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

A PROJECT TOPIC ON:

“TECHNOLOGICAL MANUFACTURING PROCESS OF A PART “SHAFT HOUSING”

Written By:

HAPPY NATHAN UDOINYANG

Group: MT84A

In Partial Fulfillment for the award of a Bachelor Degree

Supervisor:

Assoc. Prof. Maksym Gladsky.

DATE: June 15/2022

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"IGOR SIKORSKY KYIV POLYTECHNIC INSTITUTE"
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
_______ Olga Koliavik
«___»_____________2022

ASSIGNMENT
for the student's diploma project
HAPPY NATHAN UDOINYANG

1.Topic of the project "Technological preparation of a manufacturing process to produce a part "Shaft housing"
Project supervisor _Phd, associate professor Maksym Gladsky

approved by the University Order of «__» may 2022 № _______
2. Deadline for submission of the project «1» June 2022
3. Initial data for the project Part drawing and material, Production quantity per annum, working conditions of the part in the assembly unit.
4. Content of the text part (explanatory note) _ Design of the operational manufacturing process plan, calculation of the allowance, calculation of cutting conditions for 2 manufacturing steps, estimation of necessary clamping force.
5. List of the graphic material (indicating mandatory drawings, posters, presentations, etc.) 3-D drawing of the part and drawing of the workpiece. Schematic representation of a technological operation.
6. Date of the task issue ___

Student ___________
Kyiv 2022

Time schedule

No	The stage of the diploma project execution	Deadline	Notes
1	Analysis of design features of the part		completed
2	Determining the type of production		completed
3	Calculation of the allowance		completed
4	Design of the typical surfaces processing routes		completed
5	Design of the operational manufacturing process plan		completed
6	Setting cutting conditions		completed
7	Development of the fixture design		completed
8	Calculation of the cost processing		completed

Student

Name, Surname
Happy Nathan Udoinyang

Group: MT-84

Supervisor. *Name, Surname*

«____» ____________2022

Kyiv 2022

CONTENT

Abstract

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

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

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

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

Furthermore, the technological processes which involved:

Analysis of the part in the assembly unit, the type of material for production, taken into account the condition of service environment, the size and weight of the part, best locating scheme for Production, the cutting tools and its cutting forces, the production type and the choice of machine were all integrated into the study.

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

Acknowledgement

With most gratitude to God, I want to say a big thank you to my precious mum, Mrs. Blessing Nathan for her Support throughout the period of my academic pursuit, and my elder brother, Engr. Answer Nathan for standing by me irrespective of the hurdles. Furthermore, a big shout out to my supervisor, Professor Maksym Gladsky, for making me scale through this project despite the ongoing war. I am sincerely grateful to everyone.

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

1.1.1 Analysis of design features of the part and its classification

Considering the configuration of the part ‘Bearing Housing’ we defined that it belongs to the class “Body”

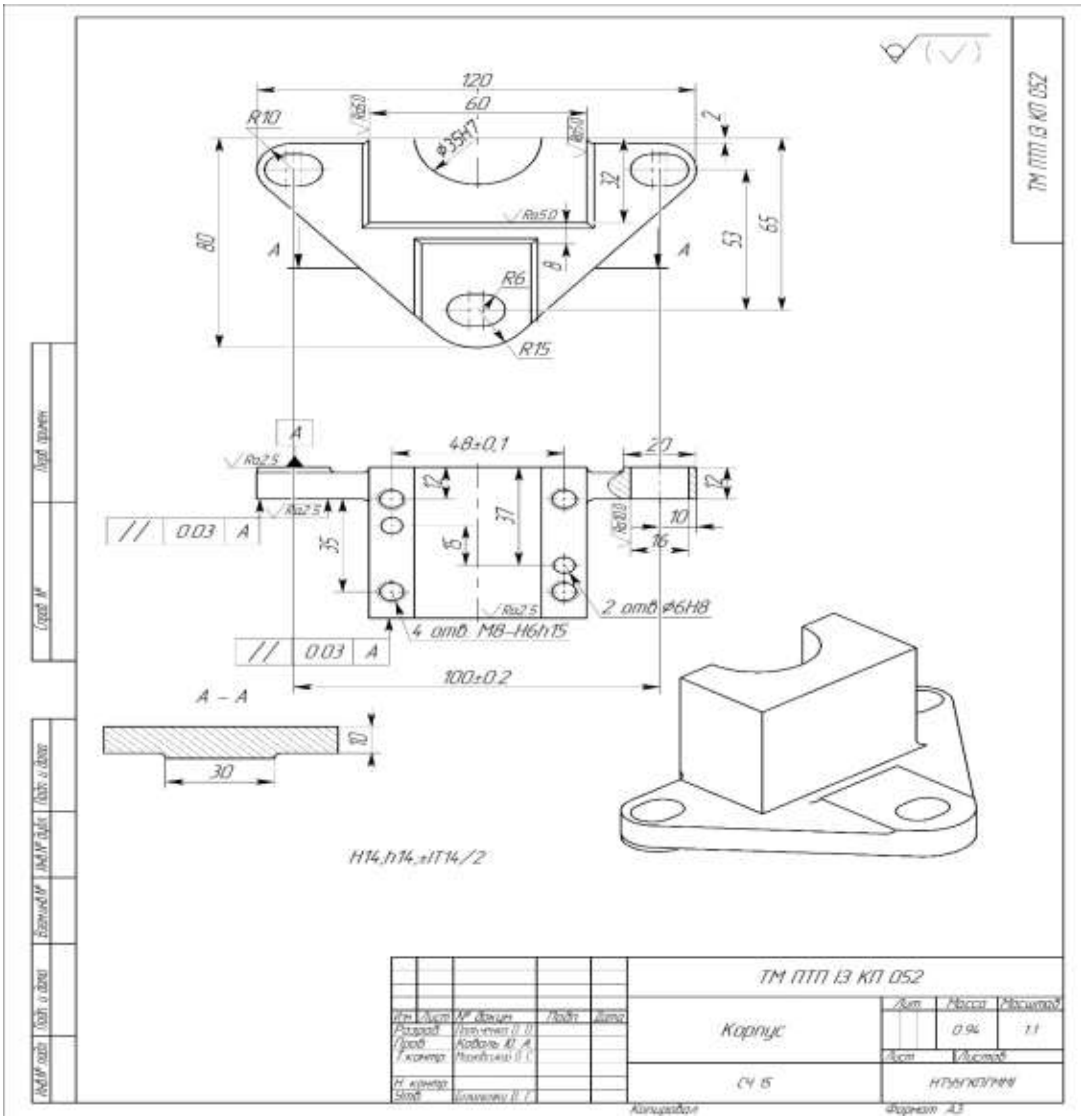
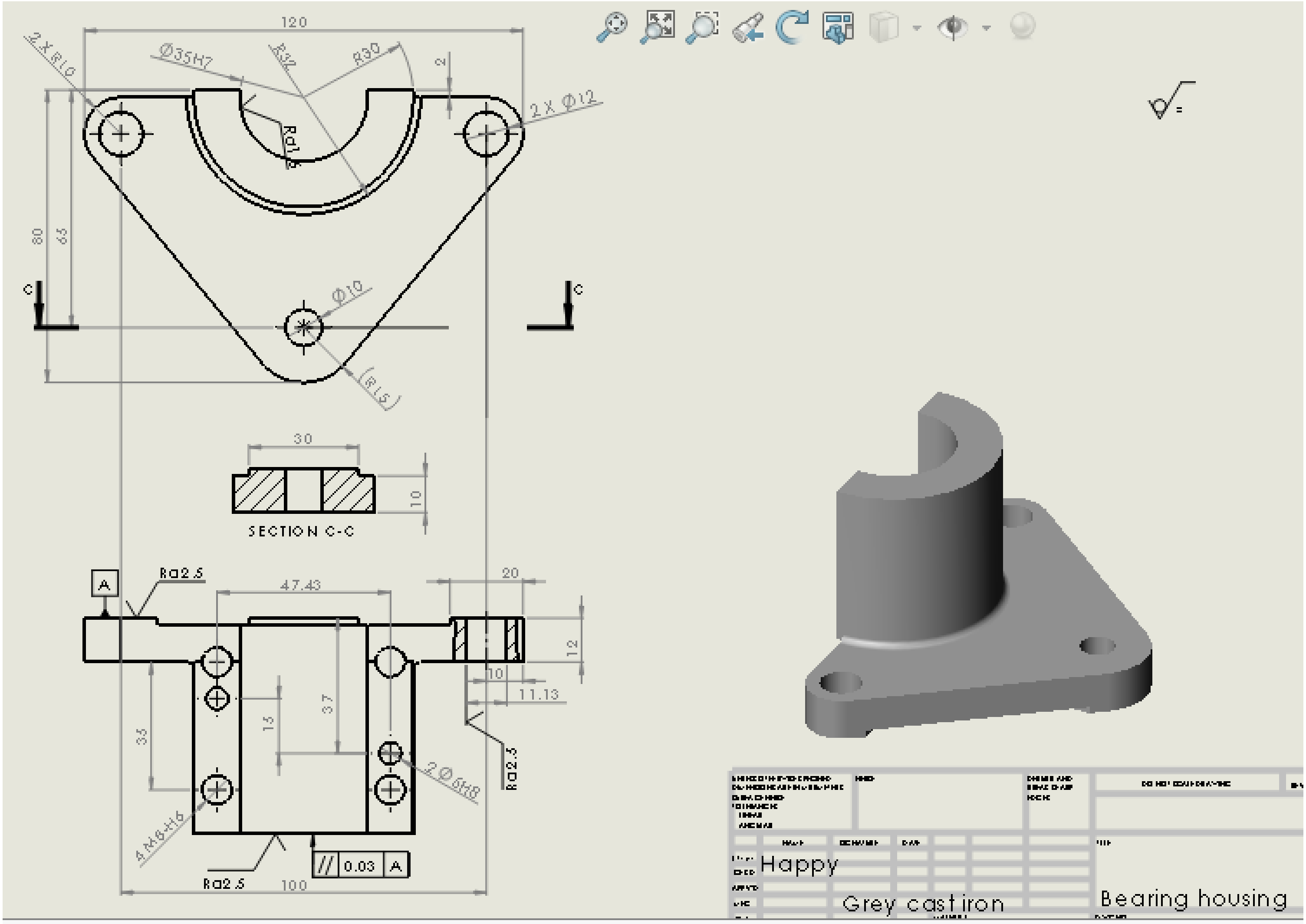
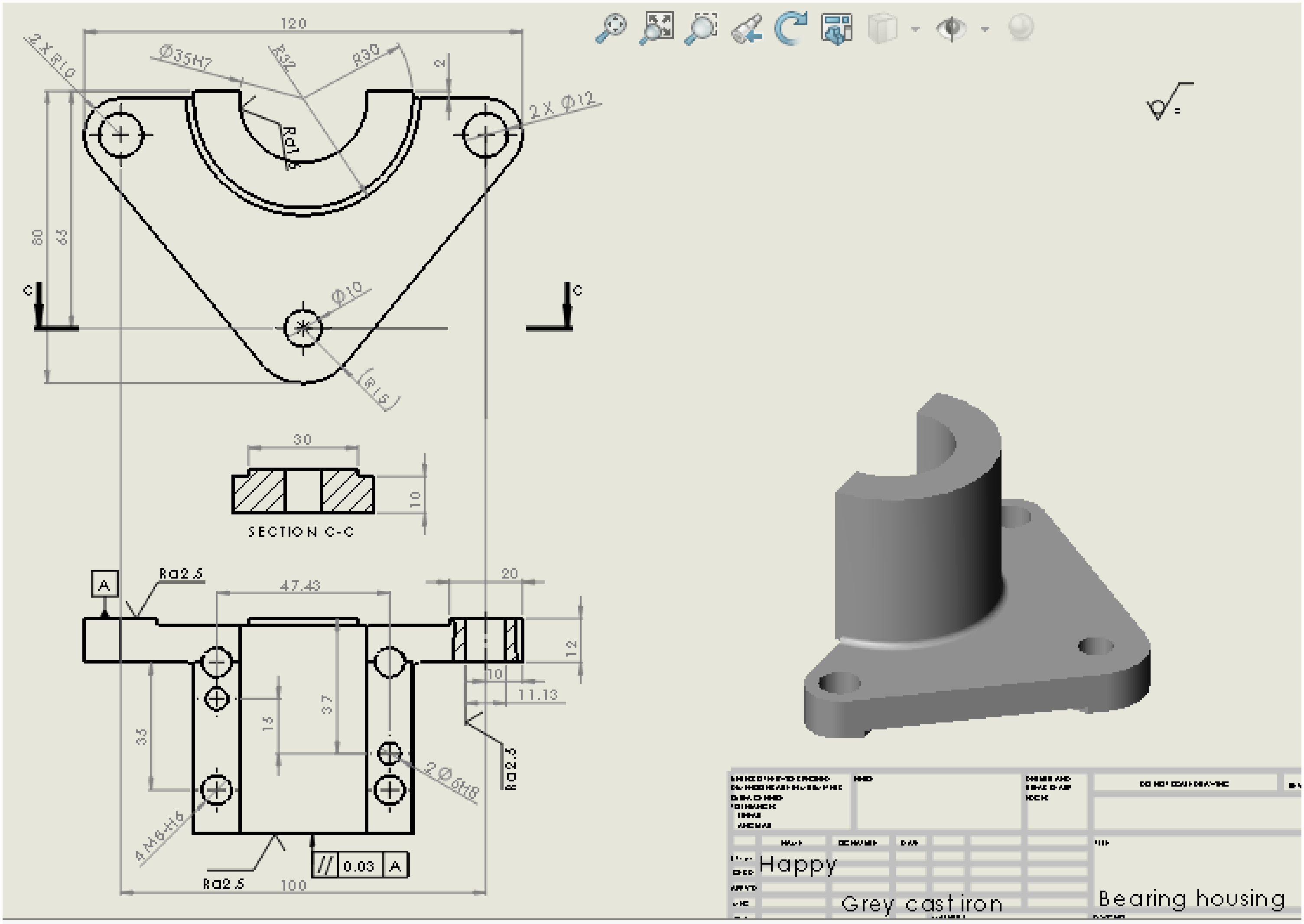


Fig.1.1 – Drawing of the part ‘Housing’

Modified part drawing




120
2 X R10
Ø35H7
R32
R30
2
2 X Ø12
Ra1.6
80
65
C
C
Ø10
R15
30
10
SECTION C-C
A
Ra2.5
47.43
20
12
10
11.13
Ra2.5
35
15
37
2 Ø 6H8
4 M6-H6
Ra2.5
// 0.03 A
100
Happy
Grey cast iron
Bearing housing

Note: the part was modified for better design, cost effectiveness, serviceability, market competitive advantage and acceptability. In general, the requirements for the accuracy and quality of the surfaces of the part are not very high, however, the top surface is of increased requirements, since it has to be parallel and not deviating from the datum surface by 0.03mm, and the surface of the internal semi-circular cylinder should be finished to an accuracy of 35 H7 Ra1.6. During manufacturing a special attention must be paid to the machining of the top surface, ensuring it's parallelism to the datum surface and also the finishing of the semi cylindrical core.

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

The "housing" is designed to install and hold a semi-circular or circular shafts, with holes, threaded and unthreaded, to keep the mounting bearing in position, in addition to a basement support. The unthreaded and threaded holes, 6H8 and M8-6H, are for fastening and also Jix and Fixture support.

During operation, the part is exposed to significant, long-term alternating loads and vibrations, which is been prevented by the basement and holes support to be attach by a grip system.

1.1.3 Analysis of the material

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

Chemical composition (in %)

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

Linear shrinkage: 1.1%

Tensile strength $\sigma_в$= 152 MPa; hardness HB=130…241; density ρ= 0.01g/mm^3.

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

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

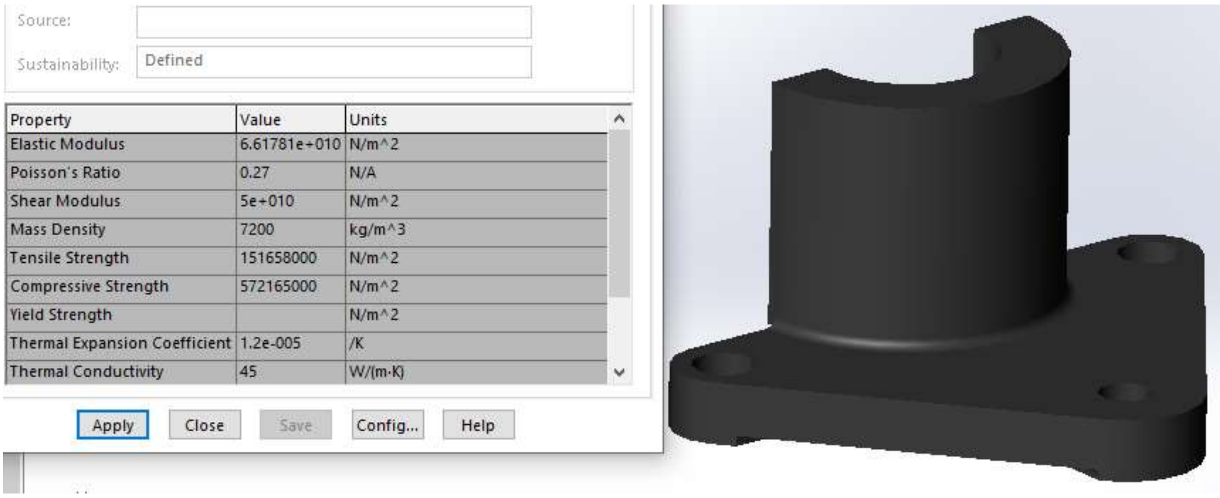
The sort of generation may be a classification category of generation, determined by the characteristics of the breadth of the classification, regularity, stability, and volume of generation. One of the most quantitative characteristics of the sort of production is the solidification of operations rate Kco. Depending on the volume and nature of the generation of parts, a distinction is made between single, serial, and mass production. The sort of generation depends on the coefficient of solidification of operations Kco, which is calculated as the proportion of the number of all different manufacturing operations performed or to be performed by the generation unit during the month, to the number of workstations that perform diverse operations

This equation can be utilized as it were for existing items for a genuine work shop with the gear found and the built-up generation program. Hence for educational purposes, we'll utilize analog strategies of assignment of generation type based on the weight of a portion and generation volume.

For educational purposes we will use analog methods of designation of production type based on weight of a part and production volume. Part weight m=706.87g (Fig. 1.2) Production volume N_p =2500.

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

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



Property	Value	Units
Elastic Modulus	6.61781e+010	N/m^2
Poisson's Ratio	0.27	N/A
Shear Modulus	5e+010	N/m^2
Mass Density	7200	kg/m^3
Tensile Strength	151658000	N/m^2
Compressive Strength	572165000	N/m^2
Yield Strength		N/m^2
Thermal Expansion Coefficient	1.2e-005	/K
Thermal Conductivity	45	W/(m·K)

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

Note: the part was modified for better design, cost effectiveness, serviceability, market competitive advantage and acceptability.

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

1.3 Selection of the base process and design of the blank

The choice of the method of obtaining the workpiece is influenced by: the material of the part, its purpose and technical requirements for manufacture, volume and serial production, the shape of the surfaces and the size of the part.

The optimal method of manufacturing the workpiece will be a method that ensures the manufacturability of the part made of it, at a minimum cost. The optimal method is determined on the basis of detailed
comprehensive analysis of the above factors.

In mechanical engineering, the main methods of obtaining the workpiece are:

- plastic deformation;
- Lithuania;
- from the rental.

The "Pump housing" part is made of gray cast iron SC-25, so the workpiece for the manufacture of such a part can not be obtained by plastic deformation, because cast iron is a very fragile material. Moreover, it is impossible to obtain a blank for such a case from the rental.

In this case, the most appropriate method of obtaining the workpiece will be casting. In mechanical engineering there are several types of castings:

- casting in sand-clay molds with manual or machine molding, on wooden or metal models;
- casting in semi-permanent (cement, graphite or asbestos and graphite-alabaster forms);
- shell casting;
- casting on smelted models;
- injection molding;
- die casting;
- centrifugal casting;
- other.

The configuration of the outer contour and inner surfaces of the housing does not cause significant difficulties. However, the casting must take place using a rod that will form the inner cylindrical hole of the housing. Since the requirements for quality and accuracy of surfaces are relatively low, the annual output is 10,000 parts per year, it is advisable to use casting in sand-clay molds with machine molding on a metal model.

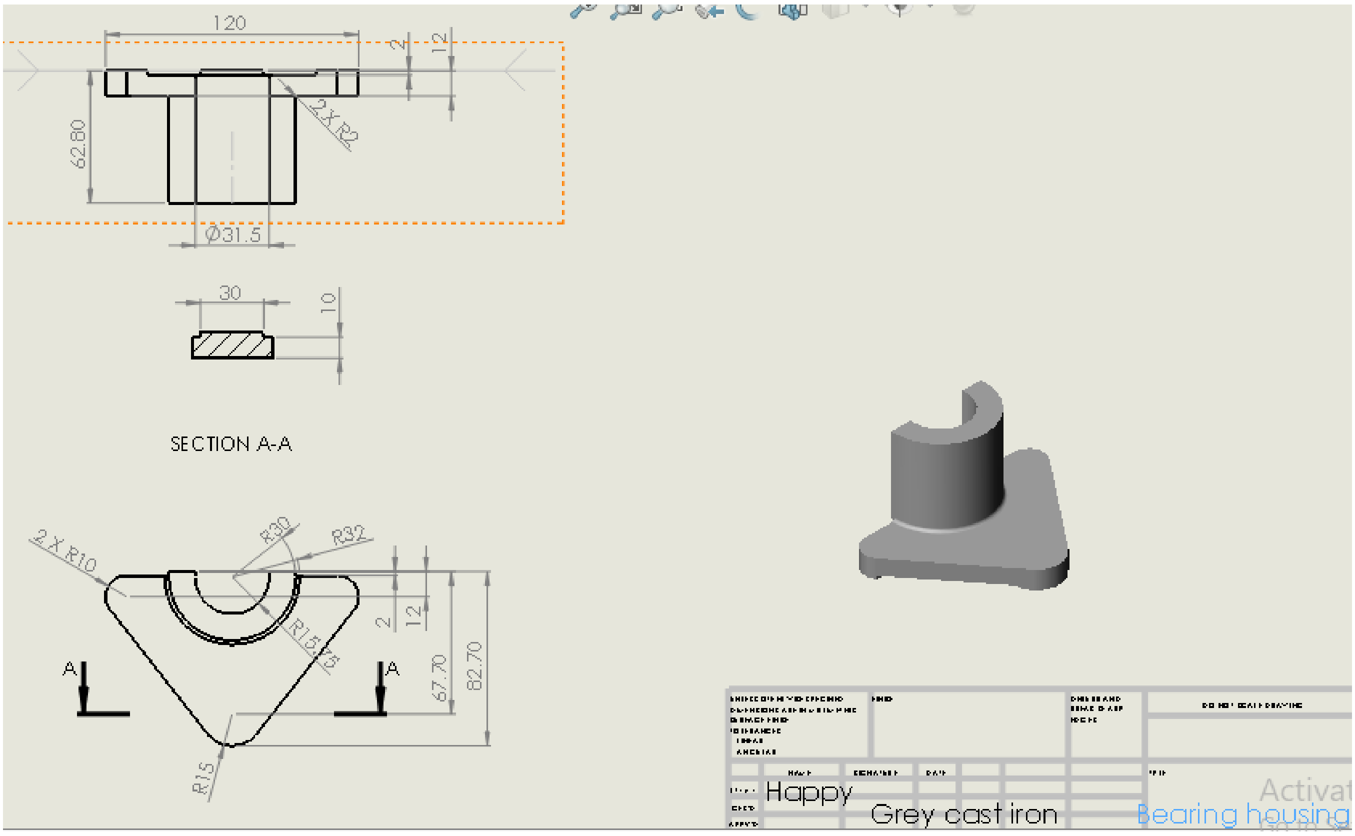
The method of casting in sand-clay forms is widely used in mechanical engineering and is quite well developed. Size, weight and accuracy tolerances achieved by this type of casting are determined by the standard.
The cost of casting obtained by casting in sand-clay molds or in the mold:

Initial data for the process selection:

drawing of a part;

material of a part – Grey Iron;

Annual output – 2500pcs



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

To estimate the required machining allowance (RMA) grade we will use Table B.1 [2]. For sand casting process and Grey Iron, since medium production, the recommended RMA grade is E; using sand casting machine mold. Required machining allowance according to the E grade and the longest dimension of the part 120mm (see drawing) is 1.1 mm according to the table 2 [2].

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

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

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

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

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

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

Dimension of a part	RMA	Min limit of size for external features (or max for internal features)	Casting tolerance, mm	Raw casting basic dimension
80	1.1	81.1	3.2	82.7±1.6
59	1.1	61.2	3.2	62.8±1.6
35	1.1	32.8	2.6	31.5±1.3
12	1.1	13.1	2.2	14.2±1.1
10	1.1	11.1	2	12.1±1.0
8	1.1	9.1	2	10.1±1.0
6	1.1	7.1	2	8.1±1.0

When designing the casting we considered the following:

a workpiece is placed in the way that corresponds to the lowest possible height in the mold;

the parting line lies within the plane of symmetry;

the casting do not contain sharp corners, radii of 2-5 mm were applied;

a draft angle of 2° was applied to all walls perpendicular to parting plane to facilitate removing the part from the mold;

the RMA should be added only to the surfaces, for which the secondary process (machining) will be applied;

the semi-circle hole of the part will be obtained using cores;

small features of the part (e.g. small holes) will be obtained by a secondary process.

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

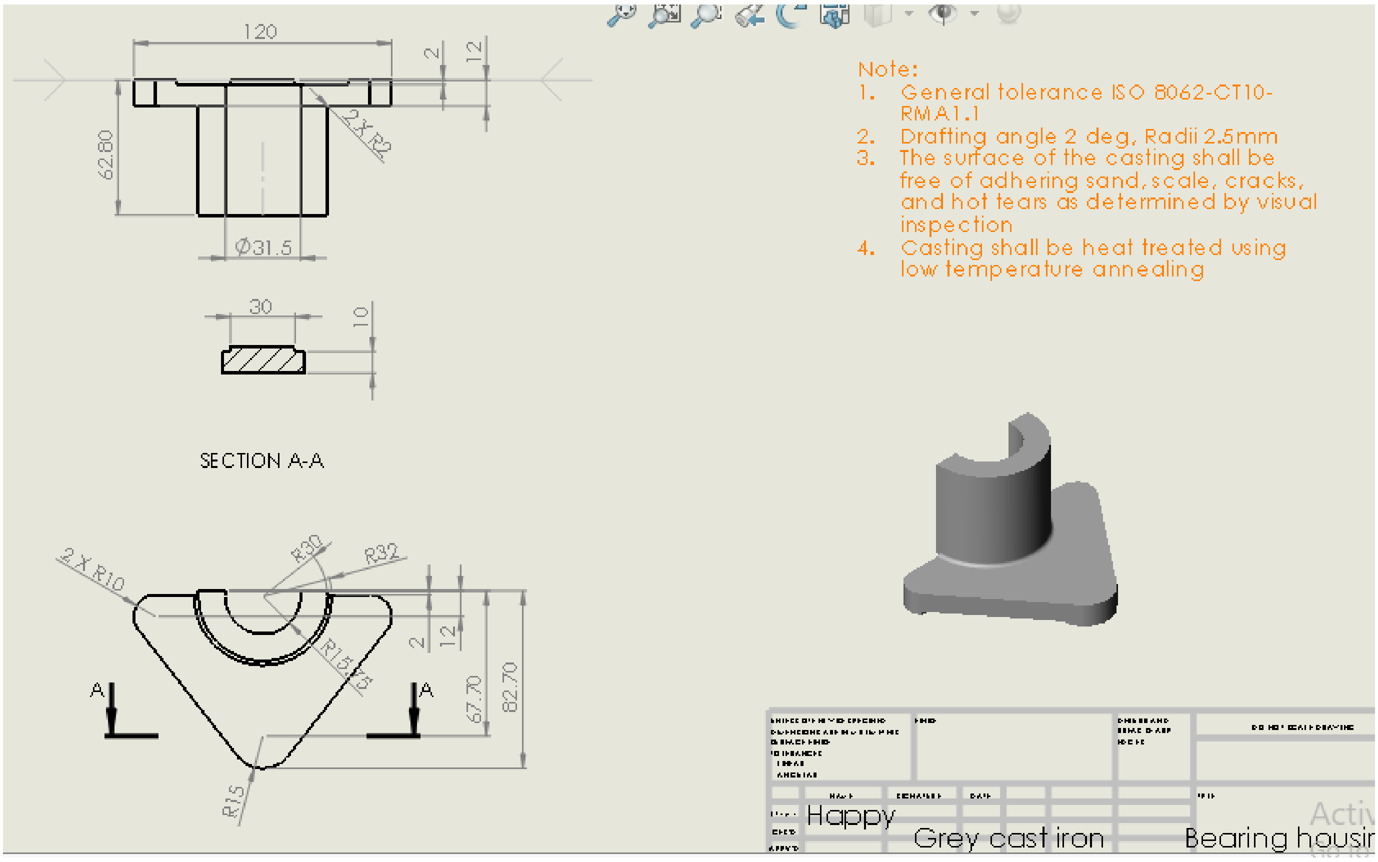
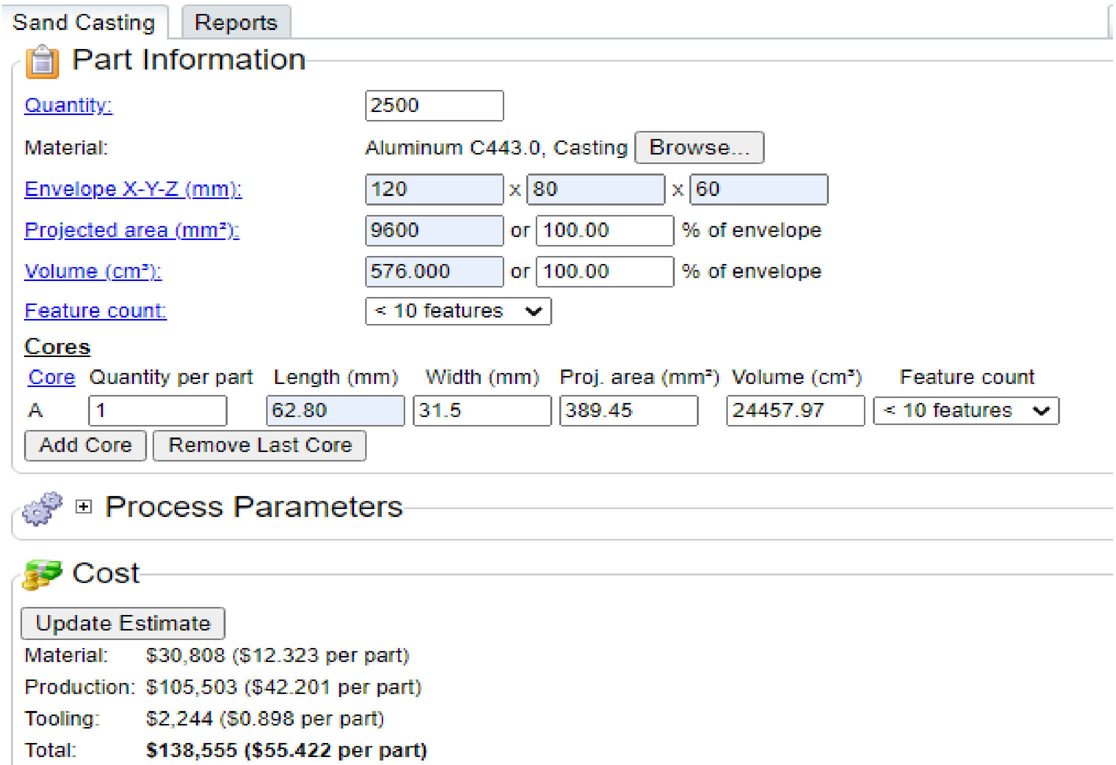


Fig. 2. Drawing of a casting

1.3.3 Cost estimation

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



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:

Main functional (design) datum

Auxiliary functional (design) datum

Fastening surfaces

Free surfaces

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

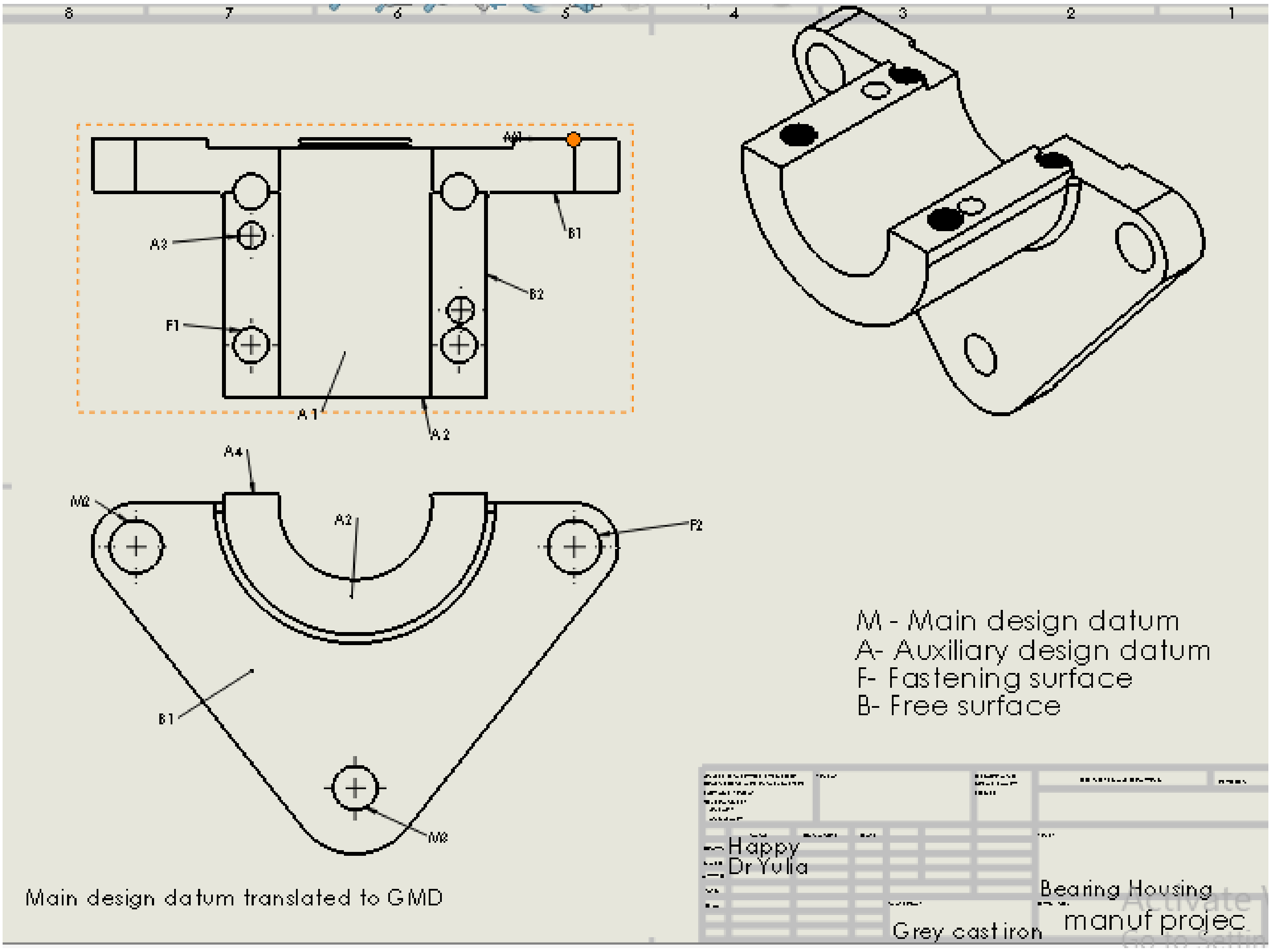
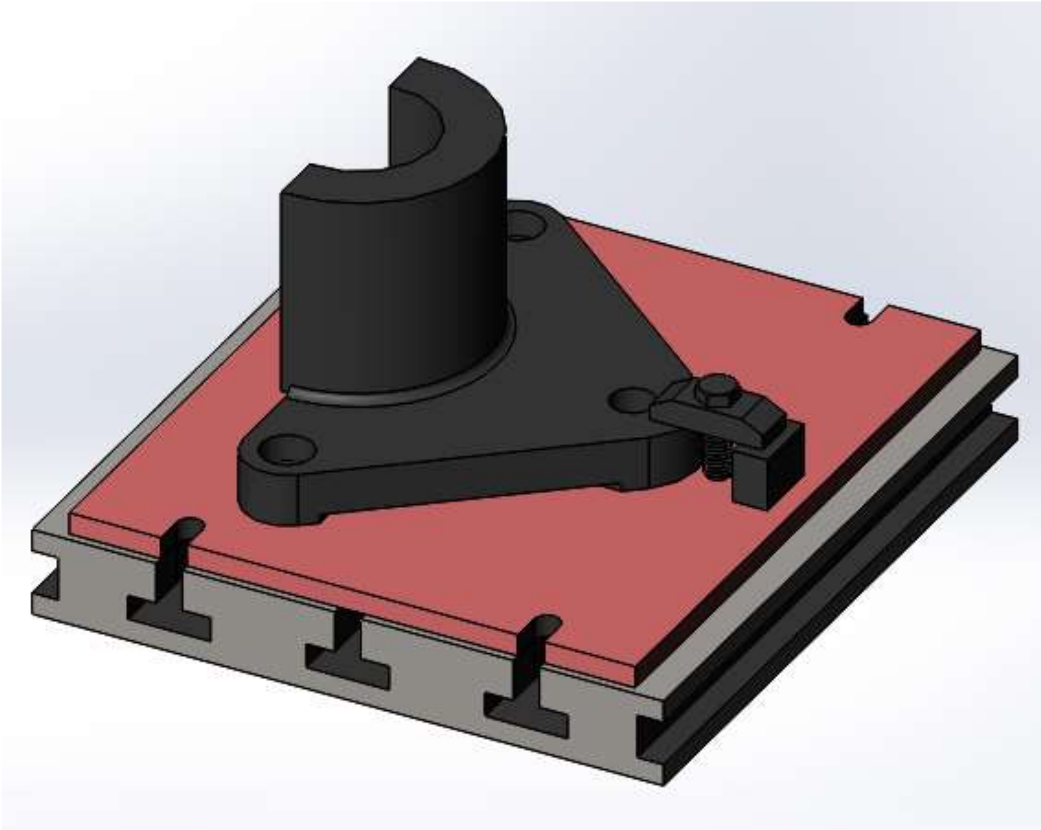


Fig 1.8 Classification of the part according to their intended purpose

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



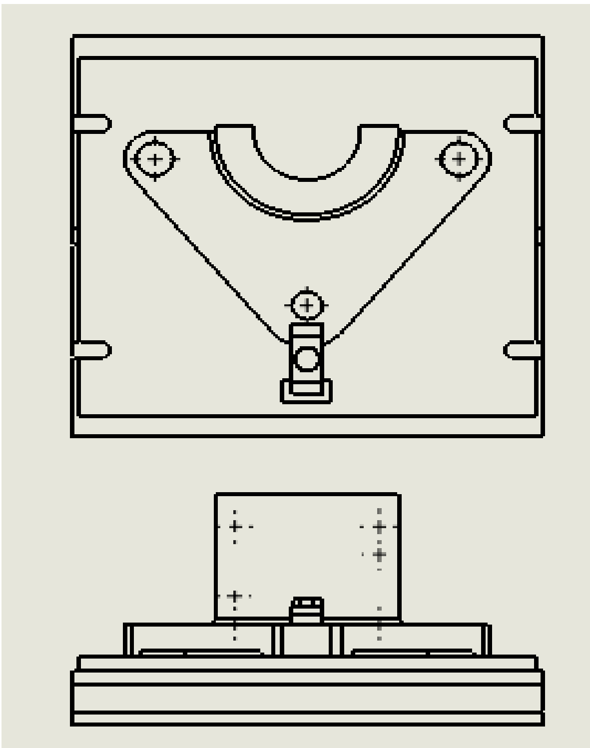


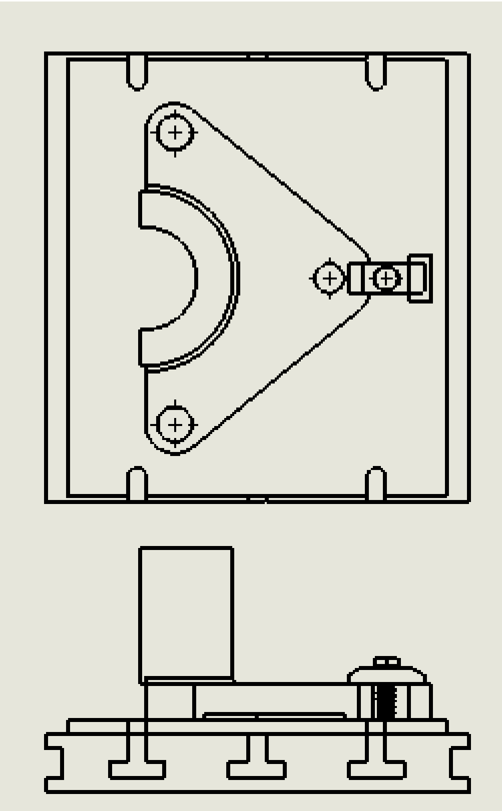
Fig 1.9 Locating scheme for GMD

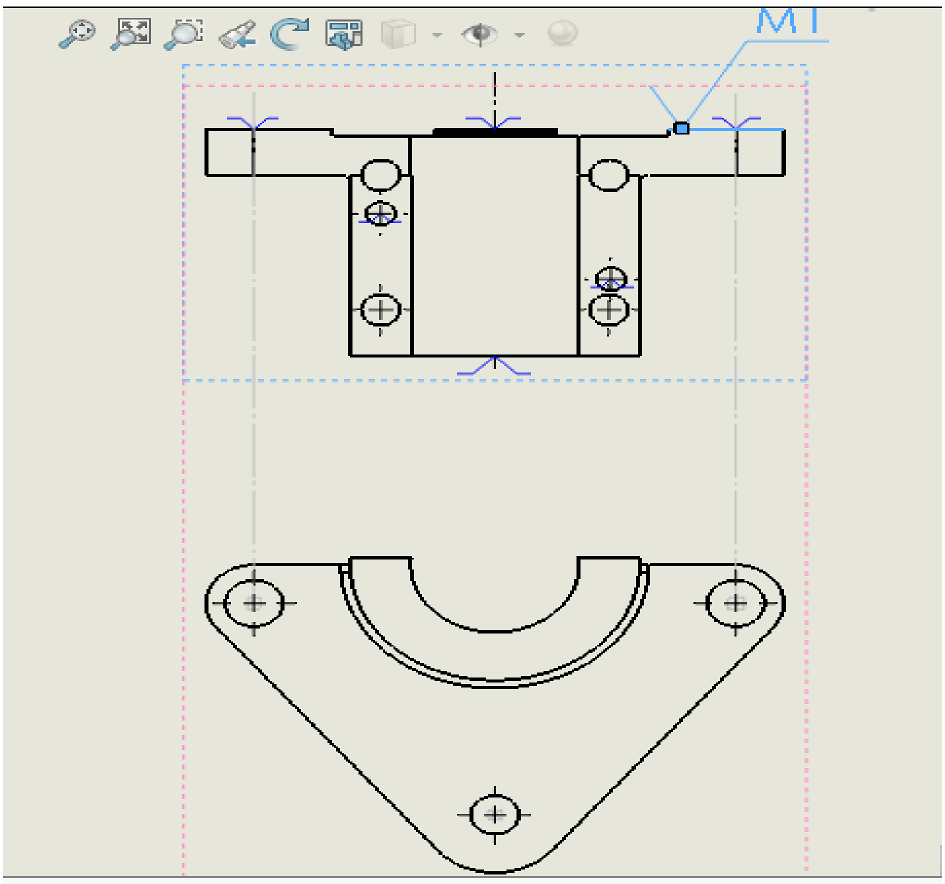
The formula for the locating scheme presented in Fig 1.9 is as follows:

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

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

DS (2) – double support datum, deprives the workpiece 2 degrees of freedom, and O(1) – support datum, deprives the workpiece 1 degree of freedom.





1.6 Design of the typical surfaces processing routes

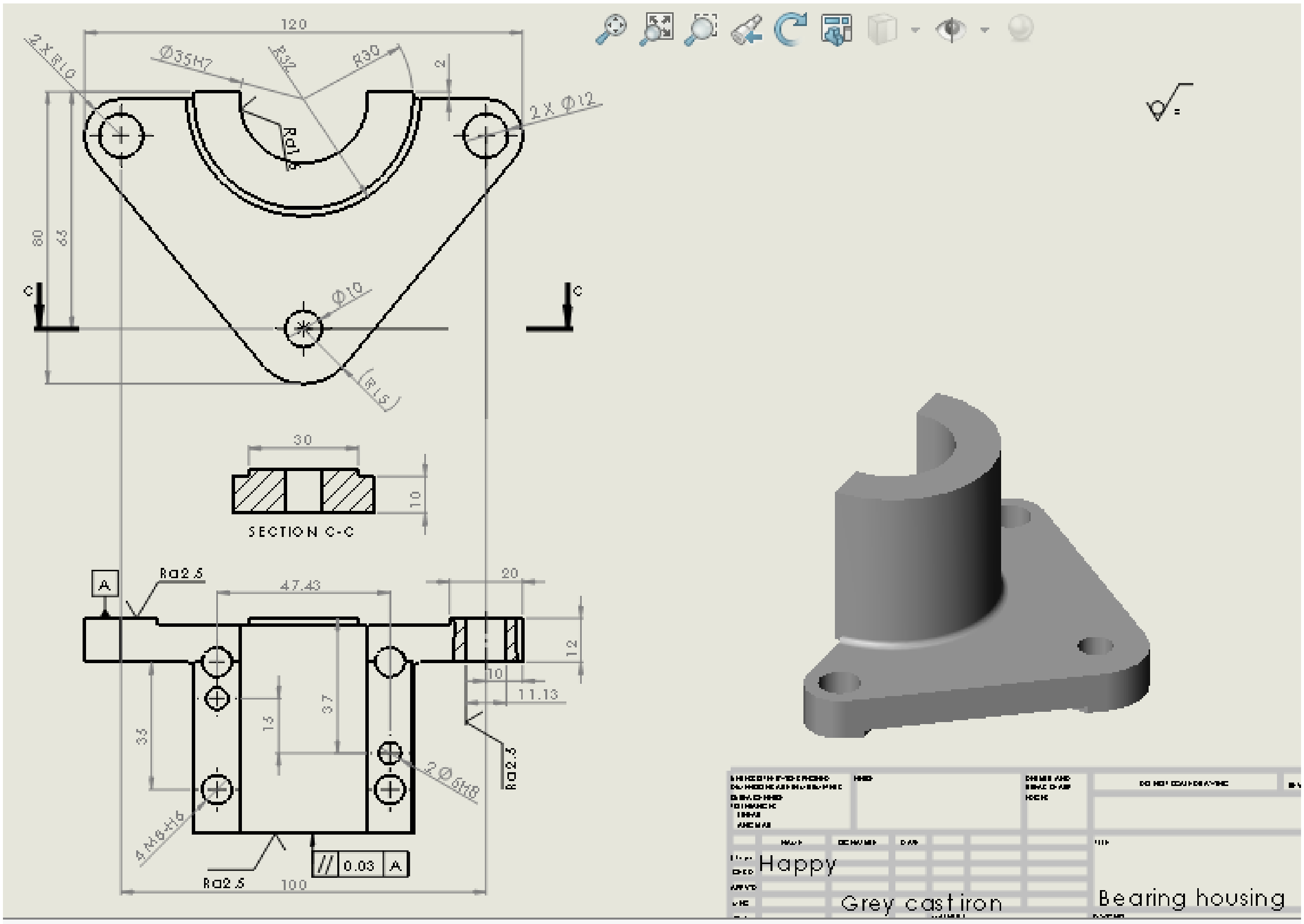
The design of a part can be divided into a set of typical geometric shapes, united by a common service purpose of the part. Typical structural elements are: cylindrical or conical external and internal surfaces, a set of planes, shaped surfaces - screw, involute and others. Depending on the type of surface,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

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

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

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

Fig. 1.15 Drawing of a part



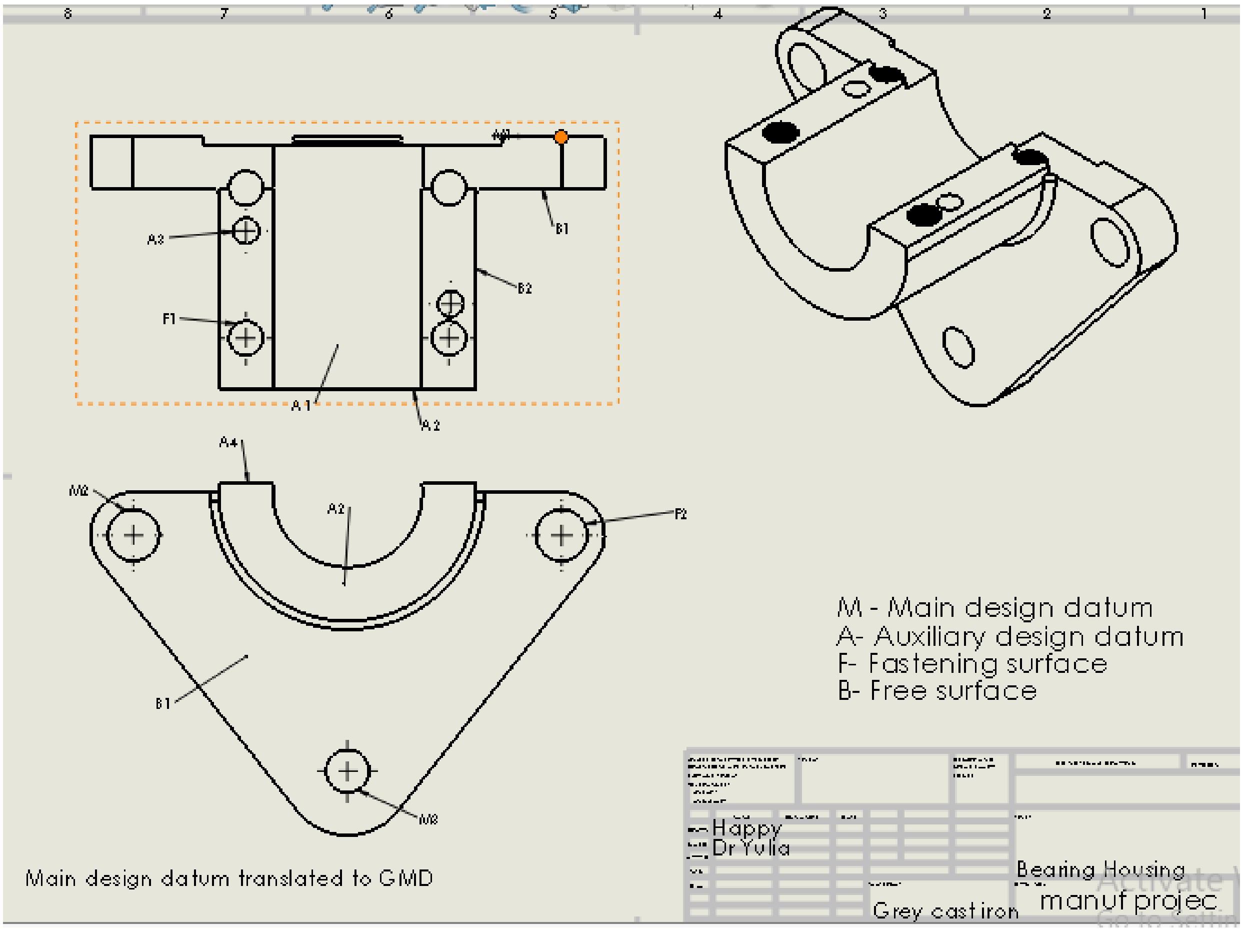


Fig 1.16 Classification of the part according to their intended purpose

Table 1.3 Processing routes for surfaces of a part “Body”

Surfaces	IT	Ra	Machining sequence	IT	Ra
	According to the draw ing			After machining	
1	2	3	4	5	6
M1	14	2,5	Rough milling Finish milling	14	6,3 2,5
M2, M3	14	10,0	Centering Drilling Reaming	14	10
A1	H7	5	Rough boring & Finish Boring	H7	5
A2	14	2,5	Rough milling Finish milling	14	6,3 2,5

F2	14	10	Centering Drilling,	14	10
F1	6H	-	Centering, Drilling, Countersinking, threading	6H	-
A3	8H	-	Centering Drilling, & reaming	8H	
A4	14	2.5	Rough milling and finish milling	14	6.3 2.5

1.7. Design of manufacturing technological process plan

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

Let's consider the following recommendations:

Surfaces that are the datums for the subsequent stages of processing should be processed first

Each subsequent manufacturing step or operation must improve the quality characteristics of the treated surfaces; if this requirement is not met, e.g. when implementing heat treatment, then it is necessary to return to the processing of the workpiece surfaces, which are datum for subsequent processing stages.

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.

For timely detection of defects on surfaces where they are not allowed, these surfaces should be processed at the early stages of the manufacturing process.

During roughing the first should be processed surfaces that have the highest allowance and the most responsible surfaces

Finishing of the most responsible surfaces must be performed at the latest manufacturing steps.

The surfaces which least reduce the overall stiffness of the workpiece should be processed first

Surfaces with a precise relative spatial position should be processed in one installation

Do not change the tool when finishing precise responsible surfaces

Fastening surfaces must be processed at the 3rd stage of the manufacturing process, after finishing the related surface

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

Machine: HAAS-VDT-2

A. Install, secure, remove

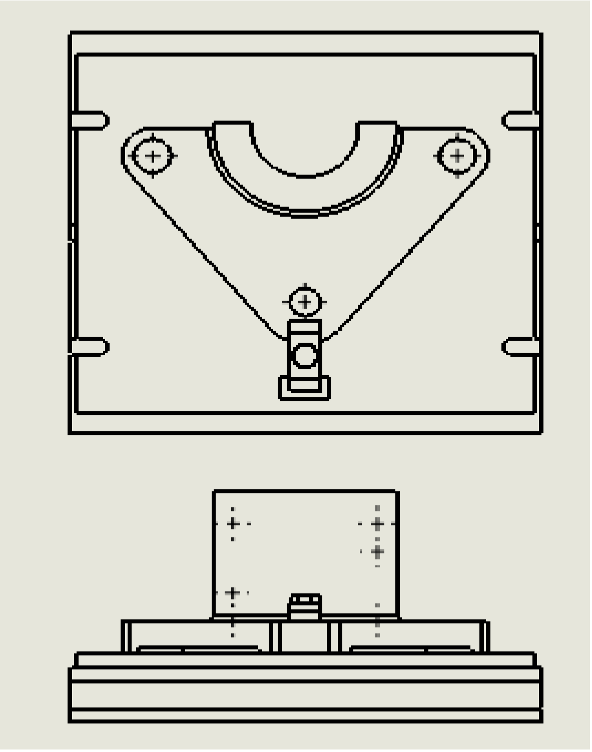
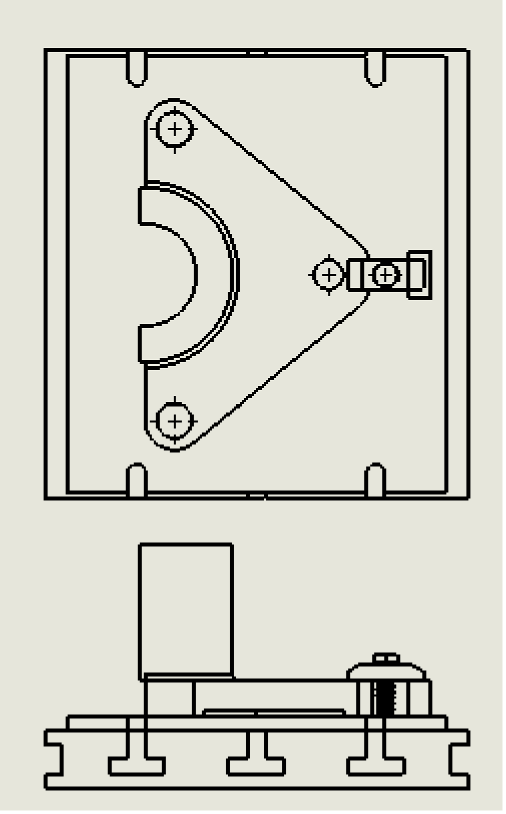
No:	Operation	Casting method	Production	Quantity
10	Base; cast to length 120* width 82.7* height 12 Semi-circle; cast to OD ø60 and ID ø31.5 with height 50.8	Machine mold	Medium batch	2500

Part No:031393	Part Name: Bearing housing	Rev 2	Page 1 of 2
Mat: Grey-cast iron	Size: 120mm long*82.7mm width*62.8 height	Planner: Happy Intl Ltd	Date: 27/12/2021

No	Operation	Dept.	Machine	Tooling gauges	Setup time	Cycle time

20	Face milling; M1, A2, & A4. to width 80* height 59 Rough 2.5, IT 14		HAASVDT2			
30	Centering, drilling & reaming; 2*A3. to ø6 H8					
40	Centering, drilling, countersinking, & threading; 4*F1. to M8 – 6H					
50	Reverse fixture 90° Rough & finish Boring; A1. to ø35 – H7 and Ra 1.6					
60	Centering, drilling, & reaming; M2 & F2. to ø12 Ra 10, and IT 14					
70	Centering, drilling, & reaming; M3. to ø10 Ra 10, and IT 14					

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

20		Haas model VDT2 5xa	UZP-12	The mill is final D73mm GOST 17025-71 Spiral drills GOST 10902-77. Sweeps GOST 3266-81
30		Haas model VDT2 5xa	UZP-12	The mill is final D73mm GOST 17025-71 Sweeps GOST 3266-81 Drill spirals GOST 10902-77. Tap GOST 3266-81

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

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%
O0001(3D MANUF MODEL H NC1)
( SETUP1 - 5/20/2022 - 14:45:40 )
( FEATURECAM - HAAS VF )
( MACHINE TIME = 1:10:34.7 )

N35 ( ROUGH1 SIDE SIDE1 )
N40 G0 G17 G21 G40 G94
N45 T1 M6 ( ENDMILL1000:4REG  25.4 DIA. )
N50 G54 G90 X104.609 Y18.182 S954 M3
N55 G43 H1 Z25.0 M8
N60 Z3.0
N65 G1 Z-22.875 F145.
N70 P9901 M97
N75 G0 Z25.0
N80 X104.609 Y18.182
N85 Z-19.875
N90 G1 Z-45.75 F145.
N95 P9901 M97
N100 G0 Z25.0
N105 G53 G49 Z0. M9
N110 M1

N115 ( FINISH SIDE SIDE1 )
N120 G0 G17 G40 G94
N125 T2 M6 ( ENDMILL1000:HIGH  25.4 DIA. )
N130 G54 G90 X78.127 Y146.299 S343 M3
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N135 G43 H2 Z25.0 M8
N140 Z3.0
N145 G1 Z-47.0 F17.
N150 X81.161 Y132.662 F34.
N155 G2 X92.704 Y117.61 I-79.161 J-72.657 F39.
N160 G1 X105.087 Y111.142 F34.
N165 X102.889 Y77.835
N170 X92.704 Y87.397
N175 G3 X62.753 Y132.715 I-90.704 J-27.392 F39.
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N185 G0 Z25.0
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N195 Z3.0
N200 G1 Z-47.0 F17.
N205 X92.704 Y2.401 F34.
N210 G2 X81.165 Y-12.647 I-90.704 J57.604 F39.
N215 G1 X78.131 Y-26.283 F34.
N220 X57.953 Y-25.818
N225 X62.757 Y-12.7
N230 G3 X92.704 Y32.614 I-60.757 J72.706 F39.
N235 G1 X102.889 Y42.176 F34.
N240 X32.545 Y-24.497
N245 X40.028 Y-12.7
N250 G3 X40.02 Y132.715 I-38.028 J72.706 F40.
N255 G1 X32.536 Y144.511 F34.
N260 X-15.16 Y135.364
N265 X-2.623 Y129.201
N270 G2 X-2.623 Y-9.19 I4.623 J-69.196 F42.
N275 G1 X-15.16 Y-15.353 F34.
```

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N280 X-14.314 Y-2.681
N285 X-1.777 Y3.482
N290 G3 X-1.777 Y116.53 I3.777 J56.524 F44.
N295 G1 X-14.314 Y122.692 F34.
N300 X-13.467 Y110.021
N305 X-0.93 Y103.858
N310 G2 X-0.93 Y16.153 I2.93 J-43.852 F48.
N315 G1 X-13.467 Y9.99 F34.
N320 X-13.384 Y108.773
N325 X-0.847 Y102.611
N330 G2 X-0.847 Y17.401 I2.847 J-42.605 F48.
N335 G1 X-13.384 Y11.238 F34.
N340 G0 Z25.0
N345 G53 G49 Z0. M9
N350 M1

N355 ( ROUGH1 SIDE SIDE2 )
N360 G0 G17 G40 G94
N365 T3 M6 ( ENDMILL1000:HIGH+  25.4 DIA. )
N370 G54 G90 X-10.098 Y63.441 S214 M3
N375 G43 H3 Z25.0 M8
N380 Z3.0
N385 G1 Z-20.0 F16.
N390 P9902 M97
N395 G1 Y63.441
N400 Z-40.0 F16.
N405 P9902 M97
N410 G1 Y63.441
N415 Z-60.0 F16.
```

```
N420 P9902 M97

N425 ( FINISH SIDE SIDE2 )
N430 G1 G54 G90 X-10.098 Y56.571 Z-60.0 S257
N435 Y62.191 F25.
N440 X2.0 Y55.206
N445 G3 X2.0 Y64.806 I0. J4.8 F13.
N450 G1 X-10.098 Y57.821 F25.
N455 G0 Z25.0

N460 G53 G49 Z0. M9
N465 G53 Y0.
N470 M30

N9901 ( MACRO FOR ROUGH1 SIDE1 )
N475 G1 X-11.905 Y-7.311 F291.
N480 G2 X-17.524 Y-23.571 I-90.704 J49.134
N485 G1 X-3.571 Y-13.506
N490 X-13.744 Y0.391
N495 X4.813 Y13.115
N500 G3 X30.026 Y45.49 I-60.678 J72.706
N505 G1 X10.167 Y9.581
N510 X1.738 Y59.458
N515 X-11.905 Y7.311
N520 G3 X-17.528 Y23.575 I-90.704 J-49.134
N525 G1 X-3.572 Y13.506
N530 X-13.744 Y-0.392
N535 X4.813 Y-13.114
N540 G2 X30.031 Y-45.494 I-60.673 J-72.709
```

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N545 G1 X10.167 Y-9.581
N550 X-60.938 Y67.47
N555 X6.444 Y-12.395
N560 G2 X0.006 Y-145.415 I-46.377 J-72.709
N565 G1 X-6.442 Y-12.396
N570 X-21.126 Y1.568
N575 X8.827 Y10.828
N580 G3 X-0.011 Y145.415 I-27.642 J72.706
N585 G1 X-8.828 Y10.827
N590 X-35.962 Y-8.203
N595 X12.537 Y-6.163
N600 G2 X0. Y-138.341 I4.622 J-69.17
N605 G1 X-12.537 Y-6.163
N610 X0.564 Y8.44
N615 X12.537 Y6.163
N620 G3 X0. Y121.462 I4.058 J60.731
N625 G1 X-12.537 Y6.162
N630 X0.564 Y-8.439
N635 X12.537 Y-6.163
N640 G2 X0. Y-104.583 I3.494 J-52.292
N645 G1 X-12.537 Y-6.163
N650 X0.564 Y8.439
N655 X12.537 Y6.163
N660 G3 X0. Y87.705 I2.93 J43.852
N665 G1 X-12.537 Y6.163
N670 M99

N9902 ( MACRO FOR ROUGH1 SIDE2 )
N675 G1 X12.098 Y-6.985 F33.
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```
N680 G3 X0. Y7.1 I0. J3.55
N685 G1 X-12.098 Y-6.985
N690 M99
%
```

90 Washing

100 Control and inspection

1.9 Determination of the cutting and clapping forces

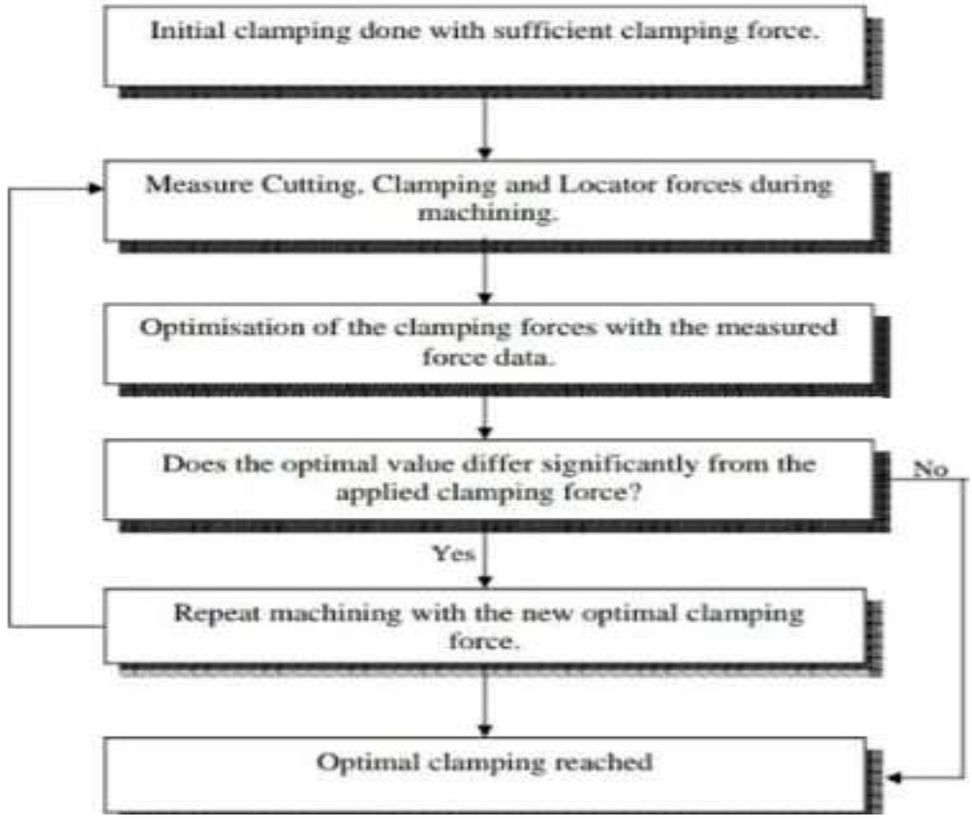
Control of clamping forces is an important feature implemented in recent fixturing systems to overcome the drawbacks of conventional fixturing arrangements with constant clamping forces, which are usually applied manually.

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

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

The algorithm below, shows another simple steps of determining clamping force:

The optimisation follows an iterative procedure as illustrated in Figure 6.1. The first machining operation is performed applying sufficient clamping force to ensure that the workpiece remains stable. The machining process is repeated with the same cutting parameters and the clamping force is progressively optimised for each subsequent machining operation to reach the final optimal clamping force.



According to [10, table 3.] for milling, choose the geometric parameters of the cutting part of the cutter:

$\varphi = 45°$; $\alpha = 12°$; $\gamma = 10°$; $\varphi_1 = 3°$; $\lambda = 0°$; r =1 mm; f =0.6 mm

take the depth of cut t = 0.39

Choose the feed S = 0.5-0.3 mm / rev ([3] table 11, p.266),

take S = 0.4 mm / rev.

Adjust the feed taking into account the correction factors ([4] map 11, p.52):

$$S = S1 \cdot K_{SM} \cdot K_{S\Pi} \cdot K_{Si} \cdot K_{Sp} \cdot K_{SD} \cdot K_{S\varphi} \cdot K_{SL}$$

Ksm = 1,05 - coefficient taking into account the mechanical properties of the workpiece material;

Ksp = 1,0 - coefficient that takes into account the state of the workpiece surface;

Ks = 1,15 - coefficient that takes into account the influence of the tool material;

Ksp = 1,0 - coefficient that takes into account the method of mounting the plate;

KsD = 0,62 - coefficient taking into account the diameter of the part;

Ksφ = 1,0 - coefficient that takes into account the geometric parameters of the cutter;

KsL = 0.82 - coefficient that takes into account the departure of the cutter;

$$S = 0.4 \cdot 1.05 \cdot 1.0 \cdot 1.0 \cdot 1.0 \cdot 0.62 \cdot 1.15 \cdot 0.82 = 0.25$$

Determine the cutting speed by the formula, m / min:

$$[V] = \frac{C_v K_v}{T^m t^{x_v} S^{y_v}}, \ mm/rev$$

where Sv is the coefficient that will determine the stability of the cutting tool, its material, geometry, size, cutting conditions.

Cv = 292 ([3] table 17, p.269);

T - normative period of stability of the cutter, T = 90 min;

m, xv, yv - exponents; m = 0.2; xv = 0.15; yv = 0.3; ([3] Table 17, p. 269);

Kv is the total correction factor for the cutting speed.

$$K_v = K_{M_v} K_{n_v} K_{i_v} K_{d_v}$$

where: K_{M_v} - quality of the processed material

K_{n_v} - the condition of the workpiece surface

K_{i_v} - material of the cutting part of the tool

K_{d_v} - type of processing

$$Kv = 0.94 \cdot 0.8 \cdot 1.0 \cdot 0.9 = 0.67$$

Substitute the value into the formula:

$$V = \frac{292}{90^{0,2} \cdot 0,39^{0,15} \cdot 0,25^{0,3}} \cdot 0,67 = 138,58 \ mm/rev$$

Determine the speed by the formula:

where D = 72 mm

$$n_{опт} = \frac{1000 \cdot V_{опт}}{\pi \cdot D} = \frac{1000 \cdot 138{,}58}{3{,}14 \cdot 72} = 612 \;\; m/\,min$$

Adjust the speed of the machine passport:

pd = 600 rpm

Determine the actual cutting speed:

Determine the components of the cutting force:

$$V_{Д} = \frac{\pi \cdot D \cdot n_{Д}}{1000} = \frac{3{,}14 \cdot 72 \cdot 600}{1000} = 135.6 \; m/\; min$$

Determine the components of the cutting force:

Pxyz = 10 · Cp · tx · Sy · Vn · Kp

Calculate the force Pz:

where Cp = 300; x = 1.0; y = 0.75; n = -0.1 ([3] Table 22 p. 273)

Kr - total correction factor.

$$K_p = K_{M_p} K_{\varphi_p} K_{\gamma_p} K_{\lambda_p} K_{r_p}$$

where Kmr - coefficient that takes into account the impact of the material, Kmr = 1,03 [3] table 9st.273);

$K_{\varphi_p} K_{\gamma_p} K_{\lambda_p} K_{r_p}$ - coefficients that take into account the geometry of the cutter.

Kφr = 1.0; K_{γ_p} = 1.0; K_{λ_p} = 1.0; K_{r_p} = 0.93 ([3] Table 23 p. 275)

Kr = 1.0 · 1.0 · 1.0 · 0.93 = 0.93

Substituting the values in the formula we obtain:

Pz = 10 · 300 · 0.39 1 · 0.25 0.75 · 135.6-0.1 · 0.93 = 233.1H

Radial component of cutting forces:

Wed = 243; x = 0.9; y = 0.6; n = -0.2; ([3] Table 22 p. 273)

Kφr = 1.0; K_{γ_p} = 1.0; K_{λ_p} = 0.1; K_{r_p} = 0.93 ([3] Table 23 p. 275)

Kr = 0.93 · 1.0 · 0.1 · 1.0 = 0.93

Substitute the values into the formula:

Py = 10 · 243 · 0.390.9 · 0.25 0.6 · 135.6-0.2 · 0.93 = 64.7 H

Axial component of cutting forces; Cp = 339; x = 1.0; y = 0.5; n = -0.3; ([3] Table 22 p. 273)

Kφr = 1.0; K_{γ_p} = 1.0; K_{λ_p} = 1.0; K_{r_p} = 1.0 ([3] Table 23 p. 275)

Kr = 1.0 · 1.0 · 0.94 · 1.0 = 1.0

Substitute the values into the formula:

Px = 10 · 339 · 0.391 · 0.250.5 · 135.6-0.3 · 1.0 = 145.4H

Determine the cutting power by the formula:

$$N_p = \frac{Pz \cdot V}{1000 \cdot 60} = \frac{233.3 \cdot 135.6}{1000 \cdot 60} = 0.52 m/min$$

Check whether the cutting condition is maintained:

Np <Nd · ηd

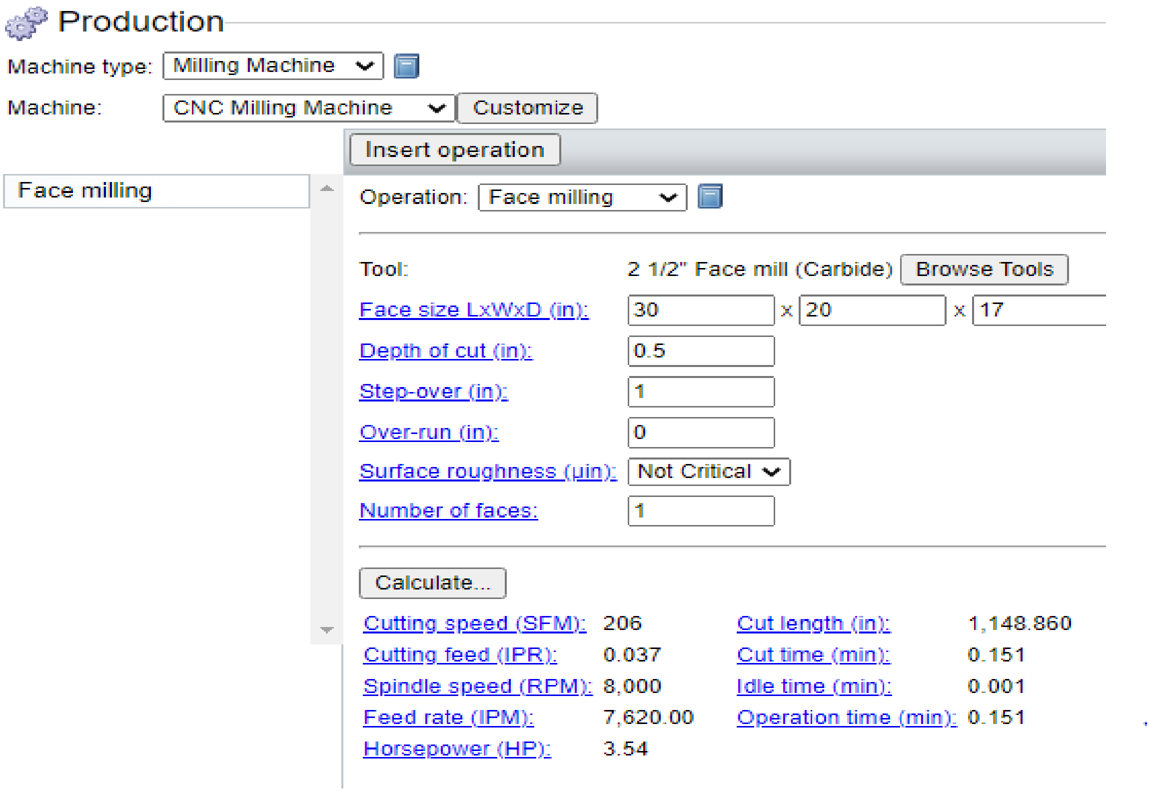
where: ηd - efficiency; ηd = 0.75 - 0.95

N = 10 kW - power of the machine motor

0.52 <8.8

Determination of the economic cost and time

Face milling (20) M1 to 120*80*12



Production

Machine type: Milling Machine

Machine: CNC Milling Machine | Customize

Insert operation

Face milling

Operation: Face milling

Tool: 2 1/2" Face mill (Carbide) | Browse Tools

Face size LxWxD (in): 30 x 20 x 17

Depth of cut (in): 0.5

Step-over (in): 1

Over-run (in): 0

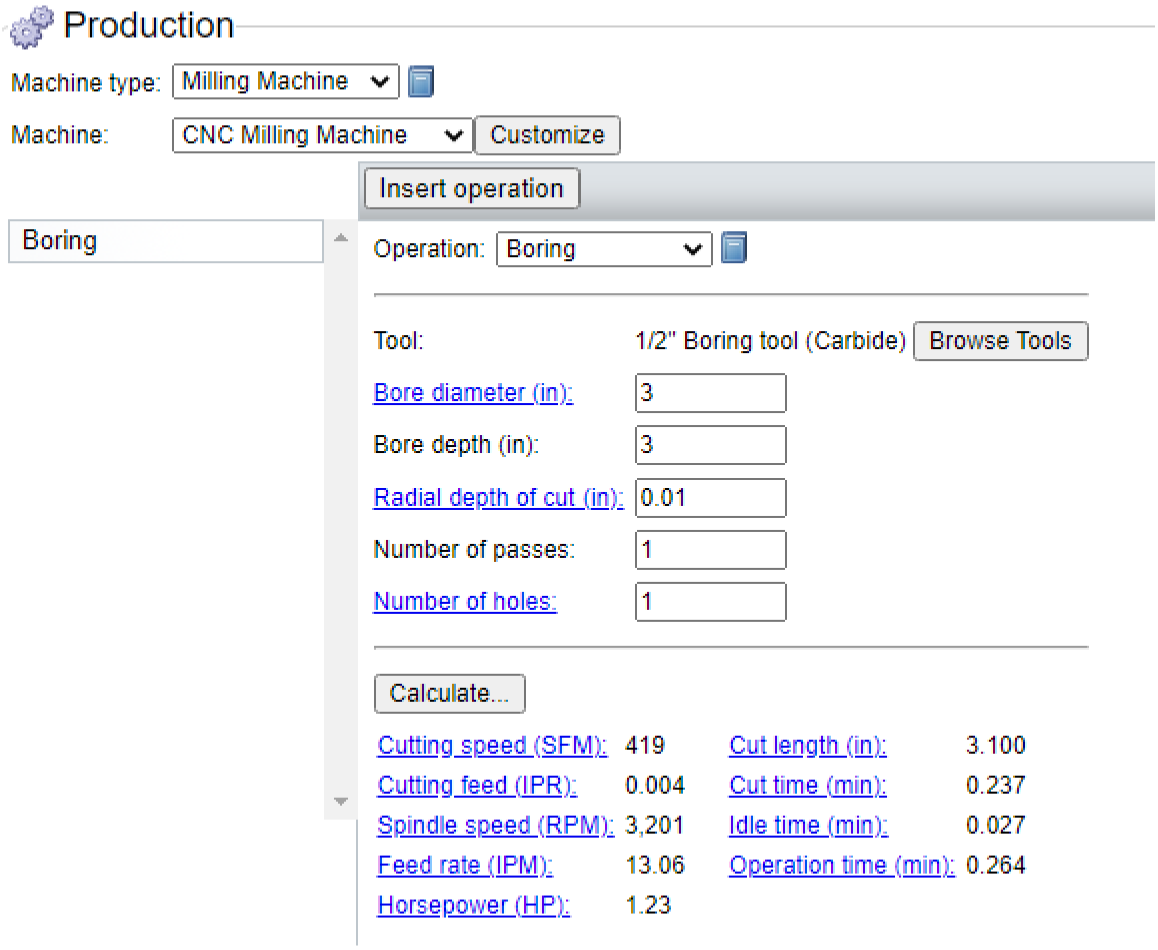
Surface roughness (μin): Not Critical

Number of faces: 1

Calculate...

Cutting speed (SFM):	206	Cut length (in):	1,148.860
Cutting feed (IPR):	0.037	Cut time (min):	0.151
Spindle speed (RPM):	8,000	Idle time (min):	0.001
Feed rate (IPM):	7,620.00	Operation time (min):	0.151
Horsepower (HP):	3.54		

Bore M2 & M3 to ø12



2.0 Machine and tool selection

2.1.1 Machine selection

Type and size of machine

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

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

Power/Force analysis

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

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

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

Capability analysis

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

Operational analysis

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

Considering all aforementioned requirements and limitations as well as process plan, developed in the previous chapter, the preliminary selected machine is the vertical machining centre HAAS-DT-2.

The vertical machining centre in the H DT-2 version (see general technical data in fig. 8.1) is a highly productive machine for the complex chip machining of parts from the steel, grey cast iron and soft metal alloys clamped on the rotary table. It enables to perform the milling operations in three mutually perpendicular X, Y, Z coordinate axes and in the rotary B axis. It also enables to perform the drilling, boring, reaming and thread cutting operations as well as the usage of the screw die heads without aligning bush in the Z axis.

TRAVELS	S.A.E	METRIC
X Axis	28.0 in	711 mm
Y Axis	16.0 in	406 mm
Z Axis	15.5 in	394 mm
Spindle Nose to Table (~ max)	21.5 in	546 mm
Spindle Nose to Table (~ min)	6.0 in	152 mm

SPINDLE	S.A.E	METRIC
Max Rating	15.0 hp	11.2 kW

Max Speed	10000 rpm	10000 rpm
Max Torque	46.0 ft-lbf @ 1700 rpm	62.0 Nm @ 1700 rpm
Drive System	Inline Direct-Drive	Inline Direct-Drive
Taper	BT30	BT30
Bearing Lubrication	Air / Oil Injection	Air / Oil Injection
Cooling	Air Cooled	Air Cooled

TABLE	S.A.E	METRIC
Length	34.0 in	864 mm

Width	15.0 in	381 mm
T-Slot Width	0.626 in to 0.630 in	15.90 mm to 16.00 mm
T-Slot Center Distance	4.92 in	125 mm
Number of Std T-Slots	3	3
Max Weight on Table (evenly distributed)	250 lb	113 kg

FEEDRATES	S.A.E	METRIC
Max Cutting	1200 ipm	30.5 m/min
Rapids on X	2400 ipm	61.0 m/min

Rapids on Y	2400 ipm	61.0 m/min
Rapids on Z	2400 ipm	61.0 m/min

AXIS MOTORS	S.A.E	METRIC
Max Thrust X	2550 lbf	11343 N
Max Thrust Y	2550 lbf	11343 N
Max Thrust Z	4200 lbf	18683 N

TOOL CHANGER	S.A.E	METRIC
Type	SMTC	SMTC

Capacity	20+1	20+1
Max Tool Diameter (full)	2.0 in	51 mm
Max Tool Length (from gage line)	7 in	178 mm
Chip-to-Chip (avg)	1.6 s	1.6 s

TAPPING	S.A.E	METRIC
Max Tapping Speed	5000 rpm	5000 rpm

GENERAL	S.A.E	METRIC
Coolant Capacity	55 gal	208 L

AIR REQUIREMENTS	S.A.E	METRIC
Air Required	4 scfm @ 100 psi	113 L/min @ 6.9 bar
Inline Air Hose	3/8 in	3/8 in
Coupler (Air)	3/8 in	3/8 in
Air Pressure Min	80 psi	5.5 bar

DIMENSIONS - SHIPPING	S.A.E	METRIC
Domestic Pallet	100 in x 91 in x 99 in	254 cm x 231 cm x 251 cm
Export Pallet	100 in x 91 in x 99 in	254 cm x 231 cm x 251 cm

Weight	5350 lb	2427.0 kg

ELECTRICAL SPECIFICATION	S.A.E	METRIC
Spindle Speed	10000 rpm	10000 rpm
Drive System	Inline Direct-Drive	Inline Direct-Drive
Spindle Power	15.0 hp	11.2 kW
Input AC Voltage (3 Phase) - Low	220 VAC	220 VAC
Full Load Amps (3 Phase) - Low	17 A	17 A
Input AC Voltage (3 Phase) - High*	440 VAC	440 VAC

Full Load Amps (3 Phase) - High*	13 A	13 A

Fig. 8.1 Technical data of the selected machine

1.8.2 Tooling selection

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

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

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

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

Selection of tooling – If single-piece tooling is being used, then a suitable toolholder 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 toolholder type and size;

• Select insert shape;

• Select insert size;

• Determine tool edge radius;

• Select insert type;

• Select tool material.

Tool selection for the manufacturing step

“005.01 Mill surface M1 to dimension 82*61”

Allowance = 2.5mm

Radial cutting width = 10mm

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

Fig. 8.2 Initial Data for tooling selection (screenshot)

Scientific Research

Effect of elastic deformation of dimension accuracy during boring

Elastic deformation from boring perspective, is the displacement of the interstitial atomic crystal bond in a mechanical component, as a result of the application of force.

However, this force can also generate heat at contact surface between the workpiece and cutting tool as a result of friction, which is largely dependent on the feed rate, depth of cut, cutting speed, coolant supply, and the boring sequences, thereby causing elastic deformation effect on the dimensional accuracy of both the cutting tool and mechanical part.

In this study, focus is paid to the force and the heat generated at the cutting zones, using the machining of a cylinder liner, which method can be applied.

It is well known that the total machining errors of the engine cylinder liner are mainly dominated by the elastic deformation caused by the cutting force and the thermal expansion caused by the temperature rise during the boring process. Clarification of the amount of machining errors resulting from the cutting force and thermal expansion is useful for determining whether thermal expansion or the cutting force has a larger influence on machining errors during the boring process. This would provide a clear approach to the optimization of cutting conditions or to product improvement, leading to a higher degree of machining accuracy.

There are a number of technological elements, during the manufacture of which there is a need to take into account elastic deformations that cause measuring instruments when controlling the size of surface treatment. An example of such elements are long thin frames, which in the future, for example, are used for the manufacture of seamless pipes. Such frames have a conical shape, which limits the use of reference equations of resistance of materials. The purpose of this work is to develop a practical method for correcting the signals of measuring instruments on CNC machines, due to the deflection of cantilever-fixed cone arches under the action of service forces of devices on a spring basis.

In Fig. 2. 1 2 presents the calculated load scheme of the cantilever-fixed conical beam.

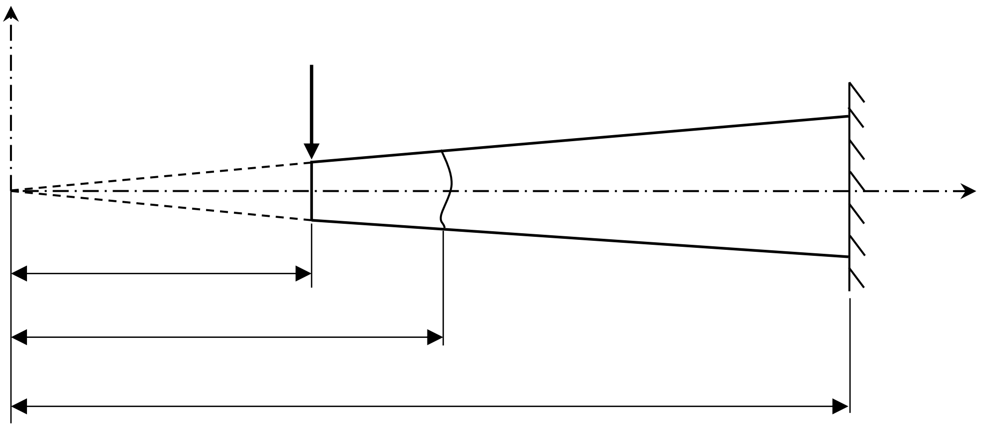


Fig. 1. The calculated scheme of the conical beam

It is assumed that at the place of fixation of the beam there are no movements and the angle of rotation of the transverse section is zero.

It is clear that the left side, which is depicted dotted in Fig. 2. 1, will not resist and will not affect the deflection at the point of application of force and therefore it is necessary to consider only the right part of the system under study.

Let the cone of the studied beam be given $k = D_{\max}/H$, де H – this is the length of the cone and $D_{\max}$ – cross-sectional diameter at the place of fixing the cone. Consider an arbitrary cross section at a distance z, as shown in Fig. 2. 1. Then the diameter in the studied cross section can be expressed in the form of

$$D(z) = k \cdot z \,.$$

The deflection at the point of application of force can be determined using the differential equation of the bent axis of the beam in the following form:

$$\frac{d^2 w}{dz^2} = \frac{M(z)}{E \cdot I(z)}, \tag{1}$$

де $M(z)$, $I(z)$ bending moment and moment of inertia, respectively. It is accepted that the frame is made of one material with a constant elasticity module E. We find the bending moment and moment of inertia:

$$M(z) = P \cdot (z - z_P)$$

$$I(z) = \frac{\pi \cdot D(z)^4}{64}$$

where z_P – force application point P.

Let's rewrite the equation (1):

$$\frac{d^2 w}{dz^2} = \frac{P \cdot (z - z_P)}{E \cdot \frac{\pi \cdot D(z)^4}{64}} = \frac{64P}{E \cdot \pi \cdot k^4}\left[\frac{1}{z^3} - \frac{z_P}{z^4}\right]. \tag{2}$$

By integrating twice the equation (2) we get

$$w(z) = \frac{64P}{E \cdot \pi \cdot k^4}\left[\frac{1}{2z} - \frac{z_P}{6z^2}\right] + C_1 z + C_2 \,.$$

Integration constants are found from the boundary conditions for fixing the beam:

$$w_A = 0\,,\ \theta_A = \frac{dw}{dz} = 0\,.$$

Then the equation of the bent axis of the beam takes the following form:

$$w(z)=\frac{64P}{E\cdot\pi\cdot k^4}\left[\frac{1}{2z}-\frac{z_P}{6z^2}+z\left(\frac{1}{2H^2}-\frac{z_P}{3H^3}\right)-\frac{1}{H}+\frac{z_P}{2H^2}\right].$$

Taking $z_P=z$ finally get

$$w(z_P)=\frac{64P}{E\cdot\pi\cdot k^4}\left[-\frac{1}{3H^3}z^2+\frac{1}{H^2}z+\frac{1}{3z}-\frac{1}{H}\right]. \qquad (3)$$

The resulting equation allows you to determine the deflection of the cantilever-fixed frame of the cone shape at an arbitrary point of application of force and adjust the indicators of measuring equipment during the control of the size of the processing surface.

It should be noted that in some engineering solutions they find an approximate value of the deflection of conical beams by determining the movements of the equivalent cylindrical beam by the average diameter of the cone. However, this is accompanied by the emergence of a certain error. To accurately solve the problem, it is necessary to determine the equivalent diameter of the cylinder, which will exert the same resistance compared to the conical beam. We determine the movement at the point of application of the force of the cylindrical beam. Applying the above described algorithm, we finally get:

$$w(z_P)_{екв}=\frac{64P}{E\cdot\pi\cdot D^4}\left[-\frac{1}{3}z^3+H\cdot z^2-H^2\cdot z+\frac{1}{3}H^3\right], \qquad (4)$$

where D – cylinder diameter.

By comparing equations (3) and (4), we find the diameter of the equivalent cylinder, provided $w(z_P)_{екв}=w(z_P)$:

$$D_{екв}=k\cdot H^{3/4}\cdot z^{1/4}.$$

In Fig. 2. 2 shows a comparative analysis of the determination of the deflection of the conical beam by the average diameter of the cone and by the proposed method. As can be seen from the picture, when $z_P/H=0.35$ the error reaches 70%. Equation (5) allows the use of reference equations of resistance of materials to determine the deflection of an arbitrary beam of conical shape.

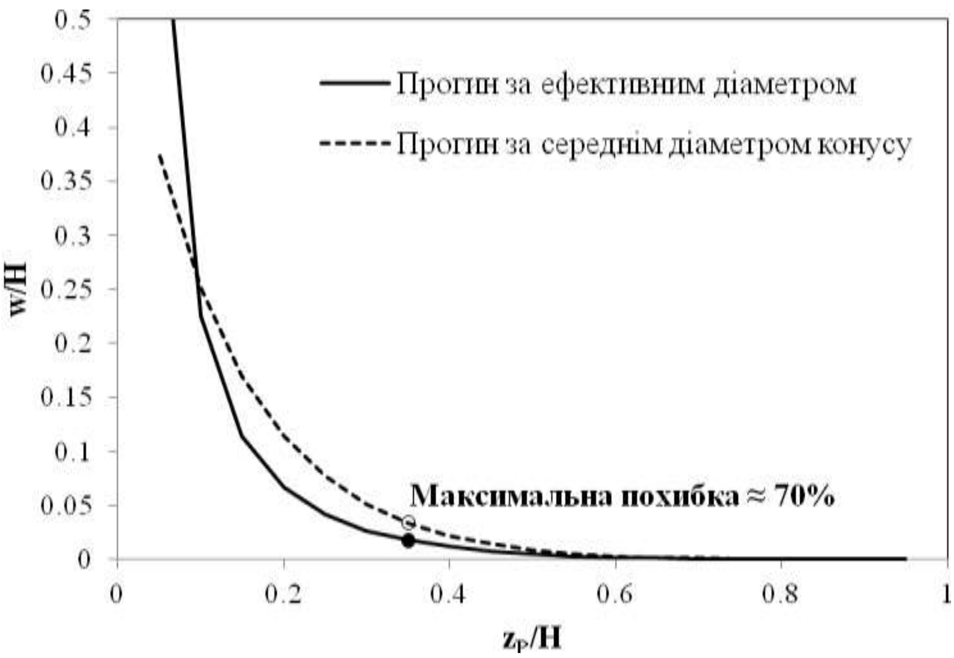


Fig. 2. Comparative analysis of determining the deflection of the conical beam

Environmental protection

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

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

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

There is a risk of fires due to the accumulation of oil in the pits under the presses and hammers. The autoignition temperature of petroleum oils is 250 - 400 oC, fuel oil - 380-420 oC.

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

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

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

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

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

Create dangerous conditions and can lead to injuries:

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

- breakage of the piston rod and stamp due to insufficient heating or cracks;
- lifting the hammer to a height;
- disconnection of a rod with falling parts of a hammer and the subsequent blow of the piston about the top cover of the cylinder;
- failure of the piston from the rod;
- breakdown of a cover of the cylinder of a hammer owing to blow of the piston;
- explosion of the pipeline from the formation of condensate in the cylinder;
- the use of incorrect methods of work when removing the workpiece that is stuck in the stamp;

- departure of wedges, crackers, linings, etc., which fix the stamp; - incorrect methods of work on hoisting and transport mechanisms; - lack of safe passages, passages, etc.

In procurement departments characteristic injuries are:

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

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

1 Increased gassiness or dust in the working air zones of toxic gases, which may belong to the controlled atmospheres and source gases. These are carbon monoxide CO, ammonia NH_3, sulfur dioxide SO_2, hydrogen sulfide H_2S, benzene C_6H_6 and others. The appearance of a pungent odor of some gases, such as ammonia, sulfur dioxide, propane, is a warning of problems.

Cyanide salts (KCN, NaCN, etc.), which are the strongest poisons, can be used in heat treatment processes. In the presence of moisture, acids, and carbon dioxide contained in the air, cyanide salts emit hydrogen cyanide (hydrocyanic acid HCN), which causes rapid suffocation due to paralysis of the tissues of the respiratory organs.

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

2 **Elevated temperature of materials or surfaces** equipment, high levels of thermal radiation. Burns can be obtained from emissions of melts due to disruption of the technological process, from the flash of hardening oils, from flashes of combustible

gases, which are used as controlled atmospheres. When touching heated products or parts of furnaces, when touching external parts of equipment (doors, handles, etc.), the temperature of which has risen due to failure of thermal insulation. Possible eye burns during operation of plasma, electron beam, optical, etc. furnaces that operate at very high temperatures. Overheating and burns of workers are also possible due to intense thermal radiation.

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

4 **Increased electromagnetic field strength.**

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

6 **Moving machines and mechanisms.**

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

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

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

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

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

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

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

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

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

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

References:

1. https://www.sandvik.coromant.com/en-gb/products/Pages/toolguide.aspx
2. https://www.haascnc.com/index.html
3. Fundamentals of modern manufacturing, third edition, by Mikel P. Groover.
4. https://www.custompartnet.com/estimate/sand-casting/
5. (1Zhang, G.M., and Kapoor, S.G., Dynamic Modeling and Analysis of the Boring Machining System, Journal of Engineering for Industry, Transactions of the ASME, Vol.109 (1987), pp.219–226.

6. Reddy, R.G., Kapoor, S.G., DeVor, R.E., A Mechanistic Force Model for Contour Turning,
Journal of Manufacturing Science and Engineering, Vol.122 (2000), pp.398-405.

7. Subramani, G., Kapoor, S.G., DeVor, R.E., A Model for the Prediction of Bore Cylindricity
during Machining, Journal of Engineering for Industry, Transactions of the ASME, Vol.115 (1993), pp.15–22.

8. Tang, Y.L. and Sasahara, H., Investigation of Thermal Behavior on Cylinder Liner During its Boring Process, International Journal of Machine Tools and Manufacture, Vol.47, Issue 14, (2007), pp.2162-2171.

9. Kakade, N.N. and Chow, J. G., Finite Element Analysis of Engine Bore Distortions During Boring Operation, Journal of Engineering for Industry, Transactions of the ASME, Vol.115 (1993), pp.376–384.

10. Dunaevsky, V. and Rudzitis, J., Clarification of a Semi-Empirical Approach in Piston Ring-Cylinder Bore Conformability Prediction, Journal of Tribology, Vol.129 (2007), pp.430-435.

11. Kakade, N.N. and Chow, J.G., Computer Simulation of Bore Distortions for Engine Boring Operation, Proc. of the Symp. on Collected Papers in Heat Transfer, Winter Annual Meeting, San Francisco, CA, Vol.123, (2003) pp.259–265.

12. Zheng, Y., Li H., Olson, W.W., and Sutherland, J.W., Evaluating Cutting Fluid Effects on Cylinder Boring Surface Errors by Inverse Heat Transfer and Finite Element Methods, Journal of Manufacturing Science and Engineering, Vol.122 (2000), pp.377-383.
13. Tang, Y.L., Sasahara, H., Nishimura, K. and Watanabe, T., Dummy Heat Source Technique for Estimating the Machining Error Caused by Thermal Behavior in Fine Boring, Proceedings of the 35th International MATADOR Conference, (2007), pp.211-214.