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

Readiness for qualification
Acting head of the department
_______ Olexander OKHRIMENKO

«___»____________2022

Diploma project
Level of higher education – first (bachelor)
Program subject area – 131 “Applied Mechanics”
Educational Program “Manufacturing Engineering”

topic: Technological preparation of a manufacturing process to produce a part “lever arm”

Student :

Josaphat Kibondo Yalwamba

Supervisor:

Assoc. Prof. Danylova Liudmyla. __________

Reviewer:

Assoc. Prof. Krasnovyd Dmytro. _______________

I confirmed that in this diploma project there are no borrowings from the works of other authors without proper references.
Student

Kyiv 2022

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APPROVED
Acting head of the department
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«___»____________2022

ASSIGNMENT
for the student's diploma project

Josaphat Kibondo Yalwamba

1. Topic of the project Technological preparation of a manufacturing process to produce a part “lever arm”

Project supervisor _____Phd, associate professor Danylova Liudmyla__

approved by the University Order of «6» _ June _2022 № 73

2. Deadline for submission of the project «17» June 2022

3. Initial data for the project Part drawing and material, Production quantity per annum, working conditions of the part in the assembly unit. _____ _________ Fundamental study of exit burr formation mechanisms during orthogonal cutting

4. Content of the text part (explanatory note) Design of the operational ______ _manufacturing process plan, calculation of the allowance, calculation of cutting

conditions for 2 manufacturing steps, estimation of necessary clamping force.

5. List of the graphic material (indicating mandatory drawings, posters, presentations, etc.) 3-D drawing of the part and drawing of the workpiece.

Schematic representation of a technological operation. Assembly drawing of the machine tool. Study of exit burr formation mechanisms during orthogonal cutting illustration.

6. Date of the task issue 20. 04.2022

Time schedule

No	The stage of the diploma project	Deadline	Notes
1	Analysis of design features of the part	20.04.22	completed
2	Determining the type of production	20.04.22	completed
3	Calculation of the allowance	30.04.22	completed
4	Design of the typical surfaces processing routes	10.05.22	completed
5	Design of the operational manufacturing process plan	15.05.22	completed
6	Setting cutting conditions	20.05.22	completed
7	Development of the fixture design	30.05.22	completed
8.	Calculation of the cost processing	30.05.22	completed
9	Fundamental study of exit burr formation mechanisms during orthogonal cutting	15.06.22	completed

Student Josaphat Kibondo YALWAMBA

Supervisor Liudmyla DANYLOVA

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Abstract

УДК 658.512

Manufacturing technology is the techniques and processes designed to improve manufacturing quality, productivity and practices, including quality control, shop floor management, inventory management and worker training, as well as manufacturing equipment and software.

However, there are different manufacturing processes to obtain a part. But in this study, the process chosen were casting and finally machining to required standard with consideration to choice of material.

This project work is focused on the design and manufacturing technological processes of producing a part.

Firstly, the part was studied to see the feasibility of its manufacturability, with respect to (DFM), Hence, the part was designed.

Furthermore, the technological processes which involved:

Analysis of the part in the assembly unit, the type of material for production, taken into account

The condition of service environment, the size and weight of the part, best locating scheme.

Production, the cutting tools and its cutting forces, the production type and the choice of machine were all integrated into the study.

Hence, the economic indicators of the production technology of the part are presented.

Keywords: manufacturing process, cutting tools, manufacturability.

Josaphat Kibondo Yalwamba

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Acknowledgement

With gratitude to God, I want to say a big thank you to my esteemed dad, Mr. Kibondo Yalwamba for his Support throughout the period of my academic pursuit, and my mom for standing by me during this period.

Also, a big shout out to my supervisor, Professor Liudmyla Danylova, for making me scale through this project despite the ongoing war. I am sincerely grateful to everyone.

1 . Technological section

1.1. Analysis of the service purpose and operating conditions of the part in the node

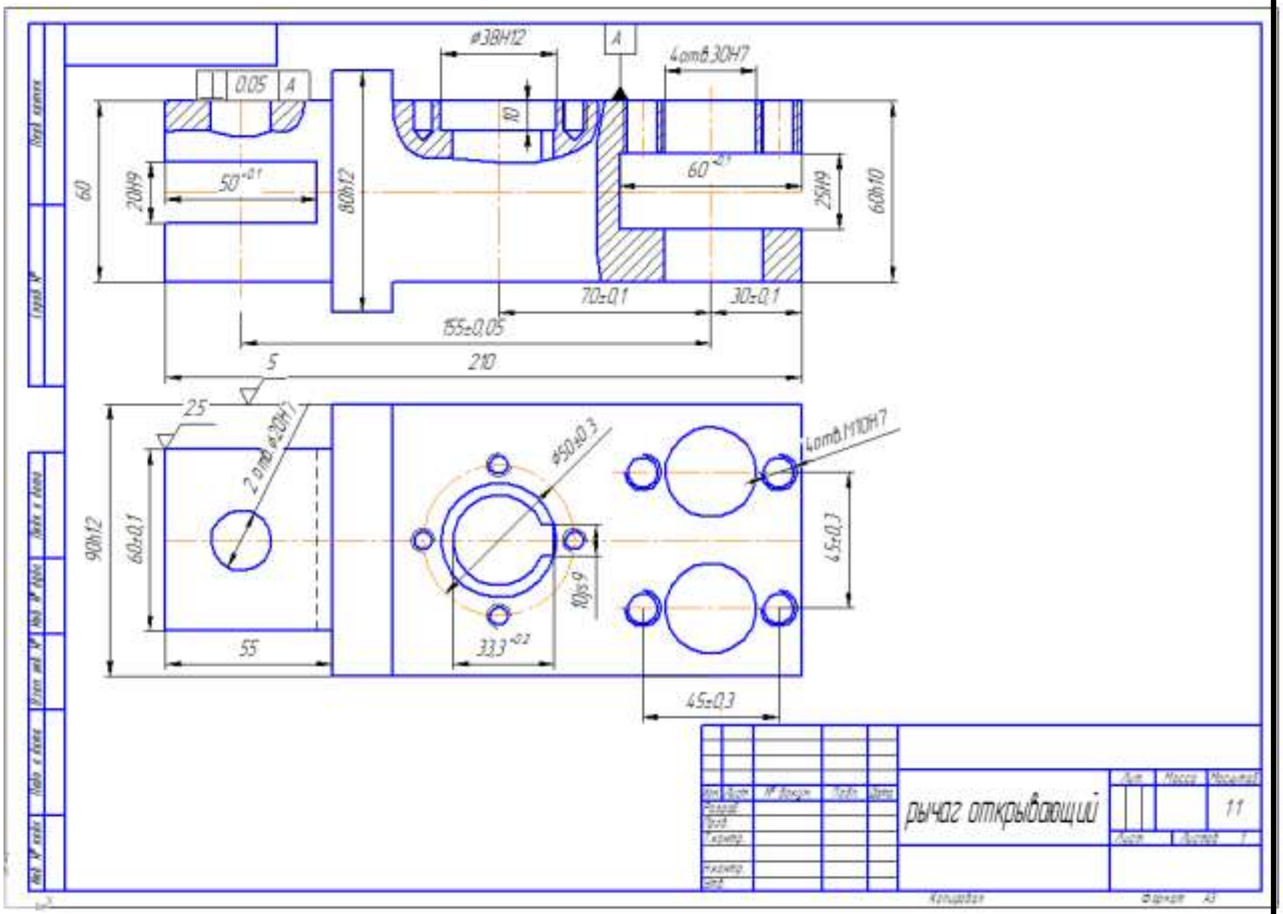


Figure 1.1 - Drawing details " Opening lever "

The lack of assembly assembly of the drawing, which includes the lever, and data on the service purpose of the part creates difficulties in accurately determining the purpose of the part.

Looking at the configuration and dimensions of the lever , we can assume that it is a detail of the average engineering.

Detail “Lever opening ” works in the conditions of alternating loadings.

In the unit, the lever is connected to other parts by two holes ø38H8, four through holes ø30H7, two holes ø20H7, four bolts M10-7H and four M6-7H.

The lever is made of gray cast iron SC 25 GOST 1412-85 of the following chemical composition and mechanical properties:

Table 1.1-Chemical composition and mechanical properties of cast iron

material	Elements	ε

	C	Yes	Mn	R	S	(linear shrinkage,%)
MS 25	0.33 ... 0.35	1.4..2.4	0.7… 1.0	up to 0.2	up to 0.15	1.2

Tensile strength: tensile σ_B = 250 MPa ;

when bending σ_P = 392 MPa ; HB = 1668 ... 2364

density: γ = 7.1 g / cm ^{3} .

Conclusion. The part works in the conditions of alternating loadings and action of aggressive environments. The material of the part adopted by the designer ensures the operability of the part in these conditions.

1.2 **Determining the type of production and analysis of its impact on the tasks of technological preparation of production**

Type of production is a classification category of production, which is distinguished by the breadth of the range, regularity and volume of production. In accordance with the standards of GOST 3.1108-74 of the Unified System of Technological Documentation (USTD) and GOST 14.004-74 of the Unified System of Technological Preparation (ESTP) one of the main characteristics of the type of production is the coefficient of consolidation of operations (K_{zo}), which is defined as the ratio of all operations , performed or to be performed during the base period of time to the total number of jobs.

As at this stage of work it is not yet known not the number of operations, not the number of jobs, it is impossible to determine the coefficient of consolidation of operations. Since it is known that the weight of the part is 7 kg, and the annual output is 5,000 parts per year, we assign the type of production according to the following table.

Table 1.2 Determination of the type of production

Type of production	Annual volume of production of parts of one name, pcs		
	light, mass up to 20 kg.	medium, weighing 20 ... 30 kg.	heavy, weighing more than 30 kg
Single	up to 100	to 10	1 ... 5
Small series	101 ... 500	11 ... 200	6 ... 100
Medium series	501 ... 5000	201 ... 1000	101 ... 300
Large series	5001 ... 50000	1001 ... 5000	301 ... 1000
Masses	more than 50,000	more than 5000	more than 1000

Therefore, for the above conditions of production, we accept the average series type of production. For this type of production K is $_{set}$ within 10 ... 20. We accept K_{zo} = 11.

Conclusion. The type of production is medium -scale , so we will perform all further calculations and make technological decisions for the medium -scale type of production with K_{zo} = 11.

1.3. Working out of a design of a detail on manufacturability

Working out of a design of a detail on manufacturability needs to be carried out according to ESTPV. General rules for ensuring the manufacturability of the product design are determined in accordance with the standard GOST 14.201-83, and the rules for selecting indicators of manufacturability of the product design in accordance with the standard GOST 14.202-73. This standard provides for two types of assessment of manufacturability: qualitative and quantitative.

Qualitative assessment characterizes the manufacturability of the product design in general, based on the production experience of the contractor.

Quantitative assessment of the manufacturability of the product design involves the definition of indicators, the numerical value of which characterizes the degree of satisfaction of the requirements for the manufacturability of the structure.

1.3.1. Qualitative assessment of the manufacturability of the structure.

Knowing the material of the part and its configuration, you can use to obtain a blank method of casting in sand-clay molds on metal models with machine molding. The most effective way to obtain blanks from gray cast iron is casting. The configuration of the casting is quite simple and allows you to easily remove its model from the mold; the whole casting will be formed in one crucible and the mold will have one flat connector.

The fact that the lever is a symmetrical part - it increases its manufacturability.

The configuration of the lever provides free access of the cutting and measuring tool to the processed surfaces.

The design has high rigidity and allows intensive cutting modes.

Knowing the annual production program and the configuration of the lever, it is impractical to change the material of the part or use a welded instead of a cast blank.

The design provides surfaces and holes that can be machined with a standard tool.

In general, the design is technological.

1.3.2. Quantitative characteristics of the manufacturability of the design of the part.

Let's define quantitative characteristics of manufacturability which characterize technical characteristics of a design of a detail.

1.3.2.1. The coefficient of manufacturability of the structure using the material of the workpiece is determined by the formula:

$$K_{BM} = \frac{M_Д}{M_З} \geq 0,7$$

where MD is the mass of the finished part, kg; M_D = 7 kg ; M_C - weight of the workpiece, M_C = 9.5 kg

So:

$$K_{вм} = \frac{7}{9.5} = 0,73.$$

The method of manufacturing blanks is considered technological, as the previous ratio is fulfilled.

1.3.2.2. The coefficient of manufacturability of the structure and the accuracy of the dimensions of the surfaces K_{TO} is determined by the formula:

$$K_{TO} = 1 - \frac{1}{A_{cp}} \geq [K_{TO}] = 0,8,$$

where $A_{cp} = \frac{\sum A_i \cdot n_i}{\sum n_i}$ - the average class of accuracy of product processing;

n_i is the number of dimensions of the corresponding accuracy class; T - accuracy class of processing.

$$A_{cp} = \frac{7 \cdot 18 + 8 \cdot 2 + 10 \cdot 1 + 12 \cdot 6 + 14 \cdot 13}{40} = 10,15 \cdot$$

$$K_{TO} = 1 - \frac{1}{10,15} = 0,9 > [K_{TO}] = 0,8$$

So, according to this indicator, the detail is technological.

1.3.2.3. The coefficient of manufacturability of the structure on the surface roughness K_w is determined by the formula:

$$K_ш = \frac{1}{Б_{cp}} \geq [K_ш] = 0,32,$$

where $Б_{ср} = \frac{\sum Б_i \cdot n_i}{\sum n_i}$ is the average parameter of the surface roughness of the product; B - surface roughness parameter; n $_i$ is the number of surfaces of the corresponding roughness class.

$$Б_{ср} = \frac{1{,}25 \cdot 4 + 5 \cdot 10 + 10 \cdot 10}{24} = 6{,}45$$

$$К_{ш} = \frac{1}{6{,}45} = 0{,}15 < [К_{ш}] = 0{,}32$$

According to this indicator, the detail is not technological .

Conclusion. The design of the lever is technological as most conditions are met: the use of the workpiece material, the accuracy of surface dimensions.

1.4. Rationale for choosing the type and method of manufacturing the workpiece

In accordance with the requirements of the drawing and as a result of the analysis of the design of the lever we come to the conclusion that it is most appropriate to use a cast blank.

Given the size and material of the lever , low requirements for the quality of the casting and the lowest cost of casting in sand-clay molds, the workpiece will be obtained by casting in molds with machine molding on metal models. Requirements for cast iron castings are specified in GOST 3212-80.

On the basis of the specified standards the sketch of casting of the lever (fig. 1) which considers foundry inclinations, allowances for machining is developed.

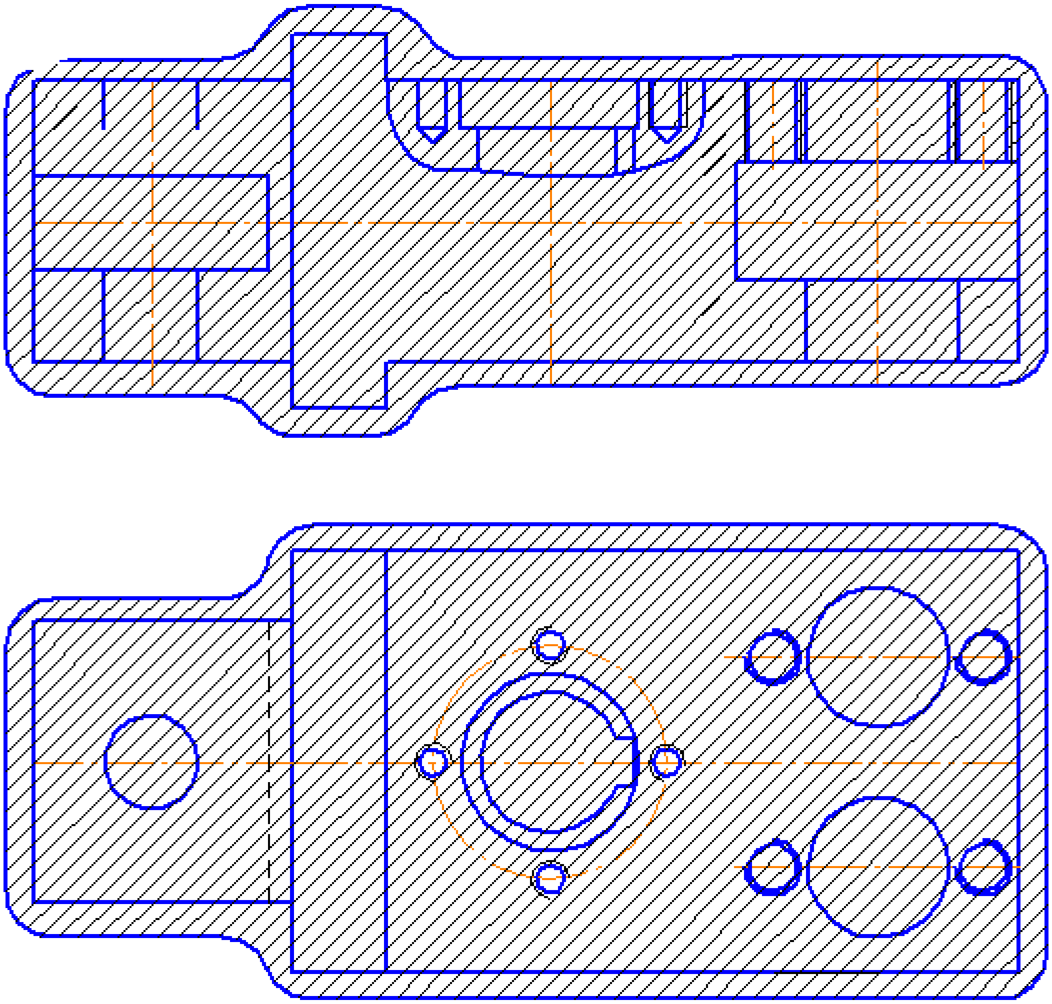


Fig.1.2 Opening lever arm (casting)

Conclusion. The workpiece is obtained by casting in molds with machine molding on metal models.

1.5. Rationale for the choice of technological bases

The general algorithm of a choice of technological bases provides consecutive performance of two stages:

- justification choice common technological bases (STB);
- justification choice technological bases (TB) for processing ZTB.

hole.

Auxiliary design bases of the "Opening Lever arm " part will be:

through two holes Ø20H7, four holes Ø30H7 and two grooves in length
Fastening surfaces are used to determine the position of fasteners and elements. The fastening surfaces of the "Lever opening" part will be all threaded holes.
General technological bases are called a set of technological bases, which ensures the execution of the entire technological process of processing or a certain part of it.

For implementation _ the choice of ZTB is performed classification surfaces for office purpose (Fig.2.4). Construction any details maybe be represented as a whole four species surfaces:

- basic design bases (OKB);
- auxiliary design bases (DKB);
- fasteners surface (KP);
- free surface (VP).

The main design bases for the part "Opening lever" will be:
plane A and the adjacent body.
Free surfaces - all other surfaces of the part. Free surfaces - not to be processed, and also those which do not contact directly with other details and connection .
Check the possibility of using the surfaces of the main design bases (OKB) as a general technological base (ZTB), which would be used to base the "Opening Lever" in the processing process.

OKB = > ZTB

Such a transformation is possible, therefore, in the first operation you need to process STB.

Let's analyze possible schemes of basing (SB) on OKB . For the best realization and balancing of a detail on ZTB, it is necessary to use a DKB surface, opening Ø20N7.

Only one SAT is possible for this part.

Given that the main design basis is the base plane hole Ø30H9 , the following scheme of basing on the general technological base is possible.

plane and two holes.

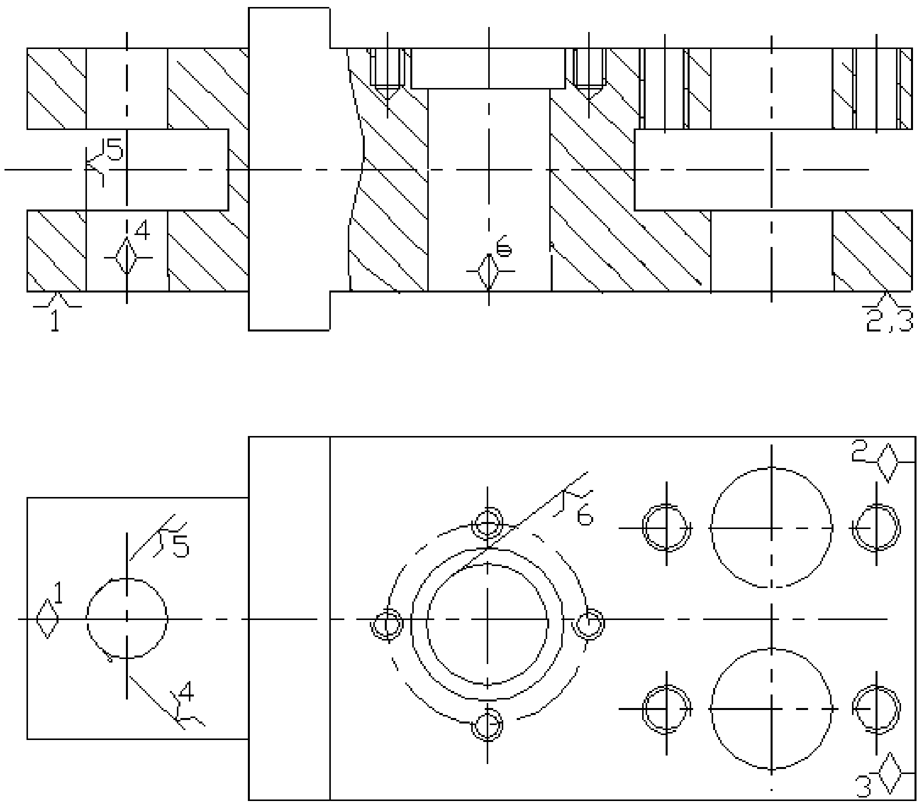


Fig.1. 3 Scheme of basing on general technological bases

The structural formula of the base scheme on the surfaces of general technological bases has the form:

SB $_{ZTB}$ = U (3) + PO (2) + O (1)

In - the installation base, deprives three degrees of freedom, namely - one longitudinal movement and two rotating.

PO - double-support base deprives two degrees of freedom, namely - two longitudinal movements.

Support base, deprives one degree of freedom, namely - one longitudinal movement.

Advantages: - the most traditional;

- opens the workpiece for processing on four sides;
- simple enough constructively in implementation.

Disadvantages: - increased requirements for the quality of the base hole;

- increased requirements for the perpendicularity of the axes

We are checking the possibility of using a fixed set of STB for the entire technological process. In our case, the set of ZTB remains unchanged:

ZTB => unchanged

1.5.2 Justification of the choice of technological bases for the first technological operations

Rationale technological bases for the first operations technological process carried out with the help sketch of the workpiece (Fig. 1.3). The first operations technological process provide processing a set of common technological bases. When substantiating TV selection for the first operations technological process necessary to provide implementation the following tasks:

- to provide processing of the set of ZTB for one first operation that provide the highest possible precision spatial position sun them surfaces that _ are included in the set of ZTB;
- If processing of the set of ZTB is not possible, then on the first TP operations are required predict processing surfaces that _ leave the workpiece at least three degrees in the presence (In (3), PN (4)). Note that the reinstallation of the workpiece during the first technological operations on a set of all of them untreated surfaces are not allowed.

Consider possible schemes TV - based for first operations technological process.

For this we use an algorithm to select TV:

- as TV we accept surface , treatment which according to the drawing is not provided ;
- if Sun and the surface of the workpiece is processed , then we accept as TV surfaces that _ have the smallest allowance (it is warns occurrence of marriage on this surface on the further processing);
- if the allowances are uniform , it is necessary to choose surfaces on which the lack is not allowed ;

- choose as TV surfaces for which _ necessary to provide p uniform allowance for the following stages processing ;
- if is few possible TV -based schemes , we accept as TV version with the shortest dimensional chain .

In order to process ZTB, with which we will base the exact detail, we will consider all possible options for technological bases (TB) for processing ZTB (Fig. 1.4).

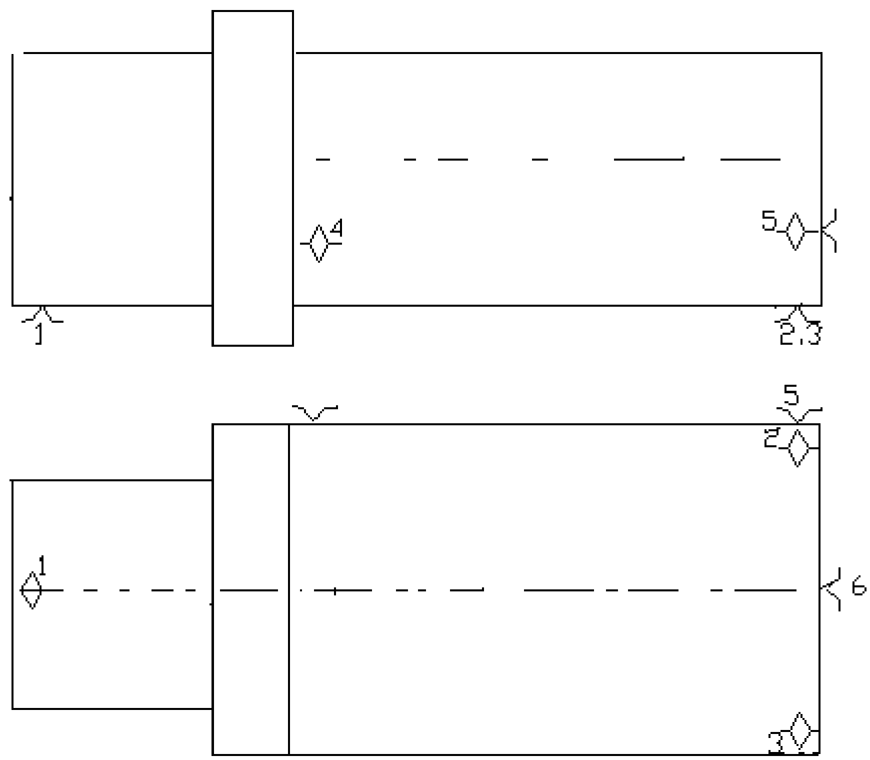


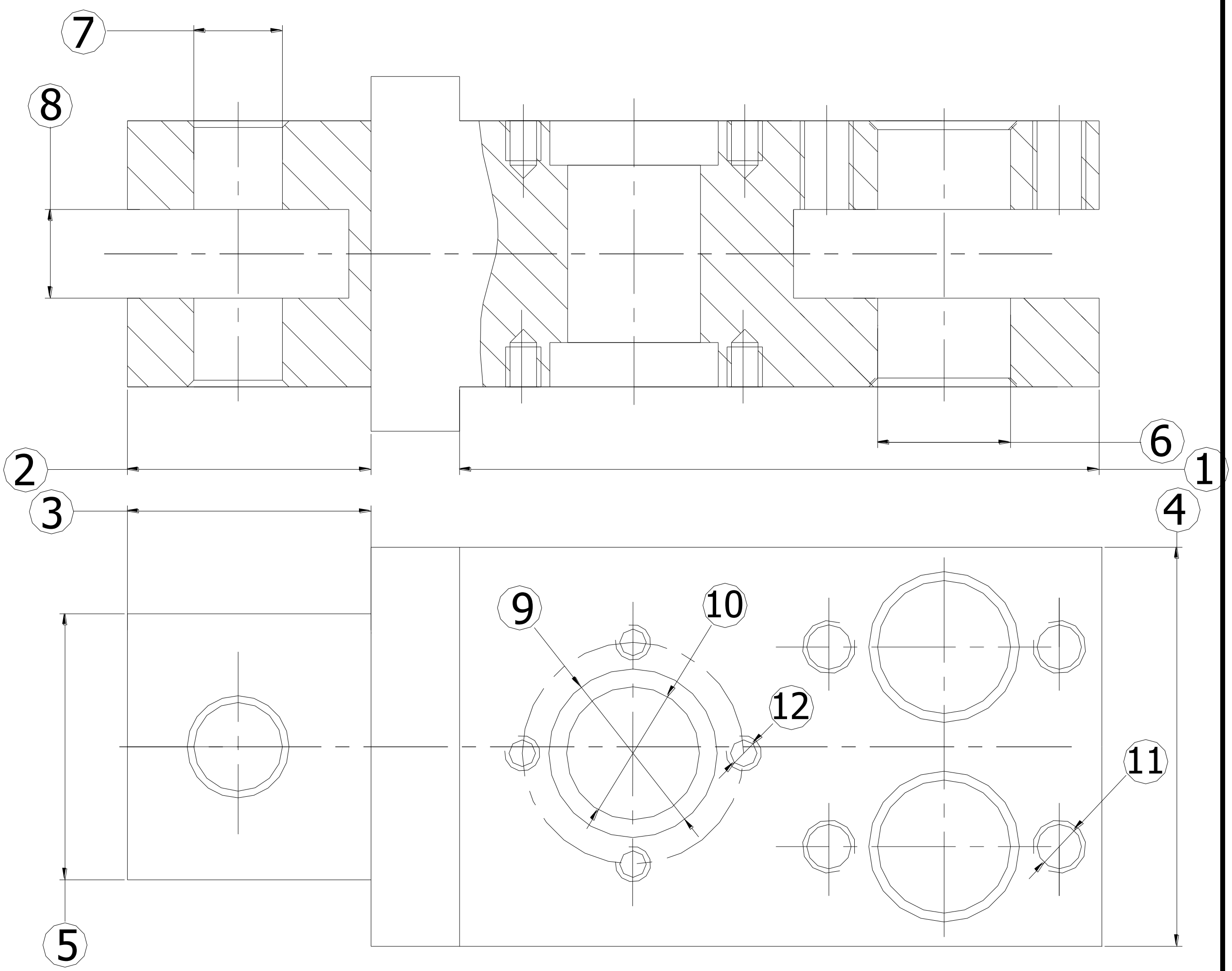
Fig. 1 .4. Choice of TV for ZTB processing

Therefore, having analyzed the options for processing ZTB, we choose the fastening of the workpiece, which is shown in Fig. 3, a.

After processing the TV, choose the scheme based on ZTB, which is shown in Fig.2.

1.6. Design of processing sequences surface details

The design of any part can be divided into a set of typical geometric shapes, the surfaces of which, according to the working drawing, there are certain requirements for the parameters of accuracy and quality. The practice of machine-building production has accumulated experience in the effective treatment of such surfaces with the achievement of the required accuracy of dimensions and quality



parameters of the surface layer.

Fig.1.5. Detail sketch and surface numbering

The table shows the technological sequences of surface treatment of the part "Lever opening ” .

Table 1.3. Typical technological sequences of surface treatment of the part “Lever open ” and the corresponding characteristics of quality and accuracy

№	Characteristics of surface quality according to the drawing		Technological sequence of processing	Surface quality characteristics after treatment	
	IT sizing accuracy	The roughness parameter R_a, μm		IT sizing accuracy	The roughness parameter R_a, μm
1	2	3	4	5	6
1	10	5	Milling: 1. previous (draft) 2. preliminary (semi -finished) 3. final	 14 12 10	 20 10 5
2	10	5	Milling: 1. previous (draft) 2. preliminary (semi -finished) 3. final	 14 12 10	 20 10 5
3	12	10	Milling: 1. previous (draft) 2. final (semi -finished)	 14 12	 20 10
4	12	10	Milling: 1. previous (draft) 2. final (semi -finished)	 14 12	 20 10
5	12	10	Milling: 1. previous (draft) 2. final (semi -finished)	 14 12	 20 10
6	7	1.25	Drilling Countersinking Pre-deployment Deployment is final	12 11 9 7	20 10 5 1.25
7	7	1.25	Drilling Countersinking Pre-deployment Deployment is final	12 11 9 7	20 10 5 1.25
1	2	3	4	5	6
8	12	5	Milling:		

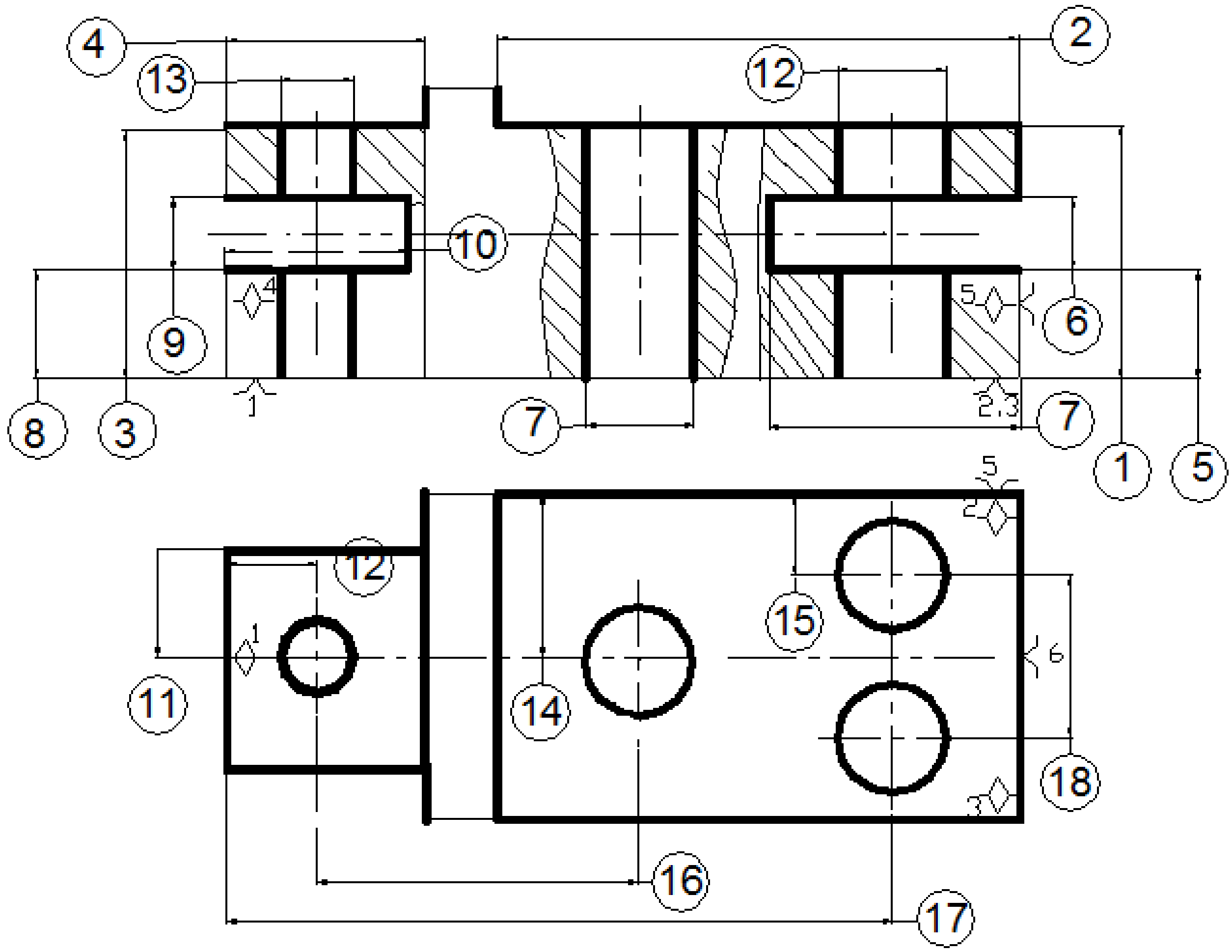
			1. previous (draft) 2. final (semi -finished)	14 12	10 5
9	8	1.25	Boring: 1. previous (draft) 2. preliminary (semi -finished) 3. final	 12 10 8	 10 5 1.25
10	14	10	Drilling Countersinking	12 11	20 10
11	7	2.5	Drilling Countersinking Cutting the cut with a tap	12 10 7	10 5 2.5
12	7	2.5	Drilling Countersinking Cutting the cut with a tap	12 10 7	10 5 2.5

Conclusion. The main variants of typical sequences of surface treatment have been developed.

1 .6. Designing the content of technological operations

005 Milling. Machine - TongTai TMV400.

A. Install, secure, remove



A. Install, secure, remove.

005.01. Mill horizontal surface previously _ enduring dimensions 1.2

005.02. Mill horizontal surface previously _ enduring dimensions 3.4

005.03. Mill internal surface finally, withstanding sizes 6 and 7

005.04. Mill internal surface finally, withstanding sizes 8,9 and 10

005.05. Center afterwards _ position axles holes , withstanding dimensions 11,12,14,15,16,17 and 18

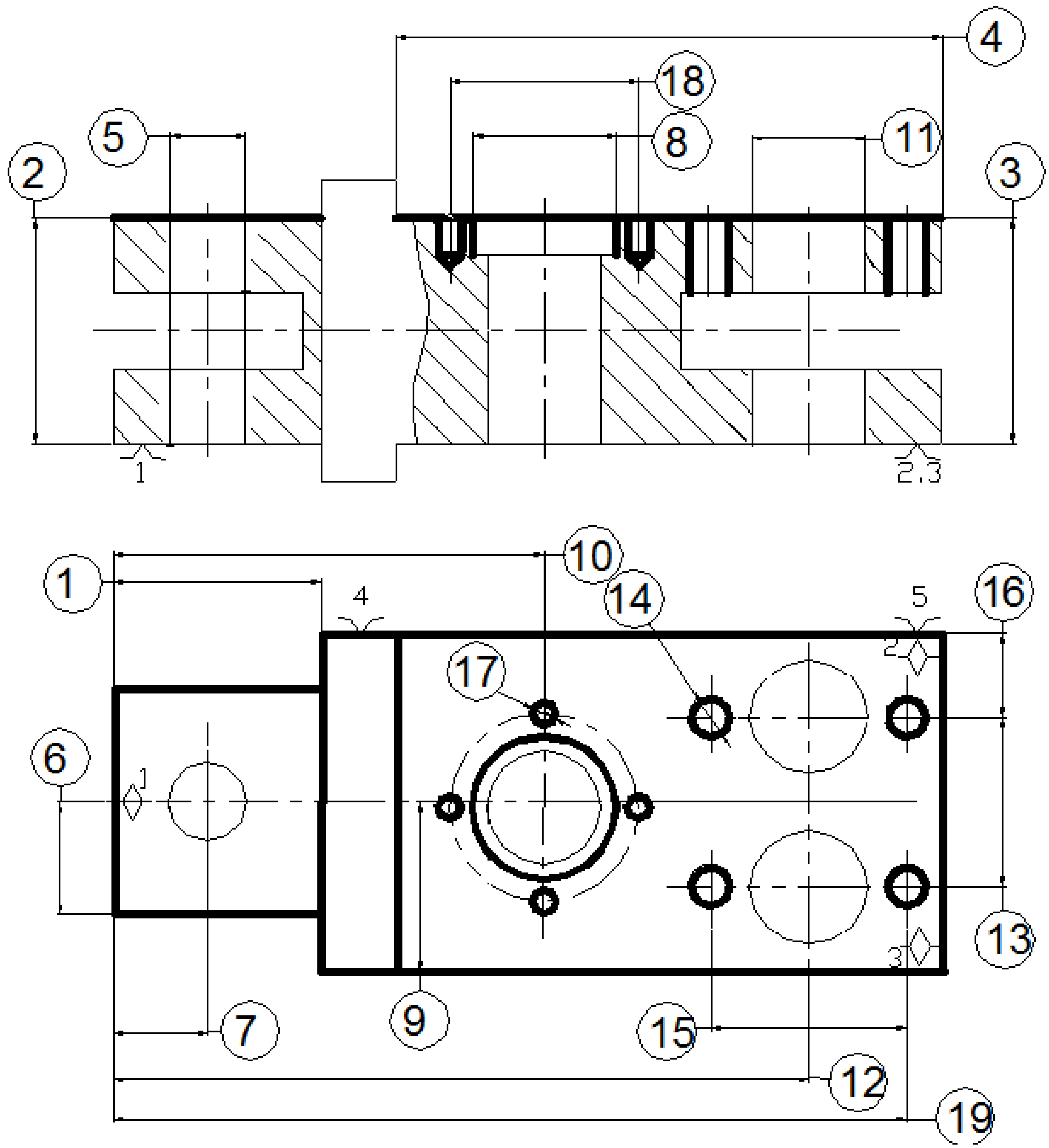
005.06. Drill through otv ir previously enduring sizes 7, 16

005.07. Drill otv ir pre - sustaining dimensions 12.13

005.08. Drill two holes in succession , pre - holding sizes 12, 14, 18

010 Multipurpose. Machine - TongTai TMV400

A. Install, secure, remove



040.01. Mill horizontal surface finally, withstanding
sizes 1,2,3,4

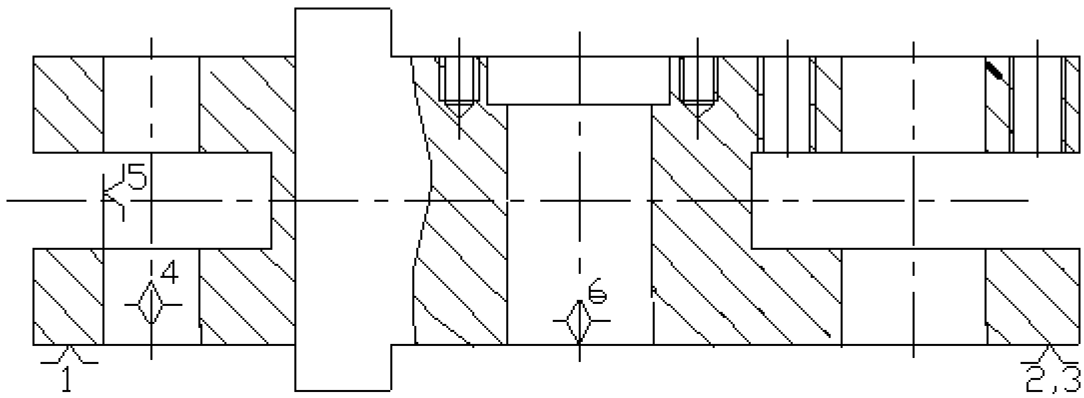
040.02. Grind sun and holes pre - holding dimensions 5,6,7,8,9,10,11,12,13

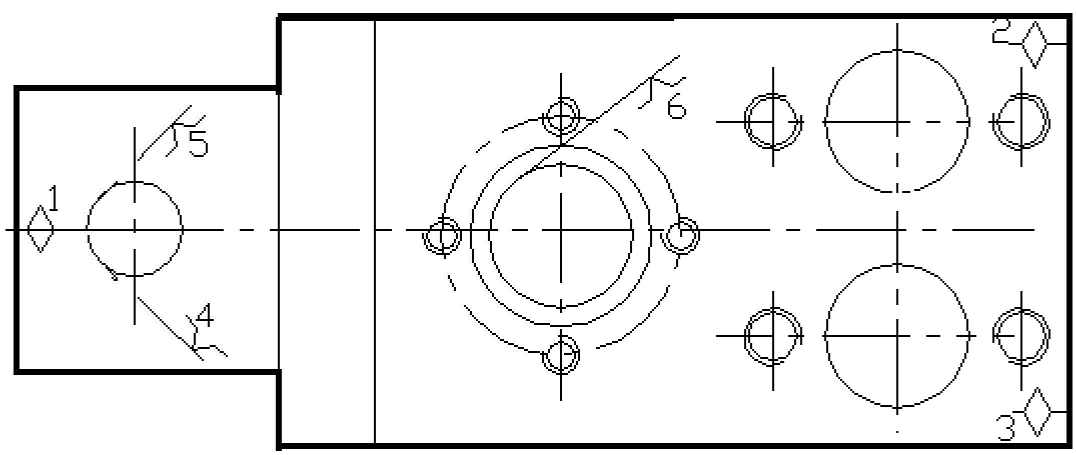
040.03. Center afterwards _ position axles holes , withstanding
dimensions 9,10,13,14,15,16,17,18,19

040.04. Drill then open the holes
dimensions 9,10,13,14,15,16,17,18,19
040.05. Cut p iz , enduring dimensions 9,10,13,14,15,16,17,18,19

015. Milling Machine - TongTai TMV400.

A. Install, secure, remove





A. Install, secure, remove

045.01. Mill the surface, keeping the sizes 1,2 , 3

045.02. Turn 180 °and mill the surface on the other side, withstanding the dimensions of 1,2,3

1.1 Analysis of the purpose and operating conditions of the part in the assembly

1.1.1 Analysis of design features of the part and its classification

Considering the configuration of the geometry 'Part of a housing shaft holder' we defined that it belongs to the class "Body"

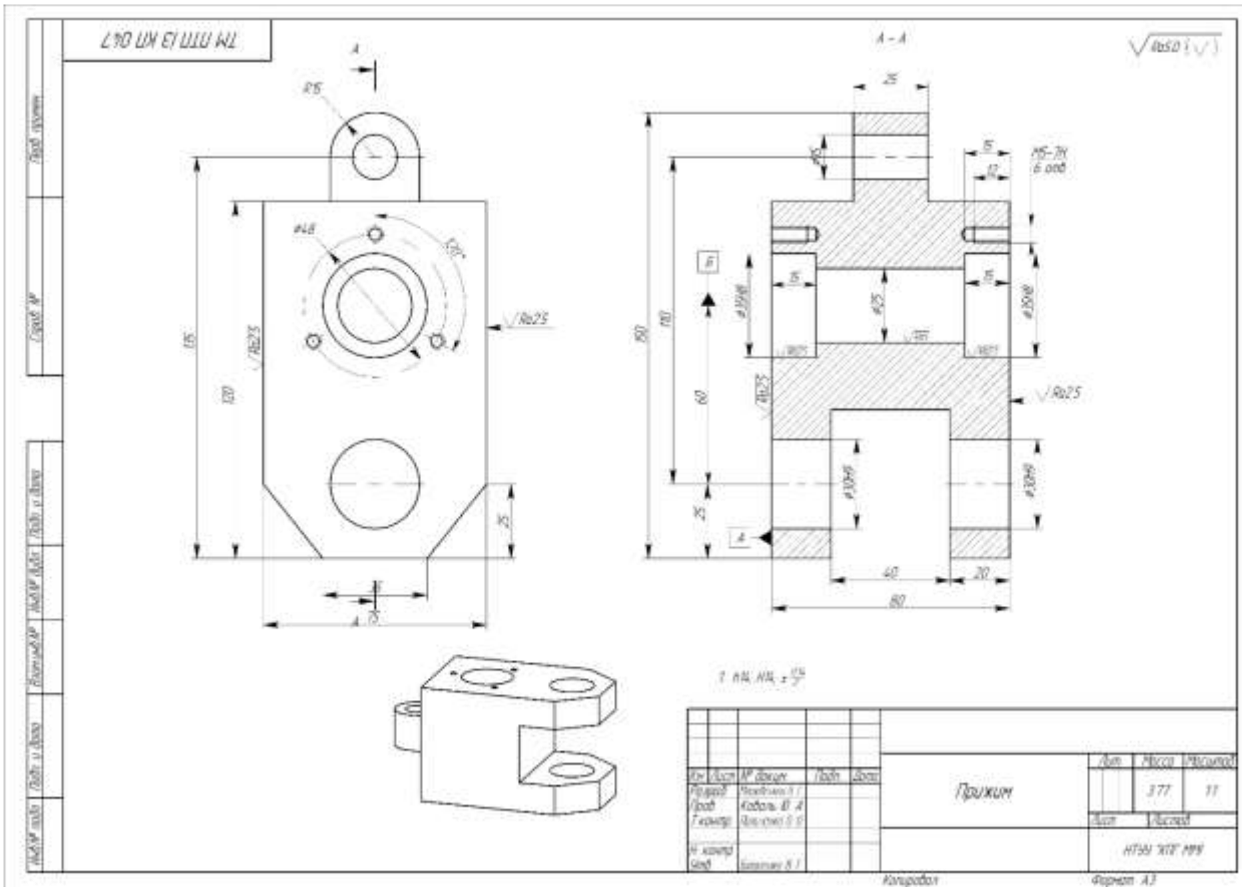
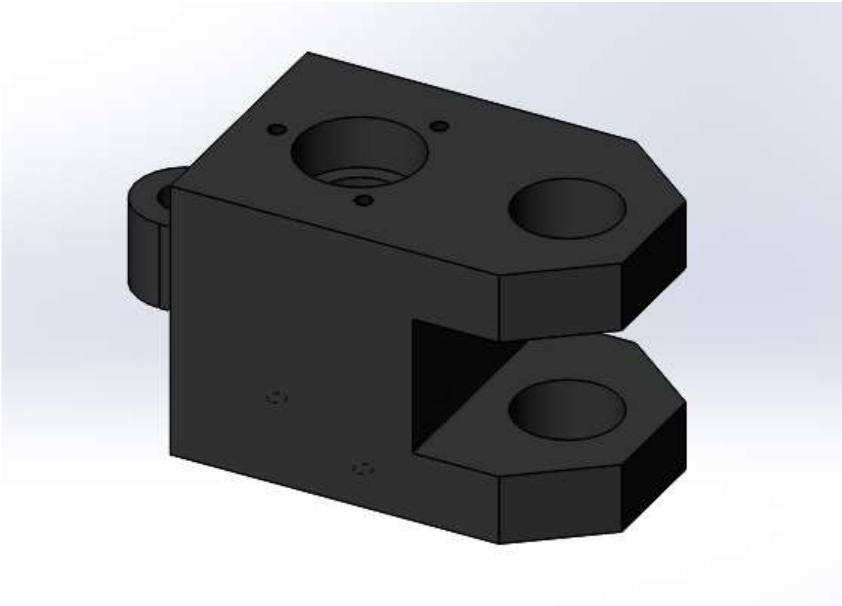


Fig.1.1 – 3D Drawing of the part 'Holder



In general, due to the nature of the part for housing shaft, the accuracy requirements are not very high. However, the requirement for the quality of the surfaces of the holes, and the perpendicularity of plan B to A are of very paramount important.

During manufacturing, a special attention must be paid to the machining of the surfaces of the holes, ensuring it's required finish grade are maintained as indicated in the drawing. Example: ø35H8, ø30H9, and 6M5-7H.

Furthermore, the holes dimensional tolerances as can be seen in the drawing.

1.1.2 Analysis of the part's working conditions in the assembly unit

The "shaft housing " is designed to install and holed a shaft, with holes, threaded and unthreaded, to keep the mounting shaft in position. The unthreaded and threaded holes, 6*M5-7H, ø15, are for fastening and also support.

During operation, the part is exposed to significant long-term alternating or cyclic loads and vibrations. As its use for supporting lifting mechanical system. This is been prevented through the holes, been attached to a fixed grip or support systems, to prevent these alternating loads and vibration, from causing serious damage to the entire mechanical system.

1.1.3 Analysis of the material

Material of the part is Gray Cast Iron (ISO 185 - Class 150), it has the following chemical composition and mechanical characteristics.

Chemical composition (in %)

C	Si	Mn	S	P
3.5 - 3.7	2 - 2.4	0.5 - 0.8	до 0.15	до 0.2

Linear shrinkage: 1.1%

Tensile strength $\sigma_в$= 152 MPa; hardness HB=130…241; density ρ= 7.2 g/cm^3.

Taking into account the information given above, it can be concluded that the part works with periodic loading and is not under the influence of an aggressive environment and the material proposed by the designer ensures the operability of the part in such conditions. The drawing of the part has a sufficient number of types, hidden call out sections with detailed dimensioning, which provide a complete understanding of the design features of the part.

1.2 Determining the type of production and analysis of its impact on the manufacturing process plan

For educational purposes we will use analog methods of designation of production type based on weight of a part and production volume. Part weight m=3475.47g (Fig. 1.2) Production volume N_p =1000.

Let's determine the type of production according to the following table (table. 1.1)

Table 1.1 – Estimation of the production type

Weight of a part, kg	Type of production				
	Single	Small batch	Medium batch	High volume batch	Mass
<1	< 10	10 .. 2000	2000 .. 75000	75000 .. 200000	> 200000
>1 .. 2.5	< 10	10 .. 1000	1000 .. 50000	50000 .. 100000	>100000
> 2.5 .. 5.0	< 10	10 .. 500	500 .. 35000	35000 .. 75000	>75000
> 5.0 .. 10.0	< 10	10 .. 300	300 .. 25000	25000 .. 50000	>50000
> 10.0	< 10	10 .. 200	200 .. 10000	10000 .. 25000	>25000

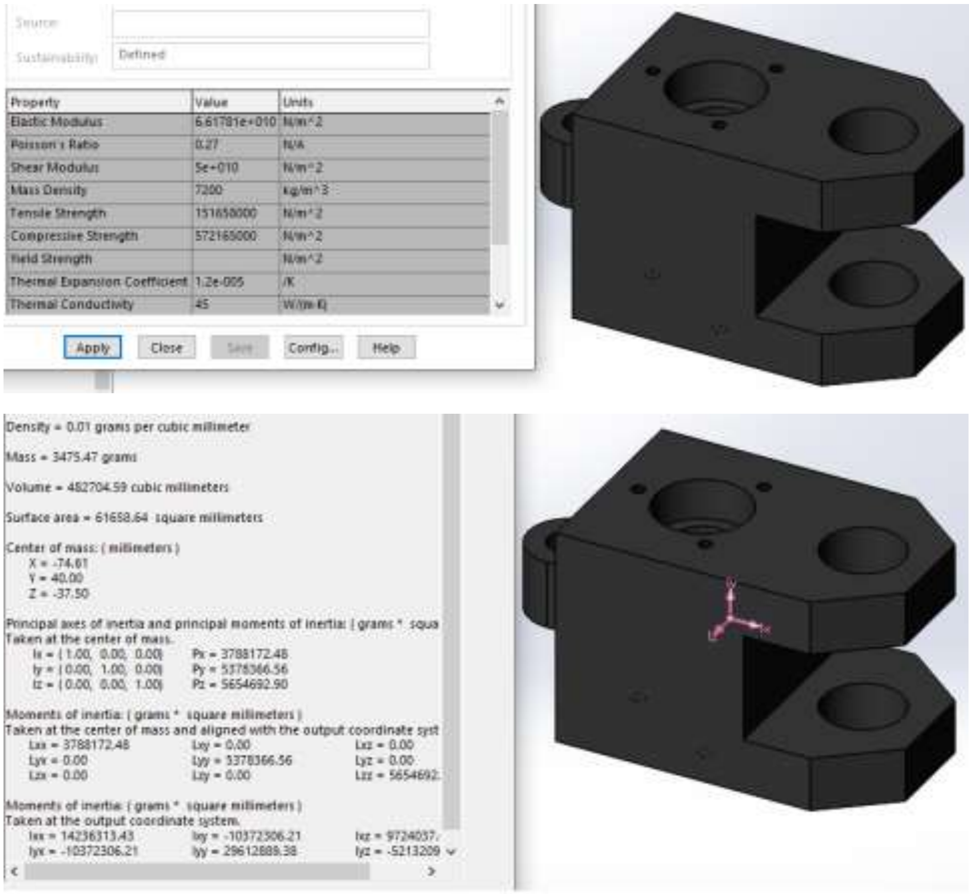


Fig. 1.2 – Characteristics of the part 'Housing' and its 3-D model

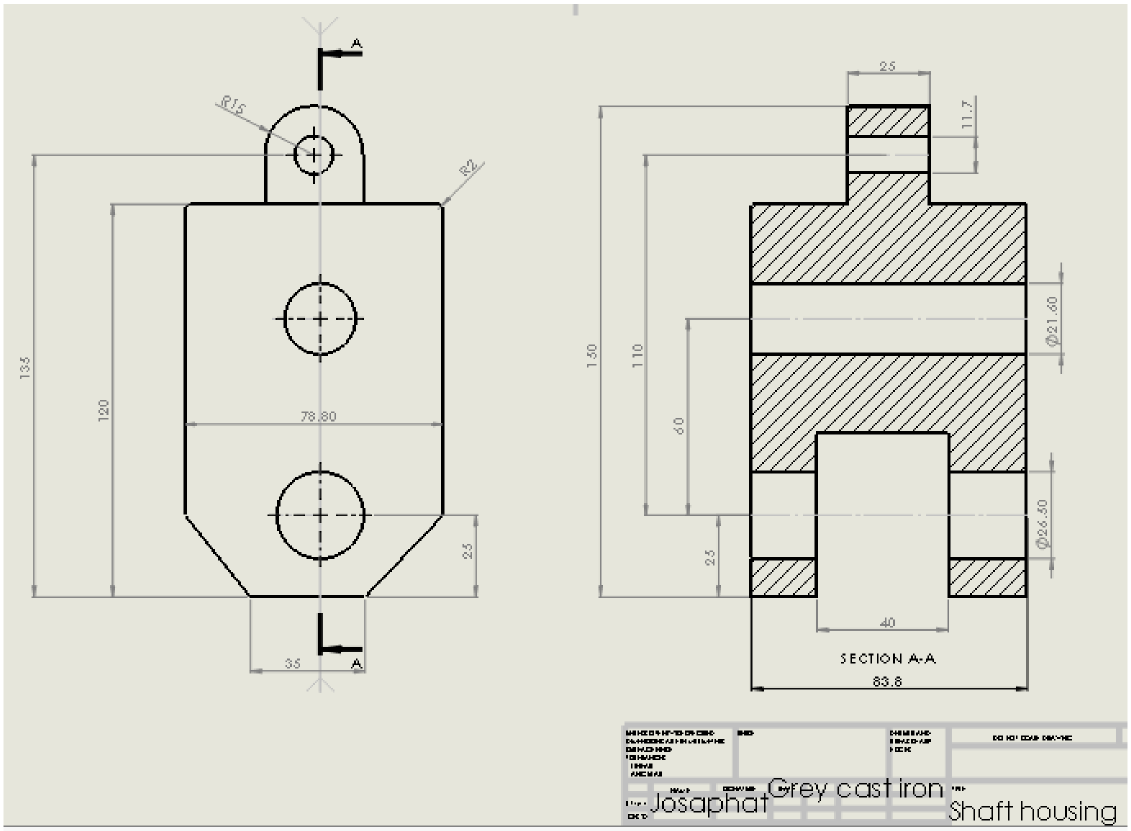
Conclusion: the production type – medium batch, therefore, we will perform all further calculations and make technological decisions for the medium-volume type of production.

1.3 Selection of the base process and design of the blank

Initial data for the process selection:

- drawing of a part;
- material of a part – Grey cast Iron;

Annual output – 1000pcs

- 

Considering the material and geometry of a part, the sand casting process could be Applied as the base process.

To estimate the required machining allowance (RMA) grade we will use Table B.1 [2]. For sand casting process and Grey Iron, since medium production, the recommended RMA grade is E; using sand casting machine mold. Required machining allowance according to the E grade and the longest dimension of the part 150mm (see drawing) is 1.1 mm according to the table 2 [2].

Table B.1 — Typical required machining allowance grades for raw castings

Method	Required machining allowance grade								
	Casting material								
	Steel	Grey Iron	S. G. Iron	Malleable iron	Copper alloys	Zinc alloys	Light-metal alloys	Nickel-based alloys	Cobalt-based alloys
Sand cast, hand-moulded	G to K	F to H	F to H	F to H	F to H	F to H	F to H	G to K	G to K
Sand cast, machine-moulded, and shell moulding	F to H	E to G	E to G	E to G	E to G	E to G	E to G	F to H	F to H
Metallic permanent mould (gravity and low-pressure)	—	D to F	D to F	D to F	D to F	D to F	D to F	—	—
Pressure die casting	—	—	—	—	B to D	B to D	B to D	—	—
Investment casting	E	E	E	—	E	—	E	E	E

To estimate casting tolerance (CT) grade we will use table A1 (for longseries) [2]. For the sand casting process machine mold, and the Grey Iron the CT10 could be applied. The results of estimation of casting tolerances are presented in Table 1.

Table A.1 — Tolerance grades for long-series production raw castings

Method	Tolerance grade CT								
	Casting material								
	Steel	Grey iron	S. G. iron	Malleable iron	Copper alloys	Zinc alloys	Light-metal alloys	Nickel-based alloys	Cobalt-based alloys
Sand cast, hand-moulded	11 to 14	11 to 14	11 to 14	11 to 14	10 to 13	10 to 13	9 to 12	11 to 14	11 to 14
Sand cast, machine-moulded and shell moulding	8 to 12	8 to 12	8 to 12	8 to 12	8 to 10	8 to 10	7 to 9	8 to 12	8 to 12
Metallic permanent mould (gravity and low-pressure)	Work is proceeding to establish appropriate data. Meanwhile consultation should take place between the foundry and the customer to agree upon values used.								
Pressure die casting									
Investment casting									

The sketches of RMA and CT location are presented in Fig. 1.

Dimension of a part	RMA	Min limit of size for external features (or max for internal features)	Casting tolerance, mm	Raw casting basic dimension
80	1.1	82.2	3.2	83.8±1.6
75	1.1	77.2	3.2	78.8±1.6
35	1.1	32.8	2.6	32.8±1.3
30	1.1	27.8	2.6	26.5±1.3
25	1.1	22.8	2.4	21.6±1.2
15	1.1	12.8	2.2	11.7±1.1
5	1.1	2.8	2	2.8±1.0

When designing the casting we considered the following:

- a workpiece is placed in the way that corresponds to the lowest possible height in the mold;
- the parting line lies within the plane of symmetry;
- the casting do not contain sharp corners, radii of 2-5 mm were applied;
- a draft angle of 2° was applied to all walls perpendicular to parting plane to facilitate removing the part from the mold;
- the RMA should be added only to the surfaces, for which the secondary process (machining) will be applied;
- the circle holes of the part will be obtained using cores;
- small features of the part (e.g. small holes) will be obtained by a secondary process.

The results of the workpiece design are presented in Fig. 2.

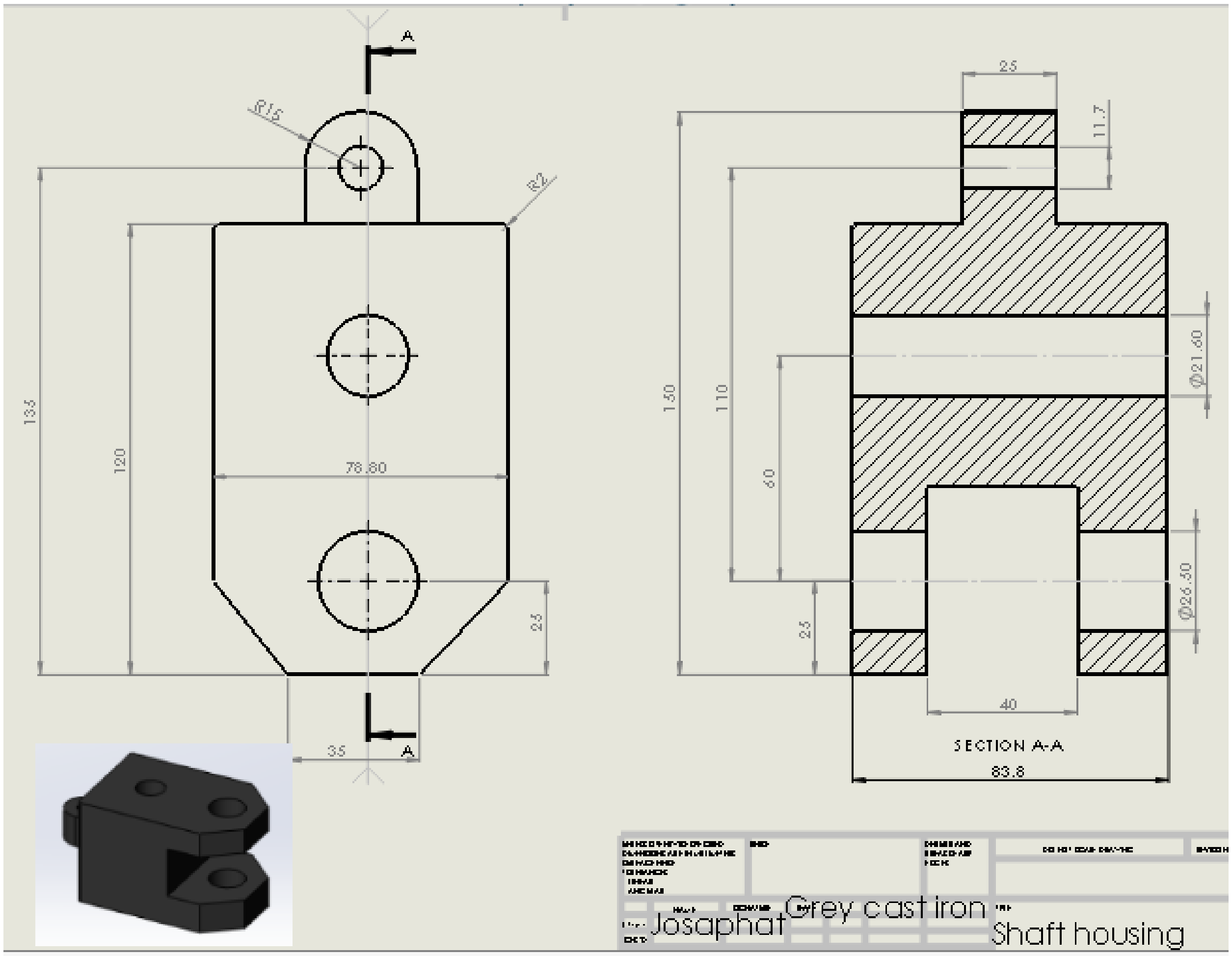
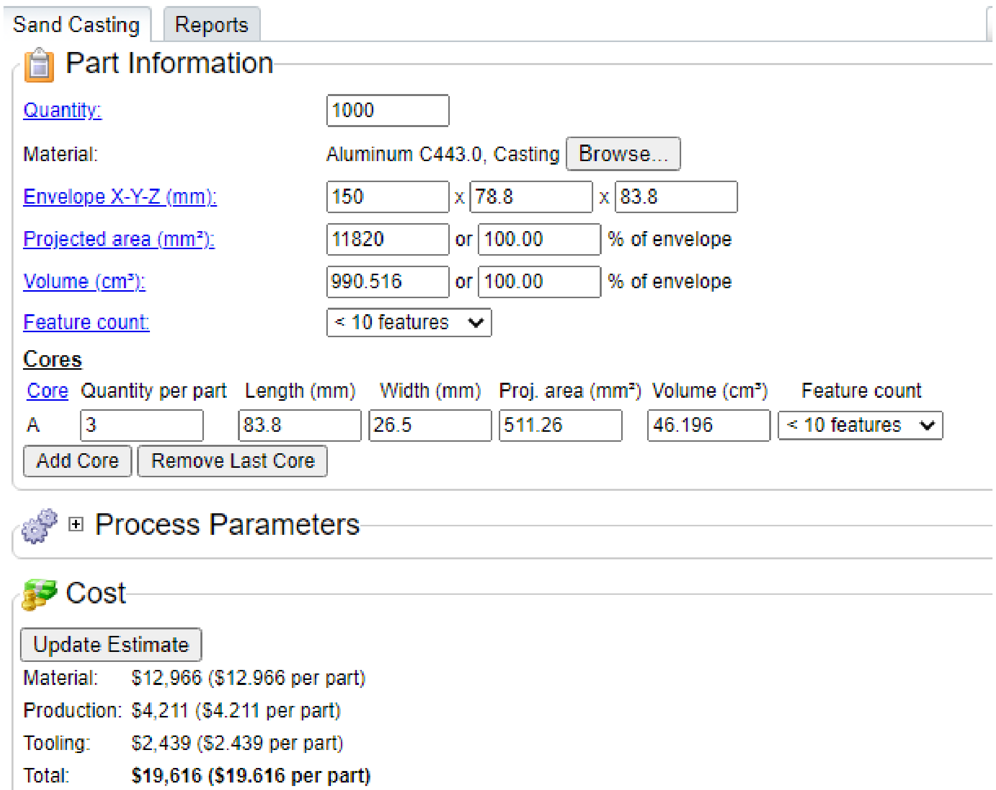


Fig. 2. Drawing of a casting

1.3.3 Cost estimation

To estimate the cost of casting we will use the on-line application Cost Estimator at the *custompartnet.com* [1].



1. ISO 8062 Castings – System of dimensional tolerances and machining allowances.

1.4 Locating scheme selection

The general algorithm of substantiation of manufacturing datum (MD) includes two stages:

- Rationale for the choice of general manufacturing datum (GMD)
- Rationale for the choice of manufacturing datum for the first manufacturing operations

1.4.1 Rationale for the choice of general manufacturing datum

General manufacturing datum (GMD) is a set of datum surfaces that can be used to perform all operations of the manufacturing process or most of it.

The initial data to justify the choice of GMD are the working drawing of the part. To solve the problems of the first stage, it is necessary to classify the surfaces of the part for their intended purpose.

The design of any part can be represented as a set of four types of surfaces:

1. Main functional (design) datum
2. Auxiliary functional (design) datum
3. Fastening surfaces
4. Free surfaces

For further analysis let’s classify surfaces of a given part according to their purpose (Fig. 1.8).

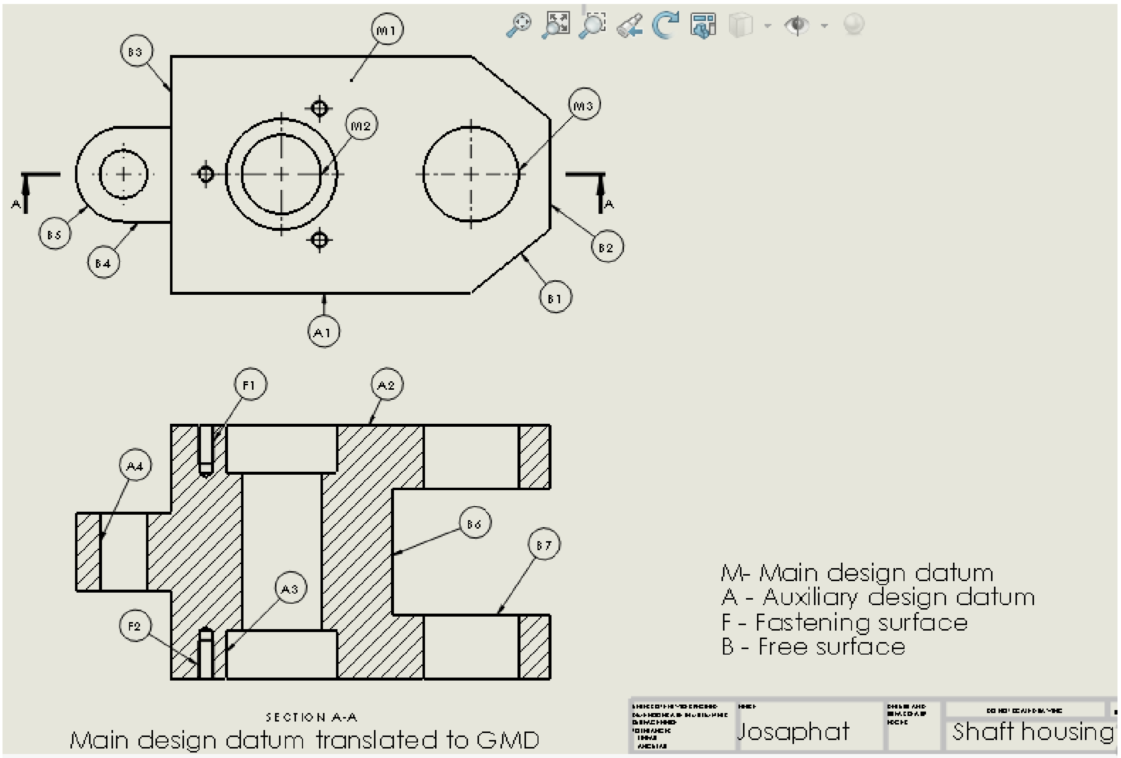
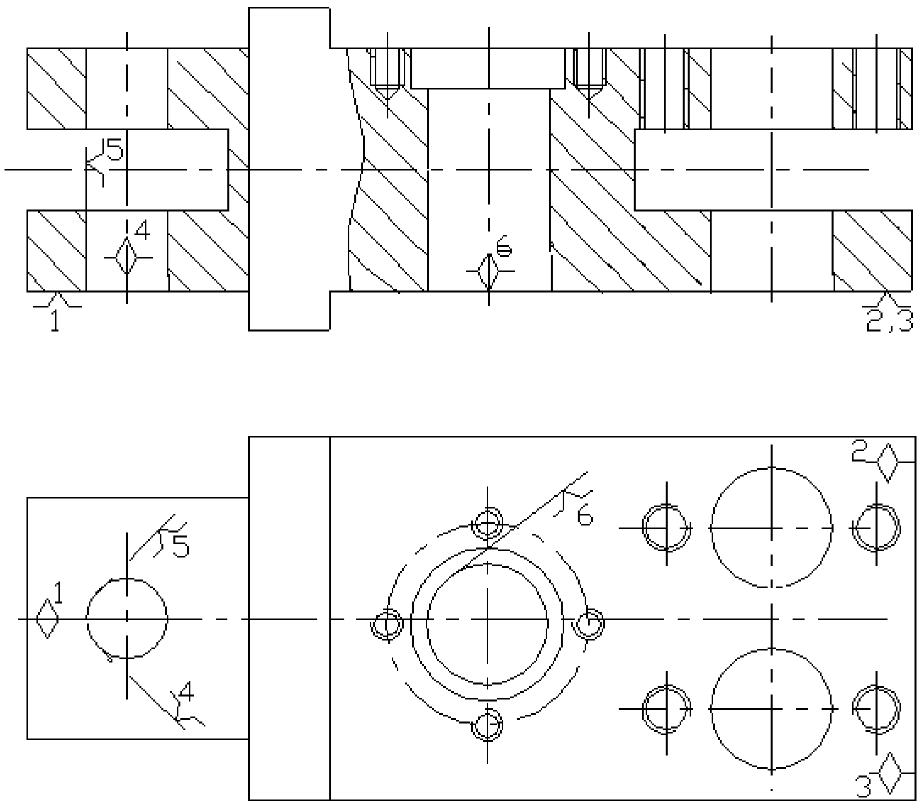


Fig 1.8 Classification of the part according to their intended purpose

Let's consider the possibility to transform Main design datum to GMD. The two variants of corresponding locating schemes are presented in Fig 1.9


5
4
6
1
2,3
2
6
5
1
4
3

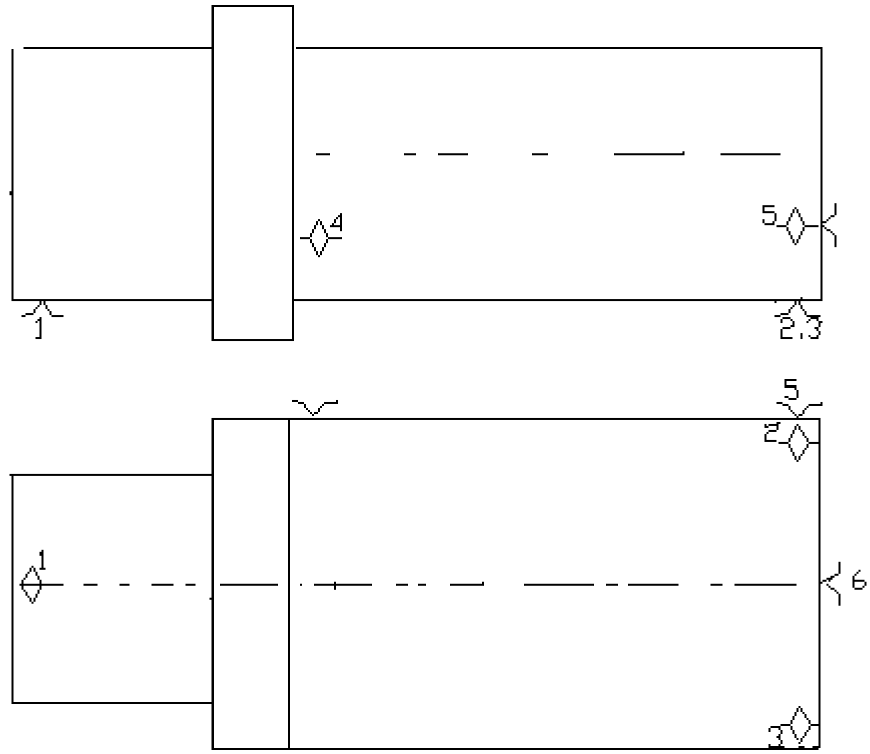


Fig 1.9 Locating scheme for GMD

The formula for the locating scheme presented in Fig 1.9 is as follows:

LS_{GMD} =>S(3)+DS(2)+ O(1),

where S(3) – setting datum, deprives the workpiece 3 degrees of freedom,

DS (2) – double support datum, deprives the workpiece 2 degrees of freedom, and

O(1) – support datum, deprives the workpiece 1 degree of freedom.

1.6 Design of the typical surfaces processing routes

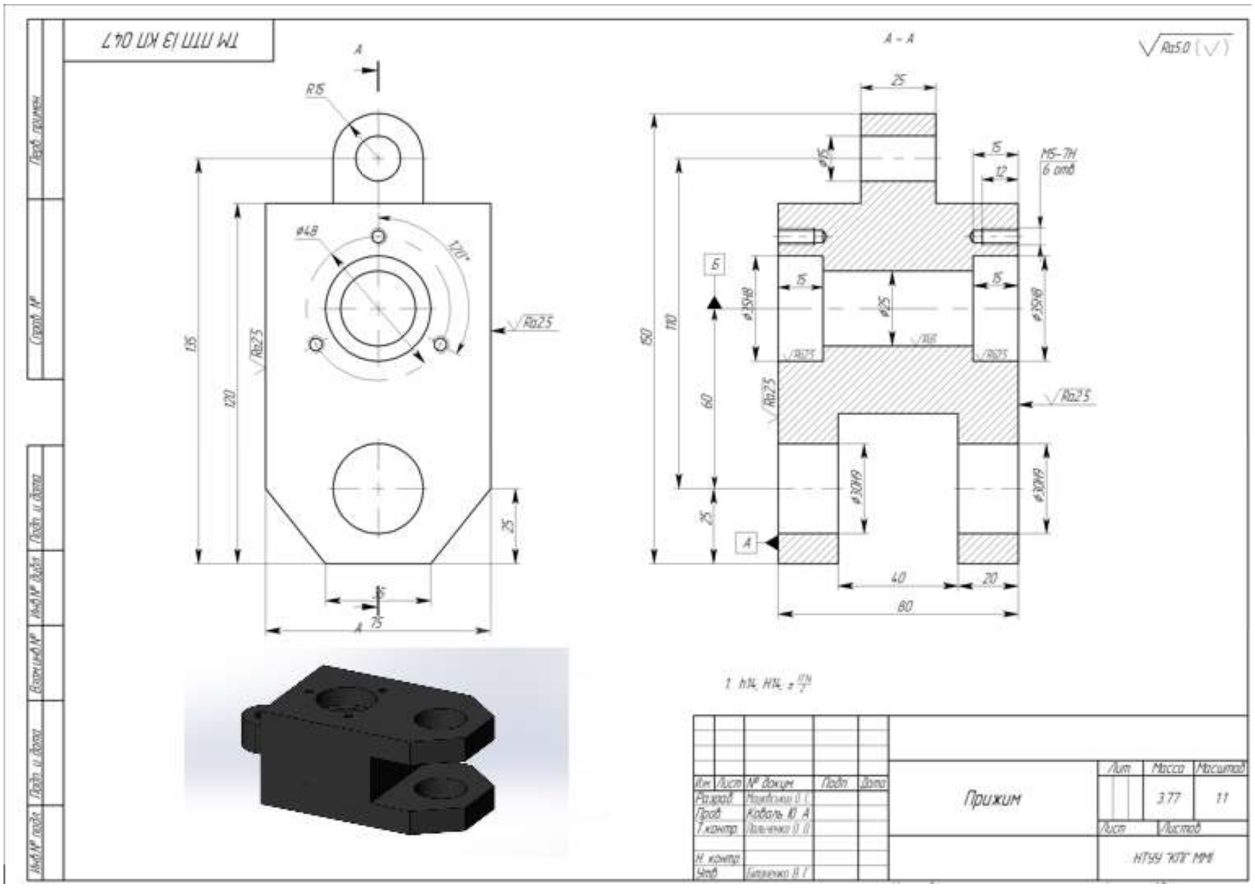
The design of a part can be divided into a set of typical geometric shapes, united by a common service purpose of the part. Typical structural elements are: cylindrical or conical external and internal surfaces, a set of planes, shaped surfaces - screw, involute and others. Depending on the type of surface, different cutting tools can be used to achieve a given surface accuracy and, as a result, there are different sequences of surface treatment.

The development of machining routes for individual surfaces is the first of seven tasks solved in the design of process plan. The manufacturing process thus created, rolled up in time and space, solves the problems of dimensional accuracy, shape and quality of individual surfaces, but does not take into account the accuracy of the relative position at all. This task will be solved later by assigning the locating schemes and dividing the processing stages into modules - rough, finish and final.

When developing a manufacturing process, it is necessary to select one of several possible machining options, which will provide the best economic solution. Therefore, in order to save time, it is necessary to use standard, proven in practice, processes for manufacturing parts and machining their main surfaces.

For a part, presented in fig. 1.15, selected typical machining sequences as well as achieved accuracy and roughness of working surfaces are given in table 1.3. The surfaces classification is given in fig. 1.16.

Fig. 1.15 Drawing of a part



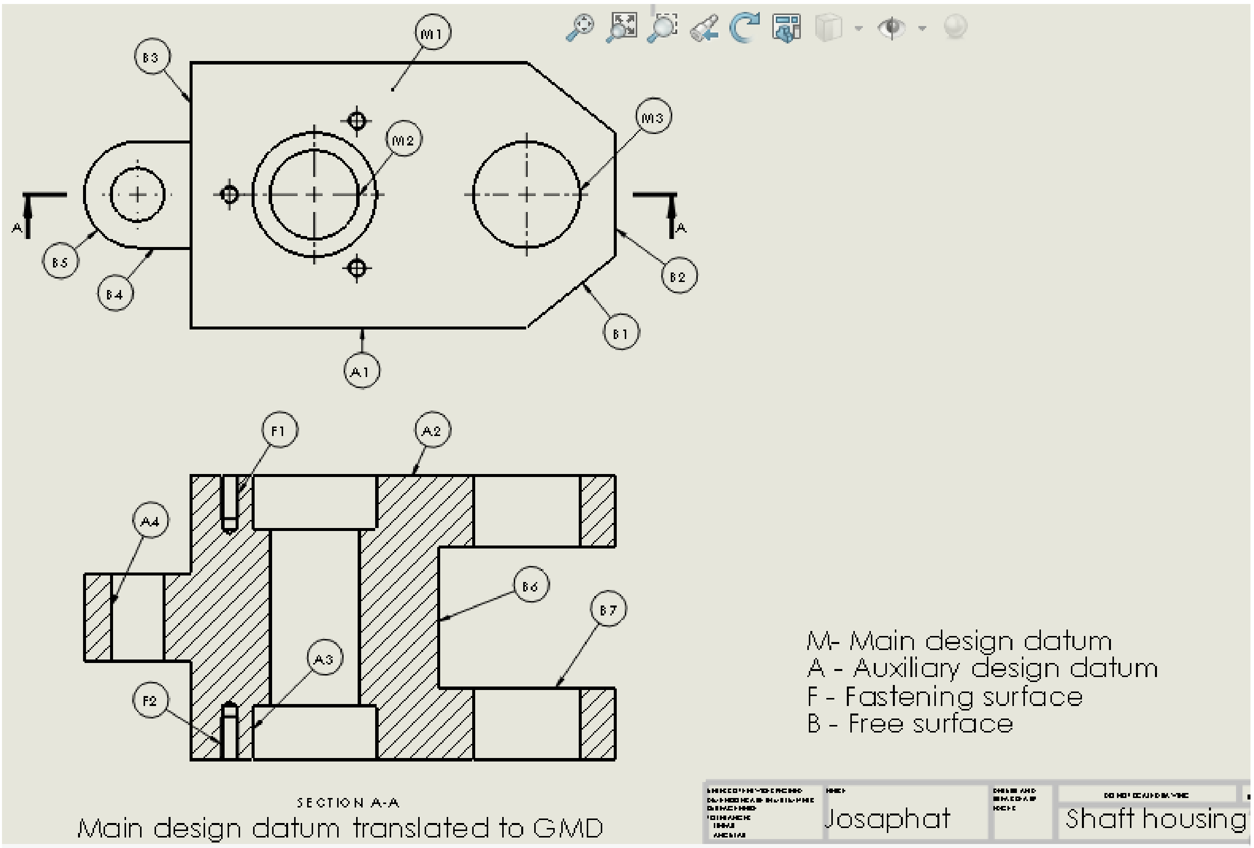


Fig 1.16 Classification of the part according to their intended purpose Table 1.3 Processing routes for surfaces of a part "Body"

Surfaces	IT	Ra	Machining sequence	IT	Ra
	Accordi ng to the draw ing			After machining	
1	2	3	4	5	6
M1	14	2,5	Rough milling & Finish milling	14	6,3 2,5
M2	14	5	Boring & Reaming	14	5
M3	H9	5	Boring & Reaming	H9	5
A1	14	2.5	Rough milling & finish milling	14	2.5

A2	14	2.5	Rough milling & finish milling	14	2.5
A3	H8	2.5	Counter boring & finish	H8	2.5
A4	14	5	Boring & Reaming	14	5
F1,F2	7H	-	Centering, Drilling, Reaming & Threading	7H	-

1.7. Design of the technological manufacturing process plan

Objective: to develop the manufacturing process plan that will meet all the requirements of manufacturing accuracy, complexity, and cost.

Let's consider the following recommendations:

1. Surfaces that are the datums for the subsequent stages of processing should be processed first
2. Each subsequent manufacturing step or operation must improve the quality characteristics of the treated surfaces. If this requirement is not met, e.g. when implementing heat treatment, then it is necessary to return to the processing of the workpiece surfaces, which are datum for subsequent processing stages.
3. The roughing must be separated from the next stages of processing by a certain period of time, or aging operations should be provided, especially for critical, large-sized and high-value parts.

4. For timely detection of defects on surfaces where they are not allowed, these surfaces should be processed at the early stages of the manufacturing process.
5. During roughing the first should be processed surfaces that have the highest allowance and the most responsible surfaces
6. Finishing of the most responsible surfaces must be performed at the latest manufacturing steps.
7. The surfaces which least reduce the overall stiffness of the workpiece should be processed first
8. Surfaces with a precise relative spatial position should be processed in one installation
9. Do not change the tool when finishing precise responsible surfaces
10. Fastening surfaces must be processed at the 3rd stage of the manufacturing process, after finishing the related surface

We will develop a possible variant of the manufacturing process plan based on: analysis of working conditions and technical requirements to the part, performed in chapter 1.1; type of production, defined in chapter 1.2; geometry of the workpiece, developed in chapter 1.3; and surfaces processing routes, developed in chapter 1.6.

Machine: TAJMAC-ZPS H500

A. Install, secure, remove

Position 1

005.01 M1, Rough milling & finish to (150*70) Ra 2.5 and tolerance of 14

005.02 M2, Boring & reaming to ø25, Ra 5 and tolerance of 14

005.03 M3, Boring & reaming to ø30, Ra 5 and tolerance H9

005.04 A3, Counter boring & reaming to ø35, Ra 2.5 and tolerance H8

005.05 F1, Centering, drilling, reaming, & threading. to M5-7H

Position 2

005.06 A2, rotate workpiece fixture(CW 90^{o}), Rough milling & finish to (150*80) Ra 2.5 and tolerance of 14

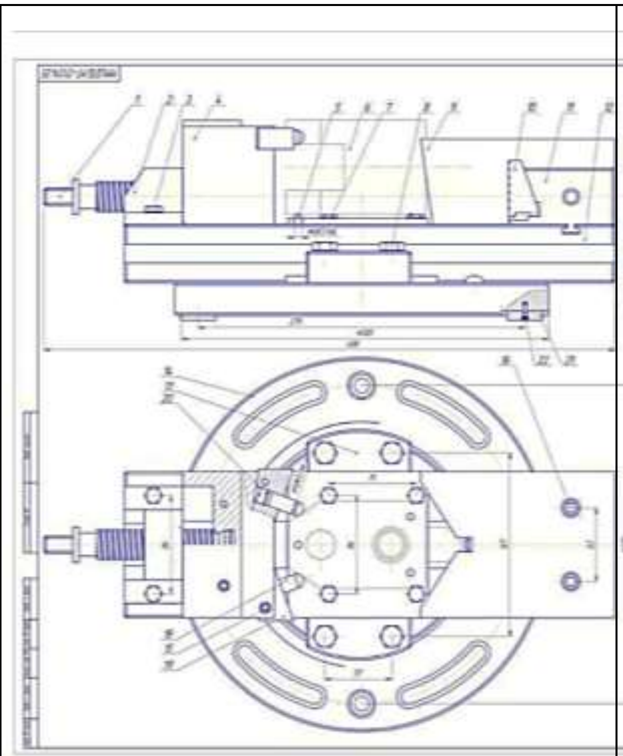
Position 3

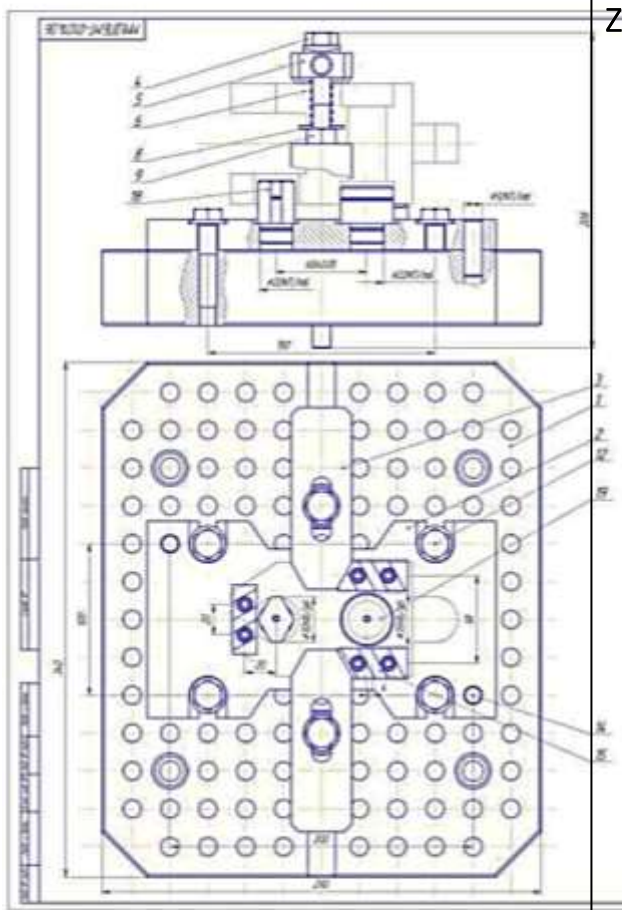
005.07 rotate workpiece fixture(CCW 180^{o}) Repeat same process from 005.01 to 005.06

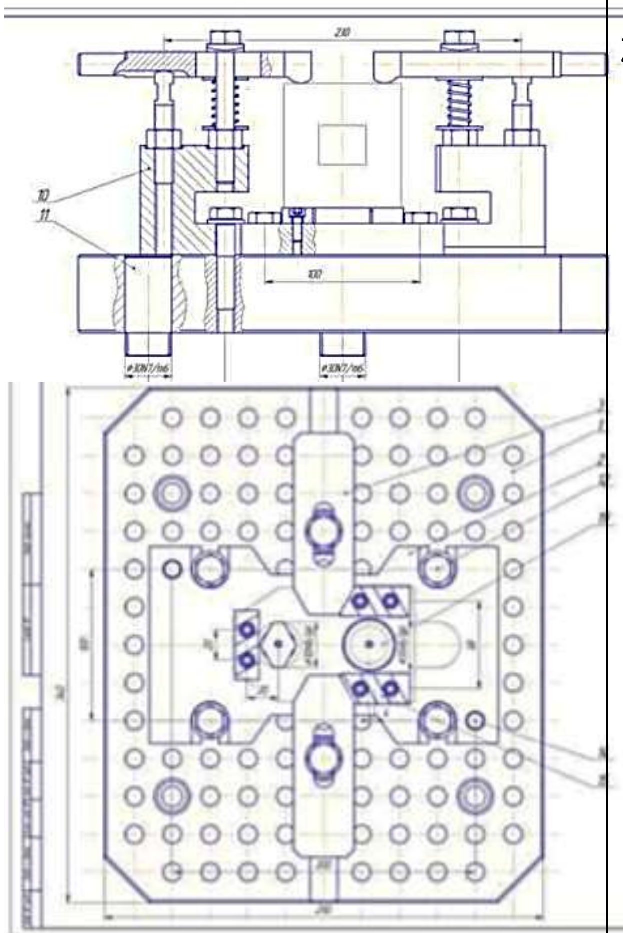
050.10 Washing

050.11 Control and inspection

№ operations	The name of the operation and the theoretical scheme of basing	Type of equipment	Snap system	Cutting tool
1	2	3	4	5

005		TAJMAC-ZPS H500	UZP-12	The mill is final D73mm GOST 17025-71 Spiral drills GOST 10902-77. Sweeps GOST 3266-81

005		TAJMAC-ZPS H500	UZP- 12	The mill is final D73mm GOST 17025-71 Sweeps GOST 3266- 81 Drill spirals GOST 10902-77. Tap GOST 3266- 81

006		TAJMAC-ZPS H500	UZP-12	Sweeps GOST 3266-81

1.8 Example of technological process implementation for CNC machines Haas VDT2.

% G90 G94 G54 S558 F1.86 T1 M3 M8 G00 z0 y0 z50 G00 z25 G01 x0 y250 z25 S362 F4.44 G01 x1 y10 S401 F3.6 x2 y250 G00 x0 y0 z50 S558 F1.86 G00 z25 y-40	G01 x1 y-40 S401 F3.6 x2 y240 G00 x0 y0 z50 S558 F1.86 G00 x18 y -40 z25 G01 y5 S349 F4.44 x19 y-40 S401 F3.6 x20 y5 G00 x0 y0 z50	G00 z25 G01 x18 G01 y215 S349 F4.44 x19 y250 S401 F3.6 x20 y215G00 z50 x0 y0 G95 S355 F0.56 T2 M3 M8 G81 X0 Y100 Z90 R25 F M8 G00 x0 y0 z50 S500 F0.80 T3 M3 M8	S500 F0.40 T4 M3 M8 G81 X20 Y20 Z50 R25 F M8 G00 x0 y0 z50 S1000 F0.56 T5 M3 M8 G81 X20 Y20 Z50 R25 F M8 G00 x0 y0 z50 M05 M02

G01 x0 y240 z25 S362 F4.44	S558 F1.86 G00 x0 and 250 z50	G81 X0 Y100 Z90 R25 F M8 G00 x0 y0 z50	

% G90 G94 G54 S558 F1.86 T1 M3 M8 G00 x0 y0 z90 z35 G01 y220 z70 y40 G00 x0 y0 z90 S354 F4.44 z35 G01 x1 G01 y220 z70 y40 G00 x0 y0 z90 S401 F3.6 z35 G01 x2 G01 y220 z70 y40 G00 x0 y0 z90 S558 F1.86 G00 x 23 y10 G01 z0 y48.5	z50 G00 x0 y0 z90 S558 F1.86 G00 x10 y5 G01 z50 S349 F4.44 x12 z90 S401 F3.6 x12.5 z50 G00 x0 y0 z90 S571 F1.86 G00 y30 z25 G01 and 280 S362 F4.44 x2 y30 G00 x0 y0 z90 T2 S584 F1.86 G00 y105 z25 G01 x40 x0 G00 x0 y0 z90	S1400 F0.28 T5 M3 M8 G81 X0 Y105 Z14 R25 F M8 G00 x0 y0 z90 S254 F254 T6 M3 M8 G81 X0 Y105 Z14 R25 F M8 G00 x0 y0 z90 S1000 F0.28 T7 M3 M8 G81 X0 Y10 Z25 R10 F M8 X0 Y50 X0 y50 R80 X0 Y10 G00 x0 y0 z90 M9 S1400 F0.28

		T8 M3 M8

z90 G00 x0 y0 z90 S354 F4.44 G00 x24 y10 G01 z0 y48.5 z90 G00 x0 y0 z90 S401 F3.6 G00 x25 y10 G01 z0 y48.5 z90 G00 x0 y0 z90 S558 F1.86 G00 x10 y215 G01 z50 S349 F4.44 x12 z90 S401 F3.6 x12.5	T2 S362 F4.44 G00 y105 z25 G01 x40 x0 G00 x0 y0 z90 G95 S1400 F0.20 T3 M3 M8 G81 X0 Y105 Z14 R25 F M8 G00 x0 y0 z90 S1400 F0.20 T4 M3 M8 G81 X0 Y105 Z14 R25 F M8 G00 x0 y0 z90	G81 X0 Y10 Z25 R10 F M8 X0 Y50 X0 y50 R80 X0 Y10 G00 x0 y0 z90 M9 S1400 F0.40 T9 M3 M8 G81 X0 Y10 Z25 R10 F M8 X0 Y50 X0 y50 R80 X0 Y10 G00 x0 y0 z90 M9 S257 F257 T10 M3 M8 G81 X0 Y10 Z25 R10 F M8 X0 Y50 X0 y50 R80 X0 Y10 G00 x0 y0 z90 M9 M05 M02

1.9 Determination of the cutting and clapping forces

Control of clamping forces is an important feature implemented in recent fixturing systems to overcome the drawbacks of conventional fixturing arrangements with constant clamping forces, which are usually applied manually.

In order to achieve dynamic clamping, pneumatic, hydraulic and electromechanical clamping systems are used. Electro-mechanical clamping is generally preferred as it is more convenient to use, has a fast response time, is easy to control and has a high resolution and very good precision. Pneumatic and hydraulic clamps are also used to meet specific requirements.

For any flexible manufacturing system, it is important to know the cutting forces during the machining operation. The knowledge of the cutting forces helps to determine the clamping forces required and hence the design of the fixturing system.

Table 2.0 Tangential and radial components of the cutting force during milling

СИЛА РЕЗАНИЯ.* Чугун. Фрезы торцовые с пластинами из твердого сплава и быстрорежущей стали	Фрезерование плоскостей
	Карта 68

№ поз.	Диаметр фрезы D, мм, до	Ширина фрезерования B, мм	Число зубьев фрезы z	Глубина резания t, мм, до	Подача на зуб S_z, мм/зуб, до							
					0,2		0,4		0,5		Св. 0,5	
					$P_{y_т}$	$P_{z_т}$	$P_{y_т}$	$P_{z_т}$	$P_{y_т}$	$P_{z_т}$	$P_{y_т}$	$P_{z_т}$
1	200	120	20	2	1030	2950	1650	4800	1900	5500	2500	7200
2				5	2250	6500	3750	10 800	4400	12 600	5700	16 500
3				8	3500	10 000	5700	16 400	7100	20 300	8800	25 200
4				12	4550	13 000	6300	18 000	8300	23 800	12 700	36 300
5	400	240	36	2	1610	4600	2650	7700	3200	9200	4550	13 000
6				5	3700	10 600	6100	17 600	7200	20 500	9400	27 000
7				8	5600	16 000	9400	27 000	10 300	29 600	15 000	43 000
8				12	7300	21 000	12 700	36 500	14 300	41 000	21 000	60 000
9	630	370	52	2	2300	6700	3250	9300	4200	12 000	6400	18 400
10				5	4200	12 200	8200	23 600	9600	27 400	14 700	42 000
11				8	6700	19 300	11 900	34 100	14 500	41 600	22 400	64 000
12				12	12 600	36 000	17 800	51 000	21 000	60 000	31 000	91 000
Индекс					а	б	в	г	д	е	ж	з

Pz is the tangential component

Py- radial component

From the table we take: Pz = 4800 N; Py = 1650 N

3.0 Checking a sufficient number of clamping elements
3.1 Calculation of fastening force

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

$$К \cdot P = (Q(r_{ср} \tan(\alpha + \varphi_{пр}) + 0.33f\frac{D_н^3 - D_в^3}{D_н^2 - D_в^2}))/l$$

Clamping force:

$$Q_{теор} = К \cdot P \cdot l/((r_{ср} \tan(\alpha + \varphi_{пр}) + 0.33f\frac{D_н^3 - D_в^3}{D_н^2 - D_в^2}))$$

Where, P = 147 N force on the key; l = 14d - the distance from the axis of the screw to the point of application of force;

rsr - average radius of a carving, mm;

□□ 2,5□−3,5□- angle of rise of the screw of a carving; □*пр*

□ 6,5□- the reduced angle of friction in a threaded pair; f =

0.1-0.15-coefficient of friction at flat contact of two surfaces;

K - stock ratio;

$К = К_0 \cdot К_1 \cdot К_2 \cdot К_3 \cdot К_4 \cdot К_5 \cdot К_6$;

$К_0$= 2.5 - guaranteed stock ratio;

$К_1$= 1.0 - for finishing;

$К_2$= 1,2 - takes into account the increase in cutting force due to blunting of the tool;

$К_3$= 1.0 - with continuous cutting;

$К_4$= 1,2 - with non-mechanized clamp;

$К_5$ = 1,0 - at a convenient arrangement of the handle;

$К_6$= 1.5 - for a support element with a large contact area.

K = 2.5 1,01,21,01,21,01,5 = 5,4......

$$Q_{\text{теор}} = 5{,}4 \cdot 147 \cdot 112/((11{,}18\tan(3° + 6{,}5°) + 0.33 \cdot 0{,}1\frac{12^3 - 10{,}64^3}{12^2 - 10{,}64^2}))= 9420 \text{ N}$$

3.2 Calculation of the required fastening force

Case 1.

Condition to be checked: Qneobh.Qr;≥

Compose the equation of the sum of all forces relative to the X axis:
∑x = 0; 3Ft1 + Qt = kPy; Qp =; Qp =, where $\frac{кPy - 3F_{Т}1}{f_2}$ $\frac{кPy}{1{,}5f_1 + f_2}$

Qt = Qf1, where×

f is the coefficient of friction. = 0.8;1

Ft1 - friction force and is determined by: Ft1 =; = 0.6; $\frac{Q}{2} \times f_2 f_2$

k is the stock ratio. k = 2.5;

Pz - axial cutting force .Pz = 5200H.

Qp =; Qp = 7222 N. $\frac{2{,}5 \times 5200}{1{,}5 \times 0{,}8 \quad +0{,}6}$

Compose the equation of the sum of all forces relative to the axis B:

∑y = 0; Qp = kPy; , where

k is the stock ratio. k = 2.5;

Py is the radial cutting force. Py = 1850H.

Qp = 2.5 * 1850; Qp = 4625 N.

Add the sum of the moments of all forces relative to so:

∑Mo = 0; kPy (l1 + l2) -Q * l1 = 0; Q =; where $\frac{kPy \times (l1 + l2)}{l1}$

k is the stock ratio. k = 2.5;

Py is the radial cutting force. Py = 1850H.

l1, l2 - the distance from t. O to the clamping force and the radial cutting force, respectively.

l1 = 55 mm; l2 = 52.5 mm;

Qp =; Qp = 9039 H;$\frac{2{,}5\times1850\times(55+52.5)}{55}$

The condition is fulfilled.

Case 2.

Condition to be checked: Qneobh.Qr;≥

Compose the equation of the sum of all forces about the x-axis:

∑x = 0; Ft1 + Qt = kPz; Qp =; Qp =, where$\frac{\kappa Pz-F\tau 1}{f_2}$ $\frac{\kappa Pz}{0{,}5f_2+f_1}$

Qt = Qf1, where×

f is the coefficient of friction. = 0.8; = 0.6;f_1f_2
Ft1 - friction force and is determined by: Ft1 =;$\frac{Q}{2}\times f_2$

k is the stock ratio. k = 2.5;

Pz - axial cutting force.Pz = 5200 H.

Qp =; Qp = 9232H.$\frac{2{,}5\times5200}{0{,}5\times0{,}6+0{,}8}$

The condition is fulfilled.

3.3 Determination of cutting forces when drilling a hole

Axial force during drilling is calculated by the following formula:
$P_z = 10 \cdot Cp \cdot t^x \cdot S^y \cdot Kp$;

$M_{kp} = 10 \cdot C_M \cdot D^q \cdot t^x \cdot S^y \cdot Kp$, where

Cp, Cм - coefficients, taking into account cutting conditions.

Determine Cp, Cm and exponents according to table 2.1

Table 2.1. Values of indicators and coefficients in the formulas Mcr and Po

Обрабатываемый материал	Операция	Материал инструмента	Коэффициенты и показатели в формулах							
			Крутящего момента				Осевой силы			
			$C_м$	q	x	y	$C_р$	q	x	y
Конструкционная сталь	Сверление	Быстрорежущая сталь	0,034	2,0	-	0,8	68	1,0	-	0,7
	Рассверливание и зенкерование		0,090	1,0	0,9	0,8	67	-	1,2	0,65
Конструкционный чугун	Сверление	Твёрдый сплав	0,012	2,2	-	0,8	42	1,2	-	0,75
	Рассверливание и зенкерование		0,196	0,85	0,8	0,7	46	-	1,0	0,4
	Сверление	Быстрорежущая сталь	0,021	2,0	-	0,8	42,7	1,0	-	0,8
	Рассверливание и зенкерование		0,085	-	0,75	0,8	23,5	-	1,2	0,4
Медные сплавы	Сверление	Быстрорежущая сталь	0,012	2,0	-	0,8	31,5	1,0	-	0,8
	Рассверливание и зенкерование		0,031	0,85	0,75	0,8	17,2	-	1,0	0,4
Алюминиевые сплавы	Сверление		0,005	2,0	-	0,8	9,8	1,0	-	0,7

Assign:

Cm = 0.021, x = 0, q = 2.0; y = 0.8;

Cp = 42.7, q = 1.0, y = 0.8; x = 0;

Determine the coefficient Kr from table 2.2.

Table 2.2. Correction factor Kr, taking into account the influence of the quality of the processed material.

Обрабатываемый материал	Расчётная формула	Показатель степени n при определении		
		P_z при обработке резцами	$M_{кр}$ и P_0 при сверлении, рассверливании и зенкеровании	окружной силы P_z при фрезеровании
Конструкционная углеродистая и легированная сталь при:	$K_{мр}=\left(\frac{\sigma_в}{750}\right)^n$			
$\sigma_в \le 600$ МПа		0,75/0,35	0,75/0,75	0,3
$\sigma_в > 600$ МПа		0,75/0,75	0,75/0,75	0,3
Серый чугун	$K_{мр}=\left(\frac{HB}{1900}\right)^n$	0,4/0,55	0,6/0,6	1,0/0,55
Ковкий чугун	$K_{мр}=\left(\frac{HB}{1500}\right)^n$	0,4/0,55	0,6/0,6	1,0/0,55

We accept:

$$Kr=\left(\frac{HB}{1900}\right)^n \quad Kr=\left(\frac{1600}{1900}\right)^1 = 0,84$$

Then:

$$P_z = 10\cdot Cp\cdot t^x\cdot S^y\cdot Kp;\ P_z = 10\cdot 42,7\cdot 0.96^{0,8}\cdot 0,84 = 5200H$$

$$M_{kp} = 10\cdot C\grave{i}\cdot D^q\cdot t^x\cdot S^y\cdot K\eth;\ M_{kp} = 10\cdot 0,021\cdot 19,5^{2.0}\cdot 90^0\cdot 0.96^{0,8}\cdot 0,9 = 7\acute{I}\,\grave{i}$$

3.4 MACHINE AND TOOL SELECTION

3.4.1 Machine selection

Type and size of machine

The types of machine are specified by the already preselected manufacturing processes. For example, if turning is the selected process then a lathe (or turning center) will be the type of machine to be used.

At the first cut selection the only factor considered is the physical size of the machine in relation to the workpiece. E.g. a lathe whose machine bed is shorter than that of the length of the part cannot be used to turn that part.

Power/Force Analysis

After having calculated the power requirements for all operations, those machines that cannot meet the maximum power requirement can be discounted.

The exception of this is if there are no other machines available. In this case, reducing feeds and speeds and/or the depth of cut can reduce the power required.

On the other hand, those machines with a far greater power output than required can also be discounted. The only exception of this is if such a machine has a higher spindle speed required by one or more operations.

Capability Analysis

The factors considered in the capability analysis are the dimensional and geometric accuracy and the surface finish required.

Operational Analysis

The operational factor to be considered by the process planner is that of the batch size. Those machines that do not meet the economic batch quantity should be discounted.

Considering all aforementioned requirements and limitations as well as process plan, developed in the previous chapter, the preliminary selected machine is the horizontal machining centre is TAJMAC-ZPS H500.

The horizontal machining centre in the H 500 version (see general technical data in fig. 8.1) is a highly productive machine for the complex chip machining of parts from the steel, grey cast iron and soft metal alloys clamped on the rotary table. It enables to perform the milling operations in three mutually perpendicular X, Y, Z coordinate axes and in the rotary B axis. It also enables to perform the drilling, boring, reaming and thread cutting operations as well as the usage of the screw die heads without aligning bush in the Z axis.

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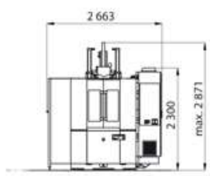

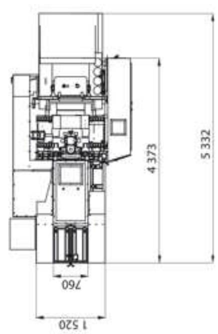

Travels			
X-axis (column)	560 mm		
Y-axis (spindle head)	560 mm		
Z-axis (table)	560 mm		
Max. working feed	50 m/min		
Rapid traverse	50 m/min		
Acceleration	5 m/sec^2		
Spindle			
Tool interface	ISO 40	ISO 40	HSK-A63
Maximum speed	10 000 rpm	15 000 rpm*	18 000 rpm*
Continuous output S1 / overload S6 – 40 %	20/30 kW	25/31 kW	25/31 kW
Torque S1 / overloading S6 – 40 %	76/115 Nm	159/197 Nm	159/197 Nm
Transmission type	belt drive	electrospindle	
Rotary table with pallet			
Pallet dimensions	500 × 500 mm		
Range of turning	360 °		
Pallet max. load	300 kg		
Workpiece max. size (dia × height)	ø 600 × 750 mm		
Pallet change time	10 sec		
Measuring accuracy (VDI/DGQ 3441)	**direct / indirect**		
Positioning accuracy (P)	0.008/0.010 mm		
Repeatability (Ps max.)	0.005/0.006 mm		
NC table positioning accuracy (P)	6/22 arc sec		
Distances			
Spindle nose to rotary table axis	130 – 690 mm		
Spindle axis to pallet clamping surface	50 – 610 mm		
Working pallet to floor	1 010 mm		
Tool magazine			
Number of tool pots in magazine	45		
Tool interchange time	3.5 sec		
Tool maximum diameter:			
– fully occupied magazine	70 / 90 mm		
– without adjacent tools	125 mm		
Tool maximum length	300 mm		
Tool maximum weight	7 kg		
Power supplies			
Nominal voltage of mains	3 × 400 V/50 Hz, 3 × 480 V/60 Hz		
Operational power input (depending on spindle and equipment)	38 / 51 / 64 kVA		
Compressed air	0,6 – 0,8 MPa		
Complementary data			
Machine floor layout	5 332 × 2 663 mm		
Machine maximum height	2 871 mm		
Machine weight	10 000 kg		
Control system	SIEMENS, HEIDENHAIN*, FANUC*		

STANDARD EQUIPMENT

- Digital drives
- Direct measuring in all axes
- Continuous rotary table, B-axis
- Automatic pallet changer, 2 pallets 500 × 500 mm
- Electronic compensation of thermal dilatations
- Automatic tool changer, 45 tool pots
- Coolant unit with tool cooling system
- Tool holder automatic blasting with air
- Worm-type chip conveyors 2 pcs
- Rake-type chip conveyor

OPTIONAL EQUIPMENT*

- Indirect measuring
- Tool cooling with coolant through spindle axis
- Tool cooling with air through spindle axis
- Coolant unit with filtration unit for tool cooling through spindle axis
- Tool cooling with oil mist
- Automatic tool changer with capacity of 75
- Tool interface CAT 40, BT 40, HSK-A63
- Workpiece dimension checking probe
- Tool dimension checking probe
- Work zone washing-off
- Steelbelt chip conveyor
- Chip bucket (300 kg)
- Vapour exhaustion from work zone
- Work zone manual washing-off
- Machine 5-axis version
- Climatization of electrical cabinets
- Remote diagnostics
- Supply of hydraulics into pallet
- Rotary glass wiper
- Vibrodiagnostics

Descriptions of illustrations and specifications may not always correspond with the machine latest version.

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Fig. 8.1 Technical data of the selected machine

3.4.2 Tooling Selection

Evaluation of process and machine selections – Provided the selection of processes and machines is satisfactory, the range of tools that can be used should be limited to those suitable for the processes and machines selected. Therefore this limits the initial list of possible suitable tooling.

Analysis of machining operations – A specific machine will carry out every operation required. Each machine tool to be used will have specific tool types to carry our certain operations. This analysis should enable the identification of specific tool types for specific operations.

Analysis of workpiece characteristics – At this step the following should be considered: workpiece material and geometry, dimensional and geometric accuracy, and surface finish. This enables to identify suitable tool materials and geometry.

Tooling analysis – Using the tooling data available, the general tooling specifications generated ant the 3rd stage can be translated into a statement of tooling requirements for the job, that is, a tooling list. This will obviously reflect whatever tooling is actually available for the operations required.

Selection of tooling – If single-piece tooling is being used, then a suitable Tool holder should be selected before fully defining the tool geometry and material.

If insert-type tooling is being used then the following steps should be followed:

- Select clamping system;
- Select tool holder type and size;
- Select insert shape;
- Select insert size;
- Determine tool edge radius;
- Select insert type;
- Select tool material.

Tool selection for the manufacturing step

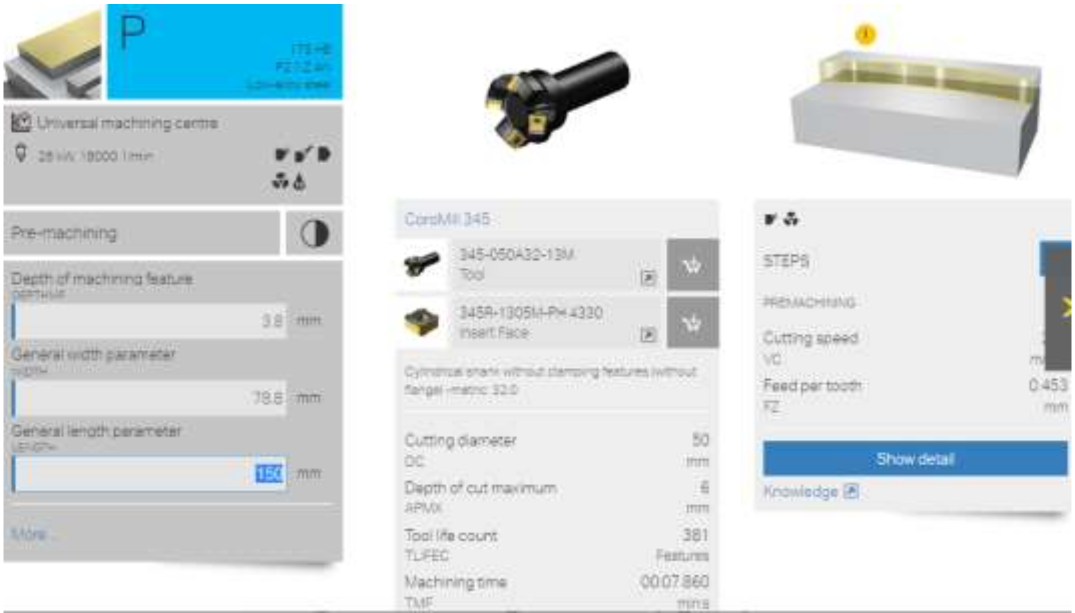
“005.01 Mill surface M1 to dimension 80*75”

Allowance = 2.5mm

Radial cutting width = 10mm

To select the appropriate cutting tool and cutting conditions we will use CoroPlus® ToolGuide [1] Firstly, enter the initial data, incl. type of surface, depth of cut, radial cutting width and workpiece material (fig. 8.2).

Fig. 8.2 Initial Data for tooling selection (screenshot)



Scientific Research

4.0 Drilling Burr Minimization

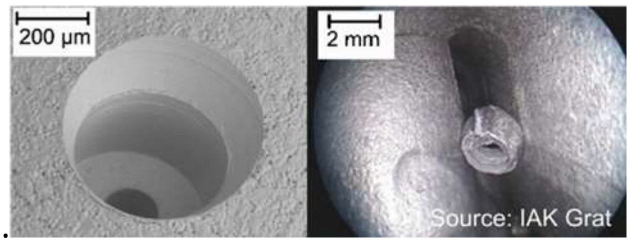
Increasing demands on function and performance call for burr-free workpiece edges after machining. Since deburring is a costly and non-value-added operation, the understanding and control of burr formation is a research topic with high relevance to industrial applications. Following a review of burr classifications along with the corresponding measurement technologies, burr formation mechanisms in machining are described. Deburring and burr control are two possible ways to deal with burrs. For both, an insight into current research results are presented. Finally, a number of case studies on burr formation, control and deburring along with their economic implications are presented:

The demands placed by designers on workpiece performance and functionality are increasing rapidly. Important aspects of manufacturing's contribution to the fulfillment of these demands are the conditions at the workpiece edges. While the geometries generated by designers in a CAD system or a technical drawing generally are clean and straight, the real geometry of the workpiece edges is to a large extent determined by the formation of burrs in the final manufacturing process. In many cases, is time consuming and expensive deburring processes have to be applied in order to ensure the desired part functionality.

Recent studies have shown a large economic impact of burrs and their effects. Not only is deburring a non-value-added process, but in many cases increasing burr formation is a key factor of cutting tool wear and leads to replacement of tools which are otherwise still operating without problems.

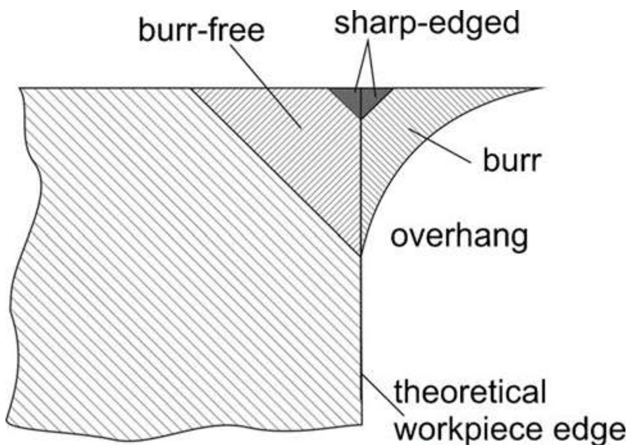
If burrs do not have to be removed from a workpiece for functional reasons, there are still two dangers remaining. Firstly, burrs are often quite sharp and can lead to small finger injuries for assembly workers. Secondly, burrs which initially stick to a part can become loose during operation of a product and cause damage later on

(see for example Fig. 1.1).

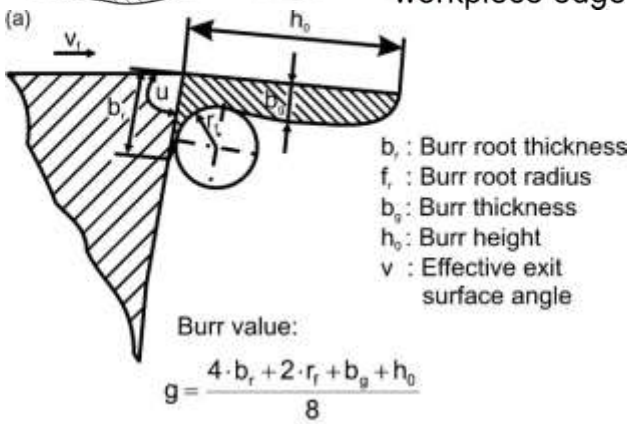


A well-known example for this are burrs caused by drilling operations in engine cylinder heads, where the burr is located in channels of the cooling system, comes loose during operation of the engine, is then carried by the cooling fluid on to different locations of the engine where it can potentially cause a complete engine failure

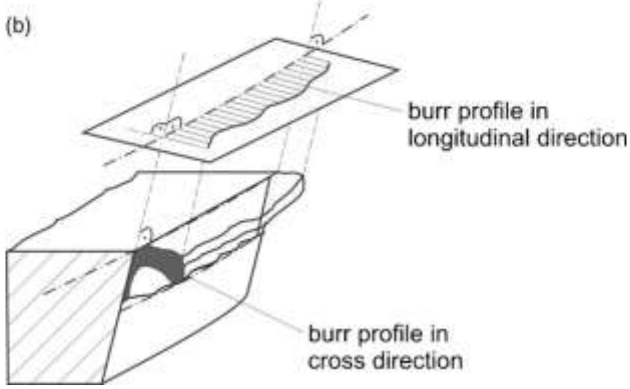
Fig. 1. Burr in an injection hole of a fuel system (left) chip in a fluid loop (right).



(a)

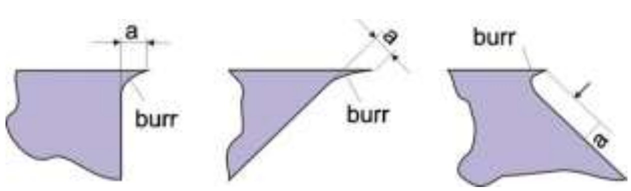


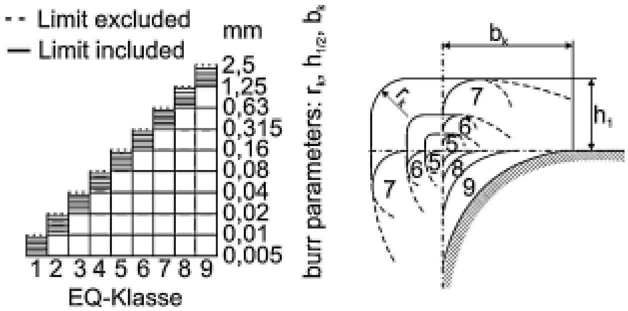
(b)



Standards for burr classification

There are various general standards for evaluating the quality of component edges and for classification of burrs build by a material removal process.





Types of burrs in material removal

Today, there exist numerous different burr descriptions depending on application, manufacturing process, shape, formation mechanism and material properties.

Four types of machining burrs were detected: Poisson burr, rollover burr, tear burr and cut-off burr.

Fig. 7. ''Poisson'' effect as known from Engineering Mechanics is only applicable in the elastic range.

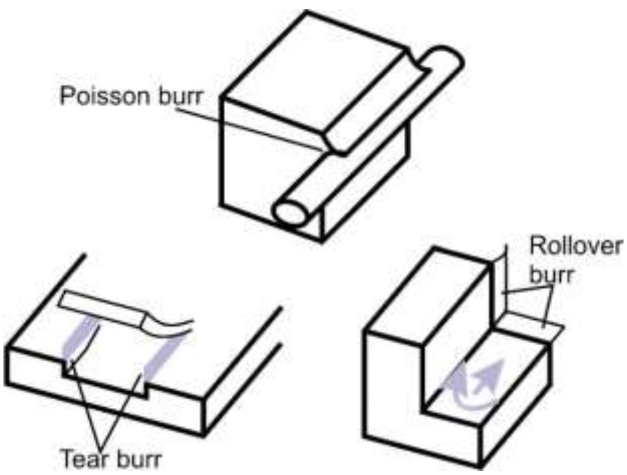
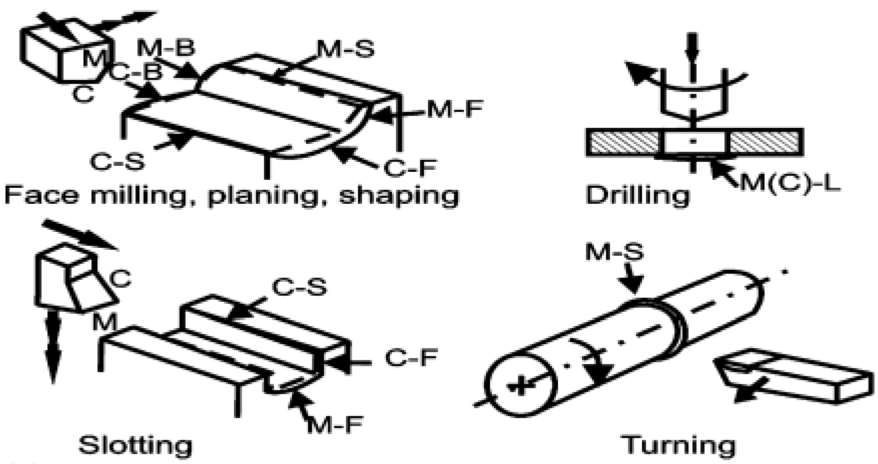


Fig. 7. Schematic of Poisson, tear and rollover burr

(1) Cutting edge directly concerned	
Major cutting edge	M
Corner or minor cutting edge	C
(2) Mode an direction of formation	
Backward flow	B (Backward or entrance flow)
Sideward flow	S (Sideward burr)
Forward flow	F (Forward or exit burr)
Leaning to feed direction	L (Leaned burr)

(a)



(b)

Types of machining burrs

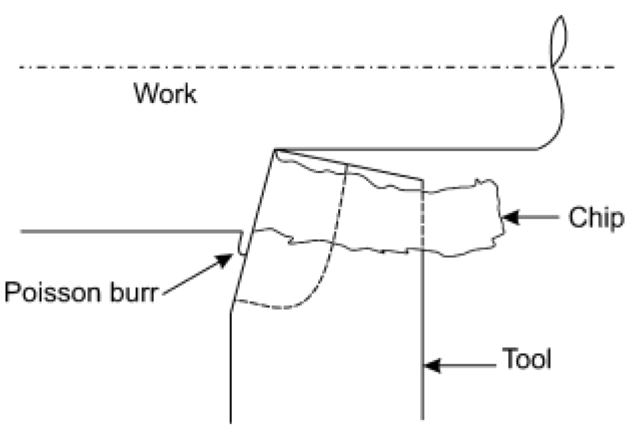
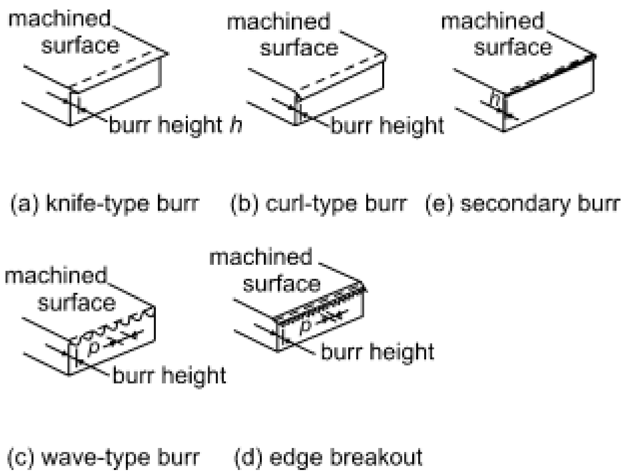


Fig 8. Poisson burr formed when cutting edge of tool extends past edge of workpiece



Burr formation mechanisms

Mechanics of burr formation/analytical models

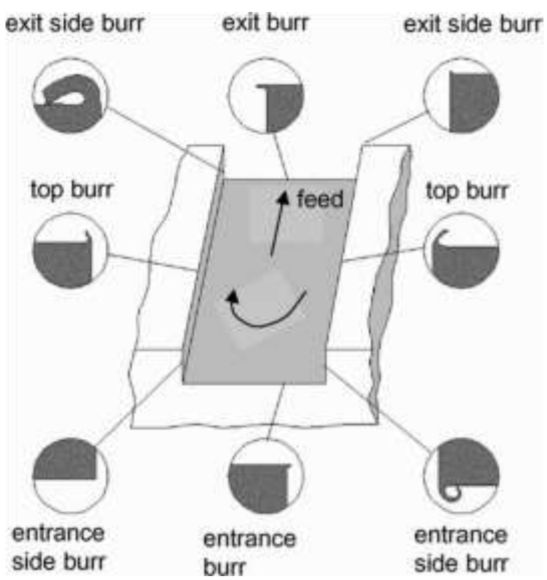


Fig. 9. Types of milling burrs

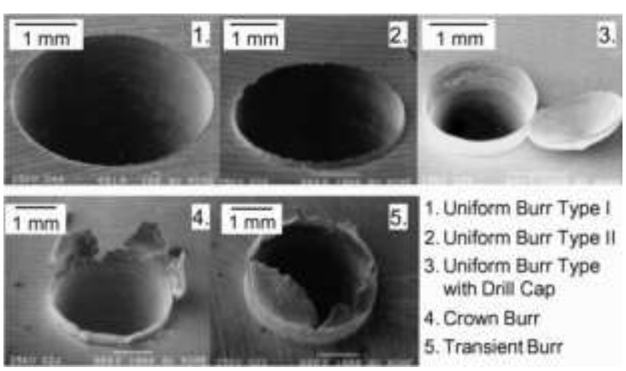


Fig. 10. Typical drilling burr types

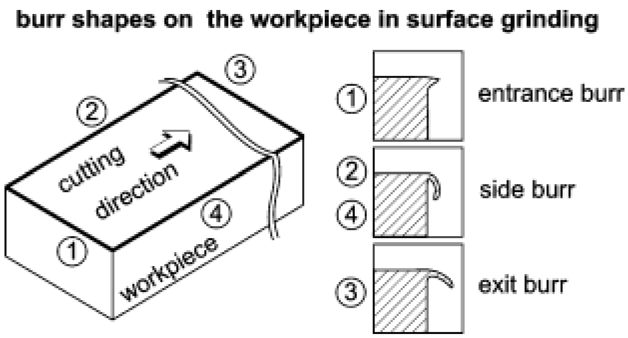


Fig. 11. Burr shapes on the workpiece in surface grinding

Research work is chip formation rather than burr formation in particular. Due to the fact that burr formation very much depends on chip formation mechanisms.

1. Displacement of material in burr forming force direction.
2. Displacement of material normal to burr forming force.

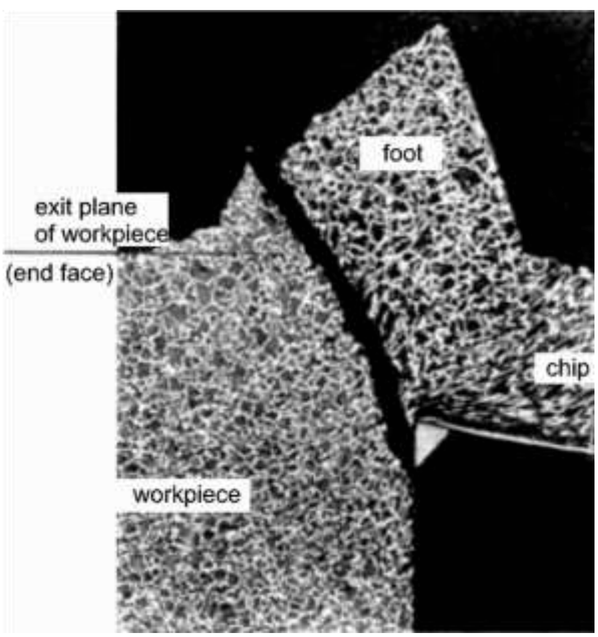


Fig. 12. Micrograph of the chip root showing the exit failure, negative shear, and foot formation.

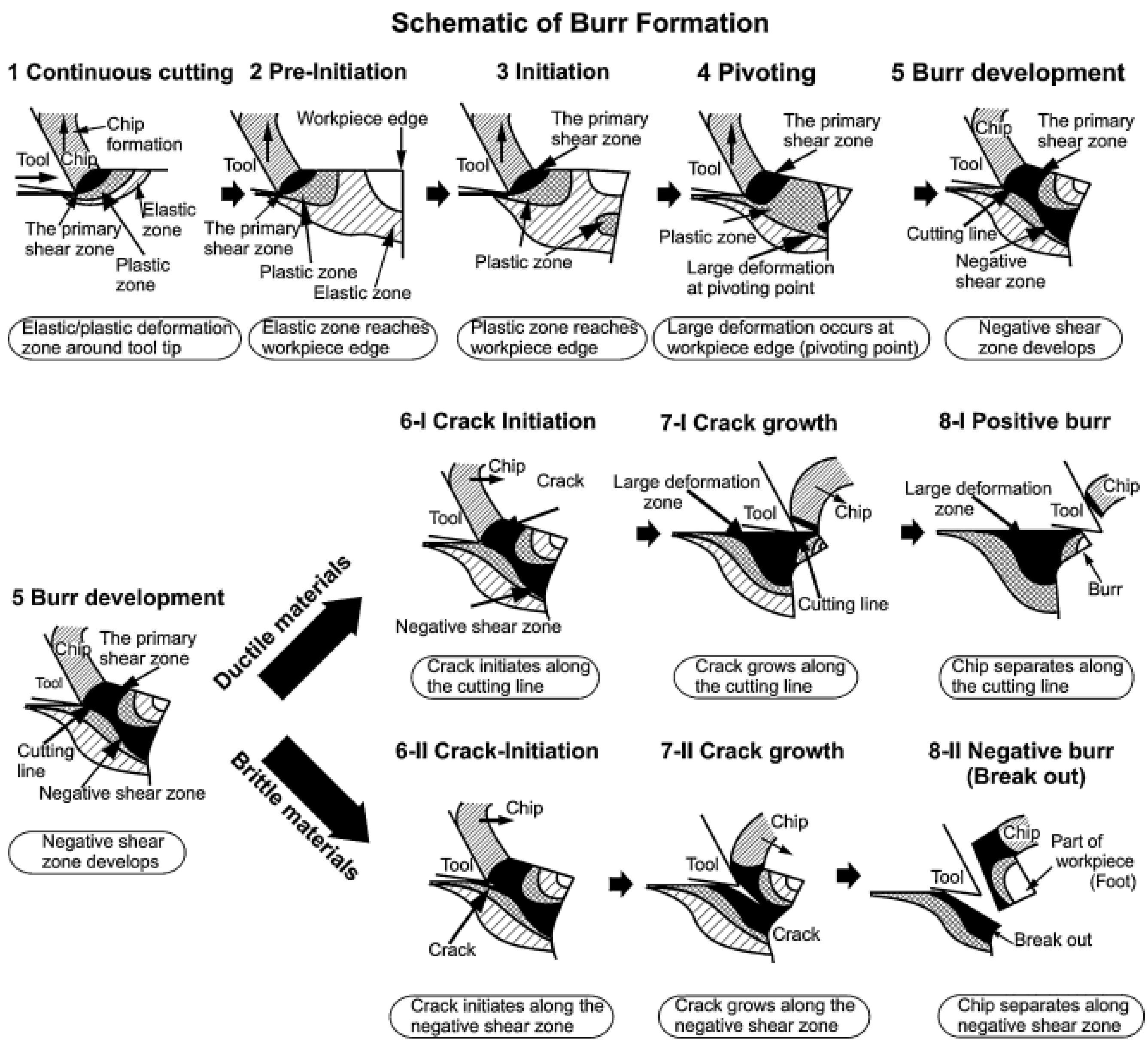


Fig. 13. Schematic of burr formation

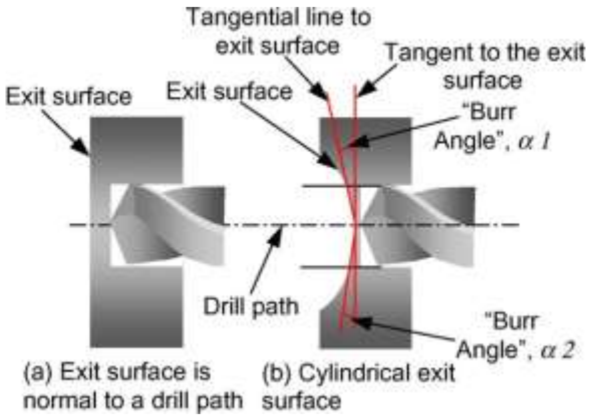
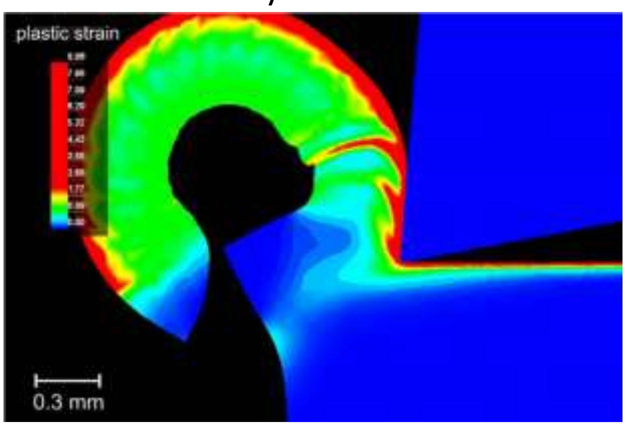


Fig. 14. Influence of exit order on Burr formation when drilling.

FEM analysis and burr formation simulation

Finite element method analysis can be used as a tool to understand and predict formation.



Burr formation processes in orthogonal cutting

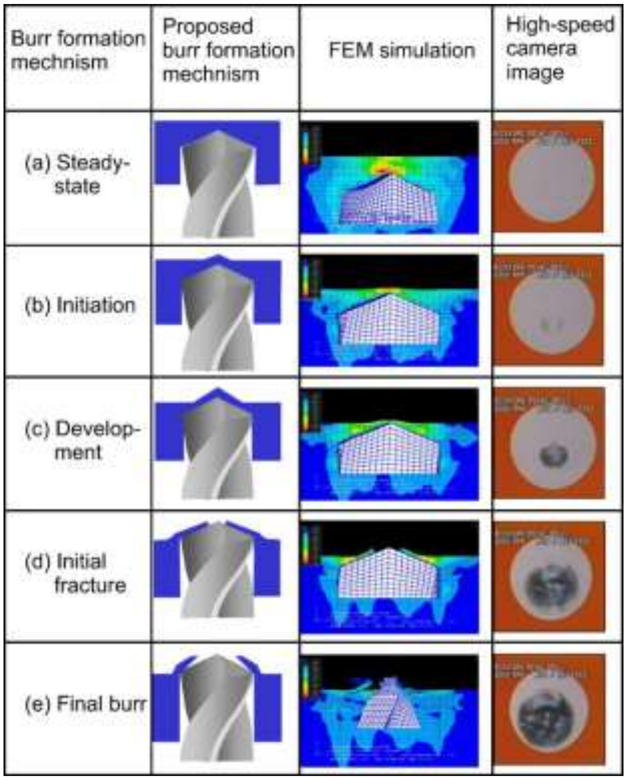
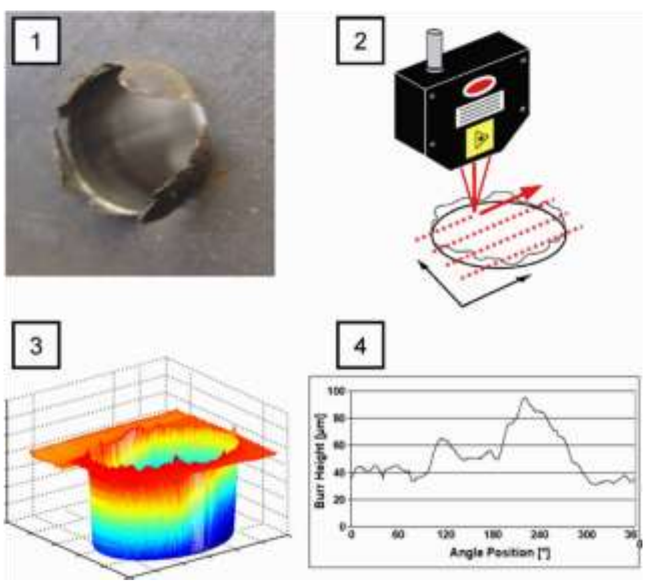


Fig. 16. FEM simulation of burr formation in drilling.

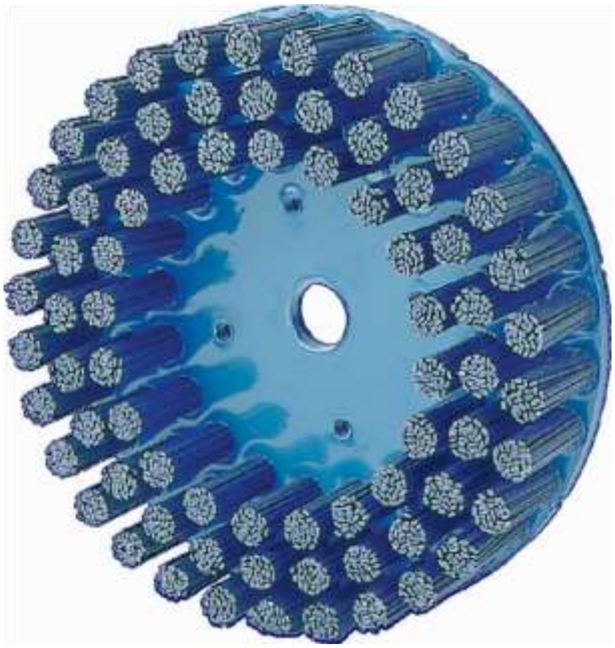
Method of Burr detection and measurement control



Non-contact measurement of burrs with means of a laser triangulation system.

Mechanical deburring

In mechanical deburring operations the burrs are reduced or removed by mechanical abrasion.



Deburring brush.

In conclusion, burr in manufacturing cannot be overemphasize; however, it may be concluded that it can be control, depending on the techniques apply as indicated from this studies above.

Environmental protection

The main sources of air pollution (dust, carbon monoxide, sulfur dioxide) and reservoirs with mechanical suspensions in foundries are cast iron and steelmaking units and equipment of the mixture preparation department, etc. Foundry with an annual output of 100 thousand tons of Lithuania, equipped with dust collectors with a cleaning efficiency of 0.7-0.8 emits up to 1000 tons of dust per year, i.e 1 ton of dust per 100 tons of Lithuania.

The main types of wastewater pollution are sand, scale, dust, fluxes, etc. The mass concentration of suspensions in wastewater can reach 3000 mg / l.

Danger of electric shock occurs when using resistance furnaces to heat the workpieces.

There is a risk of fires due to the accumulation of oil in the pits under the presses and hammers. The auto ignition temperature of petroleum oils is 250 - 400 ^{o}C, fuel oil - 380-420 ^{o}C.

Fire can occur during the treatment of flammable metals (for example, the presence of magnesium classifies the room as fire hazard category A).

To avoid spontaneous combustion of the used wiping material (ends, rags, rags, etc.) it should be stored away from heated objects, heaters, electrical equipment in metal boxes, which are tightly closed. Used wiping material must be removed from the box at least once per shift.

An explosion may occur when starting gas heating furnaces due to incorrect ignition, when the blast stops suddenly, when gas enters the production room, as well as when air enters gas communications. To avoid explosion gas pipelines are made of the integral pipes which are connected by welding, thus it is not allowed to use carving and flange connections. The shop gas pipeline network is equipped with closing and switching devices, pressure regulators and purge plugs.

Explosion-proof electrical equipment is installed at the sites of preparation of technological lubricants that contain combustible substances (kerosene, oils, alcohols, etc.) to prevent an explosion. Such sections are equipped with supply and exhaust ventilation to prevent the formation of explosive concentrations of these substances in the air.

When packaging scrap and waste of ferrous and non-ferrous metals on packaging presses, it is necessary to control and remove explosive objects, which is carried out under the guidance of a specially trained controller-pyro technician.

Create dangerous conditions and can lead to injuries:

Malfunction of the hammer or press; insufficient or excessive heating of workpieces; violation of the technological process; incorrect stamp mounting; use of inappropriate or faulty tools and devices; poor workplace organization; insufficient knowledge and experience; lack of discipline to comply with safety requirements. Of course, the causes of injuries to workers on hammers and presses can be:

- breakage of the piston rod and stamp due to insufficient heating or cracks;
- lifting the hammer to a height;

- disconnection of a rod with falling parts of a hammer and the

  subsequent blow of the piston about the top cover of the cylinder;
- failure of the piston from the rod;
- breakdown of a cover of the cylinder of a hammer owing to blow of the piston;
- explosion of the pipeline from the formation of condensate in the cylinder;
- the use of incorrect methods of work when removing the workpiece that is stuck in the stamp;
- departure of wedges, crackers, linings, etc., which fix the stamp;
- incorrect methods of work on hoisting and transport mechanisms;
- lack of safe passages, passages, etc.

In procurement departments characteristic injuries are:

- injury to workers when removing the strapping wire;
- blows by preparations at their movement on the roller conveyor and the ends of rods at cutting;
- cuts of hands on sharp edges and burrs of preparations.

The main harmful or dangerous production factors during heat treatment can be:

1. Increased gassiness or dust in the working air zones of toxic gases, which may belong to the controlled atmospheres and source gases. These are carbon monoxide CO, ammonia NH_3, sulfur dioxide SO_2, hydrogen sulfide H_2S, benzene C_6H_6 and others. The appearance of a pungent odor of some gases, such as ammonia, sulfur dioxide, propane, is a warning of problems.
   Cyanide salts (KCN, NaCN, etc.), which are the strongest poisons, can be used in heat treatment processes. In the presence of moisture, acids, and carbon dioxide contained in the air, cyanide salts emit hydrogen cyanide (hydrocyanic acid HCN), which causes rapid suffocation due to paralysis of the tissues of the respiratory organs.

When working with salt melts, they can evaporate and spray as a result of chemical reactions that occur both on the treated material and on the interface between the working media and the atmosphere (reactions with oxygen, moisture). At the same time alkali vapors, small drops of water vapor in combination with carbonates, nitrates, hydroxides, etc. salts can cause respiratory irritation, unpleasant effects on the mucous membranes and eyes;

2. Elevated temperature of materials or surfaces equipment, high levels of thermal radiation. Burns can be obtained from emissions of melts due to disruption of the technological process, from the flash of hardening oils, from flashes of combustible gases, which are used as controlled atmospheres. When touching heated products or parts of furnaces, when touching external parts of equipment (doors, handles, etc.), the temperature of which has risen due to failure of thermal insulation. Possible eye burns during operation of plasma, electron beam, optical, etc. furnaces that operate at very high temperatures. Overheating and burns of workers are also possible due to intense thermal radiation.

3. Increased voltage in electrical networks Electro thermal equipment has live parts directly in the work space, often without electrical insulation. This is dangerous if you can come in contact with them when loading or moving products.

4. Increased electromagnetic field strength.

5. Increased noise level during operation of some types of furnaces.

6. Moving machines and mechanisms.

7. Possibility of explosion or ignition when used in the process of heat treatment of oils.

8. Organization of safe work during machining of materials, safety in galvanic shops

When machining metals, plastics, etc. materials on metal-cutting machines (turning, milling, drilling, grinding, sharpening, etc.) there are a number of physical, chemical, psychophysiological and biological dangerous and harmful production factors:

- parts of production equipment, moving products and blanks;
- chips of processed materials;
- fragments of tools in case of their destruction;
- high surface temperature of parts and tools;
- increased voltage in electrical networks or static electricity, which can cause a short circuit through the human body.

When processing brittle materials (cast iron, brass, bronze, graphite, carbolite, textolite, etc.) at high cutting speeds, the chips from the machine fly a distance of 35 m. Metal shavings, which are formed especially when cutting plastic metals (alloy steels), has a high temperature (400-600oC), long length, creates a serious danger not only for the worker on the machine, but also for people near the machine. The most common in machine operators are eye injuries. So at turning from total number of industrial injuries eye damage exceeds 50%, at milling - 10% and about 8% at tool sharpening and grinding. The eyes are damaged by flying chips, dust particles of the processed material, fragments of the cutting tool and abrasive particles.

Harmful physical production factors characteristic of the cutting process are increased dust and air pollution of the working area; high noise and vibration; insufficient lighting of the working area; increased pulsation of light flux. In the absence of means of protection of dust of air environment in a breathing zone of machine tools at turning, milling and drilling of fragile materials can exceed maximum admissible concentrations. When processing brass and bronze, the amount of dust in the room air is relatively small (14.5-20 mg / m3). However, some alloys (brass LC40C) contain lead, so the toxicity of dust generated during their processing should be assessed taking into account the amount of lead in the alloy and its maximum allowable concentration. The size of dust particles in the respiratory zone varies in a wide range - from 2 to 60 microns.

In the process of mechanical processing of polymeric materials there are mechanical and physicochemical changes in their structure (thermal destruction). When working with a blunt cutting tool, there is intense heating, as a result of which dust and chips turn into vapor and gaseous states, and sometimes there is ignition of the material, for example, when processing textolite. Thus, when processing plastics, a complex mixture of steam, gases and aerosols enters the air of the working area, which are chemically harmful production factors.

Products of thermal destruction (marginal and non-marginal hydrocarbons, aromatic hydrocarbons) can cause narcotic effects, changes in the CNS, vascular system, hematopoietic organs, internal organs, as well as skin and trophic disorders. Aerosols of petroleum oils, which are part of the lubricating and cooling fluids (coolants), can irritate the mucous membranes of the upper respiratory tract, leading to decreased immunity.

Harmful psychophysiological production factors of the process of material processing by cutting include physical overload during installation, fastening and removal of large parts, eyestrain, monotony of work.

Biological factors include pathogenic microorganisms and bacteria that are activated when working with coolants.

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