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
«___»_____________2023

Diploma project
Level of higher education – first (bachelor)
Program subject area – 131 “Applied Mechanics”
Educational Program “Manufacturing Engineering”
topic: Manufacturing Process Design for the Part "Housing"

Signature:
Student: Pransukh Banerjee

Supervisor: Shuplietsov Danylo

Reviewer: PhD, assoc.prof. Olha Kholiavik

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

Kyiv 2023

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

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

APPROVED
Acting head of the department
______ Olexander OKHRIMENKO
«___»_____________2023

ASSIGNMENT

for the student's diploma project

Pransukh Banerjee

1.Topic of the project

“Manufacturing Process Design for the Part "Housing"”

Project supervisor   Shuplietsov Danylo

approved by the University Order of «__» _______2023 № _______

2. Deadline for submission of the project «06» June 2023

Time schedule

No	The stage of the diploma project execution	Deadline	Notes
1	Analysis of the service purpose of the part "Housing"	01.02-10.02	
2	Development of the drawing of the part "Housing"	13.02-09.03	
3	Designing the manufacturing process of the part "Housing"	10.03-21.04	
4	Development of the design of technological equipment for processing details on CNC machines	21.04-10.05	
5	Execution of assembly drawings of machine tooling	10.05-03.06	
6	Development of a control program for a CNC machine by using software	21.04-03.06	

Student *Pransukh Banerjee*

Supervisor *Shuplietsov Danylo*

Abstract

The completed work consists of 5 sheets of the graphic part of A1 format and 78 sheets of explanatory notes of A4 format. The explanatory note contains a complete description of the work, including necessary explanations, tables, and illustrations.

Various sources of literature were used to write the work, such as methodological guidelines, books, magazines, catalogs, various websites for guidance and context, etc.

As part of the work, the following tasks were solved:

- The method of production of the workpiece is chosen, allowances and tolerances for the execution of the main surfaces are determined.
- A 3D model of the part and a 3D model of the technological equipment were developed.
- Technological tasks were solved, allowances and cutting modes were calculated using the analytical method.
- Devices for a 3-axis CNC milling machine for part processing have been developed with g-codes added to it.

Introduction

In today's world, mechanical engineering is fundamental to the economy of any country and plays a crucial role in establishing the material and technical foundation of the economy.

It holds significant importance in driving scientific and technological progress in modern times. Through the production of machinery and equipment for various sectors of the national economy, mechanical engineering enables complex mechanization and automation of production processes.

The multi-industry machine-building complex in Ukraine has emerged as a robust sector of the country's industry, bringing together more than 11,000 enterprises. With a share exceeding 15% of Ukrainian industry and approximately 12% of the GDP, the machine-building industry holds significant importance. Mechanical engineering alone concentrates over 15% of fixed assets' value, nearly 6% of current assets in the domestic industry, and employs more than 22% of the total workforce.

Innovation is a key requirement for modernizing the economy and transitioning to a new post-industrial stage of social progress. Science-intensive mechanical engineering serves as a constant source of innovative initiatives in developed countries.

This is why countries like the United States, Germany, Japan, and England exhibit a production structure that emphasizes a higher proportion of science-intensive manufacturing in their machine-building sectors.

1. OVERALL ASPECTS OF MECHANICAL ENGINEERING

Introduction

The assessment of machining technologies relies on three fundamental measures: productivity, quality, and durability, which determine their overall performance. The ultimate objective is to achieve optimal processing speed, exceptional part quality, and efficient utilization of energy and resources. Extensive research and development endeavors have been devoted to the realm of metal cutting and processing in order to meet these objectives. Among the noteworthy advancements, high-speed processing technology has emerged, accompanied by a multitude of sophisticated methodologies and processes aimed at maximizing productivity, ensuring superior quality outcomes, and promoting sustainability.

Nowadays, the primary focus in processing technology revolves around obtaining high-quality machine parts while keeping costs low and minimizing environmental impact

1) Consequently, the industry is actively exploring new manufacturing technologies and processes that enhance part quality and improve processing efficiency. In the context of environmental concerns, this has led to the development of new regulations and standards aimed at protecting the environment and preserving natural energy resources

2). As a result, various manufacturing methods and technological processes are striving to reduce environmentally harmful production techniques, prioritizing both environmental and health considerations.

To promote environmental sustainability in manufacturing processes, different cooling technologies have been developed, specifically for cutting operations. These include high-pressure cooling, minimum quantity lubrication and cryocooling. Among them, cryogenics stands out as a cleaner alternative because it does not produce any disposable liquid waste. The regular use of coolant adversely affects the working environment and the health of workers, while the disposal of liquid waste presents complex challenges and additional costs. In contrast, using a cryogenic environment in the cutting process is considered a clean cooling method, taking into account these factors.

Despite the advantages of liquid nitrogen, the high initial installation cost in practical manufacturing applications may limit its economic viability. However, cryocooling technology offers several advantages in terms of environmental impact, tool lifespan, and resulting surface characteristics.

Additionally, cryocutting not only supports environmental consciousness but also improves the effective properties of the processed parts.

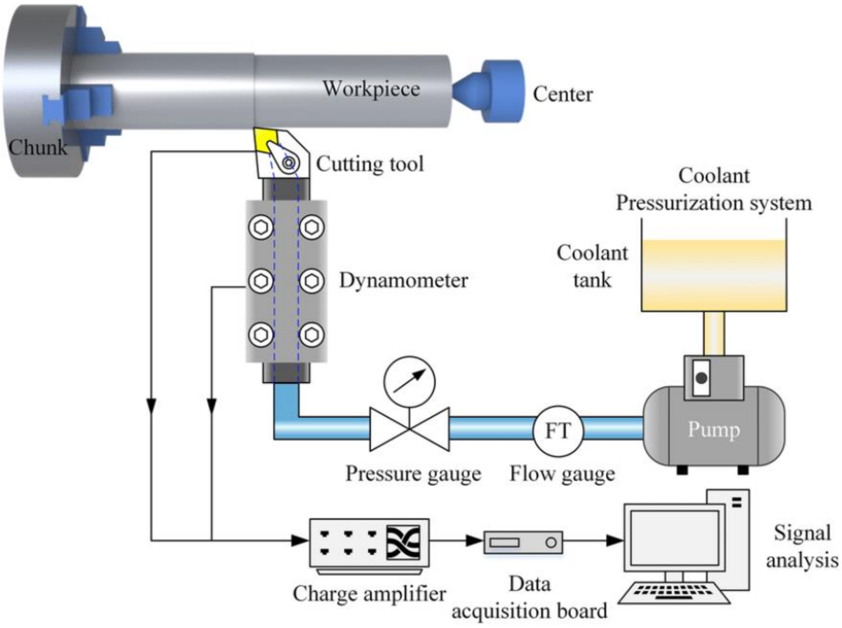
The impact of cryocooling on cutting performance is determined by factors such as tool lifespan, cutting temperature, friction, and cutting power. The heating and friction that occur during cutting between the tool and the workpiece present challenges in terms of tool lifespan and surface integrity.

The interaction between the cutting tool and the workpiece generates friction, which, when increased, leads to tool wear or breakage. This, in turn, causes cracks to appear on the cutting tool, negatively impacting both its lifespan and the quality of the surface. These phenomena are also influenced by plasticity (flowability) and crack propagation.

Methods for cooling during the cutting process aim to counteract the detrimental effects of high temperatures at the tool-workpiece interface, which can lead to tool wear, increased cutting forces, and diminished surface quality [11]. To mitigate these issues, a variety of cooling techniques are utilized in the cutting zone. These include cryogenic cooling, minimum lubrication machining or dry machining, high-pressure coolers, solid coolers or lubricants, as well as air cooling, steam, or gases. Employing these methods effectively regulates the temperature, thereby enhancing cutting efficiency.

Gas coolers, renowned for their ability to maintain gas properties at room temperature, offer an environmentally friendly cooling solution for cutting processes. Additionally, they can be pressurized for utilization in material processing. Commonly used gas carriers, such as air, argon (Ar), helium (He), nitrogen (N2), or carbon dioxide (CO2), serve as inert gases. These gases not only exhibit high corrosion resistance but also possess oxidizing properties that benefit both the cutting tool and the machined surface during high-temperature forming. Furthermore, they can be combined with traditional coolants in the form of mists or droplets to enhance lubrication capabilities.

MQL, known as minimum lubrication machining, represents an economical and environmentally friendly approach to cooling. Sometimes referred to as almost dry and micro lubricating technique, MQL offers several key advantages, including reduced coolant consumption, cost savings, minimized environmental impact, improved cutting performance, and enhanced surface integrity. The fundamental principle of MQL involves the application of a fine mist, consisting of a precise mixture of air and liquid coolant, onto the cutting tool (as depicted in this figure.



Heat generation during cutting

Heat generation during cutting is an incredibly important phenomenon in the field of mechanical engineering. When you're cutting something, the tool you're using and the material it's cutting create heat. This happens because of two main reasons: the material gets deformed and there's friction between the tool and the material.

When you're cutting, the tool applies force on the material, which changes its shape. This requires energy, and that energy turns into heat. The amount of heat produced depends on things like how fast you're cutting, how deep you're cutting, and the properties of the material. The faster and deeper you cut, the more heat you generate because you need more energy to deform the material.

Friction is another big reason for heat generation during cutting. As the tool rubs against the material, the friction turns mechanical energy into heat energy. The amount of heat produced by friction depends on things like how smooth the surfaces are, the shape of the tool, the cutting conditions, and the roughness of the material. If there's more friction or the surfaces are rougher, you'll generate more heat.

Generating too much heat during cutting can cause a lot of problems. One of the main issues is that it wears down the tool quickly. High temperatures can make the tool material softer, which leads to faster wear and a shorter tool lifespan. The heat can also put stress on the tool, causing it to crack or deform. And it doesn't just affect the tool; it can also change the structure of the material being cut, causing dimensional errors and residual stresses.

To deal with the negative effects of heat generation during cutting, there are a few strategies used in mechanical engineering. One common approach is to use coolants or lubricants to cool down the cutting area. These fluids help reduce the cutting temperature, lower friction, and remove chips. It's also important to optimize the cutting parameters, like speed, feed rate, and depth of cut, to control heat generation.

In summary, heat generation during cutting is a significant aspect of mechanical engineering. It's important to understand how it happens and to use the right methods to manage and control the heat. This helps improve cutting efficiency, extend tool life, and ensure the integrity of the material being cut. Ongoing research in this field aims to minimize heat generation and make cutting processes more efficient in various industries.

In orthogonal processing, heat generation occurs in the following zones:

1. Cutting Zone: Where the tool contacts and removes material from the workpiece.

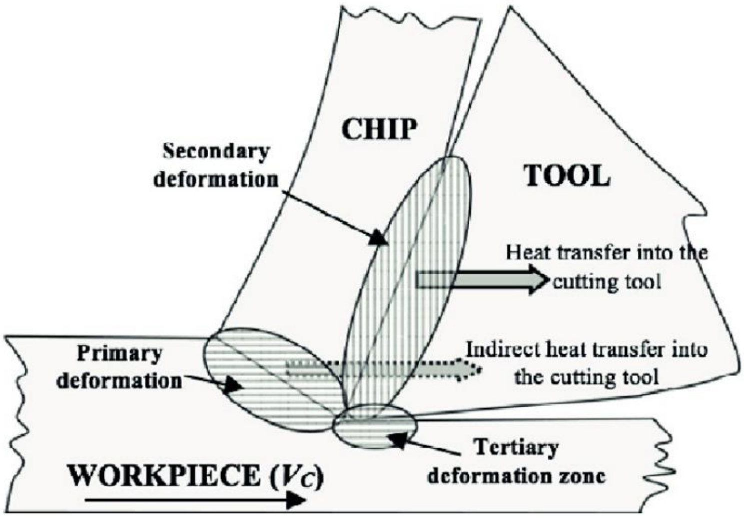
2. Tool-Workpiece Interface: The interface between the tool and workpiece, where friction generates heat.

3. Chip Formation Zone: Heat is generated as material undergoes plastic deformation during chip formation.

4. Tool Flank and Rake Face: These surfaces experience friction and rubbing against the workpiece, leading to localized heat generation.

5. Cutting Fluid Interaction Zones: Heat transfer occurs at the interface between cutting fluid and the tool-workpiece, aiding in cooling.

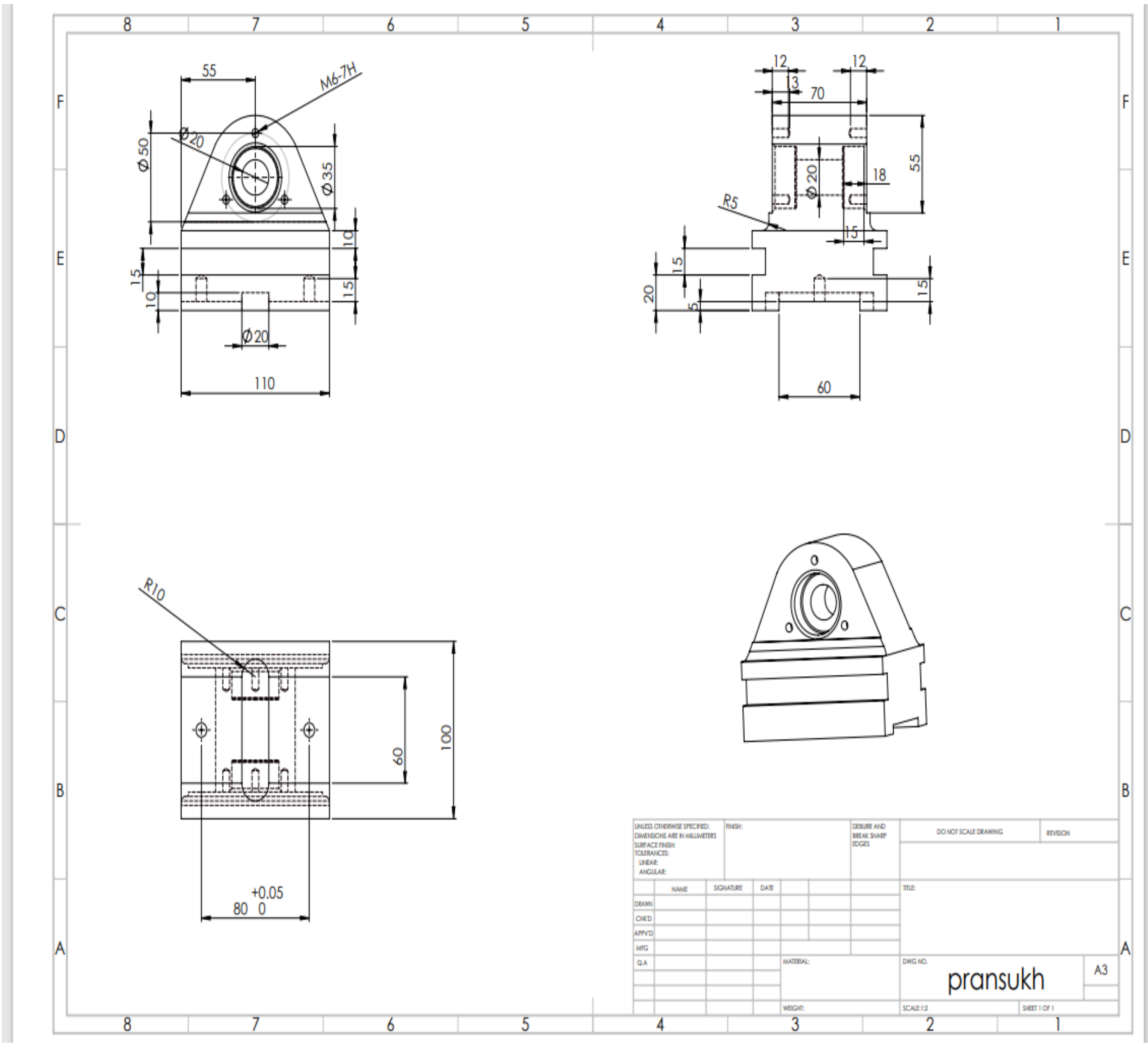
Heat generation can vary based on factors like cutting parameters, tool and workpiece materials, and cooling mechanisms. Proper management is essential to avoid issues like tool wear and thermal damage.



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

Analysis of design features of the part and its classification

Considering the configuration of the part straight support we defined that it belongs to the body support



Drawing of a partstraight support

Overall, the part does not have stringent demands regarding surface accuracy and quality, although there are specific surfaces that require higher levels of precision.

Moreover, special attention should be given to the machining of the 35mm diameter holes to ensure they are perpendicular to the alignment.

1.1.1 Analysis of the part’s working conditions in the assembly unit

The primary purpose of the straight support is to provide support for the rotating shaft and facilitate its rotational movement. Furthermore, within the 35mm hole, there is a bearing installed, and the bearing cap is fastened to it using six M6 holes.

Additionally, the bottom frame of the straight support will be securely attached to the frame body using four holes. It is important to note that during operation, the part is subjected to substantial and prolonged alternating loads as well as vibrations.

Analysis of the material

Material of the part is Steel (AISI1020)it has the following chemical composition and mechanical characteristics. Chemical composition (in%)

	Si	Mn	S	P
17-0.230 %	1 – 1.5%	0.30-0.60 %	<= 0.050 %	≤0.040%

Mechanical properties

Linear shrinkage: 1.5%

Tensile strength $\sigma_{в}$= 482 MPa ; hardness HB= 121; density ρ=7.80 g/cc.

Based on the provided information, we can draw the following conclusions: The part is subjected to periodic loading and is not exposed to a corrosive environment. The material suggested by the designer is capable of ensuring the functionality of the part under these conditions. The drawing of the part includes an ample variety of types and sections, which facilitates a comprehensive understanding of the part's design characteristics.

Now, let's move on to determining the type of production and analyzing its influence on the manufacturing process plan. For educational purposes, we will employ analog methods of categorizing production types based on the weight of the part and the production volume.

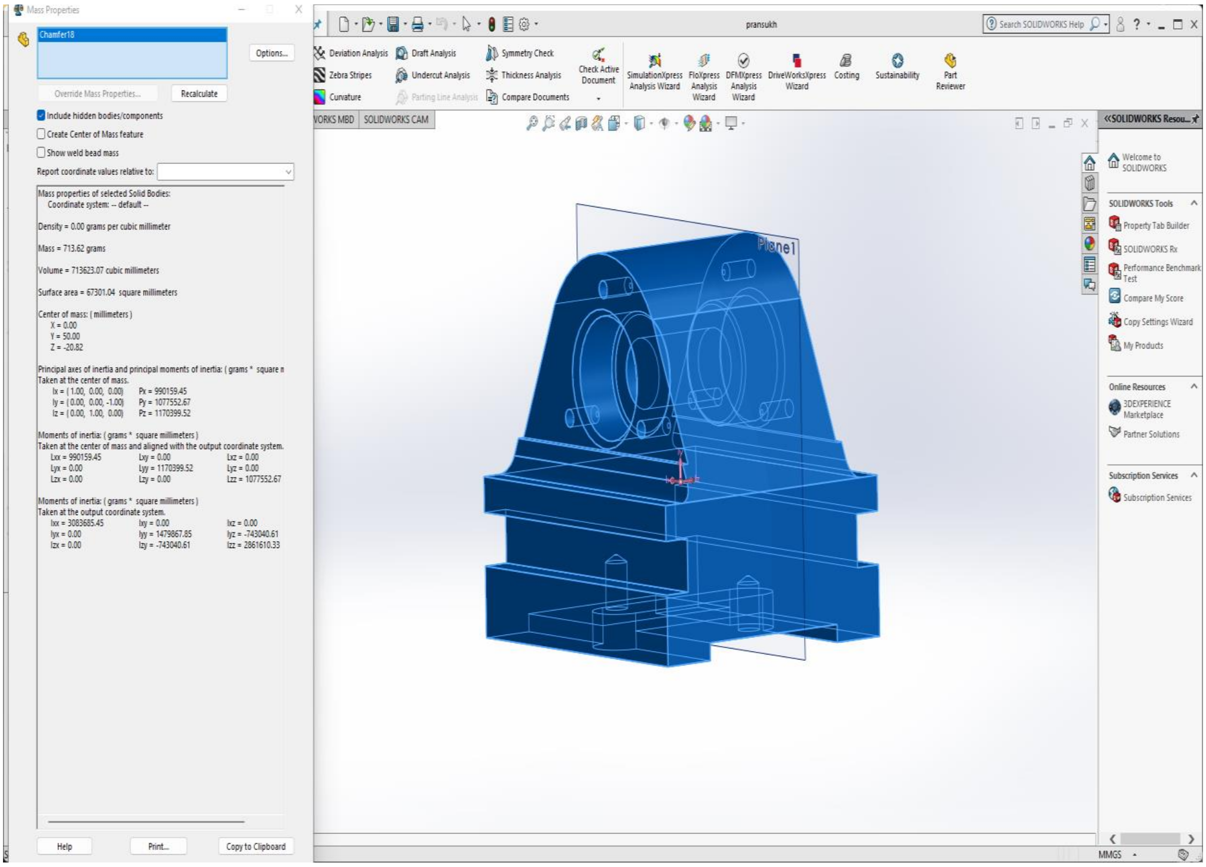
Part weight= 7.13 Kg

Production volume N_p=100 .

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

Table1.1– Estimation of the production type

Weight of apart, 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



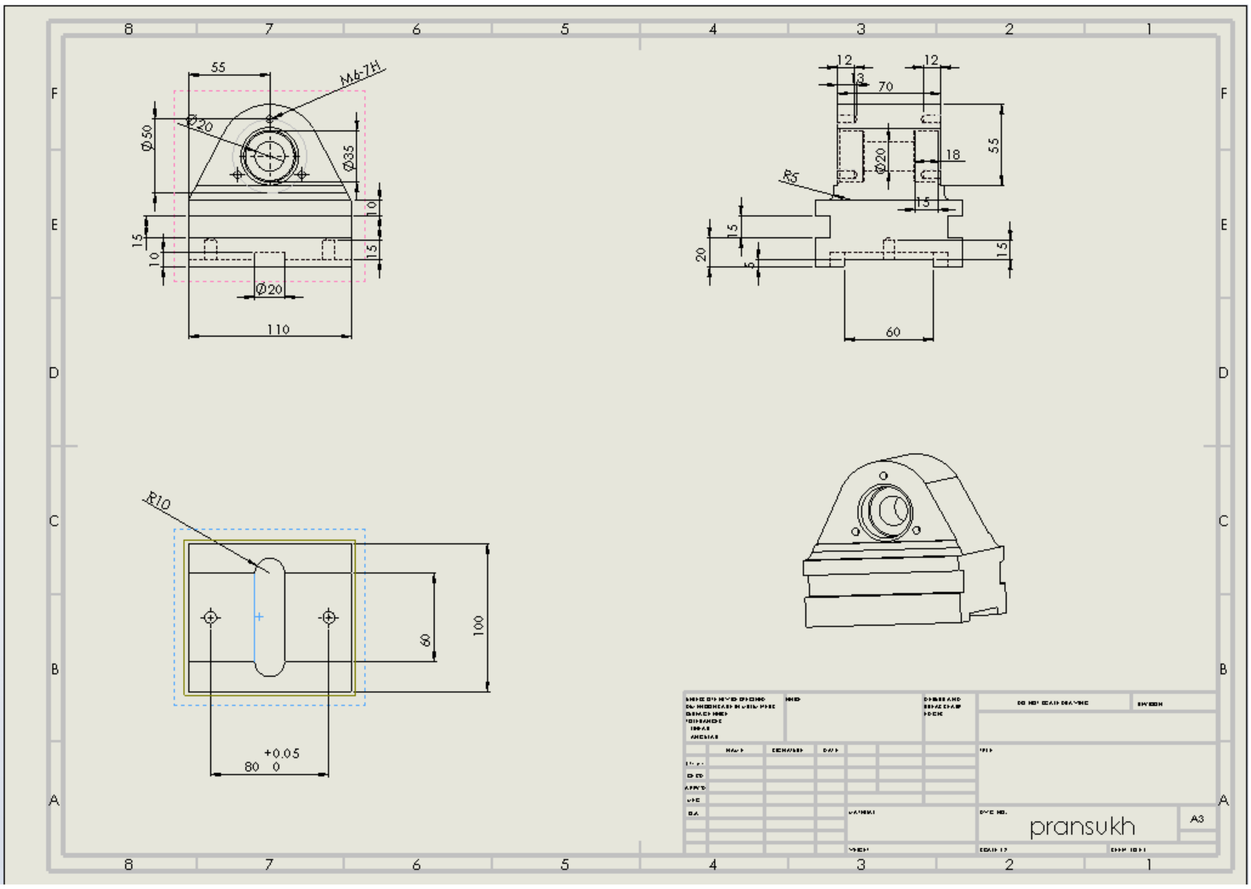
.1.2–Characteristics of the part ‘Housing’ and its 3-D model

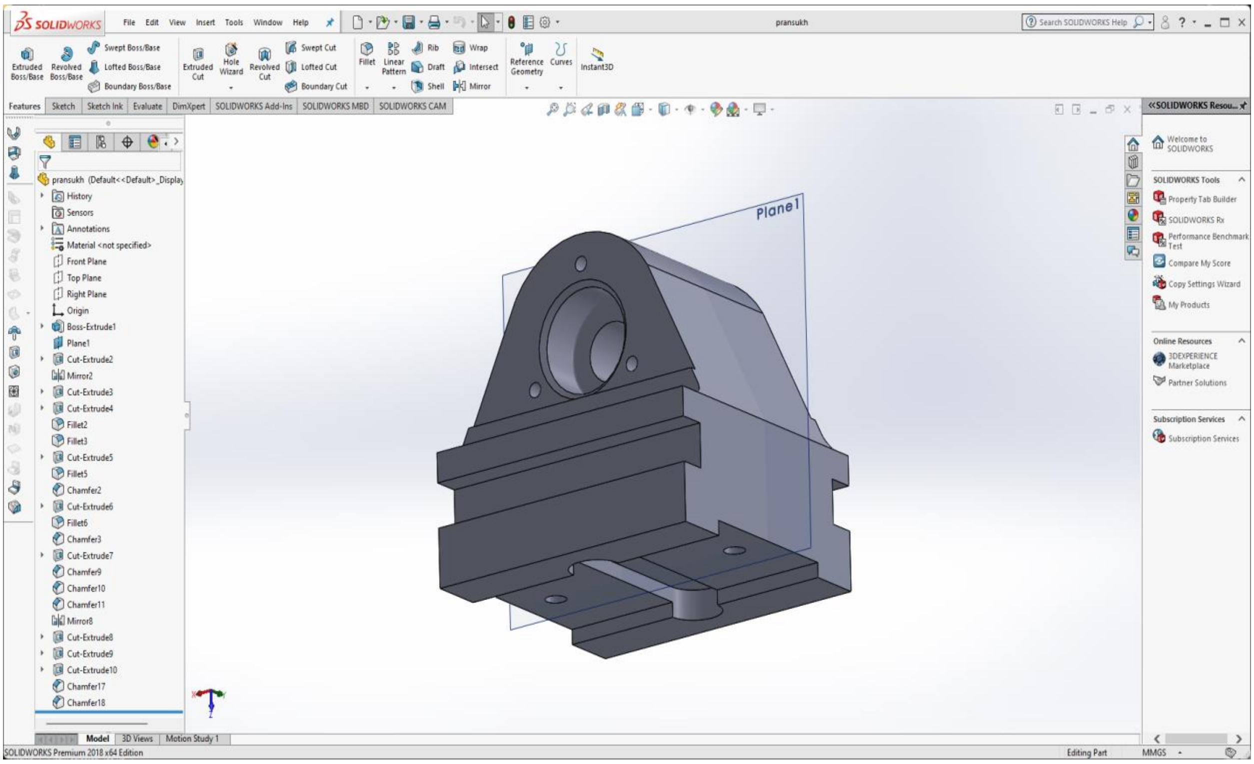
Conclusion: the production type – small batch, therefore, we will perform all further calculations and make technological decisions for the medium-volume type of production.

Selection of the base process and design of the blank

Initial data for the process selection (according to the variant):

- Drawing of a part;
- Material of a part – Grey Iron;
- Annual output – 30000 pcs.





The sand casting process can serve as the fundamental method based on the material and geometry of a component.

In order to determine the required machining allowance (RMA) grade, we will refer to Table B.1 [2]. For Grey Iron and the sand casting process, the recommended RMA grade is F. By consulting Table 2 [2] and considering the largest dimension of the part, which is 125mm (as indicated in the drawing), the calculated machining allowance is 1.5 mm.

To assess the casting tolerance (CT) grade, we will consult table A1 (for long series) [2]. For Grey Iron and the sand casting process, CT grade 11 is applicable. The estimation results for casting tolerances can be found in Table 1. Figure 1 illustrates the location of RMA and CT as depicted in the sketches.

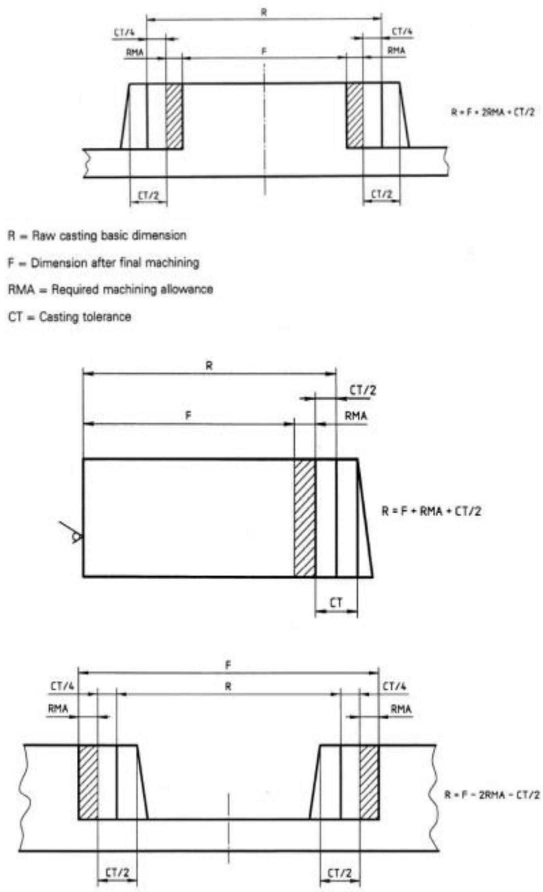


Fig. 1 Sketches for determining Raw casting basic dimension

Table 1 Casting tolerances

Dimension of a part	RMA	Min limit of size for	Casting tolerance, mm	Raw casting basic

		external features (or max for internal features)		dimension
110	1.5	113	5	112.5 ±2.5
20	1.5	23	3.2	21.6±1.6
35	1.5	38	3.6	39.8±1.8
20	1.5	16	3	14.5±1.5
100	1.5	103	5	106.5±2.5

During the casting design process, the following considerations were taken into account:

1. Optimal Placement: The workpiece was positioned in a manner that allows for the lowest possible height within the mold.

2. Parting Line: The parting line, which separates the mold into two halves, was located within the plane of symmetry of the part.

3. Corner Design: Sharp corners were avoided, and radii ranging from 2 to 5 mm were applied instead. This helps to reduce stress concentrations and facilitate the casting process.

4. Draft Angle: A draft angle of 2° was incorporated on all walls perpendicular to the parting plane. This draft angle enables easy removal of the part from the mold.

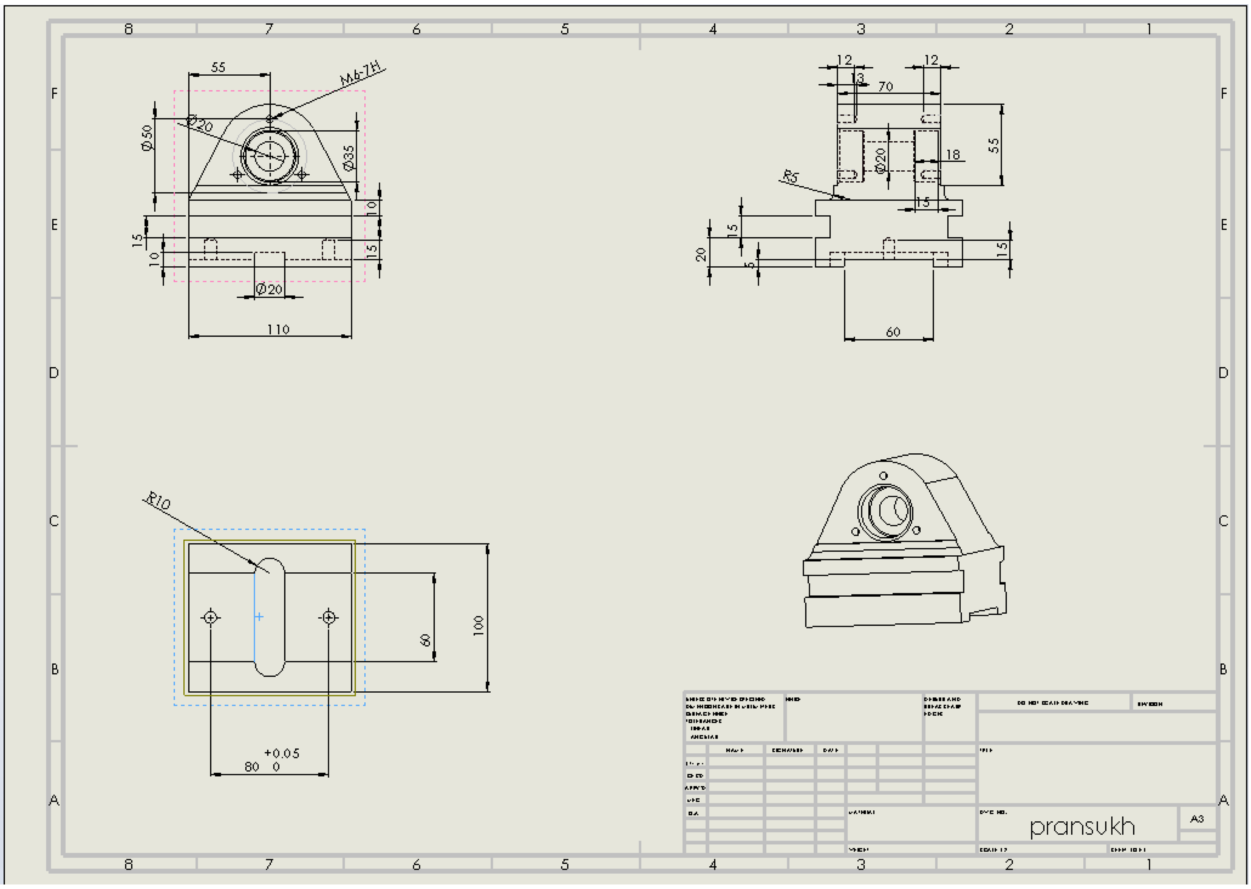
5. Machining Allowance (RMA): RMA is only applied to the surfaces that require secondary processes, such as machining. Other surfaces do not have additional material allowance.

6. Cores: The two center holes and the main pocket of the part will be formed using cores, which are removable structures used to create internal features in the casting.

7. Secondary Processes: Small features of the part, like small holes, will be achieved through secondary processes, separate from the casting process itself.

The outcomes of the workpiece design can be observed in Figure 2.

Drawing of 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].

References

[Sand Casting Cost Estimator (custompartnet.com)]

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).

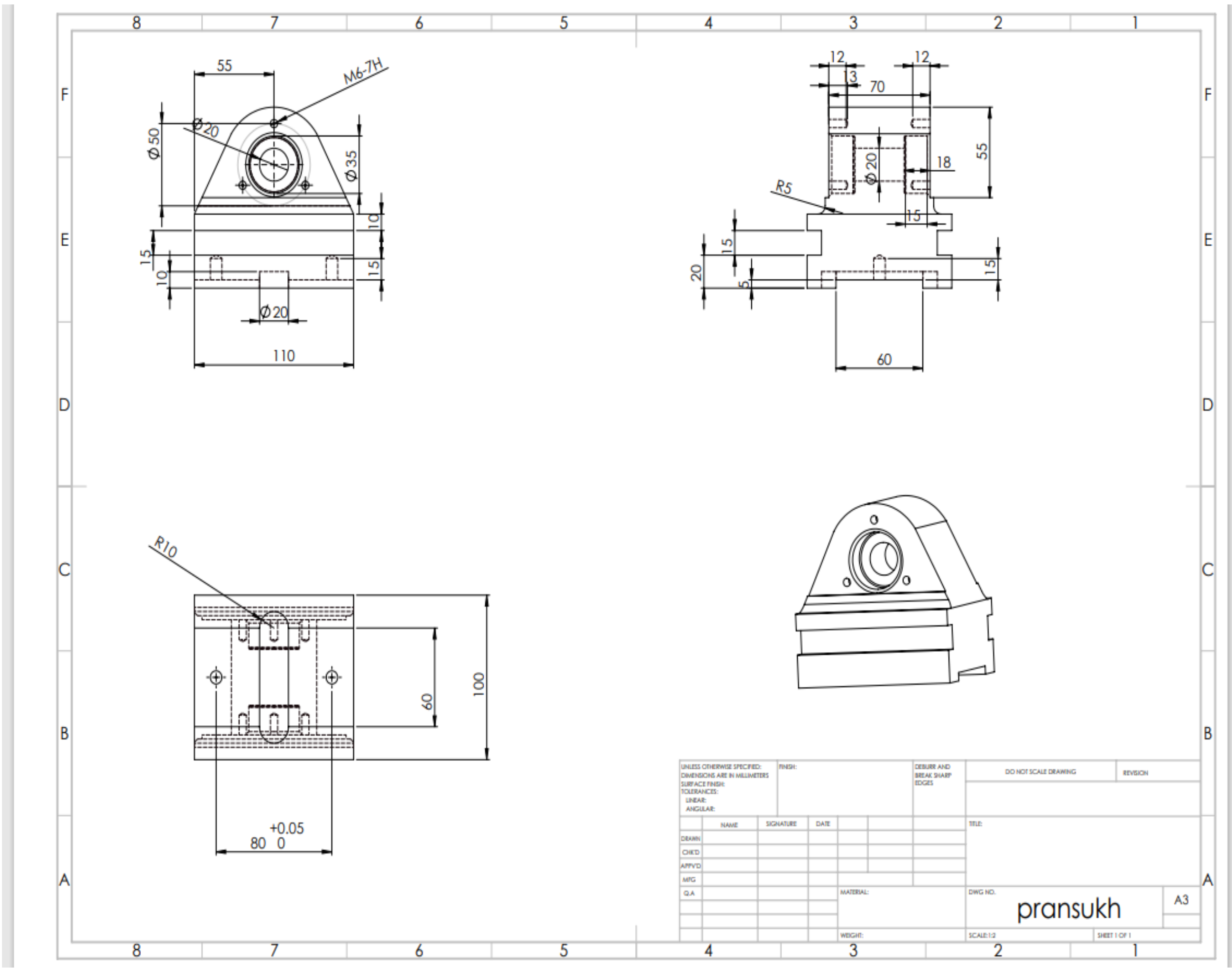


Fig 1.14 – Locating scheme for the first manufacturing operation

The formula for the locating scheme presented in Fig 1.13 is as follows:

LSMD=>S(3) + G(2) + O(1) (2.6)

Conclusion: The forth locating scheme (Fig. 1.14) is easy to implement, and provides the correct spatial position of the untreated surfaces relative to the processed surfaces. The given scheme allows processing several additional surfaces besides the general manufacturing datum during the first manufacturing operation. Therefore, we will use the forth variant of locating scheme for processing general manufacturing datum.

Advantages:

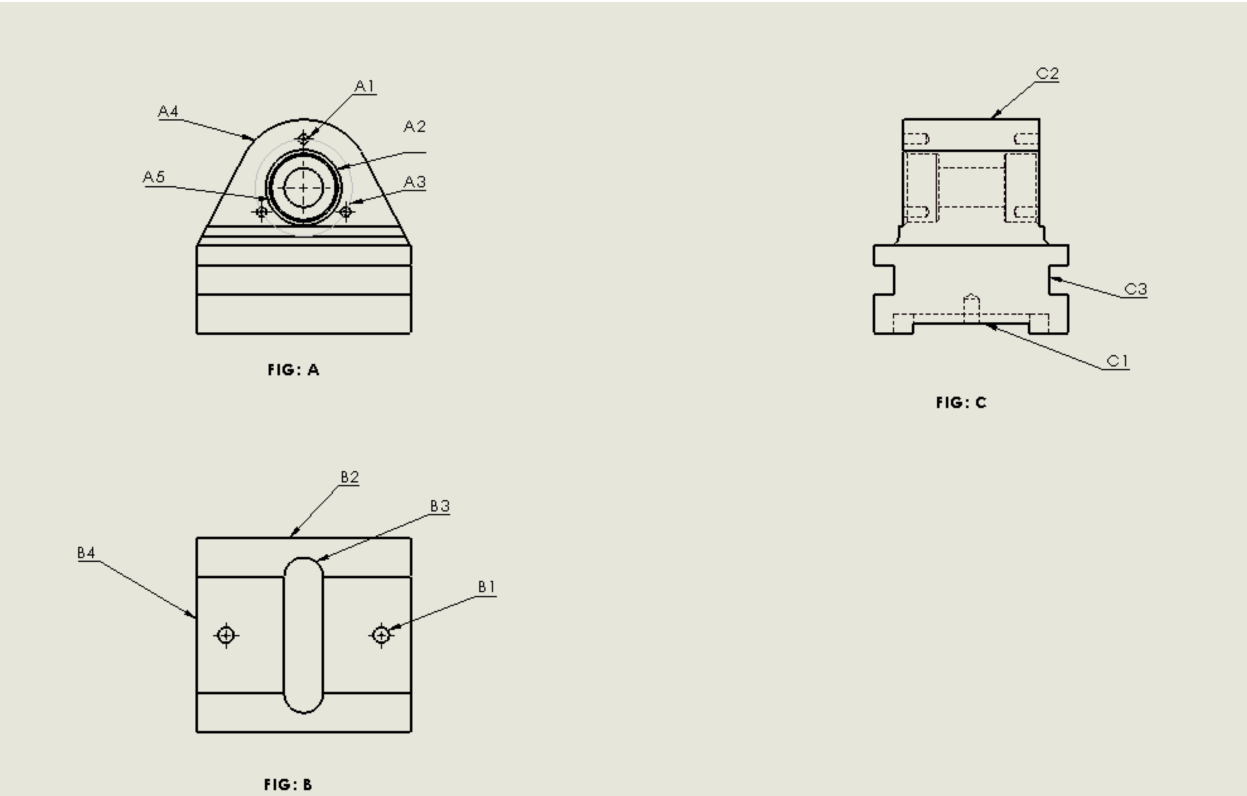
- Easy to implement: The chosen approach is straightforward and can be readily implemented in the manufacturing process.

- Ensures perpendicularity: The method ensures that the untreated surface of the workpiece is perpendicular to the datum surface, meeting the desired dimensional requirements.

Disadvantages:

- Blocks processing from three sides: The selected approach may restrict access to the workpiece, making it challenging to perform machining or other operations from three sides.

- Uneven allowance for main holes: The method may result in an uneven machining allowance for the main holes in the housing, potentially causingdifficulties in subsequent processing stages.



<u>Design of the routes for</u>

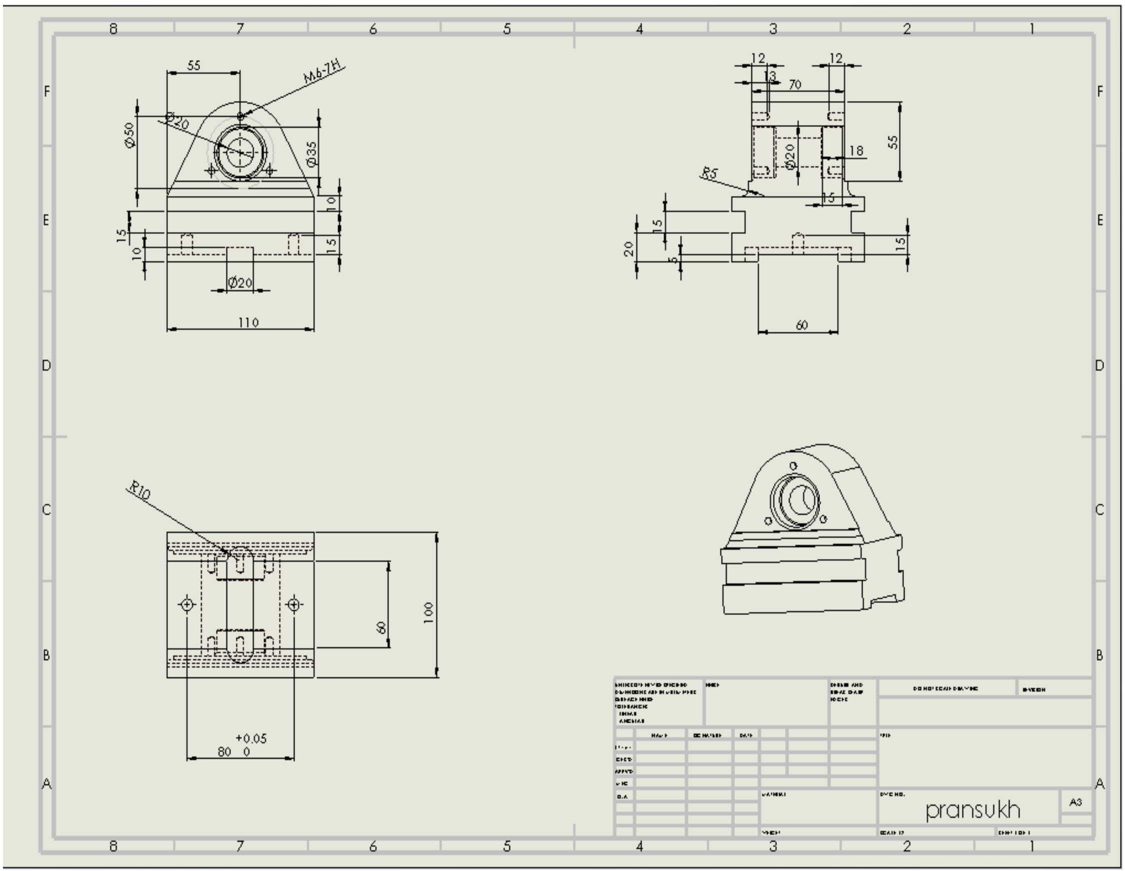
<u>machining surfaces of a part</u>

The design of the part can be analyzed as a combination of various geometric shapes, all working together to fulfill the part's intended function. The typical geometric elements found in the design include cylindrical external and internal surfaces, planes, shaped surfaces (such as screws), and others. Different types of cutting tools are employed depending on the specific surface type in order to achieve the required surface accuracy.

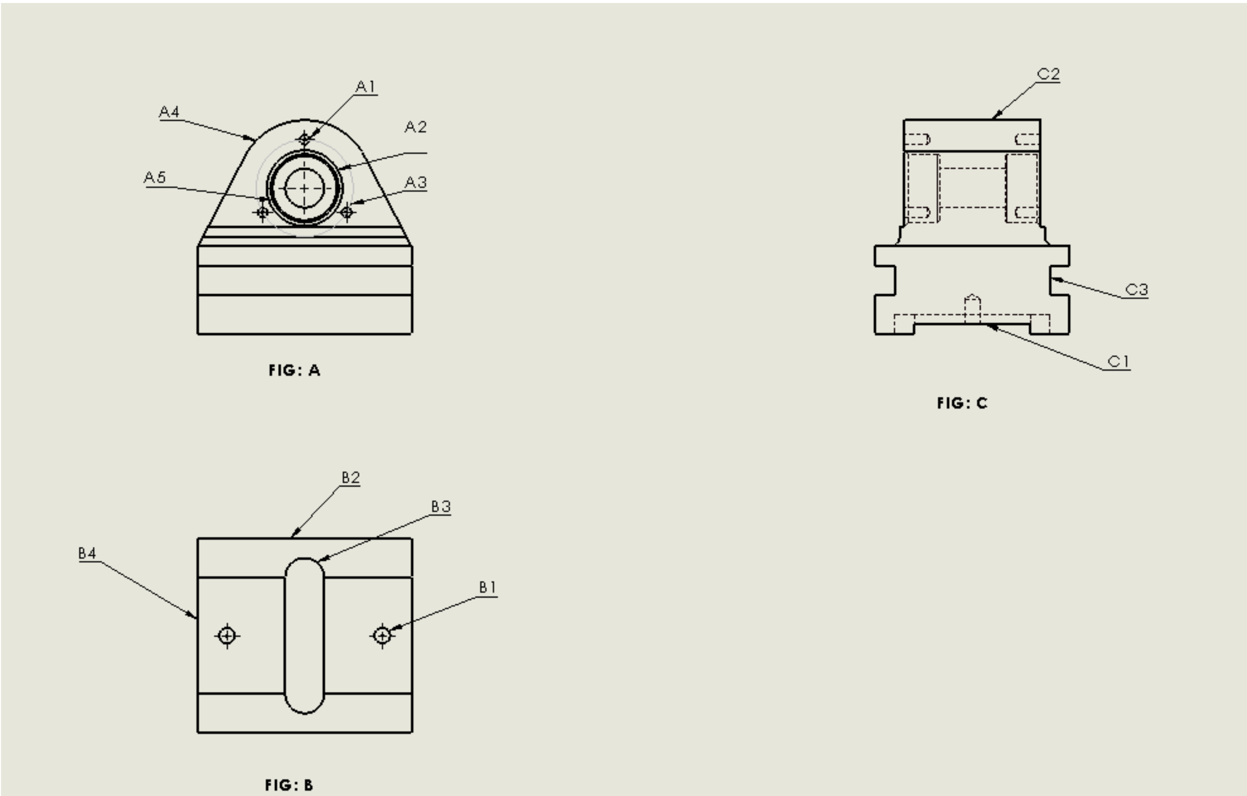
The initial step in the process planning is the development of machining routes for each individual surface of the part. This is the first of seven tasks involved in the design of the process plan. The resulting manufacturing process addresses the challenges related to dimensional accuracy, as well as the shape and quality of individual surfaces, but it does not take into account the accuracy of the relative positions. To address this, locating schemes are assigned to ensure proper alignment.

During the development of the manufacturing process, the most suitable machining option is chosen from several alternatives, considering the best economic solution. To expedite the process, standard processes for manufacturing parts and machining their main surfaces, which have been proven effective in practice, are utilized.

For the specific part "Housing of a Guide," Table 2.3 provides information on selected machining sequences, achieved accuracy, and surface roughness. The classification of surfaces can be found in Figure 2.6.



<u>Drawing of a part</u>



<u>Design of the routes for machining surfaces of a part</u>

Surfaces	IT	Ra	Machiningsequence	IT	Ra
	According to The drawing			After machining	
1	2	3	4	5	6
A1,A3	7H		Rough boring Finish boring Countersinking	7H	
A2,A5	14	2,5	Rough milling Finish milling	14	2,5 1,25
B1	14	10	Centering Drilling Countersinking	14	10
B4	14	2,5	milling	14	6,3 2,5
C2	14	10	milling	14	10
C3	7	1.25	Milling	14	10

Design of manufacturing process plan

*the development is based on solutions from previous chapters

Objective: to develop the manufacturing process plan that will meet all therequirements 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 work piece surfaces, which are datum for subsequent

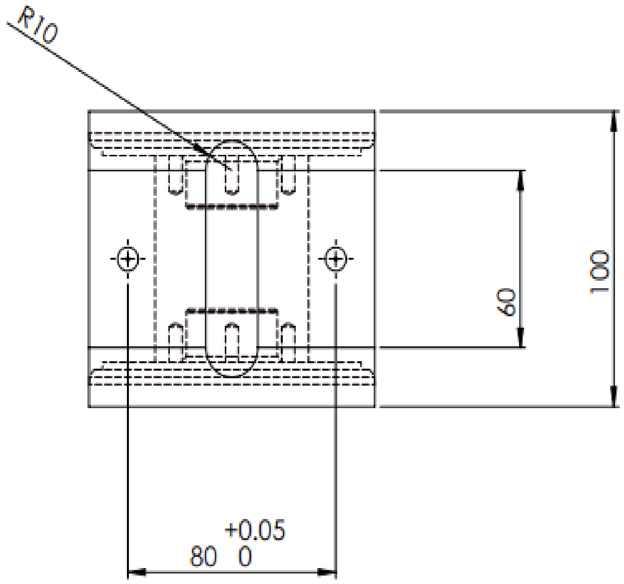
processing stages.

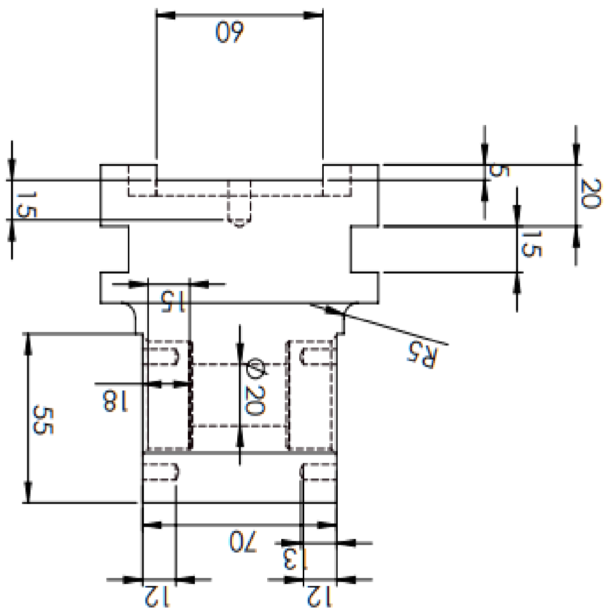
3. The roughing must be separated from the next stages of processing by a certain period of time, or aging operations should be provided, especially for critical, large-sized and high- value parts.
4. For timely detection of defects on surfaces where they are not allowed, thesesurfacesshouldbeprocessedattheearlystagesofthemanufacturingproces s.
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 work piece 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

005 Multipurpose

Machine: TAJMAC- ZPSH500

A. Install, secure, remove





05.01 Rough mill the surface M1 to dimension 1

05.02 Finish mill the surface M1 to dimension 1΄

05.03 Center the position of 2 holes F3, M2,at dimensions 2,3;2,5 and simultaneously make chamfers in 2 holes to dimension 8.

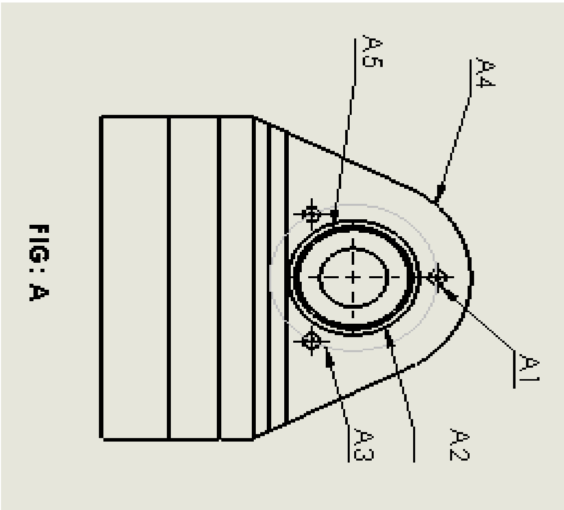
05.04 Drill 2through holes F3 at dia.6, maintain the position of the holes' centers:2,3.

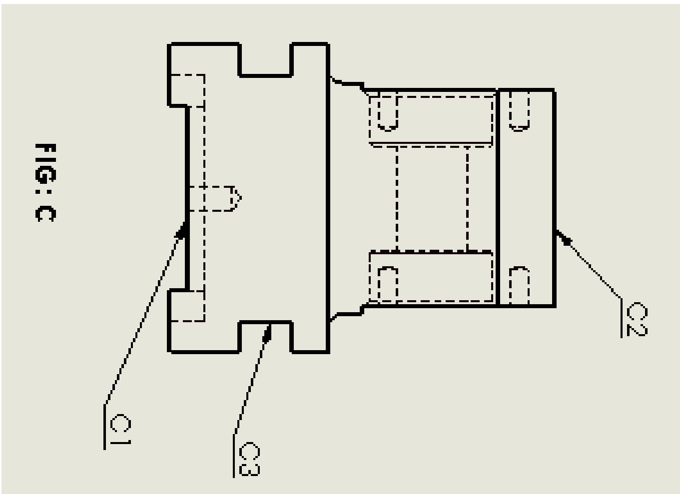
05.05 Drill 2 holes M2, M3 at dia.7;maintain the position of the holes'centers: 2,5;4,3.

05.06 Ream 2 holes F3 at dia.6´(holes' centers position: 2,3)

Position 2

Turn the table 90 degrees clockwise





Mill surface A3 to dimension 9.

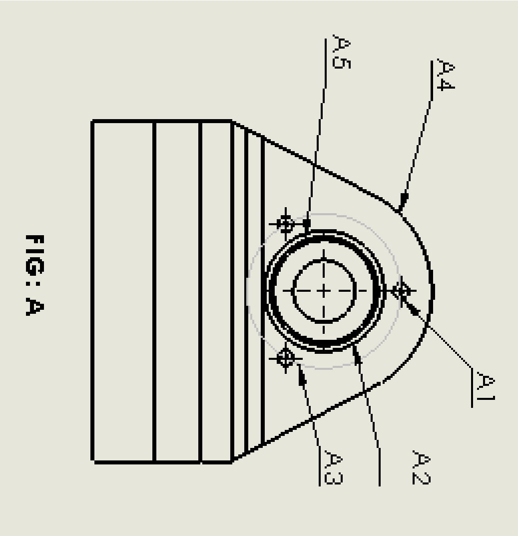
05.10 Center the hole F3 at dimensions1011.

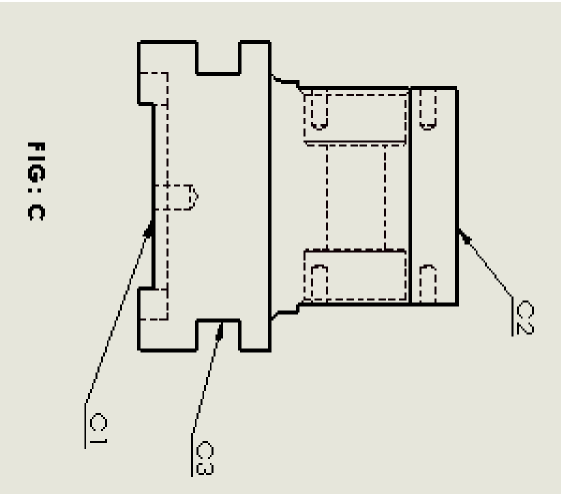
05.11 Drill the through hole F3 atdia.12,maintain the position of the hole center: 10,11.

05.12 Cut a thread in the through hole F3 at dim.14 (holecenterposition:10,11)

Position3

Turnthetable90ºclockwise





005.16 Center the 4 holes F4 at dim.16,17;16,18;18,19;17,19.

005.17Drill 4 blind holes F4 at dia. 21& depth 20, maintain the position of the holes centers: 16,17;16,18; 18,19;17,19.

005.20 Cut a thread in 4 holes F4 at dim.21´& 20deep (position of holes centers:16,17;16,18; 18,19;17,19).

10 Multipurpose

Machine: TAJMAC-ZPSH500

A. Install, secure,remove

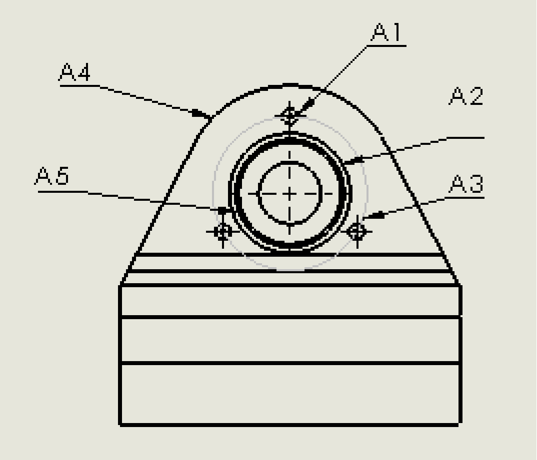


FIG: A

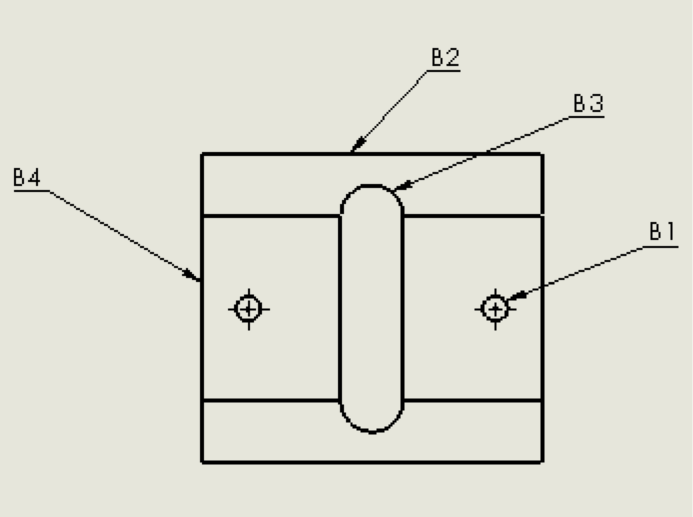


FIG: B

Position1.

10.01. Rough mill the surface A1 to dimension

5.Position 2.Turn the table 180□

10.02. Rough mill the surface A2 to dimension 6.

10.03. Rough bore 4 holes A3, A1 at dia.4,maintain the holes' centers at1,2,3.

10.04. Mill the surface A4 to dimension 7.

15 Multipurpose

Machine:TAJMAC-ZPSH500

A. Install, secure, remove

Position1

15.01. Finish mill the surface A2 at dimension1.

Position2.Turntable180□

15.02. Finish mill the surface A1 to dimension 1□.

15.03. Rough bore the 4 holes A1,A3at dia. 5, maintain the position of holes' centersat2,3,4 and requirements for spatial accuracy and surface roughness

15.04. Center the position of 8 holes F5 at dimensions 2,3,4,7,8,9and simultaneously make chamfers in 8 holes to dimension1

Drill 8 blind holes F5 at dia. 12 & depth 11, maintain the position of holes'centersto2,3, 4,7,8,9.

15.05. Cut a thread in 6 holes F5 at dia.12□& depth 11(the holes centers position:

2, 3, 4,7,8, 9).

Position3.Turntable180□

15.06. Centerthepositionof8holesF5atdimensions2,3,4,7,8,9 and simultaneously make chamfers in 8 holes todimension10.

15.07. Drill 8 blind holes F5 at dia. 12 & depth 11, maintain the position of holes'centersto2,3,4,7,8,9.

15.08. Cut a thread in 8 holes F5 at dia.12□& depth 11 (the holes' centers position: 2,3,4,7,8,9).

015.12. Finish bore the 4 holes A5 at dia. 5□, maintain the position of holes' centersat2,3,4and requirements for spatial accuracy and surface roughness

020.Washing

025.Control

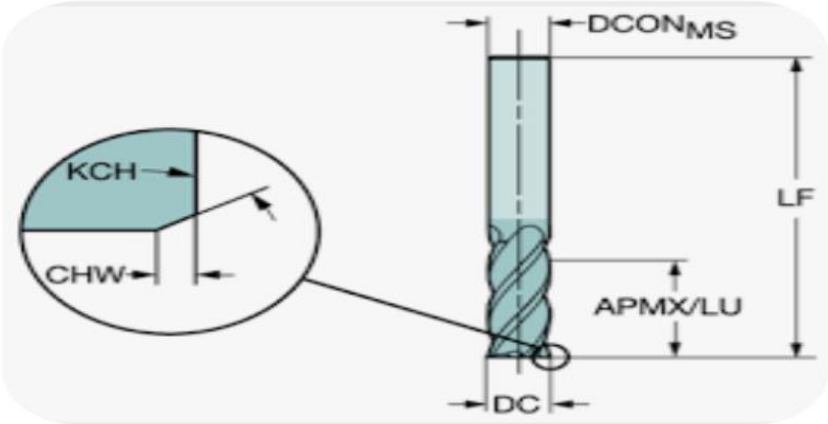
1.8 Machine and tool selection

1.8.1 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 requiredcan 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

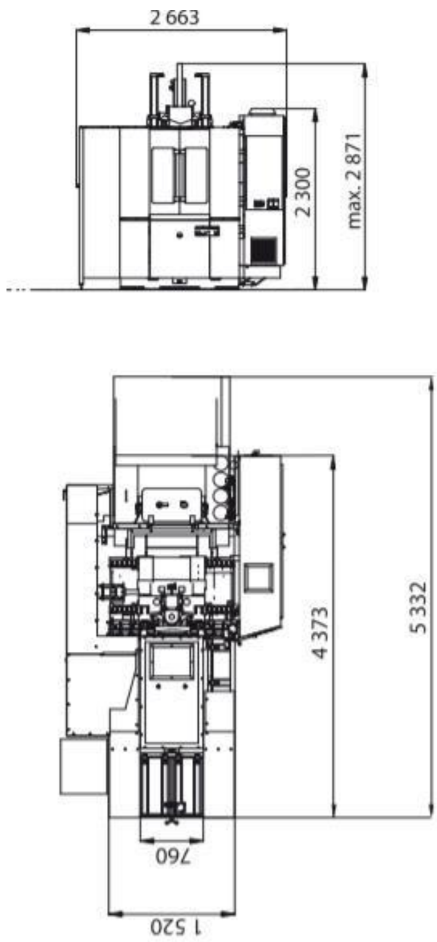
The factors considered in the capability analysis are the dimensional and geometric accuracy and the surface finish required.

During the operational analysis, the process planner needs to take into account the batch size. Machines that cannot meet the economic batch quantity should be disregarded.

Taking into consideration all the mentioned requirements, limitations, and the process plan developed in the previous chapter, the preliminary selected machine for the task is the TAJMAC-ZPSH500 horizontal machining center.The H 500 version of the horizontal machining center (refer to general technical data in

Figure 8.1) is a highly efficient machine designed for the intricate machining of components made from steel, grey cast iron, and soft metal alloys. These parts are securely held on the rotary table during the machining process.

The machine is capable of performing milling operations in three mutually perpendicular coordinate axes, namely X, Y, and Z, as well as in the rotary B axis. Additionally, it facilitates drilling, boring, reaming, and thread cutting operations. Moreover, the machine allows the use of screw die heads without the need for aligning bushings along the Z axis.



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		

Fig.8.1Technicaldataoftheselected machine

1.8.2 Tooling selection

Evaluation of process and machine selections:

Once the processes and machines have been selected, it is important to limit the range of tools to those that are suitable for the chosen processes and machines. This helps narrow down the initial list of possible tooling options.

Analysis of machining operations:

Each specific machine will be responsible for carrying out the required operations. Different machine tools will require specific types of tools to perform certain operations. This analysis allows for the identification of appropriate tool types for each operation.

Analysis of workpiece characteristics:

Considerations such as the workpiece material, geometry, dimensional and geometric accuracy, and surface finish need to be taken into account. This analysis helps identify suitable tool materials and geometries that will work best for the specific workpiece characteristics.

Tooling analysis:

Using the available tooling data and the general tooling specifications generated in the previous stages, a statement of tooling requirements, known as a tooling list, can be created for the job. This list will reflect the actual tooling available for the required operations.

Selection of tooling:

If single-piece tooling is being used, a suitable tool holder should be selected first before finalizing the tool's geometry and material. If insert-type tooling is being used, the following steps should be followed:

1. Select a clamping system.

2. Choose the appropriate tool holder type and size.

3. Select the insert shape.

4. Determine the insert size.

5. Define the tool's edge radius.

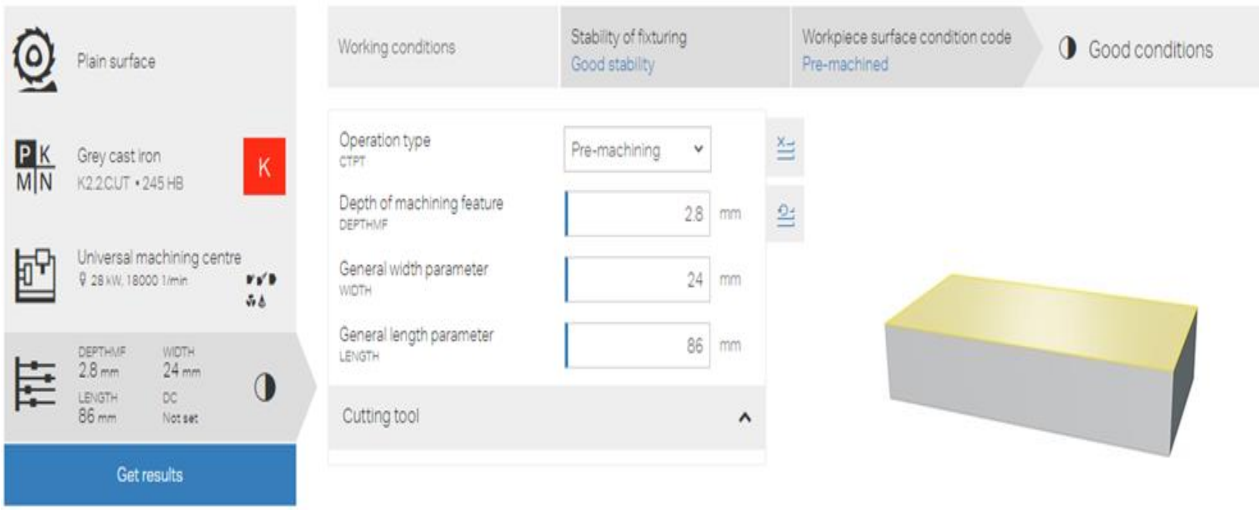
6. Choose the insert type.

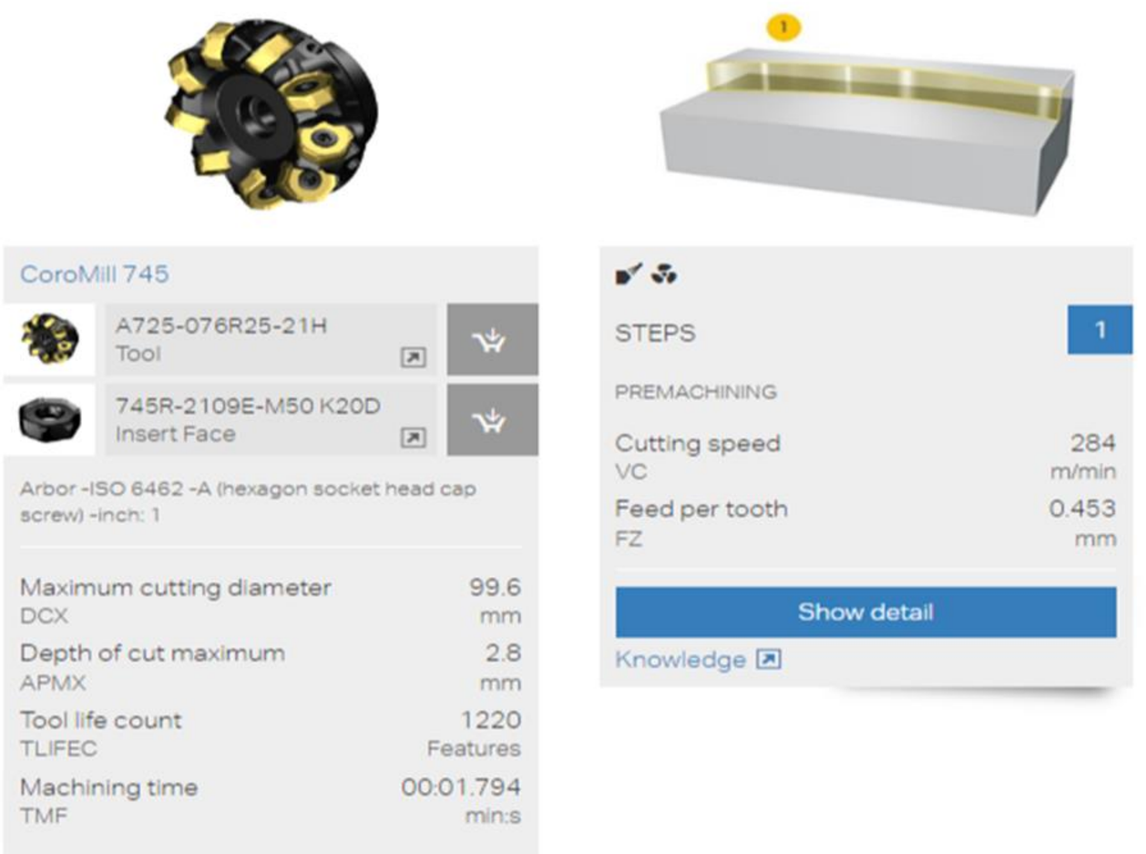
7. Select the tool material.

Tool selection for the manufacturing step“005.09 Mill surface A3 to dimension 9”Allowance=2.8mm

Radial cutting width= 24mm

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





sis:

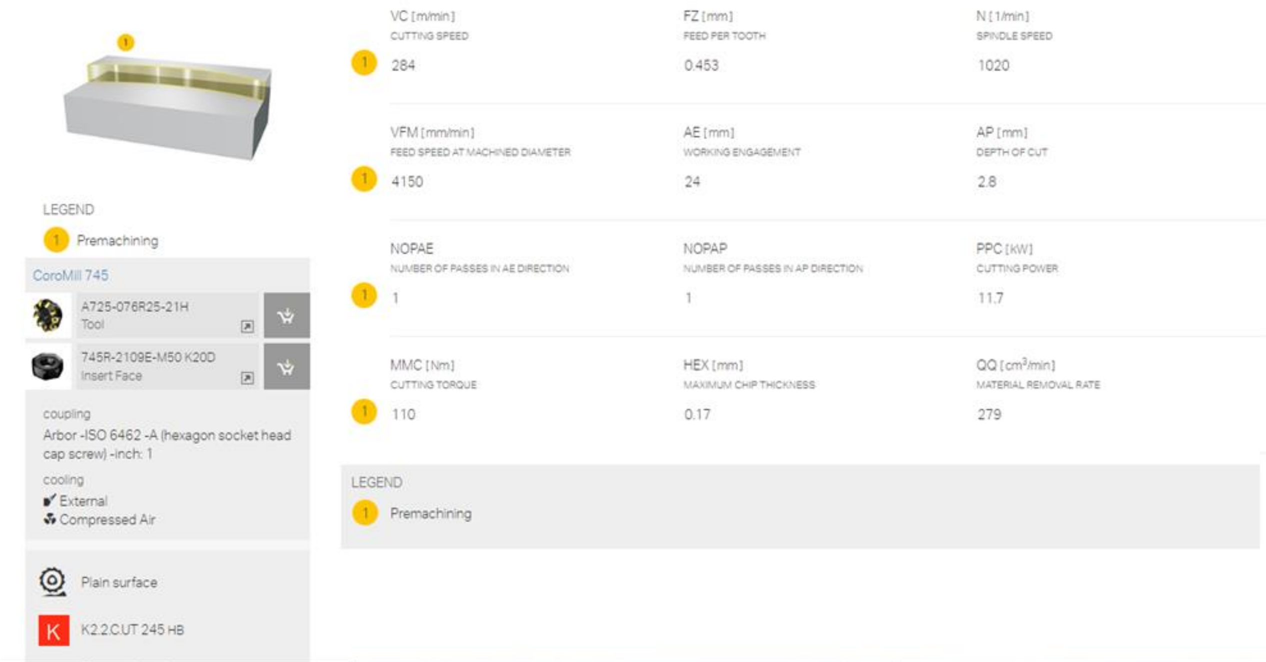
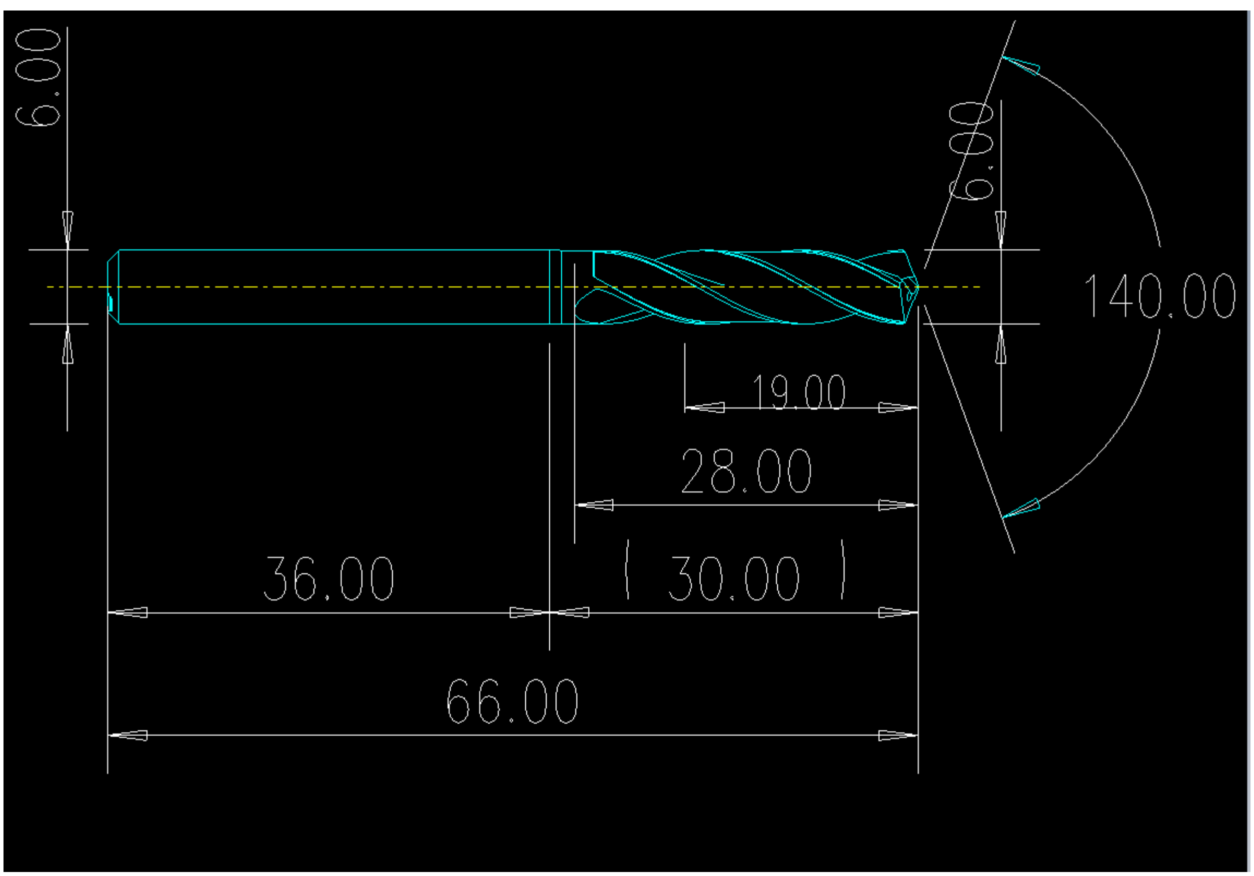


Fig.8.3 Recommended cutting tool and cutting data.



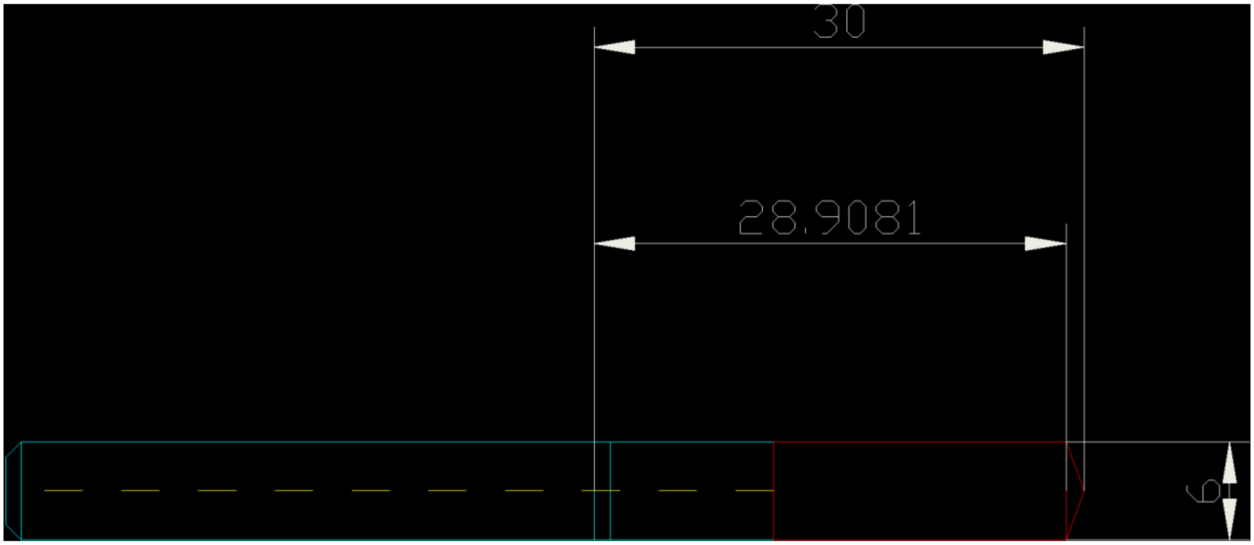
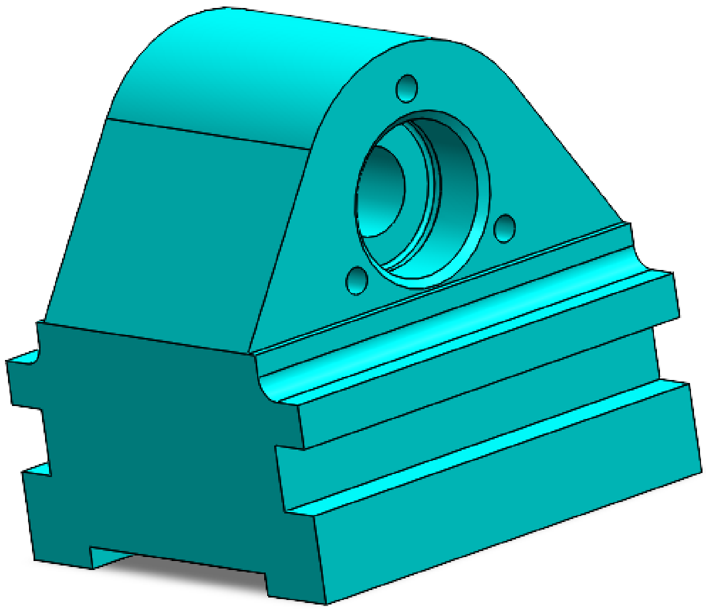


Table of Contents

<u>Task for device design</u>

Name	-	Device for milling 8 holes and diameter of 35 & 25 mm in the housing.
Service purpose	-	The device is designed to install a single part.
Location	-	8 holes. Ensure the implementation of positional tolerance 0.05mm

Manufacturing operation	-	The operation is performed on the Horizontal Milling Machine CNC.
Clamping mechanism type	-	Screw manual. Standard time for installation and removal of the work piece is up to 0.8 minutes.
Layout	-	The device is assembled from the unified



Elements of the modular fixture system.

1. Calculation of clamping force

For any fixture, clamping force should be greater than the cutting force,

Cutting Force = 4.5kfdb / Cutting Speed

K= Material Constant

F = Feed

d = Depth of cut

b = Width

Cutting Speed = 3.14*75*1200/60000

= 7.71

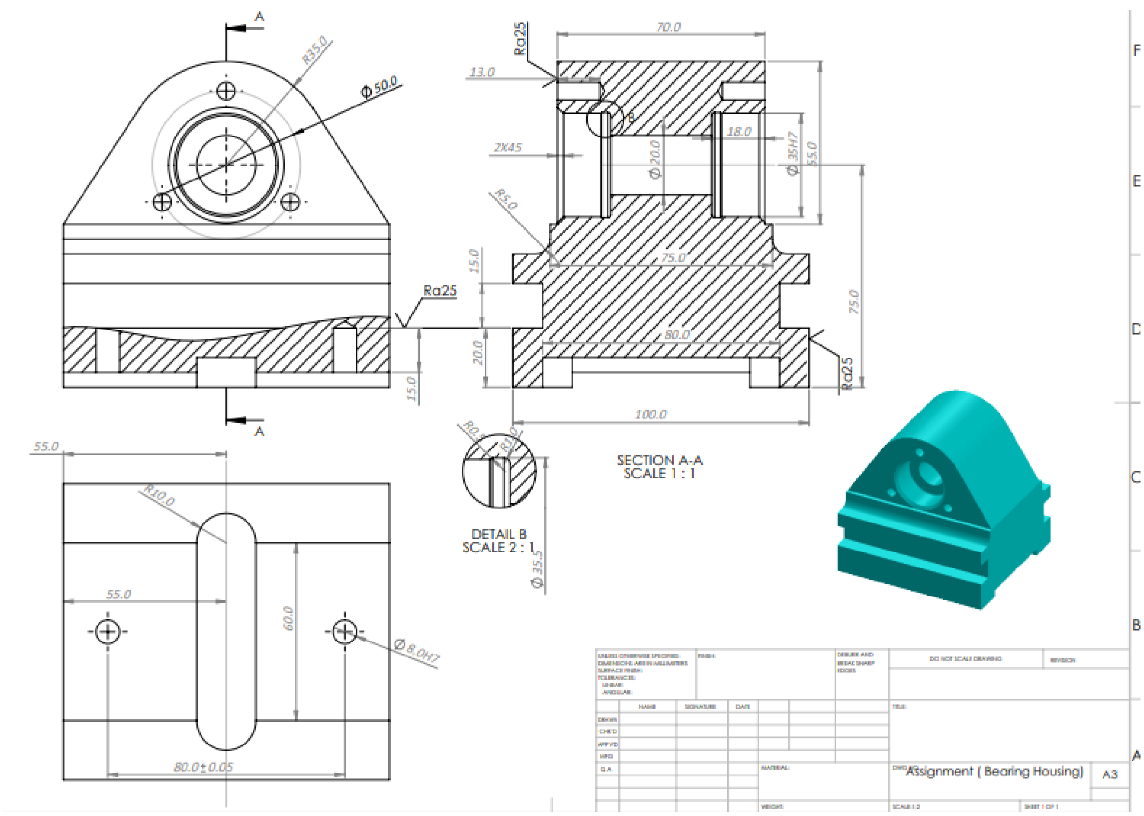
Cutting Force: 4.5*5*0.3*75*112.5/4.71 = 2418.39 N

Clamping Force = Cutting Force / Frictional Coefficient

=2418.39 N / 0.3

Clamping Force = 8061.3 N

<u>Design scheme</u>



The cutting force is the force applied to the work piece during the machining process. It depends on factors such as the material being machined, the cutting tool, the machining parameters, and the desired material removal rate.

The frictional coefficient represents the friction between the work piece and the fixture. A dimensionless value depends on the materials in contact, surface conditions, and the clamping method.

To calculate the clamping force accurately, it is important to have precise values for the cutting force and frictional coefficient. These values can be obtained from machining data, tool manufacturers, or experimental testing.

It is worth mentioning that there might be formulas that are more complex or specific considerations depending on the particular fixture design and machining process. Therefore, it is recommended to consult relevant literature, engineering handbooks, or seek the expertise of an experienced engineer to ensure accurate calculations for your specific application.

1. Fixture Design

Base elements

Asbasic,rectangular,squareorroundplateswithT-shapedgroovesareusedinthe modularfixturesystem.Ideally,theplateshouldbeofminimumdimensions(from the available sizes) in which you can "fit" the work piece and orientation/clamping elements.
Since the work piece has a dimension of 100x137.5mm, and the nearest plate

size, the basic element will be prefabricated,whichmakesitsuseinadvisable). Based on the foregoing, the base element will be made of square plate 1 (Fig. 4); their mutual orientation is carried out by means of keys, and fastening carried out using bolts.

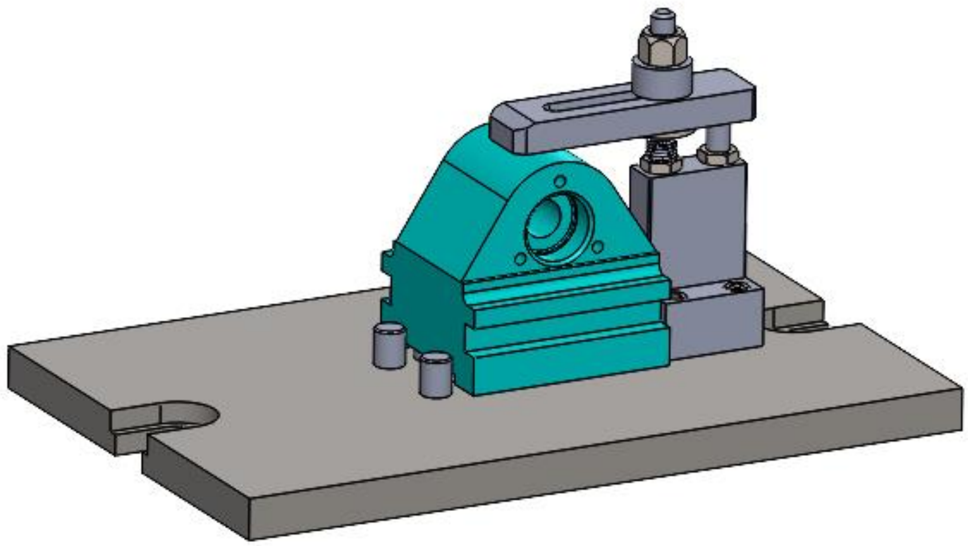
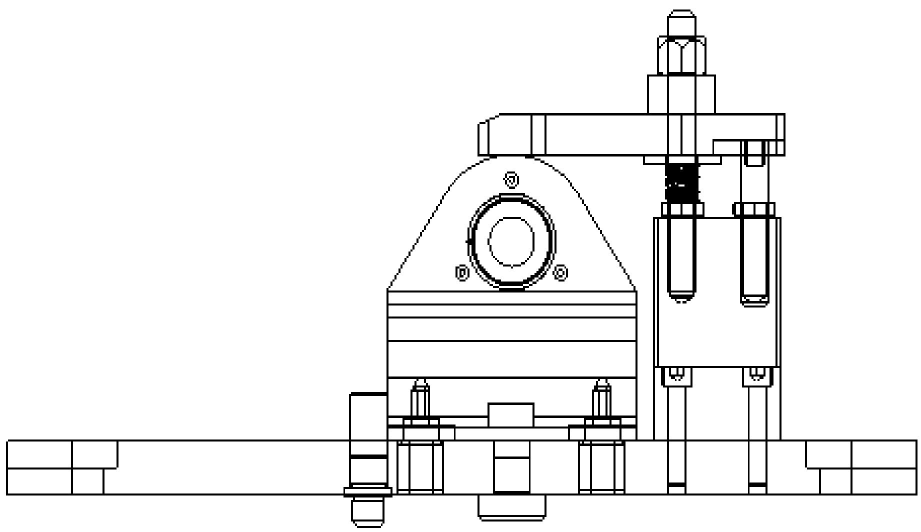


Figure 4 - The basic element of the device:

Selection of Locating Elements

In accordance with the task, to implement the locating scheme, it is necessary to have a set of supports for installing blanks with flat surfaces;As supports in modular fixture design, spherical supports, notched, support washers or plates are most often used.

With relatively small dimensions of the work piece, there may be a problem with the location of such elements, when their total dimensions significantly exceed the dimensions of the work piece. Therefore, you should try to combine several functions in one design. In this case, the functions of the support element and the guide for pins will be combined into the ". A tight tolerance is set for the distance between the axis of the pins, and their simple installation in the plate only on threaded surfaces (for example, with studs) will not give the desired accuracy (threaded surfaces are not centering). For this reason, smooth cylindrical surfaces of the bar 2 and pins 1, 6 (Fig. 5, a) are used as guides.



Inthecaseofadiamondpin,thedesignissomewhatcomplicated,becauseitisalso necessarytoensureitsangularposition.Sincethestructureoftheselectedbarand pin does not provide for any additional adjustments of the angular position.

Afterselectingthedesignsoftheelementsforlocating,itisnecessarytodetermine theirlocationontheplate. Device and machine and introduce the appropriate correction to the CNCsystem.

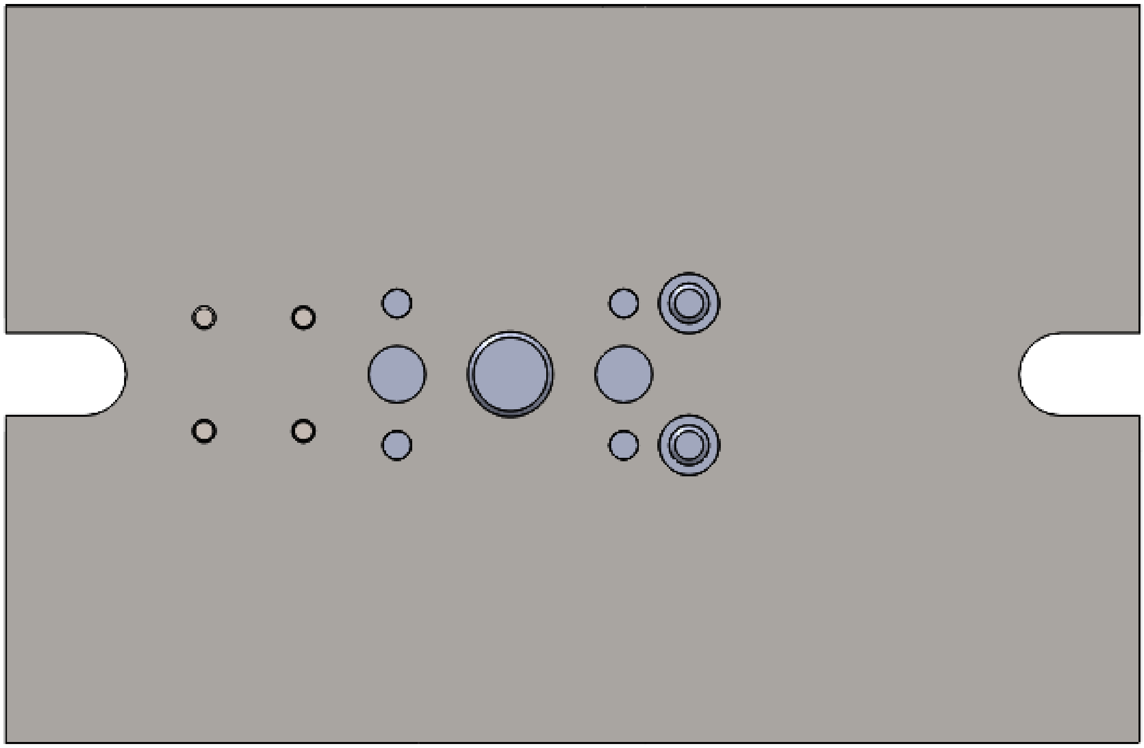


Figure 6 - Options for placing slats with locating pins

From Fig. 6 it is easy to see that the position of the work piece, when applying fastening and cutting forces, will not be stable. Therefore, as the final version, another bar of similar sizes will be introduced into the design (Fig. 7).

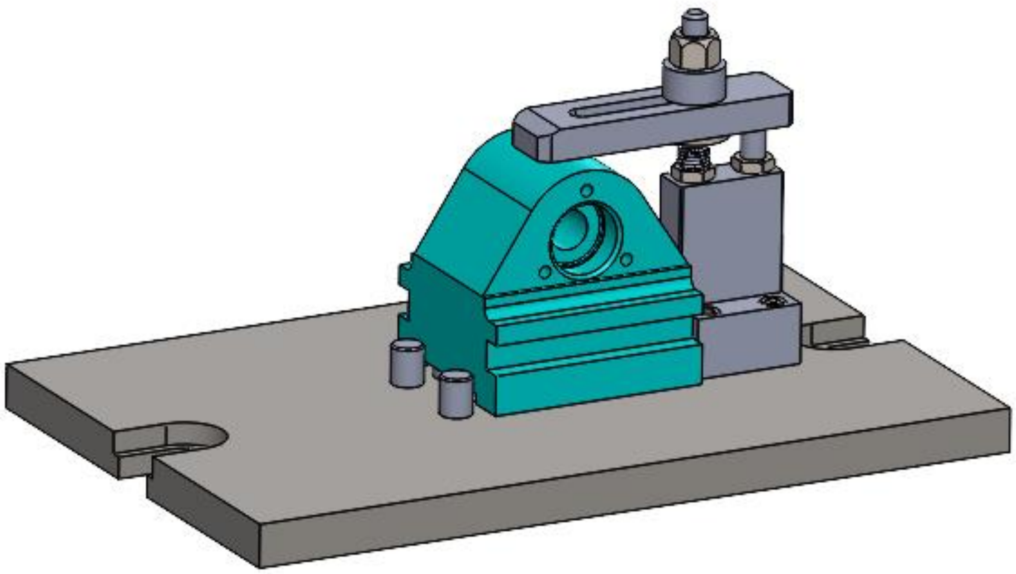


Figure 7 - Implementation of the work piece-locating scheme

<u>Clamping elements</u>

1. Base Pin
2. Base Plate
3. Bolt
4. Bottom Plate
5. Clamping Unit Body
6. Die Clump
7. Locating Pin
8. Pin D 16 mm & 14mm

MountofthefixtureontheCNC-machine

The locating scheme of the device depends primarily on the design of themachine table. Since the task uses a vertical milling machine Horizontal Milling Machine CNC, the dimensions of which are shown in Fig. 9, 16mm grooves on the machine table will be used to center thedevice.

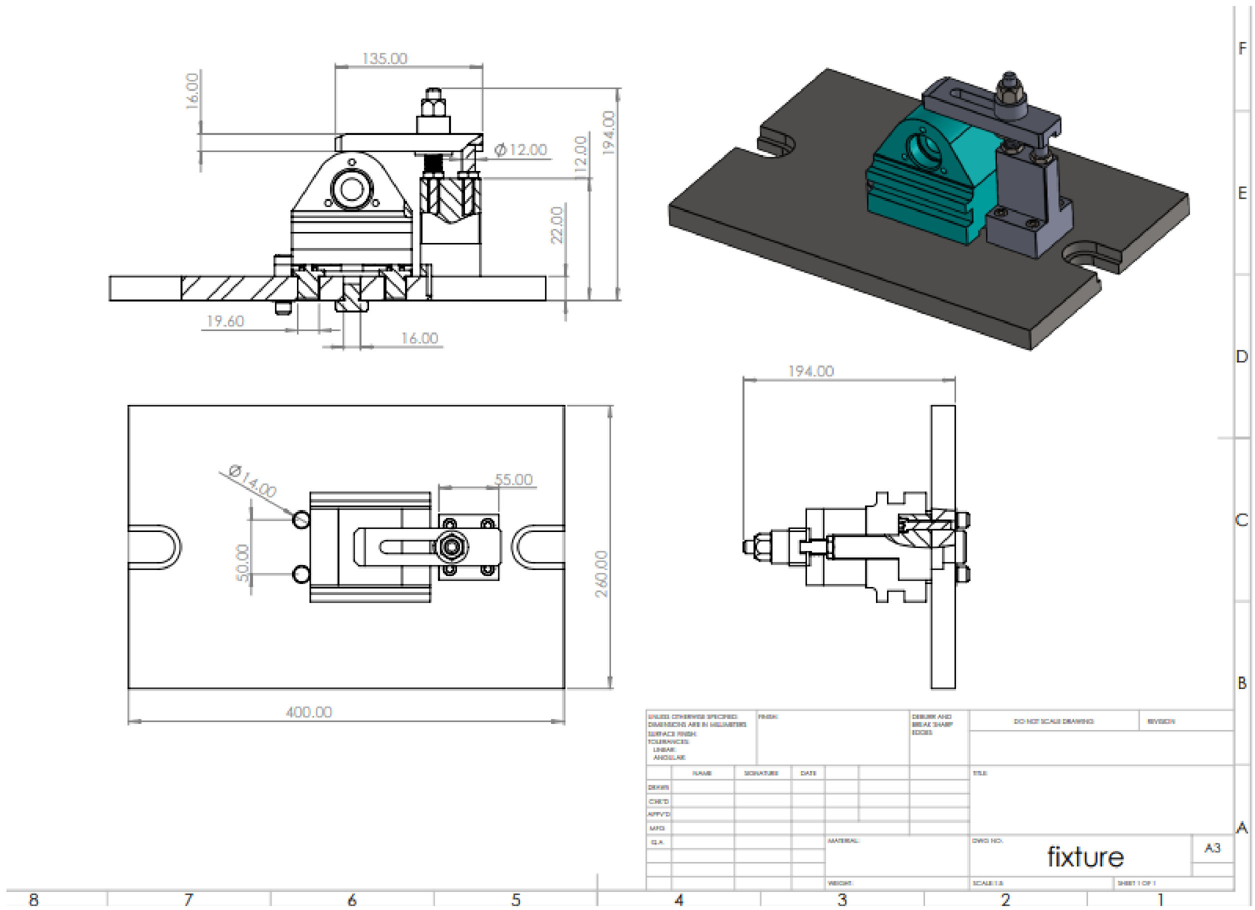


Figure 10 - Diagram of fixture and drawing

Having collected all the structural elements into a single whole, a variant of the design of the fixture device will be obtained (Fig. 11.).

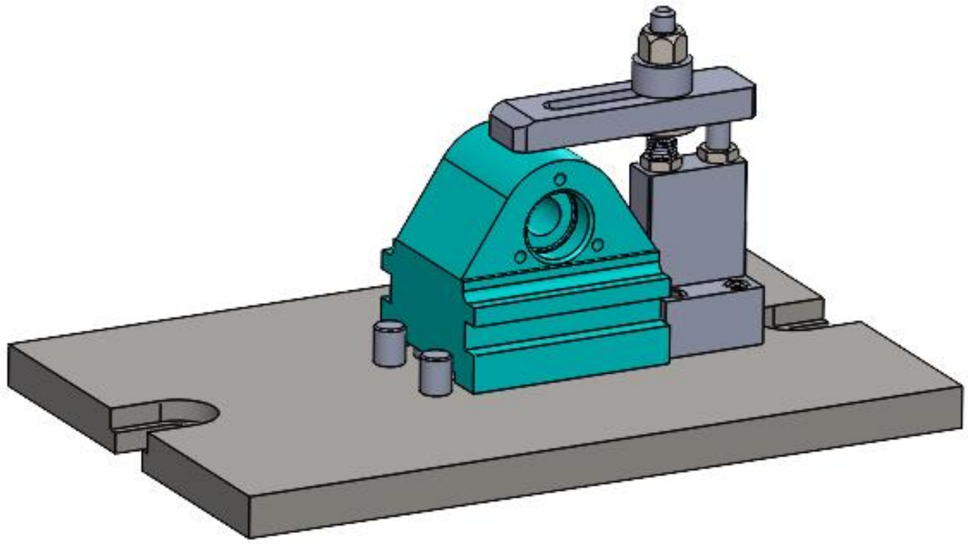
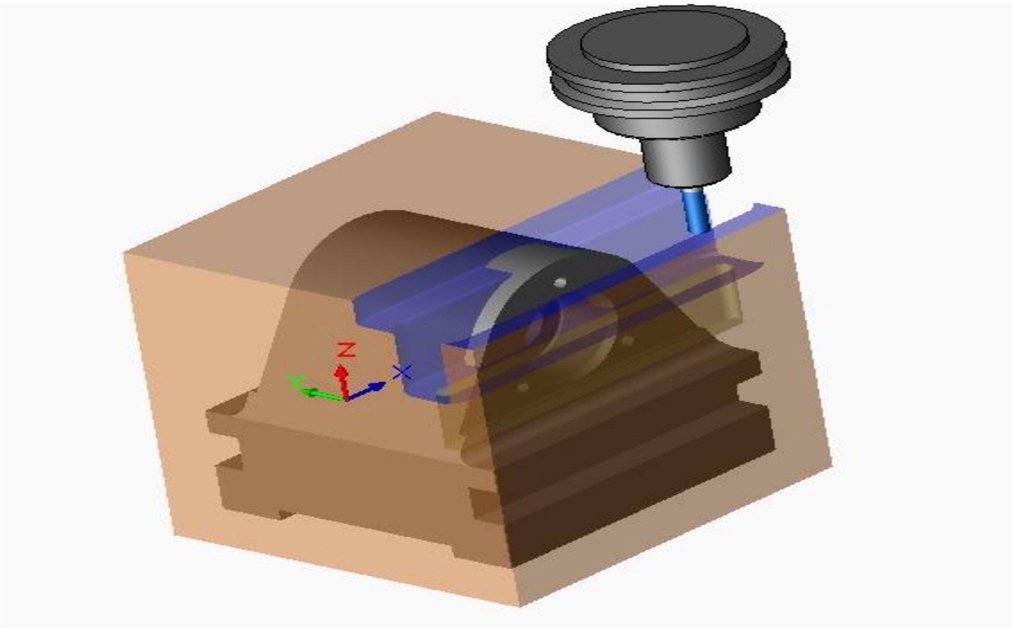
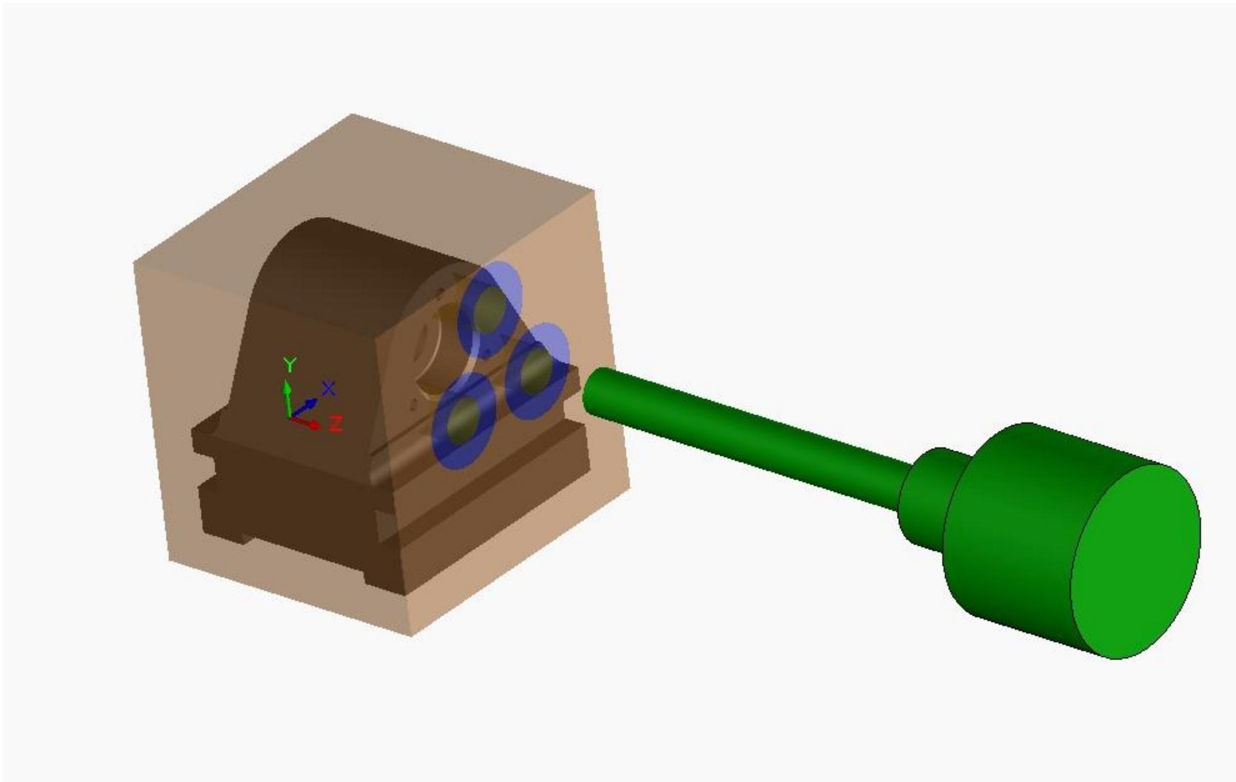


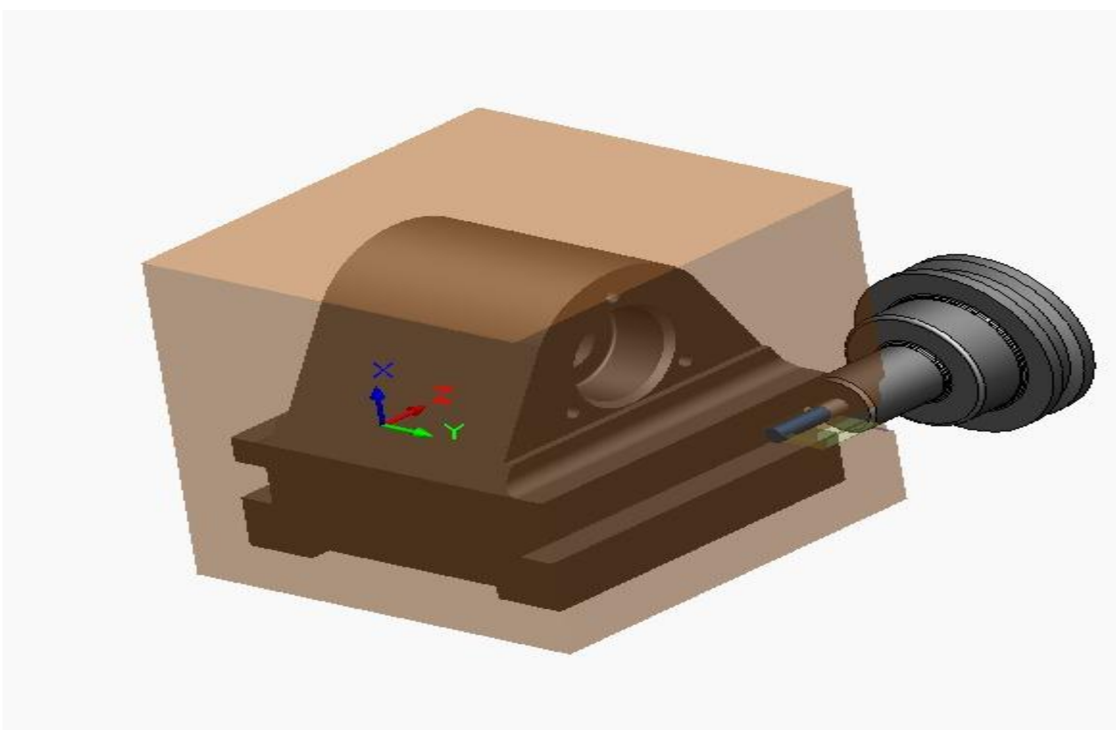
Figure 11 - General view of the fixture design

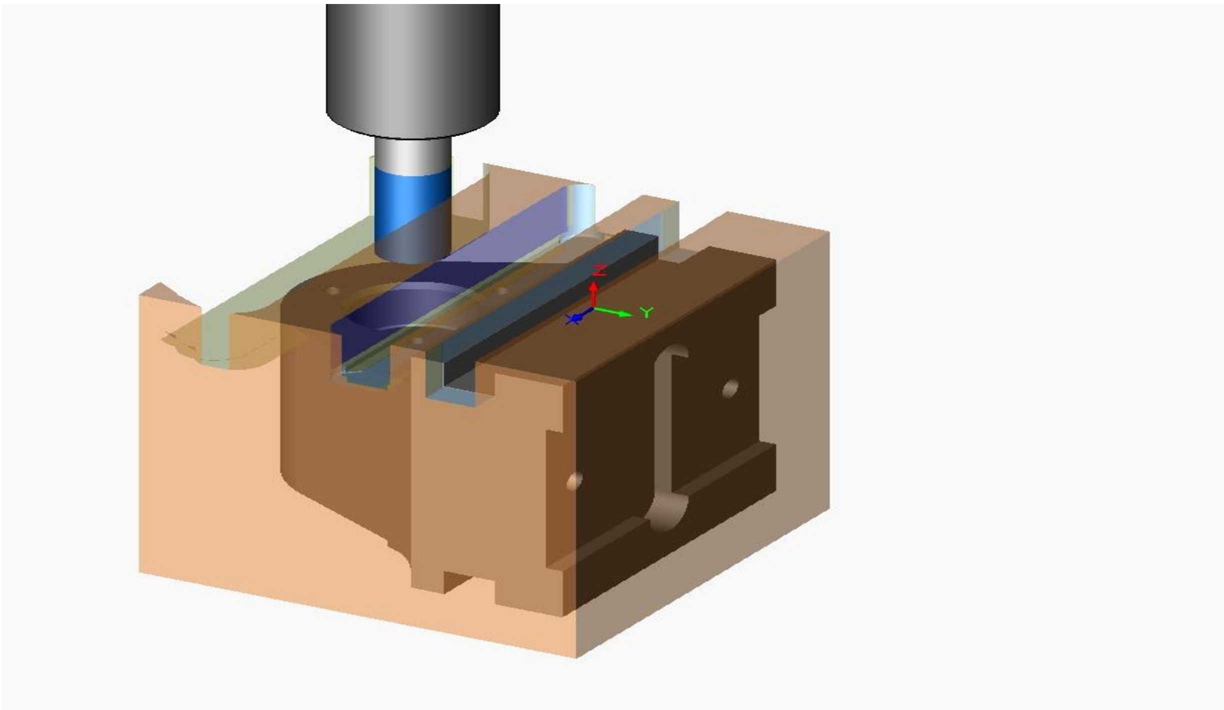
The graphic part of the course work contains an assembly drawing of the fixture and its specification

<u>Programming Machines with CNC</u>

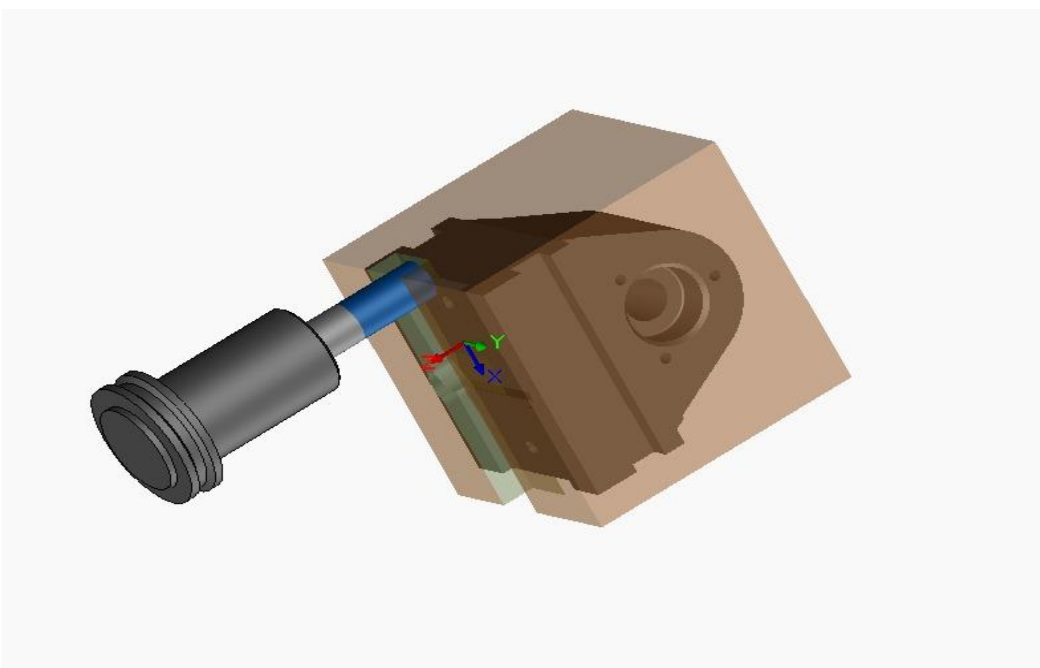



Y
X
Z

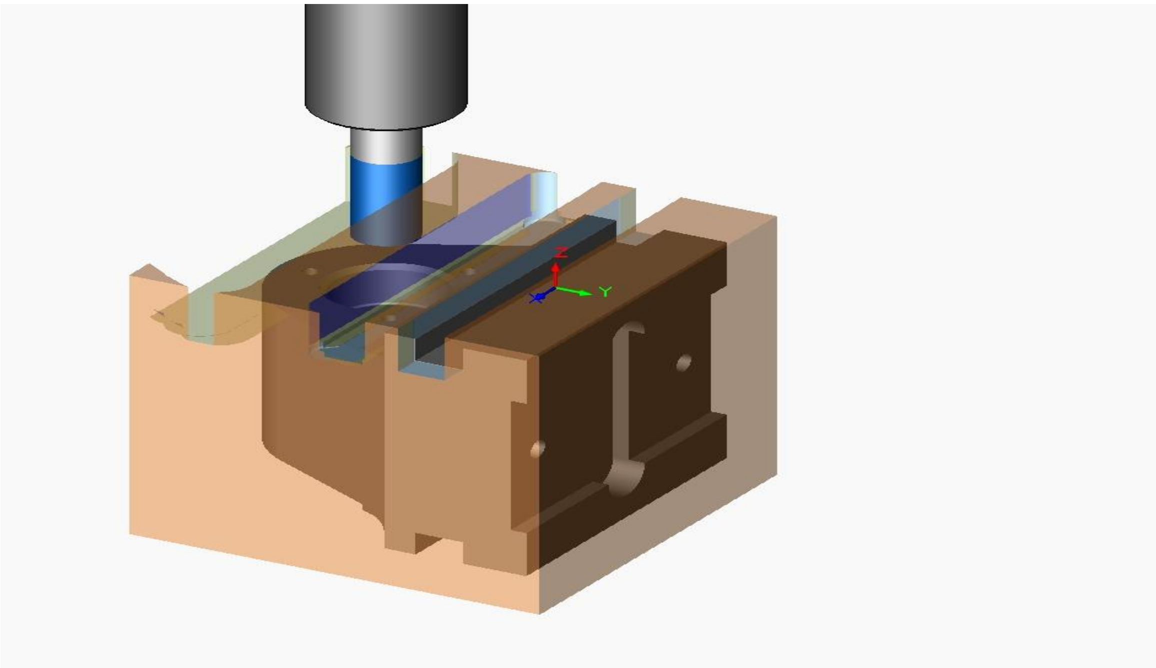

X
Z
Y



Z
X
Y



Y
Z
X



Computer Numerical Control, which is a computerized manufacturing process that uses pre-programmed software to control the movement of machines and tools. It is commonly used in various industries, including manufacturing, woodworking, metalworking, and 3D printing.

CNC machines are automated systems that can accurately and efficiently perform tasks such as cutting, milling, drilling, and shaping materials..

Also, G codes consist of a letter followed by a numerical value. Each code represents a specific command or function that the machine should execute. Here are some commonly used G codes:

1. G0/G1: Rapid Move/Linear Interpolation

   - G0: Rapid positioning move at maximum speed.

   - G1: Linear interpolation at a defined feed rate.

2. G2/G3: Circular Interpolation (Clockwise/Counterclockwise)

- G2: Clockwise circular interpolation.
- G3: Counterclockwise circular interpolation.

3. G4: Dwell

- Pauses the machine for a specified time.

4. G17/G18/G19: Plane Selection

- G17: Selects the XY plane.
- G18: Selects the XZ plane.
- G19: Selects the YZ plane.

5. G20/G21: Inch/Metric Units

- G20: Switches to inch units.
- G21: Switches to metric units.

6. G90/G91: Absolute/Incremental Programming

- G90: Absolute programming mode.
- G91: Incremental programming mode.

These are just a few examples of the many G codes available. CNC operators and programmers use these codes to create programs that define the tool's movement, tool changes, spindle speed, coolant control, and other machine operations.

By using G codes, operators can create precise and complex tool paths, enabling CNC machines to produce intricate and accurate parts and products. The codes provide flexibility and automation, allowing manufacturers to achieve consistent results while reducing human error and increasing efficiency.

The G Codes are as follows –

```
( PART NAME=gcodes )
( PROGRAM NUMBER=0001 )
( MACHINE=CAMWorks 5AXIS )
( CONTROLLER=GENERIC FANUC )
( MATERIAL=  )
( THICKNESS=25.4 )
( ESTIMATED MACHINE TIME=0 HRS.  9 MIN.  48 SEC. )
( STATION  TOOL TYPE  DIAMETER  CORNER RADIUS  DESCRIPTION
)
( -------  ---------  --------  -------------  -------------------- )
(  005     ENDMILL     020.00                    20MM CRB 2FL 38 LOC  )
(  004     ENDMILL     016.00                    16MM CRB 2FL 32 LOC  )
(  003     ENDMILL     012.00                    12MM CRB 2FL 25 LOC  )
```

(014   CENTER DRILL 010.00   10MM X 90DEG CRB SPOT DRILL)

(015   DRILL   019.00   19.0mm JOBBER DRILL)

(PART NAME=gcode2)

(PROGRAM NUMBER=0001)

(MACHINE=CAMWorks 5AXIS)

(CONTROLLER=GENERIC FANUC)

(MATERIAL=)

(THICKNESS=25.4)

(ESTIMATED MACHINE TIME=0 HRS. 25 MIN. 3 SEC.)

(STATION TOOL TYPE DIAMETER CORNER RADIUS DESCRIPTION)

(------- --------- -------- ------------- --------------------)

(002   ENDMILL   010.00   10MM CRB 2FL 22 LOC)

(001   ENDMILL   006.00   6MM CRB 2FL 19 LOC)

(016   HOGNOSE   012.00   001.00   12mm CRB 3FL HGN 1R 32MM LOC)

(005   ENDMILL   020.00   20MM CRB 2FL 38 LOC)

(004   ENDMILL   016.00   16MM CRB 2FL 32 LOC)

(014   CENTER DRILL 010.00   10MM X 90DEG CRB SPOT DRILL)

(015   DRILL   019.00   19.0mm JOBBER DRILL)

(PART NAME=gcode3)

(PROGRAM NUMBER=0001)

(MACHINE=CAMWorks 5AXIS)

(CONTROLLER=GENERIC FANUC)

(MATERIAL=)

(THICKNESS=25.4)

(ESTIMATED MACHINE TIME=0 HRS. 1 MIN. 10 SEC.)

(STATION TOOL TYPE DIAMETER CORNER RADIUS DESCRIPTION)

(------- --------- -------- ------------- --------------------)

(014   CENTER DRILL 010.00   10MM X 90DEG CRB SPOT DRILL)

(015   DRILL   019.00   19.0mm JOBBER DRILL)

(PART NAME=gcode4)

(PROGRAM NUMBER=0001)

(MACHINE=CAMWorks 5AXIS)

(CONTROLLER=GENERIC FANUC)

(MATERIAL=)

(THICKNESS=25.4)

(ESTIMATED MACHINE TIME=0 HRS. 34 MIN. 10 SEC.)

(STATION TOOL TYPE DIAMETER CORNER RADIUS DESCRIPTION)

(------- --------- -------- ------------- --------------------)

(001   ENDMILL   006.00   6MM CRB 2FL 19 LOC)

(016   HOGNOSE   012.00   001.00   12mm CRB 3FL HGN 1R 32MM LOC)

(PART NAME=gcode5)

(PROGRAM NUMBER=0001)

(MACHINE=CAMWorks 5AXIS)

(CONTROLLER=GENERIC FANUC)

(MATERIAL=)

(THICKNESS=25.4)

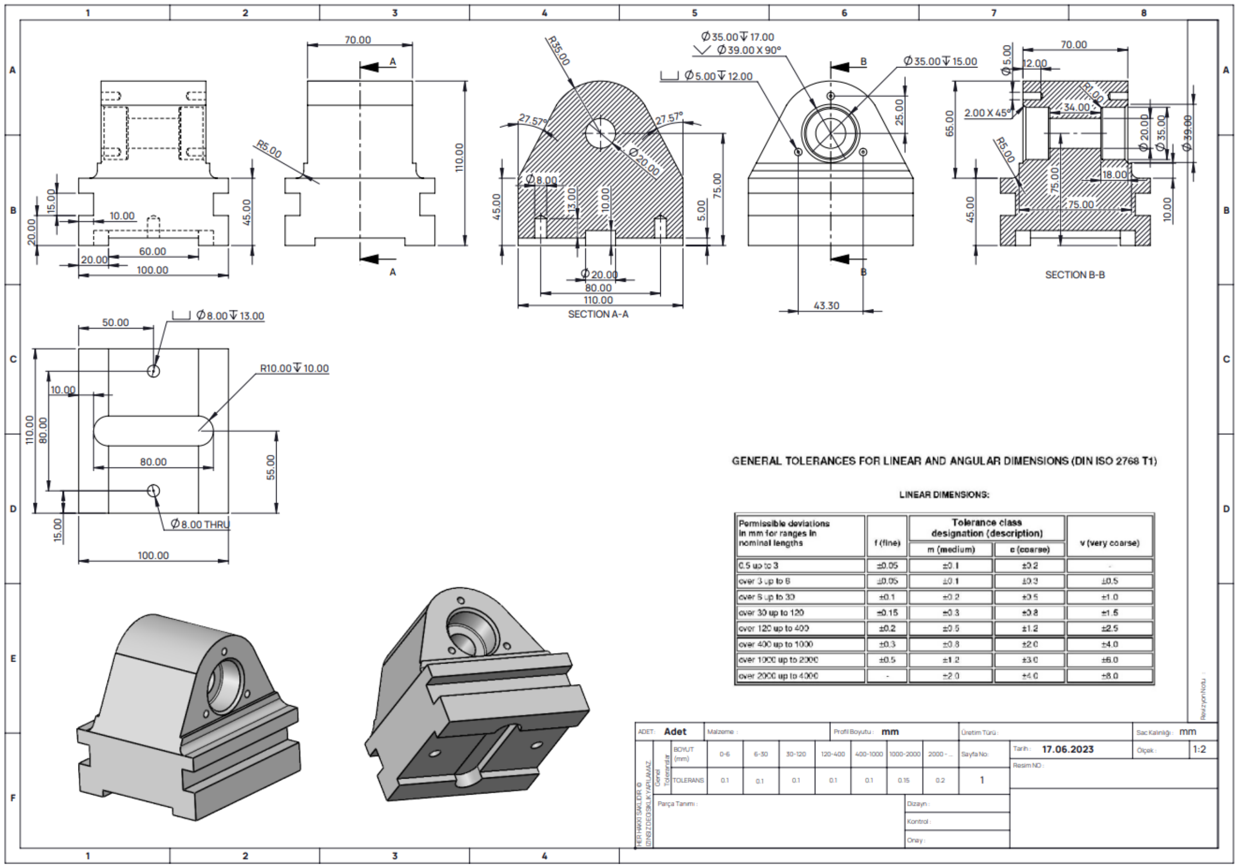
(ESTIMATED MACHINE TIME=0 HRS. 21 MIN. 24 SEC.)

(STATION TOOL TYPE DIAMETER CORNER RADIUS DESCRIPTION)

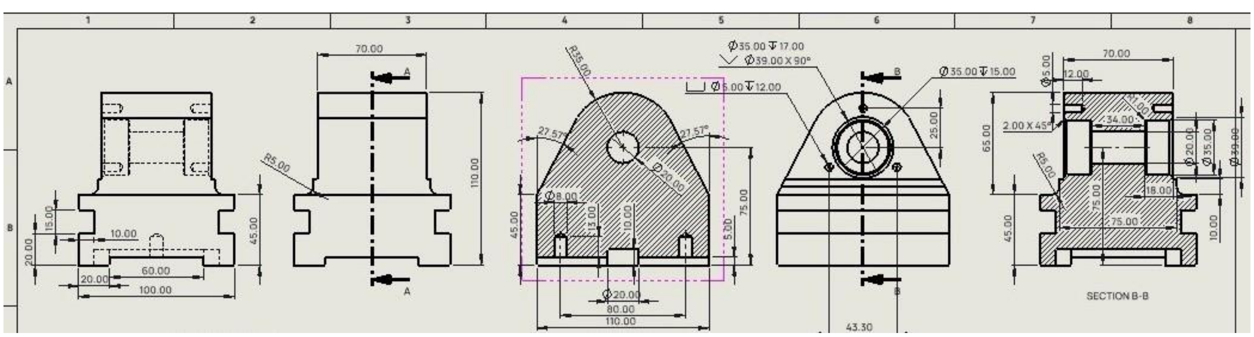
(------- --------- -------- ------------- --------------------)

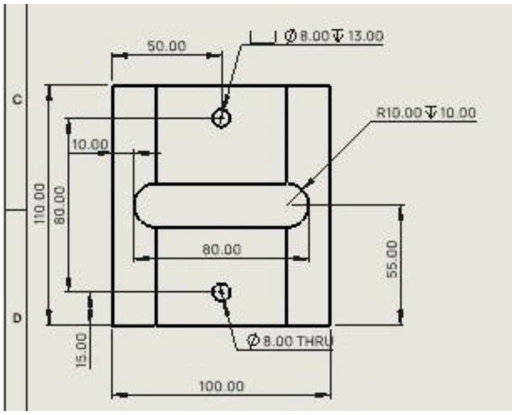
(001   ENDMILL   006.00   6MM CRB 2FL 19 LOC)

<u>Images of the operational technological process</u>



Permissible deviations in mm for ranges in nominal lengths	f (fine)	Tolerance class designation (description)		v (very coarse)
		m (medium)	c (coarse)	
0.5 up to 3	±0.05	±0.1	±0.2	-
over 3 up to 6	±0.05	±0.1	±0.3	±0.5
over 6 up to 30	±0.1	±0.2	±0.5	±1.0
over 30 up to 120	±0.15	±0.3	±0.8	±1.5
over 120 up to 400	±0.2	±0.5	±1.2	±2.5
over 400 up to 1000	±0.3	±0.8	±2.0	±4.0
over 1000 up to 2000	±0.5	±1.2	±3.0	±6.0
over 2000 up to 4000	-	±2.0	±4.0	±8.0





4. ECONOMIC SECTION

The cost price denotes the present expenditures incurred by enterprises, scientific institutions, and technical organizations for the production and sale of products, quantified in monetary terms. These costs must be recouped through proceeds generated from sales during the course of production and business activities.

For a production technologist involved in organizational aspects, comprehending the magnitude of costs associated with product manufacturing is of utmost importance. This knowledge enables them to competently carry out their functional duties and anticipate the potential consequences of engineering solutions on product costs. Consequently, engineers need to explore viable avenues to minimize specific cost components, while also possessing the ability to ascertain the cost of a product at various stages of development and production for new products.

Calculation of material costs involves considering cost norms, prices, as well as transport and procurement expenses:

$C_m = k_{t.z.} \cdot q_m \cdot C_m = 1.1 \cdot 3.1 \cdot 60 = 204.6$ UAH/pc.

Here, q_m represents the standard material consumption per unit of the product, which is taken as 3.1 kg/piece. Cm denotes the price per kilogram of material, specifically UAH 60/kg for steel 35KHM. $k_{t.z.}$ is a coefficient accounting for transport and procurement costs, assumed as 1.1.

For the production of work pieces, the cost of blanks, including forming rods in rod boxes, metal models, special frames, etc., amounts to UAH 110,000. The cost per unit of the product is calculated as:

$C_{total} = 110000/1000 = 111$ UAH/piece

Regarding return waste, it encompasses leftover semi-finished products, materials, raw materials, and other types of material resources resulting from the overall material costs.

The cost of returnable waste per unit of production is calculated as:

$C_v = q_v \cdot C_v = 0.7 \cdot 13 = 9.1$ UAH/piece. (4.3)

Here, q_v represents the amount of returnable waste per unit of production, assumed as 0.7 kg/pc. Cv denotes the price of a unit of returnable waste, specifically 13 hryvnias/kg.

Fuel and energy costs for technological purposes encompass the expenses associated with all types of fuel and energy used in the production process.

The costs for technological purposes and electricity (C_{en}) per year can be calculated using the formula:

$C_{en} = \text{Price} \cdot n_o \cdot N_v \cdot T_r \cdot k_{ech} \cdot k_{ep} = 1.75 \cdot 1 \cdot 28 \cdot 2200 \cdot 0.8 \cdot 0.85 = 73304$ UAH (4.4)

Here, N_v represents the installed capacity of the equipment, N_v = 28 kW. Price refers to the tariffs for one kWh of electricity, which is UAH 1.75. n_o represents the number of installed equipment utilizing electricity as technological energy (n_o = 1). $k_{еп}$ represents the coefficient of use of electrical equipment by power ($k_{еп}$ = 0.85). T_p represents the annual useful fund of equipment operation time (T_p = 2200 hours), and $k_{ев}$ represents the coefficient of use of electrical equipment over time ($k_{ев}$ = 0.8).

The distribution of all costs per product unit can be calculated as:

$C_{en1} = C_{en}/Q$ = 73304/1000 = 73.3 UAH/pc.

<u>Wage Calculation</u>

Under the provisions of the Law of Ukraine "On Collection and Accounting of a Single Contribution to Mandatory State Social Insurance," enterprises, institutions, and organizations are responsible for paying a single contribution. This contribution is calculated based on the total amount of wages earned, encompassing basic wages, additional wages, incentive and compensatory payments (including non-monetary benefits), as determined in accordance with the Law of Ukraine "On Labor Payment," and remuneration for individuals performing work (or providing services) under civil law contracts.

For the 45th class of occupational risk in production, the standard rate for the single contribution to mandatory state social insurance is 38.11%:

$C_{str} = (C_{zo} + C_{zd}) \cdot 0.3811 = (23.7 + 7.11) \cdot 0.3811 = 11.74$ UAH/piece.

Equipment Maintenance and Operation Costs

The cost of the machine tool equipment, specifically a vertical machining center with HAAS VF-2 CNC, is recorded at UAH 2,000,000 as of June 12, 2020.

To sustain the uninterrupted production process, regular replenishment of worn-out fixed assets is essential. This practice ensures the refurbishment and upkeep of the company's fixed assets.

The depreciation calculation method for fixed assets, including machines, in Ukraine typically follows the guidelines outlined in the Ukrainian Accounting Standards (UAS) or the International Financial Reporting Standards (IFRS), depending on the reporting requirements of the company.

In Ukraine, the most commonly used depreciation method for fixed assets is the straight-line method. Under this method, the cost of the machine (or fixed asset) is spread equally over its estimated useful life. The formula for calculating annual depreciation using the straight-line method is as follows:

Annual Depreciation Expense = (Cost of Machine - Residual Value) / Useful Life

Where:

- Cost of Machine refers to the original cost of the machine, including any expenses related to its acquisition, transportation, installation, and commissioning.

- Residual Value represents the estimated value of the machine at the end of its useful life. It is often assumed to be zero, but in some cases, it may have a nonzero value.

- Useful Life denotes the estimated period over which the machine is expected to generate economic benefits. The useful life is determined based on factors such as technological obsolescence, wear and tear, and the company's industry practices.

Once the annual depreciation expense is calculated, it is typically allocated on a monthly or annual basis, depending on the reporting requirements. The accumulated depreciation is recorded as a contra-asset account, reducing the book value of the machine over time.

It's important to note that while the straight-line method is commonly used, there are alternative depreciation methods available, such as the reducing balance method or the units of production method. However, the straight-line method is generally preferred due to its simplicity and ease of application.

Economic calculations

The provided table encompasses the time required for each processing sequence, with the added factor of process accuracy influencing the duration. Moreover, the cut depth and feed rate also contribute to the overall time.

For more advanced calculations, we have the option to utilize the online Cost Estimator available at http://Custompart.net. This powerful tool enables us to perform comprehensive cost analyses tailored to our specific manufacturing requirements.

To effectively meet the customer's demands, it is crucial to consider the quantity of parts needed for the manufacturing process. In our case, we have an annual order of 10,000 parts. It's noteworthy that the defect rate is 3%, representing the percentage of the production quantity that is projected to be defective. By considering these factors, we can ensure accurate cost estimations and optimize our manufacturing processes accordingly.

Calculation of depreciation deductions on the basis of - Depreciation deductions in hryvnias , Accrued depreciation deductions in hryvnias and Residual value in hryvnias

Year	Depreciation Deductions (in hryvnias)	Accrued Depreciation Deductions (in hryvnias)	Residual Value (in hryvnias)
1	**10,000**	**10,000**	**90,000**
2	**10,000**	**20,000**	**80,000**
3	**10,000**	**30,000**	**70,000**
4	**10,000**	**40,000**	**60,000**

5	**10,000**	**50,000**	**50,000**
6	**10,000**	**60,000**	**40,000**
7	**10,000**	**70,000**	**30,000**
8	**10,000**	**80,000**	**20,000**
9	**10,000**	**90,000**	**10,000**
10	**10,000**	**100,000**	**0**

In this example, the depreciation deductions remain constant at 10,000 hryvnias per year. The accrued depreciation deductions increase by 10,000 hryvnias each year, starting from 10,000 hryvnias in the first year and reaching 100,000 hryvnias in the tenth year. The residual value decreases by 10,000 hryvnias each year, starting from 90,000 hryvnias in the first year and reaching 0 hryvnias in the tenth year. Again, please note that these values are for illustrative purposes and may vary based on specific depreciation methods and asset characteristics.

The reimbursement of wear and tear of tools and costs of machine tools can vary depending on the specific circumstances and the policies of the organization or individual involved. However, I can provide you with some general information on this topic.

1. Wear and Tear of Tools:

- In most cases, the normal wear and tear of tools is considered a regular expense that is expected during their useful life. Therefore, it is typically the responsibility of the owner or the organization to bear the costs of replacing or repairing worn-out tools.

- Some companies or organizations may have specific policies in place regarding tool maintenance and replacement. They might allocate a budget for tool replacement or provide guidelines on when and how tools should be replaced or repaired. In such cases, reimbursement may be possible if the wear and tear of tools fall within the defined criteria.

- It's essential to review the specific policies or agreements in place within your organization to understand the reimbursement process and any limitations or requirements.

2. Costs of Machine Tools:

- The costs of machine tools are generally considered a capital expenditure. These expenses are typically incurred when purchasing or leasing new or used machinery and equipment.

- Depending on the organization and the nature of the business, there may be different approaches to handling machine tool costs. Some possibilities include:

a. Outright Purchase: If a company purchases machine tools outright, the costs are typically not reimbursed, as they are considered a long-term investment in the business.

b. Leasing or Renting: In some cases, companies may choose to lease or rent machine tools rather than purchasing them. In such situations, the rental or leasing costs may be reimbursable, subject to the terms of the agreement.

c. Employer Reimbursement: In certain circumstances, an employer may reimburse an employee for machine tool costs if they are specifically required for the job. However, this is more likely to occur in specialized industries or professions where employees are responsible for providing their own tools.

It's important to note that the specific reimbursement policies and practices can vary significantly depending on the industry, organization, and local regulations. Therefore, it is recommended to consult with your employer, human resources department, or relevant policies to understand the exact guidelines and processes for reimbursement of wear and tear of tools and costs of machine tools.

Here are examples of advanced and larger machine tools for two different operations, along with their names, unit costs, quantities, and cost per lot:

1. Operation: Turning

   - Machine Tool: CNC Lathe (Computer Numerical Control Lathe)

   - Unit Cost: $100,000

   - Quantity: 3

   - Cost per Lot: $300,000 (assuming one lot consists of three machines)

Additional Details:

- The CNC Lathe features advanced control systems and automation capabilities, allowing for precise and efficient turning operations.
- It may have a large swing diameter and bed length, enabling the machining of larger workpieces.
- The machine could include features like automatic tool changers, live tooling options, and high spindle speeds for increased versatility and productivity.

2. Operation: Milling

- Machine Tool: 5-Axis CNC Milling Machine
- Unit Cost: $200,000
- Quantity: 2
- Cost per Lot: $400,000 (assuming one lot consists of two machines)

Additional Details:

- The 5-Axis CNC Milling Machine offers advanced capabilities for complex machining tasks by allowing simultaneous movement in five axes (X, Y, Z, and two rotational axes).
- It may have a high-speed spindle and advanced tooling options, enabling precision milling of intricate shapes and contours.
- The machine could feature a large working envelope, providing flexibility to handle a wide range of part sizes and geometries.
- Advanced control systems and software may be included to optimize cutting paths, improve surface finishes, and minimize machining time.

CNC machines offer advanced automation and precision control, enabling complex machining operations and reducing manual intervention. The 5-axis CNC milling machine, in particular, provides additional flexibility by allowing simultaneous movement in multiple axes.

LABOR PROTECTION

Introduction:

Occupational health and safety comprises a range of measures and strategies aimed at ensuring the protection and well-being of individuals, safeguarding their lives, health, and work capacity during employment. These measures encompass various legislative acts that encompass economic, social, medical, preventive, organizational, hygienic, and other approaches.

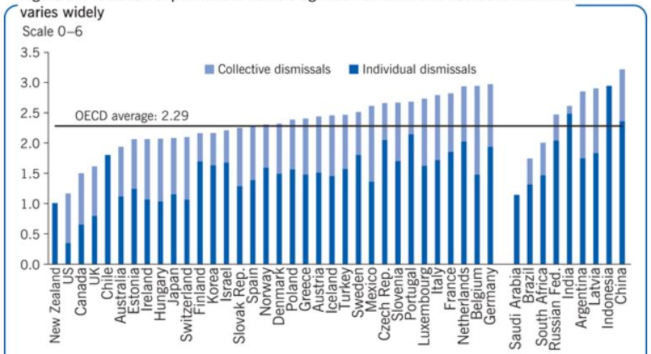
Each workplace carries its own level of risk and toxicity, necessitating the improvement of conditions. The objectives of healthcare interventions are twofold: to minimize the risk of diseases and injuries among workers, and to provide comfortable conditions without compromising productivity. Harmful and hazardous factors in the work environment have a direct impact on real industrial conditions.

Since its establishment in 1972, the System of Labor Safety Standards (SSBP) has been addressing this issue. This system enhances labor productivity and product quality, while simultaneously improving working conditions and reinforcing safety measures.

The implementation of SSBP measures yields numerous positive outcomes. Firstly, safety and working conditions are enhanced, which ensures the well-being of workers and reduces the occurrence of occupational diseases and injuries. Moreover, it significantly reduces costs related to medical treatment, benefits, and compensations associated with such work. Improved working conditions also contribute to lower employee turnover and reduced expenses for training new staff members.

Positive social impacts arise from changes in working conditions within the production sector. Employees benefit from a higher level of health protection, leading to improved job satisfaction. These changes also promote greater labor discipline and contribute to various indicators that determine social development.

Figure 1. Protection of permanent workers against individual and collective dismissal varies widely



Notes: Data refer to 2013 for OECD countries and Latvia and 2012 for other countries. The height of the bar represents the value of the overall indicator on a scale of least stringent (0) to most stringent (6).

Source: OECD. *Employment Outlook*. Paris: OECD Publishing, 2013 [2]; data for Israel, http://dx.doi.org/10.1787/888932315602.

IZA World of Labor

Essentials for workplace premises:

The computer manufacturer's documentation includes operational and regulatory requirements for the buildings and premises housing the workplaces.

Operator workstations are situated in buildings and premises that must meet a minimum fire resistance rating of the second level. The zone class, as defined by the NPAOP index 40.1-1.01-97, is a mandatory condition for buildings and premises accommodating workplaces. This pertinent information should be prominently displayed on the doors of all premises.

The use of basements and cellars for computer workstations is strictly prohibited. Additionally, it is important to emphasize that wet technological processes should not be conducted in these premises.

Optimal placement of personal computers necessitates rooms equipped with adjustable window openings, featuring devices like external visors, curtains, or blinds. The interior decor of the computer room should consist of diffuse-reflective materials, boasting a reflection coefficient of 0.7-0.8 for the ceiling and 0.5-0.6 for the walls.

Restrictions dictate that only matte flooring with a reflection coefficient of 0.3-0.5 should be employed, ensuring it possesses antistatic properties and avoids any curved or slippery surfaces.

Polymer materials, including synthetic, wood-chip, and layered paper textures that contain chemical substances and pose a potential risk, are strictly prohibited for furnishing computer workstations. However, polymer materials that have been approved by the relevant sanitary-epidemiological service are an exception to this rule.

In computer-occupied spaces, adequate provisions must be made for cabinets, racks, and shelves, serving as storage for documents and magnetic disks.

To guarantee the safety and comfort of workers, several appropriate systems should be implemented. This includes the installation of dielectric shields or nets on grounded structures such as water pipes, heating batteries, and cables, to protect workers against potential electrical hazards.

In compliance with Ukrainian legislation, fire alarms and easily accessible fire extinguishers are mandatory features within workspaces, ensuring the prompt response to emergency situations.

Maintaining a tidy environment through regular wet cleaning is paramount to workplace orderliness.

In addition to fire safety measures, it is imperative to have readily available first aid kits on-site. Additionally, dedicated areas for physical and psychological rest should be designated within rooms housing household equipment.

When organizing and equipping computer workstations, careful attention should be given to the placement of work desks. Personal computers should be positioned with a minimum distance of 1.2 meters between their side surfaces, while ensuring a separation of at least 2.5 meters between the back of one computer and the screen of another.

A measure frequently implemented to ensure uninterrupted focus during work is the installation of a substantial partition between operator seats, preventing employees from encroaching on each other's concentration.

To adhere to the ergonomics of the workstation layout featuring personal computers, employees are expected to maintain a face-to-face posture conducive to optimal work performance.

Ergonomics standards dictate specific requirements for maintaining the ideal conditions of the work surface, taking into account the presence of diverse equipment and documents within the workspace.

An additional crucial aspect entails the meticulous adjustment of the desktop surface, encompassing dimensions such as height, width, and depth, to align with recommended specifications for facilitating various tasks.

The workstation necessitates meticulous customization based on numerous parameters that should be easily adjustable. A desk accommodating personal computers must provide generous legroom, surpassing a height of 600mm, a width exceeding 500mm, and a depth at knee level surpassing 450mm. Furthermore, the accompanying chair should possess lift-swivel capabilities, enabling height, tilt, distance from the edge of the desk, and seating surface adjustments. The seating surface should be flat with a gently curved front edge.

Regarding the chair, its seat height should range from 400-500mm, with a width and depth surpassing 400mm. The backrest height should measure approximately 300+-20mm, boasting a width of 380mm and a surface curvature spanning 400mm. The inclination angle relative to the vertical surface should fall between 1-30 degrees.

The adjustability of the chair extends to the backrest, catering to individual preferences. Additionally, the inclusion of armrests plays a pivotal role in preventing strain on the upper limbs. The armrests should possess adjustable height and distance, and they can either be flexible or fixed, with a length surpassing 250mm and a width ranging from 50-70mm.

Furthermore, the chair's seating and backrest surfaces should be designed with materials that are neither rigid nor slippery, devoid of static electricity buildup. Complementing the workspace setup, a footrest beneath the desk is essential, offering adjustable parameters such as a maximum height of 150mm and a maximum slope of 20 degrees. The footrest's width should exceed 300mm and exhibit a textured surface.

It is worth noting that the arrangement of light sources in the workspace should prioritize illuminating only the left side with natural light. Paying heed to visual well-being norms is imperative, particularly when considering the positioning of the monitor screen on the desk, as it significantly impacts the quality and convenience of the user's visual capabilities. To maintain a comfortable eye level, the monitor should be tilted at an angle of approximately +30 degrees from the vertical plane. Moreover, an optimal distance of 600-700mm between the monitor screen and the viewer's eyes should be maintained, taking into account the size of symbols and signs.

The design of the computer keyboard is specifically tailored to its placement on the table, recommended to be positioned 100-300 mm away from the edge. To minimize unnecessary movement of the keyboard, a support material has been developed to reduce friction against the table surface. The height and angle of inclination of the keys, covered with a matte material, can be adjusted within a maximum range of 30 mm.

The positioning of devices is crucial in the workplace, particularly for optimal visibility of the monitor screen to effectively convey information. Vibrating mats are employed for dot matrix printers to prevent unwarranted and distracting noises in the working environment. Additionally, a lectern is provided for convenient movement of documents within the computer room.

Measures are implemented to preserve and protect the vision of workers. These include the utilization of near-screen filters to enhance vision and the application of light filters. Accredited laboratories have approved these safety methods, which have obtained hygienic certification.

Safety precautions should be observed when working with personal computers. Regular cleaning of the workspace is necessary, ensuring that all equipment is free from dirt before commencing work. At the end of the workflow, it is essential to power off all devices and computers, even in emergency situations.

Performing preventive maintenance, equipment adjustments, and computer maintenance at the operator's workspace is strictly prohibited.

The workspace surface should always be kept tidy, minimizing the presence of unnecessary items on the tables. Hence, storing parts, flash drives, documents, discs, or papers near computers and devices should be avoided unless absolutely necessary.

Employees are not permitted to independently modify or debug computers and devices. Additionally, automatic shutdown of protective systems is not allowed.

In the event of abnormalities in computer and device operations, such as unusual signals or an unstable screen image, employees must cease their work immediately.

The use of a vibrating mat and a raised cover is mandatory when operating a dot matrix printer.

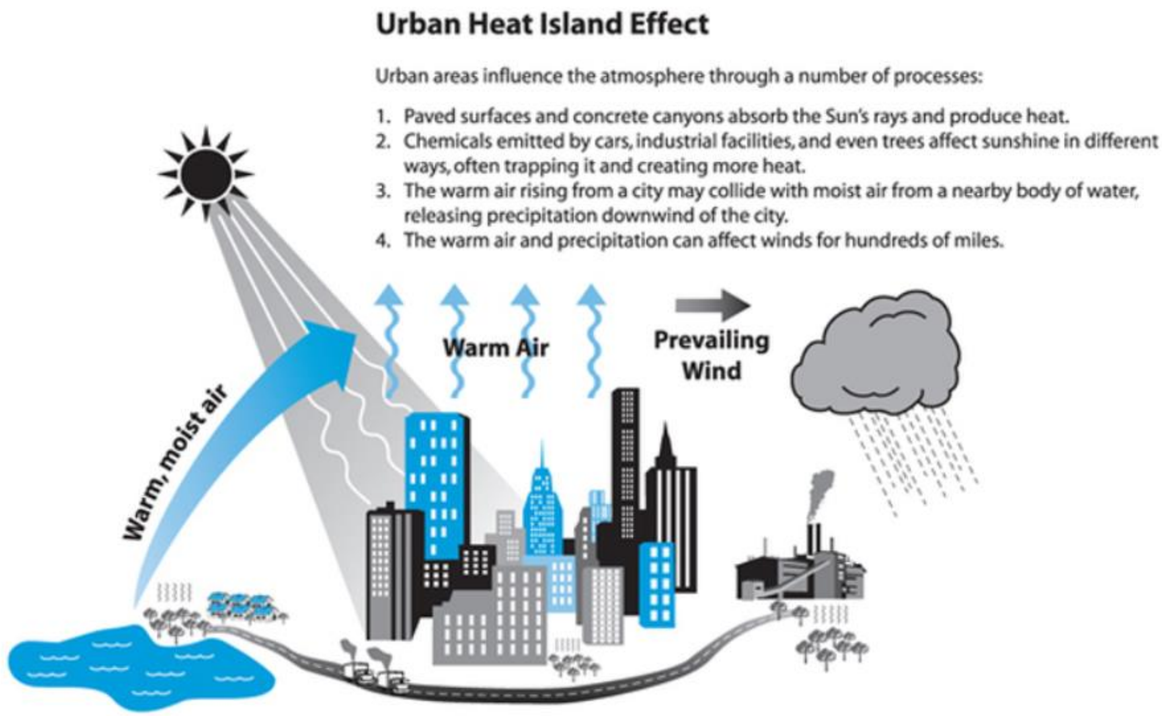
Microclimate refers to the atmospheric conditions and environmental factors that exist within a relatively small and localized area, typically smaller than a city or region. It refers to the unique climate conditions experienced within that specific area, which may differ from the larger surrounding region or macroclimate.

Various factors contribute to the formation of microclimates, including geographical features, vegetation, land cover, elevation, aspect (orientation towards the sun), and local weather patterns. These factors interact to create variations in temperature, humidity, wind patterns, precipitation levels, and other climatic elements.

Microclimates can be found in different settings, such as urban areas, parks, gardens, forests, valleys, and coastal regions. For example, a city may have warmer temperatures than the surrounding rural areas due to the urban heat island effect, where buildings and concrete absorb and retain heat.

Microclimates are essential to consider in fields like agriculture, horticulture, and urban planning, as they influence the suitability of specific crops, the growth of plants, and the design of urban spaces. Understanding microclimates helps in making informed decisions about planting choices, managing outdoor spaces, and adapting to local weather patterns.

In summary, microclimate refers to the distinct climate conditions found within a small and specific area, influenced by localized factors and varying from the larger surrounding region or macroclimate.



In the northern or northeastern regions, it is common to have openings that allow natural light to enter, aiming for a coefficient of illumination higher than 1.5%. The calculation of the coefficient follows the guidelines outlined in SNiP II-4-79, which governs the assessment of natural lighting.

An essential aspect of the lighting system in premises is achieving uniform artificial lighting. To optimize document-related tasks, individual workstations are equipped with both general artificial lighting and localized lighting systems.

For the designated document area, the recommended illuminance level on the employee's desktop surface ranges between 300 and 500 lux. To enhance areas with insufficient lighting, localized lighting sources are strategically placed throughout the premises. It is crucial to ensure that this supplementary lighting system avoids creating glare on the monitor surface, with a maximum illuminance of 300 lux. Fluorescent lamps, such as the LB type, are commonly employed in the overall artificial lighting system.

In workplaces requiring reflected lighting, 250 W metallogenic lamps are typically used, while local lighting fixtures often utilize incandescent lamps.

To optimize ergonomic factors, workers are advised to install their lighting systems on the left side, taking into consideration their line of sight and the positioning of the light sources.

Sources and References

1. Mechanical Engineering Magazine - Provides articles, news, and insights about the latest trends and developments in mechanical engineering.

Website: https://www.asme.org/topics-resources/content/mechanical-engineering-magazine

2. American Society of Mechanical Engineers (ASME) - Offers a wealth of resources, including technical articles, journals, standards, and industry news.

Website: https://www.asme.org/

3. Mechanical Engineering Channel (YouTube) - Features videos covering various topics in mechanical engineering, including design, manufacturing, and analysis.

Website: https://www.youtube.com/c/MechanicalEngineeringChannel

4. Engineering.com - A comprehensive engineering website with a dedicated section for mechanical engineering, offering articles, forums, and resources.

Website: https://www.engineering.com/

5. MIT OpenCourseWare - Provides free access to course materials from the Massachusetts Institute of Technology (MIT), including mechanical engineering courses.

Website: https://ocw.mit.edu/courses/mechanical-engineering/

6. Mechanical Engineering Stack Exchange - An online community where you can ask questions related to mechanical engineering and get answers from experts.

Website: https://engineering.stackexchange.com/

7. National Institute of Standards and Technology (NIST) - Offers publications, standards, and technical resources relevant to mechanical engineering.

Website: https://www.nist.gov/topics/engineering-mechanics

8. Engineering Toolbox - A website with a wide range of engineering resources, including calculators, unit conversions, and technical data.

Website: https://www.engineeringtoolbox.com/

9. Mechanical Engineering Online (YouTube) - Provides video lectures, tutorials, and demonstrations on mechanical engineering topics.

Website: https://www.youtube.com/c/MechanicalEngineeringOnline

10. ScienceDirect - A leading platform for scientific, technical, and medical research, offering access to numerous mechanical engineering journals and articles.

Website: https://www.sciencedirect.com/

11. Mechanical Engineering Pro Tips - Offers practical tips, advice, and insights on various mechanical engineering topics.

Website: https://www.machinedesign.com/mechanical-engineering-pro-tips

12. Engineering Village - A comprehensive search platform for engineering research, including mechanical engineering literature and patents.

Website: https://www.engineeringvillage.com/

13. Mechanical Engineering Books - Provides a curated list of mechanical engineering books covering various sub-disciplines.

Website: https://www.mechanicalengineeringbooks.net/

14. Mechanical Engineering World - A blog that shares news, articles, and resources related to mechanical engineering.

Website: https://www.mechanicalengineeringblog.com/

15. Institution of Mechanical Engineers (IMechE) - Features publications, technical resources, and industry insights for mechanical engineers.

Website: https://www.imeche.org/

16. American Society for Testing and Materials (ASTM) - Offers standards and technical publications related to materials and testing in mechanical engineering.

Website: https://www.astm.org/

17. Mechanical Engineering Reddit - A community-driven platform where you can find discussions, questions, and resources related to mechanical engineering.

Website: https://www.reddit.com/r/MechanicalEngineering/

18. Mechanical Engineering Projects - A website showcasing various mechanical engineering projects and ideas for inspiration.

Website: https://mechanicalengineeringprojects.net/

19. National Aeronautics and Space Administration (NASA) - Provides technical reports, publications, and resources related to aerospace and mechanical engineering.

Website: https://www.nasa.gov/

20. LinkedIn Groups - Join relevant LinkedIn groups focused on mechanical engineering to connect with professionals and access industry discussions.

Website: https://www.linkedin.com/