

MINISTRY OF EDUCATION AND SCIENCE OF UKRAINE
NATIONAL TECHNICAL UNIVERSITY OF UKRAINE
“IGOR SIKORSKY KYIV POLYTECHNIC INSTITUTE”
EDUCATIONAL AND RESEARCH
INSTITUTE OF MECHANICAL ENGINEERING
Department of Manufacturing Engineering

Level of higher education – first (bachelor)

Program subject area – 131 “Applied Mechanics”

Educational Program “Manufacturing Engineering”

APPROVED

Acting head of the department

_____ Olexander
OKHRIMENKO

« ____ » _____ 2023

ASSIGNMENT
for the student's diploma project
Moati Ali Al-Amir Zakaria

1. Topic of the project: Manufacturing Process Design for the Part "Bearing Shell"

Project supervisor: Maksym Gladskyi, PhD

approved by the University Order № 49/23-ci of 23.05.2023.

2. Deadline for submission of the project: June 16, 2023

3. Initial data for the project:

Assessment of the stress-strain state and determination of the allowable tool loads during drilling

4. Content of the text part (explanatory note):

Four chapters required: 1 Study section, 2 Technological section, 3 Design of machine tools, 4 Financial section.

5. List of the graphic material (indicating mandatory drawings, posters, presentations, etc.):

Presentation is required, 3-5 drawings of detail, workpiece, process example, machine tools.

6. Date of the task issue: April 24, 2023.

Time schedule

No	The stage of the diploma project execution	Deadline	Notes
1	Definition of allowable load for drilling tools	May 1, 2023	completed
2	Design of detail and workpiece	May 8, 2023	completed
3	Process planning	May 31, 2023	completed
4	Design of machine tools	June 7, 2023	completed
5	Finance chapter and work finalization	June 14, 2023	completed

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Introduction

Mechanical engineering is a leading complex of branches in industry. Its level determines the further development of the entire national economy. Development of mechanical engineering poses new problems related to improving the quality of products and labor productivity and requires their solution. Modern mechanical engineering is used in almost all spheres of human life activity, achieved great success in increasing its efficiency and eventually turned into a technological base of the industry, which determines the level technical development of the country and its security.

Mechanical engineering technology, as a branch of science, is engaged in the study of technological processes of manufacturing mechanical engineering products in order to use the research results to ensure the required quality and quantity of products with the highest technical and economic indicators. Modern technology is developing in the following main directions: creation of new materials; development of new technological principles, methods, processes, equipment; mechanisation and automation of technological processes that reduces direct human participation in them.

Construction of the material and technical base and the need for continuous increasing labor productivity on the basis of modern means of production poses rather responsible tasks for mechanical engineering. They include improving the quality of machines, reducing their material consumption, labor intensity and cost of production, normalisation and the unification of their elements, the introduction of current methods of production, its mechanisation and automation, as well as shortening the terms of preparation for the production of new objects. The solution of the indicated problems is provided by improving the design of machines, improving the technology of production, application progressive means and methods of production. In connection with the continuously growing requirements for the quality of products, rapid changes in the range of products increase the amount of technological preparation of production per unit of time. Thus, a problem arises, which is that a technologist in modern conditions must perform not only a larger volume of work, but also do it at a higher quality level. Solving this problem involves automating the technologist's work, and this, in turn, requires further development of the scientific foundations of mechanical engineering technology. All this should be in the direction of a more in-depth study of regularities technological processes, increasing the level of generalisations, formalisation of research results, application of mathematical methods, improvement of calculation methods and development of technological processes, design of means.

1. Solving general mechanical engineering issues

Assessment of the stress-strain state and determination of the maximum allowable tool loads when drilling holes

The process of drilling holes from hard-to-machine materials to which high-strength, heat-resistant, stainless, titanium; others highly alloyed alloys, associated with the need to choose tools, processing modes and methods, as well as rational designs power tool. Defects that accompany the drilling operation can arise as a result of the deviation of the axis of the drill from the given direction, vibrations that lead to faceting on the surface of the processed hole, as well as changes force load on the tool in the process of deepening, which lead to tool breakage.

1.1 Stress-deformed state of the drill during compression and torsion

In the process of drilling, the tool perceives complex resistance - compression with torsion. Bending is possible due to the internal application of the longitudinal strength Let's calculate the centrally applied longitudinal force, which is possible buckling. The critical force of the drill is determined by Euler's formula:

$$P_{kp} = \frac{\pi^2 EJ_{\min}}{(v \cdot l)^2}$$

Where E is the modulus of elasticity of the drill material $E (= 2 \cdot 10^{11} \text{ Pa})$; $J_{\min}$ - the minimum axial moment of inertia of the cross-section of the drill; E Jmin - bending stiffness of the drill; - length reduction factor ($v = 0.7$); 1 - the length of the drill bit (we assume $1 = 0.2 \text{ m}$). The paper proposes to calculate the moment of inertia of the drill by dividing its cross-section into simple geometric shapes, determining the moments of inertia of these shapes, and then calculating the total moment of inertia of the cross-section (Fig. 1.1).

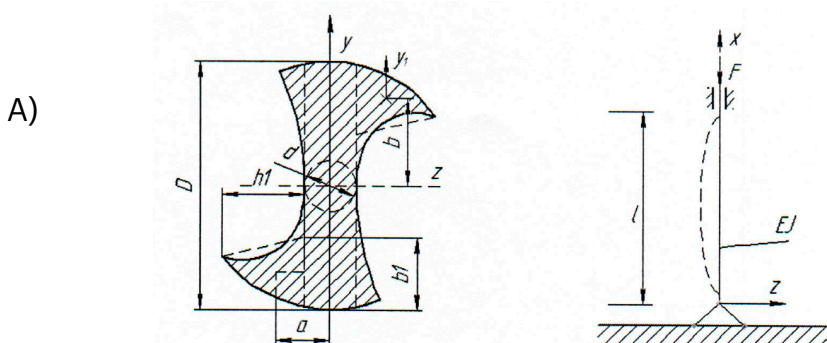


Fig. 1.1. Cross section of the drill (a) and longitudinal bend of the drill (b)

In our opinion, this approach requires significant time costs. On modern equal moments of inertia are calculated in one of the applications of the SolidWorks program automatically for a section of any complexity, provided there is a virtual solid model of the section. In fig. 1.2 shows an example of this calculation for a spiral drill.

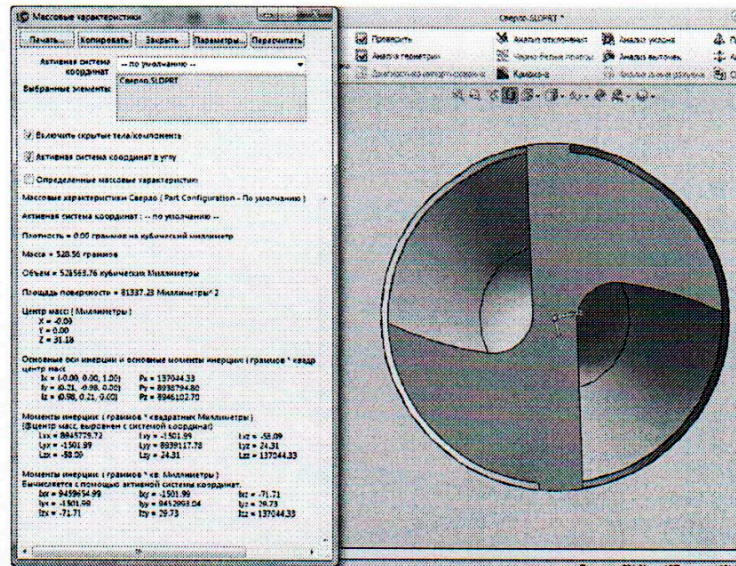


Fig. 1.2. Calculation of moments of inertia in the SolidWorks program The permissible load according to the stability of the drill is defined in [1] as

$$[\sigma_c] = \sigma_{kp} / n_{3c}, \quad \sigma_{kp} = P_{kp} / F,$$

Where Φ_{kr} is the critical load; - n_{3c} coefficient of stability reserve; - F cross-sectional area of the drill.

To exclude the loss of stability, condition (2) must be fulfilled:

$$\sigma_\delta \leq [\sigma_c],$$

Where $\sigma_\delta = N_{\max} / F$, σ_δ applied tension; $N_{\max}$ is the maximum possible

Longitudinal force during drilling. Without taking into account the longitudinal bending of the drill, the condition of strength must be fulfilled, taking into account the complex resistance - compression and torsion (2):

$$\sigma_{екв} = \sqrt{\sigma^2 + 4\tau^2} \leq [\sigma],$$

Where t is tangential stress during torsion; $[\Phi]$ - permissible stress. The allowable stress can be found using the formula

$$\sigma = N_{\max} / F, \quad \tau = M_{kp}^{\max} / W_p,$$

Where W_p is the polar moment of resistance of the cross-section of the drill; M_{kp} Max maximum torque when drilling

The moment of resistance is calculated by to $W_p = \frac{J_p}{R}$, де J_p - where J_p polar

moment of inertia cross section of the drill ($p = J_z + J_y$). Moments of inertia of the drill section relative to the z and y axes, the polar moment of inertia is automatically calculated using the same SolidWorks application.

In fig. 1.3 shows the constructed diagrams of the internal forces of the drill 2 (- diagram of movements of the axis of the drill in the radial direction, σ - diagram of stresses, N - diagram of loads under the action of longitudinal force).

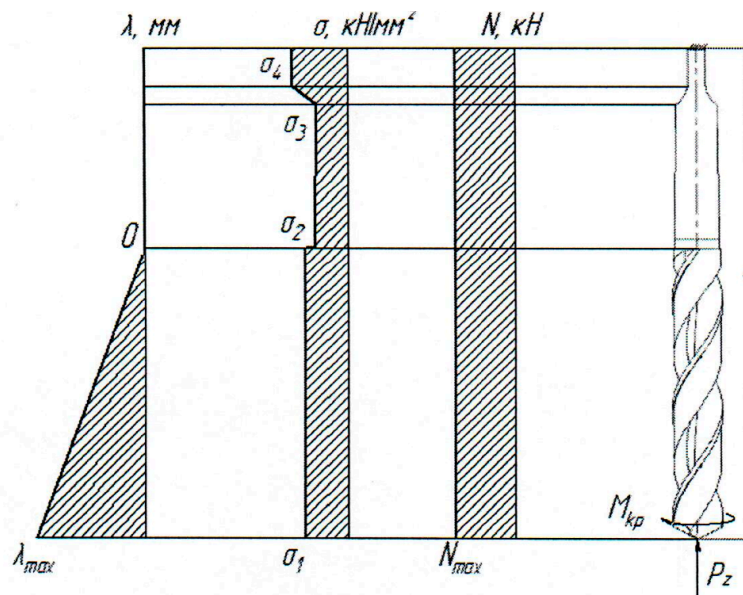


Fig. 1.3. Plots of the internal forces of the drill

1.2. Study of drill oscillations

Complex mixed oscillations of the drill occur near a stable equilibrium position. In order to study the longitudinal and torsional vibrations as the most characteristic vibrations of the drill, the frequencies of natural vibrations were found. For example, the frequency of the first tone of longitudinal vibrations of a drill as a cantilever rod calculated by the formula:

$$P_1 = \frac{\pi}{2l} \sqrt{\frac{E}{\rho}} = 39770 c^{-1},$$

Where p is the density of the material. The frequency of the first tone of torsional oscillations for a drill with a fixed cross-section is calculated as:

$$P_1 = \frac{\pi}{2l} \sqrt{\frac{G}{\rho}} = 225153 c^{-1},$$

Where G is the modulus of elasticity of the second kind. As follows from the theory of oscillations, when a longitudinal force constant in time is suddenly applied, displacement and stress increase twice. Similarly, the tangential stress increases when a torque is suddenly applied, which can take place in the cut-in phase if the loads increase almost suddenly, ie in this case

$\sigma_d = 2\sigma$. $\tau_d = 2\tau$. Then the equivalent loads are defined as:

$$\sigma_{\text{экв}} = 2\sqrt{\sigma^2 + 4\tau^2} = 1,21 \cdot 10^8 \leq [\sigma].$$

In this case, for this type of drill, the equivalent loads also do not exceed those allowed ($1,21 \cdot 10^8 < 1,6 \cdot 10^8$).

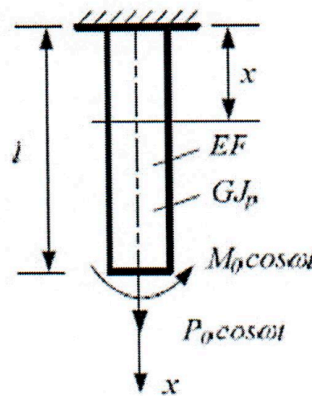


Fig. 1.4. Dynamic model of longitudinal and torsional vibrations of the drill
In the case of forced longitudinal oscillations, the differential solution equation:

$$\frac{\partial^2 u}{\partial x^2} - \frac{1}{c_0^2} \frac{\partial^2 u}{\partial t^2} = 0$$

under boundary conditions

$$u(0, t) = 0, EF \frac{\partial u(l, t)}{\partial x} = P_0 \cos \omega t$$

we find as:

$$u(x,t) = \frac{P_0 c_0}{EF \omega \cos(\frac{\omega}{c_0} l)} \sin(\frac{\omega}{c_0} x) \cos \omega t,$$

where ω is the rotation frequency of the drill; P_0 - amplitude value of vibration action; - $c_0 = \sqrt{E/\rho}$ coefficient. According to Hooke's law,

the normal stresses in this case are equal to:

$$\sigma = E \frac{\partial u}{\partial x} = \frac{P_0}{F \cos(\frac{\omega}{c_0} l)} \cos(\frac{\omega}{c_0} x) \cos \omega t.$$

For example, when $x = l$, $\sigma = 0$ follows, $-P_0/F$

In the case of forced torsional oscillations, the solution of the differential equation

$$\frac{\partial^2 \varphi}{\partial x^2} - \frac{1}{c_1^2} \frac{\partial^2 \varphi}{\partial t^2} = 0,$$

Where $c_1 = \sqrt{G/\rho}$, under boundary conditions

$$\varphi(0,t) = 0, \quad GI_p \frac{\partial \varphi(l,t)}{\partial x} = M_0 \cos \omega t,$$

Where M_0 is the amplitude value of the vibration effect, solved by the Fourier method.

$$\varphi(x,t) = \frac{M_0 c_1}{GJ_p \omega \cos(\frac{\omega}{c_1} l)} \sin(\frac{\omega}{c_1} x) \cos \omega t.$$

The tangential stresses in this case are equal

$$\tau = G\gamma = G\theta \frac{D}{2} = \frac{Gd}{2} \frac{\partial \varphi}{\partial x} = \frac{M_0 D}{2J_p \omega \cos(\frac{\omega}{c_1} l)} \cos(\frac{\omega}{c_1} x) \cos \omega t.$$

For example, when $x = 1$, $t = 0$ follows $\tau = M_0/W_p$.

Thus, in connection with the forced oscillations, conditioned vibration deterministic load, there are variable normal and tangential loads: at the same time, the total equivalent load is not should exceed the permissible. In connection with repeated and changing loads, which are conditioned mixed (longitudinal - torsional) vibrations of the drill, when evaluating the normal and tangential load should be taken into account in the general margin of safety. In order to exclude failures (damage or destruction of the drill), it is necessary that during operation the internal forces differ insignificantly from the actual reserves of the carrying capacity of the drill.

1.3. Fatigue drill calculation

With repeated dynamic loads of variable sign, it is of interest to calculate the fatigue strength of the tool. At the same time, strength is ensured if the calculated margin ratio is greater than the normative one. When calculating fatigue, the standard calculation procedure is used, used in the mechanics of a deformable solid body. Determination of effective normal and tangent concentration coefficients voltage:

$$k_\sigma = 1 + q_\sigma(\alpha_\sigma - 1) = 1,6;$$

$$k_\tau = 1 + q_\tau(\alpha_\tau - 1) = 1,52;$$

Where $\alpha_\sigma, \alpha_\tau$ theoretical concentration coefficients ($\alpha_\sigma = 2, \alpha_\tau = 2$);

q_σ, q_τ - coefficients of sensitivity to the concentration of normal and tangent stress ($q_\sigma = 0.6, q_\tau = 0.52$);

$$\sigma_a = \frac{(\sigma_{\max} - \sigma_{\min})}{2} = 2,37 \cdot 10^7 \text{ Pa},$$

$$\sigma_c = \frac{(\sigma_{\max} - \sigma_{\min})}{2} = 2,37 \cdot 10^7 \text{ Pa},$$

$$\tau_a = \frac{(\tau_{\max} - \tau_{\min})}{2} = 9,4 \cdot 10^6 \text{ Pa},$$

$$\tau_c = \frac{(\tau_{\max} - \tau_{\min})}{2} = 9,4 \cdot 10^6 \text{ Pa},$$

Where (Beta max - Beta min. maximum and minimum values of normal power cycles (Beta max=4,74x10⁷, Beta min=0) tmax tmin - maximum and minimum values of the tangential load of the cycle (tmax= 1,88x10⁷ Pa, tmin=0)

$$n_{\tau} = \frac{\sigma_{-1}}{\psi_{\sigma}\sigma_c + \sigma_a k_{\sigma} / k_F k_V} = 5,47;$$

where pK is the coefficient of influence of roughness (Kf = 0.95); kv - scale factor (kv = 0.95); o.- the limit of endurance of the material according to normal stress (Beta-1= 2.4*10⁸ Pa); - coefficient of sensitivity of the material to cycle asymmetry in terms of normal stresses (YBeta= 0.2).

Determination of the margin of fatigue strength by tangential stress.

$$n_{\tau} = \frac{\tau_{-1}}{\psi_{\tau}\tau_c + \tau_a k_{\tau} / k_F k_V} = 7,33;$$

where t-1 is the endurance limit of the material in terms of tangential stress (t-1 = 1,4*10⁸Pa);

Yt- coefficient of sensitivity of the material to asymmetry of the tangential voltage cycle

(Yt=0.17).Verification of the strength condition.

$$n = \frac{n_{\tau} n_{\sigma}}{\sqrt{n_{\sigma}^2 + n_{\tau}^2}} = 4,39 > [n],$$

where [n] is the normative safety factor for fatigue strength ([n] =4).

Conducted studies of the stressed-deformed state of the tool allow us to evaluate its bearing capacity, when various dynamic actions are combined. It is shown that the reliability of the tool is ensured if, during the drilling process, the internal forces under dynamic loads do not exceed those that are allowed. The calculation procedure is necessary to justify the choice of the tool.'

1.4 Study of power characteristics during drilling and reaming [3]

An axial cutting tool is a cutting blade tool with a rotary main cutting motion and a feed motion along the axis of the main cutting motion. Axial cutting tools include: drills, countersinks, reamers, taps, dies, countersinks and countersinks. Typical sequences of machining with axial tools provide machining of holes with IT12-IT7 size accuracy and roughness parameters of the machined surface $Ra_{20} - Ra_{1.25}$. Average machining accuracy with individual axial tools, the roughness parameter of the treated surface and the sequence of their rational application are given in the table. 1.. Technological sequences of processing and the recommended values of the depth of cut are the basis for determining the dimensions of axial cutting tools.

The biggest labor intensive processing axial cutting tools in solid material is drilling. Drill - an axial cutting tool for creating a hole in solid material and (or) increasing the diameter of the pre-processed hole. The most common design of drills are screw spiral drills, the cutting part of which has two main cutting edges and is made of high-speed tool steels. For processing fibreglass, special drills are made from metal-ceramic hard alloys, mainly from the VK group, for example, VK6, VK8, BK10M, BK100M. For processing of cast irons are used modern constructions of prefabricated drills, which are equipped with replaceable polygons plates with mechanical fastening, but these designs of axial cutting tools are used for processing holes with a diameter of more than 20 mm.

Table 1.1. _ typical sequences processing holes axial tools in solid material.

Type of axial processing	Average cutting depth, mm	Processing accuracy	Roughness Ra , μm
Drilling	$D/2$	H12...H11	20...10
Countering is preliminary	1,5...2,5	H11...H10	10...6,3
Countering is final	0,5;1,5	H10...H9	6,3...5,0
Deployment previous	0,05...0,2	H9...H8	5,0...2,5
The deployment is complete	0,025...0,05	H8...H7	2,5...1,25

High-speed tool steels (HSS) are widely used for the manufacture of cutting tools that work under conditions of significant power loads and medium temperatures at the cutting edges. The main ones physical and mechanical characteristics which ensure constant performance of cutting tools are: high strength and viscosity; high surface hardness of working surfaces; wear resistance of contact surfaces, satisfactory heat resistance up to 600...650°C.

Variation of alloying elements and modes of heat treatment gives the ability to purposefully change individual characteristics of high-speed tool steels.

Mechanical characteristics basic marks of high-speed tool steels and their heat resistance temperature in accordance with the GOST 19265-73 standard are given in the table. 1.2.

In the table 1.2 gives the main physical and mechanical characteristics of the most common grades of high-speed steels, which are necessary for calculations of cutting mode elements during drilling, which ensure safe processing of the hole and excludes fragile destruction of the cutting tool.

For calculations on the strength of the cross-section of the drill, it is necessary to take the smallest value of the permissible tangential stress of the tool material, which is given in the table. 1.2.

Table 1.2. Mechanical characteristics of cutting tool steels of normal performance.

SHIS brand	Hardness HRC	Bending strength, MPa	Permissible tangential stress, Mpa	Temperature heat resistance (HRC 58), ^C
P 1 8	63-64	2600-3000	1500-1730	620
P 12	62-63	2600-3500	1500-2020	620
P 9	62-63	2800-3200	1615-1845	620
P6M5	64-65	3200-3600	1845-2075	620
P6M3	62-64	3200-3600	1845-2075	620
10P6M5	64-65	2600-3000	1500-1730	625
11R3MZF2B	63-64	3400-3800	1960-2190	620

The design of modern technological processes of mechanical processing using CAM systems requires the determination of forces and moments acting in technological processing system, as well as energy costs for implementation separate technological operation. Since such power characteristics of the process cutting is mainly determined by the parameters of the allowance layer being cut, there is a need for their calculation. Geometric parameters of the allowance layer, which cut off during drilling, are determined according to the scheme shown in Fig. 2.1

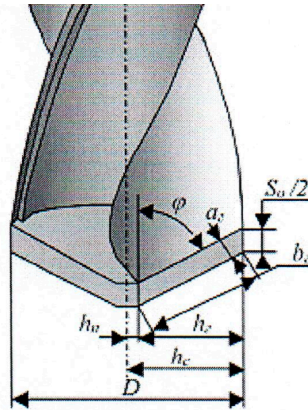


Fig. 1.5. Geometric parameters of the shearing allowance layer

The diameter D of the drill is measured by tapes. The cutting depth when drilling in solid material is equal to half the diameter of the drill: $h_c = D/2$.

As can be seen from the diagram (Fig. 2.1), the cutting depth consists of two parts:

$$h_c = h_n + h_z,$$

Where h_n , h_z cutting depth on the transverse and main cutting edges, respectively.

Cross-sectional area of the allowance layer cut by one main cutter the edge determined by thickness a and width b_z . 3 ratios of the scheme in

Fig. 2.1 are easy to obtain:

$$a_z = \frac{S_0}{2} \sin \varphi, b_z = \frac{h_z}{\sin \varphi}.$$

To study the features of the force interaction of the drill with the processed material, the cutting force is divided into three components according to the generally accepted coordinate system OZ, OY, OX. Components of cutting forces acting on cutting machines the edges of the drill are shown in Fig. 2.2 The total component of the cutting force, which is a projection on the OX axis, can be defined as the sum of:

$$\vec{P}_x = \sum_{i=1}^6 \vec{P}_{xi}.$$

Since the direction of the OX axis coincides with the axis of the drill, this component of the cutting force is called the axial force P.

The sum of all components projected onto axis O should theoretically be zero, since the drill has an even number of cutting edges:

$$\vec{P}_y = \sum_{i=1}^6 \vec{P}_{yi} = 0,$$

and the components projected onto the OZ axis create a moment relative to the axis of the tool, which is commonly called the drilling moment:

$$M_{cg} = \sum_{i=1}^6 P_{zi} l_i$$

In accordance with the above, it was established that in the process of cutting, the axial force P_0 and the drilling moment M_∞ act on the drill. The characteristics of the force action on the drill are determined by the influence of all factors that determine the mode cutting of the machining process, physical and mechanical characteristics of the workpiece material, physical and mechanical characteristics of the tool material, geometric parameters of the cutting part of the tool, characteristics of the lubricating and cooling technological medium.

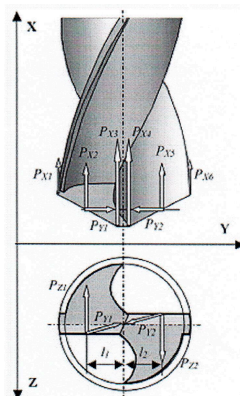


Fig. 1.6. Scheme of cutting force components

Similarly, for turning processes for drilling and reaming, empirical dependences in the form of power-law mathematical models are adopted, which reflect the influence of the parameters of the cutting mode on the axial force of P0. and moment Ms drilling, and same.

$$P_0 = C_p D^{Z_p} h^{X_p} S^{Y_p} V^{n_p} k_p, (1.1)$$

$$M_{cb} = C_M D^{Z_M} h^{X_M} S^{Y_M} V^{n_M} k_M, (1.2)$$

Where D - drilling diameter (mm), / - cutting depth (mm), - rotation (mm/rev), V - cutting speed (m/min).

Dependencies (1.1), (1.2) are used for machining by drilling and de-drilling. Unknown parameters of the model, exactly exponents of degree 2r, 2l; Hr, Hu. Ur, Uzh; P, m and proportionality coefficients C, and C" for acceptable standard conditions of processing processes were established based on the results of experimental studies, and their numerical values for drilling and undrilling are given in the reference literature [14].

The difference between the specific processing conditions and those adopted during their installation are taken into account by the correction coefficients kta k", which determine the influence of the physical and mechanical characteristics of the processed material, the shape of the sharpening of the cutting part of the drill, and the state of the cutting edges. In the work, it is assumed that the processes of drilling and de-drilling with drills that have a normal form of sharpening with sharpening of the transverse edge and a double form of sharpening with sharpening of the transverse edge are studied.

To simulate the processes of drilling and undrilling in the mathematical model that is the basis of the application program, the influence of the cutting speed on the drilling moment and the axial force is taken into account by the exponent nm=np=-0,05.

In addition, when drilling with an increase in the length of the hole, the conditions for chip removal deteriorate, and the force of friction of the drill with the machined surface increases. Accordingly, the axial component of the cutting force and the cutting torque increase. In order to reflect this phenomenon and to increase the adequacy of the mathematical models for P0. and Mcb, an additional coefficient is introduced, which depends on the ratio of the drilling length L to the diameter:

$$k_L = [1 + k_1 (\frac{L}{D})^2], (1.3)$$

where k is a coefficient accepted within 0.003...0.005.

With taking into account the above, for modelling the axial force and drilling moment during drilling and undrilling is carried out according to the following mathematical models for drilling:

$$P_0 = 10C_p D^{Z_p} S^{Y_p} V^{n_p} k_L k_p, (1.4)$$

$$M_{c\delta} = 10C_M D^{Z_M} S^{Y_p} V^{n_p} k_L k_M, (1.5)$$

for drilling:

$$P_0 = 10C_p h^{X_p} S^{Y_p} V^{n_p} k_L k_p, (1.6)$$

$$M_{c\delta} = 10C_M D^{Z_M} h^{X_M} S^{Y_M} V^{n_M} k_L k_M, (1.7)$$

Complicated conditions of the cutting process, which are determined by the features of chip and heat removal from the cutting zone, the action of sufficiently large components of the cutting force, which create the axial cutting force and the drilling moment often lead to brittle destruction of the tool. Therefore, when modelling processes, it is necessary to provide for the verification of all the strength conditions of the drill rod, or at least the most important one - according to tangential stresses:

$$\tau \leq [\tau]. (1.8)$$

The tangential stresses arising in the drill rod during machining are determined by the formula:

$$\tau = M_{c\delta} / W, (1.9)$$

where M. is the drilling moment (Nm), W is the moment of resistance of the cross section of the drill (m³).

The moment of resistance, taking into account the shape of the cross-section of the drill and the size range, is determined by the formula:

$$W = kD^3, (1.10)$$

Taking into account the dimensionality in formula (1.9), the diameter D of the drill is substituted by um . For drills, it is necessary to take the value $k=0.025$, for $k=0.02$. The permissible value of tangential stresses $[t]$ according to the strength characteristics of the tool material is given in table. 1.2.

The generalisation of the practical experience of machine-building production shows that it is advisable to use pre-drilled holes for processing of holes in the range of diameters 20-50 mm. Accordingly, to ensure stable conditions of the cutting process during milling, it is necessary to predict the depth of cutting. Thus, the diameter of the hole prepared for the drilling operation should not exceed $D_c - h_{min}$.

Calculation example

To perform the practical part, the "Drilling" application program is used, which is located on the disk, and its main interface is presented in Fig. 1.7. Instructions and explanations for working with the application program appear on the additional interface when pressing the H button.

The interface contains output data task windows and buttons control, as well as the animation window 1 of the turning process and the image of the oscilloscope 2. The registration of processes on the oscilloscope and the movement in the animation window are synchronised. Oscillograms of its characteristics appear on the oscilloscope image (synchronously with the cutting process in graphic window 1 of the interface): line 3 is the axial component of the cutting force, line 4 is the cutting torque.

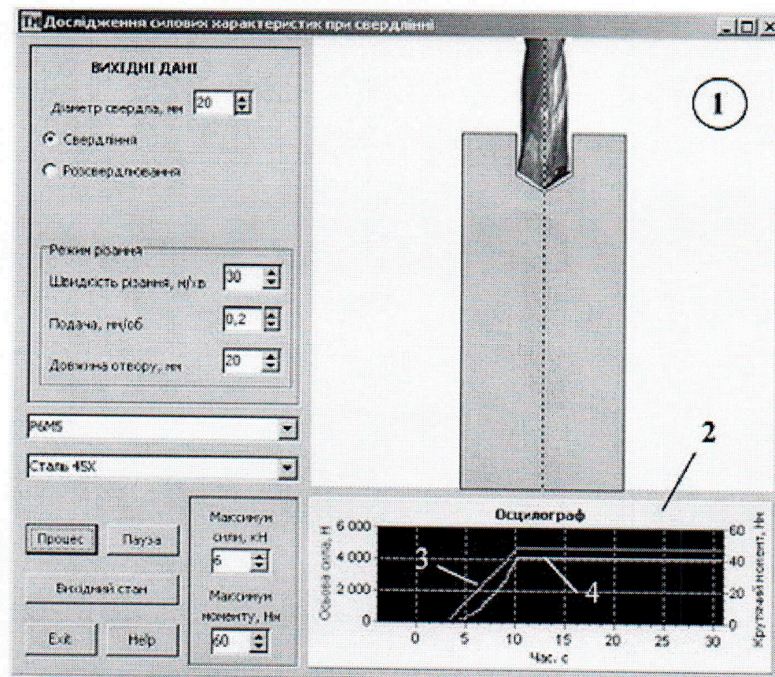


Fig. 1.7. The main interface of the simulation program.

The graphic representation of the animation of drilling is constructed in such a way that when the diameter of the drill is changed, the corresponding changes are displayed in the graphic window, and the depth of drilling is displayed on the same scale as the drill. In addition, increasing the feed causes a proportional acceleration of the movement of the drill in the animation window. In fig. 1.7 the recorded moment 32 s after the start of the simulation. The entire cycle starts from the “ ” second mark and includes drill feeding (no cutting), cutting (cutting force and torque gradually increase) and steady drilling.

In the process of preparing experimental studies, it is necessary to focus on the following ranges of changes in the parameters of the processing process, which are provided by the program.

The diameter of the drill can be chosen from the following series: 5, 10, 15, 20, 25, 30, 35; cutting speed V can vary from 5 m/min to 80 m/min in steps of 1 m/min; feed S - y in the range of 0.05...1mm/rev with a step of 0.05 mm/rev; drilling length L is in the range of 5...130 mm with a step of 1 mm.

It is necessary to experimentally determine the following dependencies of the axial component of the cutting force and the torque:

- from axial feed during drilling;
- from the diameter of the drill when drilling;
- from the ratio of drilling length to diameter;
- from the ratio of the diameter of the hole of the workpiece to the diameter of the drill during re-drilling.

Research is carried out by the method of one-factor experiments, and the ranges of parameter changes are chosen taking into account the ranges that were given above, thus, to demonstrate as much as possible some general trend. The results of measurements are recorded in the table of experimental data, according to which it is necessary to build the corresponding graphs of dependencies in each experiment.

The procedure for performing laboratory work is expediently based on an example, the initial data for which are given in the table. 1.3.

Table 1.3. Example output

Material		DcB,mm	D3,mm	V, m/c	S, mm/Ob	L,mm
blank	instrument	20	10	30	0.2	20
Steel 45X	P6M5					

Before activating the application program, it is necessary to prepare tables for recording experimental data. After activating the program, enter the output data, set the first value of the changing parameter and consistently determine the necessary characteristics according to the oscillograms of the drilling process.

The first series of experiments in accordance with the task is carried out for determination of the dependences of the axial component of the cutting force and the torque on the axial feed when drilling in solid material. The results of such experiments are noted in the table. 1.4.

Table 1.4. Dependence of power characteristics of the drilling process on axial feed.

No.	S, mm/ob	RO, N	M, Nm	No	S, MM/Ob	RO, N	M, Nm
1	0,1	2930	23,6	6	0,6	10260	99,0
2	0,2	4750	41,0	7	0,7	11440	112,0
3	0,3	6310	56,8	8	0,8	12550	124,0
4	0,4	7720	71,5	9	0,9	13640	137,0
5	0,5	9000	85,5	10	0,10	P.C.	P.C.

When conducting experiments with an axial feed of 1.0 mm/rev, the program automatically recorded a violation of the drill's strength conditions. Such a moment is recorded in fig. 1.8 and indicated in the table. 1.4 abbreviation "P.C." destruction of the drill. The simulation can be continued only with a decrease in the value of the axial feed.

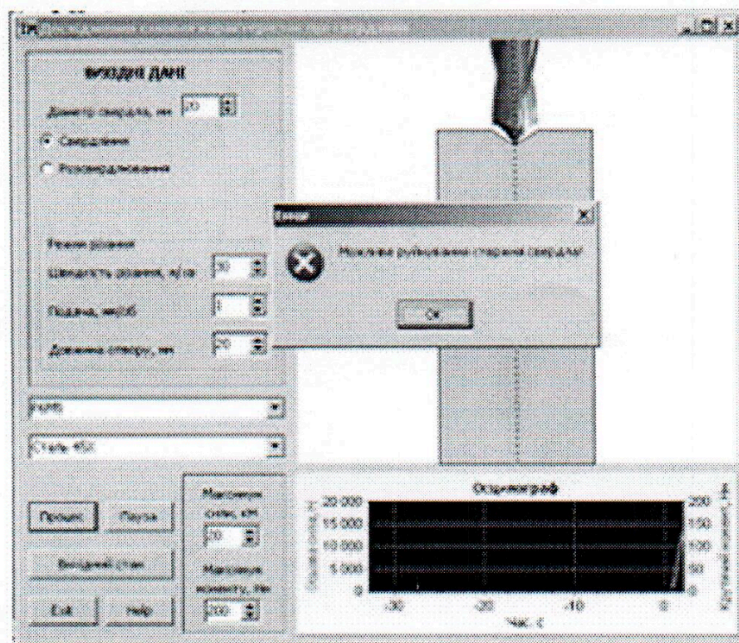


Fig. 1.8. The state of the interface in case of violation of the strength conditions of the drill.

The results of the experiments according to the data in the table. 1.4 are presented graphically in fig. 1.9.

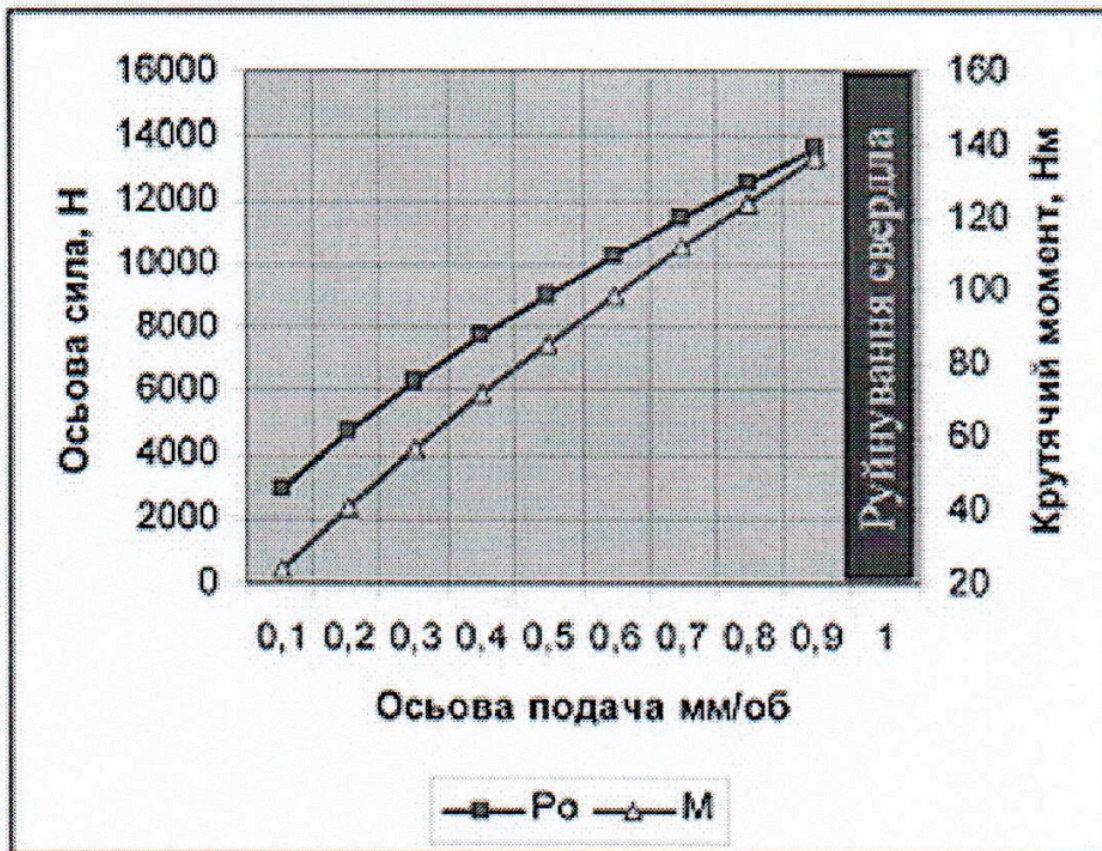


Fig. 1.9. Graphs of the dependence of P_o and M on the supply of S

The following experiments are carried out in order to establish the dependence of the axial force and torque on the diameter of the drill. It should be noted here that the cutting speed is displayed on the interface as the output data of the process, and not drill rotation frequency. Therefore, when changing the diameter of the drill, to maintain the specified speed cutting, is automatically changed in the program rotation frequency. Thus, with a constant axial feed to the rotation of the drill The processing time changes, which was recorded during the experiments (Table 1.5).

Table 1.5. Dependence of power characteristics on drill diameter

№	$D_{св},$ мм	P_o, H	M, Hm	$t_o, \text{с}$
1	5	p.c.	p.c.	
2	10	2450	10,5	16,5
3	15	3600	23,3	26
4	20	4750	41,0	37
5	25	5950	64,0	48
6	30	7120	92,0	59
7	35	8300	124,0	74

When conducting experiments based on the initial data of the example that given in the table. 1.3, it turned out that the specified cutting mode is unacceptable for the drill.

Based on the results of experiments 3, graphs of the corresponding dependencies were constructed using the Exell package (Fig. 1.10).

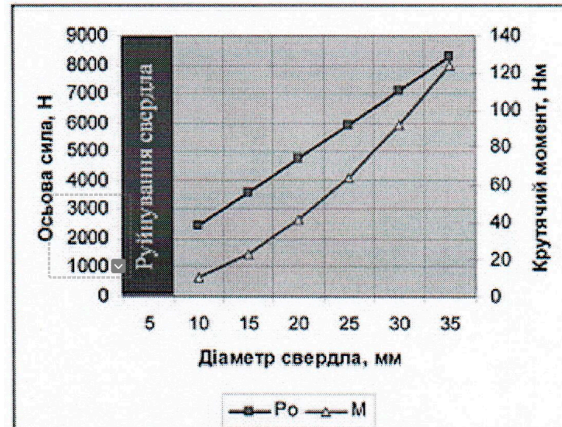


Fig. 1.10. Graphs of experimental dependencies of axial force and torque on drill diameter.

Experiments to study the drilling process were carried out with the aim of establishing the dependence of the axial force R and the torque M with the ratio of the diameter D , dimensions of the blanks are presented in the table. 1.6. To the diameter D , • drill. The results Table 1.6.

Dependence of power characteristics on the ratio of the diameter of the hole of the workpiece to the diameter of the drill during reaming

No.	D3/Dc6	D3,MM	PO, H	M, Hm
1	0,1	2	3540	38,5
2	0,2	4	3070	34,7
3	0,3	6	2620	30,8
4	0,4	8	2170	26,8
5	0,5	10	1750	22,8
6	0,6	12	1340	18,6
7	0,7	14	countersinking	

Program, What models provides for the determination of cases when reaming is not a rational method of processing holes and recommends apply countersinking. Such a case was recorded at $D/D_c = 0.7$, and therefore experiments with a further increase in the D/D_c ratio were not conducted. According to the results of experimental studies, the graphs presented in fig. 1.11

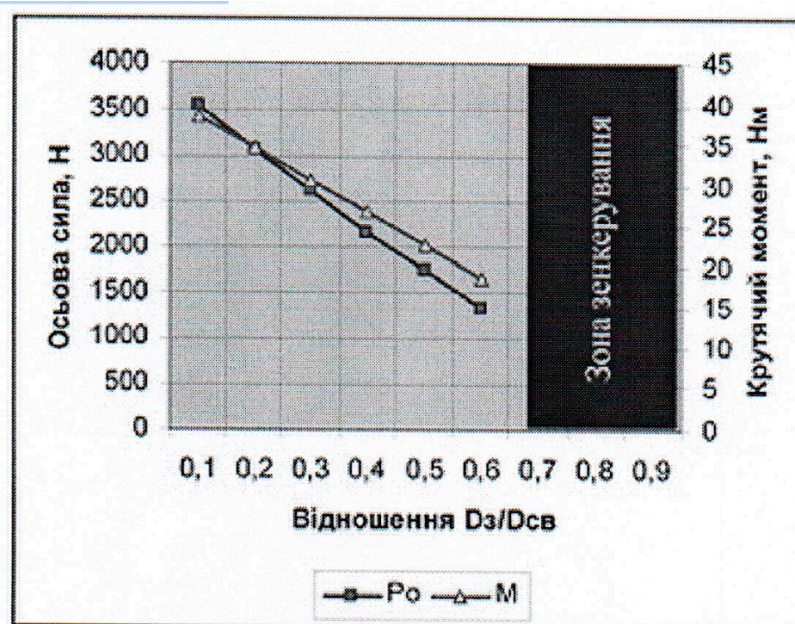


Fig. 1.11. Graphs of dependences of axial force and torque when drilling holes

The last series of experiments on the task is designed to study addition force characteristics of the drilling process length drilling, more precisely from the ratio of length to the diameter of the drill. When preparing a table of experimental data according to the selected ratio, it is necessary to calculate the length of drilling taking into account the limitations of the range of change. When conducting experiments, measurements of axial force and torque should be carried out according to oscillograms at the end of the cycle at the maximum drilling depth for each experiment. Experimental doe are presented in table 17. and corresponding graphs are constructed according to them dependencies (Fig. 1.12).

Table 1.7. Dependence of axial force and torque on drilling length.

№	$L/D_{св}$	L , мм	P_o , Н	M , Нм
1	1	20	4750	41,0
2	2	40	4820	41,7
3	3	60	4950	42,8
4	4	80	5120	44,2
5	5	100	5340	46,2
6	6	120	5610	48,4

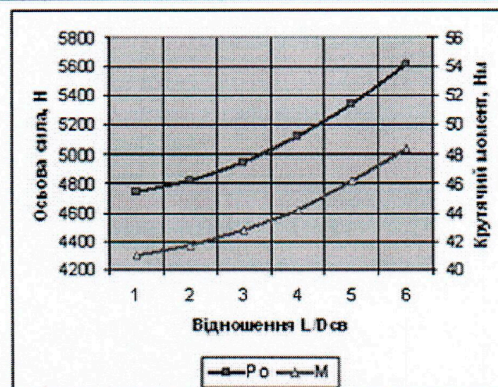


Fig. 1.12. Graphs of the dependence of R. and Mvid on the ratio of the drilling depth to the diameter

The analysis of the obtained experimental dependences allows us to draw the following conclusions, which correspond to the studied range of the drilling and reaming mode of the tool materials, workpieces and other constant parameters of the cutting process specified in the example:

1. Experimental studies on establishing axial dependencies force and torque from the axial feed during drilling demonstrated a significant influence of the feed on all power characteristics of the cutting process. Moreover, the change in feed has a stronger effect on the torque than on the axial cutting force. So, when the feed is increased by 9 times, the torque increases by 5.8 times, and the axial force by 4.7 times. With the help of such an experiment, it is possible to determine the maximum permissible axial feed, at which the drill is destroyed. For the initial data of the example, this feed is 0.9 mm/rev.
2. An increase in the drilling diameter with other parameters unchanged of the process causes a directly proportional increase in the axial cutting force, and the torque is more strongly affected. In addition, under the conditions of the experiment, while maintaining the cutting speed, a change in the diameter of the drill leads to a change in rotation frequency. Thanks to this, it is possible to draw several interesting conclusions derived from the results of the experiment.
3. First, it is possible to evaluate the reaction of the cutting power to the change diameter of the drill, which is calculated according to the well-known formula:

$$N_{cg} = \omega M, \text{ де } \omega$$

drill rotation frequency (rad/s). The rotation frequency of the drill can be calculated from the cutting speed and the diameter of the drill:

$$\omega = \frac{2\pi \cdot 1000 \cdot V}{\pi \cdot D_{cg} \cdot 60} = \frac{33,3 \cdot V}{D_{cg}} \quad \text{Where} \quad N_{cg} = \frac{33,3 \cdot V \cdot M}{D_{cg}}, \quad \text{that is, taking into account the}$$

dependence (2.4) and the magnitude of the exponent m is directly proportional to the diameter of the drill.

Verification of this conclusion based on the results of the experimental data of the table. 1.5 confirms this conclusion. Indeed, At $D_{c6} = 10\text{mm}$ power

$$N_{cg} = 33,3 \cdot 30 \cdot 10,5 / 10 = 1050 \text{ Bm}, \quad \text{At } D_{c6} = 30\text{mm power} \quad N_{cg} = 33,3 \cdot 30 \cdot 92 / 30 = 3067 \text{ Bm}.$$

4. Secondly, the availability of experimental data on time and drilling allows you to calculate the specific cutting work at different drill diameters. The cutting work is calculated according to the known by the formula: $A = N_{cg} t_o$,

a is the volume of the removed allowance $W = \pi D_{cg}^2 L / 4$.

Thus, the specific work of cutting: $A_n = \frac{A}{W} = \frac{4 \cdot N_{cg} \cdot t_o}{\pi \cdot D_{cg}^2 \cdot L}$. The calculation is as

follows the formula shows that with an increase in the diameter of the drill, the specific work of cutting increases. Yes, with $D_c=10\text{mm}$ specific cutting robot

$$A_n = \frac{4 \cdot 1050 \cdot 16,5}{\pi \cdot 10^2 \cdot 20} = 10,8 \frac{\text{Дж}}{\text{мм}^3}, \quad \text{At } D_c=30\text{mm, specific cutting work} \quad A_n = \frac{4 \cdot 3067 \cdot 59}{\pi \cdot 30^2 \cdot 20} = 12,8 \frac{\text{Дж}}{\text{мм}^3}.$$

5. Experiments to study the milling process for the initial conditions of the example show that the power characteristics of the process: axial force and torque are almost directly proportional to the ratio D/D_c , and the axial force decreases more slowly than the torque when the ratio D/D_c increases. This character is explained by the fact that during reaming, the diameter of the drill did not change and does not depend on the diameter of the workpiece, while the depth of cutting, on the contrary, depends on the diameter of the workpiece.

6. The dependence of the axial force and torque on the drilling depth is purely non-linear, and the increase in power characteristics increases with an increase in the drilling depth. This nature of the ratio coincides with the practice of drilling deep holes with spiral drills. Therefore, to reduce the negative impact of the drilling depth on the drilling process, various methods are used, among which the most effective are technological - step-by-step drilling, i.e. with periodic removal of the drill from the hole, and instrumental - drilling with drills of special designs for deep drilling.

2. Technological section

2.1 Analysis of the service purpose and working conditions of the part in the unit.

The absence of an assembly drawing of the unit that includes "Pressure" and data on the service purpose of the product makes it difficult to accurately determine the purpose of the detail.

The "Pressure" part works under conditions of sign-changing loads. All the information indicated on the drawing allows us to draw a conclusion about a possible method of obtaining the workpiece and outline the route of the part's manufacture.

The specificity of the purpose of each detail and the conditions of its operation should, if possible, be reflected in detail when describing the official purpose. To do this, it is necessary to analyse the shape, accuracy and quality of production of all surfaces of the part, the accuracy and placement relative to other surfaces of the part. When analysing, it is necessary to pay attention to the name of the part, its technical conditions manufacturing (heat treatment, etc.) and material, from which the part is made. It is necessary to give a brief description of the material, indicate its composition, physical, mechanical and technological properties, after which determine the possible method of receiving the workpiece.

2.1.1 Classification of the design of the part.

The "Pressure" part belongs to the lever class. Levers are designed for transmission and change of direction of motion, to transform oscillatory motion into reciprocating motion and vice versa. When clarifying the official purpose of this details must indicate the transmitted forces and torques, the frequency of load changes and their nature.

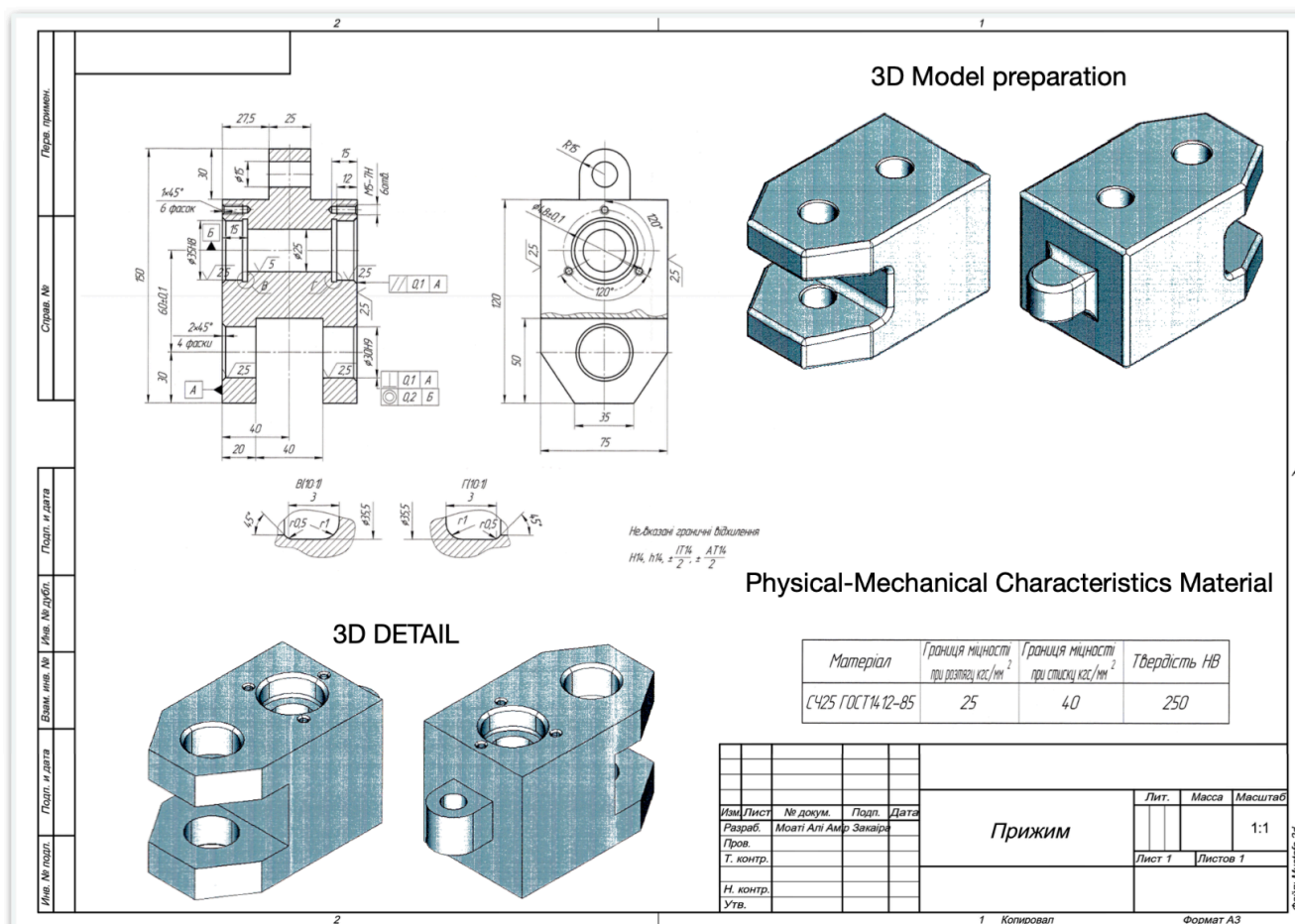


Fig. 2.1 Sketcher of the "Pressure" detail

2.1.2 Validity of the choice of workpiece material

The material of the part is cast iron C425.

After analysing the material, we conclude that the billet is made by casting, because cast iron billets can be made by casting.

The material also indicates high strength and plasticity of compression. It can work both in the impact zone and withstand plastic deformation.

Strength limit: when stretched

$$\sigma_B = 250 \text{ МПа};$$

when bending

$$\sigma_{II} = 392 \text{ МПа}; \text{ HB} = 1668 \dots 2364$$

density

$$\gamma = 7,1 \text{ г/см}^3.$$

Grey cast iron is widely used in machine tool construction, tractor construction, chemical engineering, and electrical engineering.

The clamp is made of C4 25, the physics-mechanical and chemical properties of which are given below:

Table 2.1 - Chemical composition of the material in % according to GOST 1412-85

C	Si	Mn	S	P
3.2-3.4	1.4-2.2	0.7-1	Up to 0.15	Up to 0.2

Foundry-technological properties of the material C4 25

Linear shrinkage:	1.2%
--------------------------	------

Mechanical properties at T= 200 C of material C4 25

Range	Size	E.g.	SB	ST	D5	y	KCU	Thermal conversion
-	Mm	-	MPa	MPa	%	%	kJ	-
GOST 1412-75			250	392				

Material hardness C425:	HB 10 ⁻¹ = 156 - 260 MPa
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Physical properties of the material C425.

T	E 10⁻⁵	A 10⁶	1	r	C	R 10⁹
Grade	MPa	1/Grade	Bt/(M x Grade)	KG/M ³	DJ/(KG x Grade)	OM x M
20	1		50	7200		
100		10			500	

Thus, the material of the part meets the requirements set for it.

The part works under conditions of significantly variable loads and without the action of aggressive environments, therefore the material is suitable for the manufacture of the part. The 3-D model gives a complete picture of the part. The material proposed by the designer fully corresponds to the official purpose and working conditions in the node.

2.2 Determination of the type of production

Type production is a classification category of production, distinguished by the breadth of the nomenclature, regularity and volume of production of products. In accordance with the standards of GOST 3.1108-74 of the Unified system of technological documentation (ETSD) and GOST 14.004-74 of the unified system of technological preparation of production (USTPV), one of the main characteristics of the type of production is the coefficient of fixation of operations (K_o), which is defined as the ratio of the number of all operations performed or to be performed during the base period of time to the total number of workplaces. Since at this stage of work neither the number of all operations nor the number of workplaces is yet known, it is impossible to determine the anchoring factor operations. Since it is known that the mass of the part is 3.743 kg, and the annual volume output - 5,000 parts per year, then we will assign the type of production according to table 2.2 medium series.

Table 2.2- Definition of the type of production

	Annual volume of production of parts of one denomination, pcs.		
Type of production	light, weighing up to 20 kg.	medium, weighing 20...30	heavy, weighing more than 30 kg
Unitary	Up to 100	Up to 10	1...5
Little serial	101..500	11...200	6...100
Medium series	501...5000	201...1000	101...300
Large Series	5001...50000	1001...5000	301...1000
Mass	More Than 50000	More than 5000	More than 1000

So, for specified in production conditions, we accept the medium-series type of production. For this type of production, K_{zo} is set within 10...20. We take $K_o = 1$. Since this part is intended for medium-serous type of production, it is necessary to determine the further strategy of processing the part:

1. Processing of all surfaces of the part using universal machines with convenient control;
2. Processing of all surfaces of the part using CNC machines;
3. Combined. (Execution of draft and special operations on machines with manual control, or on worn-out machines with CNC, and finishing on high-precision CNC machines);

The latter is the most balanced, since the execution of draft operations on machines with CNC leads to accelerated wear of machine equipment and a decrease in their accuracy. That is why it is recommended to use machines with ChPIK only at the finishing and finishing stages. For this detail, we choose the last strategy.

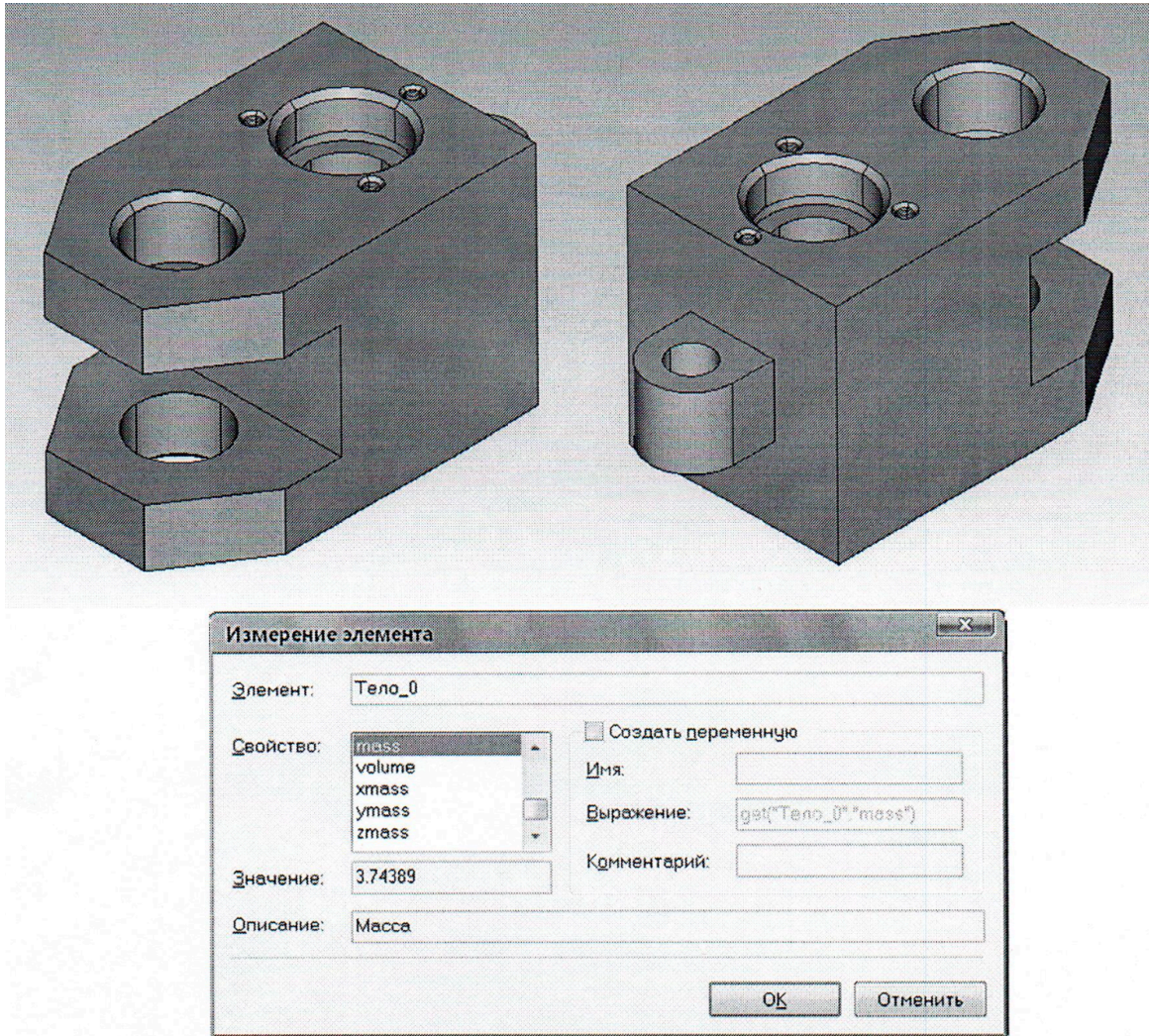


Fig. 2.2 3D model of clamping and determination of the mass of the part

2.3 Justification of the type and method of manufacturing the workpiece

The development of the manufacturing process of the part begins with the selection blanks.

The following characteristics influence the choice of the method of obtaining the workpiece: the material of the part, its configuration, the shape of the surfaces and their dimensions, the technical conditions for the manufacture of the part, the volume and serial production.

To choose a workpiece - means to determine the method of obtaining it, to calculate or select according to the tables the allowances for mechanical processing of all surfaces and specify the tolerances for the production of the workpiece. You can make the "Pressure" detail: casting in sand-clay moulds with machine forming.

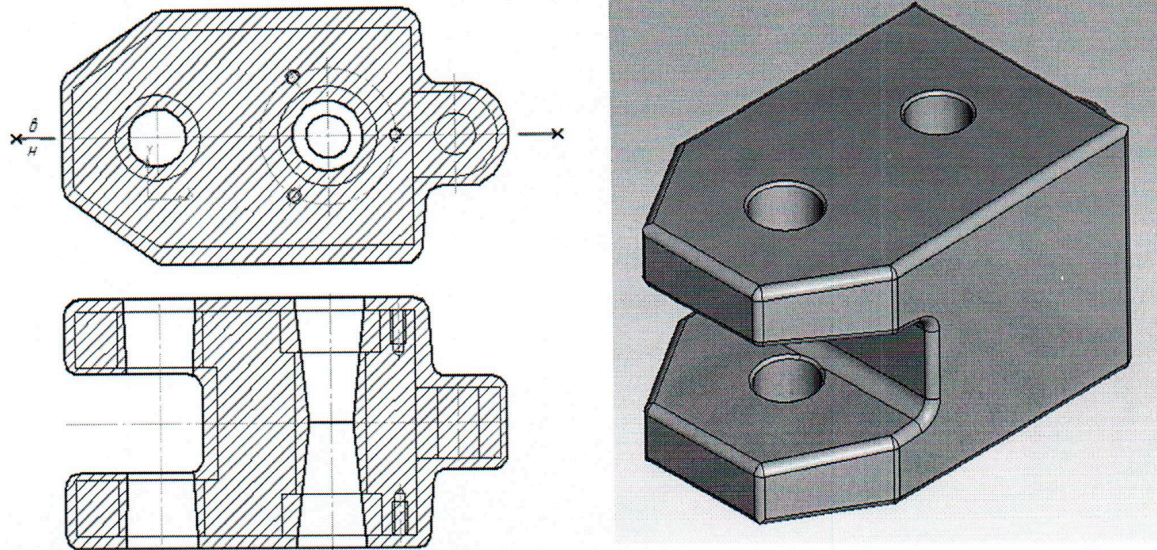


Fig. 2.3 "Pressure" part blank

2.4 General algorithm for the justification of the choice of technological bases

When developing a technological process of mechanical processing, the technologist faces the task of choosing from several possible processing options one that provides the most economical solution.

Black bases are always one end face and an outer flat surface details. For all subsequent processing, the end face and flat surface processed in the first operation are the bases. When processing parts of this class, the following sequence must be observed:

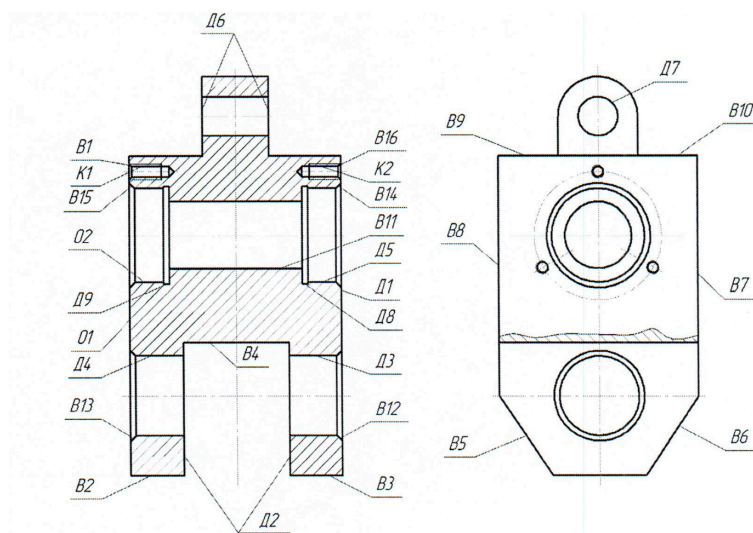


Fig. 2.4 Classification of the surfaces of the "Pressure" part

When designing technological processes, they often use the classification of bases by service purpose as follows:

Design tables - are used to orient the part in the process processing;

Mounting surfaces - used to determine the position connecting parts and elements;

Auxiliary surfaces - surfaces of the part that determine the position parts connecting to it; free surfaces - all other surfaces of the part.

2.4.1 Algorithm for justifying the choice of general technological bases

1. It is necessary to accept the surface of the workpiece as a technological base the processing of which is not foreseen by the draftsman.
2. If all surfaces of the workpiece are processed, then as technological ones bases, it is necessary to accept surfaces with variable assumptions, which will exclude the occurrence of a defect on the entire surface.
3. If the allowances on the surfaces of the workpiece are more or less uniform, then the surfaces on which defects are not allowed should be taken as the TB.
4. To ensure uniform allowances for the following stages of processing, these surfaces should be included in the set of technological bases.
5. If there are several variants of TV basing schemes, preference should be given to the scheme in which the treated surface is connected to the base by the shortest dimensional chain.

1.4.2 Algorithm for justifying the choice of technological bases for the first technological operations

The main design bases (ODB) for this part will be flat side surfaces that will determine the position of the part in the assembly or mechanism (Fig. 1.5).

The auxiliary design base (DKB) will be a flat side surface and internal flat surfaces of the groove, designed to transmit oscillating motion. Fastening surfaces (KP) - threaded holes K1, K2. All other contact surfaces will be free surfaces.

Let's check the possibility of converting the OKB into a common technological base (ZTB), which would be used to base the pressure in the processing process. Such a transformation is possible, so for the processing of pressure we will use the auxiliary technological base, implemented with the help of OKB1 and two holes.

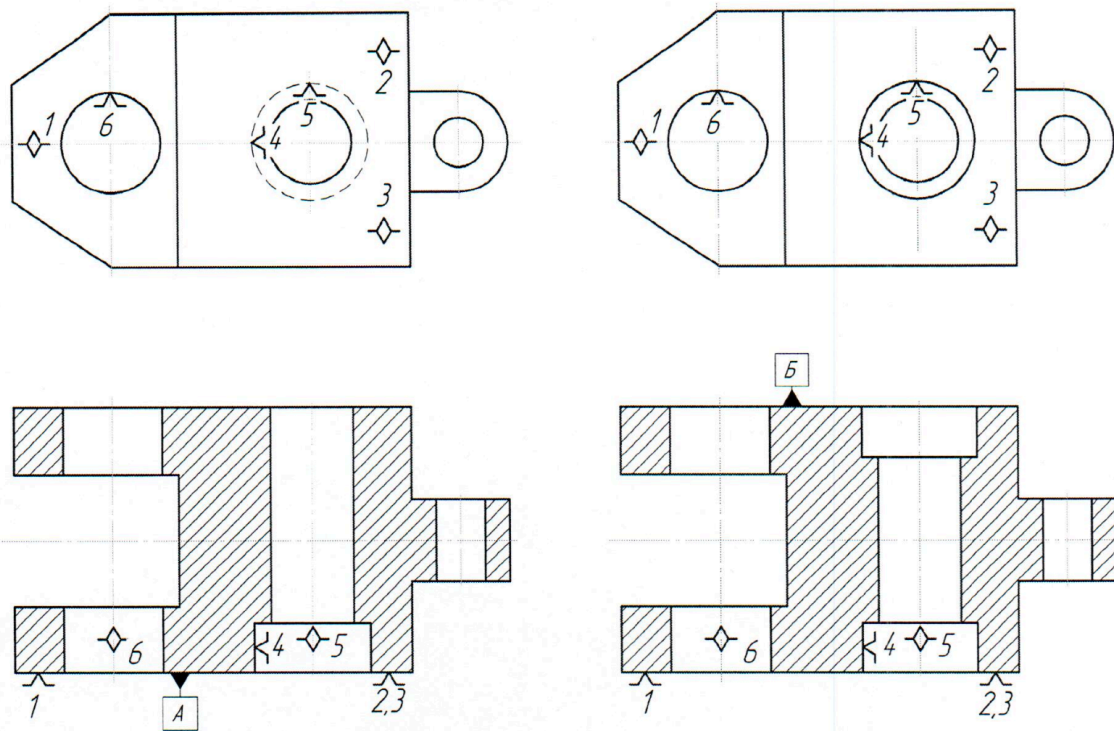


Fig. 2.5 Scheme of conversion of OKB to ZTB

The structural formula of the basing scheme: $CB_{TB} \rightarrow Y(3) + \Pi O(2) + O(1)$.

Since ZTB cannot remain unchanged, we will choose the largest a suitable base scheme for us from those proposed below.

Let's consider several options for basing the part on ZTB:

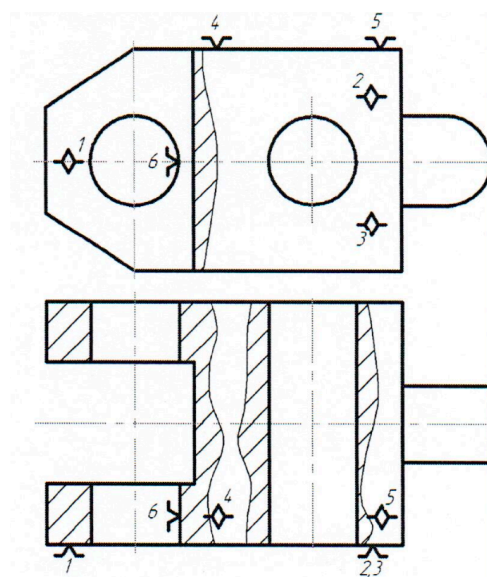


Fig. 2.6 Basing scheme by technological bases for the first operations Structural formula of the basing scheme:

$$CB_{TB} \rightarrow Y(3) + \Pi O(2) + O(1).$$

Brief Description:

-The basing scheme is simple in its constructive implementation.

Disadvantages:

-The basing scheme does not give us the opportunity to process the entire set of ZTB.

-Such a basing scheme is implemented on a plane and a rhombic finger.

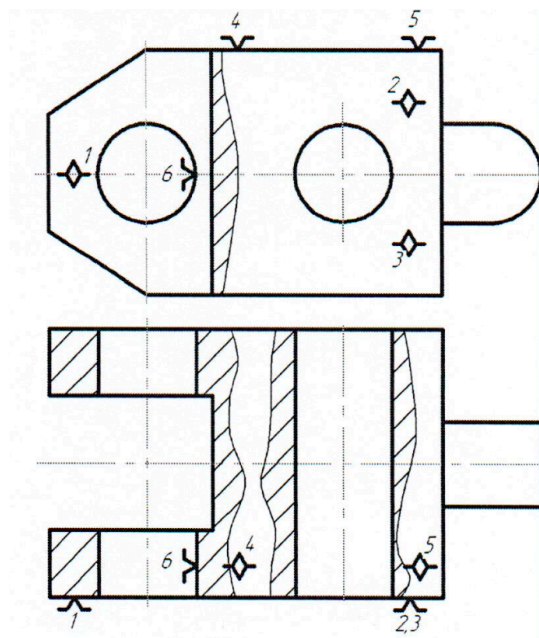


Fig. 2.7 Basing scheme by technological bases for the first operations Structural formula of the basing scheme:

$$CB_{TB} \rightarrow Y(3) + \Pi O(2) + O(1).$$

Brief description:

-The basing scheme is simple in its constructive implementation. Disadvantages:

-The base scheme does not allow us to process the entire ZTB set.

Such a basing scheme is implemented in two prisms, one movable and the other non-movable.

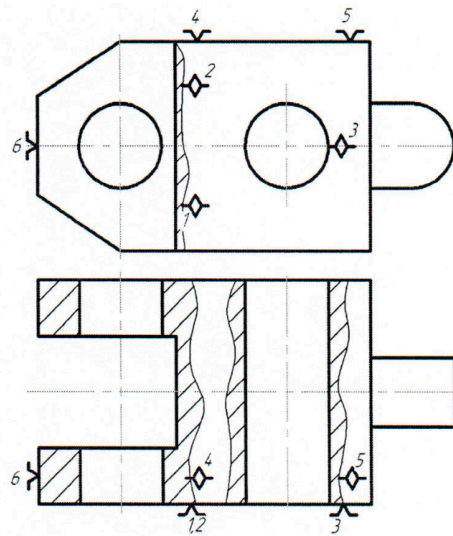


Fig. 2.8 Scheme of basing on technological bases for the first operations

The structural formula of the basing scheme: $CB_{TB} \rightarrow Y(3) + \Pi O(2) + O(1)$.

Brief description:

The basing scheme allows you to process the workpiece from 3 sides and process open

Disadvantages: does not provide uniform allowances for machining goals.

Opened

Such a basing scheme is implemented in a vice.

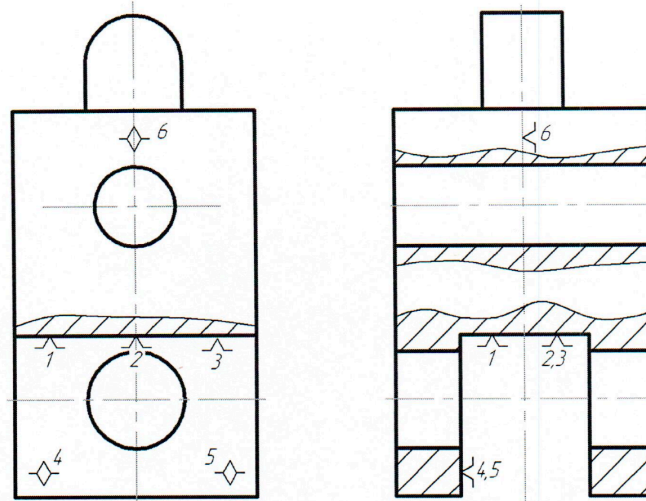


Fig. 2.9 Scheme of basing on technological bases for the first operations

The structural formula of the basing scheme: $CB_{TB} \rightarrow Y(3) + \Pi O(2) + O(1)$.

Brief Description: The basing scheme allows you to process the workpiece from 2 sides and process holes.

Such a basing scheme is implemented on a flat surface and in a self-centering vice. All further basing schemes will be considered relative to this scheme.

2.5 Design of typical sequences of workpiece surface processing

Table 2.3- Sequence of surface treatment

Surface	ITi	Ra	Processing sequence	ITi	Ra
	According to the drawing			After processing	
D1	10	2,5	Milling is preliminary Milling is final	10	2,5
D2	14	5	Milling is preliminary Milling is final	14 12	10 5
B4	14	5	Milling is preliminary Milling is final	14 12	10 5
B2,B3	14	5	Milling is preliminary Milling is final	14 12	10 5
O1	10	2,5	Milling is preliminary Milling is final	10	2,5
O2,D5	8	2,5	Boring is preliminary Boring is final Boring is final Removal of chamfers	12 10 8 12	10 5 2,5 5
D6	14	5	Centering Drilling Countersinking	- 12 11	- 10 5
K1,K2	12	5	Centering Drilling Removal of chamfers Slicing with a tap	- 12 12 10	- 10 5 5
B5,B6	14	5	Milling is preliminary Milling is final	14 12	10 5
D3,D4	9	2,5	Drilling Countersinking Boring is one-time Removal of chamfers	12 11 9 12	10 5 2,5 5
B9	14	5	Milling is preliminary Milling is final	14 12	10 5
D7	14	5	Centring Drilling	- 12	- 10
B7	14	5	Milling is preliminary Milling is final	14 12	10 5
D6	14	5	Milling is preliminary Milling is final	14 12	10 5

D8,D9	14	5	Boring is one-time	14	10
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2.6 Development of route technological process

The purpose of designing routing processes for the manufacture of a part is to determine the rational sequence of processing the surfaces of the part, rational choice of the type of equipment taking into account the type of production and the form of organisation of the technological process, determination of the required equipment system and tools to ensure the most productive processing. The technological process will be developed according to the recommendations for the development of the structure of the technological process:

1. first of all, the surfaces of the workpiece are processed, which are the basis for the next one processing;
2. each subsequent technological operation or transition should improve indicators of the quality of the treated surface;
3. rough treatment of surfaces with a significant allowance should be allocated in a separate operation and not to be combined with subsequent processing;
4. for the purpose of timely detection of defects on surfaces for which there is no defect is allowed, their processing must be foreseen at the first stages of the technological process;
5. it is necessary to provide for removal at the first operations of the technological process maximum surfaces; possible allowances from narrative processed.
6. the final treatment of the most responsible surfaces must be performed at the final stage of the technological process, which excludes random destruction of the surface and provides the maximum period of time for aging;
7. the processing of the stepped surfaces of the shafts must be performed in such a sequence as to ensure the minimum length of movements tool;
8. Technological transitions in operations should be placed in such a way sequence so that the length of the tool moves with the smallest stability was minimal;
9. at the stage of rough processing, first of all, it is necessary to process the surfaces, removing the allowance from which will reduce the rigidity of the workpiece to the smallest extent;
10. Surfaces with exact mutual position of location is necessary process in one operation for one installation, if this is impossible - according to the principle of interchangeability of bases;

11. processing of surfaces that require special complex adjustments must be carried out in separate operations;
12. when finishing the surfaces, it is necessary to exclude transitions that require rotation of the cutter holder or the turret head;
13. fastening holes must be processed at the end technological process, except when some of them are included in the set of general ones technological bases;
14. when using many instrumental settings, it is necessary to ensure it homogeneity;

In accordance with these recommendations and according to the chosen route surface treatment and the sequence of technological transitions necessary for achieving the specified accuracy and surface quality, we design the possible technological process of processing, equipment that can be applied, as well as systems of tools and technological equipment.

2.7 Calculation of allowances

One of the main tasks of mechanical engineering technology is study regularities of the flow of technological processes and detection of parameters, affecting which it is possible to intensify production and increase its accuracy. Studying the correct ones is a pressing technical and economic task allowance sizes.

A layer of material that is removed in the process is called an allowance mechanical processing of the workpiece in order to obtain a surface of specified accuracy and surface quality at a minimum cost.

Allowances are divided into general allowances, which are removed during the entire process of processing a given surface in the operating room, which are removed when performing a separate operation, and intermediate ones, which are removed when performing one technological transition. The value of the operating allowance consists of the sum of intermediate allowances, and the total allowance of the sum of operating allowances.

Allowance on one side should be minimal to reduce machining volume and material consumption. On the other hand, it should be sufficient to obtain the given parameters of accuracy and surface quality.

Analytical-calculation and experimental-static methods are used to determine the allowance for mechanical processing in mechanical engineering. In conditions of single and small-scale production during manufacture simple and relatively cheap parts use the test-static method, when general and operational allowances are determined according to the tables of GOST 26645-85 for cast blanks, GOST 7505-89- for stamped.

They are somewhat overestimated, because they do not take into account the scheme of the base of the workpiece, the errors of pre-processing and the sequence of processing. However, this method is time consuming. The calculation and analytical method is used in conditions of mass, large-scale and serial production, as well as in conditions of single production when producing valuable parts.

2.7.1 Determination of allowances by calculation and analytical method

When performing a course project, the calculation of allowances for mechanical processing is carried out using the calculation-analytical method (Kovan's method) and according to tables.

Calculation formulas

In mechanical engineering technology, there are methods of automatic dimensioning (MAOR) and individual dimensioning (MIOR).

The minimum, nominal and maximum allowances for processing at MAOR are calculated as follows.

Minimum allowance: when consecutive processing of opposite surfaces (one-sided allowance)

$$Z_{i \min} = (R_z + h)_{i-1} + \Delta_{i-1} + \varepsilon_i;$$

Where R_z - the height of profile bumps on the previous transition.

h_{i-1} - the depth of the defective surface layer at the previous transition

Δ_{i-1} - total deviation of the position of the surfaces (deviation from parallelism, perpendicularity, co-axis) and in some cases of surface shape deviation;

ε_i - workpiece installation error at the transition we are performing.

Calculation of processing allowances

1. The minimum allowance is calculated according to formula (1), using calculation map (Table 2.4) for the treated surface. In the calculation the map indicates the size determining the position of the processed surface and technological transitions in the order of their execution during processing; for everyone transition values are recorded

$$R_z, h, \Delta_{\Sigma}, \varepsilon, i T.$$

2. Tolerances and quality parameters of the surface on the final technological one transitions (R , and h), accept the parts according to the drawing, checking according to the standards the possibility of obtaining them by the designed method of processing.

3. For grey and malleable cast iron, as well as non-ferrous metals after the first technological transition and for steel after heat treatment, h is excluded from the formula when calculating the allowance. In some cases, certain elements that are included in the calculation formula for obtaining processing allowances are also excluded.

4. Deviation of position D is taken as deviation from parallelism. Calculated allowances for all transitions are entered on the calculation card (Table 2.4), (Table 2.5).

Calculation of allowances on the end outer surface, maintaining the size $80h10$ (Table 2.4).

Table 2.4 - Calculation map

Лиття в пісчано – глинясті форми	Елементи припуску, мкм				Розрахунок хуніковий припуск $Z_{\min}$, мкм	Розрахунок хуніковий розмір l , мм	Допуск на виготовлення Tl , мкм	Прийняти розміри по переходам		Отриманні граничні припуски, мм	
	R_z	h	ρ	ε				$l_{\max}$ мм	$l_{\min}$ мм	$Z_{\min}^{np}$	$Z_{\max}^{np}$
заготована	200	200	225	0	-	81,45	740	82,19	81,45	-	-
Фрезерування	50	50	-	0	1250	80,2	300	80,5	80,2	1,250	1,690
	25	25	-	0	200	80	6,86	80,007	80	0,2	0,493

Отливка

Принятые обозначения

Материал отливки:

- ☒ Чугун
- ☐ Сталь
- ☐ Цвет. металлы и сплавы

Способ литья:

- ☒ В песчано-глиняные формы
- ☐ В кокиль
- ☐ Центробежное
- ☐ В оболочковые формы

Класс точности:

- ☒ I
- ☐ II
- ☐ III

Выбор класса точности ?

Наибольший размер отливки, мм

До 500

Механическая обработка

- ☒ Точ/фрез. черн. IT 12
- ☐ Точ/фрез. чист. IT 11
- ☒ Точ/фрез. чист. IT 10
- ☐ Точ/фрез. тонк. IT 9
- ☐ Точ/фрез. тонк. IT 8
- ☐ Точ/фрез. тонк. IT 7
- ☐ Шлиф. черн. IT 9
- ☐ Шлиф. черн. IT 8
- ☐ Шлиф. чист. IT 8
- ☐ Шлиф. чист. IT 7
- ☐ Шлиф. чист. IT 6

Длина детали, мм 150

Min размер рассматриваемого сечения, мм 80

Допуск на размер рассматриваемого сечения, мкм 6,86

Вид припуска:

- ☒ двусторонний припуск
- ☐ односторонний припуск

Способ закрепления детали:

- ☐ Закрепление в центрах
- ☐ Консольное закрепление
- ☒ Другое

Расчётные данные

	R_z , мкм	h , мкм	Погр., мкм	$Z_{\min}$, мкм	$d(\min)$, мм	Td , мкм	$d(\max)$, мм	$d(\min)$, мм	$Z_{\max}$, мкм	$Z_{\min}$, мкм
Отливка	200	200	225	---	81,45	740	82,19	81,45	---	---
Точ/фрез. черн.	50	50	0	1250	80,2	300	80,5	80,2	1690	1250
Точ/фрез. чист.	25	25	0	200	80	6,86	80,00686	80	493,14	200

Окончательно принятые данные для детали

Суммарные припуски, мкм 2183,14 1450

Занести в таблицу и рассчитать

Главное меню

Fig. 2.10 Calculation of allowances during milling

Table 2.5- Calculation map

№ операції	Технологічні переходи обробки отвору Ø35H8	Елементи припуска				Розрах. припуск, $2Z_{\text{lim, max}}$ мкм	Розрах. розмір, др мм	Допуск, δ , мкм	Граничні розміри, мм		Граничні допуски, мкм	
		R_z	h	ρ	ϵ				$d_{\min}$	$d_{\max}$	$2Z_{\text{don min}}$	$2Z_{\text{don max}}$
1	Заготовка	200	200	276	-	-	19,12	620	18,5	19,12	-	-
2	Розточування попереднє	50	50	10,7	135	734	33,341	200	33,141	33,341	14221	14641
3	Розточування чистове	30	25	1	7	161,4	34,955	60	34,895	34,955	1614	1754
4	Розточування завершальне	10	25	-	-	84	35,039	39	35	35,039	84	105

After the first technological transition h for cast iron parts are excluded from calculations. The total spatial deviation for workpieces of this type is determined by the formula:

$$\rho_3 = \sqrt{\rho_{\text{ж}}^2 + \rho_{\text{зм}}^2};$$

Taking into account the grooving of the hole both in the diametrical and in the axial section, we have:

$$\rho_{\text{ж}} = \sqrt{(\Delta_{\text{ж}} d)^2 + (\Delta_{\text{ж}} l)^2} = \sqrt{(0,7 \cdot 35)^2 + (0,7 \cdot 80)^2} = 61 \text{ мкм}$$

where d , l - diameter and length of the hole being processed; A_k is the value of the specific groove for castings.

The total displacement of the hole in the casting relative to its outer surface is determined by the geometric sum of the displacement in two mutually perpendicular planes:

$$\rho_{\text{зм}} = \sqrt{\left(\frac{T_{\text{Б}}}{2}\right)^2 + \left(\frac{T_{\text{А}}}{2}\right)^2} = \sqrt{200^2 + 180^2} = 269 \text{ мкм}$$

Total spatial deviation of the workpiece:

$$\rho_3 = \sqrt{61^2 + 269^2} = 276 \text{ MKM}$$

Residual spatial deviation after pre-boring:

$$\rho_1 = 0,04 \cdot \rho_3 = 0,04 \cdot 267 = 10,67 \text{ MKM}$$

After finishing boring:

$$\rho_1 = 0,04 \cdot \rho_3 = 0,036 \cdot 10,67 = 0,384 \text{ MKM} \approx 1 \text{ MKM}$$

Installation error:

$$\varepsilon_i = \sqrt{\varepsilon_{\delta}^2 + \varepsilon_{3\alpha K}^2}$$

Error of basing the workpiece $E_b = 0$.

The error of fixing the workpiece $E_{3\alpha K}$ is taken as 135 MKM. Then the error is her installation:

$$\varepsilon_1 = \sqrt{0 + 135^2} = 135 \text{ MKM}$$

Residual error of setting the workpiece during finishing boring:

$$\varepsilon_2 = 0,05 \cdot \varepsilon_1 = 0,05 \cdot 135 = 6,75 \text{ MKM}$$

The minimum value between the operating allowance:

$$2Z_{\min i} = 2(R_{zi-1} + h_{i-1} + \rho_{i-1}) \text{ MKM}$$

$$2Z_{\min 2} = 2(50 + 50 + 267) = 734 \text{ MKM}$$

$$2Z_{\min 3} = 2(30 + 40 + 10,7) = 161,4 \text{ MKM}$$

$$2Z_{\min 4} = 2(10 + 25 + 7) = 84 \text{ MKM}$$

We calculate the smallest limit size according to the formula:

$$d_{pi-1} = d_{pi} + 2Z_{\min i} \text{ MM}$$

$$d_{p4} = 35,039 - 0,084 = 34,955 \text{ MM}$$

$$d_{p3} = 34,955 - 1,614 = 33,341 \text{ MM}$$

We calculate tolerances for calculated sizes:

$$\begin{aligned}\delta_1 &= 620 \text{ MKM} & \delta_4 &= 39 \text{ MKM} \\ \delta_2 &= 200 \text{ MKM} \\ \delta_3 &= 60 \text{ MKM}\end{aligned}$$

We calculate the maximum tolerances for individual operations according to the formula:

$$\begin{aligned}2Z_{\max i}^{\partial on} &= d_{\min i} - d_{\min i-1} \text{ MKM} \\ 2Z_{\max 5}^{\partial on} &= 34,639 - 18,5 = 15,139 \text{ MM} = 14641 \text{ MKM} \\ 2Z_{\max 4}^{\partial on} &= 34,839 - 34,639 = 0,2 \text{ MM} = 1754 \text{ MKM} \\ 2Z_{\max 3}^{\partial on} &= 34,947 - 34,839 = 0,108 \text{ MM} = 105 \text{ MKM}\end{aligned}$$

We calculate the smallest tolerances for individual operations according to the formula:

$$\begin{aligned}2Z_{\min i}^{\partial on} &= d_{\max i} - d_{\max i-1} \text{ MKM} \\ 2Z_{\min 5}^{\partial on} &= 34,799 - 19,12 = 15,679 \text{ MM} = 14221 \text{ MKM} \\ 2Z_{\min 4}^{\partial on} &= 34,939 - 34,799 = 0,14 \text{ MM} = 1614 \text{ MKM} \\ 2Z_{\min 3}^{\partial on} &= 35,009 - 34,939 = 0,07 \text{ MM} = 84 \text{ MKM}\end{aligned}$$

We calculate the largest total allowance:

$$2Z_{\max}^{\partial az} = \sum_{i=1}^n 2Z_{\max}^{\partial on} = 14,641 + 1,754 + 0,105 = 16500 \text{ MM}$$

We calculate the smallest total allowance:

$$2Z_{\min}^{\partial az} = \sum_{i=1}^n 2Z_{\min}^{\partial on} = 14,221 + 1,614 + 0,084 = 15,919 \text{ MM}$$

Verification of the accuracy of the calculation is calculated according to the formula:

$$\begin{aligned}2z_{\max 4}^{\partial p} - 2z_{\min 4}^{\partial p} &= 0,105 - 0,084 = 0,021 \text{ MM}, \\ T_3 - T_4 &= 0,06 - 0,039 = 0,021 \text{ MM} \\ 2z_{\max 3}^{\partial p} - 2z_{\min 3}^{\partial p} &= 1,754 - 1,614 = 0,14 \text{ MM}, \\ T_2 - T_3 &= 0,2 - 0,06 = 0,14 \text{ MM} \\ 2z_{\max 2}^{\partial p} - 2z_{\min 2}^{\partial p} &= 14,641 - 14,221 = 0,42 \text{ MM}, \\ T_1 - T_2 &= 0,62 - 0,2 = 0,42 \text{ MM}\end{aligned}$$

which had to be proved.

2.7.2 Determination of allowances according to the standard and regulations.

We summarise the data in Table 6. Table 2.6 - Determination of allowances by the analog method

Parameter	25h14; Ra=5,0	40h14; Ra=5,0	50h14; Ra=5,0	75h14; Ra=2,5	80h14; Ra=2,5	120h14 ;Ra=5,0	150h14 ;Ra=5,0	Φ30H9 ;Ra=2,5 ;inside	Φ25H1 4;Ra=5; inside
1	3	4	5	6	7	8	9	10	11
Admission to casting size	2,4 (±1,2)	2,8 (±1,4)	3,2 (±1,6)	3,6 (±1,8)	3,6 (±1,8)	4,0 (±2,0)	4,0 (±2,0)	1,1 (±0,6)	2,4 (±1,2)
The size and type of the processed surface to the technological base	27,5	20	70	75	80	120	30	37,5	37,5
	52,5	60	120				120	60	60
The tolerance of the cast size depends on the treated surface and technological base	2,8	2,4	3,6	3,6	3,1	4,0	2,0	2,8	2,8
	3,2	3,2	4,0				2,8	3,2	3,2

Estimated quantity transitions (operations), processing cutting	General side allowance	2.3	2.5	final	-	24.48	29.28	(+1.2)	34.78	39.38	-	0.7	1.4	-	86.86	84.66	(+1.8)	127.83	154.8	20.85	19.12	(+1.2)
General side allowance	2.3	2.5	2.1	final	-	39.38	51.68	(+1.4)	34.78	49.38	74.26	1.4	-	-	86.86	84.66	(+1.8)	127.83	154.8	20.85	19.12	(+1.2)
Technological exterior aspect side because of formative bows	2.3	2.5	2.7	final	-	49.38	51.68	(+1.6)	34.78	51.68	84.66	1.4	-	-	86.86	84.66	(+1.8)	127.83	154.8	20.85	19.12	(+1.2)
The average size of the part	2.3	2.5	2.9	final	-	74.26	84.66	(+1.8)	34.78	49.38	74.26	1.4	-	-	86.86	84.66	(+1.8)	127.83	154.8	20.85	19.12	(+1.2)
The estimated size of the casting	2.3	2.5	3.4	previous	-	30.05	30.05	20.85	20.85	30.05	30.05	1.4	-	-	20.85	20.85	20.85	20.85	20.85	20.85	19.12	(+1.2)
Accepted casting size	2.3	2.5	2.9	final	-	119.23	119.23	149.0	149.0	149.0	149.0	2.4	-	-	149.0	149.0	149.0	149.0	149.0	149.0	149.0	149.0

Designing the operational technological process of processing "Pressure" details

Designing the content of technological operations involves development the technological sketch is a conventional image of the theoretical base scheme. We will develop the technological process according to the development recommendations structures of the technological process:

1. first of all, the surfaces of the workpiece are processed, which are the bases for the next one processing;
2. each subsequent technological operation or transition should improve the quality indicators of the treated surface;
3. the rough treatment of surfaces with a significant allowance should be separated into a separate operation and not combined with the following treatment;
4. in order to timely detect defects on surfaces for which defects are not allowed, their treatment must be foreseen at the first stages of the technological process;
5. at the first operations of the technological process, it is necessary to provide for the removal of the maximum possible allowances from the responsible processed surfaces;
6. final treatment of the most responsible surfaces is necessary perform at the final stage of the technological process, which excludes accidental destruction of the surface and ensures the maximum period of time for aging;
7. processing of the stepped surfaces of the shafts must be carried out in such a way a sequence that will ensure the minimum length of movements;
8. technological transitions in operations must be placed in such a sequence that the length of tool movements with the least resistance was minimal;
9. at the stage of rough processing, first of all, it is necessary to process surfaces, the removal of the allowance from which will reduce the rigidity of the workpiece to the smallest extent;
10. surfaces with accurate relative location it is necessary to process in one operation for one installation, if this is impossible - with the principle of interchangeability of bases;
11. processing of surfaces that require special complex adjustments must be carried out in separate operations;
12. when finishing the surfaces, it is necessary to exclude transitions that require rotation of the cutter holder or the turret head;

13. fastening holes must be processed at the end of the technological process, except when some of them are included in the set of general technological bases;

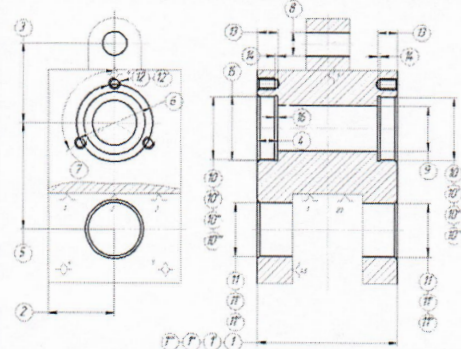
14. when using instrumental adjustments, it is necessary to ensure homogeneity;

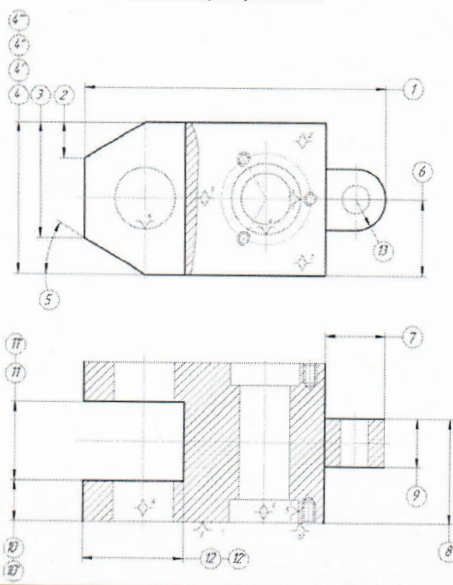
15. the number of tools designed to perform the operation should not exceed store capacity;

16. the sequence of surface treatment should ensure the required quality execution of the detail.

In accordance with these recommendations and in accordance with the selected route of surface treatment and the sequence of technological transitions necessary to achieve the required accuracy and surface quality, we design the possible the technological process of processing, the equipment that can be applied, as well as systems tools and technological equipment.

Table 2.7- Operational technological process

Operation No	The name of the operation and the theoretical basis scheme	Type of equipment	Tooling system	Cutting tool
005	Multipurpose 	Horizontal processing center mod. ES-400	Self-centering level vise	The cutting tool is standard

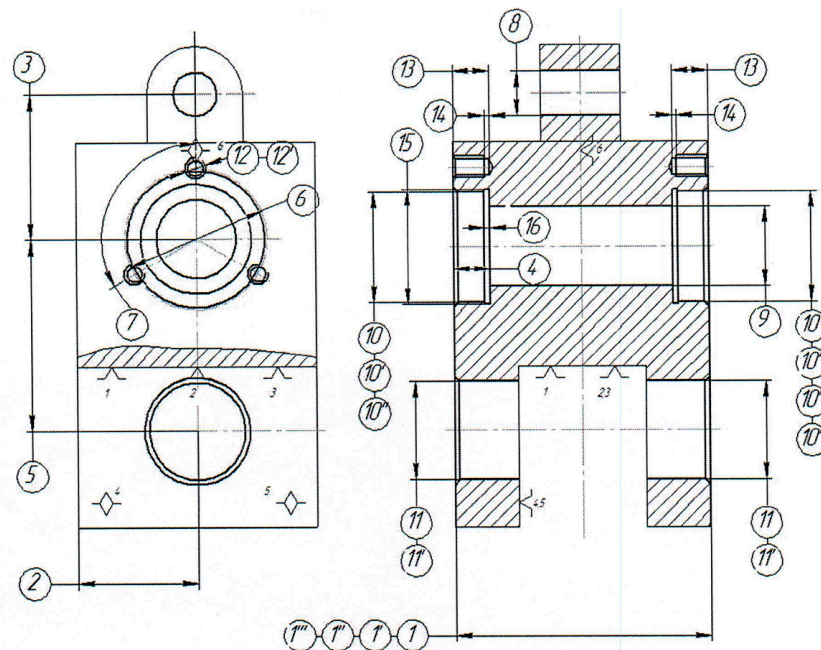
010	Multipurpose 	Horizontal processing center mod. ES-400	The equipment is special	The cutting tool is standard
015	Washing machine			
020	Control			

The purpose of designing the content of technological operations is to determine the sequence of processing certain surface details.

The content of technological operations for the part "Pressure" is given below.

005 Multipurpose with CNC.

Machine tool: horizontal machining center ES-400



A. Install, fix, remove.

005.01 Mill the vertical left surface beforehand, holding it size .1

005.02 Mill the vertical left surface finally, holding size 1.'

005.03 Center consistently the position of the axes of the holes, holding sizes 2,3,6,7.

005.04 Drill a through hole, keeping dimensions 2,3,8.

005.05 Countersink the through hole, maintaining dimensions 2,3,9.

005.06 Drill a hole in advance, keeping dimensions 2,5,11.

005.07 Drill the hole completely, keeping the dimensions 2,5,11*.

005.08 Drill the holes sequentially, maintaining dimensions 2,3,6,7,12,13. 005.09

Drill a hole in advance, keeping dimensions 2,3,10.

005.10 Mill the hole once, keeping dimensions 2,3,4,15,16. 005.11 Drill the hole cleanly, maintaining the dimensions of 2, 3, 10°.

005.12 Drill the hole completely, keeping the dimensions 2, 3, 10".

005.13 Removal of chamfers while maintaining dimensions of 2,5,11°; 2,3,10"; 2,3,7,12.

005.14 Cut the cut, keeping dimensions 2,3,6,7,14,12

B. Reinstall, fix, remove.

005.01 Mill the vertical right surface in advance, holding dimensions 1".

005.02 Mill the vertical right surface finally, holding dimensions 1"

005.03 Center consistently the position of the axes of the holes, holding sizes 2,3,6,7.

005.04 Drill a hole beforehand, keeping dimensions 2,5,11.

005.05 Drill the hole to finish, keeping the dimensions 2,5,11'.

005.06 Drill the holes sequentially, maintaining dimensions 2,3,6,7,12,13. 005.07

Drill a hole in advance, keeping dimensions 2,3,10.

005.08 Mill the hole once, keeping dimensions 2,3,4,15,16. 005.09 Drill the hole cleanly, maintaining dimensions of 2, 3, 10°.

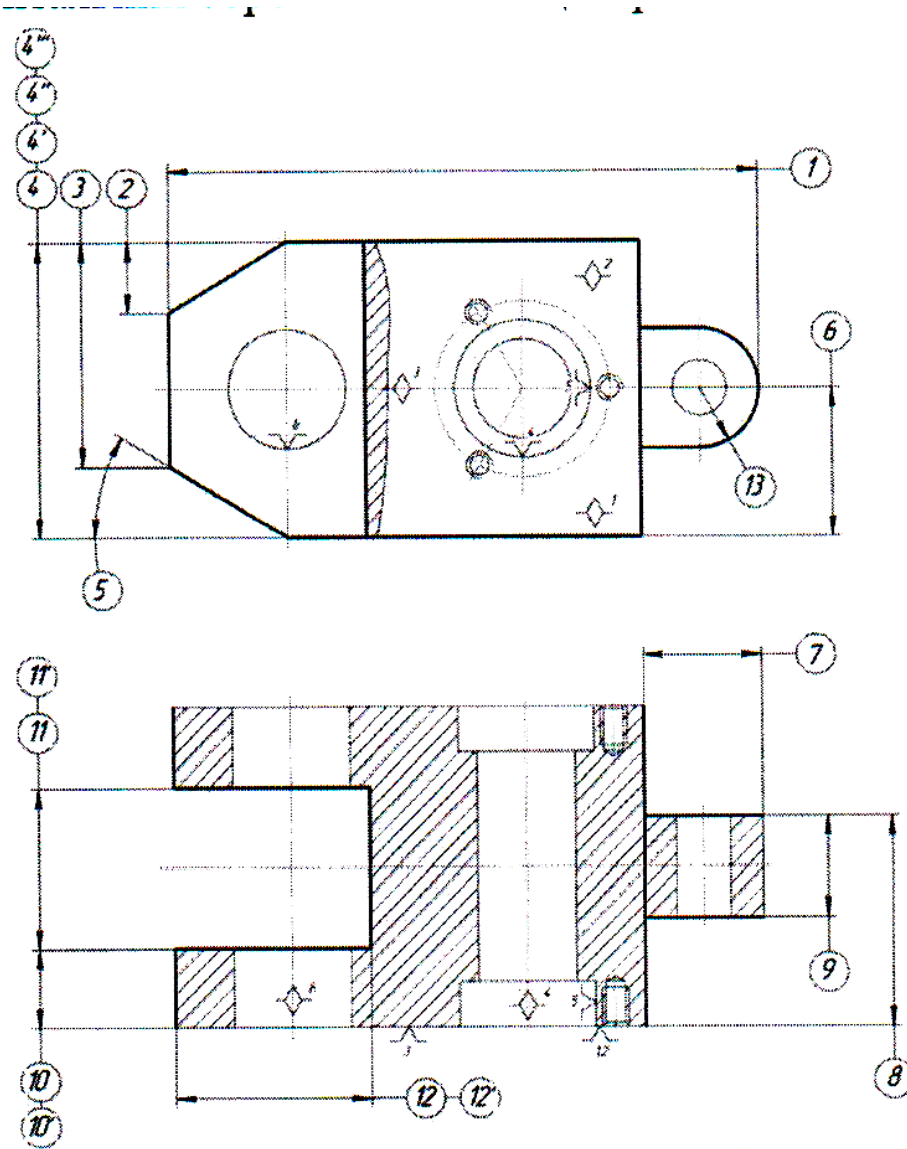
005.10 Drill the hole completely, maintaining the dimensions of 2, 3, 10".

005.11 Removal of chamfers while maintaining dimensions of 2,5,11°; 2,3,10"; 2,3,7,12.

005.12 Cut the cut, keeping dimensions 2,3,6,7,14,12

010 Multipurpose with CNC.

Machine: horizontal machining center S-400



A. Install, fasten, remove.

010.01 Mill the side surface finally, maintaining the size. 1 Turn the table 56° counter-clockwise.

010.02 Mill the flat surface finally, maintaining the dimensions 2,3,4,5. Turn the table 34° counterclockwise.

010.03 Mill the flat surface in advance, maintaining the size. 4 Turn the table 90° counterclockwise.

010.04 Mill the flat surface finally, maintaining the dimensions 6,7,8,9,13. Turn the table 90° counterclockwise.

010.05 Milling a flat surface in advance, finally holding dimensions 4*.4"

Turn the table 34° counterclockwise.

010.06 Mill the flat surface finally, maintaining the dimensions 2,3,4,5. Turn the table 56° counterclockwise.

010.07 mill the inner surfaces, pre-finally holding the size 10,11,12; 10°, 11°, 12°. Turn the table 90° counterclockwise.
010.08 Mill the flat surface finally, maintaining the size of 4'.

010 Laundry room.

010 Control room.

2.9 Calculation of cutting modes

2.9.1 Calculation of cutting modes by analytical method

output data:

Processing material - cast iron C425, tool: thrust boring cutter (P6M5, horizontal machining center machine EC-400.

Calculation of cutting modes for rough boring of the hole 035H8

D=32.5; n=2.0 mm: the machine is multi-operational. Tool: Boring cutter with p-shaped sharpening with TSK10 carbide plate, geometric parameters of the cutting part: $\phi=60^\circ$, $\phi_1=10^\circ$; $=12^\circ$; $v=4^\circ$; $a=6^\circ$; $1=0^\circ$; $f=0.4$ mm; $r=1$ m.

1. Cutting depth: $t = \frac{D1 - D2}{2} = \frac{34,5 - 32,5}{2} = 1,0 \text{ MM.}$

2. according to the feed range and recommendations, we accept feed S=0.5 mm/rev.

3. Period of stability of the cutter T=60 min.

4. Cutting speed

$$V_u = \frac{0.9 \cdot C_v}{T^m \cdot t^{xy} \cdot S^{zy}} \cdot K_v, \text{ M/XB};$$

where Kv is the general correction factor

$$K_v = K_{mv} \cdot K_{nv} \cdot K_{uv} \cdot K_{\phi_1 v} \cdot K_{rv} \cdot K_{qv} \cdot K_{ov}; \quad [5]$$

$$K_{mv} = (190/120)^{nv}; \quad n_v = 1.25; \quad K_{nv} = 0.85; \quad K_{rv} = 1.0; \quad K_{\phi_1 v} = 1.0; \quad K_{uv} = 0.8; \quad K_{ov} = 1.0;$$

$$K_v = 0,88 \cdot 1,0 \cdot 0,85 \cdot 1,0 \cdot 0,8 \cdot 1,0 = 0,6;$$

Then

$$V = \frac{0.9 \cdot 243}{60^{0.2} \cdot 1.0^{0.15} \cdot 0.5^{0.4}} \cdot 0.6 = 75,4 \text{ M/XB.}$$

5. Rotational frequency

$$n_o = \frac{1000V}{\pi d} = \frac{1000 \cdot 75.4}{3.14 \cdot 32.5} = 738 \text{ } \text{с}^{-1}$$

We correct the passport data of the machine $n_o = 630 \text{ } \text{с}^{-1}$

6. Actual speed

$$V_{\phi} = \frac{\pi D n_o}{1000} = \frac{3.14 \cdot 32.5 \cdot 630}{1000} = 64.3 \text{ } \text{м} / \text{с}$$

$$S_{\text{св}} = 0.5 \cdot 630 = 315 \text{ } \text{мм} / \text{св}$$

7. Cutting power

$$P_z = C_{pz} \cdot t^{x_{pz}} \cdot s^{y_{pz}} \cdot V^{n_{pz}} \cdot K_{pz} \quad [5]$$

For these requirements:

$$P_z = 92 \cdot 1^1 \cdot 0.5^{0.75} \cdot 64^0 \cdot \left(\frac{210}{190} \right)^{0.4} \cdot 0.92 = 1.01 \text{ } \text{кВ}$$

8. Cutting power:

$$N = \frac{P_z \cdot V}{100 \cdot 2} = \frac{1.01 \cdot 64 \cdot 10^2}{100 \cdot 60} = 1.05 \text{ } \text{кВт}$$

2.10 Designation of cutting modes according to regulatory data

Cutting modes are assigned according to normative data, depending on the nature of processing, the material of the workpiece and the tool. The prescribed cutting modes are listed in the table. 2.8.

Table 2.8- Cutting modes

No. Opera.	No. Transfer	Cutting depth t,MM	Submission of S MM/06.	Processing time To., XB.	Cutting speed V,M/XB.	Spindle rotation frequency n, rev/min.
005	01	1,25	0,3	1	125	1000
	02	0,4	0,3	1	125	1000
	03	-	-	0,3	4,95	315
	04	7,5	0,16	0,1	47,1	1000
	05	0,5	0,5	0,15	78	1000
	06	1	0,5	0,51	75,4	630
	07	1	0,5	0,68	75,4	630
	08	0,2	0,16	0,8	12,6	1000
	09	1	0,5	1,3	75,4	630
	10	0,5	0,5	1,04	106,7	1000
	11	0,75	0,5	0,71	75,4	630
	12	0,1	0,5	0,57	75,4	630
	13	-	-	0,2	37,6	315
	14	0,75	0,77	0,92	4,59	315
010	01	2,5	0,5	1,304	157	1000
	02	0,5	0,5	0,3	157	1000
	03	2	0,5	0,75	157	1000
	04	0,5	0,3	2,3	56,5	1000
	05	0,5	0,5	1,5	157	1000
	06	0,5	0,5	0,3	157	1000
	07	0,5	0,3	1,4	56,5	1000
	08	0,5	0,5	0,75	157	1000

2.11 Standardisation of technological operations

The value of labor intensity and productivity can be found by technical rationing, which is defined as the determination of the time required to perform a specific volume of work by certain methods.

The time intended for processing one part is calculated according to the formula:

$$T_{um} = T_o + T_{\partial} + T_m + T_{ope} + T_{\phi};$$

where T_o is operational time (processing); T_{∂} - auxiliary time; T_m - technical time service; T_{ope} - time of organisational service; T_r - time for rest.

For serial production:

$$T_{um} = T_o \left(1 + \frac{Z}{100} \right);$$

where $Z = 4...12\%$ - workplace maintenance costs and standardised breaks. The results of calculations are listed in Table 2.9.

Table 2.9- Rationing of technological operations

No. Operations	T_o , xB	Sht, min
005	8.78	8.78
010	9.6	9.6

2.12 Calculation of time standards

Calculation of time norms for drilling a hole

Calculation of basic time

$$T_o = \frac{L \cdot i}{n \cdot S} = \frac{25}{1000 \cdot 0,16} = 0,156 \text{ xB}$$

$L=25\text{mm}$ - tool path length

Calculation of auxiliary time

Time for installation and removal of the part: 0.12 min;

Time for cleaning the device from shavings: 0.1 min; Time associated with the passage during processing: 0.15 min;

Time for measurements: calliper 0.3 min; $TB=0.12+0.1+0.15+0.3=0.4 \times B$;

Calculation of operational time $Top-To+TB=0.156+0.4=0.556 \times B$;

Calculation of time for physical needs of the employee $Top=5.2/100=0.06 \times B$;

Preparation time calculation: 8 minutes;

Calculation of artificially calculated time:

$Tsh.k.=Top+ To+Tf.p.+Tp.z/200=0.556+0.156+0.06+ 8/200=0.812 \times B$;

3. Design Section

We will design a device for clamping the workpiece during processing for operations 005. In this operation, processing of 2 vertical planes and holes is carried out: $\Phi 30H9$, $\phi 35H8$, $\phi 25H14$, $\phi 15H14$ and 6-X holes M5-7H Processing is carried out on a horizontal machining centre ES-400. As a base surface we take a flat surface and a surface perpendicular to it, put the part on a stop.

As a device for processing semi-finished products in this operation we accept screw self-centring vices. The device consists of a rotary table 6, in which 2 grooves are made B=12, for fixing the device on the machine table, with two pins 23, the device is based in machine tool grooves 12H7. On the upper plane of the case accurate protrusion B=68g6 with polished top and side planes is made on which two carriages 2 with slats 25 move.

Carriages move in opposite directions thanks to screw 3, which has 2 sections in opposite directions threads M20 right and M20 left. On the carriages 2 are fixed jaws 1, which are replaceable and are made according to the adjustment for the processed workpiece Also on a stop 15 is installed on the upper auxiliary plane of the case. The ends of the case are closed covers 25.

The principle of operation of the device: in the initial position of sponge 1 together with carriages 2 diverted in different directions. Next, turning the screw 3 clockwise with the help of the az key, we assemble the carriages 2 with jaws 1 and clamp workpiece with sponges. 1 We carry out the necessary processing, after which we move the sponges in different directions and pull out the part.

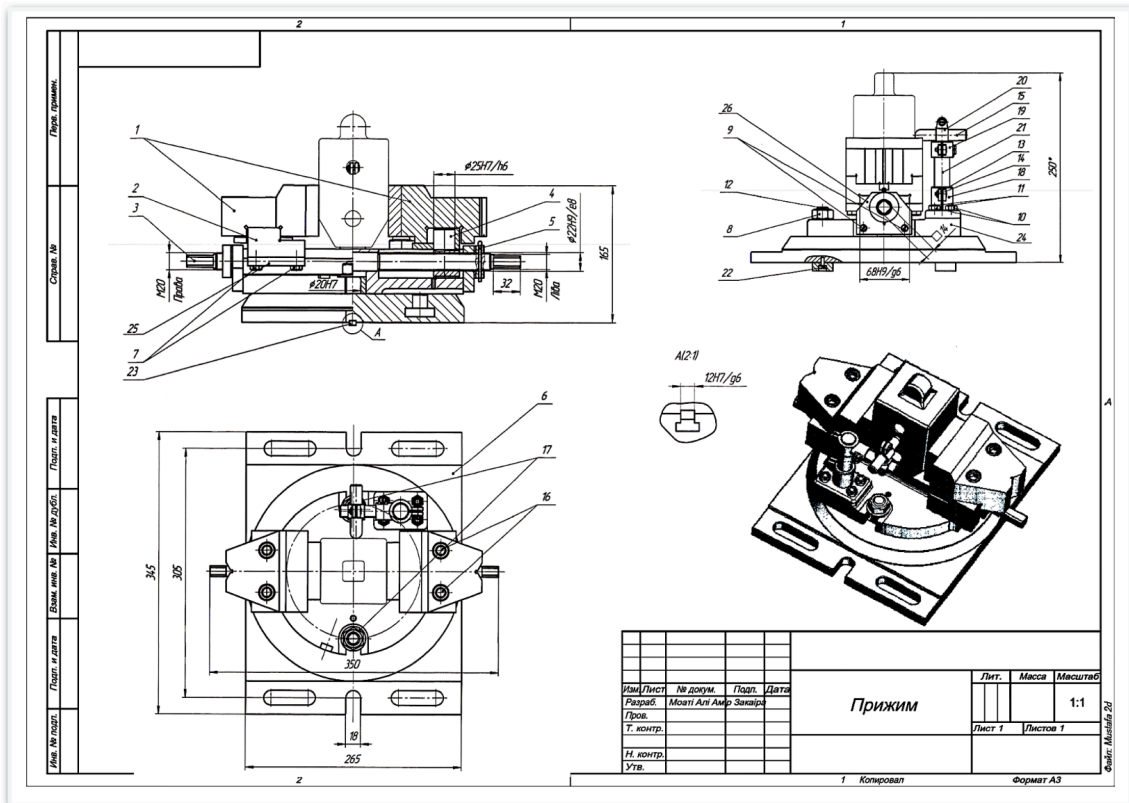


Fig. 3.1. Device for operation 005

Calculation of Vices Calculation of cutting modes when drilling $\phi 15$

Initial data: processing material - cast iron CH25, tool: drill $\phi 15$ GOST 10903-77 (R6M5).

Cutting Depth T,MM	Submission of S MM/OB	Processing Time that..., Min	Cutting Speed V,M/Min	Frequency spindle revolutions P.OB/Min
$\Phi 15H14$	0,16	0,1	47,1	1000

- Minute Supply: $S_m = S \cdot n = 0.16 \cdot 1000 = 160$ mm/min.
Axial cutting force R_o and torque

$$P_o = 10 C_p \cdot D^q \cdot S^y \cdot K_p, \quad M_{кр.} = 10 C_M \cdot D^q \cdot S^y \cdot K_p.$$

де, $K_p = K_{кр} = 1$ [1, том 2, табл.10]

$$C_p = 42 \quad q = 1,2 \quad y = 0,7$$

$$C_M = 0,012 \quad q = 2,2 \quad y = 0,8 \quad \left. \begin{array}{l} \\ \end{array} \right\} [4, \text{том 2, табл.32}]$$

$$P_o = 10 C_p \cdot D^q \cdot S^y \cdot K_p = 10 \cdot 42 \cdot 15^{1,2} \cdot 0.16^{0,7} \cdot 1 = 3002 \text{ H,}$$

$$M_{кр.} = 10 C_M \cdot D^q \cdot S^y \cdot K_p = 10 \cdot 0.012 \cdot 15^{2,2} \cdot 0.16^{0,8} \cdot 1 = 10 \text{ Hm.}$$

Development of the principle diagram of the device

According to the task, it is necessary to develop a device for processing of two flat surfaces and all holes. As base surfaces, take a flat surface B4 (installation base), D2 (double support base) and D1 (support base). This basing scheme implements 6 degrees of freedom.

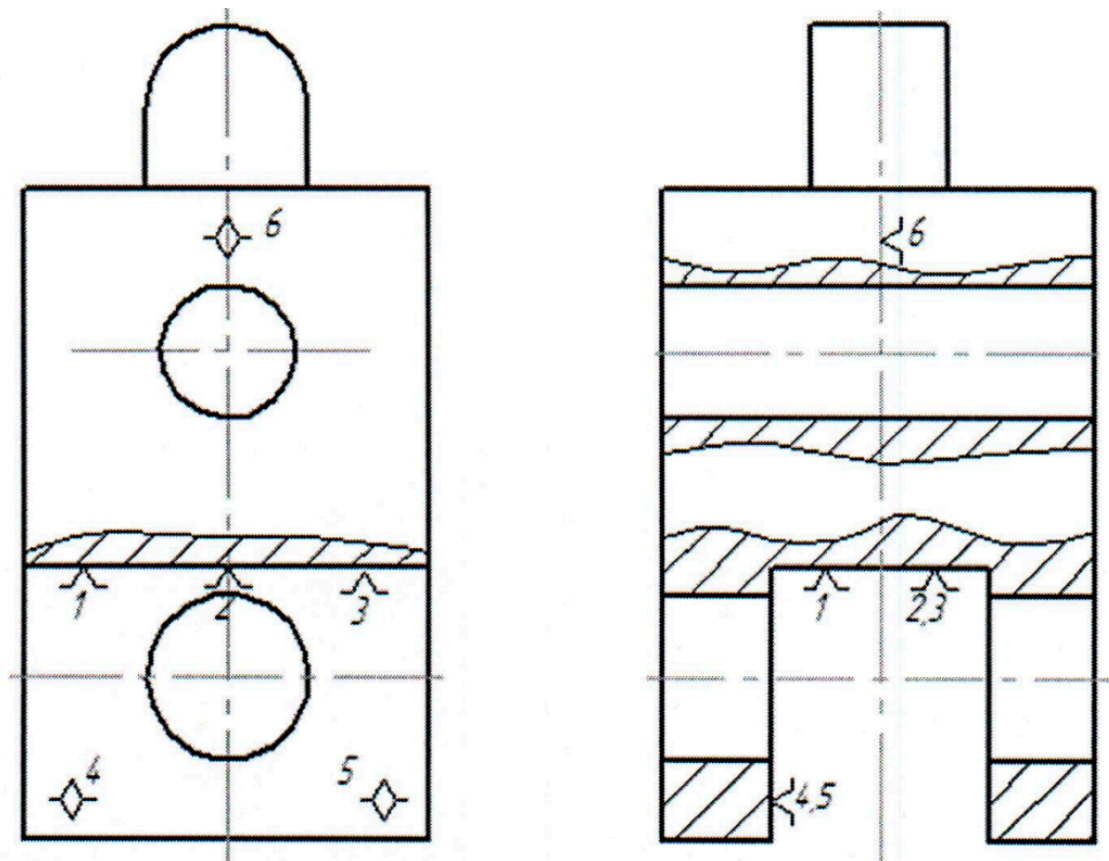


Fig. 3.2. Scheme of basing the workpiece in the fixture

Determination of the force Q required to secure the workpiece

Let's determine the most unfavourable case of location of cutting forces. Let's consider the scheme of loading the workpiece during processing:
1. Axial force when drilling holes. $\phi 15$ creates a moment that tries turn the workpiece in a vice.

This is counteracted by the force W from the drive side (Fig. 3).

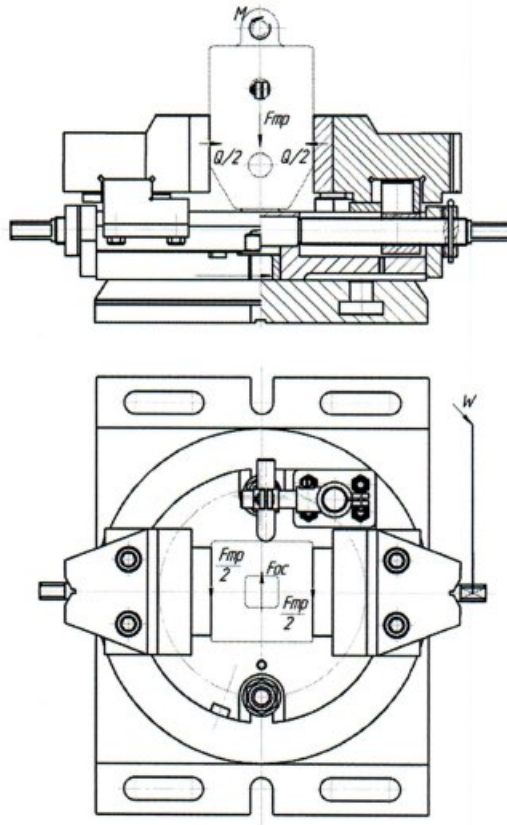


Fig. 3.3. Scheme for calculating the device

The equilibrium equation of the workpiece: $W = 2km / D \cdot 2 F$, where K is the reserve factor, taken as at least 2.5.

$$M = R_{os} \cdot L = 3002 \cdot 0,015 = 45,04 \text{ Nm}$$

$$D = 15 \text{ Mm} = 0,015 \text{ M.}$$

F - Coefficient of friction, we accept $F=0.16$.

$$W = 2 \cdot 2,5 \cdot 45.034 / 0.015 \cdot 2 \cdot 0.16 = 46910 \text{ N.}$$

Required screw diameter: $d = \sqrt{\frac{4 \cdot W}{\pi \cdot \sigma_s}} = \sqrt{\frac{4 \cdot 46910}{3.14 \cdot 610}} \approx 11 \text{ mm, as in a vise. The m20x2 screw is}$

used then the condition of a strong clamp is ensured. The moment of cutting forces tries to tear off the processed workpiece from flat surface. It counteracts the friction force F_{tr} , which is caused by the action of the force W from the side of the screw drive.

Equation of equilibrium of the workpiece: $W = K F_t / 2 f$,

$$W = 2,5 \cdot 826 / 2 \cdot 0,16 = 6463 \text{ H, which is significantly less than in the previous calculation.}$$

Conclusion: After completing the calculations, we believe that the pre-accepted screw M20×2 is completely satisfactory for us in terms of the reliability of the clamp, with it has a certain margin of strength and reliability of the clamp. Therefore, we finally accept the previously accepted adjustment.

Calculation of the error of setting the workpiece in the device

Since we use a self-centering vice, errors in the obtained dimensions for operations 005 - are not expected.

3.2 Equipment for operation 010 Design description

According to the task, it is necessary to develop a device for processing all flat surfaces.

As base surfaces accept: flat surface 01 (installation base) and two holes (double support base), and (support base). This basing scheme implements 6 degrees of freedom.

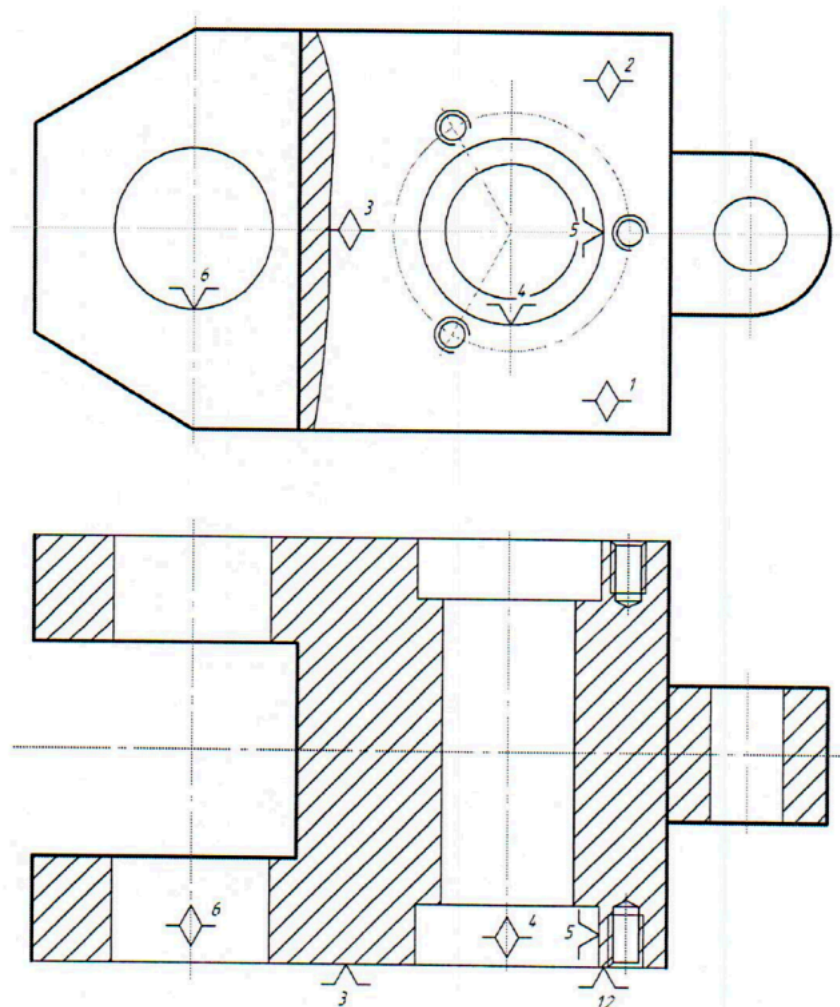


Fig. 3.4. Scheme of basing the workpiece in the fixture

Such a basing scheme is implemented using two fingers, one cylindrical, the other rhombic, and a plane.

The structural formula of the basing scheme:

$$\mathbf{SB_{tb} \longrightarrow Y(3) + PO(2) + O(1)}$$

In accordance with the developed technological process, the installation of the workpiece in the second operation is performed on three permanent supports with a flat surface and on the finger. We will analyse the possibility of installing the part on 2 fingers and on 1

cylindrical and 1 rhombic. Implementation of the basing scheme

$$S_{1\min} + S_{2\min} \geq T_n + T_f$$

$$S_{1\min} = D_{\min} - d_{\max} = 30 - 29,98 = 0,02$$

$$S_{2\min} = D_{\min} - d_{\max} = 35 - 34,975 = 0,025$$

The workpiece can return to the angle $\beta =$

$$\operatorname{tg} \beta = \frac{\frac{1}{2} S_{1\max} + \frac{1}{2} S_{2\max}}{L};$$

Where $S1 \max = 0,092\text{mm}$, $S2 \max = 0,14\text{mm}$ - guaranteed gaps in connections;

$L = 60 \text{ mm}$

-Center Distance.

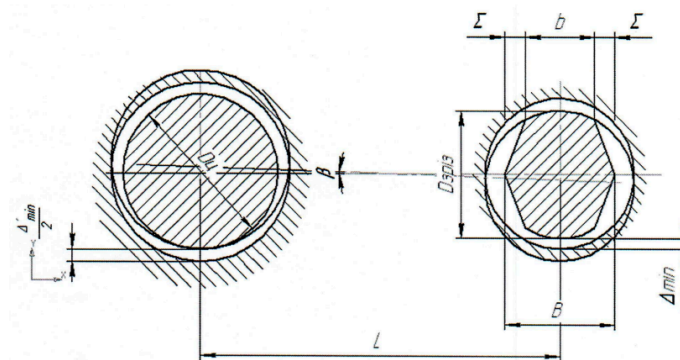


Fig. 3.5. Base error of the workpiece

$$\operatorname{tg} \beta = \frac{\frac{1}{2} 0,092 + \frac{1}{2} 0,14}{60} = 0,001708;$$

$$\beta = 0,098^{\circ}.$$

The error from turning the workpiece will be:

$$\delta_{\text{нов.}} = l * \sin \beta;$$

$$\delta_{\text{нов.}} = 60 * \sin 0,098^{\circ} = 0.103 \text{ mm} \leq Tl = 0.2 \text{ mm}.$$

Basing accuracy is ensured.

2.2.1 Selection of the design of the installation elements for the technical implementation of the accepted scheme of basing the workpiece To secure the part by pressing the selected operation, it is possible to use both special devices, ZRP, and universally assembled devices. Since the type of production is medium series, the most expedient is the use of the system Ultrasound 1-12.

The device is single-seat, with a manual clamp, intended for use on multi-purpose machines of a closed layout. The total weight of the device does not exceed 25 kg, and is 16.11 kg. The adopted basing scheme provides for the installation of the workpiece on the support plates and two fingers (cylindrical, cut). In this way, 6 degrees of freedom of the workpiece are eliminated.

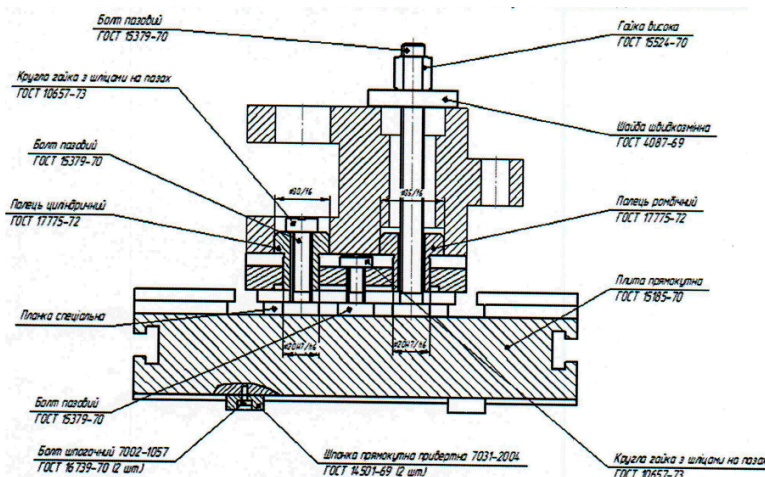


Fig. 3.6. Constructive implementation of the scheme of basing the workpiece

The processed planes are located along the contour of the part, which makes it impossible to process the workpiece without turning the device. Force calculations for reliable fixation of the workpiece. The maximum cutting force per operation is the components of the cutting force R_z , and R_u during milling. Under the action of cutting forces, the workpiece may shift in the X direction, as shown in Fig. 8

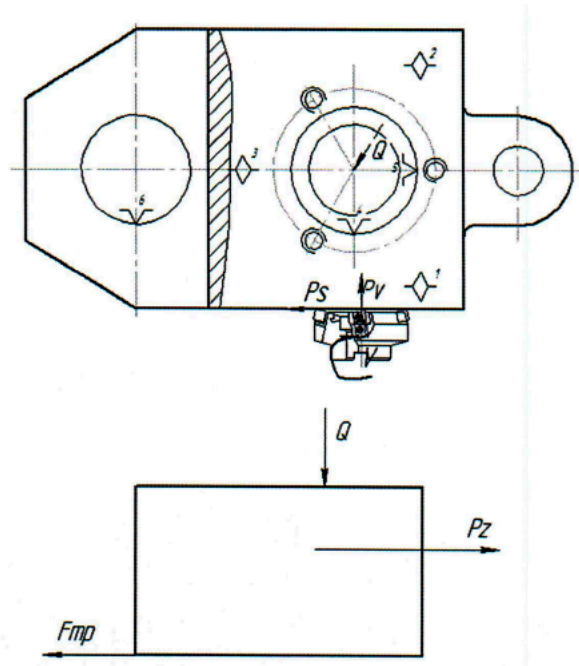


Fig. 3.7. Calculation scheme of forces

The force is applied to the key of the threaded clamp with a nut

$$P = \left\{ Q \left[r_{cp} \operatorname{tg}(\alpha + \varphi_{np}) + 0.33 f \frac{D_H^3 - D_B^3}{D_H^2 - D_B^2} \right] \right\} / l$$

Clamping Force

$$Q = Pl \left[r_{cp} \operatorname{tg}(\alpha + \varphi_{np}) + 0.33 f \frac{D_H^3 - D_B^3}{D_H^2 - D_B^2} \right]$$

Where $Q=147$ N force on the key, $l=14d$ -distance from the axis of the screw to the point of force application. r_{cp} - the average radius of the thread, mm. and $(\alpha)2.5^\circ - 3.5^\circ$ - angle of elevation of the thread screw. $\Phi_{np} 6.5^\circ$ -reduced angle of friction in a threaded pair $f=0.1-0.16$ -coefficient of friction at flat contact of two surfaces.

$$Q = 147 \cdot 140 \left[10 \operatorname{tg}(3^\circ + 6.5^\circ) + 0.33 \cdot 0.1 \frac{12^3 - 10^3}{12^2 - 10^2} \right] = 4560 H$$

Let's write the equation of moments with respect to point O

$$\Sigma M_O = 0$$

$$Ql_1 = W(l_1 + l_2)$$

$$W = Q \cdot \frac{l_1}{l_1 + l_2}$$

$$W = 4560 \cdot \frac{60}{60 + 0} = 4560 \text{ H}$$

Thus, we determined that the clamping force of the workpiece is equal to 70660N.

Processing will be carried out on the horizontal machining centre ES-400.

Processing will be carried out with an end mill and an end mill. Let's calculate the cutting force that occurs

when processing this surface.

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

$$\partial e S_z = 0.032_{MM} / 3y6$$

$$t = 5$$

$$C_p = 332$$

$$q = 0.2$$

$$x = 0.1$$

$$y = 0.4$$

$$n = 0.2$$

$$w = 0.2$$

$$D = 7$$

$$B = 7$$

$$n = 1000 o6 / x6$$

$$P_z = \frac{10 \cdot 332 \cdot 2,5^{0,1} \cdot 0,032^{0,4} \cdot 7^{0,2} \cdot 5}{7^{0,2} \cdot 1000^{0,2}} \cdot 1 = 1153 \text{ H.}$$

Calculation of the strength of the weakest link of the device

In our device, the weakest element is the M12 bolt through which the workpiece is clamped in the device. Therefore, we cannot allow the chance of destruction of this structure

$$d > \sqrt{\frac{4 \cdot 4560}{3.14 \cdot 80 \cdot 10^6}} = 0.0085 \text{ (m)}$$

We Accept $d=12\text{mm}$.

$$\begin{aligned}\gamma &= 2,03^\circ \\ \rho &= 10,47^\circ \\ f &= 0,16\end{aligned}$$

$$M_T = \frac{1}{3} \cdot 0,16 \cdot 4560 \frac{(8 \cdot 10^{-3})^3 - 0}{(8 \cdot 10^{-3})^2 - 0} = 2 \text{ Hm.}$$

$$l = 15d = 180\text{mm}$$

$$M = \frac{12 \cdot 10^{-3}}{2} \cdot 4560 \cdot \text{tg}(2,03^\circ + 10,47^\circ) + 2 = 7,07 \text{ Hm.}$$

Checking the strength of the bolt:

$$W = \frac{M}{l} = \frac{7,07}{180 \cdot 10^{-3}} = 45H < 147H$$

The weakest structural element will withstand the load.

Development of technical requirements for the device

This device is intended for fixing parts of the Lever type during their processing on multi- purpose CNC machines. The workpiece is based on two fingers, truncated and cylindrical.

It is clamped manually. Overall dimensions of the device: 240×120×194; Weight - 16.11 kg.

Based on this, we can process the finished product on closed machines layout.

G.CODE

```
G90 ; Set to absolute positioning mode
G21 ; Set to millimeters
G92 X0 Y0 Z0 ; Set current position as the origin

; Define the stock dimensions (assuming a rectangular stock)
G54 ; Select work offset 1
G92.1 ; Clear any existing coordinate system offsets
G10 L20 P1 X0 Y0 Z0 ; Set the work offset 1 to the origin
G10 L20 P1 Z-5 ; Set the work offset 1 Z-axis to the stock height (assuming

; Begin machining operations
M3 S1000 ; Start spindle, set speed to 1000 RPM
G0 X10 Y10 ; Rapid move to the starting position

; First, rough out the shape
G1 Z0 F500 ; Move to the stock surface
G1 X90 ; Move to the first point
G1 Y40 ; Move to the second point
G1 X10 ; Move to the third point
G1 Y10 ; Move to the fourth point
G1 X90 ; Move back to the starting point

; Next, finish the shape
G1 Z-1 ; Move slightly below the stock surface for finishing
G1 X80 ; Move to the first finishing point
G1 Y30 ; Move to the second finishing point
G1 X20 ; Move to the third finishing point
G1 Y20 ; Move to the fourth finishing point
G1 X80 ; Move back to the starting finishing point

; End machining operations
G1 Z5 ; Move to safe Z height
M5 ; Stop spindle
M30 ; End program
```

4. Organisational and economic part

4.1. Calculation of costs under the article "Raw materials and materials" (Vust).

The article "Raw materials and materials" contains costs for raw materials, basic, auxiliary materials, purchased products and semi-finished products, that is, costs that can be directly calculated per unit of production on the basis of cost norms and prices. In addition to the price of materials, transportation and procurement costs are taken into account (transportation fees, loading and unloading operations, commission payments to procurement organisations, etc.). The cost of waste at the price of their possible use or sale is subtracted from the cost of raw materials and materials.

Costs for raw materials and materials consist of costs for basic, auxiliary materials, and component products:

$$B_M = U_{\text{зар}} + U_{\text{доп}} + U_{\text{ком}}$$
$$B_M = 3,079 + 0 + 2,512 + 0 = 5,591 \text{ грн}$$

where V_M - costs for raw materials and materials, hryvnias; T_{svg} - the cost of the material of the rising billet, hryvnias; T_{dop} - the cost of auxiliary materials, hryvnias; $T_{\text{s kom}}$ - cost of components, hryvnias.

$$U_{\text{доп}} = 0; U_{\text{ком}} = 2,512 \text{ грн};$$

Methodology for calculating the costs of basic materials in the diploma project is reduced to the calculation of costs for the ascending workpiece.

The nature of the rising workpiece is selected at the stage of development of a new technological process.

For example, if casting or stamping is chosen as the rising material, then the cost of such rising billet is calculated according to the formula:

$$U_{\text{зар}} = \frac{C_M}{1000} \cdot Q_M \cdot K_T \cdot K_C \cdot K_M \cdot K_B - \frac{C_{\text{відх}}}{1000} \cdot Q_{\text{відх}},$$
$$U_{\text{зар}} = \frac{3800}{1000} \cdot 2,62 \cdot 0,8 \cdot 0,85 \cdot 0,9 \cdot 0,95 - \frac{2116,6}{1000} \cdot 1,28 = 5,78 - 2,709 = 3,079 \text{ грн}$$

where S_m - the cost of the material from which the workpiece is made, hryvnias/ton; S_{widh} - cost of waste material, hryvnias/ton; O_m - mass of the workpiece, kg; Q_{vidh} - mass of waste, kg; K_u , K_s , K_m , K_r - coefficients, the value of which depends on the accuracy class, complexity group, mass, volume of production of workpieces of this type.

For rising blanks in the form of castings and stampings of medium sizes and mass, as well as for workpieces of medium complexity and medium accuracy class, the following values of the coefficients included in the formula can be recommended, namely:

$$K_r = 0.70 \div 0.95; K_s = 0.85 \div 0.90; mK = 0.80 \div 0.95; K_u = 0.95 \div 0.98$$

The value of the waste material at the price of its possible realization, which can be formed as a result of mechanical processing of the rising billet, must be subtracted from the art of the rising billet. The value of the mass of returnable waste O_{vdih} (O_{vdih}) can be calculated by comparing the mass of the rising workpiece and the mass of the finished product:

$$Q_{bidh} = Q_m - M,$$

$$Q_{bidh} = 4,3 - 3,743 = 0,557 \text{ кг}$$

where M is the mass of the finished product, kg.

The cost of S_{widh} waste material can be chosen based on specific conditions their possible use. For the vast majority of waste, for example in the form of metal shavings, spruces, etc., the cost of waste can be accepted within 10 ÷ 12% of the cost of the workpiece material, i.e.:

$$C_{bidh} = 0,10 \div 0,12 \cdot C_m$$

$$C_m = 3800 \text{ грн/т};$$

$$C_{bidh} = 0,557 \cdot 3800 = 2116,6 \text{ грн}$$

The results of cost calculations for the item "Raw materials and materials" for one product should be entered in the table. 4.1

Table 4.1 - Costs of raw materials and materials

No	Name of expenses	Conventional designation	Amount of expenses, hryvnias	Specific weight of costs, %
1	2	3	4	5
1.	Rising workpiece	Tsagh	3,079	55
2.	Auxiliary materials	Tsdop	0	0
3.	Purchased and component products	Tskom	2,512	45
	Total expenses (1+2+3)	Vm	5.591	100

4.2. Calculation of expenses according to the article "Fuel and energy for technological purposes" (Wen).

The article "Fuel and energy for technological purposes" includes the cost of energy (fuel, electricity, steam, gas, etc.), which is directly used in the technological process to change the state or form of objects of work (melting, heating, welding, drying, etc.). It is calculated according to cost norms and energy tariffs.

Expenditures for the state "Fuel and energy for technological "chili" consists of the following components:

$$B_{en} = C_{el.en.} + C_{inshi} ,$$

$$B_{en} = 2.63 + 12.5 = 15.13 \text{ грн.}$$

Where Ven - fuel and energy costs for technological purposes, hryvnias;
Selenium - consumption of electrical energy used in technological processes production of the product, hryvnias; Sinshi - costs of other types of energy, which are used in the process of manufacturing the product according to the requirements of the designed technological process (natural gas, compressed air, etc.), UAH.

The consumption of electrical energy (Sel.en.) should be performed using the following formula:

$$C_{el.en.} = N_{вст} \cdot T_{ш.к.} \cdot \Pi_{en} \cdot K_B \cdot K_M ,$$

$$C_{el.en.} = 24 * 0.5 * 0.305 * 0.8 * 0.9 = 2.63 \text{ грн}$$

Where is Selenium? - consumption of electrical energy used in the technological product manufacturing process, hryvnias; Mvst - the installed capacity of the equipment where the operations of the technological process of manufacturing products are performed, kW; Price - cost of 1 kWh of electricity (tariff for electricity), UAH/kWh; Kv - a coefficient that takes into account the degree of equipment use during a work shift; Km - a coefficient that takes into account the degree of use of equipment in terms of capacity.

In practical calculations, the following values of the above should be used coefficients $K_e = 0.70 \div 0.80$, $K_m = 0.80 \div 0.90$. The cost of 1 kWh of electricity energy (percentage of its actual value at the time of Yen) is chosen depending on using calculations.

Spending on other types of energy (Blue), which are used in the process production of products according to the designed technological of the process, are carried out depending on what type of energy is used and in what quantities it is used. The results of cost calculations according to the article "Fuel and energy for technological purposes" are summarised in Tables 4.2 and 4.3.

Table 4.2- Data on the installed capacity of electrical equipment on equipment where technological operations are performed

No	Operation name	The name of the equipment	The model (type) of the equipment is n	Set Number of units on the capacity with of the equipment unit, kW	equipped NIA	Total installed of kW (5x6)
1	2	3	4	5	6	7
1.	Multipurpose Va	Processing center	HAAS EC-400	24	1	24
2.	Multi-purpose	Processing center	HAAS EC-400	24	1	24

Table 4.3- Energy consumption for technological purposes

No	Name of expenses	Conventional designation	Amount of expenses, UAH	Specific weight of costs, %
1	2	3	4	5
1.	Electric energy	Selenium.	2.63	17
2.	Other types of energy	The blue ones	12,5	83
	Total costs (1+2)	Ven	15.13	100

4.3 Calculation of costs under the article "Basic salary producers" (ZPOSN).

The article "Basic wages of producers" contains costs for wages of workers directly engaged in the production of the main products. It is calculated in accordance with the norms of time spent on technological operations and tariff rates or piece rates for operations, parts, nodes. First of all, it is necessary to calculate expenses under the article "Basic salary manufacturers" to decide with quantitative composition major manufacturers products (workers) involved in the technological operations of manufacturing the product according to the designed technology. Data on product manufacturers should be entered in table 4.4

Table 4.4- Data on manufacturers of products that work on piecework form of payment

No	l named operations	Name and model (type) of the equipment	Class of work	Profession and the specialty of manufacturers	Quantity manufacturers, persons
1	2	3	4	5	6
1.	Multipurpose and	Processing and center HAAS EC-400	5	CNC operator	1
2.	Multipurpose and	Processing and center HAAS EC-400	5	CNC operator	1

The amount of wages of producers who work on piecework payment should be calculated according to the formula:

$$3\Pi_{och} = \frac{\sum_{i=1}^n T_{u.k.i} \cdot C_{3i}}{60},$$

Where ZPosn - the amount of wages of producers, hryvnias; shku - artificially calculated time for execution and - operations of the technological process, min; Sz- hourly tariff rate of the worker who performs i- operation, hryvnias/hour; m - the number of operations of the manufacturing process of the product.

The results of the calculation of the wages of producers should be entered in table 4.5.

Table 4.5 - Data on wages of the main producers

No.	Profession and specialty of producers	Class of work	Hourly rate worker's rate, hryvnias/ hour	Artificial calculation time to perform the operation, min	Wages, hryvnias
1	2	3	4	5	6
1.	CNC operator	5	12	8.78	1,756
2.	CNC operator 5	12	9.6	1.92	

In this case, when before the operations of the designed technological producers (workers) who work on an hourly basis are involved in the process wages, the amount of expenses under the article "Basic salary" is carried out similarly.

4.4. Calculation of costs under the article "Additional wages of producers" (Z Pdod).

Additional wages (payment for vacations, time for performing public duties, additional pay for performing additional functions, etc.) are calculated as a percentage of the basic wage:

$$3\Pi_{\text{доп}} = K_{\text{зп}} \cdot 3\Pi_{\text{осн}},$$

$$3\Pi_{\text{доп}} = 0,12 \cdot 3,676 = 0,441 \text{ грн}$$

Where Z Pdod - additional wages of the main producers, hryvnias; K zp - coefficient of additional wages.

The value of the coefficient of additional wages should be taken within the limits of $K_{\text{zp}} = 0.12 \div 0.14$.

4.5. Calculation of costs under the article "Deductions for the social needs of producers" (V sots).

The amount of expenses under the article "Deductions for the social needs of producers" is carried out as a percentage of the sum of the basic and additional wages. In the calculations of the unit cost of the product, the technological process, the production of which is planned, the amount of expenses under the article "Deductions for the social needs of manufacturers" should be carried out according to the following formula:

$$B_{\text{соц}} = 0,39 \cdot (3\Pi_{\text{осн}} + 3\Pi_{\text{доп}})$$
$$B_{\text{соц}} = 0,39 \cdot (0,441 + 3,676) = 1,605 \text{ грн.}$$

where In Social Security - expenses under the article "Deduction for social insurance", hryvnias.

4.6. Calculation of costs under the article "Maintenance and operation of machines and equipment" (Vust).

Article "Maintenance and operation of machinery and equipment" is comprehensive and covers such expenses as depreciation deductions for machinery and equipment that belong to the main funds, expenses on electricity, compressed air, fuel for powering the engine, technological tools, repairs, wages with appropriate deductions for the social needs of manufacturers who service machines (adjusters, electricians, locksmiths, etc.). An estimate is made for these costs for each shop (production) per year (quarter). The cost of maintenance and operation of machines and equipment is calculated by the distribution method per unit of each type of product. The costs of maintenance and operation of machines and equipment are complex and should be calculated according to the following formula:

$$B_{\text{уст}} = AM_{\text{уст}} + AM_{\text{буд}} + AM_{\text{иши}} ,$$
$$B_{\text{уст}} = 13,021 + 8,76 + 5,41 = 27,191 \text{ грн}$$

Where AMust - depreciation deductions for cars and equipment belonging to fixed assets, hryvnias; AMbud - depreciation deductions for buildings and structures, hryvnias; Other - other components of expenses for maintenance of machines and equipment, which include the costs of repair personnel, material costs for the purchase of spare parts equipment, fuel and energy costs for repair work, etc. To calculate depreciation deductions • machinery and equipment, which belong to fixed assets, it is necessary first of all to perform cost

calculations for the purchase of equipment that is designed for the technological process.

necessary for implementation; Table 4.6 should be the source data for calculating costs for the purchase of equipment and equipment.

Table 4.6 *Equipment and equipment data*

No	The name of the operation	Name equipment (equipment)	Type (model) equipment (equipment)
1	2	3	4
1.	Multipurpose	Processing center	HAAS EC-400
2.	Multipurpose	Processing center	HAAS EC-400

The number of units of equipment and equipment, which are necessary for the implementation of the annual production program for the production of products according to the design technological process can be determined by the formula:

$$N_i = \frac{V_i \cdot T_{шт.ч.i}}{60 \cdot F_{дi} \cdot K_{BH}},$$

$$N_1 = \frac{5000 \cdot 0.146}{60 \cdot 731.6 \cdot 1.05} = 0.8 \approx 1$$

$$N_2 = \frac{5000 \cdot 0.16}{60 \cdot 800 \cdot 1.05} = 0.9 \approx 1$$

where N. is the estimated number of units of the equipment (equipment) required to perform the i-operation, units; V; - annual product release program, pcs.; Tsht h. - artificial calculation time, which is necessary for the execution and operation, min; Ed - valid annual fund of time for the operation of a unit of equipment for i-operation, h; Kvn is a coefficient that takes into account the degree of compliance with production standards. In calculations can take the value of K.. 'vn = 1.05 ÷ 1.07.

First of all, the effective annual fund of the time of operation of a unit of equipment for i-operation is determined by the formula:

$$F_{дi} = D_p \cdot \tau_{3M} \cdot 3_M \cdot K_p,$$

$$F_{д1} = 8.7 \cdot 8 \cdot 1 \cdot 0.9 = 731.200$$

$$F_{д2} = 9.6 \cdot 8 \cdot 1 \cdot 0.9 = 800.200$$

Where Chum - duration of work shift, hours; 3m - the number of workers equipment operation changes during the day; Kr is a coefficient that takes into account planned equipment downtime due to repair work and other types of maintenance equipment (for example, adjusting equipment during operation, lubricating mechanisms, etc.).

The result of calculations of the amount of equipment and equipment is entered in table 4.7.

table 4.7- *Equipment and equipment calculation data*

No	The name of the operation	The name of the equipment	Type (model) of equipment	Estimated quantity equipment, units
1	2	3	4	5
1.	Multipurpose	Processing center	HAAS EC-400	1
2.	Multipurpose	Processing center	HAAS EC-400	1

Next, we calculate the equipment load factor for each operation of the designed technological process according to the formula:

$$K_{3i} = \frac{N_i}{N_{\text{прин.}}},$$

where Ku is the load factor of the equipment according to i - operation; Myryn. accepted as a result of the performed calculations, the amount of necessary equipment, units

We calculate the costs for the purchase of equipment, which is necessary to ensure the annual production program of the production of products. With we use data on equipment prices that are published in the media, in directories, etc.

Calculation of costs for each model (type) of equipment should be carried out using the formula:

$$\Pi_{\text{уст}_i} = K_{\text{уст}_i} \cdot \Pi_{\text{од. уст}_i},$$

Where T sust, - costs for each model (type) of equipment that is intended for execution and - operations of the technological process, thousand hryvnias; Kust is a coefficient that takes into account additional costs of addition, installation and debugging works on putting new equipment into operation, thousand UAH.; Add. mouth: - costs for the purchase of a unit of a certain model (type) of equipment, thousand UAH.

For the vast majority metalworking equipment size coefficient Kust, can be taken within Kust, = 1.15 ÷ 1.25. At the same time, more value Kust, should be used for more complex and larger equipment models.

The results of cost calculations for the purchase of the main equipment are listed in Table 4.8.

Table 4.8 - Costs for the purchase of equipment

No	The name of the equipment	Type (model) of equipment	Accepted amount of Upryn equipment, units	The price of a unit of the equipment. Price: UAH 12,000	Total Acquisition Costs equipment, thousand hryvnias (5×4)
1	2	3	4	5	6
1	Multipurpose	Horizontal machining center HAAS EC-400	1	1200000	1200000
2	Multipurpose	Horizontal processing center HAAS EC-400	1	-	-

Annual depreciation deductions for the renovation of the main equipment should be calculated according to the formula:

$$A = \sum_{i=1}^n \frac{U_{ycmi} \cdot H_{ai}}{100},$$

$$A_1 = \frac{1200000 \cdot 0.1}{100} = 1200 \text{ грн}$$

Where A is annual depreciation deductions for renovation the main the equipment that is used in the technological process of manufacturing the product under development, thousand hryvnias; Cost - costs for the purchase of the i-th unit of the main equipment, UAH thousand; On; - depreciation rates of the i-th unit of the main equipment, %; n - the number of equipment units.

The results of calculations of annual depreciation deductions for depreciation of the main equipment should be entered in table 4.9.

Table 4.9 - Annual depreciation deductions for the renovation of the main equipment

No	The name of the equipment	Type (model) of equipment	Accepted amount of equipment, units.	Annual depreciation deductions per unit of equipment, thousand UAH	The total amount of annual depreciation deductions, thousand hryvnias (5x4)
1	2	3	4	5	6
1.	Horizontal processing center	HAAS EC-400	1	1.2	1.2
	-	-	7	-	

The amount of annual depreciation deductions, which unit cost of the product should be calculated according to the formula:

$$AM_{yct} = \frac{A \cdot K_{yct}}{V},$$

$$AM_{ycm} = \frac{1200 \cdot 1}{5000} = 2.4 \text{zph}$$

Where V is the production program of products, nature. community; bush - the weighted average coefficient of use of the equipment used in the designed manufacturing process of the product:

$$K_{yct} = \frac{K_{yct_1} + K_{yct_2} + K_{yct_3} + \dots + K_{yct_n}}{n}$$

$$K_{ycm} = \frac{0,9}{1} = 1$$

4.7. Calculation of costs of the figure "General production costs" (Vg.v.).

General production costs are expenses for management, production and economic maintenance within the workshop (production). This includes salary expenses with deductions for the social needs of shop management workers, specialists, service personnel, depreciation deductions for buildings and structures, funds for their maintenance, repair, labor protection and not. The amount of expenses under the article "General production expenses" can be performed using a simplified method, in this case, the amount of these expenses should be calculated according to formulas:

$$B_{\text{зг.в.}} = K_{\text{зг.в.}} \cdot (3\Pi_{\text{очн}} + 3\Pi_{\text{доп}}),$$
$$B_{\text{зг.в.}} = 1,5 \cdot (3.676 + 0,441) = 6,175 \text{ грн}$$

Where Kzg.v. - coefficient of general production costs. When performing diploma projects, it is possible to recommend the value of this coefficient Kg.v. = 1.5 ÷ 1.8.

4.8. Calculation of costs under the article "General economic costs" (Ug.g.).

General economic costs are the same as general production costs, only at the level of the enterprise as a single system. In addition, they include costs for recruiting and training personnel, business trips, mandatory payments (property insurance, payments for environmental pollution, etc.), interest payments on loans, etc.

The amount of expenses under the heading "General economic expenses" can also be performed similarly general production costs, i.e. also according to the requested methodology. That is, the amount of general economic expenses can be calculated by the formula:

$$B_{\text{зг.г.}} = K_{\text{зг.г.}} \cdot (3\Pi_{\text{очн}} + 3\Pi_{\text{доп}}),$$
$$B_{\text{зг.г.}} = 2,3 \cdot (3,676 + 0,441) = 9,4691 \text{ грн}$$

Where Kg.g. - coefficient of general economic expenses. When performing diploma projects, it is possible to recommend the value of this coefficient Kg.v. = 2.1 ÷ 2.3.

4.9. Calculation of costs under the article "Preparation and development of production of new products" (New).

These costs are debited to products in equal shares for the established the period of their reimbursement. Costs for the preparation and development of new products in serial and mass production according to the adopted procedure are financed from profits or from extra budgetary funds for financing science and technology.

The amount of expenses under the article "Preparation and development of the production of new products" can also be carried out using a simplified method. That is, the value of these costs can be calculated using the formula:

$$B_{\text{HOB}} = K_{\text{HOB}} \cdot B_{\text{ЗГ.Г.}},$$
$$B_{\text{HOB.}} = 0,15 \cdot 9.4691 = 1,42 \text{ грн}$$

Where K_{HOB} is the coefficient of costs for the preparation and development of production and new products. When performing diploma projects, it is possible to recommend the value of this coefficient $K_{\text{ЗГ.В.}} = 0.12 \div 0.15$.

4.10. Calculation of costs under the article "Non-production costs" (Vpoz).

The article "Non-production costs" includes costs for market research, advertising and product sales. Some of these costs are direct and can be calculated directly for individual products (costs on containers, packaging, advertising, transportation, to a certain area of the market). Indirect costs (for market analysis, commission payments to sales organisations, holding fairs, etc.) are distributed among products in proportion to their production cost.

The magnitude costs per article "Non-production costs" can also be carried out using a simplified method. That is, the value of these expenses can be calculated in diploma projects according to the formula:

$$B_{\text{ПОЗ}} = K_{\text{ПОЗ}} \cdot (B_{\text{ЗГ.В.}} + B_{\text{ЗГ.Г.}}),$$
$$B_{\text{ПОЗ.}} = 0,06 \cdot (6.175 + 9.4691) = 0,938 \text{ грн}$$

Where $K_{\text{ПОЗ}}$ - coefficient of non-production costs. When completing diplomas projects, it is recommended to choose the value of this coefficient $K_{\text{ПОЗ}} = 0.05 \div 0.06$.

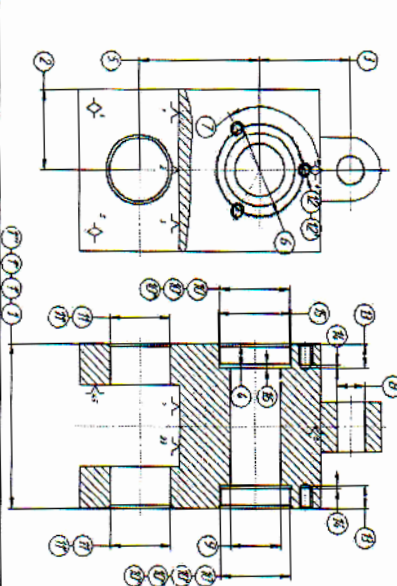
4.11. Calculation of the full unit cost of the product according to the designed technological process (S nov/povn).

Full cost calculations units product according to the designed technological process should be included in the final comparative table 4.10, which takes into account the calculations that were in sections 1 ÷ 10.

Table 4.10 - Comparative table of unit cost of the product according to the basic and designed technological process

No	Nomenclature of costing items Costs	Conventional designation	Amount of expenses, hryvnias	Specific weight of costs, %
1	2	3	4	5
1.	Raw materials and materials	V _m	5.591	7.8
2.	Fuel and energy for technological purposes	V _{en}	15.13	21.1
3.	Basic wages of producers	F _{om}	3.676	5.1
4.	Additional wages of producers	Z _{P addn}	0.441	0.6
5.	Deductions for the social needs of producers	V _{sots}	1.605	2.2
6.	Expenses for maintenance and operation of machines and equipment	mouth	27.191	37.9
7.	Total expenditures	According to	6.175	8.6
8.	General economic expenses	According to	9.46	13.2
9.	Costs for preparation and mastering the production of new products	A _{gain}	1.42	1.9
10.	Non-production costs	Γ _{Rep}	0.938	1.6
-	Full cost (1+2+3+4+5+6+7+8+9+10)	S _{baz} - full	71.627	100

Cutting processing.

GOST 3.1404-86 Form 2									
Dub.									
Acting Sub									
Product									
Development normalized									
Start TV									
Approval									
N. contr.									
Moati Ali		NTUU "KPI" gr. MT-93		pressure		DPB		005	
The name of the operation				Material					
Multi-purpose with ChPK				C425 GOST 1412-85					
Hardness		OB	Md	Profile and dimensions		4.3		KOVD	
HB 250		166	3.74	150 x 80 x 75				1	
Equipment, a device of the ChPK				Designation of the program					
Horizontal machining center ES-400				MOP					
Then		And	Tp2	Tsht					
8.78				8.78					
									
P			nl	So that in	L	t	i	S	V
001	1. Mill the vertical virgin surface 01 beforehand, maintaining size 1.								
T02	ABVH.XXXXXX.XXX. device P1; A B C D. XXXXXX.XXX.								
T03	A B C D. 391267.XXX End mill Ø50 VK8 GOST 26595-85 ABVG 391267.XX								
P04	75 1 1.25 2 0.3 1000 125								
005	2. Mill the vertical left surface 01 finally, maintaining the size 1.								
T06	ABVH.XXXXXX.XXX. device 11; ABVH.XXXXXX.XXX.								
T07	ABVH 391267.XXX End mill 050 VK8 GOST 26595-85 ABVH.391267.XXX								
P08	75 1 0.4 2 0.3 1000 125								
09									
010									
011									
OK	Cutting processing								

GOST 3.1404-86										Form 2a	
Dub.											
Acting											
Sub											
R											
012											
0013 3. Center the positions of the axes of the holes in sequence, maintaining dimensions 2,3,6,7.											
T014 ABVH.XXXXXXX.XXX. device P1; ABVH.XXXXXXX.XXX.											
T015 ABVH.391267.XXX Centering drill 05 GOST 14952-75											
P016											
O017	4. Drill a through hole, keeping dimensions 2,3,8.										
T018	ABVHXXXXXX.XXX. P1 device; ABVH.XXXXXXX.XXX.										
T 019	ABVH.391267.XXX Spiral drill Ø15 GOST 22736-77										
P020											
O021	5. Countersink the through hole, maintaining dimensions 2, 3,										
T022	9. ABVG.XXXXXXX.XXX. device P1; ABVH.XXXXXXX.XXX.										
T023	ABVH.391267.XXX Countersink Ø25 GOST 3231-71										
P024											
O025	6. Drill a hole in advance, keeping dimensions 2,5,11										
T026	ABVG.XXXXXXX.XXX. device P1; ABVH.XXXXXXX.XXX.										
T027	ABVH.391267.XXX Stop boring cutter Ø29										
P028											
029											
OK	Cutting processing										

[illegible]

GOST 3.1404-86										Form 2a		
Dub.	Acting	Sub								4	4	
R												
048												
0049	11. Drill the hole cleanly, maintaining the dimensions of 2,5,10°											
T050	ABVH.XXXXXX.XXX device P1; ABVH.XXXXXX.XXX											
	T051 ABVH 391267.XXX Stop boring cutter 034.90											
P052												
	0053 12. Drill the hole completely, maintaining the dimensions of 2, 5, 10".											
T054	ABVG.XXXXXX.XXX device P1; ABVG.XXXXXX.XXX.											
	T055 ABVH 391267.XXX Stop boring cutter 035											
P056												
0057	13. Removal of chatters while maintaining dimensions 2,5,11°, 2,3,10°, 2,3,7,12.											
T058	A B C D. XXXXXX.XXX. device P1; A B C D.											
	XXXXXX.XXX. T059 ABVH 391267. XXX Resist boring cutter 038											
P060												
0061	14. Cut the cut, maintaining the dimensions of 2,3,6,7,14,12°.											
T062	ABVH.XXXXXX.XXX. device P1; A B C D. XXXXXX.XXX.											
	T063 ABVH 391267. XXX Disc cutter M5-7N GOST 1604-71											
P064												
065												
OK	Cutting processing											

GOST 3.1404-86										Form 2a			
Dub.													
Acting													
Sub													
R													
001													
0002 1. Mill the vertical left surface 01 beforehand, maintaining the size 1".													
T003 ABVH.XXXXXX.XXX. device P1; ABVG.XXXXXX.XXX.													
T004													
P005													
ABVH.391267.XXX End mill Ø50 VK8 GOST 26595-85 ABVH 391267.XX													
0006 2. Mill the vertical left surface 01 finally, maintaining the size of 1".													
T007 ABVH.XXXXXX.XXX. device P1; ABVH.XXXXXX.XXX.													
T008													
P009													
ABVH.391267.XXX End mill Ø50 VK8 GOST 26595-85 ABVH.391267.XXX													
0010 3. Center the positions of the axes of the holes in sequence, maintaining dimensions 2,3,6,7,													
T011													
ABVG.XXXXXX.XXX. device P1; A B C D. XXXXXX.XXX.													
T012													
P013													
ABVH.391267.XXX Centering drill Ø5 GOST 14952-75													
0014 4. Drill a hole beforehand, keeping the dimensions 2,5,11													
T015													
A B C D. XXXXX.XXX. device P1; ABVH.XXXXXX.XXX.													
T016													
P017													
ABVH.391267.XXX Stop boring cutter Ø29													
P018													
20 20 1 1 Ø.5 630 75.4													
OK													
Cutting processing													

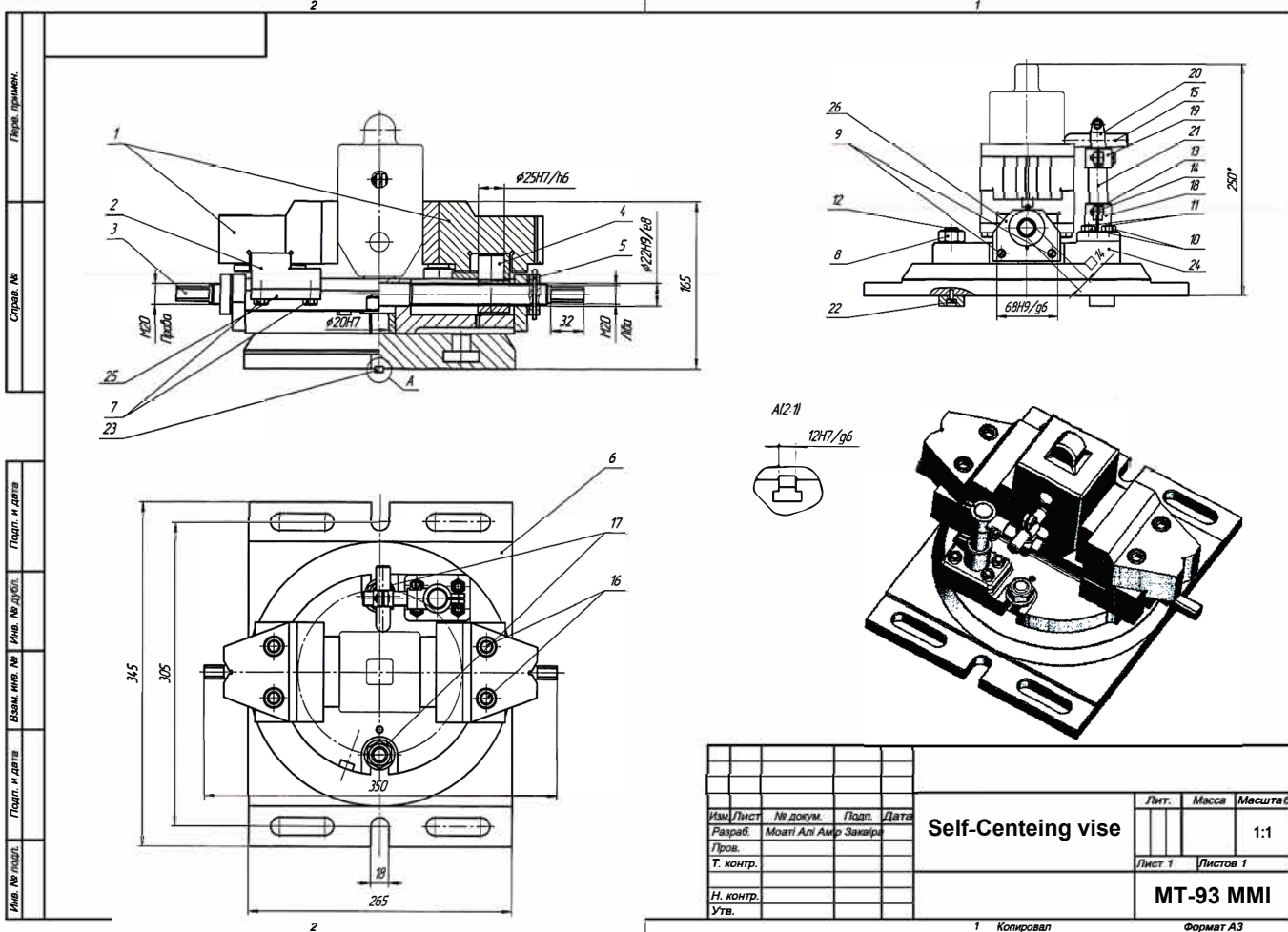
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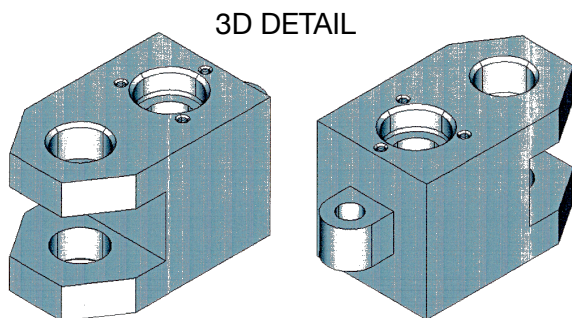
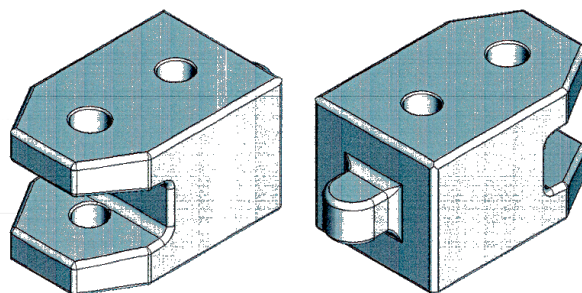
GOST 3.1406-86		Form 3									
Dub.											
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Deputy											
				Amendment Letter No. document. Deputy Date Amd.							
				MT-93							
				Letter No Deputy Yes and document							
Developer	Moati Ali										
Checked								010			
Utr.	Glasky										
N. counter.											
				pressure							
Cutting processing											
what											

/ First application											
Affairs No	A1		MT-93 MMI		Documentation						
					Assembly drawing		1				
					Standard Products						
		1			Sponge GOST 21168-75		2				
		2			Carriage GOST 21168-75		2				
		3			Screw GOST 21168-75		1				
		4			Nut GOST 21168-75 2						
		5			Splint GOST 397-79		2				
		6			Swivel base type 6587 1 Bolt						
		7			GOST 7796-70		8				
		8			Nut GOST 15526-70		2				
		9			Screw 1491-80		4				
		10			GOST 5915-70 nut		4				
		11			GOST 50796-95 bolt		4				
		12			Bolt GOST 7796-70 2						
		13			Screw GOST 1491-80		5				
		14			GOST 5927-70 nut		5				
		15			Stop special Screw		1				
		16			GOST 11738-72		4				
	Deputy and date		17			Washer GOST 10450-78		2			
			18			Angle clamp 29010		1			
		19			Angle clamp 29006		1				
		20			Cross-shaped clamp 29000		1				
		21			Round tube 29050		1				
Deputy and date Acting inv. No. Inv. duplicate number	Format	Zone	/103.	Designation		Name		Kanz	Note		
Inv. ext. no.	Amendment Letter	/No. until	Deputy	Date	MT-93 MMI						
	Developer	Moati Ali									
	Prov	Gladskyi M.M.									
	H.KOHMO										
	Approved										
Specification					Lit	Letter	Listov				
						1	2				
					NTUU "KPI" /MM, MT-93						

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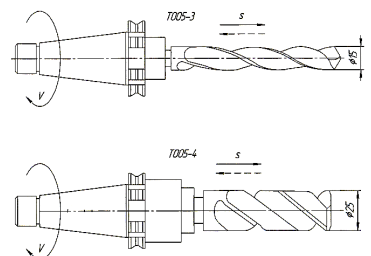
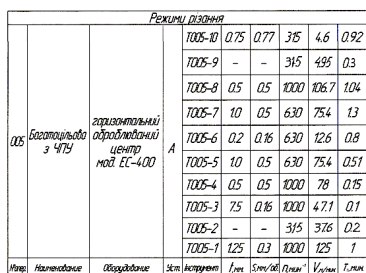
A4 format





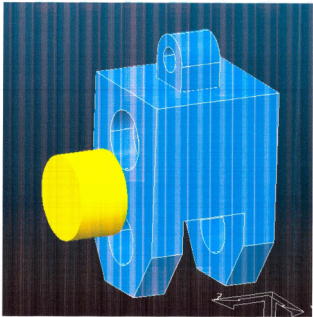
Матеріал	Границя міцності при розтягні кгс/мм ²	Границя міцності при стиску кгс/мм ²	Твердість НВ
С425 ГОСТ 14.12-85	25	40	250

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[illegible]

Generating G-code using the "Power MILL"

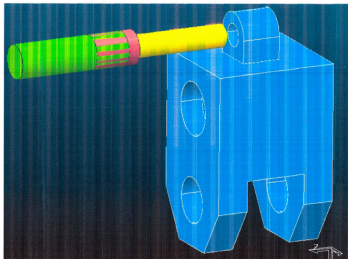
Transition 005.01 milling



Part of the control program:

014.0512 Y345.372
T01 M06 X60.8043
G90 Y330.372
M03 X180.804
S200 G00 Z33
F50 M09
M08 M11
G00 Z33 M02
X180.804 Y375.372 M30
G01 Z19
X180.804 Y375.372
X60.8043
Y360.372
X180.804

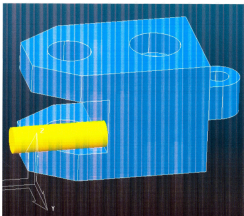
Transition 005.04 Drilling



Part of the control program:

0170512 X258.029
T02 Y514.414
G90 X333.029
G54 Y506.414
M03 X258.029
S200 Y498.414
F50 X333.029
G00 Z33 G00 Z33
M08 M11
X333.029 Y522.414 M09
G01 Z19 M02
X333.029 Y522.414 M30

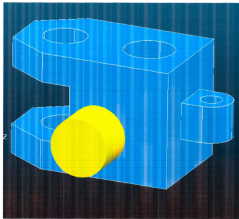
Transition 010.70 milling



Part of the control program:

0150512 Y506.414
T03 M06 X258.029
G90 Y498.414
G54 X333.029
M03 G00 Z33
S200 M11
F50 M02
G00 Z33 M30
X333.029 Y522.414
G01 Z19
X333.029 Y522.414
X258.029
Y514.414
X333.029

Transition 010.03 milling



Part of the control program:

0160512 X258.029
T04 M06 Y514.414
G90 X333.029
G54 Y506.414
M03 X258.029
S200 Y498.414
F50 X333.029
M08 G00 Z33
G00 Z33 M09
X333.029 Y522.414 M11
G01 Z19 M02
X333.029 Y522.414 M30

Изм.	Лист	№ докум.	Подп.	Дата	Лит.	Масса	Масштаб
Разраб.	Моветт Али Амир	Закайра					
Пров.							
Т. контр.					Лист 1	Листов 1	
Н. контр.							
Утв.							

Generating G-code using the "Power MILL" program

MT-93 MMI

Лист 1

Справ. №

Лист 1

Изм. №

Взам. инв. №

Лист 1

Изм. №

2

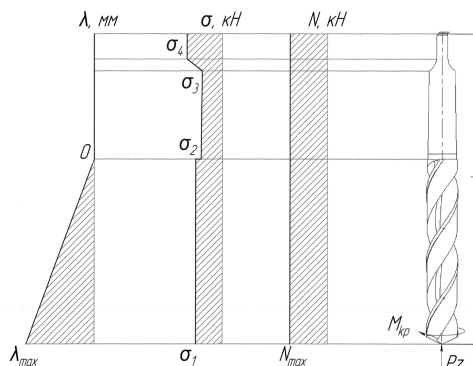
1 Копировал

Формат А3

$$\sigma_{\text{ex}} = \sqrt{\sigma^2 + 4\tau^2} \leq [\sigma]$$
$$\sigma = N_{\max} / F, \quad \tau = M_{\max}^{\max} / W_s$$
$$W_p = \frac{J_p}{D/\gamma} \quad J_p = J_z + J_y$$
$$\Delta l_i = \frac{N_i l_i}{E_i F_i}$$

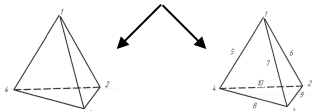
$$\lambda_0 = 0; \quad \lambda_{max} = \sum \Delta l_i$$

N-load diagram under the action of longitudinal force.

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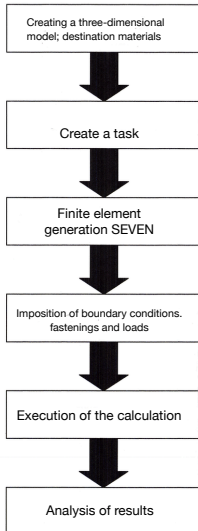
Static calculations on the strength of structures in the environment T - FLEX Analysis

Tetrahedral finite elements used in T-FLEX Analysis for modelling bulk clays:

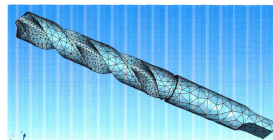
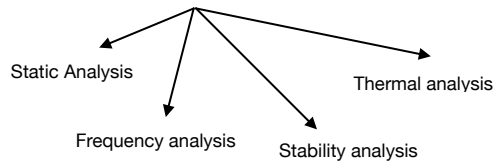


Linear, four-node
Quadratic, ten-knotted

Algorithm for performing static calculations on the strength of the system T-FLEX Analysis

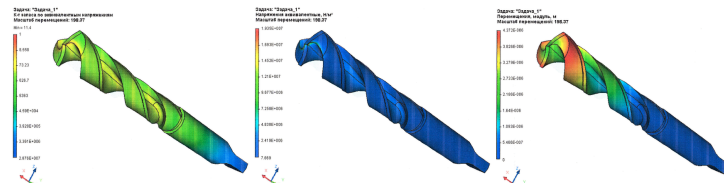
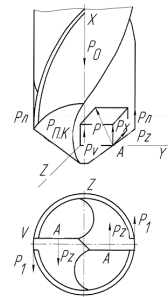


Calculation modules of the T-Flex system analysis:



Preparation for calculating the finite element model of the drill

Distribution of forces on the drill for machining a cylindrical hole



Reserve factor for equivalent stresses

Equivalent stress.

Movement, module

Изм.	Лист	№ докум.	Подп.	Дата	Analysis of drill loads and deformations		
Разраб.	Моатт Али Амир	Закайра					
Пров.					Лит. Масса Масштаб		
Т. контр.							
Н. контр.					Лист 1 Листов 1		
Утв.							
					MT-93 MMI		

1 Копировал

Формат А3

In conclusion, receiving my Manufacturing Engineering Diploma signifies the culmination of years of dedication, hard work, and unwavering commitment to my education. This achievement has equipped me with the knowledge, skills, and experiences necessary to excel in the field of manufacturing engineering.

As I embark on the next phase of my career, I am filled with a sense of excitement and readiness to contribute to the industry. I am confident in my ability to apply the principles and practices of manufacturing engineering to tackle complex challenges and drive innovation. The practical experiences and theoretical foundations I have acquired during this program have prepared me to navigate the ever-evolving landscape of manufacturing.

I am deeply grateful to the faculty and staff who have guided and supported me throughout this journey. Their expertise, guidance, and mentorship have been invaluable in shaping me into a well-rounded manufacturing engineer. I would also like to express my appreciation to my classmates and colleagues, whose collaboration and camaraderie have enriched my learning experience.

I am aware that success in the field of manufacturing engineering relies not only on technical expertise but also on effective communication, adaptability, and a commitment to continuous improvement. I am eager to embrace these qualities as I seek to make a positive impact in my future endeavours.

I would like to extend my heartfelt gratitude to my family and friends for their unwavering support and encouragement. Their belief in my abilities has been a driving force behind my accomplishments. I am grateful for their understanding during late nights of studying, missed social gatherings, and moments of stress.

Lastly, I recognise that this diploma is not the endpoint of my educational journey but rather a stepping stone towards lifelong learning and professional growth. I am committed to staying updated with the latest advancements in manufacturing engineering, exploring new technologies, and seeking opportunities for further education and skill development.

In conclusion, my Manufacturing Engineering Diploma represents more than just a piece of paper—it symbolises the dedication, perseverance, and passion that have brought me to this moment. I am excited to leverage my education and skills to contribute to the manufacturing industry, driving progress, innovation, and sustainable practices.

Thank you to everyone who has been a part of this incredible journey. I am proud to be a graduate of the Manufacturing Engineering Diploma program, and I am eager to embrace the challenges and opportunities that lie ahead.

Sincerely,

Moati Ali Al Amir Zakaria