: *S*=1,141 mm / rev;

Speed: *V*= 5,3 m/min;

Spindle speed: $n = \frac{1000 \times 5{,}3}{3{,}14 \times 13{,}6} = 120$ rpm;

Machine time: $T_{o3} = \frac{18}{120 \times 13{,}6} = 0{,}93$ min;

All calculations of cutting modes are included in the technological documentation and in the table 3.12.

Table 3.12 - Operating modes of cutting

№	Назва операції	T_o, min	*S*, mm/rev	*t*, mm	*V*, m/min	*n*, rpm
1	2	3	4	5	6	7
005	Vertical milling 1. Milling two sites in size 60×176	1.93	0.05	2.5	158	402
010	Aggregate-drilling 1. Drill 2 holes Ø17.5 and Ø18 mm.	0.128	0.35	9	37	665
	2. Unfolding 4 surfaces Ø36 mm.	0.017	0.95	9	139	123
	3. Unfolding of 2 holes Ø18-H9.	0.037	1.2	0.25	43.6	775
015	Longitudinal milling 1. Mill lateral surfaces in size $190_{-0.05}$ and the surface under					

	the lid at an angle 54˚.	7.03	0.05	2.5	251	159
020	Aggregate-drilling					
	1. Drill 20 holes Ø5 and 30 holes Ø6.7 mm.	0.08	0.22	3.35	32	1295
	2. Cut the thread in 20 holes M6-H6, in 30 – M8-7H.	0.161	1.25	3.35	3.1	123.4
025	Aggregate-boring					
	1. Bore hole Ø212, Ø90 and 2 holes Ø110 mm.	0.682	0.25	2	60	205
	2. Drill 4 holes Ø20.5 and 2 holes Ø28.5 mm.	0.606	0.8	2	37	440
	3. Unfolding 3 holes Ø90, Ø212, 2 holes Ø110, 2 holes Ø22.5, Ø30 and Ø30.1 mm.	3.36	3.6	2	12	18
030	Aggregate-drilling					
	1. Drill 3 holes under the thread M36×2, 1/4”, 3/4” .	0.93	0.15	18	42	400
	2. Mill the chamfer 1.6×45˚.	0.2	0.2	1.6	8.2	200
	3. Cut the thread M36×2.	0.93	1.141	2	5.3	120

The choice of a cutting tool is made from a number of commonly used standard tools, but you can also use a special tool. When choosing the type and design of the cutting tool, it is necessary to take into account the nature of the production, the method of treatment, the type of machine, the size, configuration and material of the workpiece to be processed, the required quality and accuracy of processing.

The choice of a cutting tool is made in the form of a table 3.13.

Table 3.13 - Choice of cutting and measuring instrument

	The name of the	Tool	
		Cutting	Measuring
1	2	3	4
005	Vertical milling: Milling two sites in size 176×60 mm. Measuring size 176 and 22 mm .	Mill Ø125 mm, ВК8, z=8 ГОСТ9475-71	Template on sizes 60, 20 and 176 mm.
010	Aggregate-drilling: 1. Drill 2 holes Ø18 and 2 holes Ø17.5 mm. 2. Unfolding 4 surfaces Ø36 mm. 3. Reamering 2 holes Ø18-H9.	Drill Ø17.5 мм ГОСТ10903. Unfolder Ø36 mm, ВК-8. Reamer Ø18-H9.	Trammel ШЦ-II-125-0.1 ГОСТ 166-80
015	Longitudinal milling: 1. Mill two lateral surfaces in the size of 190 mm and the top surface at an angle 54°.	Mill Ø500 mm, ВК-8, z=8 ГОСТ9473-71. Mill Ø250 mm, ВК-8, z=10 ГОСТ9773-71.	Template on sizes:$190_{-0\,1}$ ммі on angle 54°.
020	Aggregate-drilling: 1. Unfolding 20 holes Ø5 and 42 holes Ø6.7, hole Ø8.7, 2 holes Ø4 mm. 2. Drill 20 holes Ø5 and 42 holes Ø6.7, hoes Ø8.7 . 3. Cut the thread M6-H6 в 20holes, M8-6H in 42 holes M10-6H.	Drill centered Ø5 mm ГОСТ14962-75. Drills Ø5, Ø6.7, Ø8.7 mm ГОСТ10802-77. Taps ГОСТ3268-81.	Trammel ШЦ-II-250-0.05 ГОСТ 166-80.

025	Aggregate-boring: 1. Bore holes Ø212; Ø90; 2 holes Ø22,5 mm. Remove the chamfer 1×45°. Drill 2 holes Ø22,5; Ø30 mm. 2. Bore holes Ø212; Ø90; 2 holes Ø110 mm. Ream 2 holes Ø22,5; Ø30 mm. 3. Unfolding holes Ø212; Ø90, 2 holes Ø110; Ø22,5; Ø30; Ø30,1 mm.	Cutters ГОСТ9798-73. Drills Ø21.8, Ø28.5 mm ГОСТ10903-77. Cutters ГОСТ9798-73. Mills Ø21.9, Ø29.4 mm Reamers Ø30/30.1, Ø22.5, Ø212/90 mm	Trammel ШЦ-II-250-0.05 ГОСТ 166-80. Trammel ШЦ-II-125-0.1 ГОСТ 166-80 Plug $30^{+0.023}$. Plug $30.1^{+0.027}$.
030	Aggregate-drilling: 1. Drill 3 holes under the carving M36×2 1/4", 1/2". 2. Unfolding two holes under the thread 1/2". Mill the chamfer in the 6th openings 1/4" and in hole M36×2 . 3. Cut the carving M36×2-6H, 1/4", 1/2", 3/4".	Drills Ø34, Ø11.5, Ø17.5 ГОСТ19903-77. reamer Ø18.3 mm. Taps ГОСТ3266-81.	Trammel ШЦ-II-125-0.1 ГОСТ 166-80 Plug threaded M36×2, ¼", ½".

The calculation of the rules of time is carried out according to the formula [10]:

$$T_{шт} = T_{о} + T_{в} + T_{об} + T_{от}$$

where $T_{шт}$ – the norm of artificial time;

$T_{о}$ – main time, min;

$T_{в}$ – auxiliary time, min.

$T_{об}$ – time for servicing the workplace, min;

$T_{от}$ – time for break, rest and personal needs, min.

$$T_в = T_{ус} + T_{оз} + T_{уп} + T_{вим.}$$

where $T_{ус}$ – time to install and remove the details, min;

$T_{оз}$ – time for fastening of parts, min;

$T_{уп}$ – time at reception controls, min;

$T_{вим.}$ – time for detail measurement, min.

Operation 005. Vertical milling.

$T_о = 1{,}928$ min.

$$T_в = T_{дет.} + T_{уст.} + T_{вкл.-викл.} + T_{п.-о.} + T_{вим.} + T_{оч.}$$

where $T_{дет.} = 0{,}33$ min, [10], 434;

$T_{уст.} = 0{,}06$ min, [10],;

$T_{вкл.-викл.} = 0{,}06$ min, [10], ;

$T_{вим.} = 0{,}08$ min, [10], 446;

$T_{п.-о.} = 0{,}15 + 0{,}06 \times 6 = 0{,}51$ min, [10], ;

$T_{оч.} = 0{,}08$ min, [10], 437.

$T_в = 0{,}33 + 0{,}06 + 0{,}06 + 0{,}51 + 0{,}08 + 0{,}08 = 1{,}12$ min;

$T_{оч.} = T_о + T_в = 1{,}928 + 1{,}12 = 3{,}048$ min;

$T_{об} + T_{от} = 0{,}09 + 3{,}048 = 0{,}274$ min;

$T_{шт} = 3{,}048 + 0{,}274 = 3{,}322$ min.

Similarly, we carry out calculations for other operations.

For the processing of holes in the parts on the aggregate blade, a pneumatic fitting was designed.

The part is mounted on two supporting plates and fixed with the help of two fingers: round and rhombic. The clamp is carried out by two hooks, some driven by traction and a system of rifles. The restoration scheme for the hole is shown in Figure 3.1.

The entire system is driven by a pneumocylinder, developing a force of 30,000 H.

The technology of processing is influenced by a number of technological factors, which call the total error [2], p.78.

$$\varepsilon = \delta - k \times \sqrt{(k_1 \times \varepsilon_б)^2 + \varepsilon_д^2 + \varepsilon_у^2 + \varepsilon_{пр}^2 + \varepsilon_п^2 + (k_2 \times w)^2} = \\ = 0{,}045 - 0{,}2 \times \sqrt{(0{,}75 \times 0)^2 + 0 + 0{,}08^2 + 0{,}04^2 + 0{,}12^2 + (0{,}7 \times 0{,}1)^2} = 0{,}012 \tag{3.36}$$

where $\delta -$ admission to the size of the workpiece, $\delta = 0{,}045$;

$k -$ a coefficient that takes into account all deviations, $k = 0{,}2$;

k_1 – baseline error rate, $k_1 = 0{,}75$;

$\varepsilon_б$ – error in basing in fixtures, $\varepsilon_б = 0$;

$\varepsilon_д$ – the error is caused by deformation of the part, $\varepsilon_д = 0$;

$\varepsilon_у$ – error of installation of fixtures on the machin, $\varepsilon_у = 0{,}08$;

$\varepsilon_{пр}$ –the error of the inaccuracy of making the fixtures, $\varepsilon_{пр} = 0{,}04$;

$\varepsilon_п$ – error from wearing the fixtures, $\varepsilon_п = 0{,}12$;

k_2 – coefficient of manufacturing error, $k_2 = 0{,}7$;

$w -$ the significance of the manufacturing error, based on the economic precision of reclamation, $w = 0{,}1$.

Calculation of the clamping force of the workpiece

The calculation is reduced to the determination of the required effort of the clamping piece, which must withstand the cutting effort.

Total allowance for processing - 6 mm;

Cutting power - N = 5 kW;

Rate of rotation n = 250 rpm;

The total force of clamping is calculated from the condition:

$$M_{kp} \times k = F_3 \times f \times R \tag{3.37}$$

where M_{kp} – torque, $M_{kp} = \frac{975 \times N}{n} = \frac{975 \times 5}{205} = 237{,}8 \;\; H \times mm$;

f – coefficient of friction of steel on a steel, *f* = 0,15;

R – radius of application of force of cutting, *R* = 0,106 H;

k – coefficient of reliability, *k* =1,8.

$$F_3 = \frac{M_{kp} \times k}{f \times R} = \frac{237{,}8 \times 1{,}8}{0{,}15 \times 0{,}106} = 26920 \text{ H} \tag{3.38}$$

Calculation of the weak link of recovery.

We calculate a weak resting place for a hole. This is the threaded connection of the bolt nut on the traction.

Thread M20. [σ_T]=650 MPa Material Steel 45. Strength factor *n* =5.

Permissible tensile strength:

$$[\tau_p] = \frac{\sigma_T}{n} = \frac{650}{5} = 130 \text{ MPa}; \tag{3.39}$$

Inner thread diameter:

$$d_1 = \sqrt{\frac{4 \times 1{,}3 \times F_н}{\pi \times \left[\tau_p\right]}} = \sqrt{\frac{4 \times 1{,}3 \times 15000}{3{,}14 \times 130}} = 13 \text{ mm}; \tag{3.40}$$

where $F_н$ – the load that falls on a unit of time, $F_н = \frac{F}{2} = \frac{30000}{2} = 15000$ H.

$d_1 < 18{,}6$ mm;

$13{,}8 < 18{,}6$ mm.

3.4 Calculation of the fixtures for milling

For milling of three surfaces of parts at the same time a milling fixtures with a hydrostatic device was designed simultaneously. Figure 3.2 shows the restoration pattern for milling.

The part is mounted on two support bars and is guided by the help of two fingers. The clamping of the parts is carried out by two clamps, which are actuated by hydraulic cylinders operating on a fluid with a hydraulic system.

The part on this fitting is based in the same way as on rigorous fixtures.

Calculation of clamping force

Calculation analytically the previous one. Pressure of the cutting P = 80 MPa, cylinder diameter D = 60 mm, diameter of the rod d = 20 mm.

The force that develops the hydraulic cylinder:

$$P_y = \frac{\pi \times \left(D^2 - d^2\right)}{4} \times h = \frac{3.14 \times \left(60^2 + 20^2\right)}{4} \times 4 = 21350 \text{ H} \qquad (3.41)$$

Required clamping force in the part:

$$F_3 = \frac{M_{kp} \times k}{f \times R} = \frac{650 \times 1.8}{0{,}15 \times 0{,}25} = 31200 \text{ H} \qquad (3.42)$$

where M_{kp} – torque, $M_{kp} = 650 \;\; H \cdot mm$;

f – coefficient of friction of steel on a steel, f = 0,15;

R – radius of application of force of cutting, R = 0,25 H;

k – coefficient of reliability, k =1,8 .

So, as two hydraulic cylinders work, their total clamping force is equal: $2 \times F_з = 2 \times 21350 = 42700 > F_\partial = 31200$ H.

Fixtures serves to control a number of technological requirements of the details. This sanitization consists of a back support and a constructive sanitization of the type of sleeves and armor.

Detail is mounted on a stand with two different pysiaks. Adjustment for controlling the non-parallelism of the surfaces relative to the axis consists of a rotating mandrel Ø110 mm, the mandrel of the clip Ø90 i Ø212 mm.

After setting the scale, the scale of the indicator is set to 0. Then turning the mandrel Ø90 and Ø212 mm on 360°, take off the indicator lights. The item is suitable for displays up to 0.04 mm.

Design of special equipment and tools

Design description

Capture devices of industrial robots serve to capture and hold in a certain position of objects of manipulation. Capture devices of industrial robots can be changed depending on the requirements of a specific work task.

The gripping device centered on the expandable elastic camera is depicted in A1 format. The camera 6 is attached to the housing 3 through the intermediate ring 5 with the nut 4 and the screw 7. The air is pressurized into the chamber through the drilled holes in the housing 3. When the air is fed, the chamber is blown and the part is held to the inside surface.

The mandatory requirements for gripping devices include the reliability of capture and retention of the part, the stability of the base, the inadmissibility of damage or destruction of the object. The strength of the gripping device should be high with small overall dimensions and mass.

Particular attention should be paid to the reliability of fastening the gripping device to the hands of an industrial robot (IR). The capture is attached to the IR arm with two bolts M30×2.60.58 ГОСТ7805-70.

Calculation of the most loaded units

Calculate the threaded connection for strength.

Output data: thread M30, $[\sigma_T]$=650 MPa, material Steel 45, coefficient of strength n =5.

Permissible tensile strength:

$$[\tau_p] = \frac{650}{5} = 130 \text{ MPa};$$

Inner thread diameter:

$$d_1 = \sqrt{\frac{4 \times 1{,}3 \times F_н}{\pi \times \left[\tau_p\right]}} \tag{3.43}$$

where $F_н$ – the load that falls on a unit of time, $F_н = 30000$ H.

$$d_1 = \sqrt{\frac{4 \times 1{,}3 \times 30000}{3{,}14 \times 130}} = 19{,}6 \text{ mm};$$

$$d_1 < 30 \text{ mm};$$

$$19{,}6 < 30 \text{ mm}.$$

Consequently, the threaded connection can withstand the load

Conduct calculation of bending strength for the rod (finger), which is loaded with the body of the mechanism of reverse and mass distribution 676 H.

Output data: $a = 276$ mm, $l = 450$ mm, $P = 676$ H (see Fig.2.3).

It is necessary to check whether the flexural strength condition is met:

$$\sigma_{зг} = \frac{P}{\omega} \leq [\sigma]_{зг} \tag{3.44}$$

where $[\sigma]_{зг}$ = 160 H/m^2;

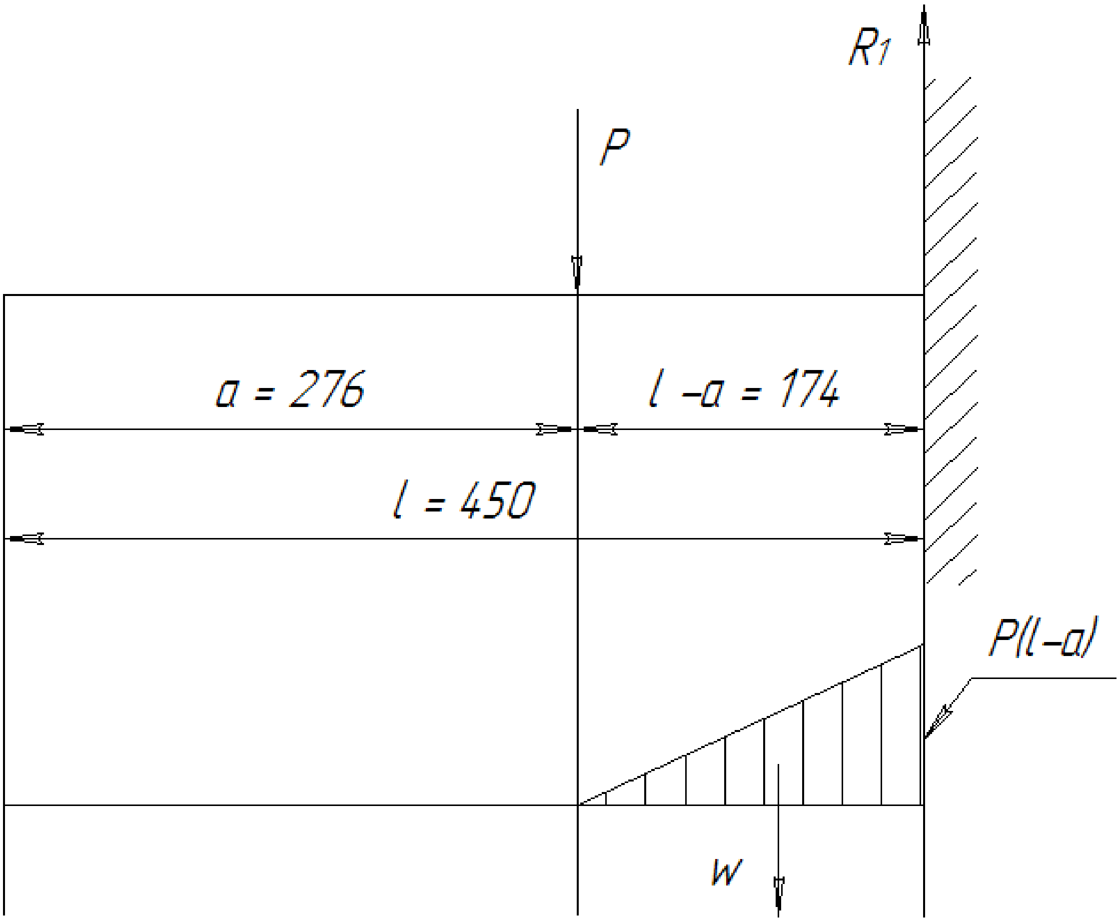


Рис. 3.1 – Scheme for calculating bending strength

$$\omega = \frac{P}{2} \times (l - a)^2 \qquad (3.45)$$

$$\omega = \frac{676}{2} \times (450 - 276)^2 = 10{,}14 \;\; m^2$$

$$\sigma_{зг} = \frac{676}{10{,}14} = 66{,}6 \leq [\sigma]_{зг},$$

Consequently, the beam (rod) will withstand this load.

4 PROJECT PART

4.1 Determination of the main and auxiliary areas of the shop

Equipment for machining parts are placed for this production in accordance with the sequence of the technological process, ie in accordance with the route of their processing. The duration of operations is synchronized according to the release time of the part.

Determination of the total number of equipment of the mechanical department is carried out by the complexity of machining the annual output of the case :

$$C = \frac{T \times N_з}{Ф_о \times k_з} \tag{4.1}$$

where $k_з$ – the average load factor of the equipment on the site. At two-shift work accept for mass production equal 0.7 [3, p.8].

$$C = \frac{0{,}466 \times 44036}{4015 \times 0{,}7} = 7{,}30 \text{ pcs.}$$

Accept 7 units of technological equipment of the site.

This production is characterized by the use of continuous production lines. The number of machines of a continuous production line is determined for each manufacturing operation. The estimated value of the number of machines is determined by the formula [4, p.128]:

$$C_p = \frac{t_{шт}}{\tau} \tag{4.2}$$

The results are presented in the form of table 6.2, the specification of the site equipment - table 4.1.

Table 4.1 - The number of machines for operations

№	Number and name of the operation	Estimated value of machines, C_p	Accepted number of machines, C_n
1	2	3	4
1	005 Vertical milling	$\frac{3,32}{5,47}=0,61$	1
2	010 Aggregate drilling	$\frac{0,67}{5,47}=0,12$	1
3	015 Longitudinal milling	$\frac{9,12}{5,47}=1,66$	2
4	020 Aggregate drilling	$\frac{0,70}{5,47}=0,13$	1
5	025 Aggregate-boring	$\frac{3,32}{5,47}=0,77$	1
6	030 Aggregate drilling	$\frac{1,52}{5,47}=0,28$	1
Total			7

Table 4.2 - Specification of the equipment of the site of manufacture of the body of the reverse mechanism and distribution ЛПЗ-304-13-318

№	Number and name of the operation	Name and model of equipment	Quantity, pcs.	Square, m^2
1	005 Vertical milling	Special two-spindle vertical milling machine	1	35
2	010 Aggregate drilling	Special aggregate drilling	1	40

		4-position machine		
3	015 Longitudinal milling	Longitudinal milling machine 6632	2	30
4	020 Aggregate drilling	Special aggregate drilling 4-position machine	1	40
5	025 Aggregate-boring	Special aggregate-boring 4-position machine	1	35
6	030 Aggregate drilling	Special aggregate drilling 4-position machine	1	40

In terms of mass production, the structure of the shop, usually the number of assembly units and parts of the product. That is, one technological workplace is assigned to each technological operation, and therefore the number of production or assembly production lines is determined by the number of manufactured parts or assembled units.

First of all, the location of sections in the middle of the shop will always depend on the location of mechanical and assembly shops of the plant for which the organizational form of mechanical assembly production is adopted. Node assembly workstations are located at the end of the machining line.

The width of the run is chosen to be 18 meters, ie such that it is possible to rationally place three rows of machines. The height of the run is determined taking into account the maximum height h_1 equipment, minimum distance h_2 between equipment and mobile cargo, as well as the height of the transported cargo h_3, crane h_4, determine the height H_1 to the head of the crane rail according to the formula:

$$H_1 = h_1 + h_2 + h_3 + h_4 \tag{4.3}$$

$$H_1 = 3 + 0.45 + 3 + 0.50 = 6.95 \text{м}$$

By size H_1 from the table 6.5 [5, p.130] determine the minimum height of the run H to the lower belt of trusses, which is equal to 10.8 meters.

The length of the section due to fire safety is 46 meters, and between them provide a main passage width of 5 meters.

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

Equipment placement plans are calculated in order to:

1. Ensuring the placement of technological and transport and lifting equipment in accordance with the documentation of technological processes, standards of rationalization of jobs.

2. Determining the final size of jobs and areas based on the location of all equipment, jobs, conveyors and other PTM;

3. Obtaining updated data for the issuance of tasks for the design of documentation for construction and installation work.

As a rule, the location of technological equipment and machines on sites is determined by the organizational form of the production process, the length of the machines themselves, their number, the type between operational transport, the method of chip removal from the cutting zone and so on.

The machines are placed along the conveyor. This creates favorable conditions for mechanization and mechanization between operational transportation and maintenance of workplaces. Yes, manipulators are used to install and unfold parts on the machine.

The machines are placed in the sequence of the technological process. After the last operation, the finished part arrives at the site of assembly.

Passive dangerous and harmful production factors that exist during the operation of machines in the designed mechanical shop are dangerous phenomena associated with insufficient strength of structures; increased loads on units and mechanisms of metal-cutting equipment; the effect of lubricants and coolants on the health of shop workers.

Thus, the above are the main active, passive-active and passive factors that occur or may occur during the operation of metalworking equipment of the designed shop of machining parts. In addition to the above, there are or may be other dangerous and harmful factors of production of all groups, the impact of which on the health of shop workers in this case will be considered less significant.

It was previously said that during the operation of metal-cutting equipment in the designed shop, vibrations will inevitably occur, which negatively affect the human body. Vibration mitigation can be achieved by certain measures, both constructive and technological: the use of dynamic vibration compensators, different types of shock absorbers, and so on. In particular, shock absorbers are used especially often for vibration isolation of metal-cutting equipment. They are made in the form of steel springs, springs, rubber gaskets and more. But the main means to reduce vibration are to improve the design of equipment; improvement of technological processes; work on modes at which there are no resonant phenomena; as well as vibration damping. A detailed analysis of the metal-cutting equipment used in this diploma project shows that to dampen or reduce the amplitude of vibrations, it is most appropriate to use vibrating supports type OV-30-2, which are installed under the support legs of the machines. Their number is equal to the number of support legs.

5 OCCUPATIONAL HEALTH AND SAFETY IN EMERGENCIES

5.1 Identification of harmful and dangerous production factors, bringing them to regulatory requirements

When designing a machining shop for a selected part, it is important to identify dangerous and harmful production factors that will occur during the operation of metalworking equipment of the shop. This is to ensure that they can be prevented. A detailed analysis of the designs of the most widely used metal-cutting machines of different groups in different load conditions allows us to conclude that the most common physical hazards in the designed shop include: moving parts of production equipment; moving workpieces and parts; shavings of the workpiece material being processed; particles of a broken metal-cutting tool; high temperatures of surfaces of the cutting tool and the processed detail; increased voltage in the electrical circuits of machines and others. The physically harmful production factors that occur during cutting in the designed shop include: high noise and vibration from the operation of metal-cutting equipment; insufficient lighting of the work area; direct and reflected shine; increased pulsation of light flux and others.

These dangerous and harmful production factors belong to the group of active factors that can affect a person due to the energy resources included in them.

Passive-active factors that occur during the operation of metal-cutting equipment in the designed mechanical shop are the unevenness of the floor surfaces of the shop and gratings, auxiliary equipment and fencing.

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

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

For grounding of metal-cutting machines, artificial group grounding conductors placed in homogeneous earth at a certain depth have become the most widespread. They are a system of vertical electrodes connected in parallel by a horizontal guide. For our case we choose the scheme of placement of electrodes in a row (fig. 5.1).

Determine the size of the electrodes.

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

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

Estimated distance *t*:

$$t = t_0 + l \;/\; 2 = 0,7 + 4 / 2 = 2,7 \text{ m.} \tag{5.2}$$

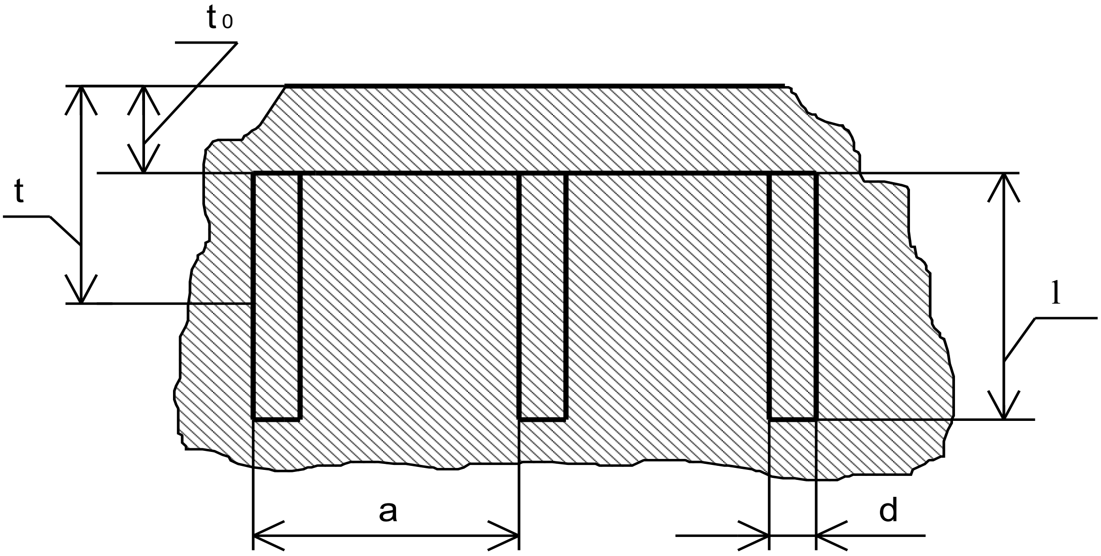


Fig. 5.1- Electrode placement scheme

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

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

where r_1 - soil resistance, Ohm / m;

l, d, t - electrode characteristics, m

$$r_1 = r_{table} \times\; z;$$

r_{table} = 50 Ohm / m.

At the size z = 1,3.

Then: r_1= 50 × 1,3 = 65 Ohm / m.

It meance:

R_b = 65 / 2× 3,14 × 4 (ln 2 × 4 / 0,012 + 0,5 ln 4× 2,7 + 4 / 4 ×2,7 - 4) = 5,2 Ohm.

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

$$ub \times n = R\,b \,/\, R_{доп1}, \tag{5.4}$$

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

Determine the number of vertical electrodes *n*.

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

So: $R_{доп} = 4$ *Ohm.*

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

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

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

$$R1 = \frac{r2}{2\pi L} \ln \frac{2L^2}{bt0} \tag{5.5}$$

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

L - length of horizontal conductor, m.

When placing the electrodes in a row [2]:

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

That is $L = 1{,}05\ (2 - 1) \times 8 = 10{,}5$ m.

Then:

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

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

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

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

$$u_г = 0{,}94; \qquad u_b = 0{,}91$$

Then:

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

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

5.3 Fire prevention. Characteristics of the building by the degree of fire safety and the degree of fire resistance

Fire - uncontrolled burning outside a special hearth, which leads to property damage.

Fire safety - the state of the object, in which the possibility of occurrence and development of fire and the impact on people of its dangerous factors is excluded with a regulated probability, as well as the protection of material values is ensured.

The causes of fires and explosions at the enterprise are violations of fire safety rules and regulations, non-compliance with the Law "On Fire Safety".

Dangerous factors of fire and explosion that can lead to injury, poisoning, death or property damage are open flames, sparks, high temperatures, toxic combustion products, smoke, low oxygen content, collapse of houses and buildings.

The state of fire safety at the enterprise is the responsibility of its managers, shop supervisors, foremen and other managers.

There are two types of fire protection at enterprises: professional and paramilitary. Paramilitary guards are created at high-risk facilities. In addition, voluntary fire brigades and teams, voluntary fire brigades and fire technical commissions of workers and employees are organized at the enterprises to strengthen fire protection. The Ministry of Internal Affairs has a fire protection department (UPR) and its local bodies. UPR includes the State Fire Supervision which carries out:

- Control over the condition of fire safety.
- Develops and approves fire regulations and rules and monitors their implementation in projects and directly on the objects of the national economy
- Conducts investigation and accounting of fires.
- Organizes fire prevention.

Fire prevention is a set of organizational and technical measures aimed at ensuring the safety of people, fire prevention, localization of their spread, as well as creating conditions for successful firefighting.

The chief engineer is the responsible manager of works on liquidation of fires and accidents at the enterprise. The head of the structural unit in which the fire broke out is the responsible executor of works on its liquidation.

Combustion and flammable properties of substances and materials.

Combustion is an oxidation process that is accompanied by intense heat and radiant energy.

Combustion occurs when there is a combustible substance, oxidizer and ignition source. Oxidizing agents can be air oxygen, Bertoletto salt, sodium peroxide, nitric acid, chlorine, fluorine, bromine, nitrogen oxides, and the like.

Combustion can be complete or incomplete. Complete - with a sufficient or excess amount of oxidant and such combustion, toxic substances are released.

Incomplete - occurs when there is insufficient oxidant. Incomplete combustion produces products of incomplete combustion, among which are toxic substances (carbon monoxide, hydrogen).

When burning homogeneous combustible mixtures, kinetic combustion occurs, the rate of propagation of which depends on the rate of heat transfer in the mixture and can reach hundreds of meters per second and is accompanied by an explosion.

GENERAL CONCLUSIONS

As a result of the thesis work the technological manufacturing of the manufacture of a component was developed, which is characterized by the following features:

1. Drilling operations combined into aggregates;
2. The union of milling operations (obrok the surface under the cover at an angle 54° and lateral surfaces in size $190_{-0.05}$).

As a result - the time for manufacturing of this part has decreased.

In the thesis I substantiated that the machine molding is economically and technologically better than manual. The plant is also using manual molding.

In the design part used pneumatic and hydropower.

The calculations in the organizational and economic part confirmed the correctness of the decisions and showed that due to the introduction of the new technological process, the cost of parts has decreased, the equipment download has improved, the volume of investments has decreased, and a number of technical and economic indicators have improved.

Implementation of the designed technological process would provide an opportunity to ensure the concentration of processing, the mobility of production, increase the level of mechanization and automation, as well as a significant reduction in the cost of equipping the production process with the production of products in general.

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