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QUALIFYING PAPER

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topic: Development of the cover MA96F3.12.604 production process

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ABSTRACT

The qualification paper topic: “Development of the cover MA96F3.12.604 production process.” Student of group IMP-42 of Ternopil Ivan Puluj National Technical University Mikhail Kirolos Khana Kamel. Paper supervisor - Assoc. Prof., Diachun A.Ye.

Keywords: mechanical engineering, technological process, operation, drilling, milling, turning.

The purpose of the work is to improve the technology of the cover MA96F3.12.604 production with the appropriate justification.

To achieve this goal, the following tasks are solved.

In the first part the design features, application, technical requirements, manufacturability of cover MA96F3.12.604 are analyzed. The basic technological process was considered in detail.

In the second part the type of production is determined, the best option for the workpiece production – casting in metal forms is chosen. The synthesis of the technological route of part machining is realized, the allowances and operational dimensions are determined. Cutting tools, technological equipment and fixtures are selected. Calculations of cutting conditions are made.

In the third part the design and the principle of a special fixture operation for flat surface milling to dimension 125 ± 0.2 in the part are presented, its accuracy and power parameters are calculated.

In the fourth part the questions of safety measures are considered.

Relevant conclusions and a list of references are presented.

In the appendix the technological process for the cover MA96F3.12.604 manufacturing and specifications for the graphic part are presented.

CONTENTS

INTRODUCTION

In the bachelor’s qualification paper the technological process of the "Cover" MA96F3.12.604 machining is improved. The part is used in the machine for the beet-roots harvesting in the gearbox of the excavator.

It is made from gray cast iron SCh20 according to the drawing of the part.

The workpiece is produced by casting in metal mold, according to the type of production, material, as well as the condition of the economic effect obtaining.

The following basic parameters are used when developing the basic technological process of the part "Cover" MA96F3.12.604 machining at the enterprise for middle lot production: the universal adjusting fixtures are used as technological equipment for machining of the part; the universal metal-cutting equipment of normal accuracy is applied; the application of universal measuring instruments to control the accuracy and the roughness of machined surfaces; the use of universal standard cutting tools for the workpieces machining; the concentration of operations of the basic technological process corresponds to the lot type of production.

The following changes were made in the design of technological process in order to increase the productivity and efficiency of the part "Cover" MA96F3.12.604 machining: more efficient and accurate method of workpiece manufacturing - casting in metal forms is provided into the design technological process, which allows to reduce the amount of machining by cutting tools and, accordingly, the processing time; multispindle turning and drilling semiautomatic machine tools with the use of multi-tool adjustments for turning and drilling of surfaces is applied; the technological fixtures and cutting tools are replaced with the change of the technological equipment, thus it is possible to the use the combined tools, fixtures with the mechanized clamping systems.

1 GENERAL-TECHNICAL PART

1.1. Official purpose of the part

The part "Cover" MA96F3.12.604 is used in the machine for the beet-roots harvesting in the gearbox of the excavator.

The part "Cover" MA96F3.12.604 is made by casting of gray cast iron SCh 20 Standard 1412-85. The part drawing has all the necessary surfaces dimensions, as well as the designation of roughness in the range from Ra 6.3 to Rz 200. Surfaces that are not machined have a roughness of Rz 200.

The main surfaces of the part that are important in its application include the following surfaces: Ø80H9$^{(+0.074)}$; Ø100h9$^{(-0.087)}$. These surfaces are basic for performing an assembly operation of gearbox.

When classifying parts according to structural characteristics, we take as a basis such features as: geometry of form, functional, parametric and structural features, as well as the official purpose of the part.

As mentioned above, the main surfaces of the part are two precise surfaces Ø80H9$^{(+0.074)}$, Ø100h9$^{(-0.087)}$ and two end faces of size 8 ± 1.5 mm. The secondary surfaces include all surfaces remaining: 4 holes Ø 11 mm are used for connecting the cover to the gearbox housing, holes Ø 88 and Ø 68 are used for placing rings and sealing, groove 14 is used for guiding fixing mechanism.

According to the ESKD classifier [2], this part belongs to class 71.

The remaining surfaces are considered as auxiliary and secondary.

The part "Cover" MA96F3.12.604 is made from gray cast iron SCh20 Stardard 1212-85 (according to the data taken from the drawing of the part).

The chemical composition, mechanical properties and technological properties of the material are presented in the following tables [3].

Table 1.1 - Chemical composition of gray cast iron SCh20, %

C	Si	Mn	P	S
3.3-3.5	1.4-2.2	0.7-1.0	0.20	0.15

Note: Low alloying with various elements (chromium, nickel, copper, titanium, etc.) is allowed.

Table 1.2 - Mechanical properties of gray cast iron SCh20

σ_{sg}, MPa	σ_{B}, MPa	σ_{zzh}, MPa	$\tau_{зж}$, MPa	ρ, g / cm^3	Deflection, mm at the distance between the supports	
					600	300
420	200-250	16	40	7.2	9.0	3.0

Technological properties of gray cast iron SCh20.

Cast iron has good antifriction properties, high wear resistance and high damping properties. Gray cast iron is a technological metal. Its melt has good fluidity, low ability to form defects. It can be used to make castings of the most complex configuration with a wall thickness of 2 to 500 mm.

Gray cast iron is used for the manufacture of: housings, walls, frames, covers, supports and more. It is a hard-to-weld metal.

1.2. The analysis of technical requirements for the product

After a detailed study of the drawing of the part, dimensional accuracy, surface roughness, their relative position and shape accuracy, each of the surfaces is assigned serial numbers and analysis of technical requirements set by the designer, which is presented in the table 1.3.

Table 1.3 - Analysis of technical requirements

Surface number	Technical requirements	Method of execution	Control method
1	2	3	4
1	End surface Ra 12.5; 19±0.2	Semifinish end turning	Vienier caliper
2, 4	Internal chamfer 1.5×45°±2°; Ra 25	Singl boring	The template for chamfer 1.5×45°
3	Internal chamfer ∅ 88 mm, h=1.5 mm, R2, Ra 12.5	Semifinish boring with a radial cutter	Vienier caliper Template radial (R2)

Continuation of the table 1.3

1	2	3	4
5	Hole ∅ 80H9 ($^{+0.074}$) l=10.5mm, Ra 6.3 | ◎ | ∅ 0.06 | A |	Finish boring	Vienier caliper Roughness patterns Plug gage (∅80) 8136-0011H9 Standard 14815-69 Special caliber for concentricity control
6	External chamfer 1.5×45º±2º; Ra 25	Singl turning	The template for chamfer 1.5×45º
7	External cylindrical surface ∅ 100h9 ($_{-0.087}$); l = 6 mm; Ra 6.3; | A |	Finish turning	Vienier caliper Roughness patterns Snap gage (∅100) 8113-0288H9 Standard 14815-69
9… 12	Holes ∅ 11H14 A = 120±0.28 mm, Ra 25	Drilling on the jig simultaneously	Special caliber for placement Plug gage (∅11) 8133-0922H14 Standard 14810-69
16	Hole ∅ 68H14, Ra 25	Singl boring	Vienier caliper
17	Flat surface 125mm, l =8±0.2 mm, Ra 6.3	Semifinish milling	Vienier caliper Roughness patterns
18	End surface Ra 12.5; 6 mm; 8 ± 0.2mm	Semifinish turning with use of uniform technological locating elements	Vienier caliper Runout control device Indicator Standart 577-68; Support Standard 10197-70
19	Side recess 14mm, l = 17 ± 0.2 mm, h =4 mm, Ra 12.5	Milling with the end milling cutter	Roughness patterns Vienier caliper

1.3. The analysis of part construction manufacturability

The design of the part "Cover" MA96F3.12.604 is not complicated and does not require simplification or change, even if the type of production is changed.

The material of the part is gray cast iron SCh20. It corresponds to the technical requirements for the part and the operating conditions of the cover in the unit. The workpiece is obtained by casting, according to the type of production, material, as well as the condition of obtaining an economic effect.

Additional artificial technological locating elements are not required for machining of a part, thus external and internal cylindrical and end face surfaces of a part are applied for location. The design of the part has no particularly precise, hard-to-reach and difficult-to-machine surfaces. There is a sufficient access for control tools use. For manufacture of the parts it is possible to use high-performance specialized and special equipment and fixtures. So, the part is technological.

Quantitative assessment of the manufacturability of the part was performed on the basis of the coefficient of machining accuracy, the surface roughness coefficient, the coefficient of unification.

To determine the indicators of manufacturability of the part "Cover" MA96F3.12.604 numerical data from table 1.4 were used.

Table 1.4. – The quantitative indicators of manufacturability

Surface number	Quantity of surfaces	Number of unified surfaces	Surface finish	Roughness	Roughness class
1	2	3	4	5	6
End surface Ra 12.5; 19±0.2	1	1	14	Ra 12.5	3
Internal chamfer 1.5×45°±2°; Ra 25	2	2	14	Ra 25	2
Internal chamfer ∅ 88 mm, h=1.5 mm, R2, Ra 12.5	1	1	14	Ra 12.5	3
Hole ∅ 80H9 ($^{+0.074}$) l=10.5mm, Ra 6.3	1	1	9	Ra 6.3	4
External chamfer 1.5×45°±2°; Ra 25	1	1	14	Ra 25	2
External cylindrical surface ∅ 100h9 ($_{-0.087}$); l = 6 mm; Ra 6.3	1	1	9	Ra 6.3	4
Holes ∅ 11H14 A = 120±0.28 mm, Ra 25	4	4	14	Ra 25	2

Continuation of the table 1.4

1	2	3	4	5	6
Hole ∅ 68H14, Ra 25	1	1	14	Ra 25	2
Flat surface 125mm, l = 8±0.2 mm, Ra 6.3	1	1	12	Ra 6.3	4
End surface Ra 12.5; 6 mm; 8 ± 0.2mm	1	1	14	Ra 12.5	3
Side recess 14mm, l = 17 ± 0.2 mm, h =4 mm, Ra 12.5	1	-	14	Ra 12.5	3
Total	15	14			

The value of the coefficient of machining accuracy of the part "Cover" MA96F3.12.604 was calculated.

$$К_{т.ч.} = 1 - \frac{1}{Т_{ср}},$$

$$Т_{ср} = \frac{\sum Т_i \cdot n_i}{\sum n_i} = \frac{14 \cdot 12 + 12 \cdot 1 + 9 \cdot 2}{15} = 13.2,$$

$$К_{Т.Ч.} = 1 - \frac{1}{13.2} = 0.92.$$

If $К_{тч}$ = 0.92> 0.8, then the "Cover" MA96F3.12.604 is technological.

The value of the surface roughness coefficient of the part "Cover" MA96F3.12.604 was calculated.

$$К_{ш} = \frac{1}{Б_{ср}},$$

$$Б_{ср} = \frac{\sum Б_i \cdot n_i}{\sum n_i} = \frac{4 \cdot 3 + 3 \cdot 3 + 2 \cdot 8}{14} = 2.64,$$

$$К_{ш} = \frac{1}{2.64} = 0.38.$$

If $К_{ш}$ = 0.38> 0.16, then the "Cover" MA96F3.12.604 is technological.

The value of the coefficient of unification of the structural elements of the part "Cover" MA96F3.12.604 was calculated.

$$К_{y.e.} = \frac{N_{y.e}}{N_e} = \frac{14}{15} = 0.93,$$

If $К_{ye}$ = 0.93> 0.6, then the "Cover" MA96F3.12.604 is technological.

Based on quantitative and qualitative analysis, it is established that the part "Cover" MA96F3.12.604 is technological and there is not need to change its design, accuracy and roughness of the surfaces to be machined.

1.4 The basic technological process analysis

The table 1.5 was formed to analyze the basic technological process of the part "Cover" MA96F3.12.604 manufacturing

Table 1.5 - The basic technological process analysis

Operation	Technological equipment	Technological jig and fixture
1	2	3
005 Turning	Turret lathe 1641	Three jaw chuck with pneumatic clamping
010 Vertical milling	Vertical milling machine tool 6P10	The special fixture with pneumatic clamping
015 Vertical drilling	Vertical drilling machine tool 2H118	The special jig
020 Vertical milling	Vertical milling machine tool 6P10	The special fixture with pneumatic clamping

The following basic parameters are used when developing the basic technological process of the part "Cover" MA96F3.12.604 machining at the enterprise for middle lot production:

- the universal adjusting fixtures are used as technological equipment for machining of the part;

- the universal metal-cutting equipment of normal accuracy is applied;

- the application of universal measuring instruments to control the accuracy and the roughness of machined surfaces;

- the use of universal standard cutting tools for the workpieces machining;

- the concentration of operations of the basic technological process corresponds to the lot type of production.

1.5. Conclusions and tasks to qualification paper

The part "Cover" MA96F3.12.604 is technological in accordance with the analysis, which is confirmed by the qualitative and quantitative indicators. In the design of the part particularly precise, hard-to-reach and difficult-to-machine surfaces are not included. There is sufficient access for the use of cutting tools and control instruments.

The requirements for the quality of the part "Cover" MA96F3.12.604 surfaces are provided by the basic technological process, and there is a need to improve it due to changes in the type of production.

In the design process it is necessary to make the following changes in order to increase the productivity and efficiency of the part "Cover" MA96F3.12.604 machining:

- the providing into the design technological process of a more efficient and accurate method of workpiece manufacturing – casting in metal forms, which allows to reduce the amount of machining by cutting tools and, accordingly, the processing time;

- for turning and drilling of surfaces it is expedient to apply multispindle turning and drilling semiautomatic machine tools with the use of multi-tool adjustments;

- the technological fixtures and cutting tools will be replaced with the change of the technological equipment, thus there is a possibility of the use of the combined tools, fixtures with the mechanized clamping systems.

2 TECHNOLOGICAL PART

2.1. The type of production determining

The type of production is determined on the basis of the task, the annual program of production N = 100000 pcs. and parts "Cover" MA96F3.12.604 weight m = 0.65 kg from standard tables, and on the basis of these data the type of production is the high lot production.

The calculation-analytical method was also used to calculate the type of production.

The type of production is determined by the coefficient of operations assignment [1]:

$$K_{з.о.} = \frac{\sum O}{\sum P}, \tag{2.1}$$

where ΣO – the total number of operations on the shop department;
ΣP – the total number of working stations on the shop department.

The data of the basic technological process are recorded in the table 2.1.

Table 2.1– Staff time of the basic technological process

Operation	Tp (Tcal) min.	Operation	Tp (Tcal) min.	Operation	Tp (Tcal) min
005 Turning	8.75 min.	010 Vertical milling	1.16 min.	015 Vertical drilling	0.87 min.
020 Vertical milling	1.3 min.				

The number of machines for each operation according to [1] is determined:

$$m_p = \frac{N \cdot T_p}{60 \cdot F_д \cdot \eta_{зн}}, \tag{2.2}$$

where N – annual program of production, pcs. N = 100000 pcs., $F_Д$=3979 hours for two shifts, $\eta_{з.н.}$=0.75 for lot type of production.

After determining the number of machines for each operation $m_р$, the number of workplaces P as integers is determined

$$m_{p005} = \frac{100\ \ 000 \cdot 8.75}{60 \cdot 3979 \cdot 0.75} = 4.88.\ P_{005} = 7 \text{ machine tools.}$$

$$m_{p010} = \frac{100\ \ 000 \cdot 0.87}{60 \cdot 3979 \cdot 0.75} = 0.49.\ P_{010} = 1 \text{ machine tool.}$$

$$m_{p015} = \frac{100\ \ 000 \cdot 1.16}{60 \cdot 3979 \cdot 0.75} = 0.65.\ P_{015} = 1 \text{ machine tool.}$$

$$m_{p020} = \frac{100000 \cdot 1.3}{60 \cdot 3979 \cdot 0.75} = 0.73.\ P_{020} = 1 \text{ machine tool.}$$

The actual load factor of the workplace is calculated [1]:

$$\eta_{з.ф.} = \frac{m_P}{P}, \qquad (2.3)$$

$$\eta_{з.ф.005} = \frac{4.88}{7} = 0.7;$$

$$\eta_{з.ф.010} = \frac{0.498}{1} = 0.49;$$

$$\eta_{з.ф.015} = \frac{0.65}{1} = 0.65;$$

$$\eta_{з.ф.020} = \frac{0.73}{1} = 0.73.$$

The number of operations in the workplace, rounding to an integer is calculated [1]:

$$O = \frac{\eta_{з.н.}}{\eta_{з.ф.}}, \qquad (2.4)$$

$$O_{005} = \frac{0.75}{0.70} = 1.07.\ O_{005} = 2 \text{ operations.}$$

$$O_{010} = \frac{0.75}{0.49} = 1.53. \ O_{010} = 2 \text{ operations.}$$

$$O_{015} = \frac{0.75}{0.65} = 1.15. \ O_{015} = 2 \text{ operations.}$$

$$O_{020} = \frac{0.75}{0.73} = 1.03. \ O_{020} = 2 \text{ operations.}$$

The coefficient of operations assignment $К_{з.о.}$ is calculated by formula (2.1):

$$К_{з.о.} = \frac{\sum O}{\sum P} = \frac{2+2+2+2}{7+1+1+1} = 0.8.$$

Thus, based on the calculation-analytical method, the type of production is the mass production.

Release rate $t_В$ [1]:

$$t_в = \frac{60 \cdot F_д}{N} = \frac{60 \cdot 3979}{100\ 000} = 2.38 \text{ min.}$$

2.2. Selection of the workpiece production method

The comparison of two methods was made for the workpiece production of the part "Cover" MA96F3.12.604:

- the first method - casting in metal molds.

- the second method - casting in sand molds using machine forming.

According to the appendix in [1] we established for these two methods of workpiece production classes of accuracy of the sizes and masses, series of allowances for castings machining.

So, for the casting in a metal molds: classes of accuracy of the sizes and masses - 6 class; the number of allowances for machining - 2.

For casting in sand molds using machine forming: classes of accuracy of sizes and masses - 10 class; the number of allowances for machining - 3.

The mass of the workpiece was determined by the formula:

$$Q = V_{заг} \cdot \rho . \qquad (2.5)$$

Estimated total tabular allowances are presented in table 2.2.

Table 2.2 - General allowances

Machined surface, its dimension, accuracy	Surface roughness, μm	Workpiece tolerance, mm	General allowance, mm	Workpiece dimension with deviations
1	2	3	4	5
1) Casting in metal molds				
External cylindrical surface ∅ 100h9 ($_{-0.087}$); l = 6 mm; Ra 6.3	Ra 6.3	0.8	1.8 × 2 = 3.6	∅ 103.6±0.8
Hole ∅ 80H9 ($^{+0.074}$) l=10.5mm, Ra 6.3	Ra 6.3	0.7	1.8 × 2 = 3.6	∅ 76.4±0.7
Hole ∅ 68H14. Ra 25	Ra 25	0.7	1.3 × 2 = 2.6	∅ 65.4±0.7
Flat surface 125mm, l =8±0.2 mm, Ra 6.3	Ra 6.3	0.8	1.6	126.6±0.8
End surface Ra 12.5; 19±0.2	Ra 12.5	0.5	1.1	20.1±0.5
End internal surface 12 mm	Ra 12.5	0.5	1.1	10.9±0.5
End surface Ra 12.5; 6 mm; 8 ± 0.2mm	Ra 12.5	0.4	1.0	9±0.4
2) Casting in sand molds using machine forming				
External cylindrical surface ∅ 100h9 ($_{-0.087}$); l = 6 mm; Ra 6.3	Ra 6.3	3.2	5.5 × 2 = 11	∅ 111±3.2
Hole ∅ 80H9 ($^{+0.074}$) l=10.5mm, Ra 6.3	Ra 6.3	2.8	4.5 × 2= 9.0	∅ 71±2.8
Hole ∅ 68H14. Ra 25	Ra 25	2.8	3.6 × 2 = 7.2	∅ 60.8±2.8
Flat surface 125mm, l =8±0.2 mm, Ra 6.3	Ra 6.3	3.2	4.2	129.2±3.2

Continuation of the table 2.2

1	2	3	4	5
End surface Ra 12.5; 19±0.2	Ra 12.5	2.0	2.8	21.8±2.0
End internal surface 12 mm	Ra 12.5	2.0	2.8	9.2±2.0
End surface Ra 12.5; 6 mm; 8 ± 0.2mm	Ra 12.5	1.6	2.4	10.4±1.6

The volume of the workpiece for the first method of the workpiece production was determined by the formula:

$$V = \frac{\pi \cdot d^2 \cdot H}{4}.$$

Elementary volumes of the workpiece:

$$V_1 = \frac{\pi \cdot 14^2 \cdot 0.8}{4} = 123 \quad sm^3;$$

$$V_2 = \frac{\pi \cdot 9.36^2 \cdot 0.61}{4} = 42 \quad sm^3;$$

$$V_3 = \frac{\pi \cdot 8.6^2 \cdot 0.5}{4} = 29.03 \quad sm^3;$$

$$V_4 = \frac{\pi \cdot 7.64^2 \cdot 1.5}{4} = 68.7 \quad sm^3;$$

$$V_5 = \frac{\pi \cdot 6.54^2 \cdot 0.4}{4} = 13.4 \quad sm^3;$$

$$V_{заг} = V_1 + V_2 + V_3 + V_4 - V_5 - V_6;$$

$$V_{заг} = 123 + 42 + 29.03 - 68.7 - 13.4 = 112 \quad sm^3.$$

The volume of the workpiece for the second method of the workpiece production was determined:

$$V_1 = \frac{\pi \cdot 14^2 \cdot 1.04}{4} = 160 \quad sm^3;$$

$$V_2 = \frac{\pi \cdot 11.1^2 \cdot 0.64}{4} = 62 \quad sm^3;$$

$$V_3 = \frac{\pi \cdot 8.6^2 \cdot 0.5}{4} = 29.03 \quad sm^3;$$

$$V_4 = \frac{\pi \cdot 7.1^2 \cdot 1.5}{4} = 59 \quad sm^3;$$

$$V_5 = \frac{\pi \cdot 6.08^2 \cdot 0.4}{4} = 11.6 \quad sm^3;$$

$$V_{заг} = V_1 + V_2 + V_3 + V_4 - V_5 - V_6;$$

$$V_{заг} = 160 + 62 + 29.03 - 59 - 11.6 = 180.43 \quad sm^3.$$

The masses of the workpieces for the two methods were determined

$$Q_1 = 112 \cdot 7.2 = 806 \quad g = 0.81 \quad kg;$$

$$Q_2 = 180.43 \cdot 7.2 = 1300 \quad g = 1.3 \quad kg.$$

The materials utilization rates

$$К_{в.м.} = \frac{q}{Q}, \qquad (2.6)$$

- for casting in metal molds:

$$К_{В.М.1} = \frac{0.65}{0.81} = 0.8.$$

– for casting in sand molds using machine forming:

$$К_{В.М.2} = \frac{0.65}{1.3} = 0.5.$$

The method of the workpiece production by casting in metal molds was chosen due to the higher materials utilization rate for the designing of the technological process of cover manufacturing.

2.4. Design of the technological route of the part machining

The rational technological route of the part machining was selected by comparing two methods from table 2.4.

Table 2.4 – Methods of part machining

№ surface	Type of surface	Initial parameters of the part		Variants of methods and routes of surfaces machining	
		Surface finish	Rough-ness, μm	1	2
1	2	3	4	5	6
1	End surface Ra 12.5; 19±0.2	14	Ra 12.5	1. Semifinish turning	
2. 4	Internal chamfer 1.5×45°±2°; Ra 25	14	Ra 25	Single boring	
3	Internal chamfer ∅ 88 mm, h=1.5 mm, R2. Ra 12.5	14	Ra 12.5	Semifinish boring with a radial cutter	
5	Hole ∅ 80H9 ($^{+0.074}$) l=10.5mm, Ra 6.3	9	Ra 6.3	1. Semifinish boring 2. Finish boring	1. Core drilling 2. Rough reaming or 1. Semifinish boring 2. Reaming
6	External chamfer 1.5×45°±2°; Ra 25	14	Ra 25	Single turning	

Continuation of table 2.4

1	2	3	4	5	6
7	External cylindrical surface ∅ 100h9 ($_{-0.087}$); l = 6 mm; Ra 6.3	9	Ra 6.3	1. Semifinish turning 2. Finish turning	
8	External cylindrical surface ∅140; Rz 200	14	Rz 200	Not machined	
9…12	Holes ∅ 11H14 A = 120±0.28 mm, Ra 25	14	Ra 25	Drilling on the jig simultaneously	1. Centering 2. Drilling
13	End surface Rz200; 8±1.5mm	14	Rz200	Not machined	
14	Hole ∅ 86h14. Rz200	14	Rz200	Not machined	
15	End surface 19±0.2; Rz200	14	Rz200	Not machined	
16	Hole ∅ 68H14. Ra 25	14	Ra 25	Single boring	Drilling-out
17	Flat surface 125mm, l = 8±0.2 mm, Ra 6.3	14	Ra 6.3	Semifinish milling by face-milling cutter	Semifinish milling by end milling cutter
18	End surface Ra 12.5; 6 mm; 8 ± 0.2mm	14	Ra 12.5	Semifinish turning	
19	Side recess 14mm, l = 17 ± 0.2 mm, h =4 mm, Ra 12.5	14	Ra 12.5	Rough milling by end milling cutter	

In the design version it is proposed to replace the turning on turret machine operation and vertical-milling operation, which are performed on universal machines, by turning on semi-automatic machine with multiple spindles and by rotary milling operation.

The structure of the route of the part "Cover" MA96F3.12.604 machining is proposed.

Operation 005. Semiautomatic turning

1. Form turning of the end faces 1. 18 to the dimensions 19 ± 0.2 mm; 8 ± 0.2 mm; 6±0.2 mm from the transverse sliding carriage, rough turning of the surface 7. to the dimensions ∅100.5 h12($_{-0.35}$), and boring of the chamfer 4 to the dimensions 6.3×45° from the longitudinal sliding carriage simultaneously.

2. Rough boring of the holes 5. 16 to the dimensions ∅79.4H12($^{+0.3}$); l = 15 mm; ∅68H14($^{+0.74}$), rough boring of the chamfer 2 to the dimensions 1.5×45° from the longitudinal sliding carriage, rough turning of the external chamfer 6 to the dimensions 1.75×45° from the transverse sliding carriage simultaneously.

3. Rough boring of the hole 3 to the dimensions ∅88H14($^{+0.87}$); l = 1.5 mm from the longitudinal sliding carriage.

4. Finish turning of the surface 7 to the dimensions ∅100h9($_{-0.087}$); l = 6±0.2 mm from the longitudinal sliding carriage.

5. Finish boring of the hole 5 to the dimensions ∅80H9($^{+0.074}$); l = 12±0.2 mm from the longitudinal sliding carriage.

6. Control dimensions: 19±0.2 mm; 8±0.2 mm; 6 mm; ∅100.5h12($_{-0.35}$); ∅79.4$^{+0.3}$; ∅88H14($^{+0.87}$); ∅88H14($^{+0.87}$); 1.5 mm; ∅100h9($_{-0.087}$); 6±0.2; ∅80H9($^{+0.074}$); 12±0.2.

Control 30 %.

On horizontal semiautomatic multispindle machine tool with 6 spindles for turning (model 1Б240П-6К).

Operation 010. Vertical drilling

2. Drilling of four holes 9…12 using jig to dimensions ∅11H14; ∅120±0.28 simultaneously on vertical drilling machine tool (model 2H135C)

Control dimensions: ∅11H14; ∅120±0.28.

Control 30 %.

Operation 015. Rotary milling

2. Semifinish milling of the surface 17 to dimensions 125 mm; 8±0.2 mm on rotary milling machine tool (model 6A23).

Control dimensions: 125 mm; 8±0.2 mm.

Control 30 %.

Operation 020. Vertical milling

Milling of the side recess 19 to dimensions 14±0.1; 17±0.1. 4±0.1 on vertical milling machine tool (model ВФ-87).

Control dimensions: 14±0.1; 17±0.1. 4±0.1.

Control 30 %.

Operation 025. Control.

2.5. Determination of allowances for machining

The results of the allowances calculation for surfaces machining of the part "Cover" MA96F3.12.604 are presented in table 2.5.

The graphic layout chart of allowances for the surface ∅100h9 is drawn in fig. 2.3.

Table 2.5 –Calculated allowances for machining

Technological operations and operation elements	Surface finish	Surfaces roughness, μm	Tolerance, mm	Allow-ance, mm	Operational dimensions with deviations
1	2	3	4	5	6
Hole ∅80H9 mm					
Finish boring	9	6.3	0.074	0.3×2=0.6	$\varnothing 80^{+0.074}$
Semifinish boring	12	12.5	0.3	1.5×2=3.0	$\varnothing 79.4^{+0.3}$
Workpiece	6-th class	R_z200	0.7	1.8×2=3.6	∅76.4±0.7
Hole ∅68H14 mm					
Rough boring	14	25	0.74		$\varnothing 68^{+0.74}$
Workpiece	6-th class	R_z200	0.7	1.3×2=2.6	∅65.4±0.7
Flat surfaces 125±IT14/2 mm					
Semifinish milling	±IT14/2	6.3	0.5		125±0.5
Workpiece	6-th class	R_z200	0.8	1.6	126.6±0.8
End face 19±0.2 mm					
Semifinish turning	±IT14/2	12.5	0.2	–	19±0.2
Workpiece	6-th class	R_z200	0.5	1.1	20.1±0.5
End face 8±0.2 mm					
Semifinish turning	±IT14/2	12.5	0.2	–	8±0.2
Workpiece	6-th class	Rz200	0.4	1.0	9±0.4
End face 12±0.2 mm					
Semifinish boring	±IT14/2	12.5	0.2		12±0.2
Workpiece	6-th class	Rz200	0.5	1.1	10.9±0.5
External chamfer 1.5×45°					
Rough turning	14	25	0.1	1.5	1.5×45°±0.1
Internal chamfer 1.5×45°					
Rough boring	14	25	0.1	1.5	1.5×45°±0.1
Internal cylindrical surface ∅88H14 mm					
Rough boring	14	12.5	0.74	1.5	∅88±0.74
Holes ∅11H14 mm					
Drilling	14	25	0.36		$\varnothing 11^{+0.36}$
Workpiece (solid material)	6-th class	Rz200	–	5.5	–

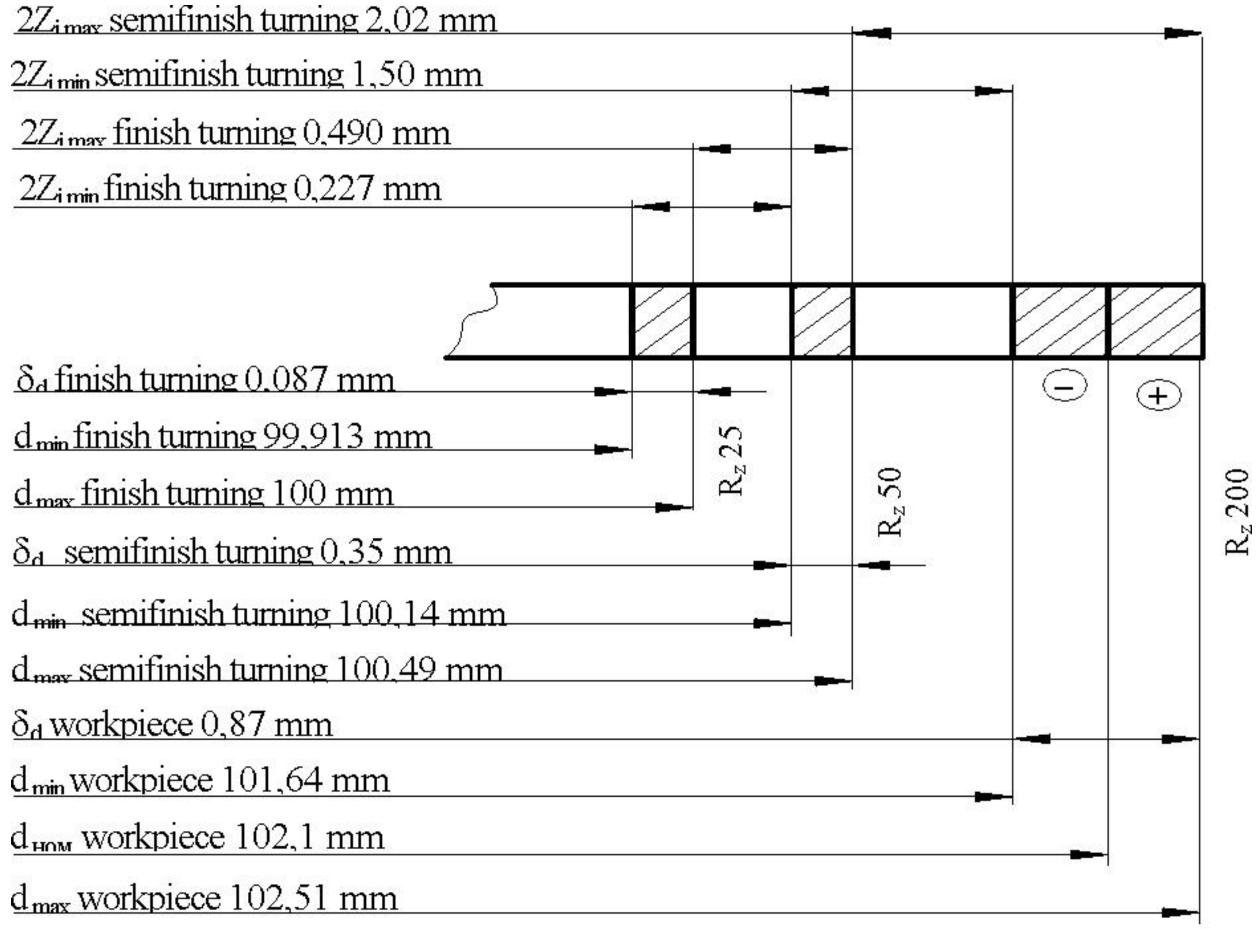

Figure 2.3 – The graphic layout chart of allowances and tolerances for a surface $\varnothing 100h9\left(_{-0,087}\right)$

2.6. Determination of cutting conditions and technical norms of time

The calculation of cutting conditions by computation-analytical method.

Operation 005. Semiautomatic turning

Position 2.

Analyzing the initial data of surface machining in this operation, we conclude that position 2 is limiting with relation to all positions of the machine tool, as it has the longest working stroke of the sliding carriage.

On this position form turning of the end faces 1. 18 to the dimensions 19 ± 0.2 mm; 8 ± 0.2 mm; 6±0.2 mm from the transverse sliding carriage, rough turning of the surface 7 to the dimensions ∅100.5 h12($_{-0.35}$), and boring of the chamfer 4 to the dimensions 6.3×45° from the longitudinal sliding carriage simultaneously is making.

The material of the insert is a hard alloy ВК6.

Cutting tools:

Cutter 1 - turning cutting tool bent special; 6 × 10; ВК6.

Cutter 2 - turning cutting tool bent special; 8 × 12; ВК6.

Cutter 3 - turning cutting tool straight; ВК6; φ=90°; 10 × 16 Standard 18879-73.

Cutter 4 - turning cutting tool straight; ВК6; φ=45°; 12 × 20 Standard 18879-73.

1. Depth of cut for each cutting tool:

For cutter 1 – t_1 = 1.0 mm.

For cutter 2 – t_2 = 1.1 mm.

For cutter 3 – t_3 = 6.3 mm.

For cutter 4 – t_4 = 1.0 mm.

The working strokes of transverse and longitudinal sliding carriages were calculated.

The working stroke of longitudinal sliding carriage is calculated for cutter 3. because it has the longest cutting length on pass $l_{різ.}$ [20]:

$$L_{р.х.} = l_{різ} + l_2 + l_{дод.} , \tag{2.7}$$

where $l_{різ.}$ = 6.3 mm;

l_2 = 4 mm – the work length before cutting;

$l_{дод.}$ = 0.

$$L_{р.х.} = 6.3 + 4 + 0 = 10.3 \quad \text{mm.}$$

The working stroke of transverse sliding carriage is calculated for cutter 1. because it has the longest cutting length on pass $l_{різ.}$

$l_{різ.}$ = 19.75 mm;

l_2 = 3 mm – the work length before cutting;

$l_{дод.} = 0.$

$$L_{p.x.} = 19.75 + 3 + 0 = 22.75 \quad mm.$$

The feed rates for sliding carriages are calculated. The total depth of cut for cutters of transverse sliding carriage:

$$\sum t_{поп.} = t_1 + t_2 = 1.0 + 1.1 = 2.1 \quad mm.$$

The total depth of cut for cutters of longitudinal sliding carriage:

$$\sum t_{позд.} = t_3 + t_4 = 6.3 + 1.0 = 7.3 \quad mm.$$

For these values of depth of cut Σt the feed rates are recommended:

For transverse sliding carriage S_o = 0.67 mm/rev [6].

For longitudinal sliding carriage S_o = 0.8 mm/rev [6].

The values of feed rates for sliding carriages are corrected. Since the operating time of the longitudinal sliding carriage is much less than the transverse sliding carriage, and they work at the same time, then we will reduce the feed rate of the longitudinal sliding carriage without reducing the productivity of the machine. This is achieved by equalizing the operating time of the longitudinal sliding carriage and transverse sliding carriage, that is by the same number of spindle revolutions per stroke of each sliding carriage:

$$\frac{L_{p.x.tr.}}{S_{o\ tr.}} = n = \frac{L_{p.x.long}}{S_{o\ long.}};$$

$$\frac{22.75}{0.67} = 33.9 = \frac{10.3}{S_{o\ long.}};$$

$$S_{o\ long.} = \frac{10.3}{33.9} = 0.3 \text{ mm/rev.}$$

The tool life of limiting tools is determined by the formula

$$T_p = T_M \cdot \lambda, \tag{2.8}$$

T_M = 175 min. – for four cutters in retooling. [12].

The cutting time factor λ is determined.

Number of spindle revolutions during cutting

For cutter 1: $\frac{l_{\text{різ.tr.}}}{S_{\text{o tr.}}} = \frac{19.75}{0.67} = 29.5;$

For cutter 3: $\frac{l_{\text{різ.tr.}}}{S_{\text{o tr.}}} = \frac{6.3}{0.3} = 21;$

Number of spindle revolutions during parallel working stroke of sliding carriages

For cutter 1: $\frac{L_{\text{p.x.tr.}}}{S_{\text{o tr.}}} = \frac{22.75}{0.67} = 33.9;$

For cutter 3: $\frac{L_{\text{p.x.tr.}}}{S_{\text{o tr.}}} = \frac{10.3}{0.3} = 34.3;$

For cutter 1: $\lambda = \frac{29.5}{33.9} = 0.87;$

For cutter 3: $\lambda = \frac{21}{34.3} = 0.6.$

In the case where $\lambda > 0.7$. it can be ignored and accepted $T_p = T_M$.

Thus, for cutter 1 T_p = 175 min., for cutter 3 $T_p = 175 \times 0.6 = 105$ min.

The cutting speed of limiting tools [20]:

$$V = \frac{C_v}{T^m \cdot t^x \cdot S^y} \cdot K_V. \qquad (2.9)$$

Cutting speed correction factor

$$K_v = K_{\text{мv}} \cdot K_{nv} \cdot K_{\text{иv}} \cdot K_{\varphi} \cdot K_{\varphi 1} \cdot K_r; \qquad (2.10)$$

Cutting speed correction factors for cutter 1 of transverse sliding carriage:

$K_{\text{мv}} = \left(\frac{190}{HB}\right)^{n_v}$ [20].

HB = 190 MPa;

n_v = 1.25 [20].

$$K_{мv} = \left(\frac{190}{190}\right)^{1.25} = 1.0,$$

K_{nv} = 1.0 [6];

$K_{иv}$ = 1.0 [20];

$K_{\varphi v}$ = 0.7 [6];

$K_{\varphi 1v}$ = 1.0 [6];

K_{rv} = 0.94 [6];

$$K_v = 1.0 \cdot 1.0 \cdot 1.0 \cdot 0.7 \cdot 1.0 \cdot 0.94 = 0.66;$$

$$V_1 = \frac{215}{175^{0,2} \cdot 1.0^{0,15} \cdot 0.67^{0,45}} \cdot 0.66 = 64 \quad \text{m/min.}$$

Cutting speed for cutter 3 longitudinal sliding carriage:

$$K_v = 1.0 \cdot 1.0 \cdot 1.0 \cdot 1.0 \cdot 0.87 \cdot 0.94 = 0.82;$$

$$V_2 = \frac{215}{105^{0,2} \cdot 6.3^{0,15} \cdot 0.3^{0,45}} \cdot 0.82 \cdot 0.9 = 97.6 \quad \text{m/min.}$$

Thus, the cutter 1 of transverse sliding carriage is limiting the speed of the main cutting movement. Therefore it was taken: V = 64 m/min.

2. Rotational spindle speed:

$$n = \frac{1000 \cdot V}{\pi \cdot d} = \frac{1000 \cdot 64}{\pi \cdot 100.5} = 202 \quad \text{min}^{-1}.$$

3. Correction according machine tool characteristics: $n_д$ = 200 min^{-1}.
4. Correction of cutting speed:

$$V_{д1} = \frac{\pi \cdot d \cdot n_д}{1000} = \frac{\pi \cdot 100.5 \cdot 200}{1000} = 63 \quad \text{m/min}.$$

$$V_{д2} = \frac{\pi \cdot d \cdot n_д}{1000} = \frac{\pi \cdot 63.8 \cdot 200}{1000} = 40 \quad \text{m/min}.$$

5. Cutting force for each cutting tool:

$$P_z = 10 \cdot C_p \cdot t^x \cdot S^y \cdot V^n \cdot K_p; \qquad (2.11)$$

Correction factor:

$$K_p = K_{мр} \cdot K_{\varphi p} \cdot K_{\gamma p} \cdot K_{\lambda p} \cdot K_{rp}; \qquad (2.12)$$

$K_{мр} = \left(\frac{HB}{190}\right)^n$ [20];

$n = 0.4$ [20];

$K_{мр} = \left(\frac{190}{190}\right)^{0,4} = 1,0$.

Correction factors for cutter 1 of transverse sliding carriage:

$K_{\varphi p} = 0.89$ [6];

$K_{\gamma p} = 1.0$ [6];

$K_{\lambda p} = 1.0$ [6];

$K_{rp} = 0.87$;

$$K_p = 1.0 \cdot 0.89 \cdot 1.0 \cdot 1.0 \cdot 0.87 = 0.77.$$

$$P_z = 10 \cdot 92 \cdot 1.0^{1.0} \cdot 0.67^{0.75} \cdot 63^0 \cdot 0.77 = 484.4 \quad N.$$

Correction factors for cutter 2 of transverse sliding carriage:

$K_{\varphi p} = 0.89$ [6];

$K_{\gamma p} = 1.0$ [6];

$K_{\lambda p} = 1.0$ [6];

$K_{rp} = 0.87$;

$$K_p = 1.0 \cdot 0.89 \cdot 1.0 \cdot 1.0 \cdot 0.87 = 0.77.$$

$$P_z = 10 \cdot 92 \cdot 1.1^{1.0} \cdot 0.67^{0.75} \cdot 63^0 \cdot 0.77 = 534 \quad N.$$

Cutting force for cutter 3 of longitudinal sliding carriage:

$$P_z = 10 \cdot 92 \cdot 6.3^{1.0} \cdot 0.3^{0.75} \cdot 40^0 \cdot 0.957 = 2246 \quad N.$$

Cutting force for cutter 4 of longitudinal sliding carriage:

$$P_z = 10 \cdot 92 \cdot 1.0^{1.0} \cdot 0.3^{0.75} \cdot 40^{0} \cdot 0.77 = 287 \quad N.$$

6. Cutting power for each cutting tool:

$$N_{\text{різ}} = \frac{P_z \cdot V}{1020 \cdot 60}, \text{ kW} \tag{2.13}$$

For cutter 1 of transverse sliding carriage

$$N_{\text{різ1}} = \frac{484.4 \cdot 63}{1020 \cdot 60} = 0.5 \quad \text{kW}.$$

For cutter 2 of transverse sliding carriage

$$N_{\text{різ2}} = \frac{534 \cdot 63}{1020 \cdot 60} = 0.55 \quad \text{kW}.$$

For cutter 3 of longitudinal sliding carriage:

$$N_{\text{різ3}} = \frac{2246 \cdot 40}{1020 \cdot 60} = 1.46 \quad \text{kW}.$$

For cutter 4 of longitudinal sliding carriage:

$$N_{\text{різ4}} = \frac{287 \cdot 40}{1020 \cdot 60} = 0.18 \quad \text{kW}.$$

$$\sum N_{\text{різ}} = N_{\text{різ1}} + N_{\text{різ2}} + N_{\text{різ3}} + N_{\text{різ4}}, \quad \text{kW}; \tag{2.14}$$

$$\sum N_{\text{різ}} = 0.5 + 0.55 + 1.46 + 0.18 = 2.69 \quad \text{kW}.$$

7. The cutting power was verified:

$$N_{\text{різ}} \le N_{\text{шп}}, \quad \text{kW}; \tag{2.15}$$

$$N_{\text{шп}} = N_{\text{д}} \cdot \eta, \quad \text{kW},$$

where $N_{\text{д}}$ – power on machine tool spindle (model 1Б240П-6К) 7 kW;
η = 0.8 - machine tool efficiency factor.

$$N_{\text{шп}} = 17 \cdot 0.8 = 13.6 \quad \text{kW};$$

$$N_{\text{різ}} = 2.69 \quad \text{кВт} \le N_{\text{шп}} = 13.6 \quad \text{kW}.$$

Cutting conditions are correct.

8. Machining time for limiting cutting tool:

$$T_o = \frac{L_{p.x.}}{S_o \cdot n} = \frac{22.75}{0.67 \cdot 200} = 0.17 \quad \min. \tag{2.16}$$

Position 3.

On this position rough boring of the holes 5. 16 to the dimensions ∅79.4H12($^{+0.3}$); l = 15 mm; ∅68H14($^{+0.74}$), rough boring of the chamfer 2 to the dimensions 1.5×45° from the longitudinal sliding carriage, rough turning of the external chamfer 6 to the dimensions 1.75×45° from the transverse sliding carriage simultaneously is making.

The material of the insert is a hard alloy BK6.

Cutting tools:

Cutter 1 – boring, BK6. φ=60°; 8 × 8 Standard 10044-73.

Cutter 2 – boring, BK6. φ=60°; 10 × 10 Standard 10044-73.

Cutter 3 – boring, BK6; 8 × 8; φ=15° special.

Cutter 4 – turning cutting tool straight, BK6. φ=45°; 12 × 20; Standard 18878-73

1. Depth of cut for each cutting tool:

For cutter 1 – t_1 = 1.3 mm.

For cutter 2 – t_2 = 1.5 mm.

For cutter 3 – t_3 = 1.5 mm.

For cutter 4 – t_4 = 1.75 mm.

The working strokes of transverse and longitudinal sliding carriages were calculated.

The working stroke of longitudinal sliding carriage is calculated for cutter 2. because it has the longest cutting length on pass $l_{різ.}$ [20]:

$$L_{р.х.} = l_{різ} + l_2 + l_{дод.} , \tag{2.17}$$

where $l_{різ.}$ = 10.5 mm;

l_2 = 2 +4.5 = 6.5 mm – the work length before cutting [12];

$l_{дод.}$ = 0.

$$L_{р.х.} = 10.5 + 6.5 + 0 = 17 \quad mm.$$

The working stroke of transverse sliding carriage is calculated for cutter 4. because it has the longest cutting length on pass $l_{різ.}$

$l_{різ.}$ = 1.75 mm;

l_2 = 1.75 mm – the work length before cutting [12];

$l_{дод.}$ = 0.

$$L_{р.х.} = 1.75 + 1.75 + 0 = 3.5 \quad \text{mm.}$$

The feed rates for sliding carriages are calculated. The total depth of cut for cutters of longitudinal sliding carriage:

$$\sum t_{позд.} = t_1 + t_2 + t_3 = 1.3 + 1.5 + 1.5 = 4.3 \quad \text{мм.}$$

The total depth of cut for cutters of transverse sliding carriage:

$$\sum t_{поп.} = t_4 = 1.75 \quad \text{mm.}$$

For these values of depth of cut Σt the feed rates are recommended:

For transverse sliding carriage S_o = 0.8 mm/rev [6].

For longitudinal sliding carriage S_o = 0.6 mm/rev [6].

The values of feed rates for sliding carriages are corrected. Since the operating time of the longitudinal sliding carriage is much less than the transverse sliding carriage, and they work at the same time, then we will reduce the feed rate of the longitudinal sliding carriage without reducing the productivity of the machine. This is achieved by equalizing the operating time of the longitudinal sliding carriage and transverse sliding carriage, that is by the same number of spindle revolutions per stroke of each sliding carriage:

$$\frac{L_{р.х.tr.}}{S_{o\ tr.}} = n = \frac{L_{р.х.пlong}}{S_{o\ long.}};$$

$$\frac{3.5}{S_{o\ tr.}} = 28.3 = \frac{17}{0.6};$$

$$S_{o\ tr.} = \frac{3.5}{28.3} = 0.12 \text{ mm/rev.}$$

When determining the feed of a non-limiting carriage, despite the results of the calculation, it is not recommended to reduce the feed rate of high alloy inserts below 0.15-0.2 mm / rev. Therefore, S_o = 0.17 mm / rev was taken.

The tool life of limiting tools is determined by the formula

$$T_p = T_M \cdot \lambda,$$

where T_M = 175 min. – for four cutters in retooling. [12].

The cutting time factor λ is determined:

$$\lambda = \frac{L_{\text{різ}}}{L_{\text{р.х.}}} = \frac{10.5}{17.5} = 0.6;$$

Thus, the tool life of cutters on this position is T_p = 175 × 0.6 = 105 min.

2. The cutting speed of limiting tools [12]:

$$V = V_{\text{табл.}} \cdot K_1 \cdot K_2 \cdot K_3 . \qquad (2.18)$$

Cutting speed correction factors for longitudinal sliding carriage

$V_{\text{табл.}}$= 88 m/min [12];

K_1 = 1.0 [12];

K_2 = 1.0 [12];

K_3 = 1.0 [12];

$$V = 88 \cdot 1.0 \cdot 1.0 \cdot 1.0 = 88 \text{ m/min},$$

Cutting speed correction factors for transverse sliding carriage

$V_{\text{табл.}}$= 130 m/min [12];

K_1 = 1.0 [12];

K_2 = 1.0 [12];

K_3 = 1.0 [12];

$$V = 130 \cdot 1.0 \cdot 1.0 \cdot 1.35 = 175.5 \text{ m/min}.$$

Thus, the cutter 2 of transverse sliding carriage is limiting the speed of the main cutting movement. Therefore it was taken: V = 88 m/min.

3. Rotational spindle speed:

$$n = \frac{1000 \cdot V}{\pi \cdot d} = \frac{1000 \cdot 88}{\pi \cdot 79.4} = 353 \quad min^{-1}.$$

Correction according machine tool characteristics: $n_д$ = 200 min^{-1}.

4. Correction of cutting speed:

For longitudinal sliding carriage (cutter 2):

$$V_{д1} = \frac{\pi \cdot d \cdot n_д}{1000} = \frac{\pi \cdot 79.4 \cdot 200}{1000} = 50 \quad m/min.$$

For longitudinal sliding carriage (cutter 4):

$$V_{д2} = \frac{\pi \cdot d \cdot n_д}{1000} = \frac{\pi \cdot 100.5 \cdot 200}{1000} = 63 \quad m/min.$$

5. Cutting force for each cutting tool:

$$P_z = P_{z\,табл.} \cdot K_1 \cdot K_2. \qquad (2.19)$$

For cutter 1:

$P_{z\,табл.}$ = 200 [12];

K_1 = 0.45 [12];

K_2 = 1.0 [12];

$$P_{z1} = 200 \cdot 0.45 \cdot 1.0 = 90 \quad kg = 900 \quad N.$$

For cutter 2:

$P_{z\,табл.}$ = 200 [12];

K_1 = 0.45 [12];

K_2 = 1.0 [12];

$$P_{z2} = 200 \cdot 0.45 \cdot 1.0 = 90 \quad kg = 900 \quad N.$$

For cutter 3:

$P_{z\,табл.}$ = 200 [12];

K_1 = 0.45 [12];

K_2 = 1.0 [12];

$$P_{z3} = 200 \cdot 0.45 \cdot 1.0 = 90 \quad kg = 900 \quad N.$$

For cutter 4:

$P_{z\,табл.}$ = 120 [12];

K_1 = 0.45 [12];

K_2 = 1.0 [12];

$$P_{z4} = 120 \cdot 0.45 \cdot 1.0 = 54 \quad kg = 540 \quad N.$$

6. Cutting power for each cutting tool:

$$N_{різ} = \frac{P_z \cdot V}{1020 \cdot 60}, kW$$

For cutter 1 of longitudinal sliding carriage:

$$N_{різ1} = \frac{900 \cdot 50}{1020 \cdot 60} = 0.73 \quad kW.$$

For cutter 2 of longitudinal sliding carriage:

$$N_{різ1} = \frac{900 \cdot 50}{1020 \cdot 60} = 0.73 \quad kW.$$

For cutter 3 of transverse sliding carriage:

$$N_{різ1} = \frac{900 \cdot 50}{1020 \cdot 60} = 0.73 \quad kW.$$

For cutter 4 of transverse sliding carriage:

$$N_{різ4} = \frac{540 \cdot 63}{1020 \cdot 60} = 0.56 \quad kW.$$

$$\sum N_{різ} = N_{різ1} + N_{різ2} + N_{різ3} + N_{різ4,} \quad kW;$$

$$\sum N_{різ} = 0.73 + 0.73 + 0.73 + 0.56 = 2.75 \quad kW.$$

7. The cutting power was verified:

$$N_{різ} \le N_{шп}, \quad kW;$$

$$N_{шп} = N_д \cdot \eta, \quad kW,$$

де where $N_д$ – power on machine tool spindle (model 1Б240П-6К) 7 kW;

η = 0.8 - machine tool efficiency factor.

$$N_{шп} = 17 \cdot 0.8 = 13.6 \quad kW;$$

$$N_{різ} = 2.75 \quad kW \le N_{шп} = 13.6 \quad kW.$$

8. Machining time for limiting cutting tool:

$$T_o = \frac{L_{p.x.}}{S_o \cdot n} = \frac{17}{0.6 \cdot 200} = 0.14 \quad \text{min}.$$

Other cutting conditions are presented in table 2.6.

Table 2.6 – Cutting conditions

Number, name of operation and operation element	t, mm	L, mm	i	T_m, min	S, mm/rew	n, rew/min	V, m/min	S_m, mm/min	T_o, min	N, kW
005 Semiautomatic turning										
Operation element 2.										
Form turning of the end faces 1. 18 to the dimensions 19 ± 0.2 mm; 8 ± 0.2 mm; 6±0.2 mm from the transverse sliding carriage	1.0	22.75	1	176	0.67	201	64	–	0.17	2.69
rough turning of the surface 7. to the dimensions ∅100.5 h12($_{-0.35}$),	1.0	–	1	106	0.3	201	41	–	–	
boring of the chamfer 4 to the dimensions 6.3×45° from the longitudinal sliding carriage simultaneously	6.3	10.3	1	106	0.3	201	41	–	–	

Continuation of table 2.6

Operation element 3. Rough boring of the holes 5. 16 to the dimensions $\varnothing 79.4H12(^{+0.3})$; l = 15 mm; $\varnothing 68H14(^{+0.74})$	1.3	17	1	106	0.6	201	51	–	0.14	
Rough boring of the chamfer 2 to the dimensions 1.5×45° from the longitudinal sliding carriage	1.5	–	1	106	0.6	201	51	–	–	2.75
Rough turning of the external chamfer 6 to the dimensions 1.75×45° from the transverse sliding carriage simultaneously	1.75	3.5	1	106	0.17	201	64	–	–	
Operation element 4. Rough boring of the hole 3 to the dimensions $\varnothing 88H14(^{+0.87})$; l = 1.5 mm from the longitudinal sliding carriage.	1.5	2.5	1	106	0.13	201	56	–	0.1	–
Operation element 5. Finish turning of the surface 7 to the dimensions $\varnothing 100h9(_{-0.087})$; l = 6±0.2 mm from the longitudinal sliding carriage.	0.25	6.0	1	176	0.3	201	62.8	–	0.1	–
Operation element 6.										

Continuation of table 2.6

Finish boring of the hole 5 to the dimensions ∅80H9($^{+0.074}$); l = 12±0.2 mm from the longitudinal sliding carriage.	0.3	17	1	106	0.5	201	51	–	0.17	–
010 Vertical drilling										
Drilling of four holes 9…12 using jig to dimensions ∅11H14; ∅120±0.28 simultaneously	5.5	18	1	100	0.13	388	13.4	–	0.36	0.62
015 Rotary milling										
Semifinish milling of the surface 17 to dimensions 125 mm; 8±0.2 mm	1.6	176.2	1	180	0.25	400	125.6	800	0.22	0.48
020 Vertical milling										
Operation element 2. Milling of the side recess 19 to dimensions 14±0.1; 17±0.1. 4±0.1	4	25	1	60	0.07 mm/ tooth	400	25	112	0.1	0.7

Technical norms of time are collected on table 2.7.

Table 2.10 – Technical norms of time

Number, name of operation	T_o, min	Additional time, $T_д$ min			$T_{оп}$, min	Service time, $T_{об}$, min		$T_{відп}$, min	$T_{шт}$, min
		$T_{в.з.}$	$T_у$	$T_в$		$T_{тех.об.}$	$T_{орг.об.}$		
005 Semiautomatic turning	0.17	0.08	0.31	0.037	0.6	0.0034	0.0174	0.03	1.0
010 Vertical drilling	0.36	–	–	–	–	–	–	–	0.47
015 Rotary milling	0.22	–	–	–	–	–	–	–	0.33
020 Vertical milling	0.1	–	–	–	–	–	–	–	0.14

3 DESIGN PART

3.1. Description of the fixture design for machining

The special fixture is designed to perform 015 rotary milling operation, on which the flat surface in the part "Cover" MA96F3.12.604 is milled to the dimension 125 ± 0.2 mm. The designed fixture increases the accuracy and productivity of machining on rotary milling machine tool 6A23.

The fixture is mounted on the table of the machine tool and fastened to it by two bolts, which are installed in the grooves of the plate 6. The part in the device is mounted on the mandrel 7 with a clearance in the central hole and with stop on the end face, and is located on a cut finger 15 in the hole. As a result of such locating, it loses six degrees of freedom.

The fixture consists of a lower plate 6, on which the base 1 is installed, in the central hole of which the mandrel 9 is pressed. On the upper plane of the base 1 devices 14 for adjusting the cutter are attached. In the central hole of the mandrel 9 with the possibility of axial movement is a rod 7, on the left end of which a C-washer 16 is installed, and on the right - the axis 10. The latter is also conjugated with a lever 8 that can oscillate relative to the second axis 10. The right part of the lever through axis 9 is connected to the stand 12, which is screwed into the rod of the pneumatic chamber, consisting of the membrane 2 and the upper cover 3. The pneumatic chamber is attached to the plate 6 by means of ten screws 12.

In the process of machining the workpiece is installed on the mandrel surface $Ø80^{+0,074}$ and on the cut finger with one hole Ø11. The workpiece is clamped by means of a rod 7 and a C- washer 16, which clamps the workpiece to the base 1. The clamping force is provided by a pneumatic chamber Ø100mm mounted in the plate of the device and transmitted to the rod 7 by means of a lever 8. Unclamping of the workpiece occurs in reverse order with the reverse stroke of the membrane of the pneumatic chamber while removing the C- washer.

3.2. Calculation of the fixture error

The accuracy of machining is affected by a number of factors that cause total error $\Delta_{\sum}$:

$$\Delta_{\sum} = \frac{1}{K}\sqrt{(K_1\Delta_{\varepsilon y})^2 + (K_2\Delta_y)^2 + (K_3\Delta_н)^2 + (K_4\Delta_i)^2 + (K_5\sum\Delta_a)^2 + (K_6\sum\Delta_t)^2}, \quad (3.1)$$

where K is the coefficient of relative scattering of the output parameter; at the set guaranteed reliability of the fixture $K = 0.683$;

$K_1 - K_6$ - coefficients that take into account the relevant laws of error distribution;

$K_1 = K_2 = K_3 = 1.0$;

$K_4 = K_5 = K_6 = 1.7$.

$\Delta_{\varepsilon y}$ - error of the workpiece installation;

Δ_y - error of the workpiece processing, which occurs due to the displacement of the elements of the technological system under the action of cutting forces;

$\Delta_н$ - error of the technological system adjustment;

Δ_i - error that occurs due to wear of the cutting tool;

$\sum\Delta_a$ - the total error of the machine tool, which occurs due to its wear during operation;

$\sum\Delta_t$ - the total temperature error.

Installation error $\Delta_{\varepsilon y}$ is the deviation of the actual position of the clamped part from the required theoretical:

$$\Delta_{\varepsilon y} = \sqrt{\varepsilon_б^2 + \varepsilon_з^2 + \varepsilon_{пр}^2}, \quad (3.2)$$

where $\Delta\varepsilon_б$, $\Delta\varepsilon_з$, $\Delta\varepsilon_{пр}$ – errors in locating, clamping and design of the device, respectively.

The error of location is calculated by the formula [12]:

$$\varepsilon_{\text{б.}} = S_{min} + Td + TD, \qquad (3.3)$$

where S_{min} – the minimum clearance;

Td – the tolerance of the locating mandrel $\varnothing 80e7\,(^{-0.06}_{-0.09})$;

TD – the tolerance of the locating hole $\varnothing 80H9\,(^{+0.074})$.

The minimum clearance:

$$S_{min}. = EI - es\,, \qquad (3.4)$$

where $EI = 0$;

$es = -0.06$ mm.

$$S_{min.} = 0 + 0.06 = 0.06 \text{ mm.}$$

The tolerance of the locating mandrel

$$Td = es - ei\,. \qquad (3.5)$$

$$Td = -0.06 - (-0.09) = 0.03 \text{ mm.}$$

The tolerance of the locating hole

$$TD = ES - EI\,. \qquad (3.6)$$

$$TD = 0.074 - 0 = 0.074 \text{ mm.}$$

Then, locating error: $\varepsilon_{\text{б.}} = 0.06 + 0.03 + 0.074 = 0.164 \text{ mm} = 164\ \mu\text{m}.$

Clamping error: $\varepsilon_{\text{з}} = 0$.

The error $\varepsilon_{\text{пр}}$ in the position of the workpiece in the fixture is a consequence of inaccuracy $\varepsilon_{\text{в}}$ in the fixture manufacture, wear of its mounting elements $\varepsilon_{\text{зн}}$ and errors in the installation of the fixture on the machine tool $\varepsilon_{\text{вст}}$:

$$\overline{\varepsilon_{\text{пр}}} = \overline{\varepsilon_{\text{в}}} + \overline{\varepsilon_{\text{зн}}} + \overline{\varepsilon_{\text{вст}}}\,. \qquad (3.7)$$

We accept $\varepsilon_{в} = 10 \mu m$.

Wear of mounting elements $\varepsilon_{зн}$:

$$\varepsilon_{зн} = \beta \cdot N \qquad (3.8)$$

where N - the number of contacts of the workpiece with the mounting elements of the fixture;

β - constant, which depends on the type of mounting elements.

$\varepsilon_{зн} = 0,0005 \cdot 100000 = 50 \mu m$.

Error in the installation of the fixture on the machine tool is $\varepsilon_{вст} = 10 \mu m$.

In absolute form, the equation is written as follows

$$\varepsilon_{пр} = t\sqrt{\lambda_1 \varepsilon_{в}^2 + \lambda_2 \varepsilon_{зн}^2} + \varepsilon_{вст}, \qquad (3.9)$$

where t - coefficient that determines the share of possible waste;

λ_1, λ_2 - coefficients that depend on the law of random variables distribution.

$$\varepsilon_{пр} = 3\sqrt{\frac{1}{9} \cdot 10^2 + \frac{1}{3} \cdot 50^2} + 10 = 97 \mu m;$$

$$\Delta\varepsilon_{у} = \sqrt{150^2 + 0^2 + 97^2} = 179 \mu m.$$

The processing error of the workpiece $\Delta_{у}$ is taken equal to 79 μm.

Technological system adjusting error $\Delta_{н}$

$$\Delta_{н} = \sqrt{(К_{р}\Delta_{р})^2 + (К_{вим}\Delta_{вим})^2}, \qquad (3.10)$$

where $К_{р}, К_{вим}$ - coefficients that take into account the laws of distribution of random variables;

$\Delta_{р}$ - adjustment error;

$\Delta_{вим}$ - measuring error.

We accept: $\Delta_{р} = 10 \mu m$; $\Delta_{вим} = 12 \mu m$; $K_{р} = 1.14$; $K_{вим} = 1.0$.

$$\Delta_{н} = \sqrt{(1.14 \cdot 10)^2 + (1.0 \cdot 12)^2} = 17\mu m.$$

The error that occurs due to wear of the cutting tool Δ_i, we take equal to 25 μm.

The total error of the machine tool $\sum \Delta_в$, which occurs due to its wear during operation, is assumed to be equal to 12 μm.

The total temperature error $\sum \Delta_t$ is assumed to be equal to 10… 15% from Δ_Σ.

The total error (excluding temperature error):

$$\Delta_\Sigma = \frac{1}{0.683}\sqrt{(1 \cdot 164)^2 + (1 \cdot 79)^2 + (1 \cdot 17)^2 + (1.73 \cdot 25)^2 + (1.73 \cdot 12)^2} = 276\mu m;$$

$$\sum \Delta_t = 276 \cdot 0.1 = 27.6\mu m.$$

The total error:

$$\Delta_\Sigma = \sqrt{276^2 + (1.73 \cdot 27.6)^2} = 280\mu m.$$

The minimum tolerance for the machining of a given surface, according to the drawing, is 400 μm. Thus, the condition is fulfilled.

Machining on this device is possible, as the accuracy of the plane machining is provided.

3.3. Calculation of the fixture drive

The design scheme was developed in order to calculate the required forces for "Cover" MA96F3.12.604 clamping on 015 rotary milling operation, during milling of 24 mm plains.

The sum of the friction moments $M_{тр}$ must be greater than cutting torque $M_{різ}$ when clamping the workpiece in order to ensure the stability of the plains milling process:

$$KM_{\text{різ}}=\sum M_{\text{тр}}, \tag{3.11}$$

where K - safety coefficient.

The cutting torque during milling is calculated:

$$M_{\text{різ}}=P_z \cdot R_3, \tag{3.12}$$

where P_z – cutting force, N;

$R_3=55$ mm – the contact radius between the workpiece and the milling cutter.

The friction moment is calculated:

$$\sum M_{\text{тр}}=Q \cdot \frac{1}{3} \cdot f \times \left(\frac{D^3\text{-}d^3}{D^2\text{-}d^2} \right), \tag{3.13}$$

where Q – the clamping force, N;

D, d – diametrical dimensions from the drawing of the fixture, mm;

$f = 0.25$ – friction coefficient on the working surfaces of the clamps [6].

The clamping force:

$$Q=\frac{K \cdot P_z \cdot R_3}{\frac{1}{3} \cdot f \cdot \left(\frac{D^3\text{-}d^3}{D^2\text{-}d^2} \right)}. \tag{3.14}$$

The cutting force during milling [20]:

$$P_z = \frac{10 \cdot C_p \cdot t^x \cdot S_z{}^y \cdot B^n \cdot z}{D^q \cdot n^w} \cdot K_{\text{мр}}. \tag{3.15}$$

Correction factor that takes into account the workpiece material [20]:

$$K_{\text{мр}} = \left(\frac{\sigma_{\text{в}}}{750} \right)^n, \tag{3.16}$$

$\sigma_{\text{в}} = 550$ MPa;

$n = 0.3$ [20];

$$K_{мр} = \left(\frac{550}{750}\right)^{0.3} = 0.9 \text{ [20]}.$$

$t = 1.6$ mm; $Sz = 0.03$ mm/tooth; $B = 8$ mm; $z = 2$; $D = 100$ mm; $n = 400$ min^{-1};

$$P_z = \frac{10 \cdot 54.5 \cdot 1.6^{0.9} \cdot 0.03^{0.74} \cdot 8^1 \cdot 2}{100^1 \cdot 400^0} \cdot 0.9 = 8.94\,\text{N}.$$

Safety coefficient [6]:

$$K = K_0 \cdot K_1 \cdot K_2 \cdot K_3 \cdot K_4 \cdot K_5 \cdot K_6 \qquad (3.17)$$

$$K = 1.5 \cdot 1.0 \cdot 1.6 \cdot 1.0 \cdot 1.3 \cdot 1.0 \cdot 1.0 = 3.12.$$

Substituting the data into formula (3.14), we obtain:

$$Q = \frac{3.12 \cdot 8.94 \cdot 55}{\frac{1}{3} \cdot 0.2 \left(\frac{100^3 - 88^3}{100^2 - 88^2}\right)} = 165\,\text{N}.$$

The condition of reliability clamping was verified:

$$Q \leq W \cdot i. \qquad (3.18)$$

The force-increase ratio of the power mechanism, taking into account the design of the fixture was calculated according to the formula [22]:

$$W = \frac{F_{шт} \cdot l_1}{l_2}, \qquad (3.19)$$

where $l_1 = 75$ mm – the length of the first part of the lever, mm;

$l_2 = 30$ mm – the length of the second part of the lever, mm;

A single-acting pneumatic chamber is selected for the workpiece clamping. For such pneumatic chambers, the pulling force on the rod is determined by the formula [22]:

$$F_{шт} = \frac{\pi}{16} \cdot (D_1 + d_1)^2 \cdot p \cdot \eta, \qquad (3.20)$$

where $D_1 = 0.1$ m; $d_2 = 0.07$ m;

p – air pressure in the system [14] ; $p = 0.4 \cdot 10^6$ Pa;

η – efficiency factor of the pneumatic drive [14]; $\eta = 0.9$.

Then $F_{шт} = \frac{3.14}{16} \cdot (0.1 + 0.07)^2 \cdot 0.4 \cdot 10^6 \cdot 0.9 = 2041$ N.

$$W = \frac{2340 \cdot 75}{30} = 5850 \text{ N}.$$

The condition of the workpiece reliability clamping

$$W > Q.$$

It is established based on the calculations, that $W = 5850$ N > $Q = 165$ N.

Conclusion: the part "Cover" MA96F3.12.604 will be securely clamped during milling on 015 rotary milling operation.

4 SAFETY MEASURES

4.1. Safe use of horizontal boring machines

The hazards associated with horizontal boring machines include entanglement at the rotating chuck and cutting tools. Crushing or trapping may also arise from other moving parts, eg from the moving table. The automated nature of CNC machines means that additional risks to safety may be present as machine movement is not always reliable or predictable. All information in this chapter is taken from [25]. Injuries may occur during: machining observation; setting and adjustment; or swarf removal.

Accident history shows that serious injuries, including severe lacerations, crushing or amputation, occur on these machines. Other injuries include skull fracture and broken limbs. Fatal accidents have also occurred.

According to the laws operator must carry out a suitable and sufficient risk assessment to determine the appropriate safeguarding measures required to control the risks. In his risk assessment, he will need to consider all operations where access to the work zone is required. This will include routine machining operations, observation and adjustment requirements and breakdowns and maintenance tasks. Risks associated with the machine being used for other machining operations, eg drilling or milling, will also need to be included in the risk assessment.

Effective measures must be taken to prevent access to any dangerous parts of machinery. The hierarchy of controls specified in the Regulations must be applied when safeguarding solutions are being determined. A safeguarding solution will need to be developed based on the specific functions of the individual horizontal boring machine. Operator will need to take into account the size and configuration of the machine and the specific applications for which the machine will be used.

During routine machining operations, access to the work zone should be prevented by fixed and/or interlocking guards. The height, position and construction of any new guards should meet appropriate standards. If physical guarding is not practicable, alternative types of safety devices may be used, eg light curtains or pressure sensitive mats.

Access into the enclosure inside the perimeter fencing should be via an interlocked gate, that either:

- includes guard locking, to prevent entry when the machine is in use; or
- stops movement of all the dangerous parts if the gate is opened during use.

Where an interlocking enclosure is not practicable and cannot be installed operator should:

- Provide perimeter fencing around the machine in order to restrict general access by personnel not associated with the machine.
- Ensure any access gates are spring-closure and include a latch arrangement, such that a deliberate two stage opening of the gate is required (ie raising the latch and pushing against the spring pressure).
- Ensure any ancillary equipment, storage facility or other non-essential items are removed from the enclosure.

Safe systems of work for all operations are required, including activities such as safe swarf removal.

Trip probes with braking devices may form part of the safeguarding solution where the risk assessment permits. However, when considering the use of trip probes as a primary safeguard, all of the following conditions should apply:

- Movement of the machine table is slow and inadvertent contact by the operator may be considered to be low risk. In these circumstances, the primary risk remains from the rotating chuck and cutting tool.

- Various individual non-standard components are being machined and a high degree of close observation is required for setting the machines.

The limitations of these devices must be recognised, both in terms of their practicability of use and the level of protection they provide. A magnetic based trip probe is able to provide improved protection as it can be moved to the most appropriate position, depending on the particular workpiece being machined.

Trip probes do not directly prevent entanglement but mitigate the extent of injury, when actuated, by applying the brake to stop the machine quickly.

Trip devices alone do not protect against other hazards such as crushing and trapping between fixed and moving parts of the machine or workpiece. Your risk assessment should determine if trip devices will be effective for the range of hazards present. A detailed risk assessment will be required to justify that other safety measures are not practicable.

CNC functionality must be disabled if use of trip probes is to be considered, due to the possibility of unexpected movement.

It is not possible to specify a minimum stopping performance for braking systems. This is because of the wide range of machine sizes and other design characteristics.

The objective should be to stop the machine as quickly as possible taking into account the particular circumstances. Where brakes are fitted to older machines care should be taken to ensure that the machine is capable of withstanding the stresses induced by the effects of braking. A braking system may be mechanical or electrical or a combination of both.

A safe system of work must be prepared for setting operations and include management arrangements for the training of operators and monitoring that the system is implemented correctly.

Where powered movement of machine elements is necessary for setting operations, and access by the operator into the work zone must be justified by the risk assessment and the risks reduced by using supplementary safeguards.

In these cases the primary safeguard, i.e. guard interlocking, may be suspended by a nominated competent person using a key-operated selector switch. The key must be controlled by the competent person and not left in the machine.

Any further hazardous movement of the machine should only be possible by using a hold-to-run control arrangement or enabling device. The selector switch should also enable the braking arrangements, eg DC injection braking. On release of the hold-to-run control (or enabling device), the braking system should be applied.

This principle may be incorporated into an existing pendant control.

Other machine controls, eg the start button or feed and speed selectors, should be clearly visible and identifiable with appropriate marking where necessary. The main controls should be positioned so that people are not at risk when operating them.

One or more emergency stop controls should be provided where appropriate. Emergency stop controls should be readily accessible. Where emergency stop controls are activated, the machine should only be able to be restarted when the emergency stop device has been reset manually and normal operating controls are used to restart the machine.

Other hazardous parts such as transmission machinery including shafts, gears, pulleys, etc should be guarded using fixed guards. Where routine access is required to any of these parts, interlocked guards should be fitted. Guards should prevent access to the dangerous parts of swarf conveyors or elevators.

All relevant health and safety information and, where appropriate, written instructions on the use of horizontal boring machines must be made available to operators.

Operators must be competent to use the machine safely and to follow all safe systems of work. Adequate training should be given to ensure they have the correct skill, knowledge and risk awareness, and to ensure that they are physically suited to the task.

Particular attention should be given to:

- dangers at the machine;
- location and operation of controls;
- precautions to reduce the risk of entanglement;
- correct use of guards and other safety devices;
- any tests, eg daily test of trip devices and the system for reporting defects; and
- safe systems of work for cleaning, maintenance, setting and adjustment, loading of workpieces etc.

4.2. Technical information to offset hazards due to lifting operations

The lifting device should be of sufficient capacity and suitable for the purpose of lifting. A lifting device which is either mobile or capable of being dismantled and which is designed for lifting loads should be used in such a way as to ensure its stability during use under all foreseeable conditions. The nature of the ground should also be taken into account. All information in this chapter is taken from [26].

The maximum permissible load of the lifting device should not be exceeded. When two or more items of machinery used for lifting nonguided loads are installed or erected on a site in such a way that their working radii overlap, appropriate measures should be taken to prevent collisions between the loads and the machinery parts themselves.

When using mobile machinery for lifting non-guided loads, measures should be taken to prevent the equipment from tilting, overturning, moving or slipping. Checks should be made to ensure that these measures are implemented properly. If the operators of machinery designed for lifting nonguided loads cannot observe the full path of the load either directly or by means of auxiliary equipment, a competent person should be in communication with the operators to guide them. Organizational measures should be taken to prevent collisions involving the load which could endanger workers.

Work should be organized in such a way that a worker can safely attach or detach a load by hand, in particular by ensuring that workers retain direct or indirect control of the machinery.

In particular, if a load has to be lifted by two or more pieces of machinery for lifting non-guided loads simultaneously, a procedure should be established and applied to ensure good coordination on the part of the operators. Measures should be taken to ensure that workers are not present underneath suspended loads, unless their presence there is required for the effective performance of the work.

If machinery designed for lifting non-guided loads cannot maintain its hold on the load in the event of a complete or partial power failure, appropriate measures should be taken to avoid exposing workers to any resultant risks. Suspended loads should not be left without surveillance unless access to the danger zone is prevented and the load has been safely suspended and is safely held.

Outdoor machinery designed for lifting non-guided loads should not continue when meteorological conditions deteriorate to the point of jeopardizing the safe use of the equipment and exposing workers to risks. Adequate protection measures, in particular to prevent the machinery from turning over, should be taken to prevent any risks to workers.

Loads should not normally be moved above unprotected workplaces that are usually occupied by workers. Where that is absolutely unavoidable because the work cannot be carried out properly in any other way, appropriate procedures should be established and applied.

Machinery should be designed and constructed in such a way that its stability is maintained both in and out of service, including at all stages of transportation, assembly and dismantling, during foreseeable component failures, and during any tests carried out in accordance with the instruction handbook (operator's manual).

Machinery should be provided with devices which act on the guide rails or tracks to prevent derailment. If, despite such devices, there remains a risk of derailment or of failure of a rail or of a running component, devices should be provided to prevent the equipment, component or load from falling or the machinery from overturning.

Machinery, lifting accessories and their components should be capable of withstanding the stresses to which they are subjected whether in use or not in use, under the installation and operating conditions provided for and in all relevant configurations, with due regard to any potential effects of conditions of use and forces exerted by persons. This requirement should also be satisfied during transport, assembly and dismantling.

Machinery and lifting accessories should be designed and constructed in such a way as to prevent failure from fatigue and wear, taking due account of their intended use.

CONCLUSIONS

In the bachelor's qualification paper in the general technical and technological parts the analysis of technical requirements of the part "Cover" MA96F3.12.604 and its official purpose is carried out. The analysis of the basic technological process for the part manufacturing is also carried out. The type of production established after the calculations is mass production. A rational method of workpiece producing is the casting in the metal mold. The technological process of the cover manufacturing is developed. The equipment and fixtures were replaced after changing the type of production from lot to mass type. In particular, turret lathes (model 1641) are replaced by horizontal semi-automatic lathes, drilling operations are performed on a drilling machine tool with a multi-spindle drilling head. Also calculations of intermediate allowances, cutting conditions and norms of time are carried out.

The reduction of the artificial calculation time was obtained as a result of the changes in the technological process, of the use of multi-tool settings and combination of operation elements, as well as the introduction into the technological process of a rational method of the workpiece production - casting in the metal mold.

REFERENCES

1. Кухарський О. М., Кущак І. В. Методичний посібник до курсового проекту по курсу “Технологія машинобудування”. Тернопіль, 2001. 58 с.

2. Классификатор ЕСКД. Иллюстрированный определитель деталей. Классы 71,72,73,74,75,76 (в отдельных книгах). М.: Издательство стандартов, 1986. 235 с.

3. Орлова П. Н., Скороходова Е. А. Краткий справочник металлиста. М.: Машиностроение, 1986. 456 с.

4. Боженко Л. І. Технологія виробництва заготовок у машинобудуванні. Київ: НМК ВО, 1990. 264 с.

5. Дьячков В. Б. Специальные металлорежущие станки общемашиностроительного применения: справочник. М.: Машиностроение, 1983. 328 с.

6. Косилова А. Г., Мещеряков Р. К. Справочник технолога-машиностроителя: в 2-х т. М. : Машиностроение, 1985. Т. 2. 496 с.

7. Кухарський, О. М., Кузьмін М. І. Визначення припусків табличним методом. Тернопіль : Видавництво ТДТУ, 2004. 135 с.

8. Паливода Ю. Є., Кухарський О. М. Визначення припусків розрахунково-аналітичним методом, Тернопіль, 2003. 81 с.

9. Косилова А.Г., Мещеряков Р. К. Справочник технолога-машиностроителя: в 2-х т. М. : Машиностроение, 1985. Т. 1. 1986. 656 с.

10. Барановский Ю. В. Режимы резания металлов. М.: Машиностроение, 1972. 258 с.

11. Паливода Ю. Є., Ткаченко І. Г., Капаціла Ю. Б., Гевко Ів. Б. Технологія оброблення корпусних деталей : навч. посіб. Тернопіль : ТНТУ, 2016. 156 с.

12. Горбацевич А. Ф. Курсовое проектирование по технологии машиностроения. Минск: Вышэйшая школа, 1975. 288 с.

13. Итин А. М., Родичев Ю. Я. Наладка и эксплуатация токарных многошпиндельных полуавтоматов. М. : Машиностроение, 1977. 136 с.

14. Ансеров М. А. Приспособления для металлорежущих станков. М.: Машиностроение, 1966. 650 с.

15. Горошкин А. К. Приспособления для металлорежущих станков. Спра-

вочник. М.: Машиностроение, 1965. 461 с.

16. Кухарський О. М. Методичні вказівки на тему “Проектування калібра-пробки, калібра-скоби” для виконання конструкторської частини дипломного проекту. Тернопіль, 2005.

17. Жидецький В. Ц., Джигирей В. Ц., Мельников О. В. Основи охорони праці : навчальний посібник. Львів: Афіша, 2000. 350 с.

18. Жидецький В. Ц. Практикум із охорони праці : еавчальний посібник. Львів: Афіша, 2000. 349 с.

19. Паливода Ю. Є., Ткаченко І. Г., Капаціла Ю. Б. Технологія оброблення валів : навч. посіб. Тернопіль : ТНТУ, 2016. 198 с.

20. Паливода Ю.Є., Дячун А.Є., Лещук Р.Я. Інструментальні матеріали, режими різання і технічне нормування механічної обробки : навчальний посібник. Тернопіль: Тернопільський національний технічний університет імені Івана Пулюя, 2019. 240 с.

21. Дячун А.Є., Капаціла Ю.Б., Паливода Ю.Є., Ткаченко І.Г. Методичний посібник з виконання курсового проекту з дисципліни «Технологія обробки типових деталей та складання машин». Тернопіль: ТНТУ, 2016. 75с.

22. Дичковський М. Г. Технологічна оснастка. Проектно-конструкторські розрахунки пристосувань: навч. посіб. Тернопіль : ТДТУ, 2001. 277с.

23. Паливода Ю.Є, Дячун А.Є. Технологія виготовлення деталей класу «Порожнисті циліндри» (втулки) : методичні вказівки до практичних занять та виконання індивідуальних завдань з дисциплін «Технологія обробки типових деталей та складання машин» та «Технологія машинобудування» Тернопіль : Тернопільський національний технічний університет імені Івана Пулюя, 2019. 56с.

24. Паливода Ю.Є., Дячун А.Є., Капаціла Ю.Б, Ткаченко І.Г. Розмірні ланцюги: навчально-методичний посібник: Тернопіль: Тернопільський національний технічний університет імені Івана Пулюя, 2018. 132с.

25. Health and Safety Executive information sheet. Safe use of horizontal boring machines Engineering Information Sheet No 28 (Revision 1). This document is available at: www.hse.gov.uk/pubns/eis28.pdf.

26. Safety and health in the use of machinery. ILO code of practice Geneva, International Labour Office, Programme on Safety and Health at Work and the Environment, 2013.

27. Ibrahim A. Al-Zkeri, M.S. Finite element modeling of hard turning. The Ohio State University, 2007.

28. Mikell P. Groover. Fundamentals of Modern Manufacturing. Materials, Processes, and Systems. Fifth Edition. John Wiley & Sons, Inc., 2013.

29. Kalpakjian, S., and Schmid S. R. Manufacturing Processes for Engineering Materials, 6th ed. Pearson Prentice Hall, Upper Saddle River, New Jersey, 2010.

30. Groover, M. P. Work Systems and the Methods, Measurement, and Management of Work, Pearson Prentice-Hall, Upper Saddle River, New Jersey, 2007.

31. Groover, M. P. Automation, Production Systems, and Computer Integrated Manufacturing, 3rd ed. Pearson Prentice-Hall, Upper Saddle River, New Jersey, 2008.

32. Boothroyd, G., and Knight, W. A. Fundamentals of Metal Machining and Machine Tools, 3rd ed. CRC Taylor & Francis, Boca Raton, Florida, 2006.

24. Bakerjian, R. (ed.). Tool and Manufacturing Engineers Handbook. 4th ed. Vol VI, Design for Manufacturability. Society of Manufacturing Engineers, Dearborn, Mich., 1992.

25. Parsai, H., Leep, H., and Jeon, G. The Principles of Group Technology and Cellular Manufacturing, John Wiley & Sons, Hoboken, New Jersey, 2006.