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

QUALIFYING PAPER

For the degree of

master
(educational level)

topic: Development of the reduction gear case 3411040-8902286-00 production process and the study of surface milling process

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

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Ternopil
2021

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APPROVED BY

Head of Department Okipniy I.B

ASSIGNMENT
for QUALIFYING PAPER

Ibrahim
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(surname, name, patronymic)

1. Project (thesis) theme. Development of the reduction gear case 3411040-8902286-00 production process and the study of surface milling process

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

1.Approved by university order as of 26.03. 2021 року № 4/7-222
2. Student's project (thesis) submission deadline
3. Project (thesis) design basis 1. Basic TP manufacturing parts. 2. The program is 250000 pieces/ year. 3. Drawing the body parts.

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

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

6. Advisors of design (thesis) chapters

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

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

PROJECT TIME SCHEDULE

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

Student ______ (signature) Ibrahim Mohamed Adele Mohamed Abdelaziz (surname and initials)

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

ABSTRACT

Actuality of theme. Milling is one of the most productive and common methods of cutting. On milling machines process horizontal, vertical and inclined planes, shaped surfaces; mill grooves and keyways, teeth of spur and helical gears; a set of cutters process complex surfaces, make cuts.

The purpose of the study is to improve the process of manufacturing process of the part of the gearbox housing 3411040-8902286-00 with the study of the process of milling surfaces

The object of study - the technological process of manufacturing the gearbox housing.

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

Research methods. The work is performed using the basic provisions of computer technology in mechanical engineering.

Scientific novelty: The influence of technological parameters of milling on the quality of treated surfaces is analyzed.

Practical significance. The improved technology of manufacturing of the case of a reducer is offered and influence of process of milling on quality of a detail is investigated.

Approbation of the results of the master's qualification work. Material Proceedings of the IV International Student Scientific and Technical Conference "Natural and human sciences. Current issues »

The structure and scope of the master's qualification work. The work consists of an introduction, four sections, a list of used sources and appendices. The full volume of the master's qualification work is 79 pages, including 29 figures, 6 tables, bibliographies from 20 sources to two pages.

The purpose of the study is to improve the manufacturing process of the part of the gearbox housing 3411040-8902286-00 with the study of the process of milling surfaces

CONTENT

INTRODUCTION

Nowadays, milling has become one of the most commonly used methods for obtaining surfaces by cutting, since the latest trends in the field of mechanical engineering are the combination of several types of processing in one operation, one of which is often milling. This is evidenced by the creation of modular and multi-purpose, as well as five coordinate milling machines.

The main advantages of this processing method are high productivity, accuracy and quality of the processed surfaces. However, the main feature of the process, which limits the scope of its application, is its dynamic imbalance, which is caused by a constant change in the cut thickness, and, accordingly, a change in the cutting force. This work is devoted to the study of the laws of change in the cut thickness and the influence of this phenomenon on the stability of the cutting process during milling.

When designing technological processes for the manufacture of machine parts, it is necessary to take into account the main directions in modern engineering technology:

Approximation of workpieces in shape, size and surface quality to finished parts, which makes it possible to reduce material consumption, significantly reduce the labor intensity of processing parts on metal-cutting machines, and also reduce the cost of cutting tools, electricity, etc.

Increase in labor productivity through the use of: automatic lines, automatic machines, modular machine tools, CNC machines, more advanced processing methods, new grades of materials for cutting tools.

Concentration of several different operations on one machine for simultaneous or sequential machining of a large number of tools with high cutting data.

1. ANALYTICAL PART

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

The problem of increasing the efficiency of the milling process has been and remains one of the most important in mechanical engineering. The complexity of its solution is due to the fact that the milling process is characterized by many interrelated factors that affect both the course of the process and its results. It should be emphasized that when milling, you can get a part of almost any configuration, and this method is often used to obtain surfaces by cutting, where the main advantages are high productivity, accuracy and quality of machined surfaces. The constant increase in requirements for accuracy, quality of the processed surface and the resource of the manufactured part lead to the need for research on all parameters of surface quality. On the basis of these studies, the development of new technological recommendations will make it possible to obtain an optimal set of properties of the processed surface when milling a part [1]. It is known that the resource of a manufactured part is influenced by roughness, work hardening of the processed surface, as well as residual stresses arising from processing, which can significantly distort the shape of the finished part, and in exceptional cases lead to irreparable defects. Thus, all this points to the need to study the quality parameters of the milled surface, develop new research methods, and solve known problems with new methods [2].

Milling is blade machining with a main rotary cutting motion imparted to the tool and having a constant path radius, as well as at least one feed movement directed perpendicular to the main motion axis.

Milling is a productive and versatile technological method for machining workpieces by cutting. In mechanical engineering, planes, ledges, grooves of rectangular and profile sections, shaped surfaces, etc. are machined by milling. Milling is also used for cutting rolled bars, threading and gear hobbing.

For processing flat and shaped surfaces on milling machines, milling cutters are used - a multi-tooth (multi-edge) tool. Each cutter tooth is a simple cutter.

Appointment of cutters. The main types of cutters are shown in Fig. 1.1. For processing open planes on horizontal milling machines, solid cylindrical cutters are used (Figure 1.1, a) and prefabricated with plug-in knives (Figure 1.1, b).

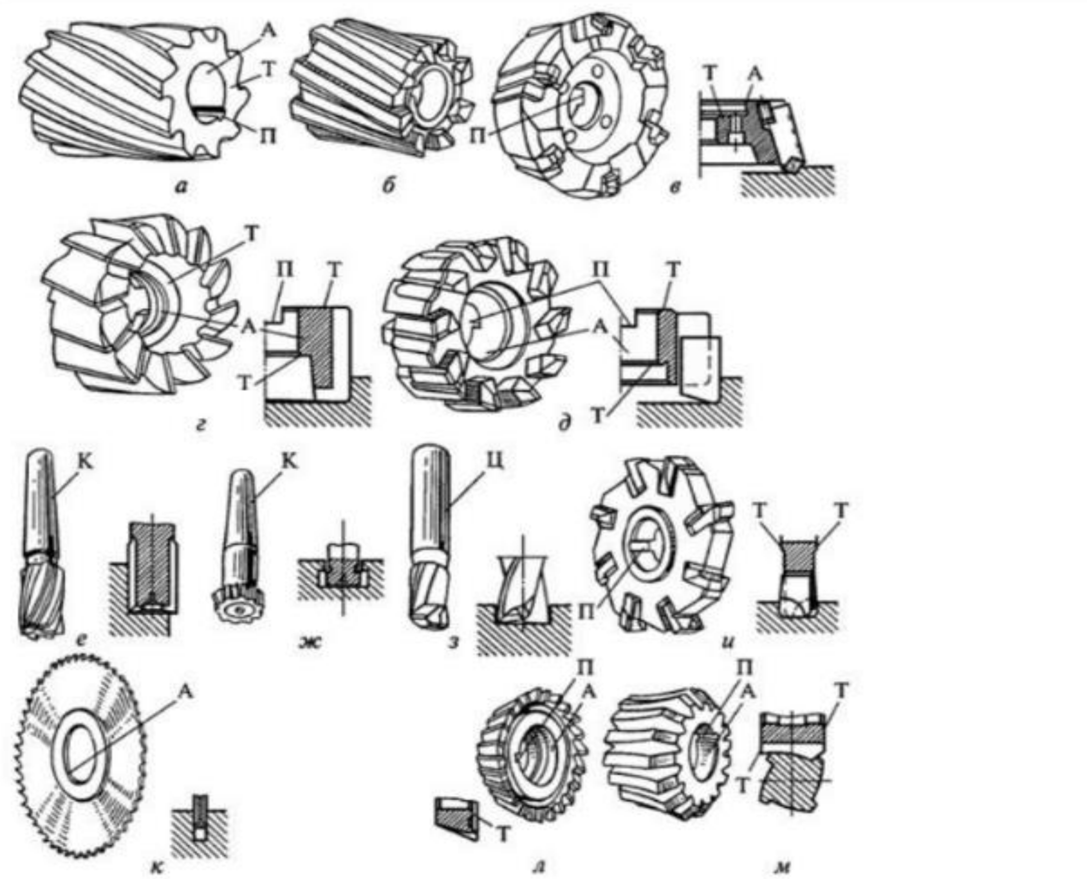

Figure 1.1 - The main types of cutters

For high-performance processing of solid and intermittent planes on vertical milling and special machines, face milling heads are used (Fig. 1.1, c) equipped with carbide knives.

The processing of conjugate planes located at different levels, parallel or inclined (cube faces, hexagons, bevels, ledges, etc.), is carried out with end shell cutters solid (Figure1.11, d) and with plug-in knives (Figure 1.1, d).

Milling grooves and ledges is carried out with end (Fig. 1.1, f, g), keyway (Fig. 1.1, h) and disk (Fig. 1.1, i) cutters. For processing half-open planes, grooves and for copying work, end mills are widely used (see Fig. 1.1, e). For processing closed keyways, key cutters are used (see Fig. 1.1, h).

Slotting of slots and narrow slots is performed by cutting (Fig. 1.1, k) and spline cutters. Corner cutters (Fig. 1.1, l) are used for milling straight and helical grooves between the teeth in the manufacture of cutters, reamers, countersinks and other tools. Milling of shaped surfaces is performed with shaped cutters (Fig. 1.1, m).

When classifying cutters, in addition to their purpose, their design is taken into account; the way they are fixed on the machine; the design of the teeth; the location of the teeth relative to the axis; direction of the teeth.

There are the following designs of cutters: solid; composite, (for example, with soldered or glued cutting elements); prefabricated (for example, equipped with multi-faceted carbide plates); typesetting (sets of cutters), consisting of several separate standard or special cutters and designed for the simultaneous processing of several surfaces.

Fastening of cutters on machines. Connecting parts - fastening bases - for cutters can serve as cylindrical holes with longitudinal or transverse keyways, tapered and cylindrical shanks (see Fig. 1.1).

Cylindrical, disc, end shell, angle and shape cutters are fixed on milling mandrels. To reduce the runout of the milling mandrel, the support ends of the cutters must be strictly parallel to each other and perpendicular to the axis of the cutter. The deviation of the supporting end surfaces from the cutter axis should not exceed 0.04 ... 0.05 mm. Rotation to milling cutters fixed on a mandrel is transmitted by a longitudinal or face key.

Shell end mills with a fine tooth are attached to shortened mandrels with a screw, and with a large tooth and insert knives - on special mandrels. End mills and keyway cutters with a diameter of up to 20 mm, for which a cylindrical shank serves as a mounting base, are fixed to end mandrels using a collet clamp. End, end and keyway cutters with a diameter over 200 mm, for which the fastening base is a taper shank, are installed in the machine spindle directly or using reducer taper bushings. The taper shank in the taper seat of the spindle is tightened with a screw.

Face milling heads (see Fig. 1.1, c) are attached directly to the machine spindle. The base hole, the keyway and the hole for the fastening screws are made according to the dimensions of the front ends of the spindles of milling machines.

The teeth of the cutter can be sharpened (Fig. 1.3, a) and reared (Fig. 1.3, б). Sharpened teeth are sharpened along the back surface at a rear angle α (see Fig. 1.2, lines T - T).

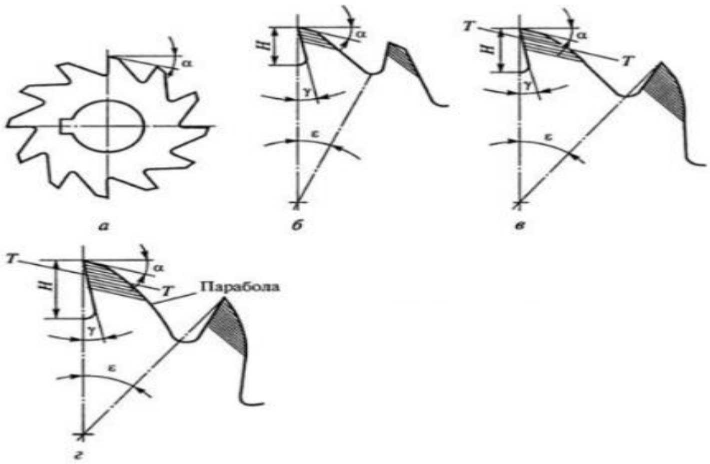

Figure 1.2 - Tooth cutter shapes

These teeth are easy to manufacture and provide a high surface finish. The disadvantages of pointed teeth are reduced tooth height and loss of profile dimensions after regrindingThree types of sharpened teeth are used: with a straight back (Figure 1.2, b), a two-angled back (Figure 1.2, c) and a curved back (Figure 1.2, d). Straight-back teeth are typical for fine-toothed milling cutters that allow 6 ... 8 tooth regrinds and are intended for light work.

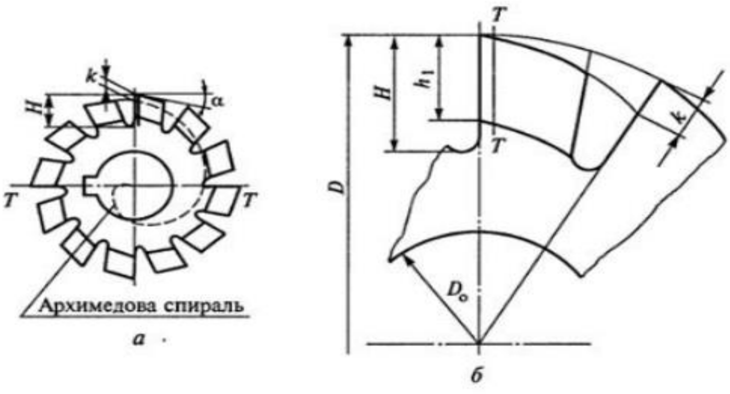

Figure 1.3 - Tooth cutter shapes

Double-backed teeth are common with coarse-tooth cutters for heavy duty applications. The back of a tooth, formed by two surfaces, is constructed so that the tooth has a shape close to a parabola. Cutters with teeth of this type, with high tooth strength, have a larger groove volume.

Teeth with a curved back, made in a parabola, have equal strength in all sections, which makes it possible to increase the height of the tooth, and, consequently, to increase the number of regrinds and increase the volume of the groove.

For relief cutters with a back surface formed along the Archimedes spiral (see Fig. 1.3, a), sharpening is carried out along the front surface (line T — T). The tooth of these cutters remains unchanged in shape (Fig. 1.3, b) and the size of the shaped profile with all regrinds until the cutter is fully used. The recessed tooth is mainly used for router bits.

According to the location of the teeth relative to the axis, they are distinguished: cylindrical cutters with teeth located on the surface of the cylinder (see Fig. 1.1, a and b); end mills with teeth located at the end of the cylinder (see Fig. 1.1, d and e); angular cutters with teeth located on a cone (see Fig. 1.1); shaped cutters with teeth located on a surface with a shaped generatrix (see Fig. 1.1, m) (with a convex and concave profile). Some types of cutters have teeth both on the cylindrical and on the end surface, for example, disc two- and three-sided (see Fig. 1.1, and and k), end (see Fig. 1.1, e), keyway (see Fig.1.1, h).

In the direction of the teeth, cutters can be: spur-toothed (see Fig. 1.1, and and k); helical (see Fig. 1.1, m) and with a helical tooth (see Fig. 1.1, a). The angle of inclination of the helical tooth serves to ensure quiet (vibration-free) milling.

When performing milling, two schemes are used: counter milling (Fig. 1.4, a). The directions of movement of the feed Ds and the cutter speed v are opposite. Cutting begins at point 1 (zero thickness of the cut off layer) and ends at point 2 (maximum thickness of the cut off layer);passing milling (Fig. 1.4, b). The direction of movement of the feed Ds coincides with the direction of the cutter speed v. Cutting starts at point 2 (maximum thickness of the cut layer) and ends at point 1 (zero thickness of the cut layer).

When working according to the first cutting scheme, plunge-in is difficult, since there is a sliding of the tooth and a large release of heat, which accelerates the bluntness of the cutter. When working according to the second scheme, a higher quality of the processed surface and a slow bluntness of the cutter are provided.

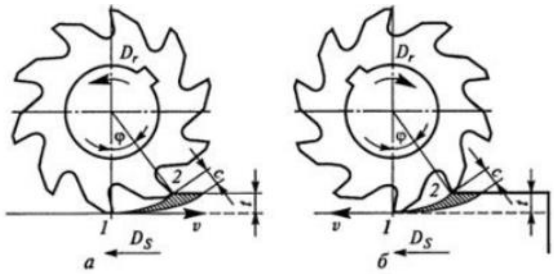

Figure 1.4 - Milling schemes

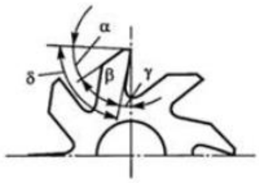

Figure 1.5- Geometric parameters of the cutter

However, the work occurs in jerks (at the time of cutting the tooth into the metal), therefore, passing milling is possible only on machines specially adapted for these purposes.

The geometric parameters of the cutters are selected depending on the following factors: the material of the workpiece and the cutting part of the cutter, its design, milling conditions. Front γ and rear α cutting angles are formed by sharpening cutters (Fig. 1.5).

The rake angle γ facilitates tool entry and chip separation. With an increase in the rake angle, the working conditions of the tool are improved, the cutting force decreases, and its durability increases.

However, too much rake angle weakens the cutting tool body against the blade and will easily chip and break. Heat dissipation in this case is impaired. Based on this, very specific rake angles are recommended for each tool.

At small angles α, friction increases, cutting forces and cutting temperature increase, the flanks of the tool wear quickly and its tool life decreases. At very large values of the angles a, the strength of the tool decreases, and heat dissipation worsens. The angle between the front and rear surfaces of the cutter blade is called the taper angle β in the cutting plane.

The elements of the cutting mode during milling are (Figure 1.6):

– cutting force (Pz);

– normal strength (Py);

– axial force (Px);

– cutting depth (t);

– cutting speed (V);

– feed (S);

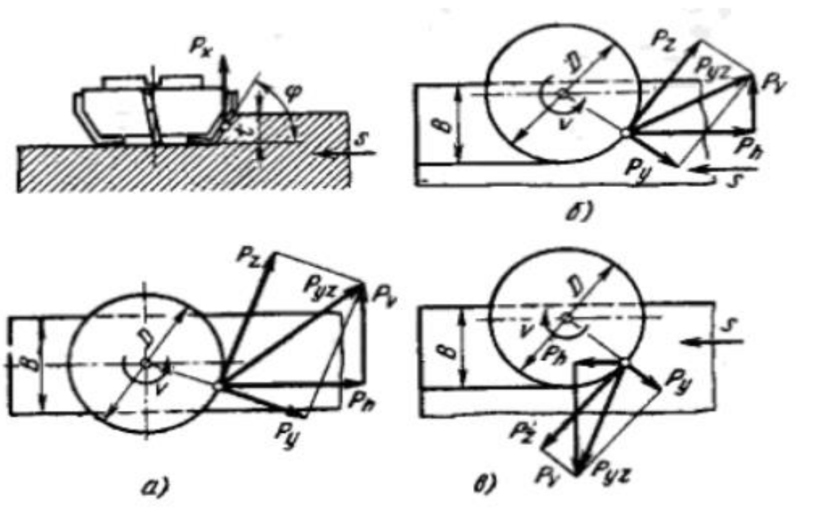

Figure 1.6 - Components of cutting modes and forces during face milling:

a) symmetric, b) asymmetrical counter-milling, c) asymmetric passing. - milling width (B).

The depth of cut (t) is selected depending on the machining allowance, power and rigidity of the machine. We should strive to conduct rough and semi-finishing milling in one pass, if the power of the machine allows it. Usually the cutting depth is 2 ... 6 mm. On powerful milling machines, when working with face mills, the depth of cut can be up to 25 mm. With a machining allowance of more than 6 mm and with increased requirements for the value of surface roughness, milling is carried out in two transitions: roughing and finishing.

With a finishing transition, the depth of cut is taken within 0.75 ... 2 mm. Regardless of the height of roughness, the depth of cut cannot be less. The cutting edge has a certain radius of rounding, which increases with wear of the tool; at a small depth of cut, the material of the surface layer is crushed and subjected to plastic deformation. In this case, no cutting occurs. As a rule, with small machining allowances and the need for finishing (roughness value Ra = 2 ... 0.4 µm), the depth of cut is taken within 1 mm.

At a shallow depth of cut, it is advisable to use cutters with round inserts (GOST 22086-76, GOST 22088-76). At a depth of cut greater than 3 ... 4 mm, cutters with six-, five- and tetrahedral inserts are used.

The milling feed is the ratio of the distance traveled by the considered point of the workpiece in the direction of feed movement to the number of revolutions of the cutter or to the part of the cutter revolution corresponding to the angular pitch of the teeth.

Thus, when milling, the feed per revolution So (mm / rev) is considered - the movement of the considered point of the workpiece in a time corresponding to one revolution of the cutter, and the feed per tooth Sz (mm / tooth) - the movement of the considered point of the workpiece during the time corresponding to the rotation of the cutter by one angular tooth pitch.

In addition, the feed rate vs is also considered (previously it was defined as a minute feed both in the old literature and on some machines this term is still used), measured in mm / min. The feed rate is the distance traveled by a given point on the workpiece along the path of that point in the feed movement per minute. This value is used on machines for setting up the required mode, since in milling machines, the feed movement and the main cutting movement are not kinematically interconnected.

1.2. Methods of solving the problem

Steps to improve the efficiency of the milling process. The first step is choosing a processing strategy. Two options are possible here [4].

The first option is associated with successive passes for processing the upper part of the workpiece, then the subsequent part, as shown in Fig. 1.7 These are areas "1", "2" and "3".

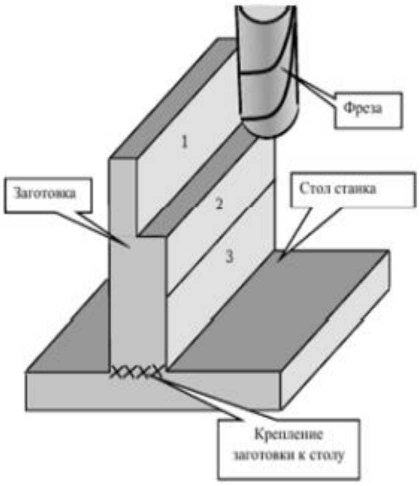

Figure 1.7 - Scheme of the first processing strategy

In this case, the lower part, due to the increased rigidity of the workpiece, reduces the rigidity of the part being machined. However, on the mating line of successive passes (boundaries of areas "1", "2", "3"), an unevenness is always formed, which leads to an error in shape. In addition, the effectiveness of this strategy is significantly reduced.

The second option is associated with processing the entire surface at once. It is more productive, but leads to the above errors. For this reason, it is necessary to leave an allowance for additional finishing cuts. Let us consider the second strategy as more productive, but difficult in analysis and synthesis [5]. The second stage is the choice of the machine. For milling a surface that is wider than the cutter diameter, it is advisable to choose a machine with five-axis contour control. This is due to the need to compensate for the bending deformation error of the cutter. In addition, to compensate for the dependence of the rigidity of the part along the trajectory of movement along the generatrix of the formed surface, it is necessary to provide a constant ratio of the force to the total reduced rigidity in the direction normal to the 24 generatrix. For this, as a possible processing strategy, the programmed control of the table speed in the direction of the generated generatrix is considered.

The third stage is diagnosing the kinematic disturbances of the machine in the unity of estimating the amplitude of the radial beats of the spindle and variations in the feed rates of the table movement. To estimate kinematic disturbances, one can use the methodology described in [6, 7]. It is based on the processing of information from feedback sensors on the position of the table, which are equipped with almost all CNC machines with contour control. The characteristics of kinematic disturbances, represented, for example, by autocorrelation functions, characterize the maximum achievable processing accuracy on a particular machine tool.

The fourth step is choosing an instrument. When choosing a tool, it is necessary to take into account the following features. 1) The number of teeth (pitch between the teeth of the cutter), taking into account the angle of inclination of the cutting blades, must ensure the continuity of the process without overlapping contacts. The cutter diameter is chosen on the basis of a compromise between the desire to increase it to provide increased rigidity and the need to shape the surface in areas of its curvature. 2) It is necessary to ensure the geometric accuracy of the cutting blades of the cutter. In the described case, the accuracy of the radius of the cutting blades should be two to three times higher than the required accuracy of the surface. It should be borne in mind that when milling, in contrast to turning, the surface formed is directly determined by the entire geometry of each tooth along the axis of rotation of the tool. 3) When sharpening the cutter teeth, it is necessary to select, if possible, the rake angle of the cutting wedge not less than 12 ° –15 °. In this case, when the tool moves, the orientation of the force has a projection that practically coincides with the direction of movement of the cutter. Then, in the areas of shaping, there will be a minimum deviation of the tool from the ideal path. 4) The angle of inclination of the cutter teeth must be selected so that the axial component of the force, as noted earlier, has a direction towards the table on which the workpiece to be processed is fixed. In the described case, this is a milling cutter with a right orientation of the inclination of the teeth. 5) Recommended values of the geometric parameters of the cutter when processing material.

The fifth stage is the selection of technological modes and control. The analysis of possible stages ensures an improvement in the surface quality during milling, including the requirements for the tool, the choice of its geometry, technological modes, and the accuracy of the machine.

1.3 Conclusions and tasks for qualification work

Thus, having analyzed the factory version of the technological process of machining, we conclude about the possibility of upgrading the existing TP. This upgrade is as follows:

- change in the structure of the technological process;
- selection of the optimal, from the point of view of the minimum prime cost and the maximum productivity, the technological equipment;
- selection of the workpiece with the minimum cost of production;
- choice of technological equipment to increase productivity and reduce the cost of processing.

The current factory technological process is developed on the basis of application of universal machines. To develop a progressive technological process is necessary:

1. Replacement of the structure of the technological process.
2. Widely use high-performance machines, aggregate machines and CNC machines.
3. The choice of obtaining a blank with a minimum cost.
4. Use of the combined tool.

2. RESEARCH PART

2.1. Characteristics of the object or subject of research

Dynamic processes in a machine tool system have a significant impact on its most important characteristics: accuracy, productivity, reliability.

The main task of the analysis of the dynamic system of the machine is to identify the direct (force) and reverse (deformation) links between the elastic system of the machine and the working processes in moving joints.

The solution of problems related to the dynamics of machine-tool systems has acquired relevance recently in connection with the widespread use of flexible automated production./44/

The beginning of a systematic approach to the study of dynamic processes in technological systems was laid by V.A. Kudinov, who introduced the concept of "closed dynamic system of the machine", which includes the elastic system of the machine, the main process is the cutting process, as well as the processes of tool wear, friction in the joints and units of the machine, processes occurring in the electric motor, etc./36/

Depending on the reasons for the occurrence of oscillations, they are divided into free, forced, parametric and self-oscillations. Free vibrations arise in an elastic system at its initial deviation from the equilibrium position and are supported only by elastic forces. In the presence of resistance (damping) forces, free vibrations are damped. The study of such vibrations can be of practical interest in the experimental determination of the characteristics of an oscillatory system (for example, natural vibration frequency, damping coefficient).

The general form of free vibrations can be described by the dependence

$$z = a_0 e^{-\varepsilon t} \sin(\omega t + \varphi), \qquad (2.1)$$

where a_0 – initial vibration amplitude;

$\omega = \sqrt{\omega_0^2 + \varepsilon^2}$ - natural vibration frequency of a damped system;

$\omega_0 = \sqrt{k/m}$ - natural frequency of free oscillations.

Forced vibrations are vibrations excited in the system by a periodic disturbing force $P = \sin(pt)$. The origin of the disturbing force can be different: transmission of vibrations through the foundation from machines with reciprocating motion, forging equipment; centrifugal forces from rotating unbalanced masses, forces from intermittent cutting, from uneven allowances, variable forces during non-stationary cutting, etc.

General equation for forced vibrations

$$z = \frac{z_{cn}}{\sqrt{\left(1 - \frac{p^2}{\omega^2}\right)^2 + \frac{4\varepsilon^2 p^2}{\omega^4}}} \sin(pt + \varphi) \tag{2.2}$$

When the frequency p of the disturbing force approaches the natural vibration frequency, the vibration amplitude increases indefinitely, which can lead to a loss of accuracy, an increase in the wear rate in gears, a decrease in rigidity, and a decrease in the service life).

Oscillations are called parametric if they are caused by changes in the parameters of the system over time. Such oscillations are possible only in nonstationary systems.

With self-oscillations, the loss of mechanical energy due to its dissipation is periodically replenished by an inflow of energy from a source that does not have vibrational properties. The emergence of a source of energy that supports self-oscillation during cutting is a consequence of the ambiguity of the dependence of the force on the path during the oscillation period. This can lead to the fact that the work of forces for each half of the oscillation period will be different, and the difference between these works, depending on the sign, will contribute to either swinging (E> 0) or damping of oscillations (E <0).

Oscillatory processes during blade processing on metal-cutting machines negatively affect the accuracy, quality of the processed surface, the durability of the cutting tool, and processing productivity. In the works on studying and decreasing the intensity of oscillations, the main attention was paid to the following tasks: study of the reasons (physical nature) of the occurrence of oscillations; studying the stability of the technological system during cutting; development of recommendations for increasing the vibration resistance of machine tools.[6] The disclosure of the physical causes of vibration excitation of technological systems during metal cutting attracted many researchers. The dynamics of machine tool systems at different times were addressed by: M.S. Becker, V.F. Bobrov, A.S. Vereshchak, G.I. Granovsky, Yu.I. Gorodetsky, V.M. Gurevich, N.A. Drozdov, I.G. Zharkov, V.M. Zaitsev, V.L. Zakovorotny, V.L. Zozarev, A.I. Isaev, Yu.G. Kabaldin, A.I. Kashirin, V.S. Komalov, K. Kono, V.A. Kudinov, L.K. Kuchma, V.S. Kushener, T.N. Loladze, I. G. Malkin, L.S. Murashkin, S.L. Murashkin, N. Ota, G.S. Pisarenko, V.N. Poduraev, M.F. Poletik, V.E. Push, N.I. Reznikov, A.M. Rosenberg, S.N. Ryzhkov, S.F. Sarnikola, S.S. Silin, N.I. Tashlitsky, A.M. Shpilev, M.E. Elyasberg, P.I. Lizardin and others.

Possible reasons for the occurrence of self-oscillations [18] are as follows: a falling characteristic of the cutting force from the oscillation speed, a delay in the change in force in relation to a change in the cut thickness, as well as "coordinate connections" between oscillations.

A sign of vibrations caused by processes in the chip formation zone and on the front surface of the tool is a wavy (or jagged) free surface of the chip (that is, the formation of articulated chips). With an increase in the area of the cut layer, the amplitude of self-oscillations increases in direct proportion to the cut area. This is easily explained by an increase in forces with an increase in the area of the cut layer.

Most researchers agree that the cause of the occurrence and development of self-oscillations during cutting is not one, but several physical phenomena that can act simultaneously or some of these phenomena can dominate. It depends on many reasons, but, first of all, on the state of the technological system, its rigidity and damping capacity.

Methods for weakening or completely damping self-oscillations during cutting are aimed at reducing the work of forces that support the oscillations and at increasing the work of resistance forces (damping).

The dynamic system of the machine is formed by a combination of an elastic system and work processes in their interaction [36].

The elastic system includes a machine, a fixture, a tool, and a part.

Work processes - cutting, friction, processes in electric motors (electromagnetic, aerodynamic or hydrodynamic), etc.

2.2. Processing of research results

The defining parameter for determining the law of changing the cutting force during milling is the thickness of the cut layer. Therefore, the definition of the law of change in the shear thickness is a necessary condition for determining the law of change in the cutting force.

Expression (2.2) gives only a general view of the dependence of the tangential component of the cutting force on the shear thickness, therefore, if we determine the law of change in the thickness of the cut layer, then we can determine the law of change in the tangential component of the cutting force depending on the angle of rotation of the cutter, and upon further transformation - and from the time of the duration of the process.

Determination of the slice thickness. Mathematically, the problem of modeling the change in the thickness of the cut layer can be formulated as follows: two material points belonging to a uniformly plane-parallel moving cylindrical body lie in the same plane. The angular velocity of the body, the linear velocity of the body Sz. It is necessary to determine the law of variation of the distance between these points in absolute coordinates.

Determination of the slice thickness for up-milling. Determine the law of change in the cut thickness a depending on the angle of rotation of the cutter □ for counter milling.

During milling, the cut thickness is constantly changing. Figure 1.3 shows a diagram showing the change in slice thickness. The shaded area shows the thickness of the cut layer. Until a certain moment, the cut thickness changes according to the law (1.4), but at the moment when □ reaches a value equal to (□m - □), the thickness of the cut layer begins to decrease, changing according to a different law / 5, 59, 61 / (Fig. 2.1).

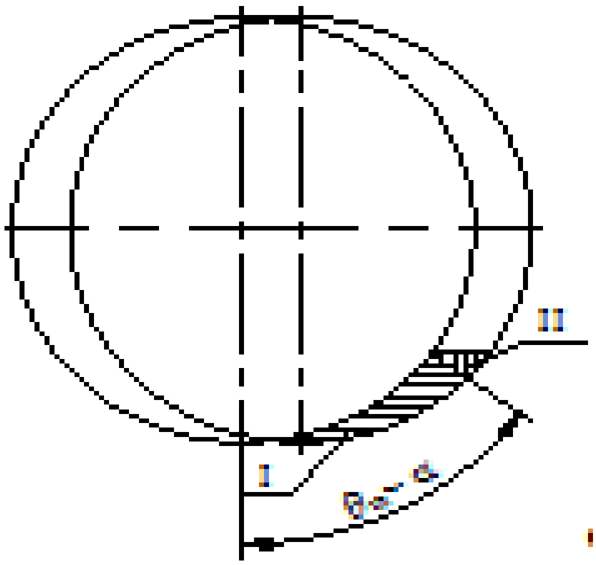

Figure 2.1 - The moment of change in the law of formation of the slice thickness I - area of operation of the law; II - zone of decrease in cut thickness

Let's define the moment of the law change. Considering that the milling process consists of a combination of the rotary movement of the cutter and the rectilinear translational movement of the feed, the following geometric calculation scheme can be derived (Figure 2.2).

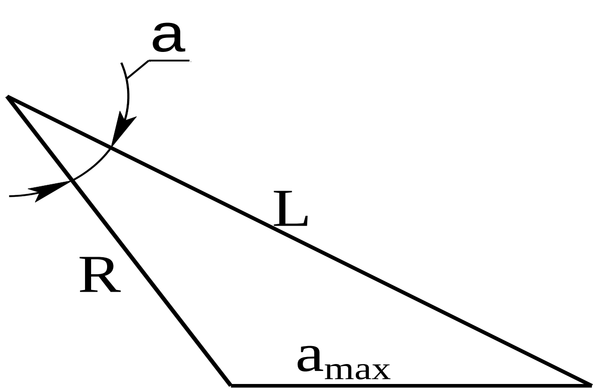

Figure 2.2 - Design scheme for determining the angle

The parameters R and L are unknown in the triangle. The length of the side L can be determined by the cosine theorem

$$L = \sqrt{a_{\max}^2 + R^2 - 2Ra_{\max}\cos(90 + \theta_m)} \tag{2.3}$$

where amax = sz - maximum thickness of the cut layer;

It is more convenient to rewrite the resulting formula through the original data.

$$L = \frac{\sqrt{4s_z^2 + D^2 + 4Ds_z \sin\theta_m}}{2} \tag{2.4}$$

where D – cutter diameter;

sz – feed per tooth;

By the sine theorem, we get:

$$\frac{a_{\max}}{\sin\alpha} = \frac{L}{\sin(90 + \theta_m)} \tag{2.5}$$

where – bend angle.

After the final transformations, we get

$$\alpha = \arcsin\frac{a_{\max}\cos\theta_m}{\sqrt{a_{\max}^2 + R^2 + 2Ra_{\max}\sin\theta_m}} \tag{2.6}$$

It is more convenient to write the resulting dependence through the initial data:

$$\alpha = \arcsin\frac{2s_z\cos\theta_m}{\sqrt{4s_z^2 + D^2 + 4Ds_z\sin\theta_m}} \tag{2.7}$$

The graphic construction fully confirms the above analytical calculations.

Figure 2.3 shows a formalized geometric scheme for determining the law of change in the thickness of the cut layer depending on the angle of rotation of the cutter

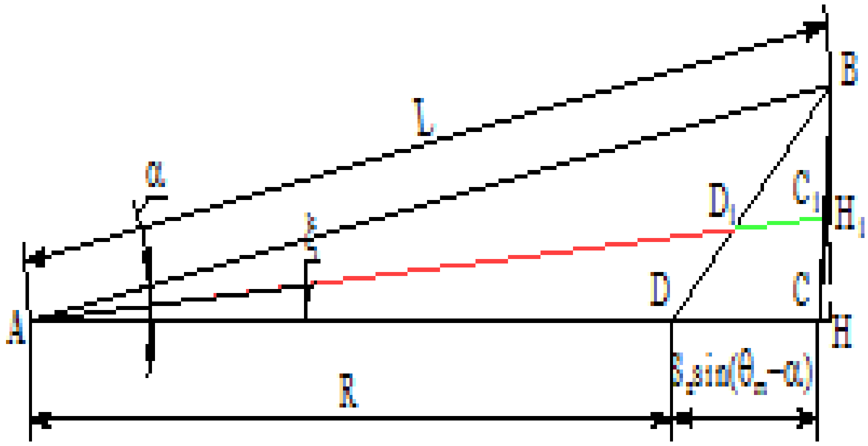

Figure 2.3 - Design scheme for determining the law of decreasing the cut thickness (counter milling)

On the picture 2.3:

A – cutter center;

B – point of exit of the cutter from the workpiece;

C – a point that defines the final coordinate of the thickness of the cut layer;

D – point of change in the law of formation of the cut thickness (inflection point);

$AD = R = \dfrac{D}{2}$ – cutter radius;

CD – thickness of the cut layer at the time of the law change;

BH – the height of the triangle ΔABC;

C1D1 – required thickness of the cut layer;

Replace the BC arc with a straight line. Such a change will have little effect on the accuracy of calculations, but will greatly simplify the solution of the problem.

So, in the triangle ΔABC, draw the straight line AH1 at the current angle that determines its position.

From the right-angled triangle ΔABH we find the line BH=Lsin.

Let us introduce the notation:

kp=□m- - critical contact angle;

kp=∠DBC – segment angle.

From the triangle ΔBCH we find the line BC. By the cosine theorem

$$BC = \sqrt{s_z^2 + s_z^2 \sin^2\theta_m - 2s_z^2 \sin\theta_m \sin\theta_{kp}} = s_z\sqrt{1+\sin^2\theta_m - 2\sin\theta_m \sin\theta_{kp}} \quad (2.8)$$

Consider a triangle ΔBCD (Figure 2.4)

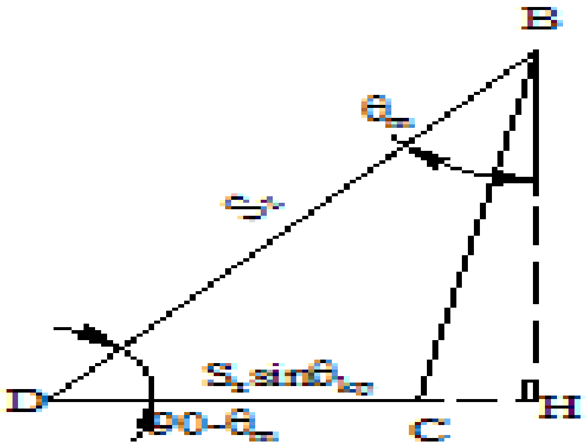

Figure 2.4 - Triangle ΔBCD

kp= ∠DBC=∠DBH–∠CBH

Find the angle CBH from a right-angled triangle CBH.

$$CBH = \arccos\frac{BH}{BC} = \arccos\frac{\cos\theta_m}{\sqrt{1+\sin^2\theta_m - 2\sin\theta_m \sin\theta_{kp}}}$$

$$\beta_{kp} = \theta_m - \arccos\frac{\cos\theta_m}{\sqrt{1+\sin^2\theta_m - 2\sin\theta_m \sin\theta_{kp}}} \quad (2.9)$$

Segment BD1 (Fig. 2.3) can be defined as the difference between the segment BD and the current straight line DD1. By the theorem of sines from a triangle ΔADD1:

$$\frac{DD_1}{\sin\xi} = \frac{R}{\sin(90-\theta_m-\xi)};$$

$$DD_1 = \frac{D\sin\xi}{2\cos(\theta_m+\xi)};$$

$$BD_1 = s_z - \frac{D\sin\xi}{2\cos(\theta_m + \xi)}.$$

By the theorem of sines from a triangle D1BC1:

$$\frac{C_1D_1}{\sin\beta_{кр}} = \frac{BD_1}{\cos(\theta_m - \beta_{кр} + \xi)},$$

$$C_1D_1 = \frac{BD_1 \sin\beta_{кр}}{\cos(\theta_m - \beta_{кр} + \xi)}.$$

Considering that - cr, we finally get the following dependence of the thickness of the cut layer on the angle of rotation of the cutter in the area

$$\varphi \in \left(\theta_{кр};\theta_m\right]$$

$$BD_1(\varphi) = s_z - \frac{D\sin(\varphi - \theta_{кр})}{2\cos(\alpha + \varphi)},$$

$$a(\varphi) = \left(s_z - \frac{D\sin(\varphi - \theta_{кр})}{2\cos(\varphi + \alpha)}\right)\frac{\sin\beta_{кр}}{\cos(\varphi + \alpha - \beta_{кр})},\ \varphi \in \left(\theta_{кр};\theta_m\right] \qquad (2.10)$$

As a result of the above mathematical calculations, finally for counter milling we obtain the following dependence of the cut thickness on the angle of rotation of the cutter in the form (2.4)

$$a(\varphi) = \begin{cases} s_z \sin\varphi, 0 \le \varphi < \theta_{kp} \\ \left(s_z - \frac{D\sin(\varphi - \theta_{kp})}{2\cos(\varphi + \alpha)}\right)\frac{\sin\beta_{кр}}{\cos(\alpha - \beta_{кр} + \varphi)}, \theta_{kp} \le \varphi \le \theta_m \end{cases} \qquad (2.11)$$

The graph of function (2.11) in general form is shown in Figure 2.5.

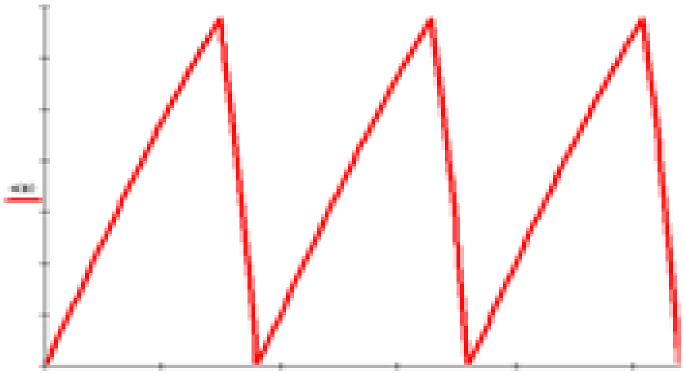

Figure 2.5 - Generalized graph of the dependence of the thickness of the cut layer on the angle of rotation of the cutter during counter milling

Analytical determination of the area of the central section of the cut in counter milling. It is necessary to analytically determine the area of the central section of the cut layer to confirm the adequacy of the developed mathematical model. Figure 2.9 shows the design scheme, according to which the area of the cut layer is determined

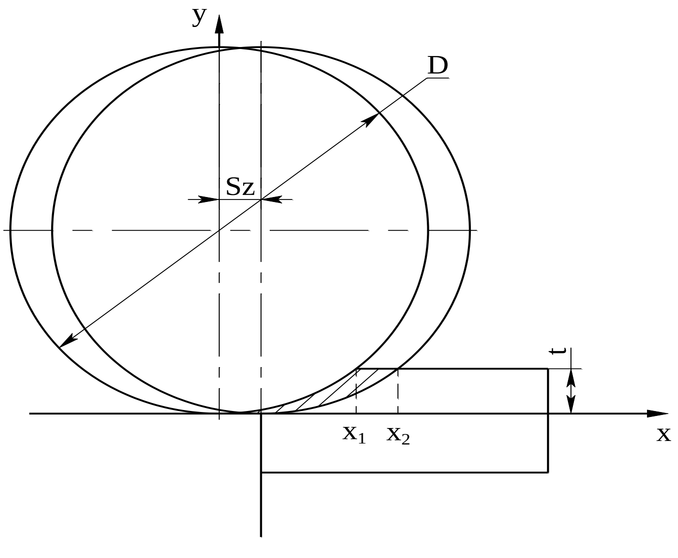

Figure 2.9 - Calculation scheme for determining the area of the cut layer

Mathematically, the problem can be formulated as follows: determine the area of a curved surface bounded by surfaces y1, y2, y3 and the x-axis (Figure 2.10).

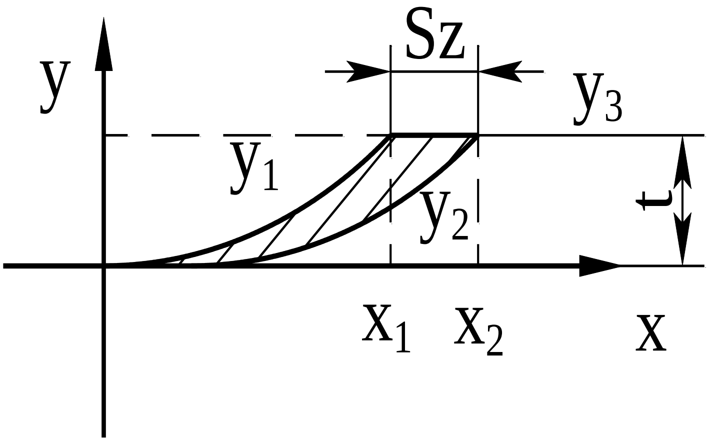

Figure 2.10 - Formalized design scheme

Functions y1, y2 represent the lower arcs of a circle with a radius equal to the radius of the cutter D / 2. Figure 2.10 shows that the function y3 is linear and graphically represents a straight line described by the equation y3 = t.

Let us compose the equations of the circles according to the known dependencies, taking into account that the center of the circle for y1 has coordinates (0, D / 2), and y2 - (sz, D / 2). Thus:

$$y_1(x) = \frac{D}{2} - \sqrt{\frac{D^2}{4} - x^2}$$
$$y_2(x) = \frac{D}{2} - \sqrt{\frac{D^2}{4} - (x - s_z)^2} \quad (2.12)$$

The coordinates of the point x1 can be defined as the intersection point of the function y1 with the function y_3.

$$y_1(x) = y_3(x)$$
$$\frac{D}{2} - \sqrt{\frac{D^2}{4} - x^2} = t \quad (2.13)$$

Expressing x from this expression and performing a series of algebraic transformations, we obtain $x = \sqrt{Dt - t^2}$.

Figures 2.9 and 2.10 show that x2=x1+sz.

Using the well-known rules for determining the area of a curved surface, we obtain the following dependence:

$$S = tx_2 - \int_0^{x_1}\left(t + \sqrt{\frac{D^2}{4} - x^2} - \frac{D}{2}\right)dx - \int_0^{x_2}\left(\frac{D}{2} - \sqrt{\frac{D^2}{4} - (x - s_z)^2}\right)dx \qquad (2.14)$$

After a number of transformations, we finally get

$$S = s_z\left(t - \frac{D}{2}\right) + \int_0^{\sqrt{tD - t^2} + s_z}\sqrt{\frac{D^2}{4} - (x - s_z)^2}\,dx - \int_0^{\sqrt{tD - t^2}}\sqrt{\frac{D^2}{4} - x^2}\,dx \qquad (2.15)$$

An experimental method for determining the slice thickness. The process of changing the thickness of the cut layer during milling is rather difficult to study, since the initial dimensions of the cut layer and the size of the chips do not coincide due to the phenomenon of chip shrinkage. Also, the geometry of the chips is affected by many unaccounted for factors that can ultimately lead to incorrect results (radial runout of the cutter teeth, different sharpening of teeth, inconsistency of the workpiece structure, etc.).

As you know, the kinematics of the milling process includes two movements: rotational uniform cutter and rectilinear uniform workpiece. The kinematics of the milling process can be simulated using a milling machine and a specially designed device / 60 /. Modeling the kinematics of the process will help to establish the law of change in the geometry of the thickness of the cut layer.

To confirm the adequacy of the developed mathematical model, it is necessary to check it under conditions that will be quite difficult to implement using cutting.

The structure (Fig. 2.11) is a disk 2, with a central hole for fixing it on a milling arbor 1, and holes for fixing drawing tools in them 3.

The principle of operation of the device is as follows : two plastic pins 3 are installed in the holes of the disc, and the disc 2 itself sits on the mandrel 1. A clamping device is installed on the machine table, in which a metal sheet 4 with a thickness of 2.5 mm is fixed, which provides sufficient rigidity. A sheet of graph paper is glued onto it, then copy paper is glued to it, and thick (at least 80 g / m2) paper 5 is glued on top of them, the presence of which allows you to avoid damage to the graph paper and carbon paper. Next, the tips of the drawing tools 3 are brought to contact with the sheet, setting a slight pressure to compensate for the possible flatness error of the metal sheet. After that, turn on the spindle rotation (at the lowest possible speed) and the table feed (the specific value of which depends on the required feed per tooth and the spindle speed).

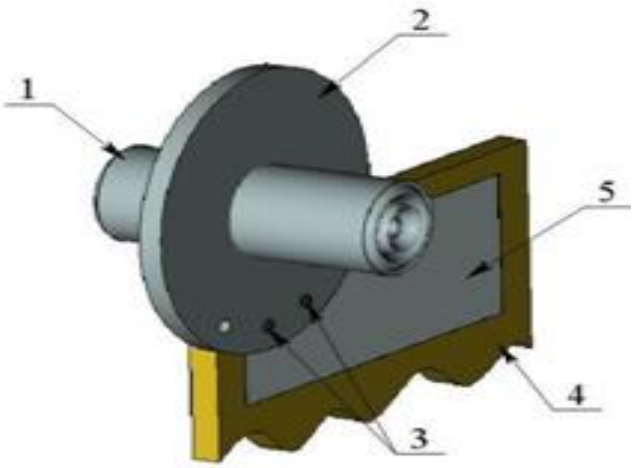

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Figure 2.11 - Scheme of the stand for studying the cut layer

1 - mandrel, 2 - disc, 3 - drawing tools,

4 - metal sheet, 5 - sheet of paper

To reduce the influence of the measurement error, the feed per tooth should be large enough, and it is clear that cutting with the required (≈1 ... 5 mm / tooth) feed per tooth cannot be performed with standard cutters, therefore the proposed method is optimal.The outlined outline will give the original dimensions of the cut layer.

The adequacy of the results obtained can be checked by the area of the outlined contour, which can be determined by graph paper. Analytically, the area is determined by the formula (2.9)

$$S = s_z\left(t-\frac{D}{2}\right)+\int_0^{\sqrt{tD-t^2}+s_z}\sqrt{\frac{D^2}{4}-(x-s_z)^2}\,dx-\int_0^{\sqrt{tD-t^2}}\sqrt{\frac{D^2}{4}-x^2}\,dx \qquad (2.16)$$

Permissible discrepancy in results – 5%.

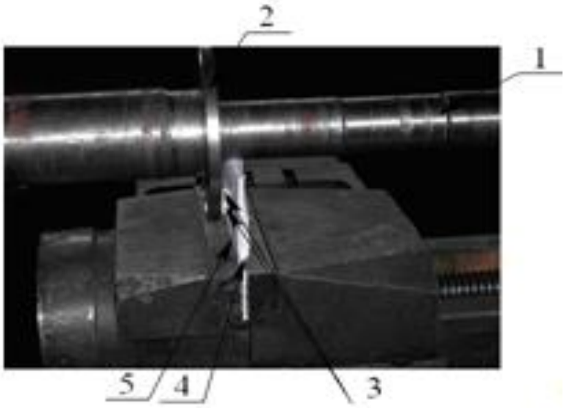

Figure 2.12 - Seend for studying the cut layer

1 - mandrel, 2 - disc, 3 - drawing tools,

4 - metal sheet, 5 - sheet of paper

Since in order to reduce the influence of errors, experiments must be carried out with the maximum possible feed per tooth, then the results must be processed for different values of cutting depths. This solution makes it possible to reduce the complexity of the experiment, since it is possible to calculate the area of the central section of the cut layer for different values of the depth of cut using one obtained figure.

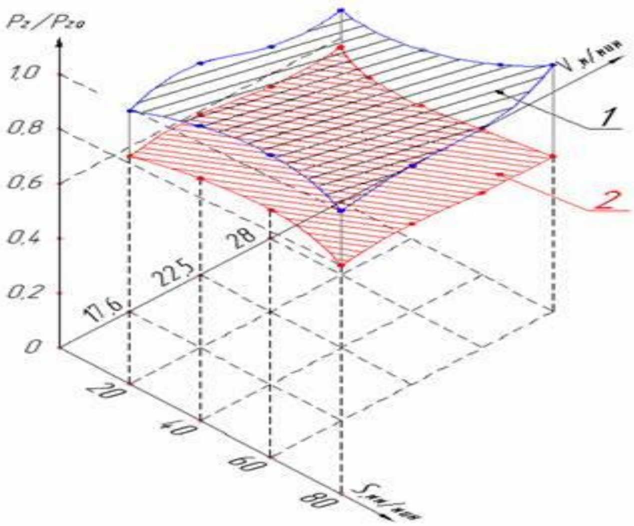

Figure 2.13 - Influence of cutting speed and feed on cutting force Pz

when milling a specimen from gray cast iron SCh20:

1 - "dry"; 2 - with ZOR

The cross-sectional area is calculated by pixels, therefore it has an accuracy of 0.04 mm2.

Based on the experimental data, we build graphs of the dependence of the cutting speed and feed on the cutting force Pz for gray cast iron SCH20 "dry" and with the use of ZOR (Fig. 2.13).

2.4. Conclusions and suggestions for the use of research results

In conclusion, the following conclusions can be drawn: 1) feed affects the component of the cutting force Pz and power to a lesser extent than the milling depth; 2) at a constant cutting speed, the force Pz decreases with an increase in the cutter diameter, since this decreases the thickness of the cut, and, consequently, the cut area; 3) the nature of milling significantly affects the power consumption, while passing milling requires less power in comparison with the usually accepted counter milling; 4) the experiments carried out showed that under the influence of ZOR, there is a decrease in the components of cutting forces, reaching 10% when processing gray cast iron SCh20.

3.TECHNOLOGICAL AND DESIGN PART

3.1 Business purpose and characteristics of the production object

Housing 3411040-8902286-00 is an integral part of the sprayer 3411040. The sprayer is designed for chemical protection of vineyards from pests and diseases by spraying them with special preparations in all areas of industrial viticulture; it can also be used for other undersized perennials. [1]

The sprayer is a frame-mounted structure that is mounted on a standard three-point tractor system. The main components are: frame, tank, gearbox, pump, fan, remote control, cardan.

The excuse from tractor power take-off shaft by cardan gear.

The one-stage conical gearbox is designed for transferring rotation to the fan wheels.

The gearbox consists of a cast iron housing, a cover, a receiving shaft, a shaft of gears, a gear wheel, glasses of bearings, covers of bearings with cuffs.

The case contains a number of surfaces that require machining. They can be divided into 2 groups: work surfaces and connection of surfaces - these are the surfaces of all flanges and pins, carved surfaces, the plane of the base.

The rest of the body surfaces are working. Hull billet - casting. Material - gray cast iron СЧ20. Body weight - 26.4 kg. Maximum geometric dimensions of the workpiece 450 × 266 × 255 mm. The housing part has three openings Ø100 H7, where in the course of assembly set drive gears. There are 4 threaded holes for mounting the covers M8 – 7H, placed at the ends.

There are holes for mounting and adjustment Ø250 H11. This opening is closed by a cap that attaches to the pump housing with eight screws M8. The details also include two blind holes Ø15 H9, which serve as reference and guide bases for processing.

The technical specifications in the assembly drawing and their sequence meet the requirements of the applicable standards and do not require any additions or regroups. The maximum accuracy of the holes is made according to IT7. Minimum surface roughness R_a=2.5 microns. The most important task that needs to be addressed in the housing fabrication process is to ensure tolerances for alignment 0,03 holes Ø100 H7, as well as the perpendicularity of the axis of the hole Ø100 H7 surface to the axis B 0,04. Consider the appropriate technical requirements of the service destination of the part. The housing part provides the necessary accuracy with respect to the position of the two conical gears.

The workpiece weight is 31 kg, when the detail weight is 26.4 kg, it can be seen that the material was used technologically. Hardness - HB 190.

In the factory, the method of obtaining billets by sand casting is used. With this factory program, this method is appropriate and rational, but there are many other advanced methods such as molding, and others. With other product and fleet programs, using these methods can have a greater economic impact. Analyzing the technological process (TP) of the manufacture of the case, we can see that very skillfully used technological bases in operations.

The principle of constancy of bases is adhered to - the detail on all operations except the first is based on two technological openings, correctly selected rough technological bases on the first operation, is based in prisms on untreated surfaces.

The equipment used in the manufacturing process is connected to existing factory equipment.

Universal machines are used: longitudinal milling machine with CNC mod. ГФ683С3, which simultaneously processes three surfaces; boring machine of mod.262 Г for the processing of main openings. Auxiliary holes and mountings are made on the radial-drilling machine mod.2A55 with using a conductor.

Analyzing the factory TP, the equipment used, it is obvious that the production factory - medium, small-scale and TP selected rationally.

But for the release program 250000 pcs. more advanced equipment may be used per year, which will be suitable for large-scale or mass production.

Table 3.1 - Basic technological process

The name of the operation is its content	Artificial time, $T_{шт}$	Number of equip.		Download ratio $K_з$	Div. Power N, kW	Accepted equipment		Cost	
		$C_р$	$C_п$			Model	Product kW	Norm	Technol
1	2	3	4	5	6	7	8	9	10
1. Screw-cutting plane Л and hole ø250	2,021	3,01	4	0,75	3,3	1М61	4	562	30,5
2. Vertically milling processing of plane Л on the contour program	2,6	3,87	4	0,96	7,2	6РВР	7,5	899	55,4
3. Vertically milling processing of hole ø250.	1,7	1,6	2	0,8	0,8	-	7,5	899	24
4. Vertical drilling processing 2 holes ø15H9 on a triple device	0,29	0,43	1	0,43	1,1	2Н150	7,5	487	2,1
8. Vertical drilling processing 8 holes M8-7H on the plane Л	0,07	0,1	1	0,1	1,76	2Н150	7,5	487	2,1
9. Longitudinal-milling simultaneous surface treatment U, K, M.	1,27	1,89	2	0,95	2,4×3	6606	11,3	872	17,1
10. Coordinate-boring sequential processing 3-x holes Ø100H7	10,8	16,1	17	0,95	3,3	2Е440А	4,5	776	140
11. Aggregate-boring simultaneous processing 3-x holes Ø100H7	1,4	2,08	3	0,7	4,8×9×9	А1	23	3560	83
12. Vertical drilling processing 12 holes ø6,7 and chamfers 1,6×45^0 on the planes U, K, M	0,27	0,4	1	0,4	0,9	2А53	4	779	3,5
13. Radial drilling processing 12 holes	0,21	0,3	1	0,3	0,22	2А53	4	779	2,7

1	2	3	4	5	6	7	8	9	10
14. Radial drilling processing hole Ø13M8-7H on the planes U, K, M for 3 passes.	0,082	0,12	1	0,12	0,93	2A53	4	779	1,06
15. Radial drilling Countering 3-x facets of the main opening successively	0,088	0,13	1	,13	1,1	2A53	4	779	1,14
16. Radial drilling hole treatment M16-7H	0,26	0,39	1	0,39	1,8	2A53	4	779	3,38

Specified release program - 250000 pieces, material of detail – СЧ20. The main task is to get 3 holes Ø100 H7 with a given roughness and precision of relative positioning. The bases are classic: the plane Л and two openings Ø15 H9. The design of the part is quite technological.

Clarification on the working surface with holes Ø100 H7 is E_y=16. The number of transition required m=3, that is, necessary rough, clean and finishing processing. Ensuring the tolerance of the axial distance of 30 microns can be achieved on multi-spindle aggregate boring machines (25-10 microns), horizontally boring when programmatically controlling the coordinate setting (25-60 microns).

Thus, for the treatment of work surfaces, there are two options: aggregate and coordinate-boring.

A competing variant is the lathe structure surface treatment Л and hole Ø250 may be the treatment of these surfaces on vertically milling machines with CNC face and end milling on the contour.

Processing of 2 holes Ø15H9 it is advisable to carry out on a vertical-boring workbench on a three-seater device with the help of 4 spindle heads.

The first position is loaded and unloaded, the second drills and faxes combined tool, the third - open the size of holes. A competing variant may be machining on a CNC machine. [6]

Design variant of technical process

005 Screw-cutting

machine 1M61:

1. Turning end face of the surface Л.
2. To drill a hole to Ø250.
3. Remove the chamfer 1×45^0.

Load factor $К_З$=0,75

Technological cost C_T=3,0 UAH.

010 Vertically drilling

machine 2H150, triple device 4-cylinder head

1. Drill 2 holes Ø14,5, chamfer.
2. Ream out 2 holes Ø15H9.

$К_З$=0,68 (together with operations 035, 040); C_T=2,1 UAH.

015 Longitudinally milling

machine 6606

1. Simultaneous milling of surfaces U, K, M

$К_З$=0,95, C_T=1,71 UAH.

020 Aggregate boring

machine A1, four-position device, rotary table

1. Simultaneous boring of 3 holes up to Ø99,5.
2. Simultaneous ream out of 3 openings up to Ø99,8.
3. Simultaneous finish ream out of 3 openings up to Ø100H7.

$К_З$=0,7 C_T=2,3 UAH.

25 Vertically drilling

machine 2H150 eight spindle head.

1. Drill 8 holes Ø6,7 and remove the chamfers 1,6×45^0 in 8 holes with a combined tool on the plane Л.

C_T=2,1 UAH.

030 Vertically drilling

machine 2H150, 8th spindle head.

1. Cut the thread M8-7H in 8 holes.

C_T=2,1 UAH.

035 Radial drilling

machine 2A53, 4 spindle head, rotary stand

1. Drill 12 holes Ø6,7 and remove simultaneously in 12 holes chamfer 1,6×45^0 for three passes with a combined tool on the plans U, K, M.

K_{3O}=0,95 (together with 040, 045, 050), C_T=3,5 UAH

040 Radial drilling

machine 2A53, 4 spindle head, rotary stand

1. Cut the thread into 12 holes M8-7H for three passes on the plans U, K, M.

C_T=2,7 UAH

045 Radial drilling

machine 2A53, rotary stand.

1. Countersink 3 chamfers 1×45^0 of the main openings consecutively.

C_T=1.14 UAH

050 Radial drilling

machine 2A53

1. Counterbore end face Ø20;
2. Drill a hole Ø13.

C_T=1,06 UAH

055 Radial drilling

machine 2A53

1. Counterbore end face Ø30;
2. Drill a hole Ø14;
3. Remove the chamfer 2×45^0;
4. Cut the thread M16-7H.

K_3=0,39, C_T=3,38 UAH

Type of production is a classification category, distinguished by the breadth of nomenclature, regularity, stability and volume of production. The type of production is determined by the factor of consolidation of the operations $К_{з.о.}$, ie the ratio of the number of all different technological operations performed or to be performed during the month, to the number of jobs. [1]

The form of organization of production depends on the established order of execution of the technological process, the location of the technological equipment, the direction of movement of products when they are made. There are two forms of production organization - streaming and group.

We establish for the two-hour work at the 41-hour workweek the next valid fund time of work of the equipment:

$$F_a = 4015\ h.$$

Determine the time of release of parts by the formula:

$$\tau = \frac{60F_a}{N}, \qquad (3.1)$$

where the N-year program is 250000 units.

$$\tau = \frac{60 \cdot 4015}{250000} = 9{,}636\ \text{(min.)}$$

The sequence of operations, their content, as well as the results of normalization by approximate formulas are shown in the table 2.1.

$$T_{шт} = \gamma_к \cdot \iota \cdot T, \qquad (3.2)$$

where $T_{шт}$- artificial time і-ї of operation, min

T_0- operating time, min;

$\varphi_к$ – coefficient depending on the type of equipment.

Determination of the coefficient of operations consolidation:

$$C_{pi} = \frac{T_{шт} \cdot N}{60F_д \cdot \eta_{зм}}, \qquad (3.3)$$

where C_{pi} – the number of units of machines required to perform the i-th operation, $\eta_{з.н}$ – standard load factor of equipment ($\eta_{з.н}$=0,75...0,8).

We accept that $\eta_{з.н}$=0,75

The total number of operations and jobs is respectively $\Sigma K_0 = 8$; $\Sigma K_{р.м} = 58$

The consolidation of operations is equal:

$$К_{3.0}=К_0/К_{Р.м.} \quad (3.4)$$

We define $К_{з.о}$:

$$К_{3.0}=8/58=0,14$$

Production - mass.

We define the organizational form of production.

The feasibility of using a streaming form of production organization, as the most effective for a given volume of parts, is established on the basis of a comparison of the average rate of artificial time $T_{сер.}$ for basic operations with a calculated stroke τ output, that is, the average number of jobs $R_м$, accounted for by one operation:

$$R_м = \frac{T_{сер}}{\tau} = \frac{N \cdot \sum_{t=1}^{n} T_{шт.i}}{\tau} = \frac{25000 \cdot 34,033}{60 \cdot 4015 \cdot 5} = 0,7$$

Since $R_м$=0,7>>0,2 we accept the streaming form of production organization.

We define a daily program for the release of parts:

$$N_a = N/Д, \quad (3.5)$$

where $Д$=254- annual number of working days.

N_a=250000/254=98,4 details / day.

Calculation of production line productivity:

$$Q_a = (P \cdot F_c \cdot \eta_{3.п}) \cdot (\sum_{s=1}^{n} T_{шт:})$$

where F_c=952 min. - daily fund of equipment operation.

The principle of manufacturability - it is such design that provides minimum labor input and material consumption.

Uniform factor is the ratio of the number of uniform surfaces to the sum of all surfaces.

$$K_{у.е} = \frac{\Sigma Q_{уніє.}}{\Sigma Q}, \quad (3.6)$$

$$K_{у.е} = \frac{24}{32} = 0,75.$$

The manufacturability condition is satisfied because $К_{у.е} \geq 0,6$

Material utilization ratio is the ratio of mass to mass of the workpiece. [1]

$$К_{м} = \frac{М_{д}}{М_{з}} \quad (3.7)$$

$$К_{М} = \frac{26.4}{31} = 0.85$$

The manufacturability condition is satisfied because $К_{m\geq}$ 0.8

We carry out design analysis of parts on surfaces.

Coefficient of processing accuracy $К_{т.ч.}$ is determined by the following formulas:

$$К_{Т.Ч.} = 1 - \frac{1}{А_{СЕР.}} \quad (3.8)$$

$$А_{СЕР.} = (n_1 \cdot k_1 + n_2 \cdot k_2 + ...) / \Sigma К \ ,$$

In these formulas $А_{сер.}$ – average quality of accuracy. Then:

$$А_{сер.} = \frac{7 \cdot 5 + 9 \cdot 1 + 11 \cdot 5}{5 + 1 + 5} = 9$$

$$К_{тч.} \ 1 - \frac{1}{9} = 0,9 \, .$$

The manufacturability condition is satisfied because $К_{тч.} \geq 0,8$.

Table 3.2 - Design analysis of parts by surfaces

№	The structural element of the part	Number of the same type items	Number uniforms. surfaces	Quality	RoughnessR_z
1	Internal surfaces of main openings Д, Е, Ж, Х	4	-	7 7 7 11	10 10 10 20
2	Exterior surfacesИ, К, Л, М	4	-	11	40

3	Threaded M8 holes M16	20 1	20 1	7 7	20 20
4	Holes Ø13 Ø 15	1 2	1 2	14 9	40 10

Surface roughness factor $K_{ш}$ is determined by the formulas:

$$K_{ш} = \frac{1}{Б_{сер.}} \tag{3.9}$$

$$Б_{сер.} = \frac{(n_1 \cdot m_1 + n_2 \cdot m_2 + ...)}{\sum_{s=1}^{n} m_s}$$

In these formulas $Б_{сер.}$ – average roughness of surfaces in R_a , (R_z=4 R_a).

Then:

$$Б_{сер} = \frac{10 \cdot 4 + 20 \cdot 2 + 5 \cdot 40 + 1 \cdot 80}{4 + 2 + 5 + 1} = 30[R_z] = 7{,}5[R_a]$$

$$K_{ш} = \frac{1}{7{,}5} = 0{,}13$$

Condition of manufacturability if $К_{ш}$< 0,3 ... 0,4.

Thus, it can be concluded that the part is technological in all respects.

3.2 Development of technological process of product manufacturing.

Workpiece - casting class I precision weighing 27.51 kg. Technological route of hole treatment Ø100H7$^{(10.035)}$ consists of three operations: rough boring, normal ream out, exact ream out. These operations are performed at one installation of the workpiece.

The workpiece bases are the plane base Л and two technological holes Ø100H7$^{(10.035)}$. The calculation of allowances is given in the table 2.5, in which consistently records the technological route of processing and all values of the elements of the allowance. Value R_Z and T choose from table 4.3 page 63 [1].

After the first technological transition T for parts of cast iron is excluded from the calculations. Therefore, we find only values in Table 4.8 R_Z.

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

$$\rho_3 = \sqrt{\rho_{KOP.}^2 + \rho_{CM.}^2}$$

The warping of the hole should be taken into account both in diametrical and axial cross sections:

$$\rho_{KOP.} = \sqrt{(\Delta_K \cdot d)^2 + (\Delta_K \cdot l)^2}$$

Warping castings are found in table 4.8 page 69 [1] (d and l - diameter and length of holes).

$$\rho_{KOP.} = \sqrt{(0.3 \cdot 100)^2 + (0.3 \cdot 106)^2} = 44\text{microns}.$$

When determining $\rho_{CM.}$ in this case it is necessary to take into account the accuracy of the location of the base surfaces used in this installation scheme and obtained in the previous operations relative to the surface being treated. [1]

Size tolerance Б=75 mm from the axis to the base surface (Fig.2.8) for casting the first class accuracy table П.1.1 [3] is 560 microns. During processing, it is possible to obtain 10 qualifications with a tolerance of 0.12 mm, respectively $\delta=(0.56+0.12)/2=0.34$ mm.

But when processing the surface 5 the base was the outer surface 6, so it is necessary to take into account the displacement of the rod, which forms an opening relative to the outer surface.

This offset should be defined as the deviation from the nominal size in the casting, determined by the tolerance on the size of the appropriate accuracy class.

Since as a base when machining holes Ø15 H9 was the side surface of the casting to determine the error location of the treated hole Ø100 H7, relative to the base holes Ø15H9 you need to take the displacement of the rod relative to the outer surface of the casting, determine the half tolerance on the size (Г=450mm) castings.

Given that the total displacement of the hole in the casting relative to its outer surface is a geometric sum in two mutually perpendicular planes, we obtain:

$$\rho_{CM} = \sqrt{\left(\frac{\delta_Б}{2}\right)^2 + \left(\frac{\delta_Г}{2}\right)^2} \tag{3.10}$$

In this formula: $\delta_Б$=$T_{ЗАГ}$ (75) =560 microns; $\delta_г$=1/2 ($T_{ЗАГ}$ (450)) =900 microns; $\delta_Б$ i $\delta_г$ – size tolerances (Б) and (Г) accuracy class according to this casting ρ_{CM}=530 microns.

Thus the total value of the spatial deviation of the workpiece:

$$\rho_{ЗАГ} = \sqrt{530^2 + 44} = 532(\text{microns}).$$

The final spatial deviation.

After the location we find ρ_i:

$$\rho_i = 0.05\ \rho_{заг} = 0.05 \times 532 = 26.6 \text{ microns.}$$

After normal ream out:

$$P_2 = 0.005\ \rho_{заг} = 0.005 \times 532 = 2.66 \text{ microns.}$$

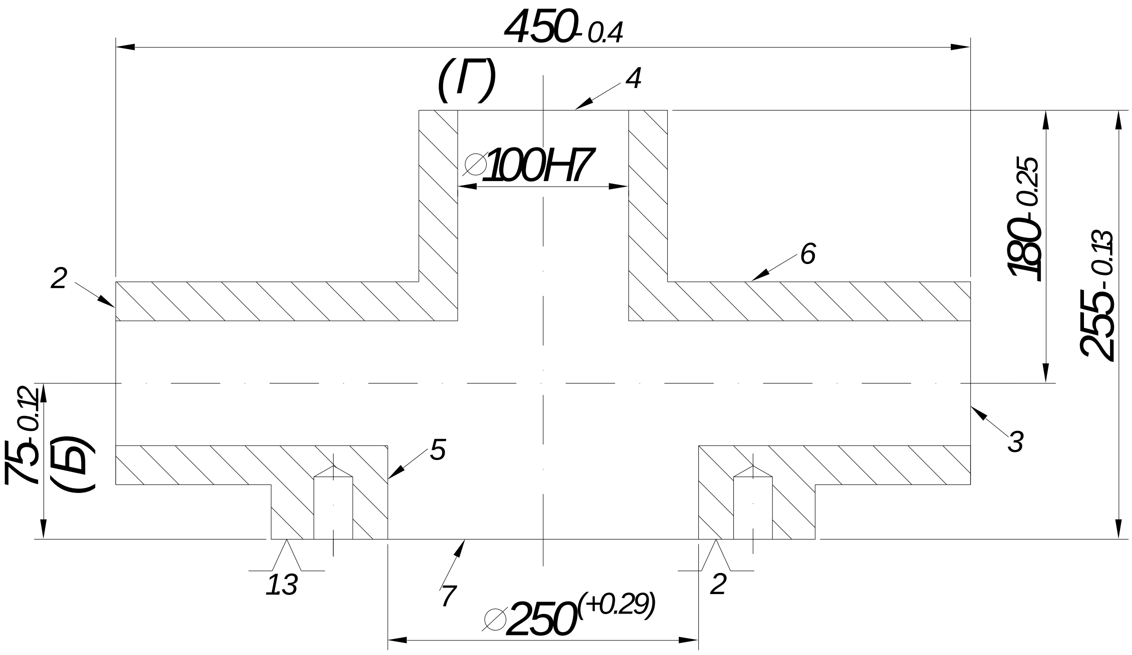

Figure 3.1 - Sketch of the gearbox housing and installation diagram when machining the hole Ø100 H7$^{(+0.035)}$

Installation error when roughing is determined by the formula:

$$\varepsilon_I = \sqrt{\varepsilon\delta^2 + \varepsilon_j} \qquad (3.11)$$

Base error ε_δ in this case arises due to the transfer of the workpiece in the horizontal plane when installed on the pin of the device. The distortion thus arises due to the gap between the largest diameter of the mounting holes and the smallest diameter of the adjustment pins:

$$S_{max}=\delta_a+ \delta_b+ S_{min} \qquad (3.12)$$

where δ_a – hole tolerance, δ_a=43 microns;

δ_b – tolerance on the pin diameter, δ_b=43 microns;

S_{min} – minimum clearance between the diameters of the pin and the hole:

$$S_{min}=T(H9/f8) =16 \text{ microns.}$$

Then the greatest angle of rotation of the workpiece on the pins can be found from the ratio of the largest clearance when turning to one side from the middle position to the distance between the base holes:

$$tg\alpha= (0.043+0.043+0.016)/275=0.0004.$$

The error of basing along the length of the machined hole: L = 106 mm

$$\varepsilon_\delta = \ell \cdot tg \cdot \alpha$$

$$\varepsilon_\delta = 106 \cdot 0{,}004 = 0{,}0424(мм) = 42(\text{microns}).$$

Error fixing the workpiece by the table 4.13 [1],

$$\varepsilon_з = 100 \ .$$

Then the installation error during boring:

$$\varepsilon_{заг} = \sqrt{42^2 + 100^2 = 108(\text{microns})}$$

Installation error during ream out:

$$\varepsilon_I = 0{,}05 \cdot \varepsilon_{заг} + \varepsilon_{інд} = 6(\text{microns}).$$

Installation error during accurate ream out:

$$\varepsilon_2 = 0{,}05 \cdot \varepsilon_{заг} + \varepsilon_{інд} = 0{,}54(\text{microns}).$$

$\varepsilon_{ind} = 0$, and how to handle one installation.

Based on the data in the table, we calculate the value of interoperable allowances using the formula:

$$2Z_{\min} = 2\cdot(R_{Zi-1} + T_{i-1} + \sqrt{\rho_{i-1}^{\ 2} + \varepsilon_i^{\ 2}}) \qquad (3.13)$$

Minimum allowance for boring

$$2Z_{\min 1} = 2\cdot(200 + 300 + \sqrt{532^2 + 108^2}) = 2\cdot 1043(\text{microns}).$$

Minimum ream out allowance:

$$2Z_{\min 2} = 2\cdot(50 + \sqrt{26{,}6^2 + 6^2}) = 2\cdot 77(\text{microns})$$

Minimum allowance for accurate ream out:

$$2Z_{\min 3} = 2\cdot(10 + \sqrt{26{,}6^2 + 0{,}54^2}) = 2\cdot 13(\text{microns})$$

Filling the table starts from the end.

In the graph d_p – estimated size:

$$d_{p3} = 100{,}035\ mm;$$

$$d_{p2} = d_{p3} - 2Z_{min3} = 100{,}035 - 0{,}026 = 100{,}009\ mm;$$

$$d_{p1} = d_{p2} - 2Z_{min2} = 100{,}009 - 0{,}154 = 99{,}855\ mm;$$

$$d_{pзаг} = d_{p1} - 2Z_{min1} = 99{,}855 - 2{,}086 = 97{,}769\ mm.$$

The tolerance values of each transition are accepted in tables [1], in accordance with the quality of a particular type of processing. In the Maximum Size column is the largest value (d_{max}) s obtained by the estimated size d_p, rounded to the nearest tolerance of the corresponding transition. The smallest size limits (d_{min}) are determined from the largest threshold sizes by subtracting the tolerances of the corresponding transitions:

$$d_{min} = d_{max};\ -\delta_i$$

Minimum allowance limits $Z^{пр.}_{min.}$ equal to the difference between the maximum thresholds of the executor and previous transitions, and the maximum values $Z^{пр.}_{max}$ – according to the difference of the smallest size limits.

Then for each ream out:

$$2Z_{min3}^{пр.} = d_{max3} - d_{max2}$$

$$2Z_{max3}^{пр} = d_{min3} - d_{min2}$$

Accordingly, for other transition.

Based on the calculation data, we build a scheme of graphical placement of allowances and tolerances for the processing of holes Ø100 $H7^{+0,035}$ (Fig.2.9).

Total minimum allowance

$$Z_{о\ ном} = Z_{о\ min} + B_3 + B_a = 2,266+0,56-0,035=2,791\ mm;$$

$$d_{3\ ном} = d_{9\ ном} - Z_{о\ ном} = 100,035-2,861=97,244\ mm.$$

On other machining surfaces of the housing of the allowance and tolerance is selected by the tables and write down their values in a table 3.5.

Table 3.3 - Calculation of allowances and limit sizes for technological transitions for hole treatment Ø100H7($^{+0,035}$)

<table>
<tr><th rowspan="2">Technological transitions processing surface the holeØ100 H7($^{+0,035}$)</th><th colspan="4">Elements allowance</th><th rowspan="2">Calculated allowance $2Z_{min}$</th><th rowspan="2">Calculated Size d_p, microns</th><th rowspan="2">Tolerance ρ, microns</th><th colspan="2">The maximum size, mm</th><th colspan="2">Limit values of allowances, microns</th></tr>
<tr><th>R_z</th><th>T</th><th>ρ</th><th>ε</th><th>d_{min}</th><th>d_{max}</th><th>$2Z_{min}^{пр.}$</th><th>$2Z_{max}^{пр}$</th></tr>
<tr><td>The workpiece</td><td>200</td><td>300</td><td>532</td><td></td><td></td><td>97,769</td><td>560</td><td>97,209</td><td>97,769</td><td>-</td><td>-</td></tr>
<tr><td>Rough boring</td><td>50</td><td>-</td><td>26,6</td><td>108</td><td>2084</td><td>99,855</td><td>220</td><td>99,635</td><td>99,855</td><td>2,086</td><td>2,426</td></tr>
<tr><td>Normal ream out</td><td>10</td><td>-</td><td>2,66</td><td>6</td><td>154</td><td>100,009</td><td>140</td><td>99,869</td><td>100,009</td><td>0,154</td><td>0,234</td></tr>
<tr><td>Accurate ream out</td><td>-</td><td>-</td><td>-</td><td>0,54</td><td>26</td><td>100,035</td><td>35</td><td>100</td><td>100,035</td><td>0,026</td><td>0,131</td></tr>
<tr><td>Together</td><td></td><td></td><td></td><td></td><td>2266</td><td></td><td></td><td></td><td></td><td>2,266</td><td>2,791</td></tr>
</table>

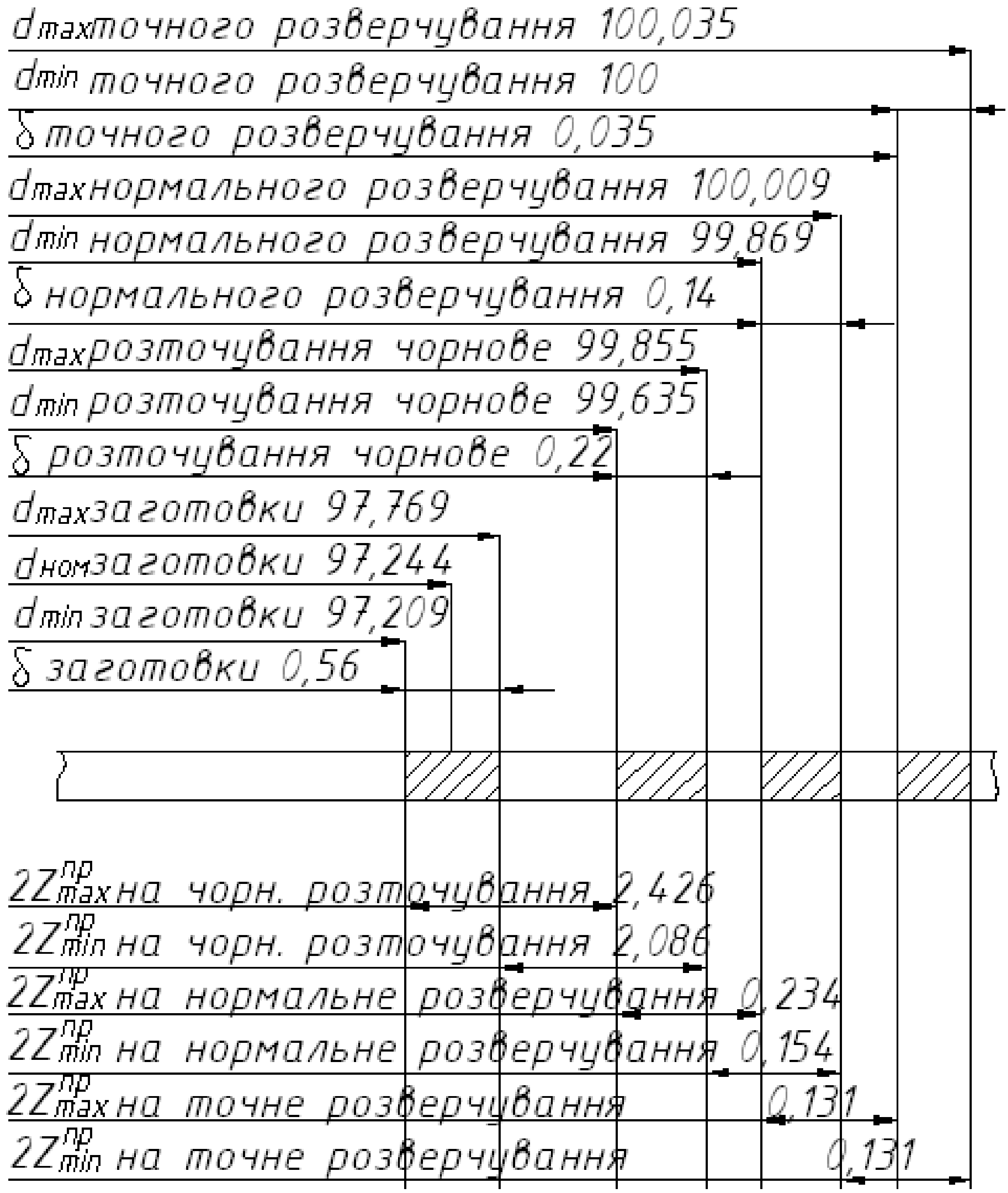

Figure 3.2 - The scheme of a graphic arrangement of allowances and tolerances on processing of an aperture of Ø100 H7Table

Table 3.4 - Allowances and tolerances on the surface, being processed housings

Surface	Size mm	The allowance, mm		Tolerance
		tabular	calculation	
1	100	2·1,2	2·1,43	±0,28
2,3	450	2·1,9	-	±0,45
4,5	255	2·1,6	-	±0,4
7	250	2·1,6	-	±0,35

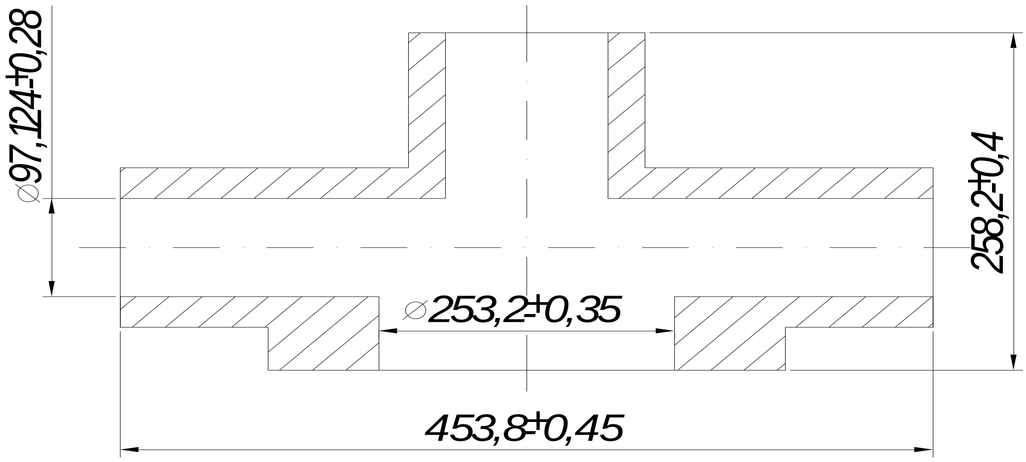

Figure 3.3 - Sketch of the workpiece housing with accrued allowances and tolerances

3.3 Determining the amount of equipment.

1. Milling planes simultaneously U, K, M on the longitudinal milling machine
   1.1 Nature of treatment - finishing. [13]
   1.2 Metal cutting tool - end milling cutter, cutting part ВК-8. front corner γ=20°, back corner α=15°; φ=30°, φ_1=10°, λ=5°; z=20; D=200mm. Marking 2214-0160.
   1.3 Cutting depth.

According to the process, it is possible to obtain a surface from Ra=10 microns. Cutting depth is equal to allowance t=1.9mm.

1.4 The filing is assigned [1], S_0=0.25 mm / tooth, then $S_z=S_0/Z=0.25/20=0.013$ mm / tooth.

1.5 Average resistance value a [1] дорівнює 240 хв.

1.6 Cutting speed:

$$v = \frac{C_V Dq}{T^m t^x S_z^y Z^p} K_V \qquad (3.14)$$

where $C_v=445,; q=0.2; m=0.32; x=0.15; y=0.35; p=0$.

The total factor that takes into account the actual cutting conditions:

$$K_v=K_{mv}*K_{nv}*K_{uv},$$

$$K_{mv} = 1; \quad K_{nv} = 0.8; \quad K_{uv} = 0.83$$

$$v = \frac{445 \cdot 200^{0.2}}{240^{0.32} \cdot 1.9^{0.15} \cdot 0.013^{0.35} \cdot 20^0} = 616 \quad m/\min;$$

1.7 Frequency of rotation of the mill:

$$П_ф = \frac{1000v}{\pi D_ф};$$

$$П_ф = \frac{1000 \cdot 616}{3{,}14 \cdot 200} = 981 \quad \text{rpm}$$

Cutting force (the main component of the cutting force:

$$P_z = \frac{10C_p \cdot t^x \cdot S_z^y \cdot B^n \cdot Z}{D^q \cdot n^w} \cdot K_{mp};$$

where C_p=54,5 for gray cast ironx=0,9; y=0,74; n=1; q=1; w=0; p. 291, Table. 41 Кмр=1 p. 264 Table. 9.

$$P_Z = \frac{10 \cdot 54.5 \cdot 1.9^{0.9} \cdot 0.013^{0.74} \cdot 46 \cdot 20}{200^1 \cdot 981^0} = 179 \quad H$$

1.8 Effective cutting power:

$$N_e = \frac{P_Z \cdot v}{1020 \cdot 60}, \quad \text{kW}$$

$$N_e = \frac{179 \cdot 616}{1020 \cdot 60} = 1.8\ \text{kW} \qquad (3.15)$$

1.9 Machine drive power:

$$N_{дв} = \frac{N_t}{\eta}, \quad \text{kW}$$

$$N_{дв} = \frac{1{,}8}{0{,}75} = 2{,}4\ \text{kW} \qquad (3.16)$$

1.10 The choice of the machine is made by type of processing, table size, capacity.

Choose the longitudinal milling machine model 6606.

Dimensions of the table 630x2000. Feed longitudinal 10-1000 mm / min. 11kW main motor drive powerx 3.

Adjust the machine cutting modes. According to the calculation:

$S_M=S_z*Z*n_{шп}$=0,013*20*981=255 mm/min.

The lowest speed of the machine spindle to the calculated frequency, at φ=1,26, n=1024 mm / rev.

Then the real cutting speed:

$$v_д = \frac{\pi D_ф \cdot n}{1000} = \frac{3{,}14 \cdot 200 \cdot 1024}{1000} = 64{,}3 \quad m/\min$$

Valid feed on the tooth of the milling cutte:

$$S_z = \frac{S_M}{zn} = \frac{255}{20 \cdot 1024} = 0.012 \quad \text{mm / tooth}$$

The true cutting force:

$$P_{zд} = \frac{10 \cdot 54{,}5 \cdot 0{,}012^{0{,}74} \cdot 1{,}9^{0{,}9} \cdot 46 \cdot 20}{200^1 \cdot 1024^0} = 169\ H$$

Really effective power:

$$N_{ед} = \frac{P_{zд} \cdot V_{д}}{1020 \cdot 60} = \frac{169 \cdot 643}{1020 \cdot 60} = 1{,}78\,kW$$

So $S_м$=255mm / min.; $n_{шп}$=1024mm / rev satisfy the processing conditions.

2. Drill a hole ∅13

2.1The tool is a drill ∅13, material - high-speed steel.

2.2Cutting depth 6.5 mm;

2.3Feed according tab. 25 p.277 [2] S=0.35 mm / rev;

2.4The stability of the drill according to table. 30 p. 280 [1] T=60 min.;

2.5Cutting speed:

$$v = \frac{C_v \cdot D^q}{T^m S^y} K_v \quad (3.17)$$

$$K_v = K_{mv} * K_{iv} * K_{uv},$$

According to the table. 28 p. 278 [2]: K_{mv}=1; K_{uv}=1; table. 4.5 p. 263 K_{iv}=1, table. 31 p 280 C_v=17.1; q=0.25; y=0.4; m=0.12.

Frequency of rotation:

$$n = \frac{1000v}{\pi D} = \frac{1000 \cdot 29.5}{3.14 \cdot 8} = 1174\ \min^{-1} \quad (3.18)$$

2.6Torque:

$$M_{кр} = 10 C_м \cdot D^q \cdot S^y K_p \quad (3.19)$$

According to the table. 32 p. 281 [2]: $C_м$=0,021, q=20, y=0.8; According to the table 10 p. 265, K_p=$K_{мр}$=1.

$$M_{кр} = 10 \cdot 0{,}021 \cdot 8^2 \cdot 0{,}35^{0{,}8} \cdot 1 = 5{,}8\ H \cdot m$$

2.7Effective power:

$$N_e = \frac{M_{кр} \cdot n}{9750}$$

$$N_e = \frac{5.8 \cdot 1174}{9750} = 0.7\ кВт \quad (3.20)$$

2.8Power of the drilling machine drive:

$$N_{дв} = \frac{N_e}{\eta} = \frac{0.7}{0.75} = 0.93 \quad \text{kW} \tag{3.21}$$

2.9 According to the engine power and the size of the table, we choose a radial drilling machine model 2A53 $N_д$=4kW p. 21 tab. 12.

The machine cutting modes are accepted: S = 0.3 mm / rev; n = 1013 rpm.

2.10 Specify machine cutting modes.

Effective cutting speed:

$$v_д = \frac{\pi Dn}{1000} = \frac{3.14 \cdot 8 \cdot 1013}{1000} = 25\, m/\text{min}$$

Since the received feed and the rotation speed are less than the calculated one, there is no need to check the power and torque.

3. Cut the thread M8-7H in the 8 holes

3.1 Tool - 8-piece machine tap, multi-spindle head.

3.2 Filing according to table.2 p. [2]: S=1.25 mm / rev.

The average value of stability according to table. 49 p. 296 [2]: T=90 min.

3.3 Cutting speed:

$$v = \frac{C_v \cdot D^q}{T^m S^y} K_v \tag{3.22}$$

According to the table. 49 p. 296: C_v*=64.8; y=0.5; q=1.2; m=0.9.* $K_v = K_{mv} * K_{iv} * K_{uv}$,

According to the table. 1-4 p.262 [2]: K_v=1

$$v = \frac{64.8 \cdot 8^{1.2}}{90^{0.9} \cdot 1.25^{0.5}} = 12.4 \text{ m/min}$$

3.4 Frequency of rotation:

$$n = \frac{1000v}{\pi D} = \frac{1000 \cdot 12.4}{3.14 \cdot 8} = 494 \min^{-1}$$

3.5 Torque:

$$M_{кр} = 10 C_м \cdot D^q \cdot P^y K_p \tag{3.23}$$

According to the table. 51 p. 298 [2]: $C_м$=0,013, q=1,4, y=1.5, P=1.25; $К_р$=$К_{мр}$=1.

$$М_{кр} = 10 \cdot 0{,}013 \cdot 8^{1.4} \cdot 1{,}25^{1,5} \cdot 1 = 3{,}3\ H \cdot m$$

3.6 Efficient power:

$$N_e = \frac{M_{кр} \cdot n}{9750}, \qquad (3.24)$$

$$N_e = \frac{3.3 \cdot 494}{9750} = 0.17 \text{ kW}$$

3.7 Power of the drive of the boring machine:

$$N_{дв} = \frac{N_e}{\eta} = \frac{0.17}{0.75} = 0.22 \quad \text{kW}$$

Since we have an 8th spindle drill head, then $N_{дв}=0{,}22*9=1{,}968\ kW$

3.8 We choose the model of the machine by the size of the table, as well as by the power, taking into account the possibility of processing with the help of the multi-spindle head, and the presence of the required speed of rotation. These analogues correspond to the vertical-boring machine model 2H150, engine power $N_{дв}$=7,5 kW.

Table 3.5- Normalization of cutting modes

№	*The name of the operation, the transition*	*i*	*t*	*S*	*v*	*n*	$N_{різ}$	*Accepted values*				$N_{вер}$
								$S_{пр}$	$v_{пр}$	$n_{пр}$	$N_{пр}$	
1	2	3	4	5	6	7	8	9	10	11	12	13
005	End trimming	1	1,6	0,8	62	70	2,5	0,8	90	100	3,3	4
	Boring of the hole.∅250	1	1,6	0,8	62	80	2,5	0,8	78	100	3,3	
	Boring of the chamfer 1x45°	1	1	0,2	38	50	0,3	0,2	78	100	3,3	
010	Simultaneous drilling and chamfering of 2 holes ∅14.5	1	7,45	0,35	30	659	0,8	0,3	29	640	1,1	7,5
	Ream out 2 holes ∅15H9		0,15									

015	Simultaneous milling of surfaces. U,K,M	1	1,9	0,25	616	981	1,8	0,25	643	1024	2,4x3	11,3
020	Ream out 3 holes ∅99.5	1	1,1	0,6	72	240	1,6x3	1	100	320	2,1x3	3x3
	Ream out normal 3 holes ∅99.8		0,1	0,3	16	50	2x3	0,1	31	100	2,6x3	3x3
	Ream out normal 3 holes ∅100		0,05	0,3	12	40	1,9x3	0,05	31	100	2,5x3	3x3
025	Drilling and countersinking of chamfers 8 holes ∅6,7	1	3,35	0,24	31	1414	5,6	0,2	32	1280	7,2	7,5
030	Thread cutting in 8 holes M8-7H	1	0,6	1,15	12	494	1,76	1,25	13	506	2,08	7,5
035	Drilling and countersinking of chamfers 12 holes ∅6,7	3	3,35	0,14	31	1414	2,8	0,2	32	1280	3,6	4
040	Thread cutting in 12 holes M8-7H	3	0,6	1,25	12	494	0,8	1,25	13	506	0,86	4
045	Countersinking of chamfers 3 1x45°	3	1	0,8	62	191	0,8	0,8	64	202	1,1	4
050	Counter boring of end face ∅20	1	1	0,35	20	318	1,2	0,3	20	320	1,6	4
	Drill a hole ∅13	1	7	0,35	30	1174	0,7	0,3	25	1013	0,9	
055	Counter boring of end face ∅30	1	1	0,35	19	202	1,4	0,3	1,9	202	1,8	4
	Drill a hole ∅14	1	7	0,35	39	1174	0,7	0,3	25	1013	0,9	

	Counter boring of chamfers 2x45°	1	2	0,2	21	446	0,3	0,2	24	506	0,4	
	Cutting thread M16-7H	1	0,6	1,25	12	494	0,2	1,25	13	506	0,22	

Cutting modes adopted on the machine: n=506 min^{-1}, then the true cutting speed:

$$v_д = \frac{\pi D n}{1000} = \frac{3.14 \cdot 8 \cdot 506}{1000} = 12.8 \text{ m/min}$$

Cutting modes for machining the remaining surfaces are determined using tables [2].

Establishment of control, auxiliary and transport operations

Output control of the workpiece details of the gearbox housing.

The appearance of the workpieces to detect material defects and mechanical damage to untreated sink surfaces with a depth of more than 1.5mm and a diameter of more than 2mm is not allowed. Ovalness and taper of workpiece surfaces not more than 0.017mm. [12]

Hardness control of the casting material: 255±0,4; 450±0,45; 100±0,28; 250±0,35.

The sample size for the input control of the batch of blanks:

- external inspection - 100% control of blanks;
- control of material hardness - 2-3 blanks from the batch;
- control of geometric sizes - 2-3 blanks from the batch.

Operational control (example for aggregate-boring operation on final processing - 3 holes opening in size ∅100 H7.

Final dimensions and surface parameters of three ∅100 H7 openings and their tolerances:

- diameter - ∅100 H7$^{+0,035}$mm;
- depth - through;
- tolerance of perpendicularity to the planeB – 0,04mm;
- tolerance of the joints of two openings – 0,03 mm;
- roughness Ra 2.5.

The maximum permissible errors of measurement of means for control of parameters of surfaces of 3 openings ∅100 H7:

- for ∅100 $H7^{+0,035}$ [Δ] we defineo: [Δ]=$A_{мет}$·T=0,3·0,035=0,0105mm;
- for placement tolerances; [Δ]=$A_{мет}$·T=0,25·0,035=0,0105mm;
- for roughness tolerance is not specified, we accept tolerances for the parameter Ra±20%.

Choice of means of control of parameters of a surface of 3 openings ∅100 H7:

- for control of tolerance and perpendicularity to the surface B is carried out by means of a control device;
- control of surface roughness with parameter Ra=2.5±20% microns is performed by the worker by comparing the roughness of the treated surfaces.

Frequency of parameters control of a surface of 3 openings ∅100 H7:

- hole diameter control - 100% control of all parts is carried out by the workbench and the control time is overlapped by machine time;
- control of surface roughness selective (5%) of parts is carried out by the workbench, control time is overlapped by machine time.

The final (receiving) control of finished parts is performed by the controller on the control operation. They are subject to control:

- appearance (the presence of all surfaces, chamfers, rounded, no burrs, sinks);
- the roughness of the treated surfaces by comparison with the roughness samples;
- geometric dimensions: ∅$100^{+0,035}$; ∅$255_{-0,13}$; ∅275±0,065; ∅$15^{+0,043}$; $450_{-0,4}$.
- tolerances of shape and deviations of mutual arrangement of surfaces; tolerance of ovality and conical surfaces Д, Е, Ж not more than 0,017mm;

- the tolerance of the perpendicularity of the hole to the surface of 0.04mm;
- tolerance of 0.03mm openings.

The operational card of technical control is filled.

Installation of transport operations.

The mass of the workpiece housing 27,51 kg, overall dimensions 450x286x255, the form is not complicated. Parts processing is carried out individually. At the site of machining workpieces are imported from a warehouse in a production container of 100 pieces. in each box. Transportation is carried out by the factory conveyor - electric truck Ф2ЕП130.

The main vehicle at the site is a roller conveyor.

The workpiece position is loaded using a manipulator ТШ 30.

Taking into account the overall dimensions and mass of the workpieces, we accept the launch of parts on the conveyor piece by piece.

The speed of movement of the conveyor:

$$v = \frac{l}{\tau \cdot n} K_3 \tag{3.25}$$

where $l = 5m$ – average distance between machines; $\tau = 0,67\ min.$ – release time; $K_3 = 1,5$ – stock factor; $M = 112m / min$. The necessary length of the conveyor will be determined when designing the site plan.

As auxiliary vehicles, we use production packaging to move blanks from the billet.

Enter in the route card TP operations of moving blanks under the number 001. The name of the operation - "Transport" with the note that it is performed after the operation 005 ... 057. After the control operation 057, the parts are stacked in the container for the finished parts, from which the electric forklift model. 3П-201 are moved to the assembly section, which is displayed in the itinerary as an operation 060.

Installation of auxiliary operations.

Marking operations should be introduced as auxiliary operations in the mechanical machining of the housing to ensure that the technical requirements are met.

Wash the finished part and Purge with compressed air for drying.

Normalization of the technical process.

Technical norms of time in the conditions of large-scale production are established by calculation and analytical method. [6]

In large-scale production is determined by the rate of artificial time $T_{шт}$:

$$T_{шт}=T_{о}+T_{доп}+T_{об}+T_{від}, \quad (3.26)$$

where To – main operating time, min.;

$T_{доп}$ – auxiliary time, min.;

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

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

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

$$T_{доп}=T_{в.з}+T_{з.в}+T_{уп}+T_{вим}, \quad (3.27)$$

where $T_{в.з}$ – time to install and remove parts, min.;

$T_{з.в}$ – time for fixing and detaching parts, min.;

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

$T_{вим}$ – time to measure parts, min.

Time for workplace maintenance $T_{об}$ in large-scale production consists of time for organizational service $T_{орг}$ and time for workplace maintenance $T_{тех}$.:

$$T_{об}=T_{орг}+T_{тех} \quad (3.28)$$

In large-scale production time for maintenance of the workplace $T_{тех}$ is determined by the formula:

$$T_{тех}=T_{о}*t_{зм}/T, \quad (3.29)$$

where $t_{зм}$ – time to change tools and set up the machine, min.;

T – a period of stability when working with one tool, or limiting.

Time for organizational servicing of the mass production workplace for all operations is determined as a percentage of the operational time. Time for rest and personal needs in standardization in large-scale production is determined by the formula:

$$T_{від}=T_{о}*П_{від}/100, \quad (3.30)$$

where $П_{від}$ – the cost of rest time as a percentage from the operative.

The above formulas for determining artificial time can be represented as:

$$T_{шт}=T_о+T_{в.з}+T_{з.в}+T_{уп}+T_{вим}+T_{тех}+T_{орг}+T_{від}, \quad (3.31)$$

All the calculated data are summarized in the table 3.6

Let's make a detailed calculation of the number of production equipment at the site of machining of the gearbox housing after normalization of the technological process.

Table 3.6 - Specified equipment calculation

Operation number	Artificial time, $T_{шт}$, хв.	The estimated amount of equipment, $C_р$	Number of equipment accepted, $C_п$	Number of equipment accepted, $K_з$
005	2,399	3,58	4	0,89
010	0,537	0,8	1	0,8
015	1,258	1,88	2	0,94
020	1,376	2,05	3	0,68
025	0,339	0,5	1	0,5
030	0,486	0,72	1	0,72
035	0,476	0,71	1	0,71
040	0,606	0,9	1	0,9
045	0,516	0,77	1	0,77
050	0,336	0,5	1	0,5
055	0,588	0,88	1	0,88

3.4 Design of special equipment and tools

Selection and justification of the principle of operation of the device, the structural diagram of the conductor.

The device is designed for drilling hole ∅13мм. It must provide the necessary clamping force, precision of the base, simplicity and reliability in use. [14]

The device (the conductor) is single, mounted on a rotary stand on the machine model 2A53.

According to the adopted scheme of the installation is carried out on two fingers (cylindrical and cut).

Calculation of a cylindrical finger as recommended. Nominal diameter of cylindrical finger:

$$d_{n1} = 15\,f9\left(^{-0.016}_{-0.059}\right)$$

The diameter of the second (cut off) finger will be determined:

$$d_{n2} = \sqrt{D_2^2 + B^2 - (B + TA + TБ - S_{\min})^2} = \sqrt{15^2 + 1.6^2 - (1.6 + 0.13 + 0.043 - 0.02)^2} = 14.98\ \text{m}m$$

where D_2=15mm – the diameter of the second hole;

B=1.6 mm – stripe width on cut off finger [2] p.353;

TA =0,13 – tolerance for inter-center distance between openings =275±0,065;

TБ=1/3TA=0,043 – tolerance to the center of the distance between the fingers, we accept the approximate standard.

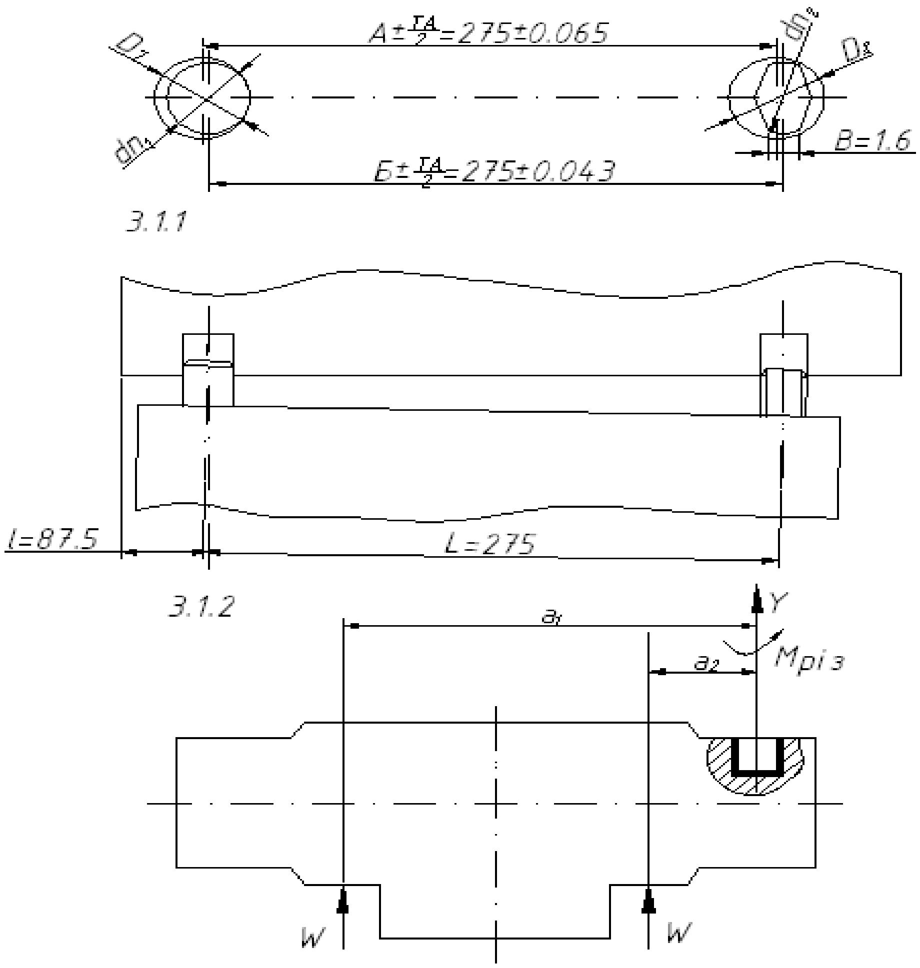

Figure 3.5 - Fitting the workpiece on fingers

ТБ=-275±0, 065mm (the nominal distance between the fingers is assumed to be equal to the nominal distance between the axes of the holes А=Б=275mm);

S_{min} – minimum gap between first finger and hole:

$$S_{min}=D_{1min}-d_{n1max}=15-14.98=0.02mm$$

Accordingly, the diameter of the second finger:

$$d_{n2}=14.98\ f9\left(^{-0.016}_{-0.059}\right)$$

In order to prevent wedging of the workpiece on the fingers (Fig. 3.1), we calculate its maximum height.

$$H=\frac{L+l+0.5D_2}{D_2+L}\cdot\sqrt{2(D_2+L)\cdot S_{1\min}}=\frac{275+87.5+0.5\cdot 15}{15+275}\cdot\sqrt{2(15+275)\cdot 0.02}=14.85\text{ mm}$$

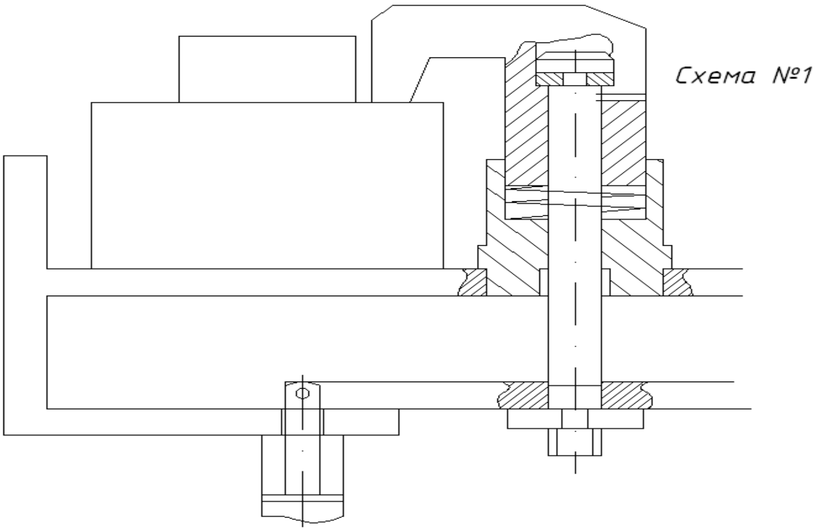

Figure 3.6 - Single lever layout

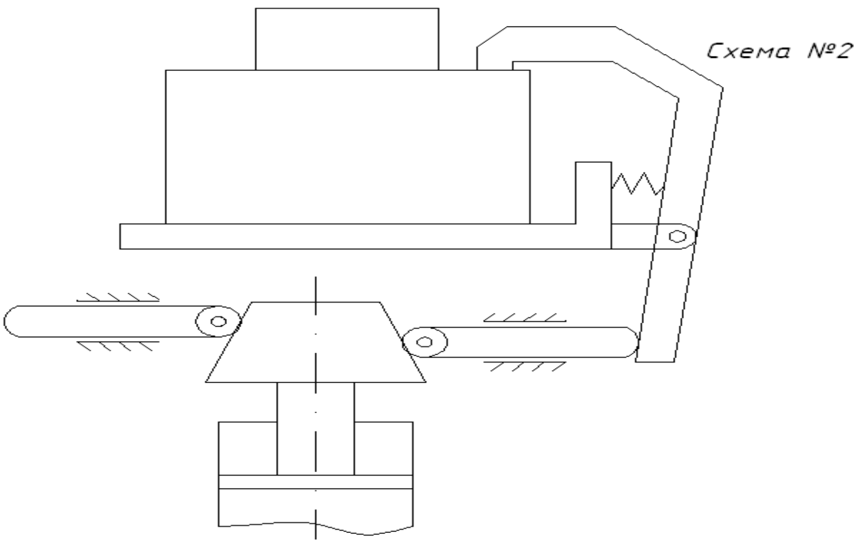

Figure 3.7 - Cone layout

Accept H = 16mm.

Based on the configuration of the part, its dimensions, mass, we accept the type of device single with a clip of the part on both sides.We make several schemes of devices.

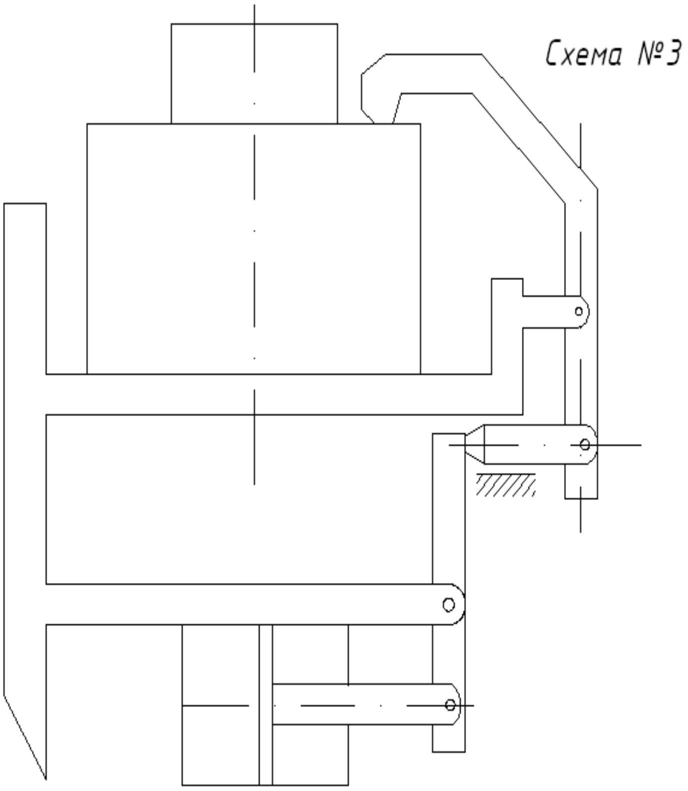

Figure 3.8 - Two-lever layout

The analysis of device circuits is performed on the basis of the total weights.

$$K_\Sigma = K_1 \cdot n_1 + K_2 \cdot n_2 + \ldots + K_m \cdot n_m, \qquad (3.32)$$

where n is the weight coefficients;

$K_1, K_2, \ldots, K_m$ – evaluation criterion coefficients.

We make a table of the criterion for evaluating the optimal circuit of the device.

We define the total criterion for each scheme:

$K_{\Sigma 1}$=1·2+1·10+0·8+1(-2)=10;

$K_{\Sigma 2}$=6·2+1·10+(-2) ·8+2(-2)=2;

$K_{\Sigma 3}$=4·2+0·10+(-1) ·8+3(-2)=-6.

Table 3.7 - Evaluation criteria for the layout of the device circuits

№ schemes	Evaluation criteria				
	Optimal gain	Possession of self-braking	Easy layout design	The presence of intermediate links	Total evaluation criterion
	$К_1$	$К_2$			
1	1	1	0	1	10
2	2×3=6	1	-2	2	2
3	2×2=4	0	-1	3	-6
n	2	10	8	2	

Power calculation of the parameters of the drive of the conductor

Having made the equation of equilibrium all the forces on the y-axis will get:

$$К_з \cdot M_{piз} = Wfa_1 + Wfa_2.$$

From here $W = \frac{К_з \cdot M_{piз}}{f(a_1 + a_2)} = \frac{2.5 \cdot 5.8}{0.14(0.28 + 0.1)} = 270\ H$

where W – required clamping force, H;

f – coefficient of friction on cast iron at rest f=0.14; $К_з$=2,5 – recommended stock ratio, a_1=0,284m; a_2=0,1m;

$M_{piз}$=5,8 H·m (from the cutting modes section).

In the acceptable scheme of the device uses a mechanism in the form of two equal-clamping and a plunger bayonet.

We make the equation of distribution of forces:

$$Q=2W=2\times 270=540H.$$

To ensure self-braking, we choose a bayonet plunger, it is recommended to take the angle of the working part of the bayonet plunger φ=5°45′.

Drive force using a bayonet plunger (Fig. 3.9).

The drive force using a bayonet plunger is determined:

$$Q=Q_1 \cdot [tg(\alpha+\varphi_1)+tg\varphi_2]=540 \cdot [tg(40^\circ+5^\circ 45')+ 540*1.1=549\ H$$

where $\varphi_1 = \varphi_2 = 5°45'$ - the angle of friction of the working part of the lock and the plunger.

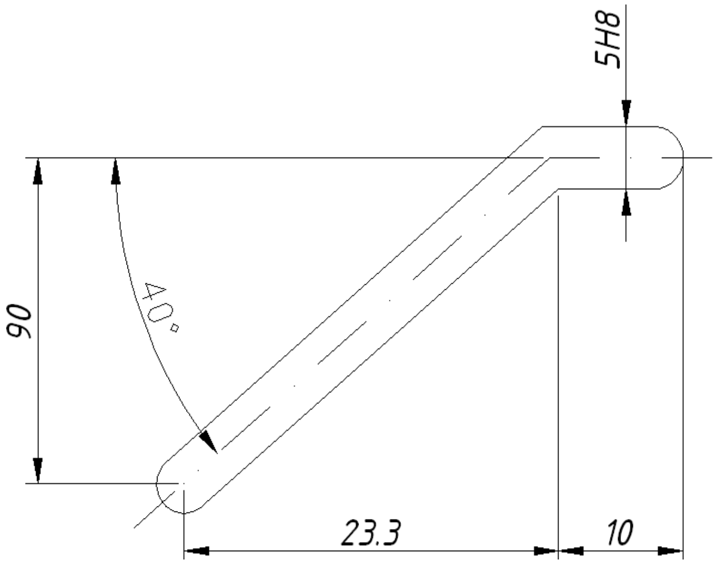

Figure 3.9 - Bayonet plunger

For mass production, it is recommended to use a pneumatic actuator (pneumatic cylinder or pneumatic chamber) p. 112-118. We calculate the required stroke of the drive stem. For free removal and installation of parts it is necessary for the springs to be able to return to 90°, the stroke of the actuator stem must be 23.3 mm for this purpose. When moving up to 40 mm, it is necessary to take a pneumatic chamber, but given the large size of the part, its weight and the necessary clamping force, it is recommended to take a pneumatic cylinder.

Determine the diameter of the plunger pneumatic cylinder by the formula:

$$D = \sqrt{\frac{4Q}{\pi P \eta}} = \sqrt{\frac{4 \cdot 594}{3.14 \cdot 0.4 \cdot 0.85}} = 47\text{mm} \qquad (3.33)$$

where Q – clamping force, H;

$P=0,4МПа$ – air pressure in the pneumatic system;

$\eta=0,85$ – efficiency of pneumatic cylinder.

We accept the standard diameter of the pneumatic cylinder $D=50mm$.

This device is still in use in the processing of mounting holes M8 7H on the planes И, К, М. In these operations, the clamping force should be approximately 4 times greater, so the diameter of the cylinder D we take 160mm.

Accuracy calculation

The calculation is made after the device is designed. It carries the calculation of the total error of calculation for accuracy ε_Σ:

$$\varepsilon_\Sigma = K\sqrt{\varepsilon_{в}^2 + \varepsilon_{рп}^2 + \varepsilon_{р.у}^2 + \varepsilon_{б}^2 + \varepsilon_{з}^2 + \varepsilon_{р.н.с}^2 + \varepsilon_{н}^2 + \varepsilon_{i}^2 + \varepsilon_{pi}^2 + \varepsilon_{t}^2} \qquad (3.34)$$

Consider each error separately:

1) $\varepsilon_в$ – Machine error in the unloaded condition. This is the size between the axis of the conductor bushing and the axis of the workpiece and the cylinder rod: 192±0,05

So:

$$\varepsilon_в < \text{на 15-20\% від } T(192)=0,1mm$$

Machine error consists:

a) perpendicularity of the course of the spindle of the machine to the mirror of the table of the device = 0,02mm;

б) non-perpendicularity of the mirror of the table of the device (plate on which the part is located) to the guides of the machine =0,03:

$$\varepsilon_в = \sqrt{0,02^2 + 0,03^2} = 0,04$$

2) $\varepsilon_{р.п}$ – location of the device on the machine. The device joins the machine "through the intermediate link" - a rotary stand.

Parallel error in securing the device to the pivot stand and spindle axis: $\varepsilon_{р.п}$=0,01.

3) $\varepsilon_{р.у}$ – error of arrangement of the constituent elements of the device relative to the surfaces of the device, which it is based on the machine.

For size 192±0,05 the mounting element is the fingers. They must be parallel to the axis of the bushing $\varepsilon_{р.у}$=0,003.

4) $\varepsilon_б$ – base error when the measurement and installation bases do not match. The margin of error will be equal to the gap between the fingers and the landing holes:

$$\varepsilon_б = \frac{S_{\max}}{L}, \quad \text{де } S_{\max} = D_{2\max} - d_{n2\min} = 15.0.43 - 14.921 = 0.122\text{mm}$$

L=275 – the distance between the fingers.

$$\varepsilon_б = \frac{0{,}122}{275} = 0{,}0004$$

5) $\varepsilon_з$ – fixing error accepted =0.

6) $\varepsilon_{р.н.е}$ – the location of the guides and the device is incorrect.

$$\varepsilon_{р.н.е}=\varepsilon_1+\varepsilon_2+\varepsilon_3+\varepsilon_{пер};$$

where ε_1 – the maximum clearance between the conductor and the intermediate bushes (Fig.3.9)

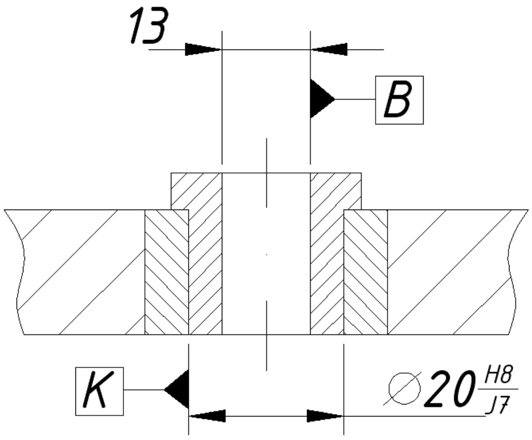

Figure 3.9 - Clearance between conductor and intermediate bushes

With a quick-change conductor bushing:

$$S_{\max}\left(\frac{H8}{g7}\right) = \left(\frac{+0.033}{-0.028}\right) = 0.061 = E_1$$

ε_2=1/3 size tolerance ∅13 on the conductor.

ε_2=1/3 T(13)=0,014.

ε_3 – surface inconsistency K and B conductor bushing (see fig. 3.9), we accept $\varepsilon_3=0$, because the surfaces are treated simultaneously.

$\varepsilon_{пер}$ – the error of misalignment of the axis of the tool and the axis of the conductor sleeve, we assume equal 0.

Thus, substituting the value into the formula:

$$\varepsilon_{р.н.е}=0{,}061+0{,}014+0+0=0{,}075$$

7) $\varepsilon_н$ – debugging error

For the conductor, this error is equal to the maximum gap between the outer diameter of the tool and the inner diameter of the conductor sleeve. We've got $\varepsilon_н=0$, the conductor is adjusted by a special mandrel.

8) ε_i – tool error. $\varepsilon_i=0$;

9) $\varepsilon_{p.i}$ – instrument placement error. $\varepsilon_{p.i}=0$;

10) $\varepsilon_{p.з}$ – dimensional wear error. $\varepsilon_{p.з}=0$;

11) ε_t – temperature error, linear expansion is very small. $\varepsilon_t=0$.

These errors are substituted into the formula of the total error:

$$\varepsilon_\Sigma = 1.2\sqrt{0.04^2 + 0.01^2 + 0.003^2 + 0.0004^2 + 0.075^2} = 0.0856$$

Thus, the total error is less than the allowable by 15%, which provides the required accuracy.

4. PROJECT PART

4.1 Determination of the main and auxiliary areas of the shop

Mechanical assembly building. Accepted rectangular shape with dimensions of width and length 1: 2. Grid of columns 12x18m. The height of the shop is 7.2 m. The number of passages is one main and two transverse. Auxiliary compartments will be located along the spans of the wall columns. The assembly room is located perpendicular to the longitudinal columns on the end side of the shop.

The layout of the production departments of the shop. For mass production with the organizational form of work is performed in accordance with the developed route TP machining of the gearbox.

Diagram of the relative position of vehicles. Associated with the type of production according to the TP of the product. One roller conveyor for machine maintenance, TSH 30 manipulators for manual mechanization were chosen as vehicles. The length of the conveyor is determined by the formula:

$$L=C_p\times l_i \quad (4.1)$$

where l_i – the length of the i-th machine, taking into account the passages between them;

C_p – number of machines.

$$L=17\times5=85м.$$

Conveyor width B=0,6m.

Approximate calculation of the area of the shop.

Production for mechanical sections:

$$F_{вир}=C_p\times F_{верст} \quad (4.2)$$

where $F_{верст}$ =15-25 m^2 for medium dimensions of machines

$F_{вир}$=134*25=3350m^2

Assembly and testing sites:

$$F_{скл.випр}=30\ldots40\%\ from\ F_{вир}= 0,4\times3325=1340m^2.$$

Auxiliary offices

a) tool sharpening:

is selected from dimensions of the products made in mechanical sites. In our case the case of a reducer concerns products of average dimensions for which:

$$F_{зат\ .від}=10\text{-}20m^2.$$

We accept $F_{зат\ .від}=20\times5=100m^2$.

б) repair base.

When counting $F_{црб}$ based on the total number of machines and the specific area under one machine, which is located in the CRH. According to the calculations of their number Wed = 2 (if the shop has more than 100 pieces of equipment). Then $F_{црб}$ determined by the formula:

$$F_{црб}= C_p \times F_{верст} =2*20=40m^2. \quad (4.3)$$

в) repair of production equipment and tools.

The area of such branch is chosen proceeding from dimensions of products. For this type of product $t_{рво}=25m^2$ on 1 machine.

We accept for 6 machines the area of branc h $_{рво}=25\times6=150\ m^2$

г) control department.

Calculated at the rate of 5-6 m^2 per controller with a factor $K_к$, taking into account the increase in area for the location of control equipment.

At two-shift work in mass production for our case two controllers are necessary. Then: $F_{кв}=PF_nK_к=2\times6\times1,75=20\ m^2$.

where P – number of controllers.

д) compositions of metal, blanks, parts, assemblies.

The area of metal warehouses, blanks is calculated:

$$S_1=\frac{A\cdot Q}{qKm}=\frac{3\cdot1000}{1.5\cdot0.6\cdot254}=108м^2 \quad (4.4)$$

For warehouses of details, knots:

$$S_1=\frac{A\cdot Q}{qKm}=\frac{7\cdot1000}{1.5\cdot0.6\cdot254}=305м^2$$

Here the value of A characterizes the storage time of blanks, materials in the warehouse, for mass production (A = 3 - 6 days); storage time of parts, assemblies, semi-finished products (A = 6-12 days). Accordingly, q is the allowable load capacity of the warehouse area, t / m2. K is the utilization factor of the warehouse area, taking into account aisles and passages (K = 0.5-0.65), m is the number of working days per year.

total area:

$$S=S_1+S_2=108+305=413m^2 \tag{4.5}$$

ж) premises of MPA and chip processing.

This area is determined based on the consumption of lubricants by the formula:

$$Q_{\text{М}} = \frac{q_{\text{М}} \cdot C_{П} \cdot 253}{1000} = 0{,}53\, t\,/\,y \tag{4.6}$$

and the cost of the emulsion by a similar formula:

$$Q_E = \frac{q_{\text{Е}} \cdot C_{П} \cdot 253}{1000} = 5{,}3\, t\,/\,y \tag{4.7}$$

here $q_м$ and $q_е$ – consumption of oils and emulsions per 1 machine per day $q_м=0{,}2kg$, $q_e=2\ kg$.

C_n – number of machines in the shop 137pcs.

253 – number of working days per year.

The area of the chip processing room is set on the condition of 1 m2 of calculation of the area per one unit of technological equipment of the mechanical shop.

$$F_{зор.пер.стр.}=C_p\times 1=137m^2 \tag{4.8}$$

з) the total area of auxiliary offices is the sum of their areas.

$$F_{заг}=F_{заг.i}+F_{црб}+F_{рво}+F_{кв}+F_{скл}+F_{зор.пер.стр}=100+40+150+20+413+137=860m^2$$

е) office and domestic premises.

The area of administrative and office premises is calculated 4m^2 per ITP, and their number is taken within 7-10% of the number of major producers. The number of MOSFETs is 1… 2% of the number of ITPs.

Then from 266 people of the basic manufacturers at the rate of the accepted 8% we will receive 22 people. ITP, from 22 people. ITP - people. ILO, a total of 24 people., For which the total area of the premises will be:

$$F_{спп}=P\times F_{пит}=24\times 4=96m^2 \tag{4.9}$$

The area under the rest area is $0{,}9\ m^2$ per employee:

$$F_{вк}=274\times 0{,}9=246\ m^2 \tag{4.10}$$

The area under the dining room and buffet is selected at the rate $1m^2$ area per employee while it is believed that the first shift employs no more than 100 people. Then:

$$F_{ст.б}=90\ чол.\times 1м^2=90\ m^2. \tag{4.11}$$

The area of sanitary facilities (medical center, locker rooms, showers, toilets, washbasins) is selected 0,9 m^2 based on when the shop employs no more than 100 people.

$$F_{стп}=150\times 0{,}9=135\ m^2 \tag{4.12}$$

The total area of office and domestic premises is:

$$F_{заг}=F_{спп}+F_{вк}+F_{стб}+F_{стп}=96+246+90+135=567\ m^2 \tag{4.13}$$

к) the total area of the mechanical assembly shop.

This area is equal to the sum of production and auxiliary departments without taking into account the area of office space.

$$F_{заг}=F_{вир}+F_{доп}=3350+860=4210\ m^2. \tag{4.14}$$

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

Carried out on the basis of the total estimated area of the shop on the basis of the use of unified standard sections of the frame of the building itself in accordance with the recommendations. In our case for without crane shop the grid of columns will be of the sizes 12 × 18m for which width and length of shop will be equal:

$18\times 3=54m;$ $12\times 9=108m$ in accordance

Then, the accepted area of the shop is determined:

$$F_{ц}=ахв=54\times 108=5832m^2 \tag{4.15}$$

Execution of the layout of the shop should be carried out in accordance with existing recommendations [1].

Due to the fact that for the manufacture of this part requires 17 units of metal-cutting equipment machines of medium size, namely: 4 turning and screw-cutting 1M61, 3 vertical drilling 1H150, 2 longitudinal milling 6606, 3 aggregate-boring, 5 radial- drilling 2A53 - machines are placed in two rows on both sides of the conveyor. For transportation of details between machines we use the roller conveyor l = 85 m long and B = 0,6 m wide. Transportation of blanks from the warehouse to the site and parts to the warehouse is carried out in containers by electric car.

5 OCCUPATIONAL HEALTH AND SAFETY IN EMERGENCIES

5.1 Structure of civil defense of the object of economic activity of machine-building profile and performance of tasks on liquidation of emergency situations

Everyone has the right to protection of their life and health from the consequences of accidents, catastrophes, fires, natural disasters and to demand guarantees of this right from the Cabinet of Ministers of Ukraine, ministries and other central executive bodies, local state administrations, local governments, management of enterprises, institutions and organizations, regardless of ownership and subordination.

The state, as a guarantor of this right, creates a system of civil defense, which aims to protect the population from the dangerous consequences of accidents and disasters of man-made, environmental, natural and military nature.

Civil Defense of Ukraine is a state system of government, forces and means created to organize and ensure protection of the population from the consequences of emergencies of man-made, environmental, natural and military nature.

The tasks of the Civil Defense of Ukraine are: prevention of emergencies of man-caused and natural nature and elimination of their consequences.

At large enterprises, such a profile as mechanical engineering, as a rule, a full-time deputy head of the Central Office is planned, who in peacetime is the main organizer of all its preparatory activities.

In addition to the staff deputy, the order of the head of the Central Office appoints deputies for the distribution and evacuation of workers and employees, engineering and technical part and logistics. Unlike a full-time deputy, they are not relieved of their duties.

The Deputy Head of the Distribution and Evacuation Center is usually appointed by the Deputy Head of General Affairs. He is usually a representative of the evacuation commission, he develops a plan for the distribution of workers, workers and their families, organizes the preparation of places in the suburbs, transporting people there, as well as delivery of work shifts to work, manages the general security service.

The chief engineer of the enterprise is appointed the deputy chief of the Central Department for engineering and technical part. He directly manages the emergency technical, fire, shelter and shelter services, as well as provides technical guidance to SiINR.

Deputy Head of the Central Office for Logistics - Deputy (Assistant) Director on these issues. He manages the logistics service.

At all sites, as a rule, there are headquarters of the Central Committee, which are staffed by officials. The number of staff members is determined by the department located at the facility.

The headquarters of a large enterprise includes: the chief of staff and his deputies (assistants) for operational and reconnaissance units, combat training, and the housing sector. It may include various specialists and representatives of general organizations.

The position of Chief of Staff of the facility is usually provided in the staffing schedule of the enterprise. The first deputy is the deputy chief of the Central Committee, the chief of staff has the right to give orders and instructions on his behalf. He organizes a stable government and a reliable notification system, intelligence, current and future planning, combat training of personnel of the formation, monitors the implementation of all activities of the Central Command.

5.2Calculation of vibration supports type OV-30 for the machine model 1M61

Determine the position of the center of mass of the machine, assuming that the mass of the machine is evenly distributed over the volume and conditionally dividing it into separate parts, the shape of which can be in the form of parallelepipeds and cubes, in any selected coordinate system.

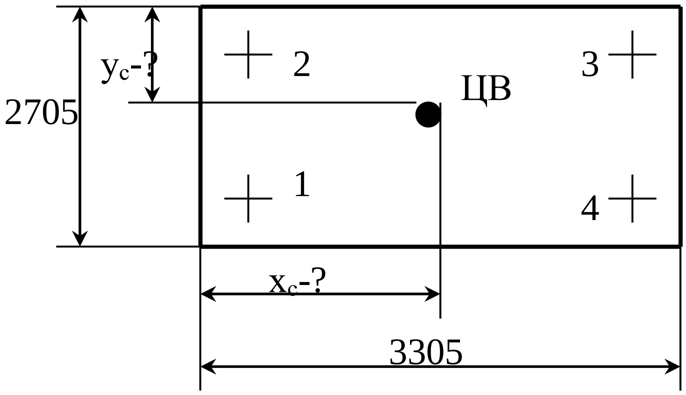

Figure 5.1 - Simplified plan view of the machine

The position of the center of mass in this case will be: [(1) Article 92]

$$X_c = \frac{\sum_{i=1}^{n} x_i \times m_i}{\sum_{i=1}^{n} m_i} = \frac{x_1 m_1 + x_2 m_2 + x_3 m_3}{m_1 + m_2 + m_3}; \qquad (5.1)$$

where xi, yi - the position of the center of mass of the i-th part;

mi is the mass of the i-th part.

$$y_c = \frac{\sum_{i=1}^{n} y_i \times m_i}{\sum m_i}; \qquad (5.2)$$

Based on the fact that the vibration-insulated machine should not lose stability and that all the supports are placed in the same way, we determine the reaction of the supports. A typical scheme of installation of the machine on the vibrosupport is shown in Figure 9.4 (which shows the scheme for determining the reactions of the vibrosupport of the machine). We use the scheme of the machine for division into 3 simple parts, and for simplification of calculations we consider that the x-axis - an axis of symmetry.

This diagram is shown in Figure 5.2.

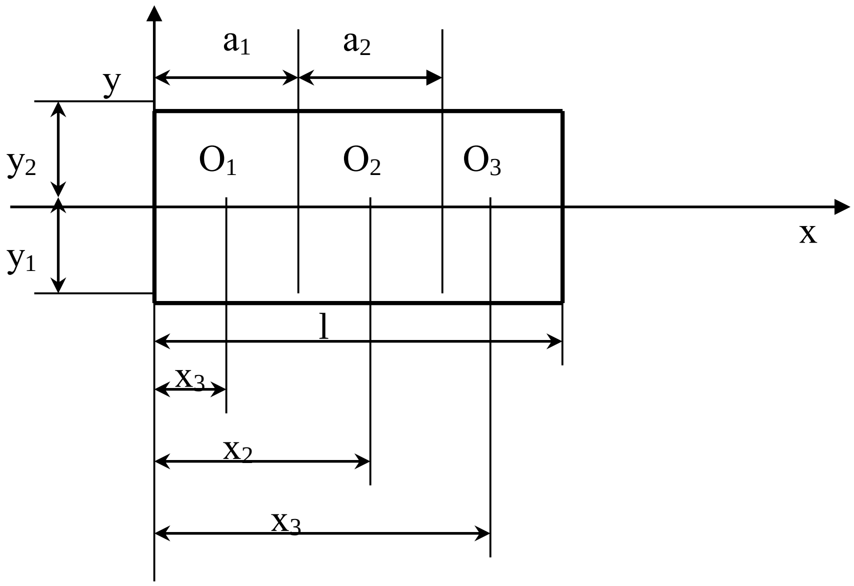

Figure 5.2 - Calculation scheme of the machine

$a_1, a_2, \ldots, a_i$ – the length of the i-th part;

$x_1, x_2, \ldots, x_i$ – position of the i-th part;

$O_1, O_2, \ldots, O_3$- centers of provisions of the i-th part;

$l = \sum_{i=1}^{n} a_i$ – total length.

l= a_1+ a_2+ a_3=3305 (mm).

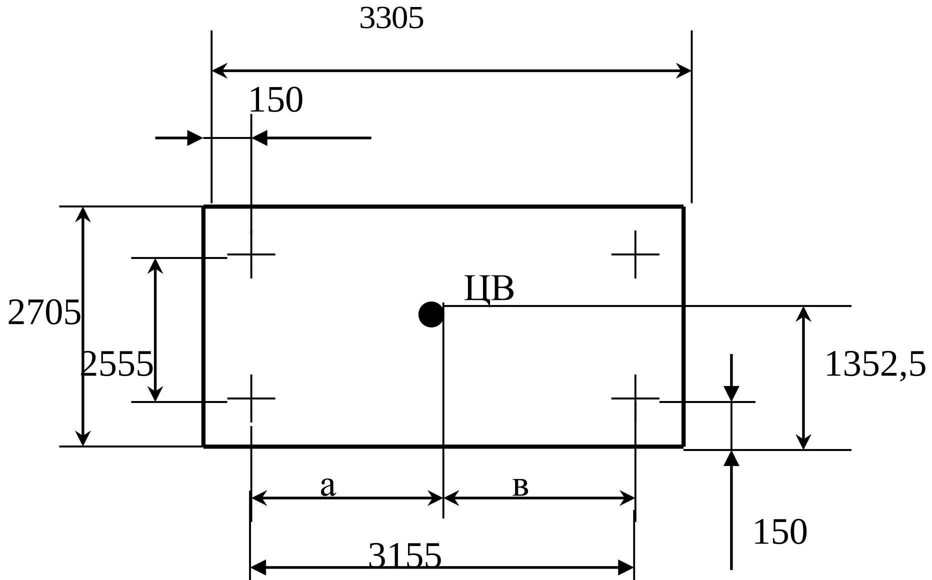

Figure 5.3 – Simplified scheme of the machine

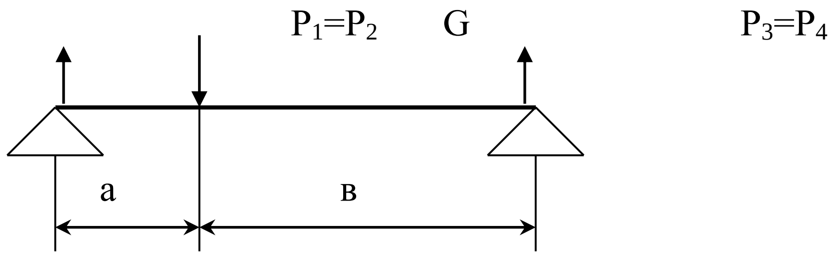

Figure 5.4 - Calculation scheme for determining the reactions of machine supports

$$P_1+P_2+P_3+P_4=G=mg, \qquad (5.3)$$

where $P_1, ..., P_4$ – support reactions of vibration isolators;

G – weight machine;

m – weight machine.

Assume that the equation of moments relative to the line passes through the center of mass. Since the load on the supports lying on line 1.2 and on line 3.4 are equal (P1 = P2 = P3 = P4), the equation:

$$P_1a+P_2a–P_3в–P_4в=0.$$

Оскільки $P_1=P_2$, а $P_3=P_4$, то

$P_1a–P_3в=0$

$P_1a=P_3в$

$P_1=в/aP_3$

$P_2=P_1=в/aP_3$

$P_3=P_4$.

We find P_1, P_2, P_3, P_4:

$$в/aP_3+в/aP_3+P_3+P_3=mg; \qquad (5.4)$$

$$X_c=\frac{x_1m_1+x_2m_2+x_3m_3}{m_1+m_2+m_3}=$$

$$=\frac{1560\times3800+1200\times3000+545\times1000}{3800+3000+1000}=1291,4(mm)$$

Determine the unknown a and c.

$$a = x_c - 150 = 1141{,}4 \text{(mm)}$$

$$в = 3155 - 1141{,}4 = 2013{,}6 \text{ (mm)}$$

Substitute the obtained values of a and b in equation (9.2) and obtain:

$$\frac{2013{,}6}{1141{,}4} P_3 + \frac{2013{,}6}{1141{,}4} P_3 + P_3 + P_3 = 76440 (H)$$

$P_4 = P_3 = 13{,}9$ *кН*

$P_1 = P_2 = 24{,}5$ *кН*

Knowing the value of the reactions of the supports on the nomogram taking into account the drilling machine, we select the appropriate type of vibration-insulating support, which in our case will be OB-30-3-3.

GENERAL CONCLUSIONS

As a result of solving the problems submitted for the diploma project, the following is fulfilled:

- the current variant of manufacturing of a part is analyzed, the shortcomings are revealed and the ways of their elimination are specified;
- new more accurate and metal-based workpiece is proposed;
- structural analysis of possible variants of manufacturing process of the part is carried out, the optimum cost option is selected;
- for the new variant of the workpiece, the values of the total and intermediate allowances of the operating sizes are calculated;
- for the new technological process are defined cutting modes, time standards and operational machining;
- modernized existing and designed new technological equipment (lathe, milling device, stands);
- the calculation of the expected economic effect of the introduction of a new technological process and comparison of the existing, payback period of 3.3 years;
- the issues of life safety were considered and analyzed and the economic justification of the decisions made.

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