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

The defense allowed:
Acting head of the department
______Olexander OKHRIMENKO
«___»_____________2022

# Diploma project

**for a bachelor's degree**

in Educational Program “Manufacturing Engineering”

Program subject area – 131 “Applied Mechanics”

**on the topic: «**Manufacturing process planning for production of a part "Bearing Housing"**»**

Developed by:
Student of the IV year of study, group MT-84
*Omar Yehia Saadeldin Hedeiry Ibrahim* _________________
_______________
(Full name) (Signature)

Supervisor:
Associate professor Volodymyr Korenkov, Ph.D. ________________

Reviewer:
_______________________________________________ ________________

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

Student _______________
signature

Kyiv – 2022

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Program subject area – 131 "Applied Mechanics"

Educational Program "Manufacturing Engineering"

APPROVED

Acting head of the department

_______ Olexander OKHRIMENKO

«___»_____________2022

**ASSIGNMENT**

**for the student's diploma project**

*Omar Yehia Saadeldin Hedeiry Ibrahim*

1. Topic of the project: Manufacturing process planning for production of a part "Bearing Housing"

Project supervisor: Volodymyr Korenkov, Ph.D.

approved by the University Order of «   » may 2022 №

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

3. Initial data for the project

- Drawing of a part " Bearing Housing "
- Annual production output: 3500 parts
- Material: Cast Iron

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

- Chapter 1

- Chapter 2 Manufacturing process planning
- Chapter 3 Fixture design
- Chapter 4 Economic calculations

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

- Presentation of the topic: ______– 1 drawing A1
- Drawing of a part and a blank – 1 drawing A1
- Manufacturing operation presentation – 1-2 drawings A1
- Drawing of fixtures – 1-2 drawings A1
- Presentation of the project – 5-10 PowerPoint slides

6. Date of the task issue «26» may 2022

Time schedule

| No | The stage of the diploma project execution | Deadline | Notes |
|---|---|---|---|
| 1 | Chapter 1 | 16.05.22 | |
| 2 | Chapter 2 Manufacturing process planning | 1.06.22 | |
| 3 | Chapter 3 Fixture design | 10.06.22 | |
| 4 | Chapter 4 Economic calculations | 15.06.22 | |
| 5 | Presentation of the project | 17.06.22 | |

Student

Supervisor Volodymyr KORENKOV

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## Task 1: Analysis of the purpose and operating conditions of the part in the Assembly and determining the type of production

### 1.1. Analysis of design features of the part and its classification

The part is categorized as “Body” while reviewing the configuration of the component

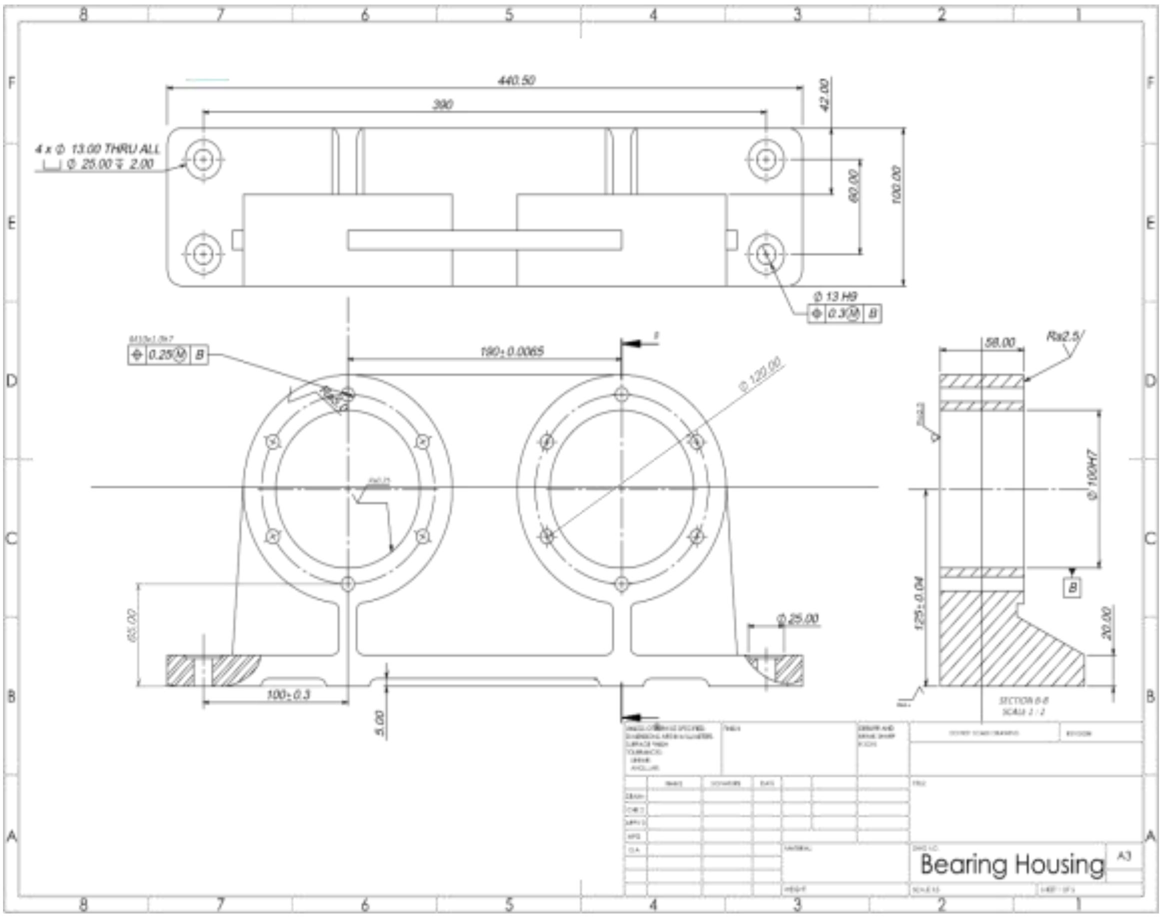



*Figure 1 drawing for ϕ100 mm –H7bearing housing*

The part is the bearing housing and hence more attention be on the bearing hole cut and its angle the surface must be maintain to ensure the perpendicularity.

The rest of the part surfaces have no such requirements in terms of refinement as they are not playing important role in the functioning.

### 1.2 Analysis of the purpose and operating conditions of the part in the assembly unit

The bearing housing is a unit which is used to hold the bearing within a machine. It is widely used with a variety of designs regarding to the types of the bearing, mounting consideration, lubrication requirement, operating environment, etc. One of the most use of the housing can be observed when a shaft need to place within an assembly.

The drawing shown above is the housing for bearing with outer diameter of 100 mm and H7 tolerance rating the vertical position of the bearings is 125 mm and center to center distance is 190 mm. There are six M10 X 1

holes which retains the bearing position. 4 X ϕ13 mm holes are used to mount the housing inside the assembly.

### 1.3 Analysis of the material

The bearing casing should be manufactured with Gray cast iron. It is the most widely used type of Iron and depicts grey color due the presence of the graphite. It has strength properties near to mild steel and is used for different applications due to ease of machinability and hence maintain low cost.

Grey Cast iron has the following chemical composition and mechanical properties

| Chemical composition of gray cast iron | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| C | S | P | Si | Mn | Cu | Cr | Ni | Mo |
| 3.04 | 0.11 | 0.068 | 2.58 | 0.42 | 0.05 | 0.07 | 0.02 | 0.005 |
| Mechanical properties | | | | | | | | |
| Hardness HB | | | Tensile strength MPa | | | Fatigue strength MPa | | |
| 205 | | | 245 | | | 100 | | |

*Figure 2 2 Chemical Composition and Mechanical Properties of Grey Cast Iron*

As it is stated that the housing will be manufactured with grey

cast iron and also it is easy machine hence it confirms that the operating conditions for the housing are soft as hard environment does not suite this material.

### 1.4. Determining the type of production and analysis of its impact on the manufacturing plane.

To evaluate the type of production of the housing we will use the analog modelling. It divides the classes of the production types based on the part weight and production volume.

Weight of the ϕ100 housing in kg = 14.776 kg

Production volume = 3500

*Table 1for identification of type of the production*

| 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 |

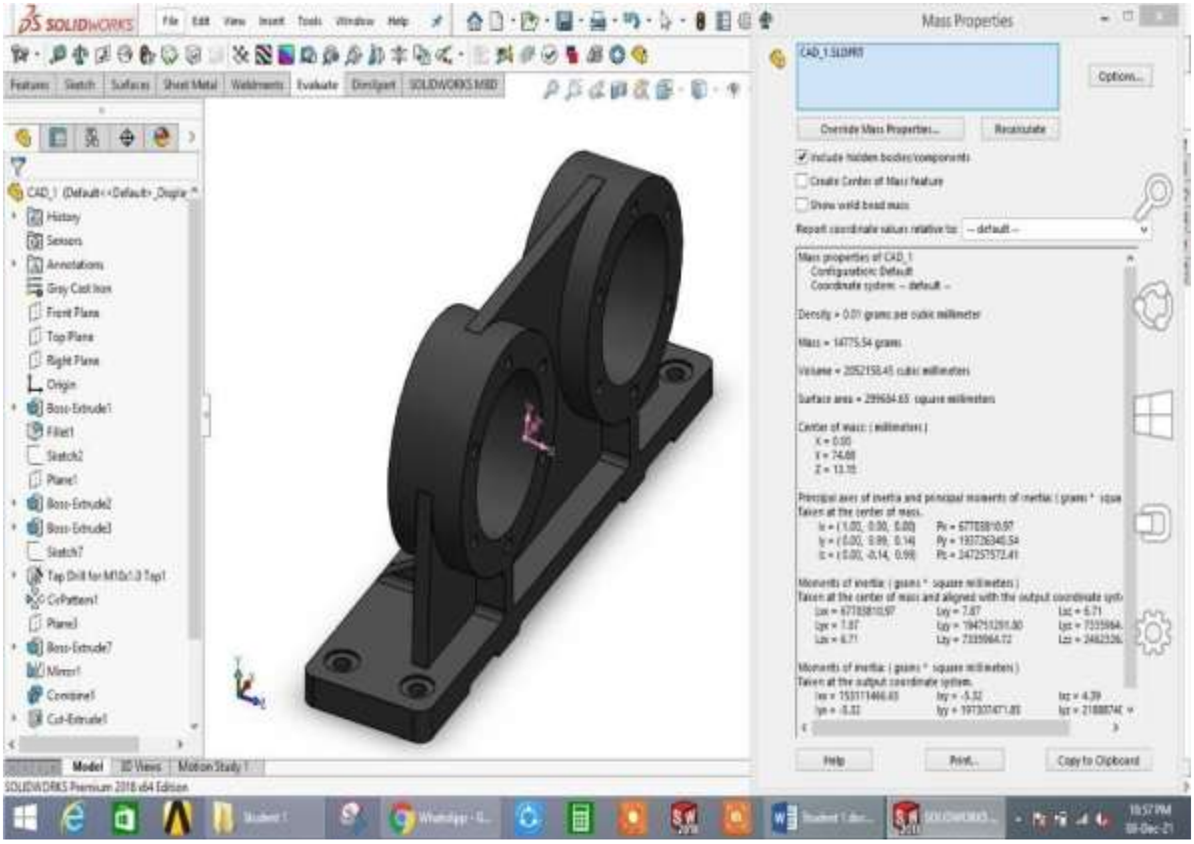



*Figure 3*

Conclusion: the part belongs to the medium production category for manufacturing. Now all the analysis discussion will be based on the medium batch production.

### Task 2: Selection of the base process and design of the blank

To select a base process, we have provided the following information regarding the housing

- Technical Drawing file for geometry aspects
- Component Material
- Production volume per annum (3500).

With the help of figure 1.3.2 we can identify the base process for our housing. The process selection is based on the material for the casting. Since the material is grey cast iron, hence the common practice is the sand-casting process.

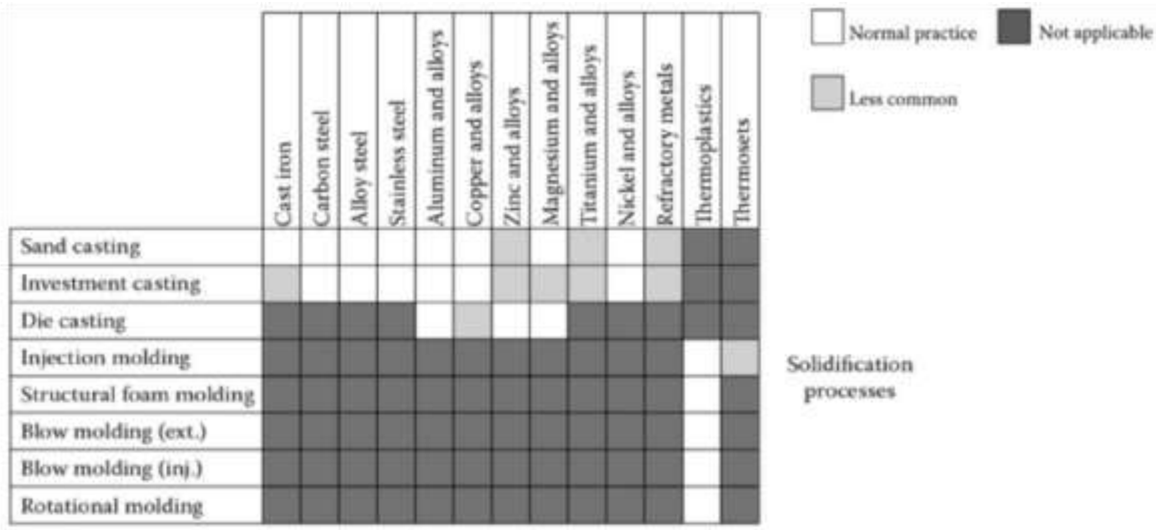
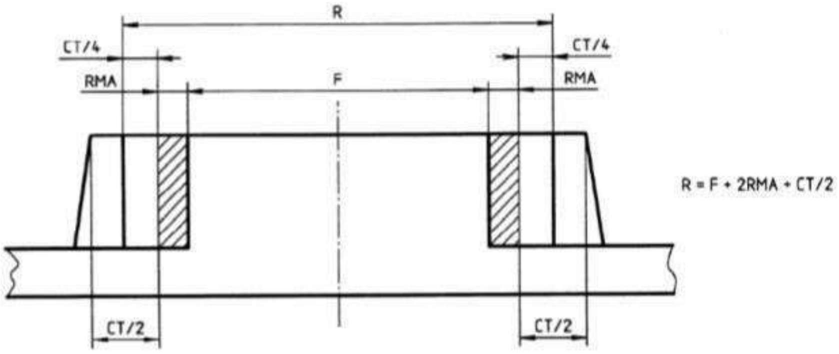



*Figure 5*

For casting, two things need to be considered i.e. one, add the casting tolerances (CT) and the second, find out the required machining allowance (RMA) grade.

Casting tolerance (CT) is the amount of the material need to be added to counter shrinkage as well as for the imperfections (defects) in the surface. This is also comprising the draft angle. From table 3.3, CT 10 can be used for the process and material specified. The table 3.2 shows the CT 10 values for the part.

The RMA as stated stands for required machining allowance is the amount of material which should be added for post machining processes. RMA is usually added when a smooth finish is required. According ISO 8062 casting recommendations the RMA grade for the grey cast iron is F-H. We select the grade F and maximum dimension in the drawing sets the RMA value to 3 mm as per Table 2.2




R = Raw casting basic dimension

F = Dimension after final machining

RMA = Required machining allowance

CT = Casting tolerance

*Figure 6 CT and RMA relationship with final machined and raw casting dimensions*

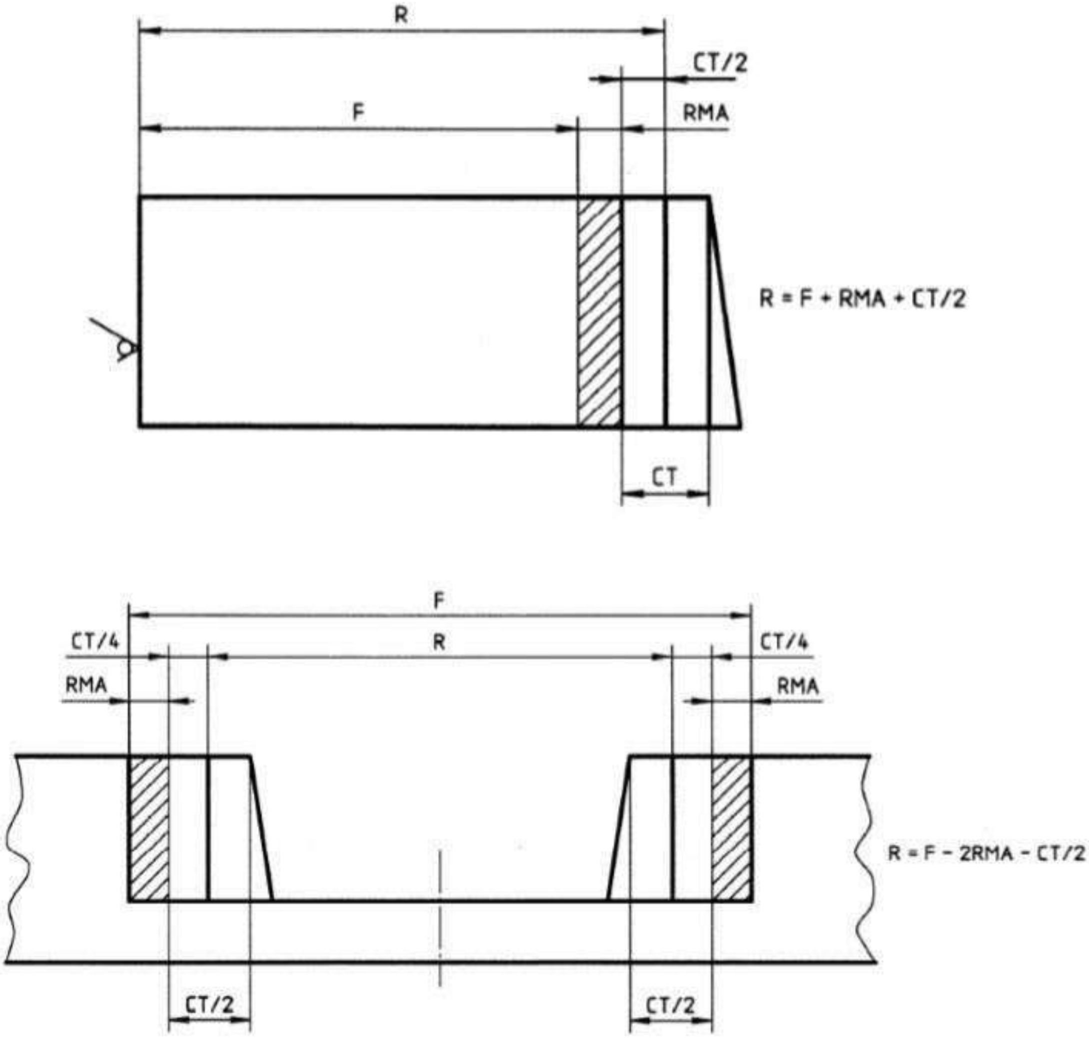



*Figure 7*

Below is the table with casting dimensions that is comprised of CT and RMA tolerances.

*Table 2 RMA, CT and Raw casting dimensions based on SFSA Data under*

| **Dimension of a part** | **RMA** | **Min limit of size for external features (or max for internal features)** | **Casting tolerance, mm** | **Raw casting basic dimension** |
|---|---|---|---|---|
| 197.5 | 3 | 200.5 | 4 | 202.5±2 |
| 20 | 3 | 23 | 2.4 | 24.2±1.2 |

| | | | | |
|---|---|---|---|---|
| 125 | 3 | 128 | 3.6 | 129.8±1.8 |
| 100 | 3 | 94 | 3.2 | 92.4±1.6 |
| 58 | 3 | 64 | 2.8 | 65.4±1.4 |

**Following recommendations should be followed while developing the model for casting'**

- The part must be oriented in a way that it has minimum dimension in the direction of gravity. z
- The parting line should be on the symmetry plan
- Fillet must be imposed on each corner with a range of 2-5 mm
- The tapering (drafting) must be applied on all the surfaces to 2 degrees with respect to the parting plane.
- the required machining allowance should only be incorporated to those faces where it is the machining is needed.
- Main features like bearing holes and large cut outs needs to be manufactured by the casting process
- The relatively smaller features should only be added by other processors.
- General tolerances ISO 8062-CT10-RMA 3 (F)
- Draft angle 2°. Radii 2-5 mm
- The final casting outcome must be free of the surface defects
- as per visual of the drawings
- Gentle heating should be provided as post casting step.

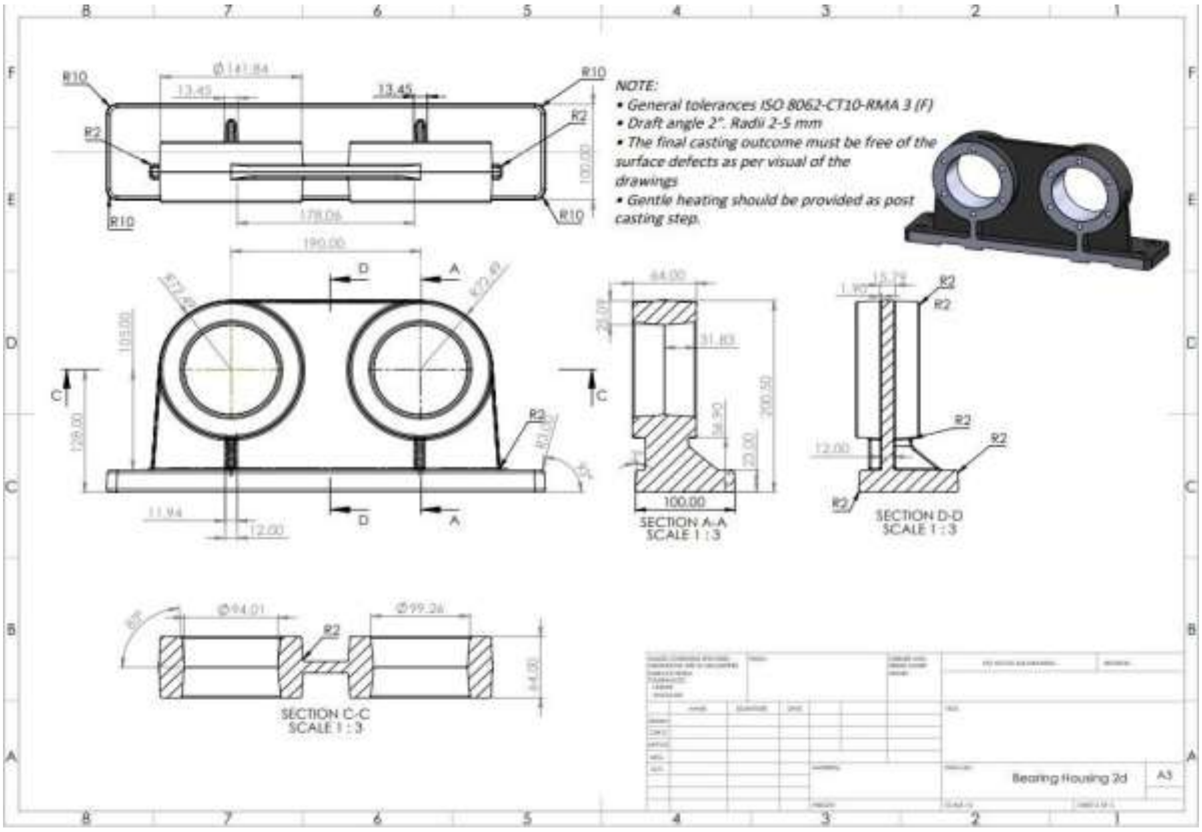



*Figure 8 Cost estimation*

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

(CustomPartNet, n.d.)

## 2.1 Selection of the base process

To select the base process we will use on-line application Process Selector at the custompartnet.com . Initial data for the process selection (according to the variant) □ Drawing of a part;

- Material of a part – Cast Iron
- Annual output – 3500 pcs (292 per month).


*Figure 9 Initial data for the process selection*

According to the results (Fig. 1.4), the metal casting processes could be applied as base processes, taking into account that we do not consider the final tolerance and surface finish (will be obtained by secondary process). The following processes could be applied:

- Centrifugal Casting,
- Investment Casting, □ Sand Casting, □ Shell-mold casting.

Among these processes Sand Casting is recommended according to all criteria except surface tolerance and roughness. Milling could be recommended as the secondary process. Let’s compare recommended base processes (Fig. 1.5)

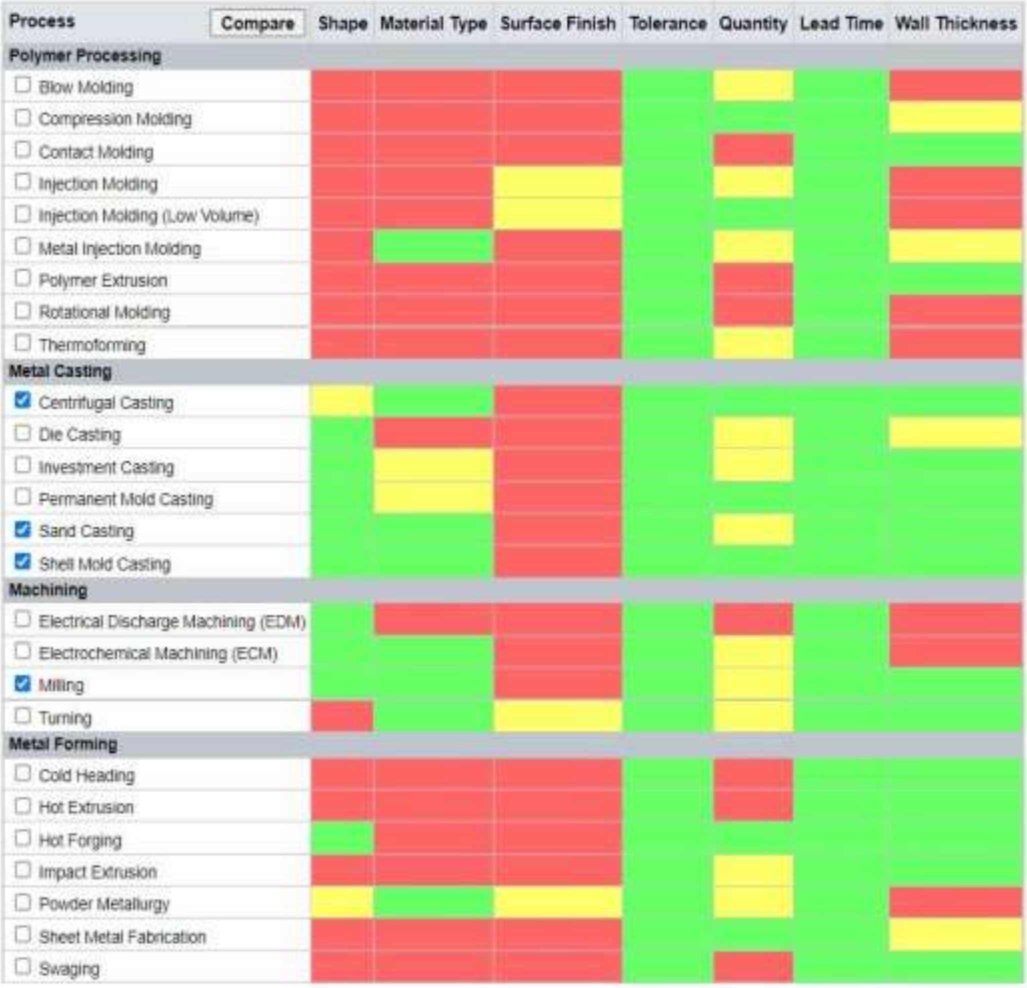



*Figure 10 Results of the process selection*

Process Comparison

| Property Name | Centrifugal Casting | Investment Casting | Sand Casting | Shell Mold Casting |
|---|---|---|---|---|
| Shapes | Thin-walled: Cylindrical, Solid: Cylindrical (Thin-walled: Complex, Solid: Complex) | Thin-walled: Complex, Solid: Cylindrical, Solid: Cubic, Solid: Complex (Flat, Thin-walled: Cylindrical, Thin-walled: Cubic) | Thin-walled: Complex, Solid: Cylindrical, Solid: Cubic, Solid: Complex (Flat, Thin-walled: Cylindrical, Thin-walled: Cubic) | Thin-walled: Complex, Solid: Cylindrical, Solid: Cubic, Solid: Complex (Flat, Thin-walled: Cylindrical, Thin-walled: Cubic) |
| Part size | Diameter: 1 - 120 in. Length: Up to 50 ft. Weight: Up to 5 tons | Weight: 0.02 oz - 500 lb | Weight: 1 oz - 450 ton | Weight: 0.5 oz - 220 lb |
| Materials | Metals, Alloy Steel, Carbon Steel, Cast Iron, Stainless Steel, Aluminum, Copper, Nickel | Metals, Alloy Steel, Carbon Steel, Stainless Steel, Aluminum, Copper, Nickel (Cast Iron, Lead, Magnesium, Tin, Titanium, Zinc) | Metals, Alloy Steel, Carbon Steel, Cast Iron, Stainless Steel, Aluminum, Copper, Magnesium, Nickel (Lead, Tin, Titanium, Zinc) | Metals, Alloy Steel, Carbon Steel, Cast Iron, Stainless Steel, Aluminum, Copper, Nickel |
| Surface finish - Ra (μin) | 63 - 500 (32 - 500) | 50 - 125 (16 - 300) | 300 - 600 (125 - 2000) | 50 - 300 (32 - 500) |
| Tolerance (in.) | ± 0.01 (± 0.002) | ± 0.005 (± 0.002) | ± 0.03 (± 0.015) | ± 0.015 (± 0.006) |
| Max wall thickness | 0.1 - 5.0 | 0.06 - 0.80 (0.025 - 5.0) | 0.125 - 5 (0.09 - 40) | 0.06 - 2.0 |
| Quantity | 100 - 10000 (1 - 10000) | 10 - 1000 (1 - 1000000) | 1 - 1000 (1 - 1000000) | 1000 - 1000000 (100 - 1000000) |
| Lead time | Weeks (Days) | Weeks (Days) | Days (Hours) | Weeks (Days) |
| Advantages | Can form very large parts, Good mechanical properties, Good surface finish and accuracy, Low equipment cost, Low labor cost, Little scrap generated | Can form complex shapes and fine details, Many material options, High strength parts, Very good surface finish and accuracy, Little need for secondary machining | Can produce very large parts, Can form complex shapes, Many material options, Low tooling and equipment cost, Scrap can be recycled, Short lead time possible | Can form complex shapes and fine details, Very good surface finish, High production rate, Low labor cost, Low tooling cost, Little scrap generated |
| Disadvantages | Limited to cylindrical parts, Secondary machining is often required for inner diameter, Long lead time possible | Time-consuming process, High labor cost, High tooling cost, Long lead time possible | Poor material strength, High porosity possible, Poor surface finish and tolerance, Secondary machining often required, Low production rate, High labor cost | High equipment cost |
| Applications | Pipes, wheels, pulleys, nozzles | Turbine blades, armament parts, pipe fittings, lock parts, handtools, jewelry | Engine blocks and manifolds, machine bases, gears, pulleys | Cylinder heads, connecting rods |

*Figure 11 Results of the process comparison*

## 2.2 Casting Design

Initial data for the work piece design (according to the variant):

- drawing of a part;
- material of a part – Cast Iron;
- selected base process – Sand Casting; Annual output – 3500 pcs (292 per month).

To estimate the required machining allowance (RMA) grade we will use Table

B.1. For the sand casting process and Grey Iron the recommended RMA grade is G. Required machining allowance according to the G grade and the largest dimension of a part 250mm (see drawing) is 2.8 mm according to the table 2. To estimate casting tolerance (CT) grade we will use table A1 (for long series). For the sand casting process and the Grey Iron the CT12 could be applied. The results of estimation casting tolerances are presented in Table 1.2. The sketches of RMA and

CT location are presented in Fig. 1.6

When designing the casting we considered the following:

- a work piece 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 (metal cutting) will be applied;
- the 2 center holes and a main pocket 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 work piece design are presented in

Cost estimation

To estimate the cost of casting we will use the on-line application Cost Estimator at the custompartnet.com . The results are presented in figure 1.8.

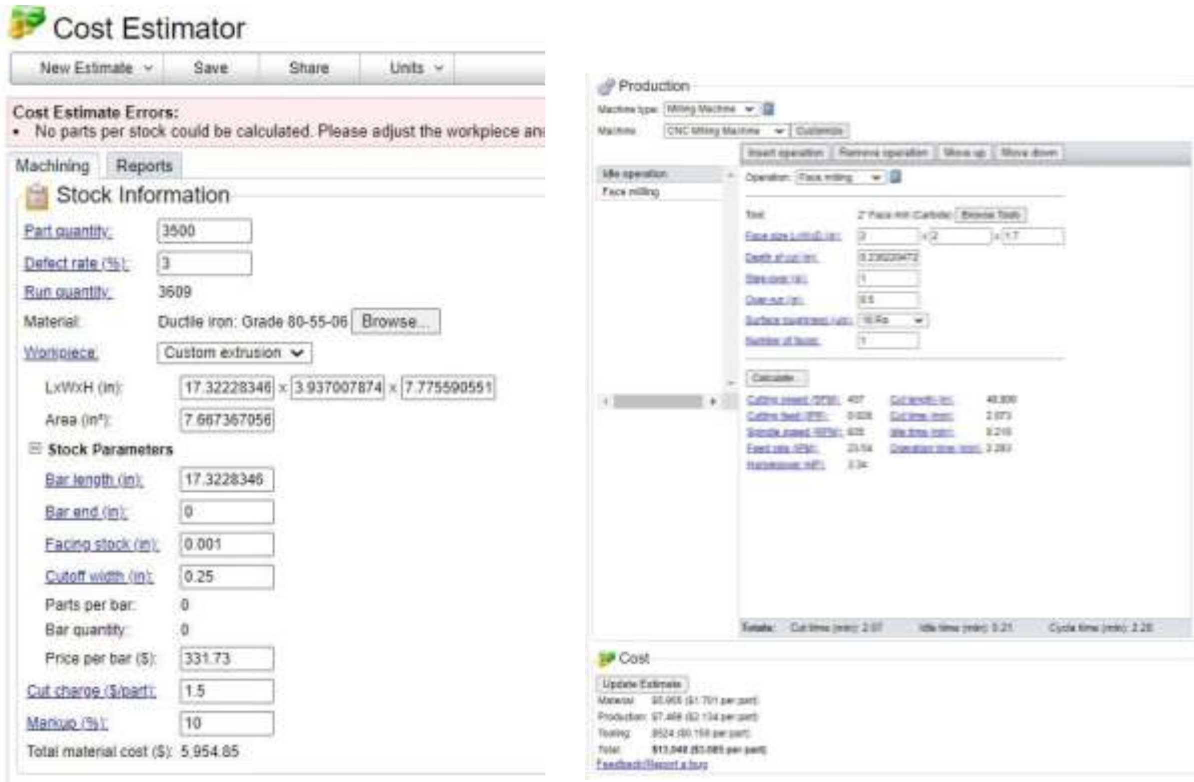



*Figure 12*

## 2.3 Locating scheme selection

The General Manufacturing Data (MD) correction algorithm consists of two stages:

- Rationale for choosing general manufacturing datum (GMD)
- Rationale for choosing a manufacturing datum for the first manufacturing operation.

## 2.4 Rationale for choosing general manufacturing datum

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

The starting point for choosing a GMD is the operating level of the section. To solve the problem of the first stage, it is necessary to classify the section surface according to its predetermined purpose.

The design of any part can be described as a combination of four types of surfaces:

1. Basic functional data (design).
2. Additional functional data (design)
3. Fastened the surfaces
4. Free superficial

To perform a more detailed analysis, we classify the surfaces of specific parts according to their use (Figure 1.8).

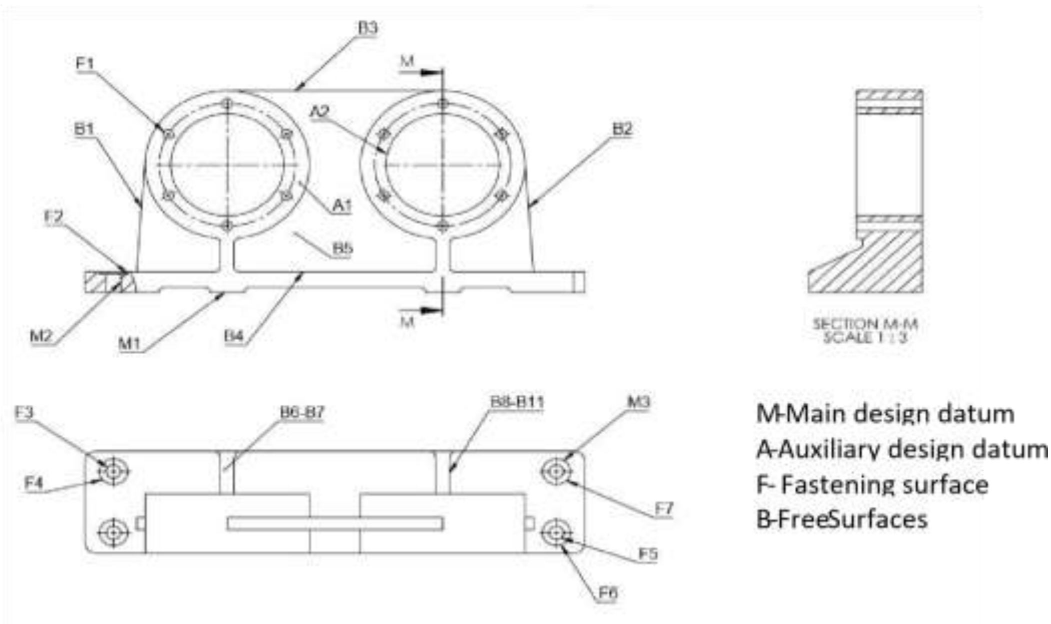
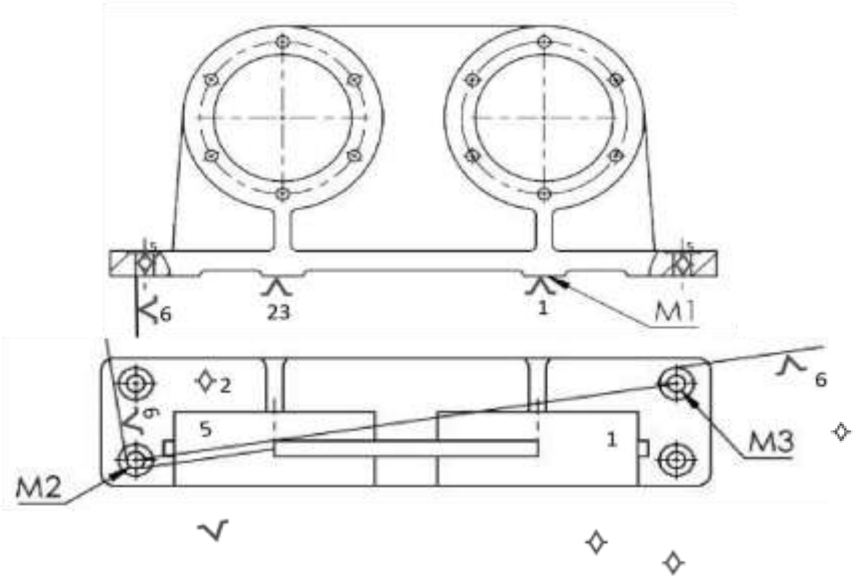



*Figure 13 Classification of the part according to their predetermined purpose*

Let's consider the possibility of converting the most important design data 1.10.




into

*Figure 14 site plan of GMD*

The formula for the ground plane shown in Figure 1.9 is as follows:

$$LS_{GMD} \Rightarrow S\ (3) + DS\ (2) + O\ (1), \qquad (1.1)$$

Between them S (3) - setting data, removes the work piece to three degrees of work independence, DS (2) - double support datum, removes the work piece to two degrees of work independence, and O (1) – support datum, removes the work piece to one degree of work independence.

The program is using in a: flat head, round and diamond head set screws. In this case, the "housing" has a sufficient orientation so that its surface can be processed according to the specific requirements of the conditions.

In our example, GMD does not change.

GMD => constant

## 2.5 Rationale for choosing a manufacturing datum for the first manufacturing operation.

When selecting data areas for primary production operations it is necessary to ensure openness processing of all GMD surfaces and to select equipment that can perform continuous GMD site processing to achieve the prescribed quality features. Otherwise it is necessary to consider whether the complete set of GMD should be considered during the next technical implementation.

Let’s consider potential schemes for getting the first manufacturing jobs as well as the pros and cons. For this purpose, we will use the following recommendations:

- For MD select surfaces that should not be considered with respect to graphically
- If all workplaces are to be considered, then as MD we are taking very low permit areas (this prevents the occurrence of defects in this area for further processing), if the resources are the same, it is necessary to choose the surfaces where disability is not permitted;
- Choose as MD surfaces where it is necessary to give the same approval for the following stages of processing;
- If there are a few potential support schemes, then as MD we accept the option with a very short dimensional series.

The first development is shown in Fig. 1.11.

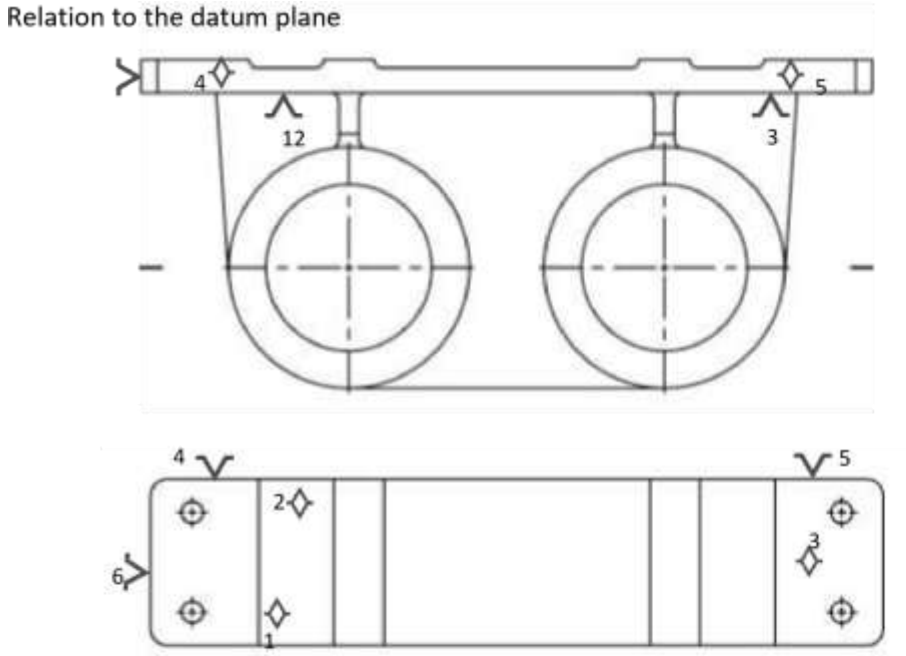
Advantages:

- Easy to use
- Ensures proper placement of raw areas compared to treated ones

Disadvantages:

- Blocks to process the work piece from three sides,

- Make unequal revenue for large housing pits in the following stages of operation; • The side planes do not guarantee the perpendicularity of (near large




holes)

*Figure 15*

Locating scheme for the first manufacturing operation the formula for the land acquisition scheme presented in Fig 1.11 is as follows:

$$LS_{MD} \Rightarrow S\ (3) + G\ (2) + O\ (1) \quad (1.3)$$

The second variant is shown in Fig. 1.12.

Advantages:

- Provides the perpendicularity of the unmanned one sided plane instead of the datum;
- The same allowance for further processing of the hole used for the acquisition. Disadvantages:
- It is very difficult to implement the design (dual support data is used by the expansion plunger mandrel;
- Proper placement of untreated areas compared to treated ones is guaranteed not in all surfaces.

Figure 1.12 - Locating scheme for the first manufacturing operation

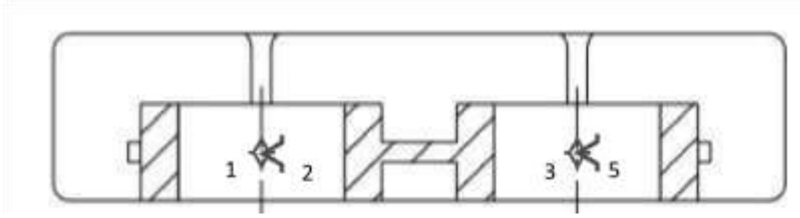
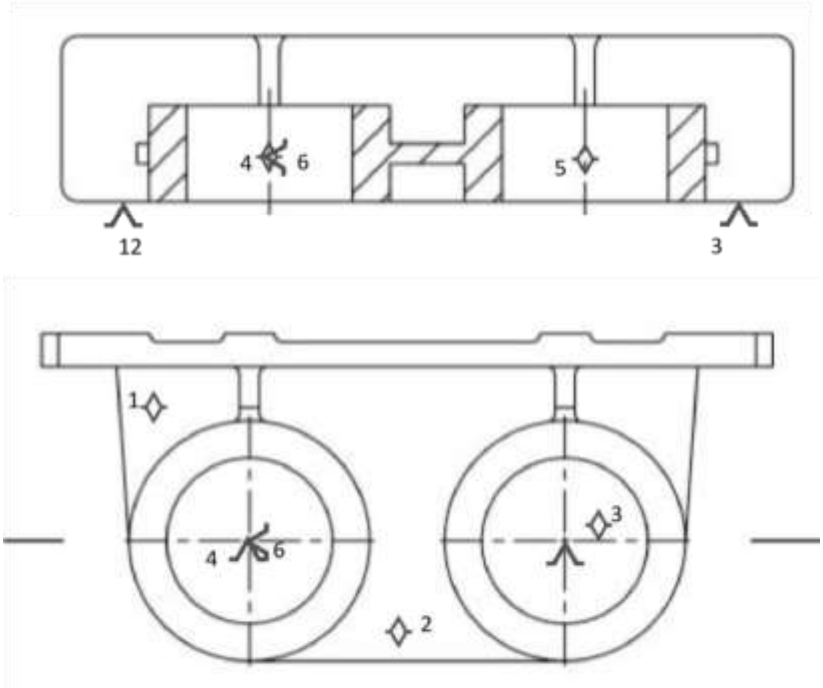



*Figure 16*




The formula for the land acquisition scheme presented in Fig 1.12 is as follows:

$LS_{MD}$ => S (3) + DS (2) + O (1)

The third variant is shown in Fig.

Advantages:

- Provides uniformity in the axis of large holes in the datum plane;
- The same grant for further processing of the two major holes;

Disadvantages:

- Rather complicated in use (double guide data is used with an expandable plunger mandrel);

- Proper placement of undeveloped areas compared to those considered has not been guaranteed.

*Figure 18*

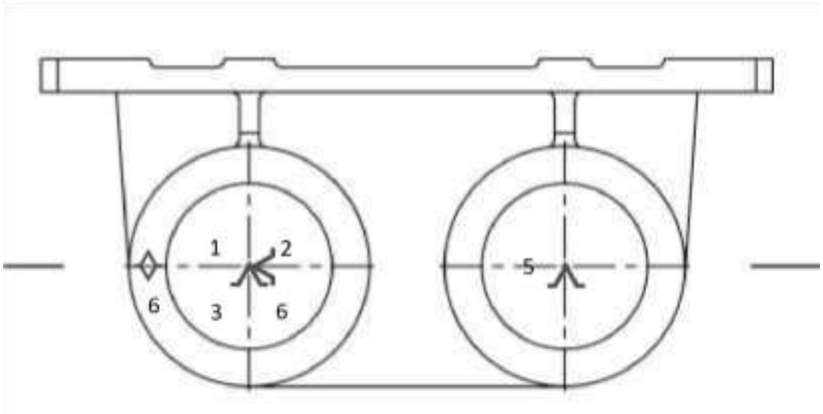



*Figure 17*

Figure 1.13 - Locating scheme for the first manufacturing operation

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

$$LS_{MD} \Rightarrow DG\ (4) + O\ (1) + O\ (1) \qquad (2.6)$$

The fourth variant is shown in Fig. 1.14.

Advantages:

- Easy to use.
- Ensures the perpendicularity of the unallocated area relative to the data surface
- Confirms the similarity of the unresolved area relative to the datum area, but only in the specified section, where the mounting objects are found.

Disadvantages:

- Prevents processing of the work piece from the three sides,
- Make unequal revenue for large housing pits in the following stages of operation;

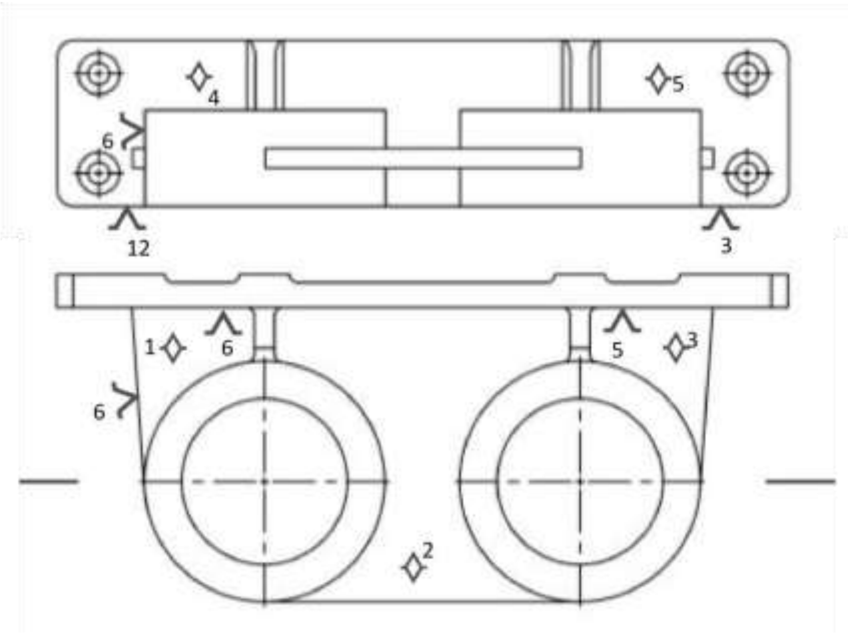



Figure 1.14 – Locating scheme for the first manufacturing operation

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

$LS_{MD}$ => S (3) + G (2) + O (1) (2.6)

**2.6. Conclusion:**

The forth location locomotive system (Figure 1.14) is easy to use, and provides a precise location for unstructured surfaces in relation to the processed surfaces. The provided system allows you to process a few additional surfaces without the usual manufacturing data during the initial production work. Therefore, we will use a different acquisition scheme like fourth variant to process standard manufacturing data.

**2.7 Design of the typical surfaces processing routes**

A component design can be divided into a set of standard geometric shapes, integrated with the common segment service of that specific part. The most common structural elements are: cylindrical or conical exterior and interior, plane set, molded areas - screw, involute and others. Depending on the type of site, different cutting tools can be used to achieve the accuracy of a given area and, as a result, there are different local treatment sequences.

The development of mechanical corridors in isolated areas is the first of seven tasks solved in the plan development of that process. The production process created in this way, wrapped in time and space, solves the problems of precision size, shape and quality of each space, but ignores the accuracy of the related area at all. Latterly, we solved this task by providing local schemes and dividing the processing stages into modules - rough, finish and final.

When process of manufacturing as developing, you need to choose one of the few

manufacturing options, which will provide the best economic solution. Therefore, to save the time, it is necessary to use standard, proven performance, parts production processes and processing of their main components.

In part, it was introduced to the fig. 1.15; the order of the selected common equipment and the accuracy achieved and the efficiency of the workplaces are given in table 1.3. Spatial distribution is given in fig.

/

## 3 Design of the typical surfaces processing routes

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Spatial distribution is given in fig. 1.16.

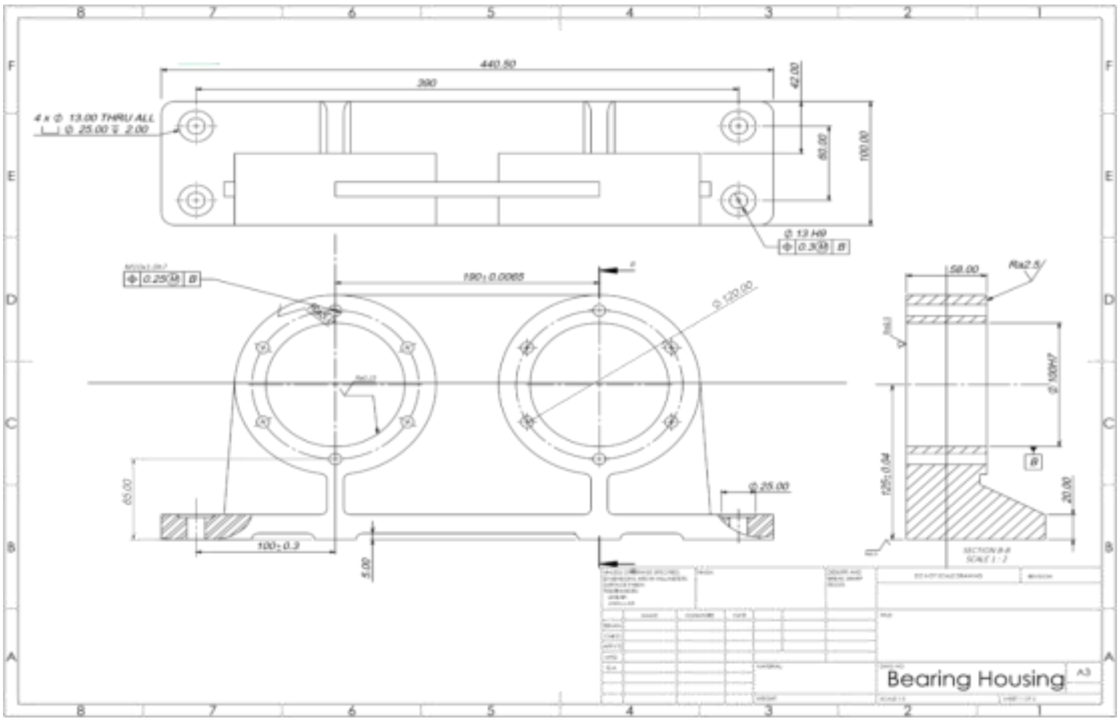



*Figure 19*

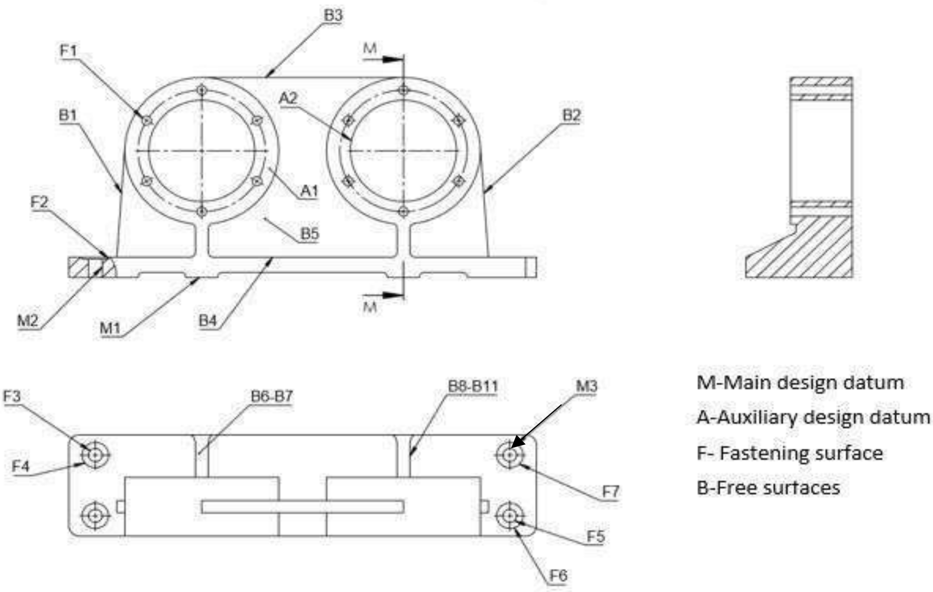

B3
F1
M
A2
B1
B2
A1
F2
B5
M2
M1
B4
M
F3
B6-B7
B8-B11
M3
F4
F7
F5
F6
M-Main design datum
A-Auxiliary design datum
F- Fastening surface
B-Free surfaces

*Table 3 design of manufacturing process plan*

| **Surfaces** | **IT** | **Ra** | **Machining sequence** | **IT** | **Ra** |
|---|---|---|---|---|---|
| | According to the drawing | | | After machining | |
| 1 | 2 | 3 | 4 | 5 | 6 |
| M1 | 14 | 2.5 | Rough milling<br>Finish milling | 14 | 6,3<br>2,5 |
| M2, M3 | H | 2.5 | Centering<br>Drilling<br>Reaming | H | 2,5<br>1,25 |
| A1 | 14 | 2.5 | Rough milling<br>Finish milling | 14 | 6,3<br>2,5 |
| A2 | H | 2.5 | Centering<br>Drilling | H | |
| | | | Reaming | | 2,5<br>1,25 |
| F1 | H | 5 | Centering<br>Drilling<br>Reaming | H | 2,5<br>1,25 |
| F3, F5 | H | 2.5 | Centering<br>Drilling<br>Reaming | H | 2,5<br>1,25 |

| | | | | | |
|---|---|---|---|---|---|
| F2, F4, F6, F7 | H | 10 | Counter boring<br>Finish | H | |

| Part No:2000 | | Part Name:<br>Bearing housing | Rev 3 | | Page 1 of 2 | | |
|---|---|---|---|---|---|---|---|
| Mat:<br>Grey-cast iron | | Size:<br>440mm long * 200mm width *<br>197.5 height | Planner:<br>Omar | | Date:<br>9/01/2022 | | |
| No | Operation | | Dept. | Machine | Tooling gauges | Setup time | Cycle time |
| 20 | Face milling; M1. to height or thickness<br>20mm<br>Rough milling; Ra 6.3<br>Finish milling; Ra 2.5, IT 14 | | | | | | |

## 3.1 Machine and tool selection

## 3.2 Machine selection

Type and size of machine The types of machines 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 work piece. 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

Center is TAJMAC-ZPS H500.

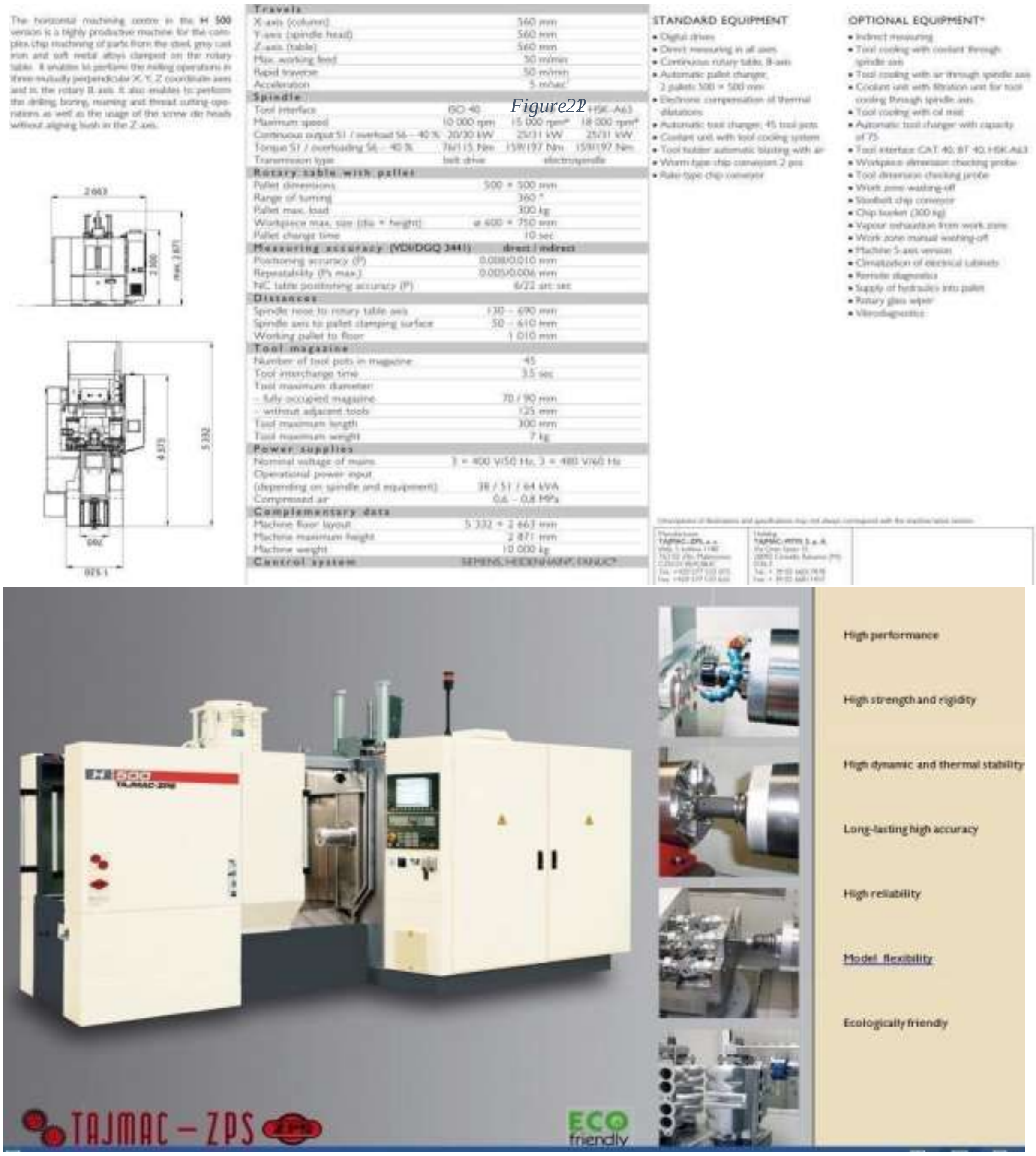



Figure22

### 3.3 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 work piece characteristics – At this step the following should be considered: work piece 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
“10 Mill surface M1 to dimension
440*200*23”

Allowance = 2.5mm

Radial cutting width = 10mm

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 workpiece material

**(fig. 8.2).**

After applying the initial data, consider the results of analysis: recommended cutting tool and cutting conditions (fig. 8.3). Fig. 8.3 Recommended cutting tool and cutting data

1.

2.

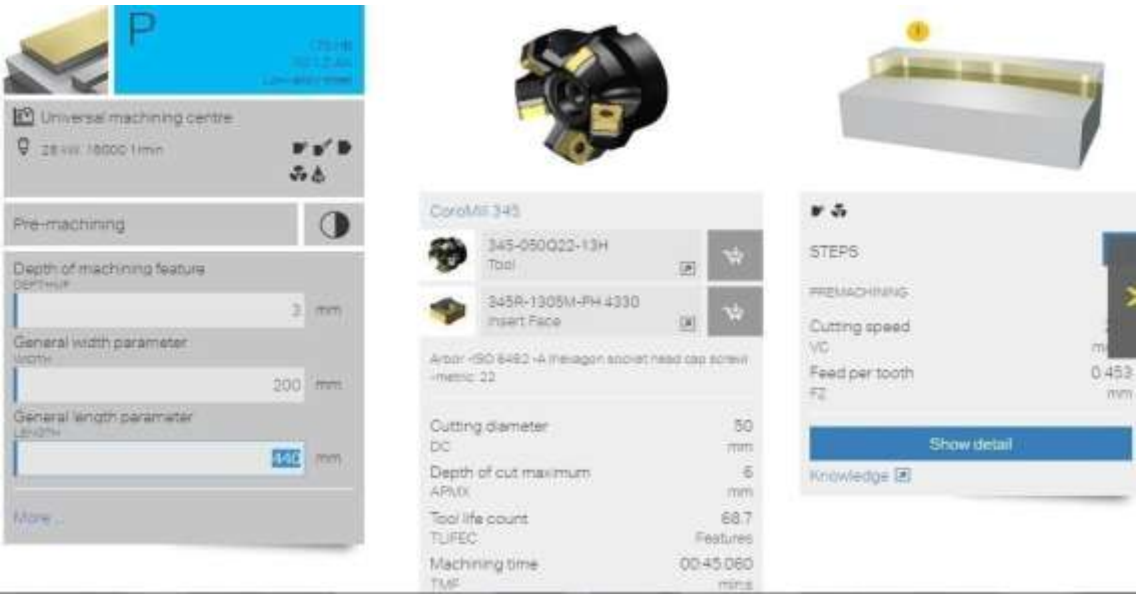
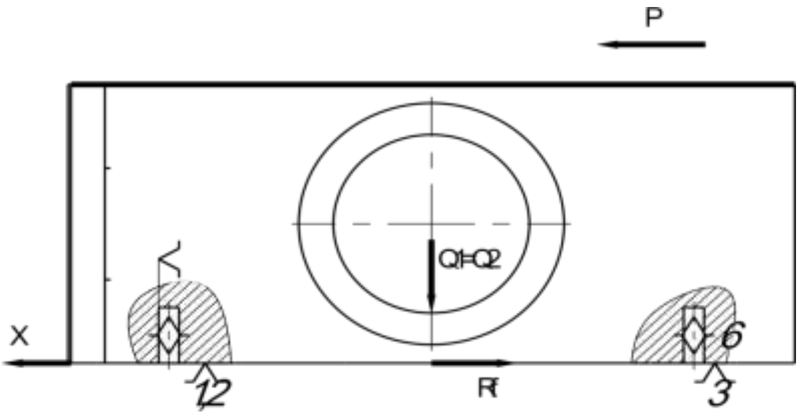



*Figure 23 Initial Data for tooling selection (screenshot)*

### 4. Modular fixture design

Maximum cutting force on operations - components of cutting forces Pz and Py when milling with an end mill. Under the action of cutting forces, the work piece may shift in the X direction, as shown in Fig.3.5. Figure 3.5 - Scheme of Forces




Accordingly for these conditions we calculate the clamping force Q required for reliable fixing of the work piece.

For calculation we accept the following simplifying assumptions:

1. The weight of the work piece is not taken into account.
2. Supports and clamping mechanism are rigid.
3. The setting fingers do not perceive the cutting force

Based on the equilibrium condition, we find the allowable force Q:

〖 〖$X = 0$, $kP = 2Q \cdot (f_1 + f_2)$, $Q = kP / (2 \cdot (f_1 + f_2))$ 〗

Where $P = \sqrt{(Pay^2 + P_z^2)} = \sqrt{(0.16P_z^2 + P_z^2)} = 1.07P_z$ Pz - tangential component of cutting during milling, Pz = 7090N (see p.2.1.5) K is the coefficient of fastening reliability; f1 is the coefficient of friction for the untreated surface at the point of contact of the clamping mechanism with the part, f1 = 0.25;

f2 is the coefficient of friction for the treated surface at the point of contact of the

part with the supports, f2 = 0.10… 0.16 = 0.10;

Then, $kP = 2Q \cdot (f_1 + f_2)$, $Q = (1.07 \cdot k \cdot P_z) / (2 \cdot (f_1 + f_2))$

Since in production conditions there may be deviations from the conditions in relation to which were calculated according to the standards of force and cutting moments, their possible increase should be taken into account by introducing a coefficient of reliability (stock) of fixing k.

The value of the reliability factor k should be chosen differentiated depending on the specific conditions of the operation and the method of fixing the work piece. Its value can be represented as the product of coefficients, each of which reflects the influence of a certain factor:

$k = k_0 \cdot k_1 \cdot k_2 \cdot k_3 \cdot k_4 \cdot k_5 \cdot k_6$ k0 - guaranteed coefficient of safety

margin, k0 = 1.5; k1 - coefficient that takes into account the increase in cutting force due to random irregularities on the work piece; k1 = 1, 2 - for roughing; k1 = 1, 0 - for finishing; k2 - coefficient that takes into account the increase in cutting force due to blunting of the tool

(Table); k3 is the coefficient that takes into account the increase in cutting force during intermittent cutting, k3 = 1,2; k4 - takes into account the inconsistency of the clamping force; k4 = 1, 3 - for manual clamps; k4 = 1, 0 - for pneumatic and hydraulic clamps; k5 - takes into account the degree of convenience of the location of the handl
in the manual Clamps; k5 = 1, 2 - at the range of the angle of deviation of the handle 900; k5 = 1, 0 - at a convenient location and small length of the handle; k6 - takes into account the uncertainty due to the unevenness of the contact of the work piece with the support elements having a large support surface (taken into account only in the presence of torque, when turning the work piece); k6 = 1,0 - for the support element having a limited contact surface with the work piece; k6 = 1.5 - for a support element with a large contact area. The value of k can range from 1.5… 8.0. If k <2.5, then when calculating the reliability of the fastening it should be taken equal to k = 2.5

(According to GOST

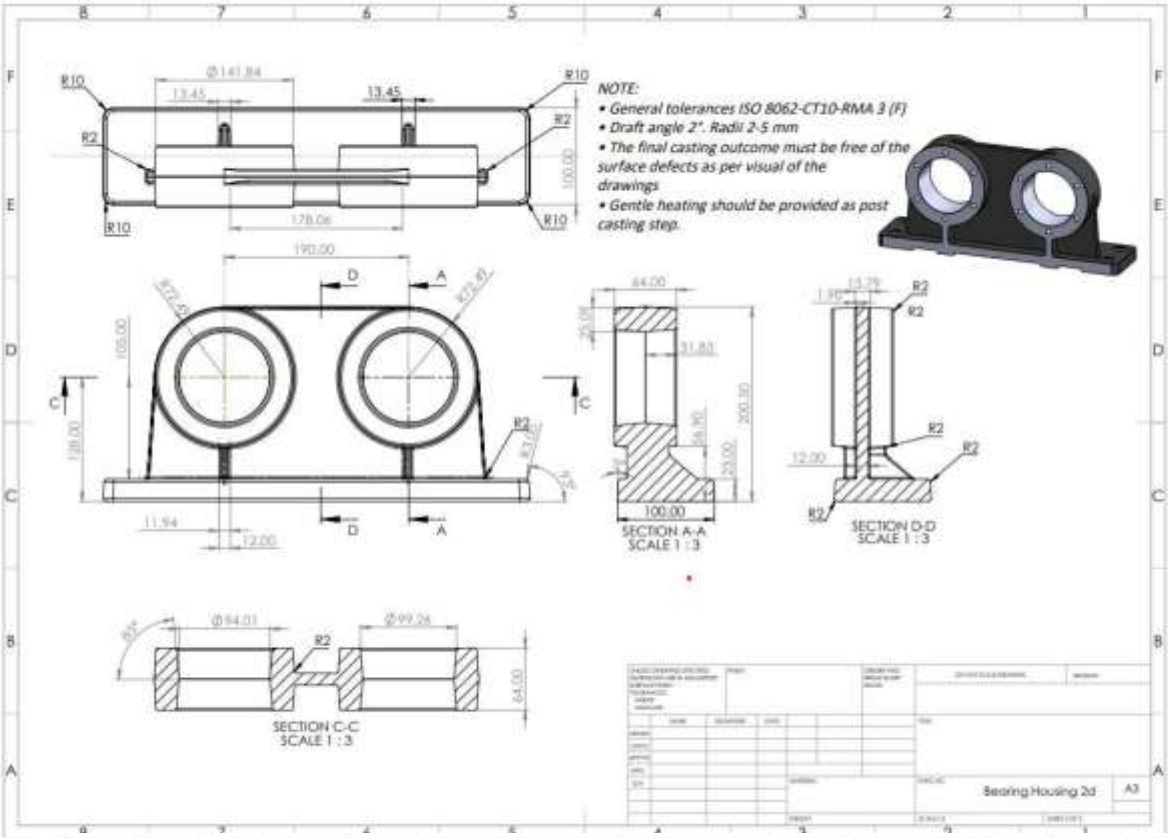
12.2.029-77). $k = 1.5 \cdot$

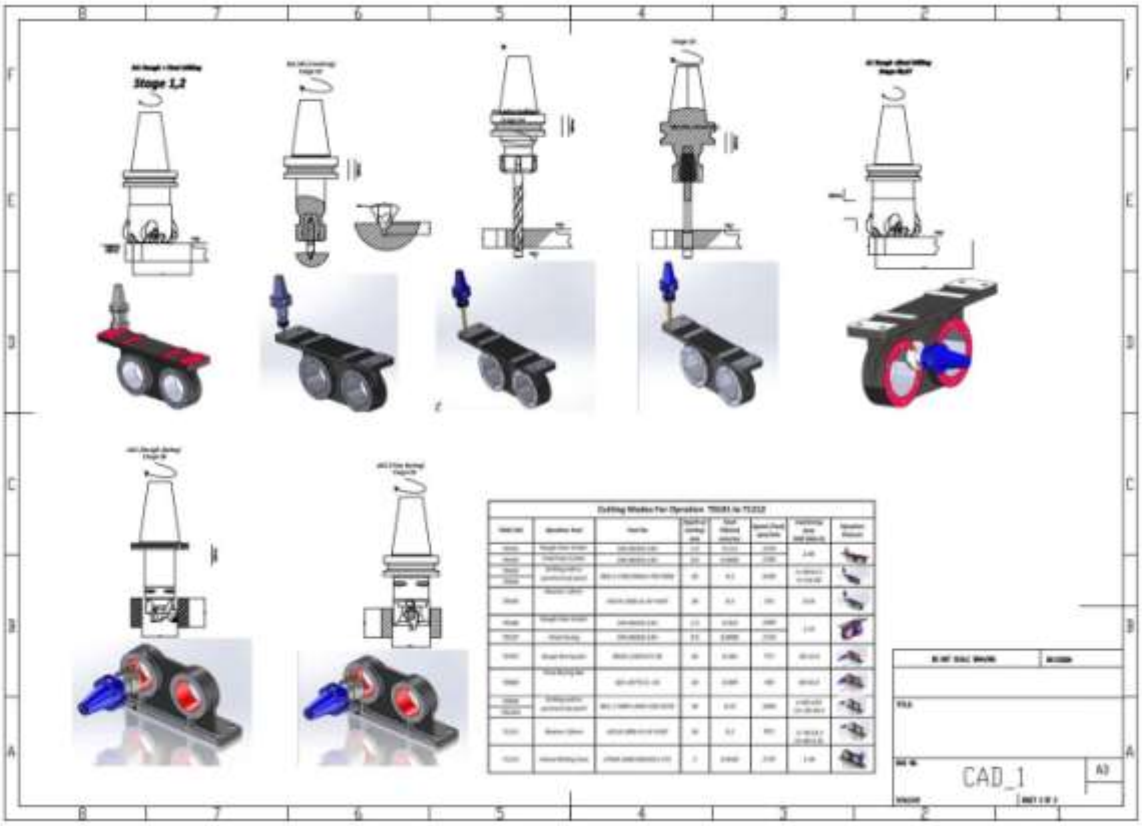
$1.2 \cdot 1.3 \cdot 1.2 \cdot 1 \cdot 1 \cdot 1 = 2.8.$

Therefore, $Q = (1.07 \cdot k \cdot P_z) / (2 \cdot (f_1 + f_2)) = (1.07 \cdot 2.8 \cdot 3486) / (2 \cdot (0.25 + 0.1)) = 4444.3H$

| Processing method | Components of cutting forces | K2 | Processed material |
|---|---|---|---|

| | | | |
|---|---|---|---|
| Drilling | Torque M<br>Axial force P0 | 1,15<br>1,10 | Cast iron |
| Preliminary countersinking | Torque M<br>Axial force P0 | 1,3<br>1,2 | Cast iron when worn o the back surface of the cutter-1.5 mm |
| Preliminary turning | Tangential force Pz<br>Radial force P0<br>Feed force Px | 1,0<br>1,4<br>1,2<br>1,6<br>1,25 | Steel and cast iron<br>Steel<br>Cast iron<br>Steel<br>Cast iron |
| Cylindrical pre- and finished milling | Wheel force Pz | 1,75-1,90<br>1,2-1,4 | Cold steel<br>Hard steels and cast irons |
| Face preliminary and final milling | Wheel force Pz | 1,75-1,90<br>1,2-1,4 | Viscous steels and cas irons<br>Hard steels and cast irons |


NOTE:
• General tolerances ISO 8062-CT10-RMA 3 (F)
• Draft angle 2°. Radii 2-5 mm
• The final casting outcome must be free of the surface defects as per visual of the drawings
• Gentle heating should be provided as post casting step.
SECTION A-A
SCALE 1 : 3
SECTION D-D
SCALE 1 : 3
SECTION C-C
SCALE 1 : 3
Bearing Housing 2d
A3


Stage 1,2
CAD_1
A3

3D viewer

392.55EH-40 25 108

- 1 + Save for later

Add

316-25HM450-25030P 1030

Downloads

Product data

Usable length (LU)
**25.6 mm**

Maximum ramping angle (RMPX)
**5 deg**

Weight of item (WT)
**1.632 kg**

Body length (LB)
**25.6 mm**

Rotational speed maximum (RPMX)
**18,000 1/min**

Depth of cut maximum (APMX)
**13.5 mm**

Cutting diameter (DC)
**25 mm**

Corner radius (RE)
**12 mm**

Axial rake angle (GAMP)
**6 deg**

Peripheral effective cutting edge count (ZEFP)
**4**

Tool style code (TSYC)
**316..HM..P**

Hand (HAND)
**R**

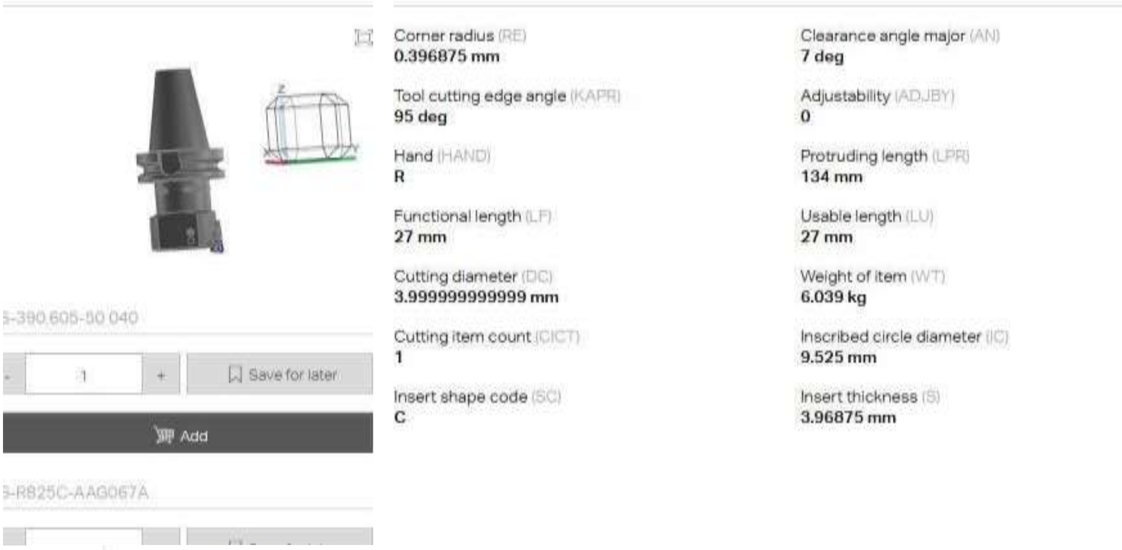
Tool cutting edge angle (KAPR)
**31.57 deg**

Functional length (LF)
**25.6 mm**

Cutting pitch differential (CPDF)
**0**

Grade (GRADE)
**1030**

Radial rake angle (GAMF)
**-18 deg**




Corner radius (RE)
**0.396875 mm**

Tool cutting edge angle (KAPR)
**95 deg**

Hand (HAND)
**R**

Functional length (LF)
**27 mm**

Cutting diameter (DC)
**3.999999999999 mm**

Cutting item count (CICT)
**1**

Insert shape code (SC)
**C**

Clearance angle major (AN)
**7 deg**

Adjustability (ADJBY)
**0**

Protruding length (LPR)
**134 mm**

Usable length (LU)
**27 mm**

Weight of item (WT)
**6.039 kg**

Inscribed circle diameter (IC)
**9.525 mm**

Insert thickness (S)
**3.96875 mm**

*Figure26*


Grade
**GC34**

Cutting diameter
**13 mm**

Point length
**1.9 mm**

Functional length
**77.0639 mm**

Body diameter
**13 mm**

Hand
**R**

Rotational speed maximum
**7,346 1/min**

Coolant entry style code
**4**

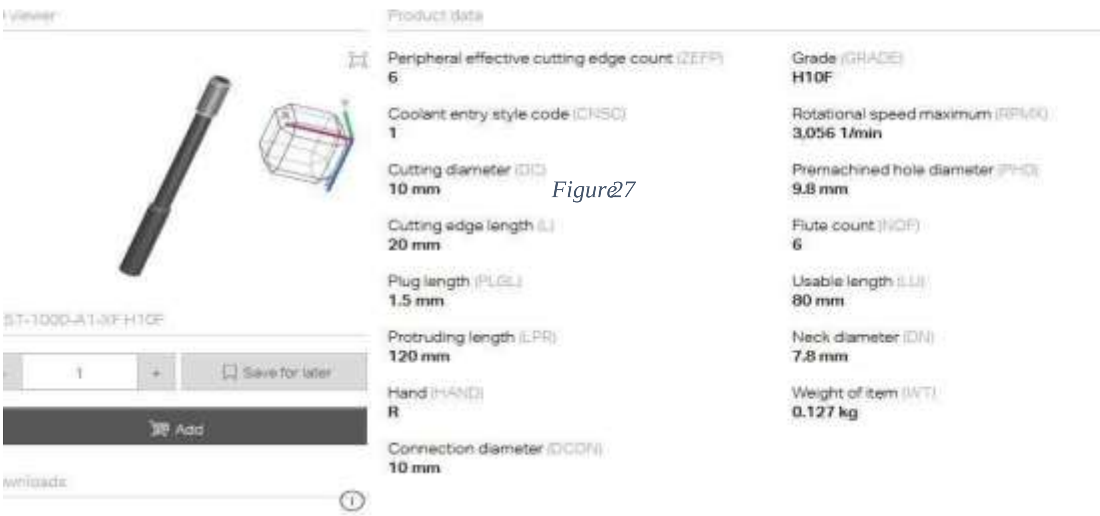
Point angle
**140 deg**

Usable length
**61.4 mm**

Protruding length
**149 mm**

Body length
**79 mm**

Weight of item
**1.485 kg**




Peripheral effective cutting edge count (ZEFP)
**6**

Coolant entry style code (CNSC)
**1**

Cutting diameter (DC)
**10 mm**

Cutting edge length (L)
**20 mm**

Plug length (PLGL)
**1.5 mm**

Protruding length (LPR)
**120 mm**

Hand (HAND)
**R**

Connection diameter (DCON)
**10 mm**

Grade (GRADE)
**H10F**

Rotational speed maximum (RPMX)
**3,056 1/min**

Premachined hole diameter (PHD)
**9.8 mm**

Flute count (NOF)
**6**

Usable length (LU)
**80 mm**

Neck diameter (DN)
**7.8 mm**

Weight of item (WT)
**0.127 kg**

*Figure27*

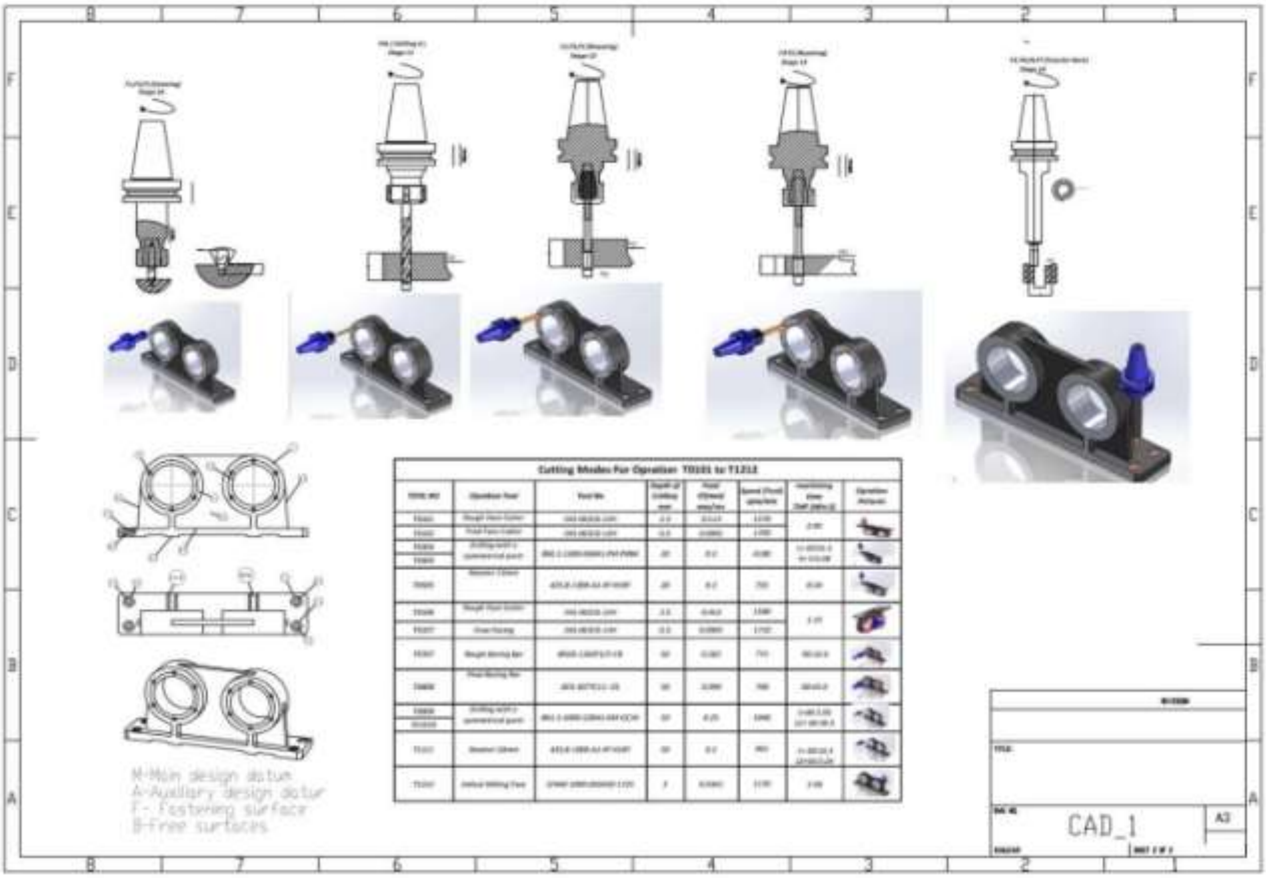



*Figure 28*

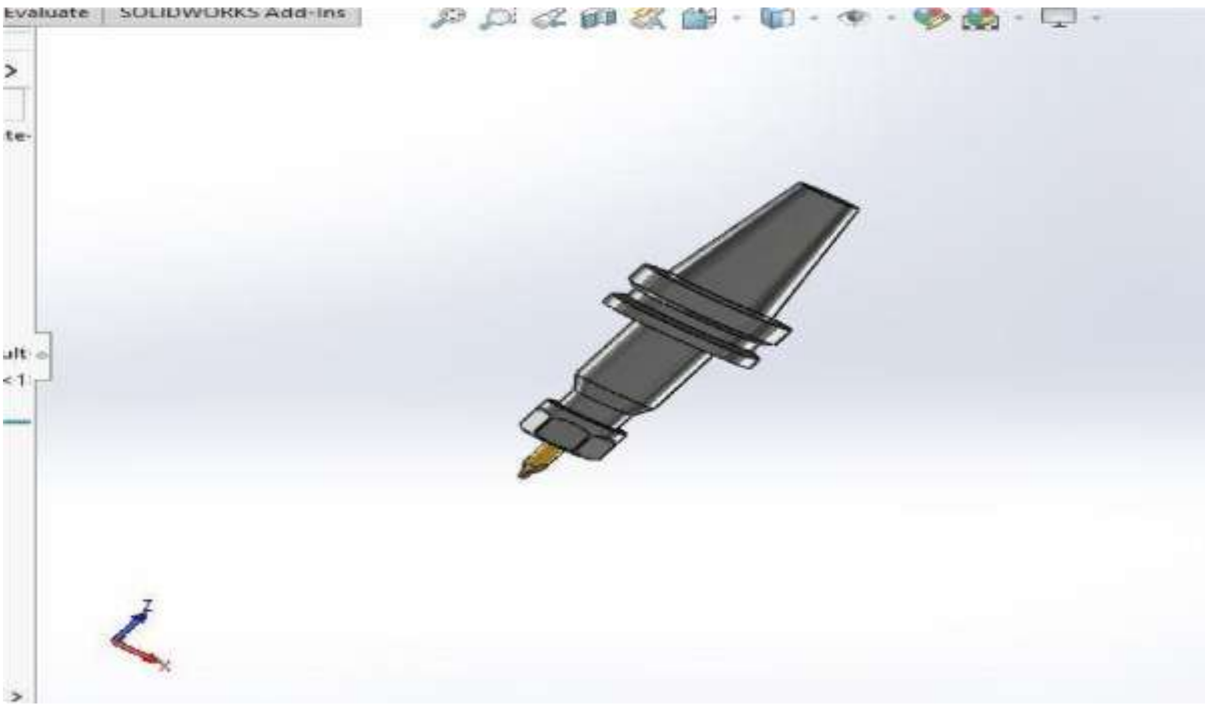
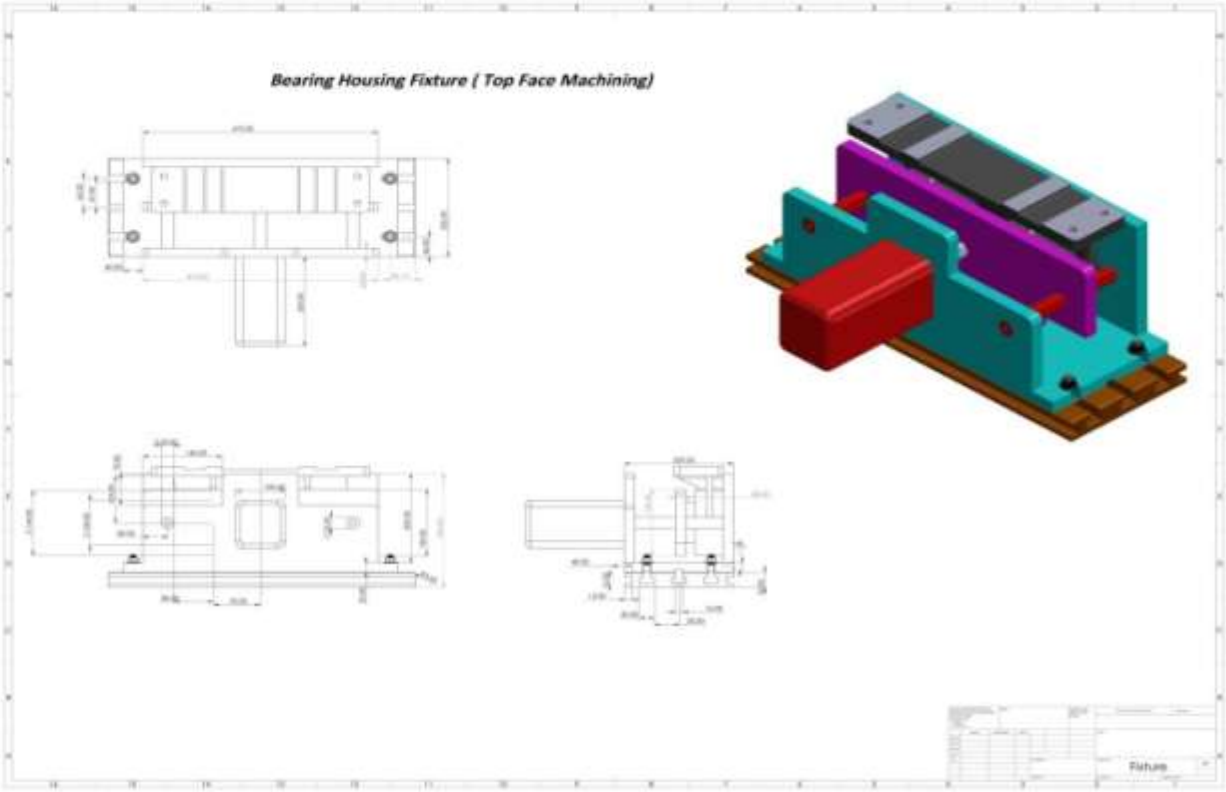
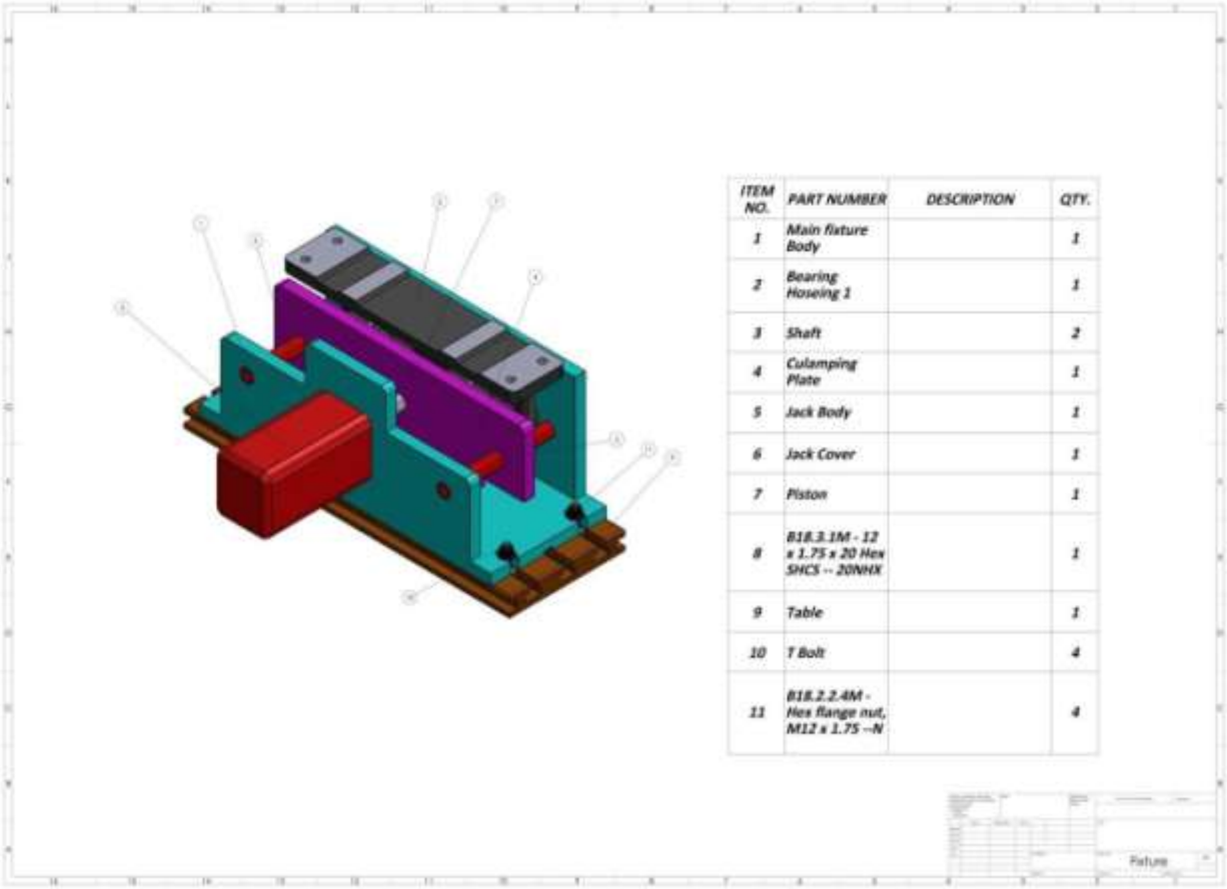


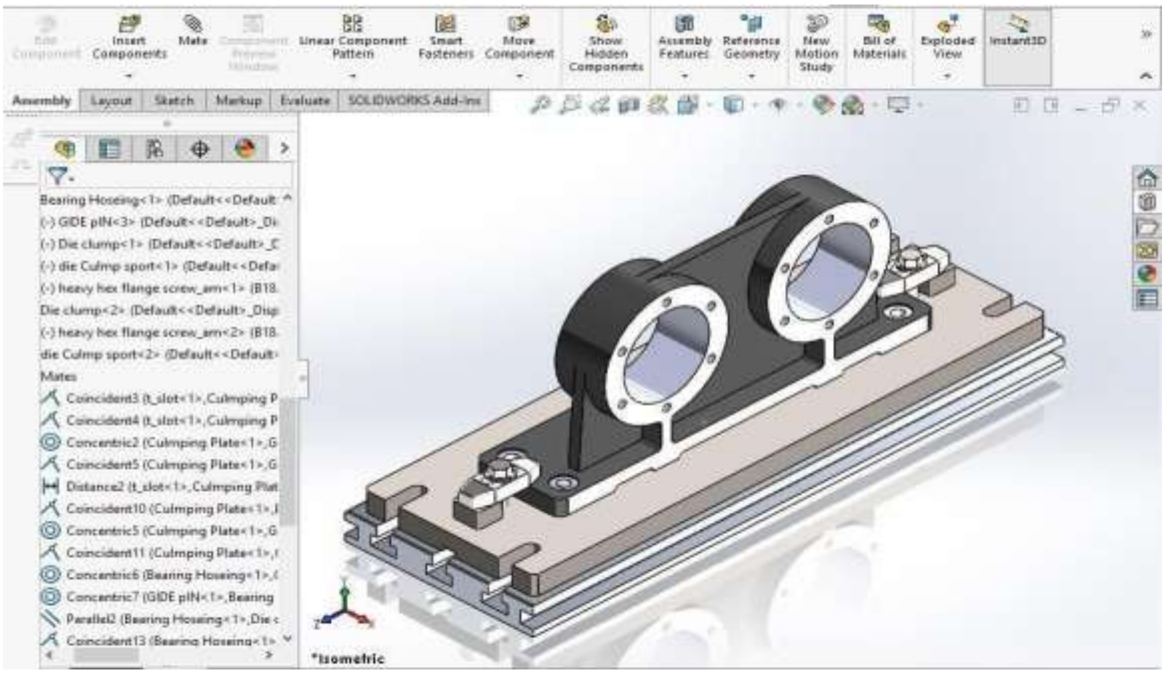

*Figure 29*




| ITEM NO. | PART NUMBER | DESCRIPTION | QTY. |
|---|---|---|---|
| 1 | Main fixture Body | | 1 |
| 2 | Bearing Hoseing 1 | | 1 |
| 3 | Shaft | | 2 |
| 4 | Culamping Plate | | 1 |
| 5 | Jack Body | | 1 |
| 6 | Jack Cover | | 1 |
| 7 | Piston | | 1 |
| 8 | B18.3.1M - 12 x 1.75 x 20 Hex SHCS -- 20NHX | | 1 |
| 9 | Table | | 1 |
| 10 | T Bolt | | 4 |
| 11 | B18.2.2.4M - Hex flange nut, M12 x 1.75 --N | | 4 |

*Figure 30*


Insert Components
Mate
Linear Component Pattern
Smart Fasteners
Move Component
Show Hidden Components
Assembly Features
Reference Geometry
New Motion Study
Bill of Materials
Exploded View
Instant3D
Assembly
Layout
Sketch
Markup
Evaluate
SOLIDWORKS Add-Ins
Bearing Hoseing<1> (Default<<Default
(-) GIDE pIN<3> (Default<<Default>_Di
(-) Die clump<1> (Default<<Default>_D
(-) die Culmp sport<1> (Default<<Defa
(-) heavy hex flange screw_am<1> (B18.
Die clump<2> (Default<<Default>_Disp
(-) heavy hex flange screw_am<2> (B18.
die Culmp sport<2> (Default<<Default>
Mates
Coincident3 (t_slot<1>,Culmping P
Coincident4 (t_slot<1>,Culmping P
Concentric2 (Culmping Plate<1>,G
Coincident5 (Culmping Plate<1>,G
Distance2 (t_slot<1>,Culmping Plat
Coincident10 (Culmping Plate<1>,
Concentric5 (Culmping Plate<1>,G
Coincident11 (Culmping Plate<1>,
Concentric6 (Bearing Hoseing<1>,
Concentric7 (GIDE pIN<1>,Bearing
Parallel2 (Bearing Hoseing<1>,Die
Coincident13 (Bearing Hoseing<1>
*Isometric

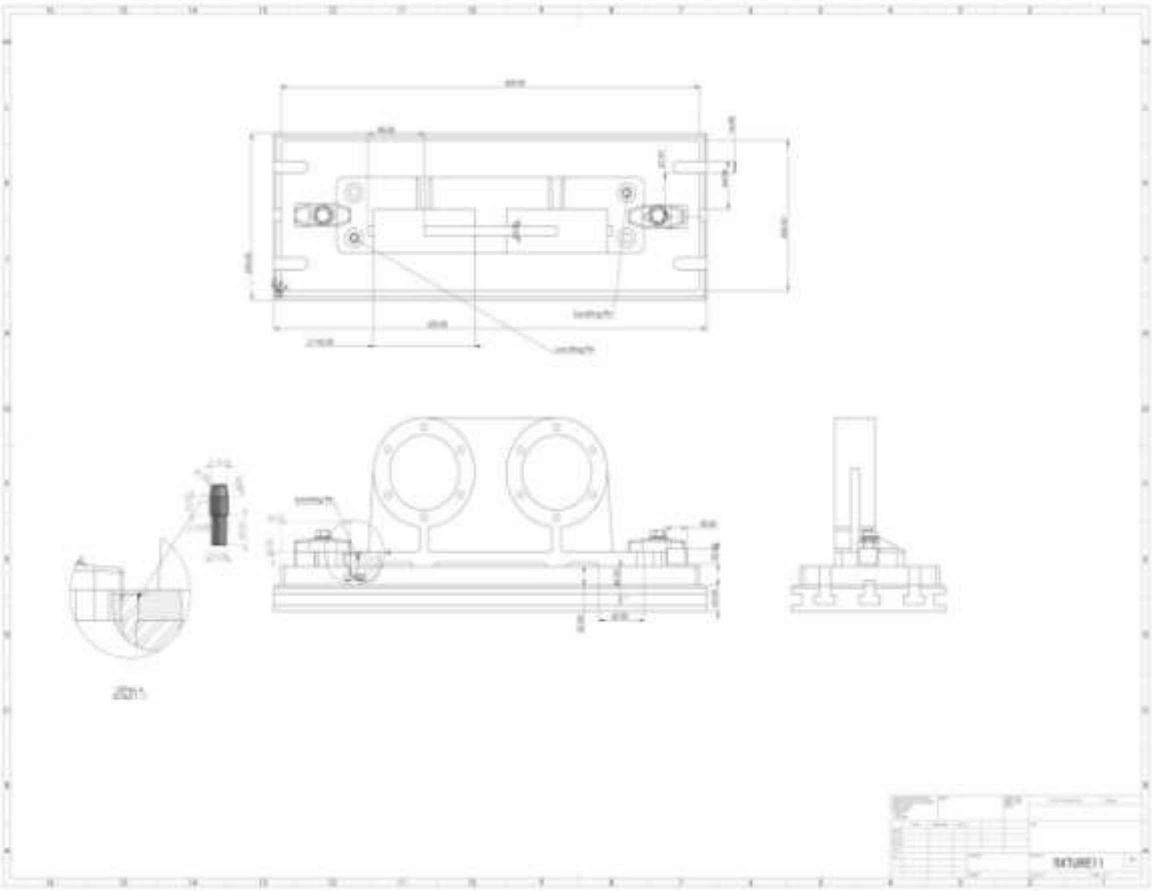
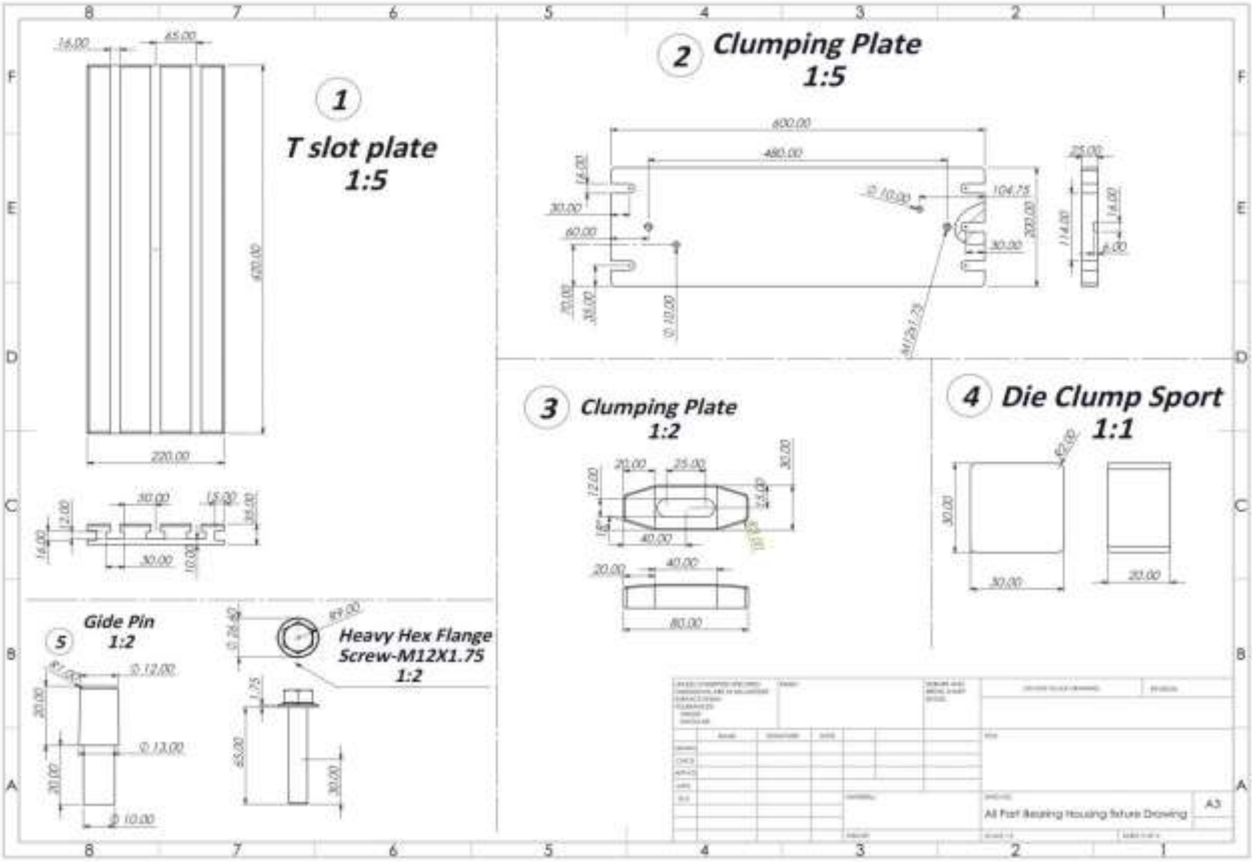


*Figure 31*



1
T slot plate
1:5
2
Clumping Plate
1:5
3
Clumping Plate
1:2
4
Die Clump Sport
1:1
5
Gide Pin
1:2
Heavy Hex Flange
Screw-M12X1.75
1:2


*Figure 32*

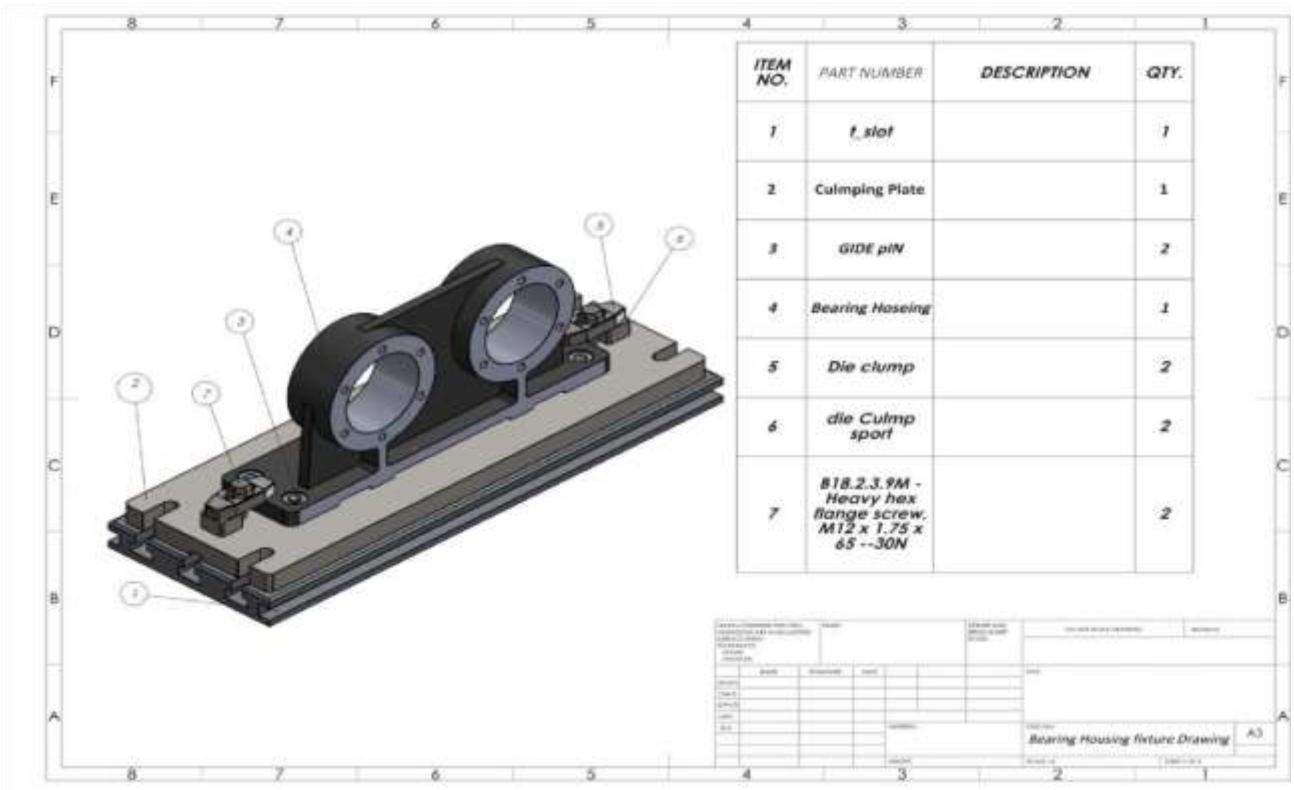
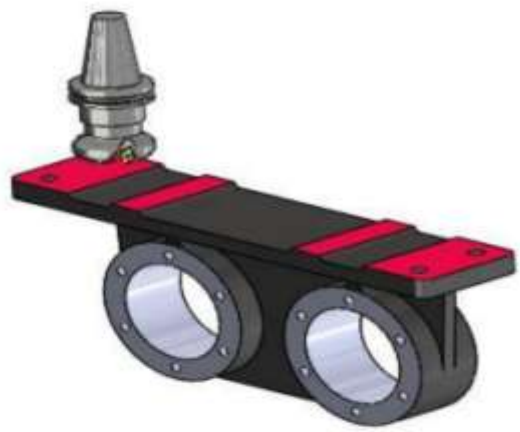



*Figure 33*



```
%

00001

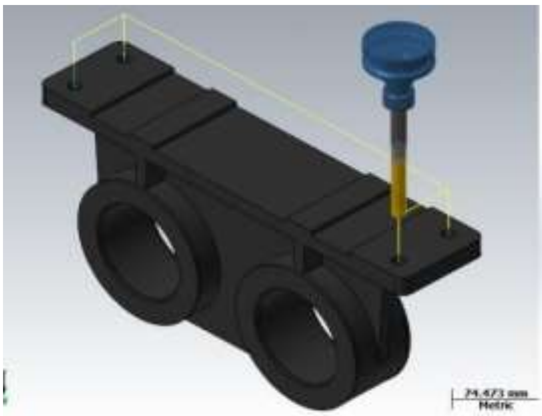
(CASTING FACING 1)

(Face 1 FACE MILL 345-
063C6-13H | H1 | XY
STOCK TO LEAVE-0. | Z
STOCK TO LEAVE - 1.)

N1 G2
N2 GO G17 G40 G49 G80
G90
N3 TO1 M6
N4 GO G90 G54 X-
68.243 Y375.498 AO.
S1570 M3
N5 G43 H1 Z25.
N6 Z1O.

N7 G1 Z-2.5 F25,
N8 X136,743 F50.
N9 X137.8 Y353.833
N10 X-37.8
N11 Y332.167
N12 X137.8
N13 Y310.502
N14 X-69.3
N15 GO Z25
. N16 X-68.243 Y375.498
```

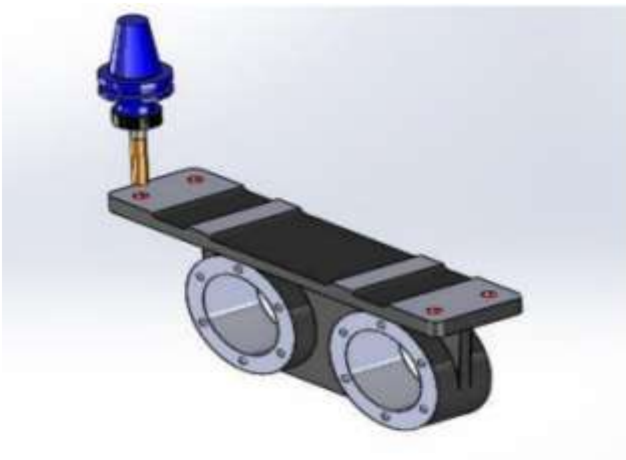
N17 Z10.
N18 G1 Z-3. F25.
N19 X136,743 F50.
N20 X137.8 Y353.833
N21 X-37.8
N22 Y332.167
N23 X137.8
N24 Y310.502
N25 X-69.3
N26 GO Z25.
N27 Y265.248
N28 Z10.
N29 G1 2-2.5 F25.
N30 X137.8 F50.
N31 Y235.252
N32 X-69.3
N33 GO Z25.
N34 Y265.248
N35 210.
N36 G1 Z-3. F25.
N37 X137.8 F50.
N38 Y235.252
N39 X-69.3
N40 GO Z25.
N41 Y75.248
N42 Z10.
N43 G1 Z-2.5 F25.
N44 X137.8 F50.
N45 Y45.252
N46 X-69.3
N47 GO Z25.
N48 Y75.248
N49 Z10.
N50 G1 Z-3. F25.
N51 X137.8 F50.
N52 Y45.252
N53 X-69.3
N54 GO Z25.
N55 Y-.002
N56 Z10.
N57 G1 2-2.5 F25.
N58 X137.8 F50.
N59 Y-21.667
N60 X-37.8
N61 Y-43.333
N62 X137.8
N63 X136.743 Y-64.998
N64 X-68.243
N65 GO Z25.
N66 X-69.3 Y-.002
N67 210.
N68 G1 Z-3. F25.
N69 X137.8 F50.
N70 Y-21.667
N73 X 279 N71 X-37.8
N72 Y-43.333
N73 X137.8
N74 X136.743 Y-64.998
N75 X-68.243
N76 GO Z25.
N77 M5 »
N78 G91 G28 ZO.
N79 G28 XO, YO. AO,
N80 M30
%




%
O0000(REQUIRED FOR THE CASTING CENTER DRILL HOLE 13 MM)
(MATERIAL - IRON MM - CAST - DUCTILE - AUSTENSITIC - 160BHN)
( T2( 860.1-1300-040A1-PM PIBM)| H2 )
N1 G21
N2 G0 G17 G40 G49 G80 G90
N3 T2 M6
N4 G0 G90 G54 X-390.5 Y0. A0. S3184 M3
N5 G43 H2 Z50. M8
N6 G98 G81 Z-3. R25. F990.2
N7 Y60.
N8 X0.
N9 Y0.
N10 G80
N11 X-390.5
N12 G98 G81 Z-22.616 R25. F990.2
N13 Y60.
N14 X0.
N15 Y0.

N16 G80
N17 X-390.5
N18 G98 G81 Z-
22.616 R25. F990.2
N19 Y60.
N20 X0.
N21 Y0.
N22 G80
N23 M5
N24 G91 G28 Z0. M9
N25 G28 X0. Y0. A0.
N26 M30

(REQUIRED FOR
THE CASTING
DRILL 13MM)
(MATERIAL - IRON
MM - CAST -
DUCTILE -
AUSTENSITIC -
160BHN)
( T2 860.1-1300-
040A1-PM PIBM ) (
H3 )
N1 G21
N2 G0 G17 G40 G49
G80 G90
N3 T2 M6
N4 G0 G90 G54 X-
390.5 Y0. A0. S4180
M3
N5 G43 H3 Z50. M8
N6 G98 G81 Z-3. R25.
F990.2
N7 Y60.
N8 X0.
N9 Y0.
N10 G80
N11 X-390.5
N12 G98 G81 Z-
22.616 R25. F990.2
N13 Y60.
N14 X0.
N15 Y0.
N16 G80
N17 X-390.5
N18 G98 G81 Z-
22.616 R25. F990.2
N19 Y60.
N20 X0.
N21 Y0.
N22 G80
N23 M5
N24 G91 G28 Z0. M9
N25 G28 X0. Y0. A0.
N26 M30
%



(REQUIRED FOR THE CASTING REAMER 13MM)
(MATERIAL - IRON MM - CAST - DUCTILE - AUSTENSITIC - 160BHN)
(T3 435.B-1300-A1-XF H10F) (H4 )
N1 G21
N2 G0 G17 G40 G49 G80 G90
N3 T3 M6
N4 G0 G90 G54 X-390.5 Y0. A0. S3184 M3
N5 G43 H4 Z50. M8
N6 G98 G81 Z-3. R25. F990.2
N7 Y60.
N8 X0.
N9 Y0.
N10 G80
N11 X-390.5
N12 G98 G81 Z-22.616 R25. F990.2
N13 Y60.
N14 X0.
N15 Y0.
N16 G80
N17 X-390.5
N18 G98 G81 Z-22.616 R25. F990.2
N19 Y60.
N20 X0.
N21 Y0.
N22 G80
N23 M5
N24 G91 G28 Z0. M9
N25 G28 X0. Y0. A0.
N26 M30
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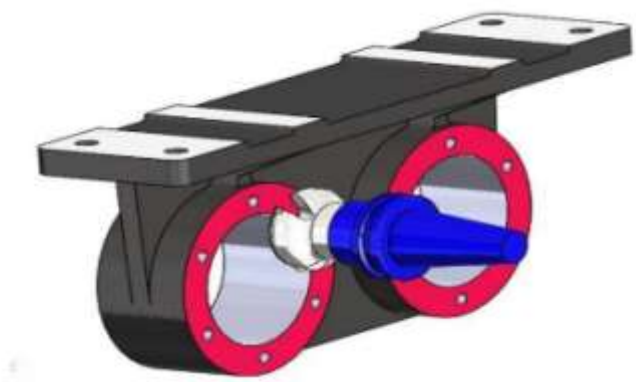

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O0200(CASTING OF FACING 2)
(MATERIAL - IRON MM - CAST - DUCTILE - AUSTENSITIC - 160BHN)
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N100 G21
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N120 T4 M6
N130 G0 G90 G54 X131.94 Y23.515 A0. S2342 M3
N140 G43 H5 Z74.411 M8
N150 Z49.411
N160 G1 X130.699 Z49.849 F3438.1
N170 X129.923 Z50.119
N180 X128.706 Z50.549
N190 X128.347 Z50.673
N200 X128.161 Z50.732

N210 X127.892
Z50.824
N220 X126.376 Z51.3
N230 X124.841
Z51.786
N240 X124.048
Z52.025
N250 X123.836
Z52.088
N260 X120.986
Z52.881
N270 X119.911
Z53.164
N280 X118.03 Z53.63
N290 X117.715 Z53.7
N300 X58.064
N310 G0 Z78.7
N320 X-58.06
N330 Z74.411
N340 Z49.411
N350 G1 X-58.267
Z49.486
N360 X-59.567
Z49.946
N370 X-60.59 Z50.297
N380 X-62.108
Z50.824
N390 X-62.355
Z50.902
N400 X-62.61 Z50.989
N410 X-63.429
Z51.247
N420 X-64.359 Z51.53
N430 X-65.4 Z51.856
N440 X-66.164
Z52.088
N450 X-66.482
Z52.177
N460 X-66.85 Z52.288
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Z52.407
N480 X-68.098
Z52.625
N490 X-69.093
Z52.901
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Z53.185
N510 X-70.531
Z53.272
N520 X-71.03 Z53.403
N530 X-71.886
Z53.599
N540 X-72.304 Z53.7
N550 X-131.932
N560 X-175.052
Y52.511
N570 Z49.411
N580 X-172.838
Z51.161
N590 X-172.15
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Z52.547
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Z53.178
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Z53.659
N630 X-169.571 Z53.7
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N650 X14.95
N660 Z49.411
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Z49.623
N680 X17.629
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N710 X20.429 Z53.7
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Y81.507
N740 Z49.411
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Z53.032
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N790 X-193.847
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Y110.502
N810 Z49.411
N820 X-197.979 Z53.7
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N840 X202.017
Y139.498
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N860 X201.35 Z50.12
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Y168.493
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N940 X175.044
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N1170 X-131.55
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N1390 G0 Z78.7
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N1410 Z74.411
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Z51.044 F3415.3
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N2430 X196.731
Y88.755
N2440 Z49.411

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N2780 X93.748
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N3190 X-93.276
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Z53.489
N3270 X92.988
Z53.426
N3280 X93.277
Z53.393
N3290 X94.094
Z53.328
N3300 X95.045
Z53.304
N3310 X95.889
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Z53.342
N3330 X96.724
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Z53.513
N3350 X98.643
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N3390 X201.462
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N3560 X-4.592
Z52.092
N3570 X-3.171
Z50.785
N3580 X-2.359
Z50.029
N3590 X-1.688
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N3610 X2.537
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Z53.287
N3810 X19.571
Z53.033
N3820 X18.791
Z52.434
N3830 X18.145
Z51.931
N3840 X17.026
Z51.051
N3850 X16.159
Z50.375
N3860 X15.824
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N3870 X15.219
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Z49.911

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Z50.792
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Z51.169
N3940 X-18.562
Z52.258
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Z51.616
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N4050 X-175.048
Z49.411
N4060 Z50.387
N4070 X-153.763
Y215.611
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N4090 X-153.413
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N4110 X-151.217
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N4170 X-147.146
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N4180 X-146.036
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N4280 G1 X37.775
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N4390 X149.96
Z51.577
N4400 X150.229
Z51.428
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N4420 X151.178
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N4460 X153.755
Z49.411
N4470 M5
N4480 G91 G0 G28
Z0. M9
N4490 G28 X0. Y0.
A0.
N4500 M30
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00200(REQUIRED FOR THE CASTING CENTER DRILL) (DATE=DD-MM-YY-04-06-22 TIME=HH:MM-00:33) (MATERIAL IRON MM-CAST - DUCTILE - AUSTENSITIC - 160BHN)
(T6 HSS/TIN CENTER DRILL 8XDC-10.0 N110 GO G17 G40 G49 G80 G90

N100 G21
N120 T6 M6
N130 GO G90 G54 X43.038 Y155. AO. S1145 M3
N140 G43 H6 Z25. M8
N150 G99 G81 Z-5. R25. F50.
N160 X95. Y185.
N170 X146.962 Y155.
N180 Y95.
N190 X95. Y65 H6)
N200 X43.038 Y95..

N210 X-43.038 Y155.
N220 X-95. Y185.
N230 X-146.962 Y155..
N240 Y95.
N250 X-95. Y65.
N260 X-43.038 Y95.
N270 G80
N280 M5
N290 G91 G28 ZO. M9.
N300 G28 XO. YO. AO.
N310 M30

00000(Rough bore FOR THE CASTING) (T7 (BR20-116SP12Y-CB) H7)
N100 G21
N110 GO G17 G40 G49 G80 G90

N120 T7 M6
N130 GO G90 G54 X-95. Y125. AO. S980 M3
N140 G43 H7 Z50.
N150 G98 G81 Z-52. R25. F1787.5

N160 X95.
N170 G80
N180 M5
N190 G91 G28 ZO.
N200 G28 XO. YO. AO.
N210 M30

Final bore FOR THE CASTING)
N150 G98 G81 Z-52. R25. F1787.5
N180 M5

(T8-825-107TC11 -C6 (H8)

N100 G21
N110 GO G17 G40 G49 G80 G90
N120 T8 M6
N130 GO G90 G54 X-95. Y125. AO. S98
N140 G43 H9 Z50.

N160 X95.
N170 G80
N190 G91 G28 ZO.
N200 G28 XO. YO. AO.
N210 M30

(REQUIRED FOR THE CASTING DRILL 10mm)
(MATERIAL - IRON MM - CAST - DUCTILE - AUSTENSITIC - 160BHN)
(T9 | 861.1-1000-120A1-GM GC34| H9 )
N100 G21
N110 G0 G17 G40 G49 G80 G90
N120 T7 M6
N130 G0 G90 G54 X43.038 Y159.5 A0. S1145 M3

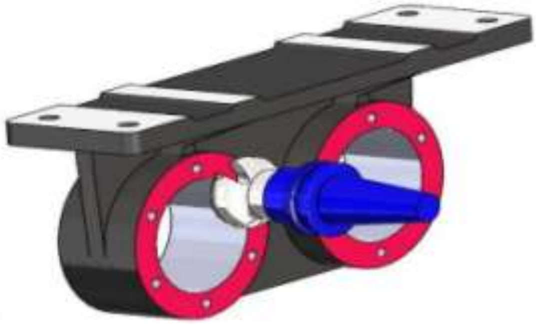
N140 G43 H9 Z25. M8
N150 G99 G83 Z50. R25. Q0. F50.
N160 G80
N170 Y155.
N180 G99 G83 Z-50.696 R25. Q10. F50.
N190 X95. Y185.
N200 X146.962 Y155.
N210 Y95.
N220 X95. Y65.
N230 X43.038 Y95.
N240 X-43.038 Y155.

N250 X-95. Y185.
N260 X-146.962 Y155.
N270 Y95.
N280 X-95. Y65.
N290 X-43.038 Y95.
N300 G80
N310 M5
N320 G91 G28 Z0. M9
N330 G28 X0. Y0. A0.
N340 M30
%

(REQUIRED FOR THE CASTING REAMER 10MM)
( T11- 435.B-1000-A1-XF H10F( H11 )
N100 G21
N110 G0 G17 G40 G49 G80 G90
N120 T11 M6
N130 G0 G90 G54 X-95. Y185. A0. S968 M3

N140 G43 H11 Z50.
N150 G98 G73 Z-53.254 R25. Q0. F210.1
N160 X-146.962 Y155.
N170 Y95.
N180 X-95. Y65.
N190 X-43.038 Y95.
N200 Y155.
N210 X43.038
N220 X95. Y185.

N230 X146.962 Y155.
N240 Y95.
N250 X95. Y65.
N260 X43.038 Y95.
N270 G80
N280 M5
N290 G91 G28 Z0.
N300 G28 X0. Y0. A0.
N310



Facing Rough+Finsh) 2nd side
(REQUIRED FOR THE CASTING FACING 2ND SIDE)

(T12-345-063C6-13H- H12)
N100 G21
N110 GO G17 G40 G49 G80 G90
N120 T12 M6
N130 GO G90 G54 X-95. Y125. AO. $980 M3
N140 G43 H12 Z50.
N150 G98 G81 Z-52. R25. F1787.5
N160 X95.
N170 G80
N180 M5
N190 G91 G28 ZO.
N200 AO.
N210 M01
N220 T11 M6
N230 GO G90 G55 X-225.978 Y90.611 AO. S2342 M3
N240 G43 H11 Z50.
N250 Z5.
N260 G1 Z-3.753 F1000.
N270 X-225.452 Z-3.548 F3438.1
N280 X-224.466 Z-3.171
N290 X-223.617 Z-2.838 »
N300 X-223.296 Z-2.724
N310 X-222.97 Z-2.599
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F3438.1

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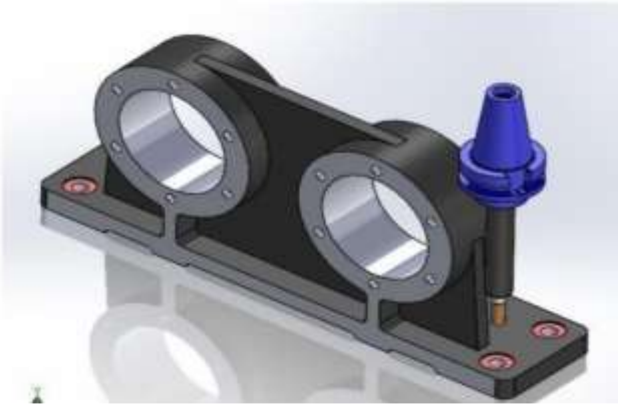

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(REQUIRED FOR
THE CASTING SPOT
FACING)
( T13- 2F440-1000-
050ASD 1725 H13 )
N100 G21
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G49 G80 G90
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2.5 Y-390.5 A0. S3500
M3
N140 G43 H13 Z50.
M8 N150 Z10.
N160 G1 Z0. F25.
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I2.5 J0. F100.
N180 X2.5 Y-390.5 I0.
J2.5
N190 X0. Y-388. I-2.5
J0.
N200 X-2.5 Y-390.5
I0. J-2.5
N210 G0 Z50. N220
X57.5
N230 Z10.
N240 G1 Z0. F25.
N250 G3 X60. Y-393.
I2.5 J0. F100.
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I0. J2.5
N270 X60. Y-388. I-
2.5 J0.
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I0. J-2.5
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J2.5
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J0.
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2.5
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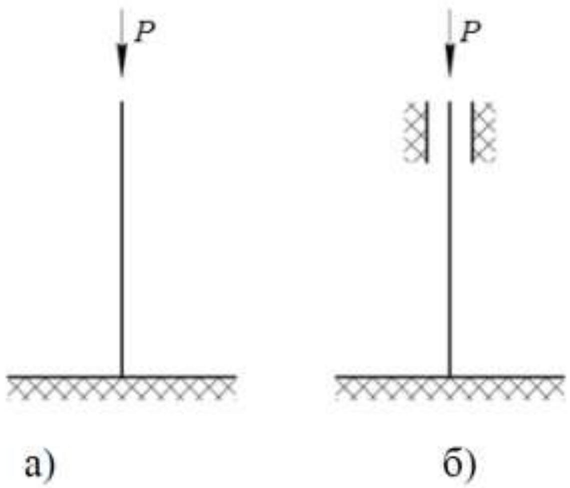
N460 M5
N470 G91 G28 Z0. M9
N480 G28 X0. Y0. A0.
N490 M30
%
```

## 5. Statistic Analysis of the drill work

The influence of the profile shape in the cross section of the tool (relative to its axis) on the axial component $P_z$ is not a significant factor, unlike the components $P_y$ and $P_x$, which are part of the axial force $P$, which is directed along the axis of the drill, and the torque acts relative to the same axis. in turn, under the influence of torque directly affect the rigidity of the tool, the accuracy of the opening processing depends on it, and the spatial placement of the real axis of the hole.

In the study, it should be borne in mind that at the time of cutting the drill, the scheme of its fixation is console and corresponds to figure 2.2 a), and at the time of operation, the drill has restrictions associated with the treated hole, the fastening scheme corresponds to figure 2.2 b),.

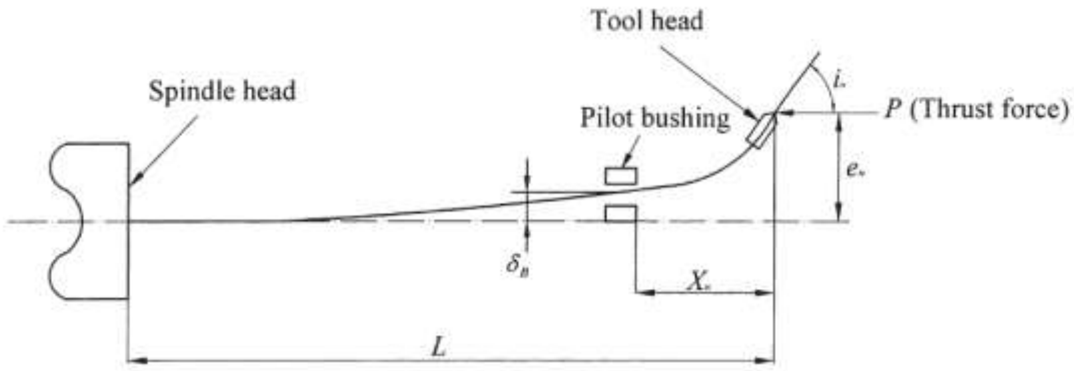



Fihure. 2.2. The scheme of fixing the drill:

a) at the time of cutting the tool into the workpiece;

b) in the process of working the instrument

If during the drilling the initial otv tilted or pushed to the side, as a result of the moment of force caused by the axial load R. The working part of the tool at the time of idle movement, moves kneearly the axis of the spindle, as shown in Figure 2.3, but changes its direction, and the lateral deviation becomes more pronounced when feeding, when the working part of the tool penetrates the workpiece.




Fihure. 2.3 Scheme of deviation of the drill at any length

Deviations of the straightness of the real axis from the theoretical axis of the holes at arbitrary depths can be mathematically expressed as

$$\delta_n = \delta_{n-1} + i_{n-1} \cdot f$$

where *the* $\delta_n$ is the values and deviations of the real waspand hole at an arbitrary depth *of* $X_n$;

$f$ – feed; ,

$n$ – speed;

$X_n$ – drilling depth;,

$i_{n-1}$ - represents the slope of the rejected drill after ($n$-$1$) revolutions.

Suppose that the inconsistency of the axis of the hole during drilling is $\delta_b$ , as shown in Fig. 1. 2.3. When the working part of the tool penetrates the workpiece, the axial force begins to affect the deviation of the drill. The deviation caused by the axial force $P$ during the submission of $V_f$ corresponds to Euler's theory, according to which the axial force $P$ should not exceed the critical force allowed by the hardness of the drill:

$$P \leq P_{\text{кр}}$$

where $P_{kr}$ is a critical force that is provided by the rigidity of the tool

To calculate the drill for the jostle, the following dependence is proposed:

$P_{кр} = P_{ж.св.} = \frac{K_y \cdot E \cdot I}{L_{закр.}}$ (2.3)

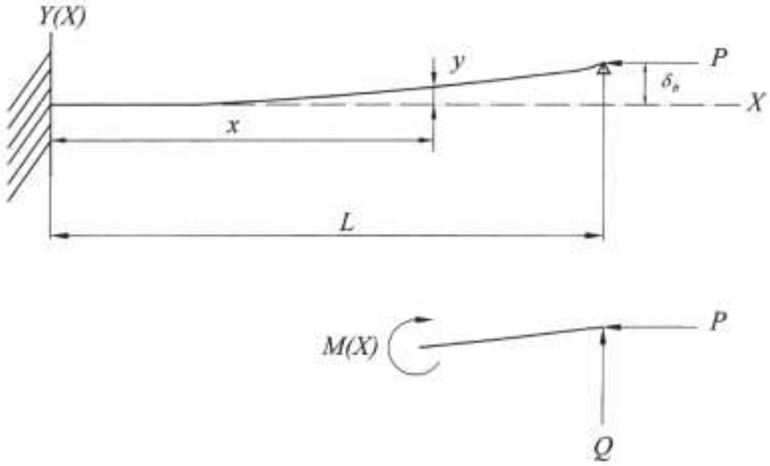
de $K_y$ – stability coefficient against longitudinal bending $K_y$ = 2.46;

$E$ - modulus of elasticity of drill material, MPa;

$I$ - polar moment of inertia of the cross section of the drill, mm4; $I \approx 0.039D^4$

$L_{shut\text{-}length}$ drill from the moment of fixation to the end of the working part, mm.

Figure 2.4 shows the dependenceof the axis of the real axis on the theoretical torsion of $M_{kr}$.




Fihure. 2.4 Scheme of deviation of the axis of the hole under the action of torque.

Not the straightness of the axis of the hole in the relative coordinate system (x, y), caused by torque, can be mathematically expressed by the following equation:

$$\delta_n = M_{кр} = P(\delta_b - y) + Q(L_{закр.} - x)$$

where $\delta_b$ is the initial deviation of the hole;

$P$ – axial force that is directed along the axis; ,

$x,y$ – inthe idtyling of the initial hole relative to the coordinate system;

$L$ shut-down length of the drill from the moment of fixation to the end of the working part, mm;

$Q$ – inthe idchentrov force is caused by torque and axial force.

In regression analysis, the planning of experiments is usually used for models that are linear relative to parameters. It is understood that the model has the form of an algebraic sum of arbitrary functions (the general expression is linear relative to unknown parameters $b_i$).

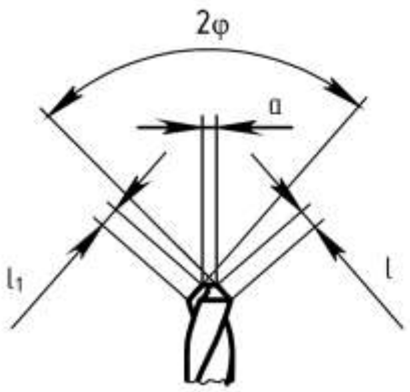
$$Y = \sum b_i \, x_i, (i = 0,1, \dots, n)$$

The most common functions are polynomials and trigonometric functions (sinus, cosine) for periodic processes, but, in general, these can be arbitrary (and different in the same expression) functions. There are classes of functions that can lead to linear, for example, by logarithming them. As a rule, in scientific and engineering studies models are used that are linear relative to parameters.

When choosing factors, the requirements for such variables were taken into account. They should directly influence the outcome of the study, be truly independent, measurable, manageable.

The requirement of independent influence on the result arises due to the fact that it is difficult to manage the factor if it is a function of others. It is necessary to be able to change each factor within some limits without affecting others. Under the manageability of the factor means the ability to install and maintain the desired value of the factor in the selected range throughout the experience or its change according to a given program.

Analysis of the drill work showed that the greatest impact on the removal of the axis is influenced by the ratio of the main cutting edges, the transverse edge and the angle at the top of 2φ, the parameters selected for the study are presented in Fig. 1. 2.5. Since the size of the transverse edge depends on the angle at the top and the main cutting edges, we neglect this parameter as one that cannot be controlled. As a result, two geometric parameters were adopted as independent variables.




Fihure. 2.5. The parameters of the cutting edge of the drill selected as factors for the experiment

Each selected factor has an area of its own definition. The boundaries of this area may be set either by fundamental restrictions that cannot be violated under any circumstances, or by technical and economic considerations, or by conditions on a case-by-case basis.

After selecting the definition area, we find a local area for the experiment. Choosing the field of experiment is a poorly formalized task, although some recommendations exist here. Usually it is solved in each case based on the meaningful meaning of the task. This procedure includes the choice of levels of factor variance. In general, levels can be any number, the distance between them can be the same or not. The number of levels is determined by the specific formulation of the task, the type of factor, the predictable complexity of the object under study.

When choosing the upper and lower limits of the change of factors, their own research, the results of research of other authors, as well as reference materials are taken into account.

The model, which can be constructed from a full factor experiment $2^2$, has the form

$$\delta_n = Y = \sum b_i \left( {}^{l_1}/_{l} \right)_i 2\varphi_i, (i = 0,1, \dots, n)$$

When researching by the planning method, centering is carried out, that is, the transfer of the origin of the coordinates of the factor space to the point with the coordinates $x_{i\,0}$, $x_{20}$ ... $x_{n0}$, where

$$x_{i0} = \frac{x_{i\,max} - x_{i\,min}}{2}$$

Point 0 is called the center of the experiment. Now it is convenient to make sure that at the coded scale the maximum (upper) level corresponds to +1, the minimum -1, and the average (main) - zero. To do this, we use formulas that link the values of factors at a coded scale ($x_i$).

$$\bar{x}_i = \frac{\bar{x}_i - \bar{x}_{i\,0}}{\Delta \bar{x}_i}$$

$$\overline{x_\iota} = \overline{x_{\iota 0}} + \Delta \overline{x_\iota}$$

where is the variance interval. $\Delta \overline{x_\iota} = x = \frac{\overline{X_{\iota\,max}} - \overline{X_{\iota\,min}}}{2}$

But in this case, a limited number of levels of variance is limited, and the simulation of the process will take place according to two experiments, so in the future the experiment is advisable to carry out according to the plan $m^n$, where n is the number of factors that we determined at the beginning, m is the number of levels of variance that can be changed during the experiment, before obtaining results that would satisfy the conditions for constructing a model. model, for example, if a two-factor experiment looks like a second-order polynomial:

$$Y = b_0 + b_1 x_1 + b_2 x_2 + b_3 x_1 x_2 + b_4 {x_1}^2 + b_5 {x_2}^2$$

Accordingly, we will try to build a model that would allow for full factor experimentation.

At the first stage of the experiment, it is necessary to give drills of the selected parameters. It should be noted that when using regressive analysis, the following initial prerequisites should be observed:

1) dependent variable (response) - a random variable with a normal distribution law;

2) variance in determining this variable does not depend on its absolute value;

3) factors are measured with a disparagingly small error compared to an error in determining the response.

On this basis, all drills used in the experimental study were subjected to careful monitoring of the main parameters after the crossing. The grinding of the tool took place on a universal sharpening machine 3V642

Taking into account the fact that in our analysis there are 2 factors, each of which was assigned 3 roosters varying the number of experiments can be determined by the usual busting, respectively, their number will be equal to 9 experiments, in order to obtain the most accurate results, it was decided to conduct a second experiment using the same set of levels of variance.

After turning the drills, each drill with a certain set of levels of variance was treated on a hole 50 mm deep in brass grade LS 59-1. Each repeated experiment with the same parameters took place after the restart of the drill. For the purity of the experimen during drilling, ZMOTS was constantly supplied, in order to avoid thermal expansion of brass, and, accordingly, the breakdown of the drill, as well as for improved shaving output.

Fihure. 3,4. Parameters of the cutting edge of the drill selected as factors for the experiment

To measure the value of the geometric processing error, it is necessary to measure the deviation of the axis of the hole in the transverse region at an arbitrary distance. To do this, it is necessary to remove the material of the workpiece along the axis of the holes, which will make it possible to measure the actual deviation of the axis. For this process, a cantilever-milling vertical machine 6N12 was selected. The milling process is shown in Fig. 2. 3,5

Fihure. 3.6. The cutting edge of the drill bit selected as factors for the experiment

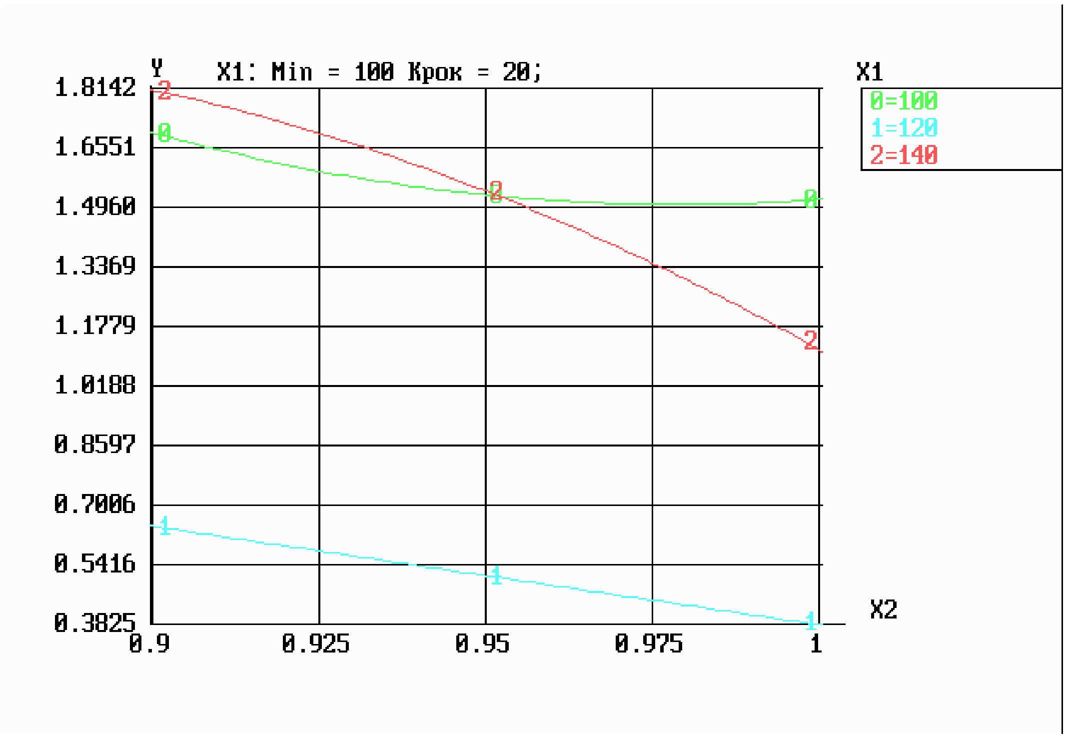
The resultsof the measurements of the function are presented in the table

| Theoretical significance Levels Varying factors | Factors | | Functions | |
|---|---|---|---|---|
| | Natural designation of factors | | Natural designation of functions | |
| | 2φ, hail. | $l_1/l_2$, mm | $\delta_n$, mm | |
| | Formalized designation of factors and natural values of their levels | | Formalized function designation | |
| $F_1$ .. $F_6$ | $X_1$ | $X_2$ | $y_1$ | |
| 0 | 120° | 1 | Results of repeated experiments | |
| 1 | 140° | 0,95 | | |
| 2 | 100° | 0,9 | | |
| Experiment No. | Factors | | $y_{1,1}$ | $y_{1,1}$ |
| 1 | 120° | 1 | 0,37 | 0,41 |
| 2 | 120° | 0,95 | 0,52 | 0,48 |
| 3 | 120° | 0,9 | 0,64 | 0,67 |
| 4 | 140° | 1 | 1,09 | 1,11 |
| 5 | 140° | 0,95 | 1,56 | 1,58 |
| 6 | 140° | 0,9 | 1,82 | 1,78 |
| 7 | 100° | 1 | 1,51 | 1,5 |
| 8 | 100° | 0,95 | 1,54 | 1,58 |
| 9 | 100° | 0,9 | 1,63 | 1,74 |

## 6. Results of mathematical modeling

The calculation of the mathematical model was made with the help of software providing PRM, during which the following data were obtained:

Checking the uniformity of the model




Fihure. 1. The cutting edge of the drill bit selected as factors for the experiment

The model:

$$Y = 1.19611+0.681111z1-0.190833x2-0.13x1x2-0.0466667x1 - 0.0583333z1x2-0.0516667x1z2$$

where:

x1 = 0.05*(X1 -120);

z1 = 1.5*((x1^2)-0.666667);

x2 = 20*(X2 -0.95);

z2 = 1.5*((x2^2)-0.666667);

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