

National Technical University of Ukraine

«Igor Sikorsky Kyiv Polytechnic Institute»

**EDUCATIONAL AND RESEARCH
INSTITUTE OF MECHANICAL ENGINEERING**
Department of Manufacturing Engineering

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«**Admitted to the defense**»
Head of the department

_____ Oleksandr
OKHRIMENKO

“ _____ ” _____ 2024

Diploma project
for a bachelor's degree
according to the educational and professional program
«Manufacturing Engineering»
in the speciality 131 «Applied mechanics»
on the topic: Manufacturing Process Planning for a part " Pedestal Bearing
Housing "

Developed by:
the student of 4th year of study, group MT-03

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

Student _____ (signature)

Kyiv – 2024

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

Level of higher education – First (bachelor)

Program subject area – 131 “Applied
Mechanics” Educational Program
“Manufacturing Engineering”

APPROVED

Acting head of the department

_____ Olexander OKHRIMENKO
« ___ » _____ 2024

**ASSIGNMENT
for the student's diploma project**

Oluwajoba Peter Adigun

1. Topic of the project: Manufacturing Process Planning for a part ” pedestal bearing housing”

Project supervisor: Phd, associate professor Danylova Liudmyla

approved by the University Order « 27 » 05 2024 №2115-c

2. Deadline for submission of the project « 10 » June 2024

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, fixture design, economic calculation. Features and machinability of gray cast iron.

5. List of the graphic material (indicating mandatory drawings, posters, presentations, etc.) 3-D drawing of the part and drawing of the workpiece. Schematic representation of a technological operation. Assembly drawing of the machine tool. Study of features and machinability of gray cast iron.

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6. Date of the task issue «20 » April 2024

No	The stage of the diploma project	Deadline	Notes
1	Analysis of design features of the part	20.04.24	completed
2	Determining the type of production	20.04.24	completed
3	Calculation of the allowance	30.04.24	completed
4	Design of the typical surfaces	10.04.24	
5	Design of the operational manufacturing	15.05.24	
6	Setting cutting conditions	20.05.24	
7	Development of the fixture design	30.05.24	
8.	Calculation of the cost processing	30.05.24	
9	Features and machinability of gray cast iron	10.06.24	

Signature:

Student

Oluwajoba Peter Adigun

Supervisor



Danylova Liudmyla

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ABSTRACT

This work primarily focuses on the Design of Manufacturing Process Plan for a part housing.

The thesis consists of 67 A4-sized sheets and draws upon a total of 27 literature sources, 4 sites including reference books and scientific papers.

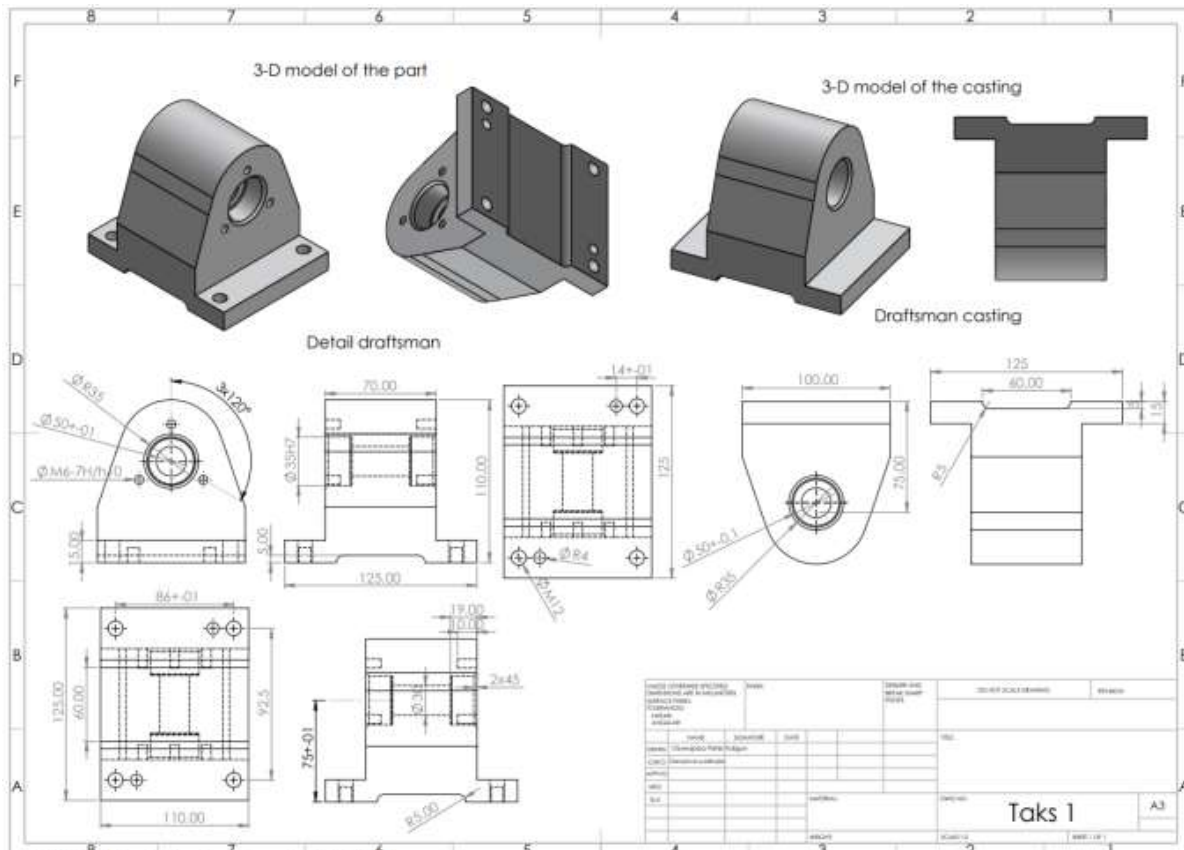
Chapter 4 of this thesis extensively discusses the Machinability of cast iron, the Difficulties and solutions to the machinability of cast iron.

The overall objective of this work is to provide a comprehensive understanding of the technological aspects involved in preparing the manufacturing process Plan for a part housing. It consist of critical elements such as process planning, fixture design, economic analysis, safety measures, and addressing the difficulties in machinability of cast iron.

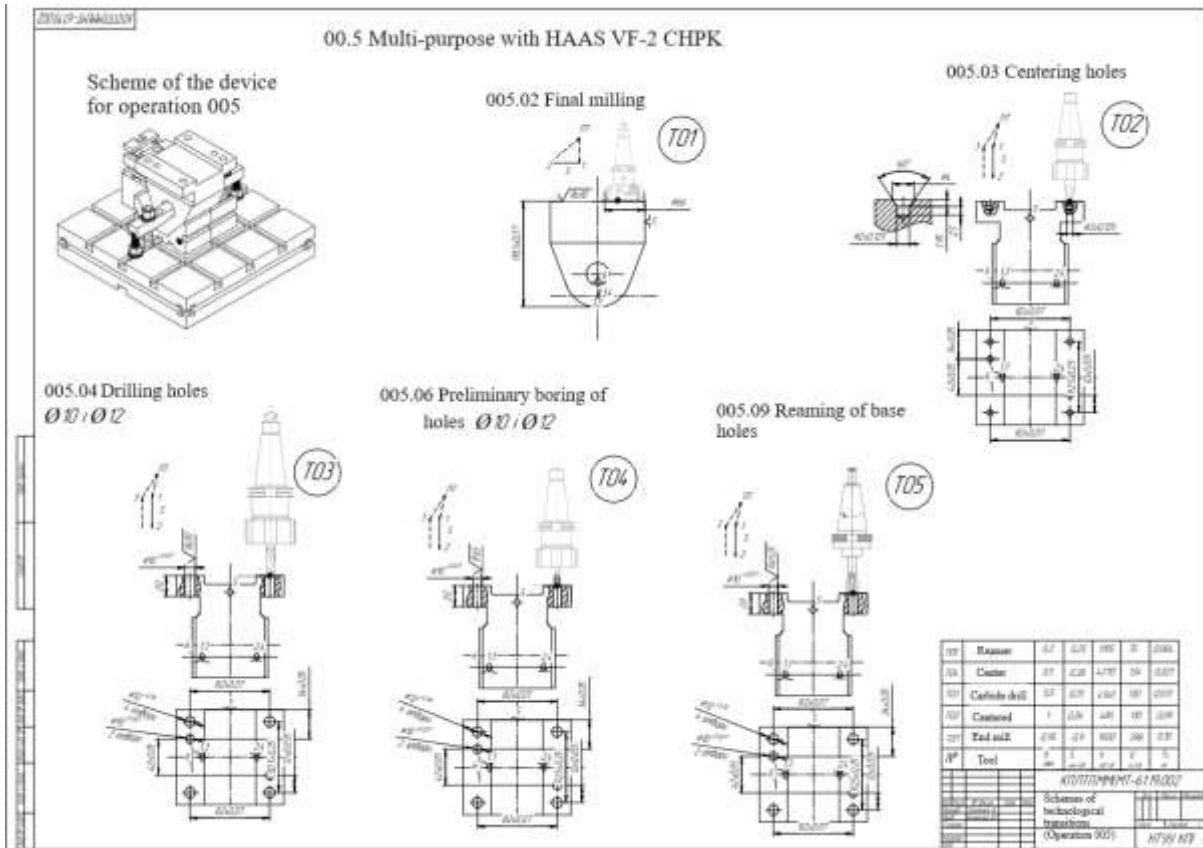
Key words: technological process, production of parts, manufacturability

CHAPTER 1

1. Drawing of a Part and a blank



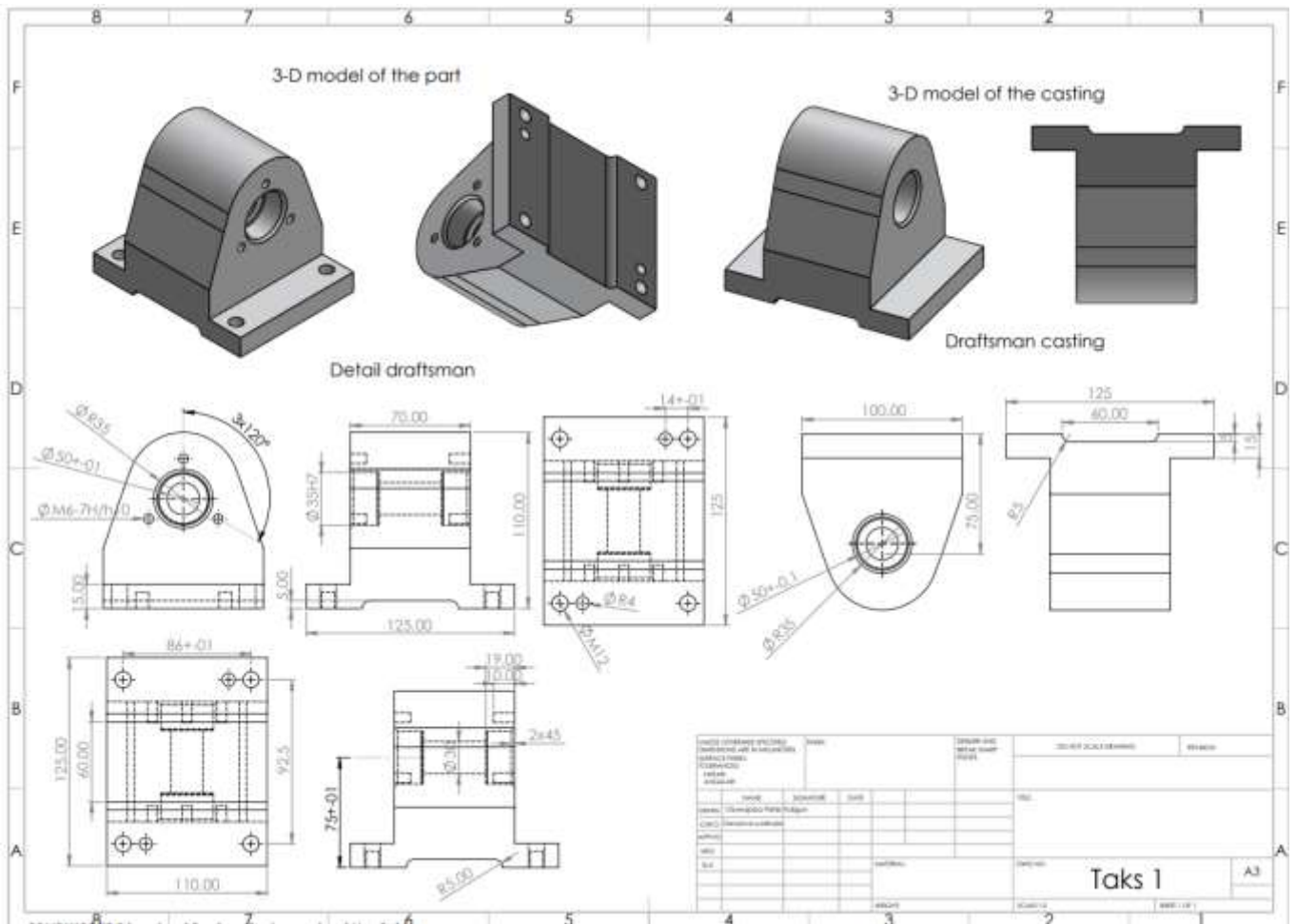
2. Manufacturing operation drawing



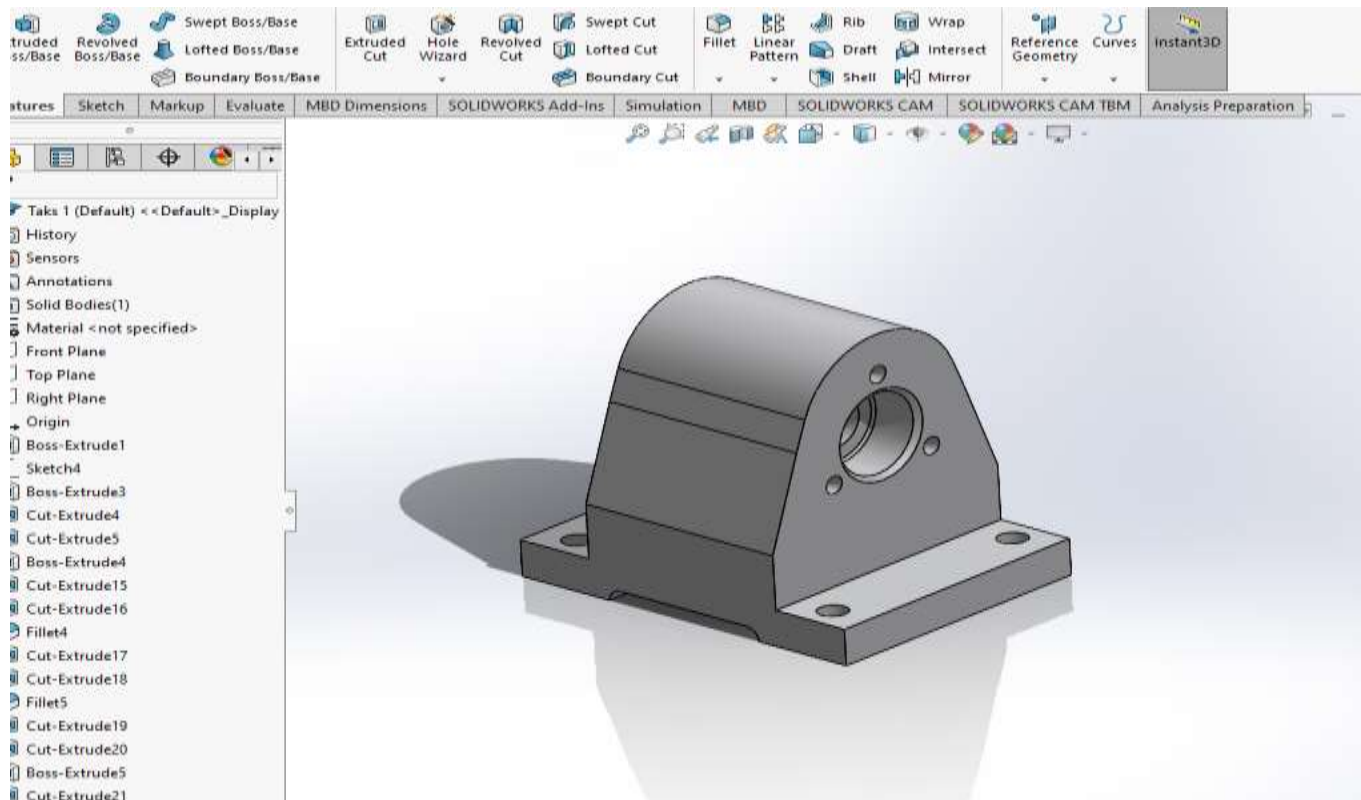
1.1 Analysis of the purpose and operating conditions of the part in the assembly

1.1.1 Analysis of design features of the part and its classification

Considering the configuration of the part 'Housing' we defined that it belongs to the class "Body."



Drawing of a part 'Housing'



Generally, the part does not demand high precision or surface quality overall, though certain surfaces require enhanced attention. Special focus must be given to accurately machining the $\varnothing 35H7$ holes to ensure their perpendicularity and alignment relative to the ends.

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

The "housing" component is engineered to secure and align gears, shafts, and bearings correctly, in addition to containing oil and preventing leaks. The $\varnothing 35H7$ holes house the bearings, while M6-7H holes are designated for securing the bearing caps. The cover is attached through three threaded M6-7H holes. The gearbox itself is firmly mounted to the frame via the $\varnothing M12$ and R4 holes. In its operational setting, the part is subject to significant and continuous alternating loads and vibrations.

1.1.3 Analysis of the material

The material used for the part is Matte chrome (ISO 185 - Class 150), which offers a tensile strength of $\sigma_B = 110$ MPa, a hardness range of $HB = 70 \dots 185$, and a density of $\rho = 676.79$ g/cm³. Given these characteristics, it is evident that the part is designed to handle

periodic loads and is resilient against aggressive environments. The specified material adequately supports the functionality of the part under these conditions. The technical drawings provide various views and sections, ensuring a thorough understanding of the part's design intricacies.

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

Educational purposes we will use analog methods of designation of production type based on weight of a part and production volume.

Part weight $m = 0.676$ kg (Fig. 1.2)

Production volume $N_p = 3000$.

Determine the type of production according to the following table (table. 1.1)

Table 1.1 – Estimation of the production type

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

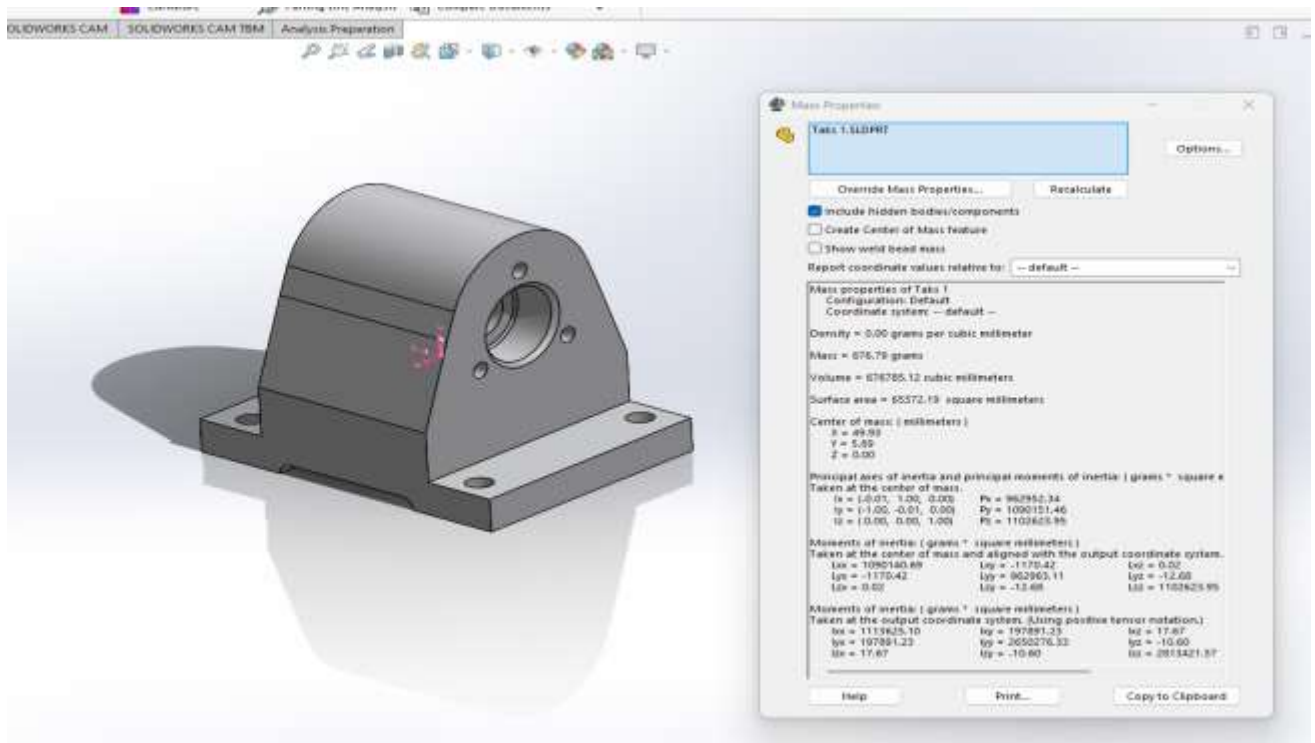


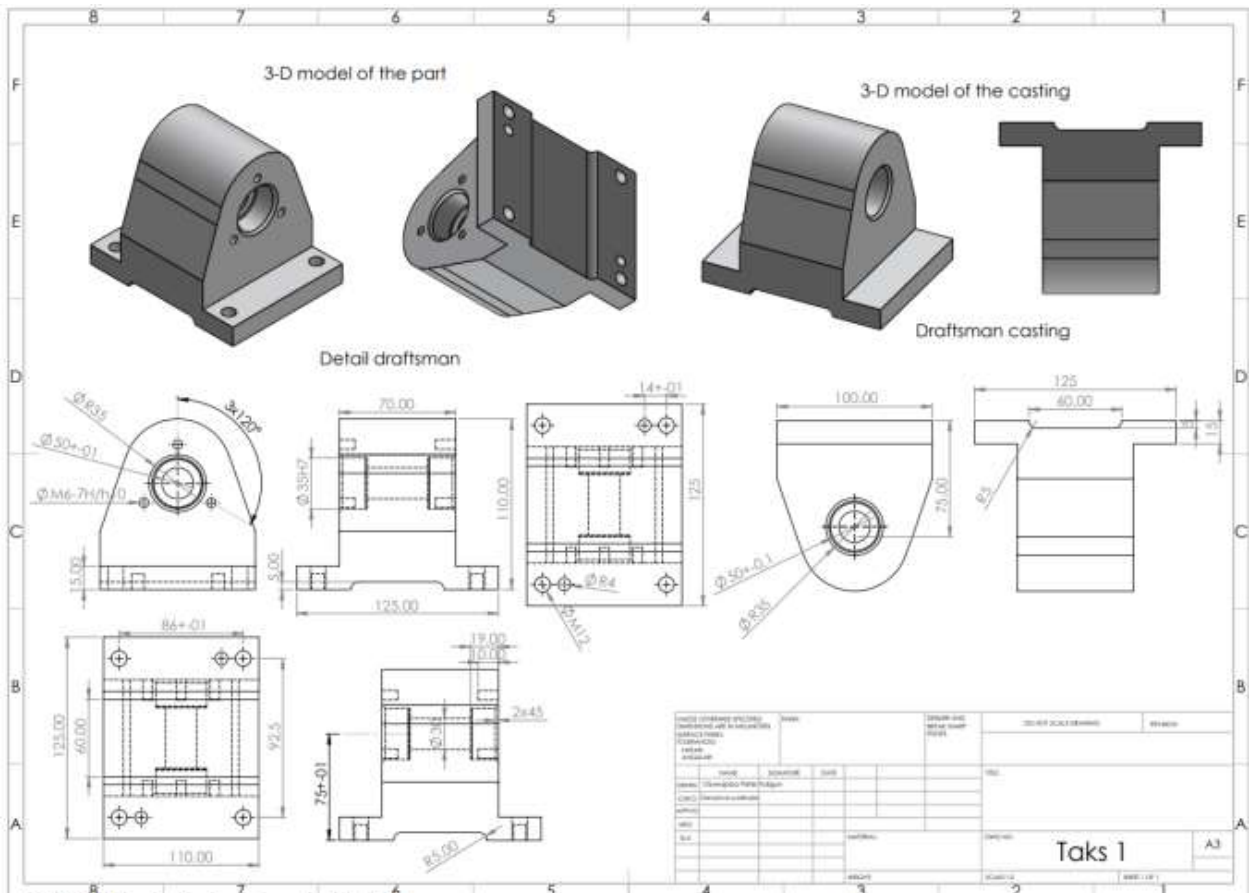
Fig. 1.2 – Characteristics of the part ‘Housing’ and its 3-D model

Conclusion: Given that the production type is classified as medium batch, we will proceed to conduct all subsequent calculations and make technological choices based on the requirements for medium-volume production.

1.3 Selection of the base process and design of the blank

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

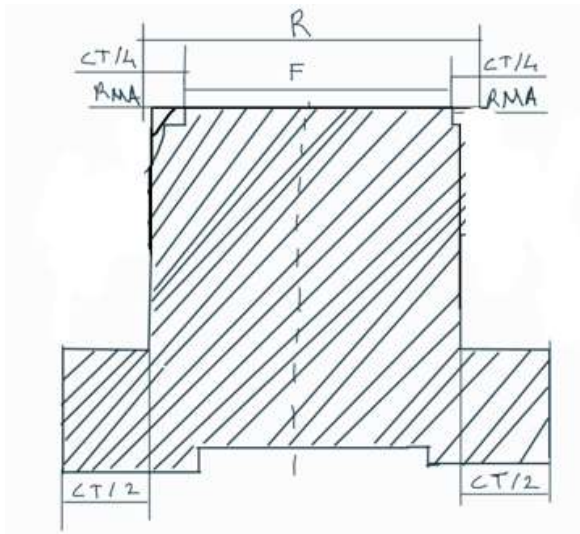
- drawing of a part;
- material of a part – Grey Iron;
- Annual output – 3000 pcs.



Given the characteristics of the material and the part's design, the sand-casting method is deemed suitable as the primary manufacturing process. To determine the necessary machining allowance (RMA), we will refer to Table B.1 [2]. For the sand-casting of Grey Iron, an RMA grade of F is suggested. Based on this grade and the largest dimension of the part being 250mm (as detailed in the drawing), a required machining allowance of 2 mm is stipulated.

To calculate the casting tolerance (CT) grade, Table A1 (for long series) [2] will be utilized. For sand-casting of Grey Iron, a CT grade of CT10 is appropriate. The calculated casting tolerances are documented in Table 1. Illustrations depicting the placement of RMA and CT are shown in Fig. 1.

Top of Form



R= Raw casting basic dimension

F= Dimension after final machining

RMA = Required machining allowance

CT = Casting tolerance

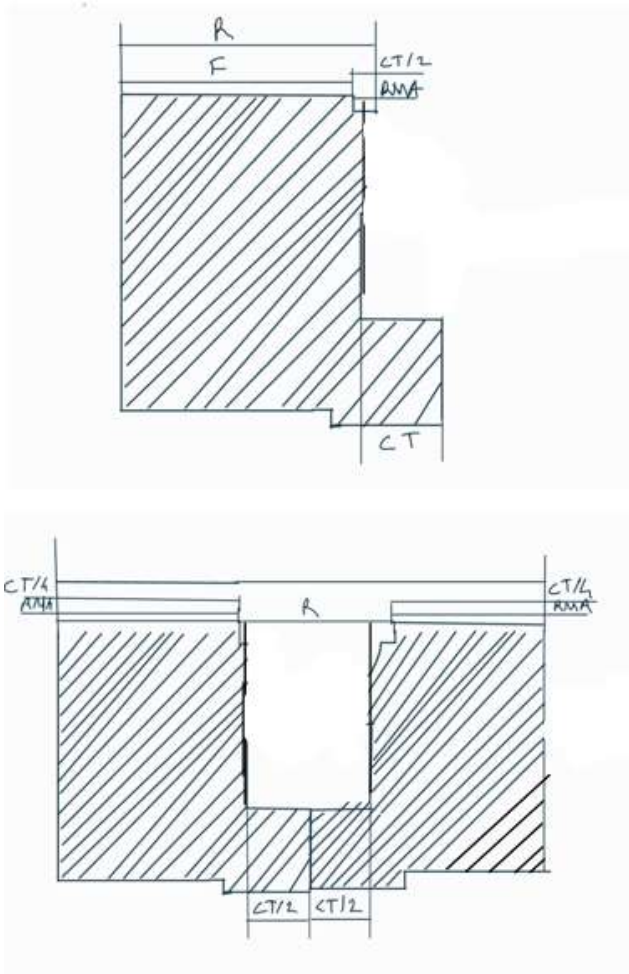


Fig. 1 Sketches for determining Raw casting basic dimension

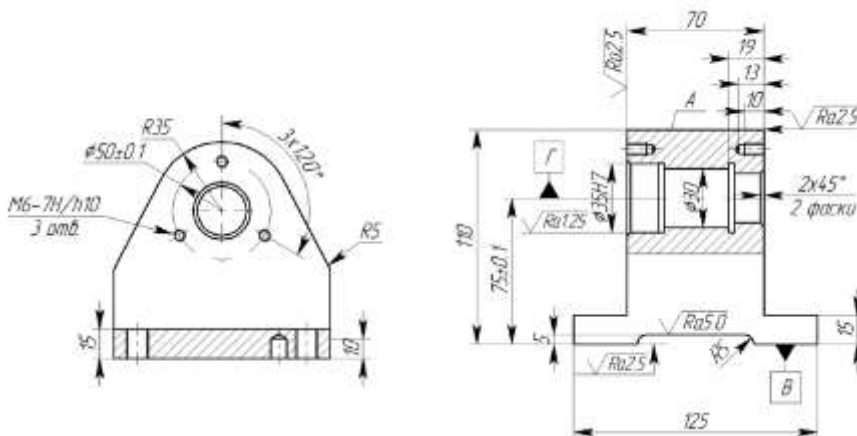
Table 1 Casting tolerances

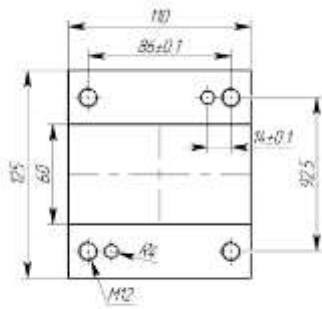
Dimension of a part	RMA	Min limit of size for external features (or max for internal features)	Casting tolerance, mm	Raw casting basic dimension
125	2	129	3.6	130.8±1.8
110	2	114	3.2	115.6±1.6
70	2	74	3.2	75.6±1.6
35	2	39	2.4	40.2±1.2

30	2	34	2.6	35.3±1.3
12	2	14	2.2	15.1±1.1
6	2	8	2.2	9.1±1.1
4	2	6	2.2	5.1±1.1

In the design of the casting, several key considerations were made:

- *The workpiece is positioned in the mold to ensure the lowest possible height.
- *The parting line is strategically placed within the plane of symmetry.
- *To prevent the formation of stress points, all corners of the casting feature radii between 2-5 mm.
- *A 2° draft angle was applied to all walls perpendicular to the parting plane, enhancing the ease of mold removal.
- *The Required Machining Allowance (RMA) is specifically applied only to those surfaces that will undergo secondary machining processes.
- *The two central holes and the main pocket of the part are formed using cores.
- *Smaller features, such as tiny holes, are created in subsequent secondary processes. The finalized design of the workpiece is illustrated in Fig. 2.





1. General tolerances ISO 8062 - CT10 - RMA 2 (F)
2. Draft angle 2°Radii 2.5 mm
3. The surface of the casting shall be free of adhering sand, scale, cracks, and hot tears as determined by visual examination
4. Castings shall be heat treated using low temperature annealing

Fig. 2. Drawing of a casting

1.4 Locating scheme selection

1.4.1 Rationale for the selection of manufacturing datum for the first manufacturing operations

The methodology for establishing a manufacturing datum (MD) consists of two phases:

*Justification for selecting a general manufacturing datum (GMD)

*Justification for choosing a manufacturing datum for initial manufacturing operations

1.4.2 Rationale for the choice of general manufacturing datum

The general manufacturing datum (GMD) comprises a collection of datum surfaces that facilitate the execution of all or most manufacturing operations. The primary basis for selecting a GMD comes from the working drawing of the part. To address the challenges in the initial phase, it's essential to categorize the part surfaces according to their functional roles. The design of any part can be represented as a set of four types of surfaces:

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

For further analysis let's classify surfaces of a given part according to their purpose (Fig. 3).

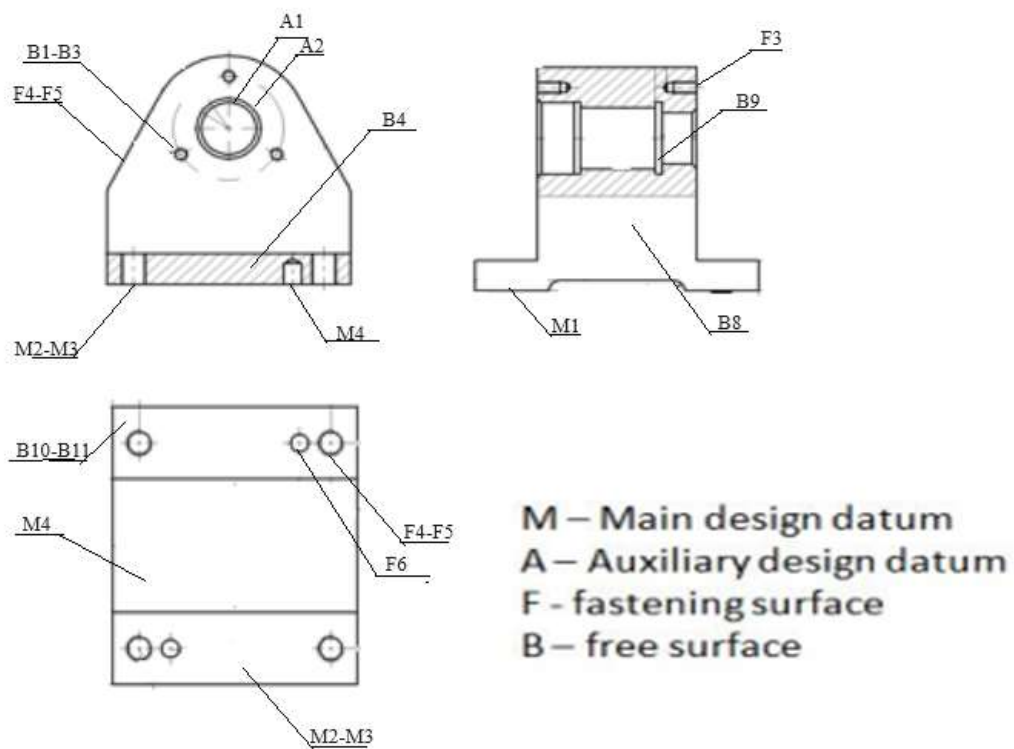


Fig 3. Classification of the part according to their intended purpose

Let's consider the possibility to transform Main design datum to GMD. The two variants of corresponding locating schemes are presented in Fig 4.

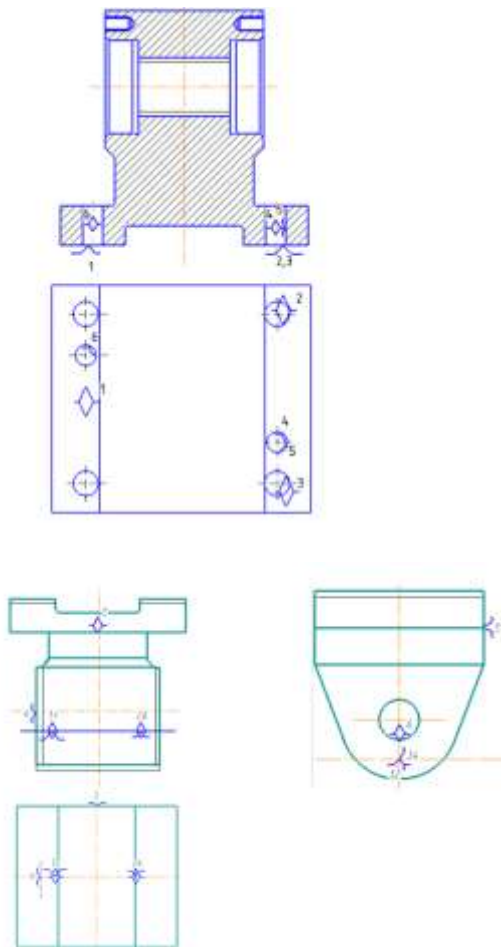


Fig 4. Locating scheme for GMD

The formula for the locating scheme illustrated in Fig 1.9 is as follows: $LSGMD \Rightarrow S(3) + DS(2) + O(1)$, (1.1) where $S(3)$ represents the setting datum, removing three degrees of freedom from the workpiece, $DS(2)$ is the double support datum, removing two degrees of freedom, and $O(1)$ is the support datum, removing one degree of freedom. This configuration employs a plane and both round head and diamond head locating pins. In this setup, the "Housing" is adequately positioned, enabling the processing of its surfaces to meet the specific spatial requirements. In this instance, the General Manufacturing Datum (GMD) remains unchanged: $GMD \Rightarrow Const$.

For selecting datum surfaces for initial manufacturing operations, it is crucial to ensure accessibility for processing all GMD surfaces and select machines capable of sequential processing of these surfaces to achieve desired quality characteristics. If the

complete set of GMD is not processed in the initial operations, the following guidelines apply:

- *Choose MD surfaces that are not intended for processing as per the drawing.

- *If processing is required for all workpiece surfaces, select MD surfaces with the lowest allowance to prevent defects during further processing; if allowances are uniform, opt for surfaces where defects are unacceptable.

- *Select MD surfaces that require a consistent allowance for subsequent processing stages.

- *If multiple basing schemes are possible, the MD should be the one with the shortest dimensional chain.

The first option is detailed Advantages:

- *Simple to implement.

- *Ensures correct alignment of untreated surfaces relative to the treated ones.

Disadvantages:

- *Restricts access to the workpiece from three sides.

- *Creates uneven allowance for the main holes of the housing in subsequent processing stages.

- *Does not guarantee the perpendicularity of side planes adjacent to the main holes relative to the datum plane.

Conclusion: The fourth locating scheme is straightforward to implement and accurately positions untreated surfaces relative to treated surfaces. This scheme also facilitates the processing of several additional surfaces apart from the GMD during the first manufacturing operation. Therefore, the two variants of the locating scheme will be adopted for processing the GMD.

1.5 Design of the typical surfaces processing routes

The architecture of a component is often segmented into common geometric shapes, each sharing a functional purpose within the part. Typical structures include cylindrical or

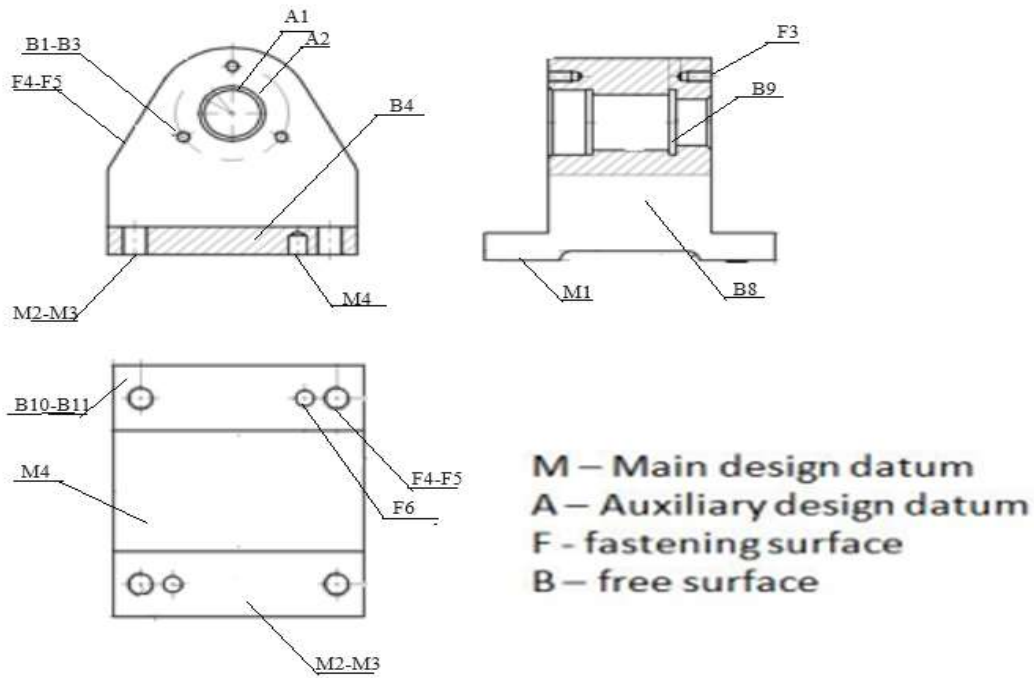


Fig 1.16 Classification of the part according to their intended purpose

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

Surface	IT	Ra	Machining sequence	IT	RA
	According to the drawing			After machining	
1	2	3	4	5	6
M1	14	2,5	Rough milling Finish milling	14	6,3 2,5
M2, M3	14	2,5	Rough milling Finish milling	14	6,3 2,5
M4	14	5	Rough milling Finish milling	14	5
A1	7	0,63	Rough boring	9	2,5

			Finish boring Final boring	7	1,5
A2	14 (7)	2,5 (1,25)	Centering Drilling Reaming	12 10	6,3 2,5
F1, F2	14	10	Centering Drilling	14	10
B8	14	2,5	Rough milling Finish milling	14	6,3 2,5
F3	14	10	Centering Drilling	14	10
B4	14	2,5	Rough milling Finish milling	14	6,3 2,5
B7	14	2,5	Rough milling Finish milling	14	6,3 2,5
F4, F5	14 (7)	2,5 (1,25)	Centering Drilling Reaming	12 10	6,3 2,5
B10	14	2,5	Rough milling Finish milling	14	6,3 2,5

1.6. Design of operational manufacturing process plan

Building on solutions from earlier chapters, the objective is to develop a manufacturing process plan that adheres to all specified requirements regarding manufacturing accuracy, complexity, and cost-effectiveness. Here are the guiding principles:

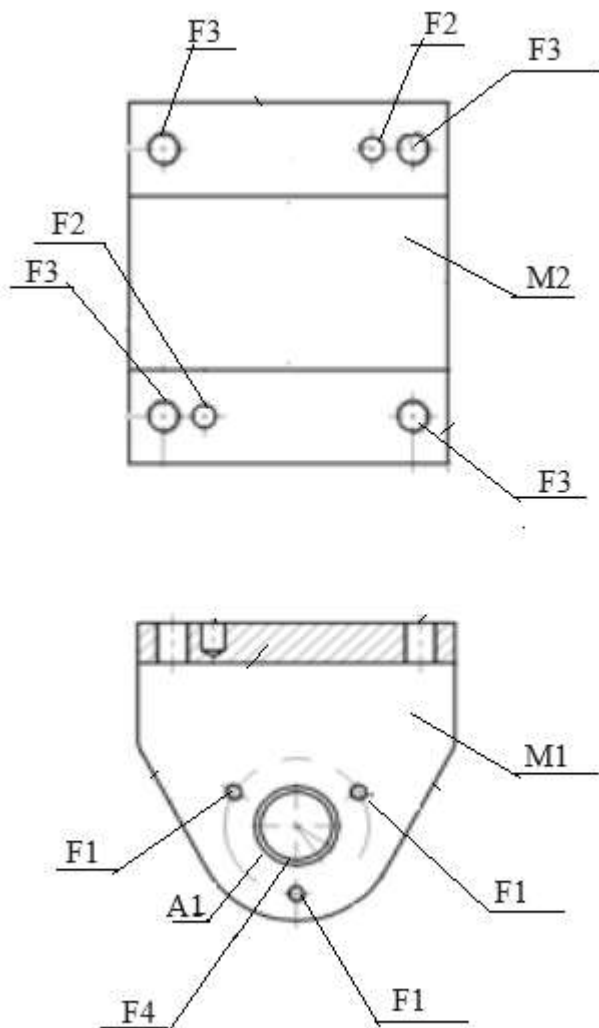
- 1) Datum surfaces used in subsequent processing stages should be machined first.
- 2) Each step in the manufacturing process should enhance the quality of the surfaces being worked on. If this criterion is not met, such as during heat treatment, it may be necessary to revisit machining the datum surfaces for subsequent stages.
- 3) Rough machining should be distinctly separated by time from subsequent processing stages or include aging operations, particularly for critical, large, or high-value parts.
- 4) Surfaces where defects are unacceptable should be processed early in the manufacturing sequence to allow for timely defect detection.
- 5) The initial roughing phase should prioritize surfaces with the greatest material allowance and those deemed most critical.
- 6) The final finishing steps should focus on the most critical surfaces.
- 7) Surfaces that contribute least to reducing the overall stiffness of the workpiece should be machined first.
- 8) Surfaces requiring precise spatial alignment should be processed in a single setup.
- 9) Tool changes should be avoided when finishing precision-critical surfaces.
- 10) Surfaces for fastening must be machined in the third stage of the process, following the finishing of related surfaces.

This process plan will be crafted based on the analysis of operational conditions and technical specifications of the part discussed in chapter 1.1; the production type outlined in chapter 1.2; the geometry of the workpiece elaborated in chapter 1.3; and the processing routes for surfaces developed in chapter 1.6.

005 Multipurpose

Machine: EC-1600ZT

A. Install, secure, remove



Position 1

005.01 Initially rough mill the surface labeled M1 to the specified depth 27.5mm.

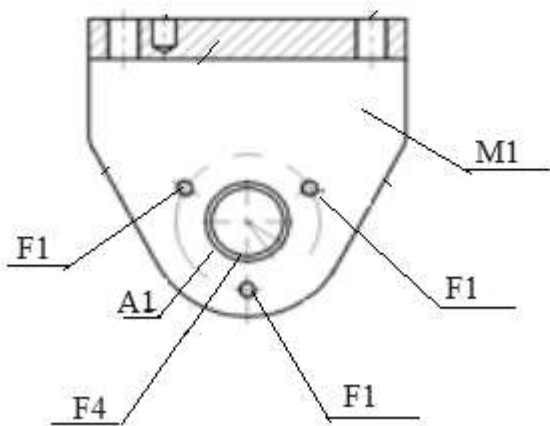
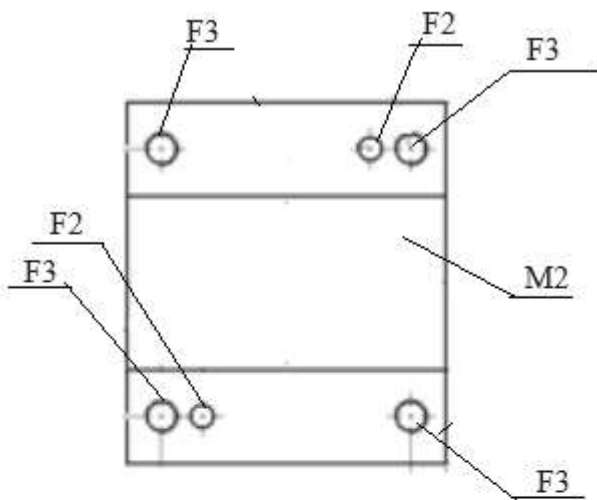
005.02 Then proceed to fine mill the same surface M1 to the refined dimension R35.

005.03 Accurately align the centers of holes, F1, to the dimension M6-7h and simultaneously create chamfers on 3 of these holes to the specified dimension 6.

005.04 Proceed to drill two through-holes at F2 and F3, F2 with diameter of M12 and F4, ensuring the center of the holes are aligned.

Position 2

Turn the table 90 ° clockwise



005.05 Mill surface A1 to dimension 35.

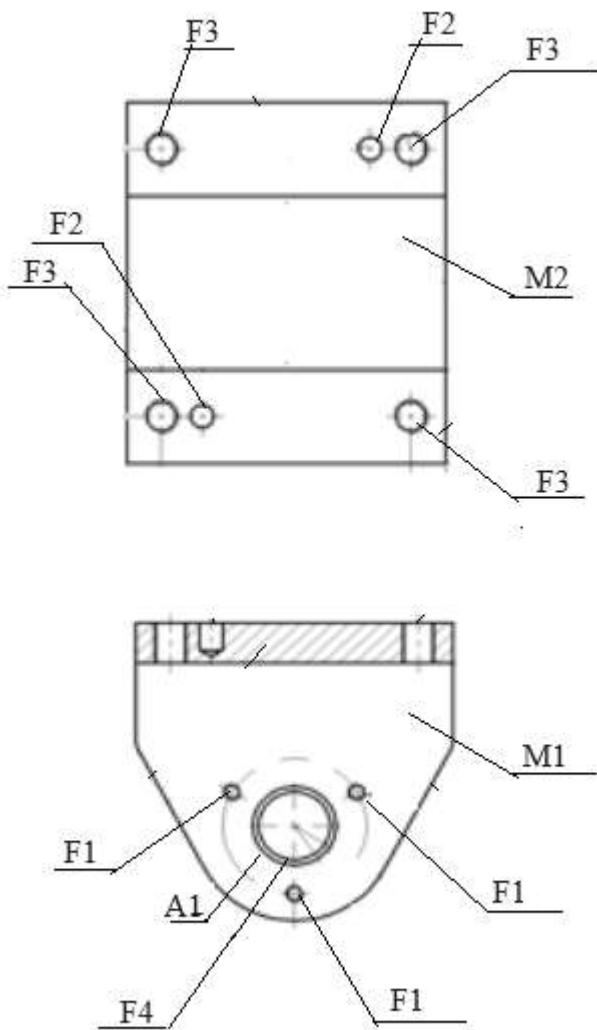
005.06 Center the hole F4 at dimensions 30.

005.07 Drill the through hole F4 at dia. 30, maintain the position of the hole center:32.

005.08 Cut a thread in the through hole F4 at dim.35.

Position 3

Turn the table 90 ° clockwise



005.09 Mill M2 to depth 5.

005.10 Center the 4 holes F3 at dim. M12 and depth 15.

005.11 Drill 2 blind holes F2 at dia. R4 & depth 10.

005.13 Cut a thread in 4 holes F3 at dim. M12 & 15 deep.

010 Multipurpose Machine: EC-1600ZT

A. Install, secure, remove

Proceed with washing.

Perform quality control.

1.7. Short description of a manufacturing equipment

Choosing a machine

When selecting the type and size of the machine, it's essential to align with the predetermined manufacturing processes. For example, turning operations necessitate a lathe or turning center. The primary consideration initially is whether the physical dimensions of the machine are adequate for the size of the workpiece. A lathe with a bed that is too short to accommodate the length of the part is obviously inappropriate.

Regarding power and force requirements, any machine that cannot meet the maximum power demands of the operations is generally ruled out. If no alternatives are available, adjustments to feeds, speeds, and the depth of cut may be made to lower the power requirements. On the other hand, machines that provide more power than needed might also be deemed unsuitable unless they possess higher spindle speeds essential for certain operations.

Capability analysis includes assessing the machines for their precision in meeting the required dimensional and geometric accuracies and achieving the specified surface finish.

From an operational perspective, the size of the production batch plays a significant role. Machines that do not offer cost-effectiveness for the specified batch size are considered unsuitable.

Taking into account these considerations and the process plan outlined in the previous chapter, the EC-1600ZT has been preliminarily selected as the appropriate machine for this task.

Top of Form



EC-1600ZT

The highly popular Haas EC Series HVMs offer large work cubes and a maximum part capacity of 10,000 lb, making them perfect solutions for your large-part machining requirements. Models are available with a 4th-axis rotary platter integrated into the T-slot table to provide access to four sides of a part or tombstone, or simultaneous 4th-axis machining. The EC-1600ZT offers more Z-axis travel than the standard EC-1600.

- Extended Z-axis travel
- Standard side-mount tool changer: 50+1 tools
- 50-taper spindle with a 3-speed gearbox
- Extra-large work envelope
- 78" max part swing with integrated 4th axis (optional)

50
TAPER

3
AXIS

7.5k
RPM

50+1
TOOL CAPACITY

COMPARE MACHINES

EXPLORE INVENTORY

TRAVELS

S.A.E

METRIC

X Axis	64.00 in	1626 mm
Y Axis	50.00 in	1270 mm
Z Axis	40.00 in	1016 mm
Spindle Centerline to Table	11.97 in	304 mm

SPINDLE

S.A.E

METRIC

Max Rating	30.0 hp	22.4 kW
Max Speed	7500 rpm	7500 rpm
Max Torque	340.0 ft-lbf @ 700 rpm	460.0 Nm @ 700 rpm
Drive System	2-Speed Gearbox	2-Speed Gearbox
Taper	CT or BT 50	CT or BT 50

TABLE	S.A.E	METRIC
Length	64.0 in	1626 mm
Width	36.0 in	914 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	7	7
Max Weight on Table (evenly distributed)	10000 lb	4536 kg

FEEDRATES	S.A.E	METRIC
Max Cutting	500 ipm	12.7 m/min
Rapids on X	600 ipm	15.2 m/min
Rapids on Y	600 ipm	15.2 m/min
Rapids on Z	600 ipm	15.2 m/min

AXIS MOTORS	S.A.E	METRIC
Max Thrust X	4000 lbf	17793 N
Max Thrust Y	8000 lbf	35586 N
Max Thrust Z	8000 lbf	35586 N

1.8. Cutting tools and cutting conditions selection

CYLINDRICAL SURFACE



N 90 HB
N1.3CA0
Aluminum based alloy

Lathe 03 - Medium (6-12" chuck)

25 (N) 4000 (mm)

Machined diameter start: 70 mm
Machined diameter end: 35 mm
Machined length: 22.5 mm
Ra roughness value longitudinal: μm

Include PrimeTurning results: **ON**

More

TURNING EXTERNAL ONLY / LONGITUDINAL / INDEXABLE



CoroTurn 107

06-850CR2020901 Tool
S02N 08 T3 08-AL-H10 Insert

Rectangular shank - metric 20 x 20

Adaptive interface machine direction: 40 (H10)

Tool life count: 758 Features
Machining time: 00:16.979 min

Save for later
Build tool assembly

CUTTING DATA



STEPS

REMOVAL-RATE

Cutting speed: 852 m/min
Feed per revolution: 0.354 mm
Number of passes in AP direction: 18
Depth of cut AP: 1.09 mm

CO₂ emissions
Carbon dioxide emission per component: 16.11 g
Work per component: 0.0521 kWh

Show detail

RESULTS

1 - 8 of 128



CoroTurn 107 06-850CR2020901 S02N 08 T3 08-AL-H10 100% 00:16.979

CoroTurn 107 06-850CR2020901 S02N 08 T3 08-AL-H10 100% 00:16.979

CoroTurn 107 850CR 2020 09 S02N 08 T3 08-AL-H10 100% 00:16.979


CoroTurn 107 06-850CR 2020 09C S02N 08 T3 08-AL-H10 100% 00:17.480

CoroTurn 107 06-850CR 2020 09C S02N 08 T3 08-AL-H10 100% 00:17.480

CoroTurn 107 06-850CR 2020 11C S02N 11 T3 08-AL-H10 100% 00:17.480

CoroTurn 107

PLAN SURFACE



N 90 HB
N1.3CA0
Aluminum based alloy

Universal machining centre

25 (N) 10000 (mm)

Pre-machining

Depth of machining feature: 22.5 mm
General width parameter: 110 mm
General length parameter: 95 mm

More

FACE MILLING / SOLID




CoroMill Dura

1K233-2000-200-NB-H10P Tool

Cutting diameter: 20 mm
Depth of cut maximum: 40 mm
Tool life count: 3100 Features
Machining time: 00:05.184 min

Save for later
Build tool assembly

CUTTING DATA



STEPS

REMOVAL-RATE

Cutting speed: 860 m/min
Feed per tooth: 0.301 mm

CO₂ emissions
Carbon dioxide emission per component: 19.3 g
Work per component: 0.0596 kWh

Show detail

RESULTS

1 - 8 of 2524



CoroMill Dura 1K233-2000-200-NB-H10P 100% 00:05.184

CoroMill Dura 1K233-2000-200-NB-H10P 100% 00:05.304

CoroMill Dura 1K233-2000-200-NB-H10P 100% 00:05.058

CoroMill Dura 1K233-2000-100-NB-H10P 100% 00:04.838

CoroMill Dura 1K233-2000-200-NB-H10P 100% 00:04.958

CoroMill Dura

CYLINDRICAL HOLE IN SOLID MATERIAL



N 6061-T6
Aluminum 6061-T6

Universal high-performance machine

200 vit 10000 rpm
200 vit 800000 l/min

Good conditions

Machined diameter Ø: 30 mm
Depth of machining feature: 18 mm

More...

POCKET MILLING / SOLID



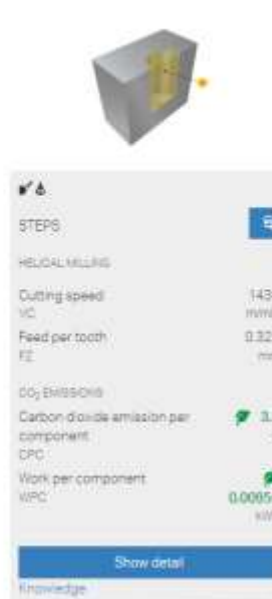
CoroMill Dura

1K223-2000-H8 H10F
Tool

Cutting diameter Ø: 20 mm
Depth of cut maximum APUL: 30 mm
Tool life count TLPEC: 8660 Holes
Machining time TAF: 00:00:00 min s

Save for later
Build tool assembly

CUTTING DATA



STEPS

HELICAL MILLING

Cutting speed VC: 1430 m/min
Feed per tooth FE: 0.322 mm
CO₂ EMISSIONS
Carbon dioxide emission per component CPC: 3.1 g
Work per component WPC: 0.00059 kWh

Show detail
Knowledge

RESULTS



1 - 8 of 13

- CoroMill Dura 1K223-2000-H8 H10F 100% 00:00:00
- CoroMill Dura 1K223-2000-H8 H10F 111% 00:00:03
- CoroMill Dura 1K223-2000-080-0H H10F 119% 00:00:00
- CoroMill Dura 1K223-2000-080-0H H10F 118% 00:00:00
- CoroMill Dura 1K223-2000-080-0H H10F 114% 00:00:00
- CoroMill Dura 1K223-2000-080-0H H10F 127% 00:00:00
- CoroMill Dura

CYLINDRICAL HOLE IN SOLID MATERIAL



P Inconel 718
Inconel 718

Universal high-performance machine

200 vit 10000 rpm
200 vit 800000 l/min

Good conditions

Machined diameter Ø: 30 mm
Depth of machining feature: 32 mm

More...

DRILLING WITH ASYMMETRICAL POINT / INDEXABLE



CoroDrill 880

880-03000L32-03
Tool

880-06 04 W10H-P-GR 4334
Insert Peronera

880-08 04 06H-C-GR 1044
Insert Central

Tool life count TLPEC: 967 Holes
Machining time TAF: 00:04:218 min s

Save for later
Build tool assembly

CUTTING DATA



STEPS

DRILLING WITH AN ASYMMETRICAL POINT

Cutting speed VC: 201 m/min
Feed per revolution FR: 0.22 mm
Feed speed at tool center VF: 459 mm/min
CO₂ EMISSIONS
Carbon dioxide emission per component CPC: 17.8 g
Work per component WPC: 0.0549 kWh

Show detail
Knowledge

RESULTS



1 - 8 of 4

- CoroDrill 880 880-03000L32-03 880-06 04 W10H-P-GR 4334 100% 00:04:218
- CoroDrill 880 880-03000L32-03 880-06 04 W10H-P-GR 4334 100% 00:04:218
- CoroDrill 880 880-03000L32-03 880-06 04 W10H-P-GR 4334 100% 00:04:218
- CoroDrill 880 880-03000C4-03 880-06 04 W10H-P-GR 4334 100% 00:04:218
- CoroDrill 880 880-03000C6-03 880-06 04 W10H-P-GR 4334 100% 00:04:218
- CoroDrill 880 880-03000C8-03 880-06 04 W10H-P-GR 4334 100% 00:04:218
- CoroDrill 880 880-03000C10-03 880-06 04 W10H-P-GR 4334 100% 00:04:218
- CoroDrill 880 880-03000C12-03 880-06 04 W10H-P-GR 4334 100% 00:04:218

CYLINDRICAL HOLE IN SOLID MATERIAL

N 6061
Al 6061 (Al)
Aluminum 6061 (Al)

Universal high-performance machine

230 kW, 10000 rpm
230 kW, 200000 rpm

Good conditions

Machined diameter: 6 mm
Depth of machining feature: 13 mm

More...

DRILLING WITH SYMMETRICAL POINT / SOLID

CoroDrill 860

860-1-0800-01841-H8F
H10F
Tool

Tool life count: 28700
TUFEC: 1696
Machining time: 00:00:117
TUF

Save for later

Build tool assembly

CUTTING DATA

STEPS 1

DRILLING WITH A SYMMETRICAL POINT

Cutting speed: 303 m/min
VC

Feed per revolution: 0.333 mm
Fz

Feed speed at tool center: 8570 mm/min
VF

CO₂ EMISSIONS

Carbon dioxide emission per component: 0.304 g
CPC

Work per component: 0.000843 kWh
WPC

Show detail

RESULTS

1 - 1 of 1

CoroDrill 860
860-1-0800-01841-H8F H10F
100% 00:00:117

PLAIN SURFACE WITH INTERRUPTED CUT

N 6061
Al 6061 (Al)
Aluminum 6061 (Al)

Universal machining center

23 kW, 18000 rpm

Pre-machining

Depth of machining feature: 3 mm
General width parameter: 60 mm
General length parameter: 110 mm
Intermittion ratio: 30 %

More...

FACE MILLING / INDEXABLE

CoroMill 245

R4245-076R25-12H
Tool

R245-12 T3 E-AL H10
Insert Face Mill

Maximum cutting diameter: 88.697 mm
DCR

Depth of cut maximum: 6.3 mm
APML

Tool life count: 1570
TUFEC: Features

Machining time: 00:01:396
TUF

Save for later

Build tool assembly

CUTTING DATA

STEPS 1

PREMACHINING

Cutting speed: 903 m/min
VC

Feed per tooth: 0.24 mm
Fz

CO₂ EMISSIONS

Carbon dioxide emission per component: 3.31 g
CPC

Work per component: 0.0103 kWh
WPC

Show detail

Knowledge

RESULTS

1 - 5 of 382

- CoroMill 245
R4245-076R25-12H
R245-12 T3 E-AL H10 8H
100% 00:01:396
- CoroMill 245
R4245-080Z17-12H
R245-12 T3 E-AL H10 8H
100% 00:01:455
- CoroMill 245
R4245-080Z54-12H
R245-12 T3 E-AL H10 8H
100% 00:01:455
- CoroMill Dura
K223-2500-N8 H10F
126% 00:01:638
- CoroMill 245
R4245-076R25-12H
R245-12 T3 E-AL H10 8H
100% 00:01:646
- CoroMill 390
R390-080Z17-11H
R390-11 T3 10E-AL H104-10H
100% 00:01:330
- CoroMill 390

THREAD IN THROUGH HOLE

THREAD CUTTING WITH TAP / SOLID

CUTTING DATA

RESULTS

CYLINDRICAL HOLE IN SOLID MATERIAL

DRILLING WITH SYMMETRICAL POINT / SOLID

CUTTING DATA

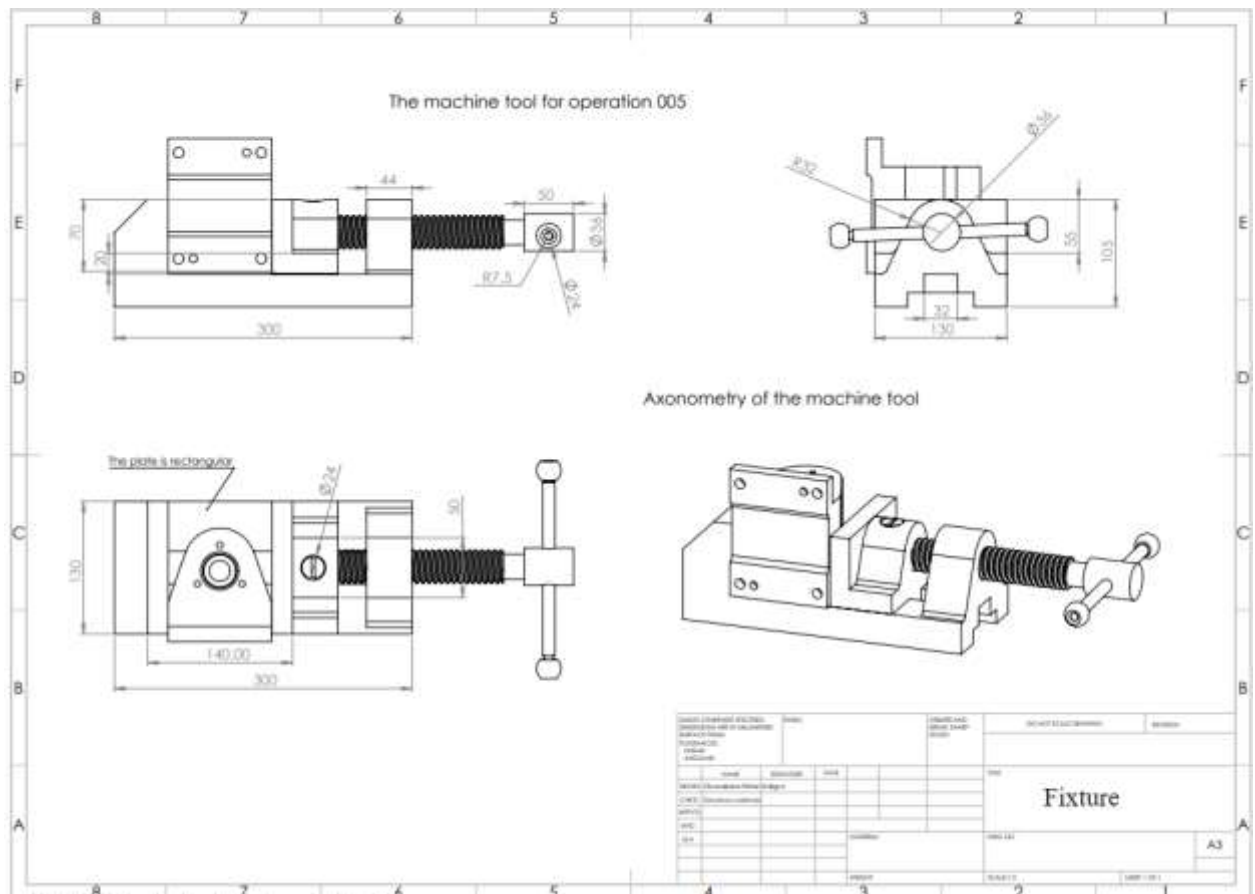
RESULTS

1.9 Time and cost calculations

Cutting parameters						Fixtures			
surface	machine operation	total time [min]	speed [m/min]	Feed per tooth [mm]	depth [mm]	Time,s	price for one [EUR]	QTY	total price [EUR]
1	Rough milling	0.0387	283	0.799	12.5	2.32	648.0000	2	1296
1'	Turning	0.1340	298	0.668	70	8.038	19.0500	2	38.1
2	Contour Milling	0.0231	304	0.0901	10	1.386	435.0000	2	870
2'	Drilling	0.0083	173	0.4	10	0.498	25.2000	2	50.4
3	Drilling	0.0095	173	0.43	13	0.572	19.3000	6	115.8
3	Drilling	0.0132	173	0.61	15	0.792	19.3000	4	77.2
3'	Drilling	0.0249	173	1.15	34	1.496	168.0000	1	168
3''	Drilling	0.0110	173	0.51	18	0.66	535.0000	2	1070
		0.2627							3685.5

CHAPTER 2

2.1 Drawing of a Fixture



2.2 Task for device design

2.2.1 Task

- Name - Milling Device for 30-0.05 mm Diameter Hole in Housing
- Service purpose - This device is engineered for the placement of individual parts.
- Location - Aligns with a Plane and 2 Holes, achieving positional tolerance of 0.05mm.

Manufacturing operation - Utilizes a EC-1600 CNC machine. The operation involves an $\square 8\text{mm}$ end mill executing a helical motion. The cutting forces are as follows:

$$*P_z = P_y = 750 \text{ N}$$

$$*P_x = 300 \text{ N}$$

Clamping mechanism type - Employs a manually operated screw mechanism. The standard time for loading and unloading the workpiece is capped at 0.2 minutes.

Layout - The setup comprises standardized components from a modular fixture system. Creating transitional keyways for alignment with the machine table's grooves is permissible.

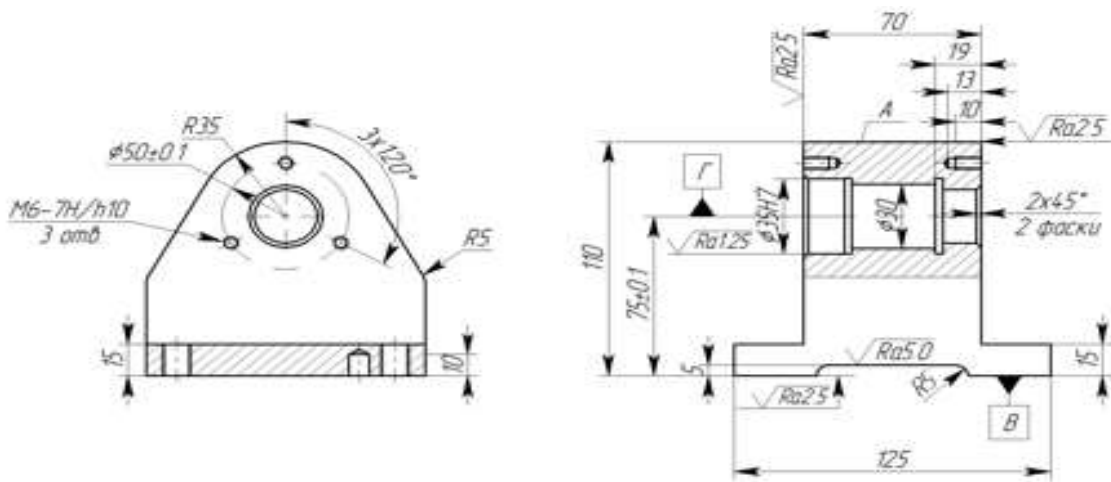


Figure 1 - Operational sketch

2.2.2 Errors Locations

The presence of clearance when positioning the workpiece on two cylindrical holes allows for potential rotational movement (angle α) relative to the locating pins, as shown in Figure 2. As a result, the center of the hole being machined might shift within a defined range for various workpieces in a batch. This shift should remain within the positional tolerance outlined in the design drawings.

Top of Form

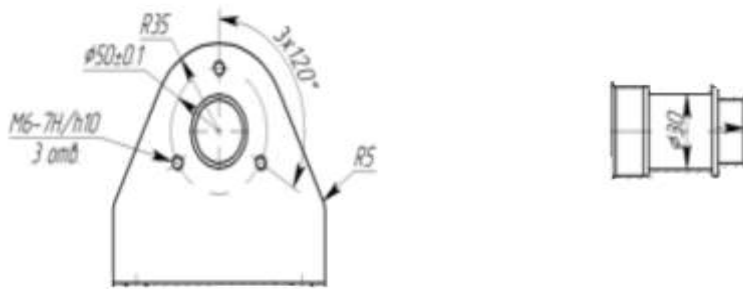


Figure 2 – Representation of the maximum rotation of the workpiece

In a scenario where the clearances are at their maximum and the nominal distances between the centers of the holes and the locating pins are identical, an approximate formula can be employed to calculate the maximum half-angle of misalignment:

$$\operatorname{tg} \alpha = \frac{S1_{max}/2 + S2_{max}/2}{L}$$

The two holes (according to the drawing) have the same diameters, and the locating pins, respectively, also have the same nominals.

The size of the workpiece hole according to the task:

$$D = \varnothing 6^{+0.1}$$

$$D_{min} = 6.0 \text{ mm}$$

$$D_{max} = 8.1 \text{ mm}$$

The size of the locating pins (purchased product):

$$d = \varnothing 30$$

$$d_{min} = 29.970\text{mm}$$

$$d_{max} = 30.030\text{ mm}$$

Maximum clearances:

$$S1_{max} = S2_{max} = D_{max} - d_{min} = 30.030 - 29.970 = 0.06\text{ mm}$$

Estimation of the angle of skew (according to drawing $L = \sqrt{110^2 + 90^2} = 142.12$

mm

Consequently, the dimensional error incurred in this process is calculated as:

$$\varepsilon = H \cdot \operatorname{tg} \alpha = \sqrt{(65^2 + 75^2)} \cdot \operatorname{tg}(0.047^\circ) = 0.08 \text{ mm.}$$

Clearly, this maximum error of ± 0.08 mm overshoots the positional tolerance of 0.05mm stipulated in the drawing, indicating that manufacturing defect-free parts under these conditions is unfeasible.

To rectify this issue, an enhancement in the precision of the technological holes beyond the drawing's specifications is required. This will be achieved by incorporating an additional reaming operation in the manufacturing process, aimed at achieving a tolerance grade of IT 7. Through this adjustment, we aim to achieve:

The size of the technological hole:

$$D' = 30$$

$$D'_{min} = 29.970 \text{ mm}$$

$$D'_{max} = 30.030 \text{ mm}$$

Maximum clearances:

$$S1_{max} = S2_{max} = D'_{max} - d_{min} = 30.030 - 29.970 = 0.06 \text{ mm}$$

2.2.3 Design scheme

In accordance with the task specifications, the clamping must be performed using a self-locking mechanism, typically a screw. Strap clamps are frequently employed for this purpose. This system operates as two sequentially connected links—a lever and a screw—which can be analyzed separately. The layout of this setup is depicted in the provided schematic (refer to Fig. 3, a).

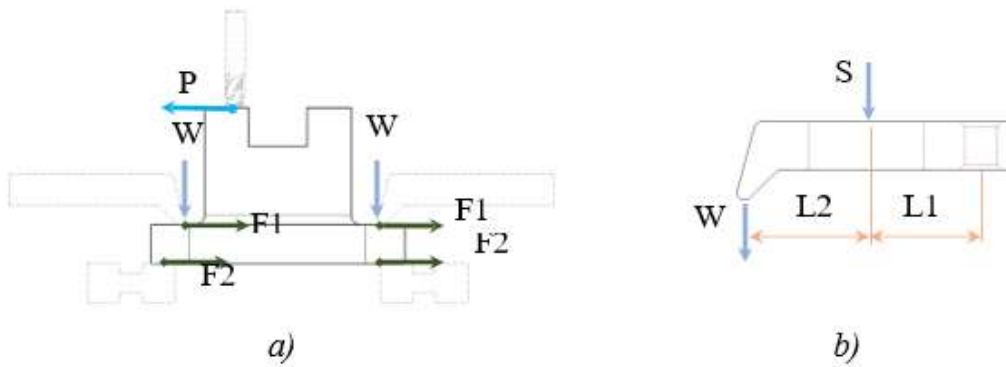


Figure 3 – Design scheme

Assuming a symmetrical configuration in the setup, the clamping forces W exerted by both clamps are identical. The equilibrium equation is represented as follows:

$$2 \cdot (F1 + F2) = k \cdot P$$

Here, $F1$ and $F2$ are the friction forces exerted between the clamp and the workpiece, and between the workpiece and the device's base, respectively, calculated as $F1 = \mu_1 \cdot W$ and $F2 = \mu_2 \cdot W$. The coefficients of friction, μ_1 and μ_2 , are approximately 0.15 and 0.10, respectively. The factor k is used to account for potential increases in cutting force, typically ranging from 2.5 to 3.

Thus, the necessary clamping force for one clamp can be calculated by:

$$W = k \cdot P / 2 \cdot (\mu_1 + \mu_2)$$

To compute the force S exerted on the lever (as depicted in Fig. 3,b), the following mechanical formula is utilized:

$$S = W \cdot (L1 + L2) / L1 \cdot \eta$$

Here, η signifies the efficiency, accounting for friction losses in the lever support, estimated at approximately 0.95.

The calculation for the tightening torque of the nut, based on the equilibrium condition, shows:

$$Mh = Mt + Mf$$

This equation suggests that the friction moments in the thread Mt and at the nut's end Mf are offset by the torque applied by the wrench Mh .

The wrench-applied torque is calculated as:

$$Mh = Q \cdot L$$

where L is the key handle length, set at 150mm for these calculations, and Q is the force applied by the operator.

The friction moment in the thread is given by:

$$Mt = S \cdot d_2 / 2 \cdot \text{tg}(\alpha + \varphi)$$

with d_2 as the median thread diameter (10.86mm for M12 thread), α the thread helix angle, and φ the friction angle.

The friction moment at the nut end is calculated as:

$$Mf = S \cdot \mu \cdot (D_3 - d_3) / 3 \cdot (D_2 - d_2)$$

where μ is the friction coefficient between the nut and clamp surfaces, D the outer diameter of the nut's support surface (20mm for M12), and d the inner diameter of the nut's support surface (12.5mm, equal to the screw hole diameter).

Integrating these formulas provides a complete model for calculating the clamping dynamics.

$$d_2 \quad \mu \cdot (D^3 - d^3) \quad \text{_____} \quad (7)$$

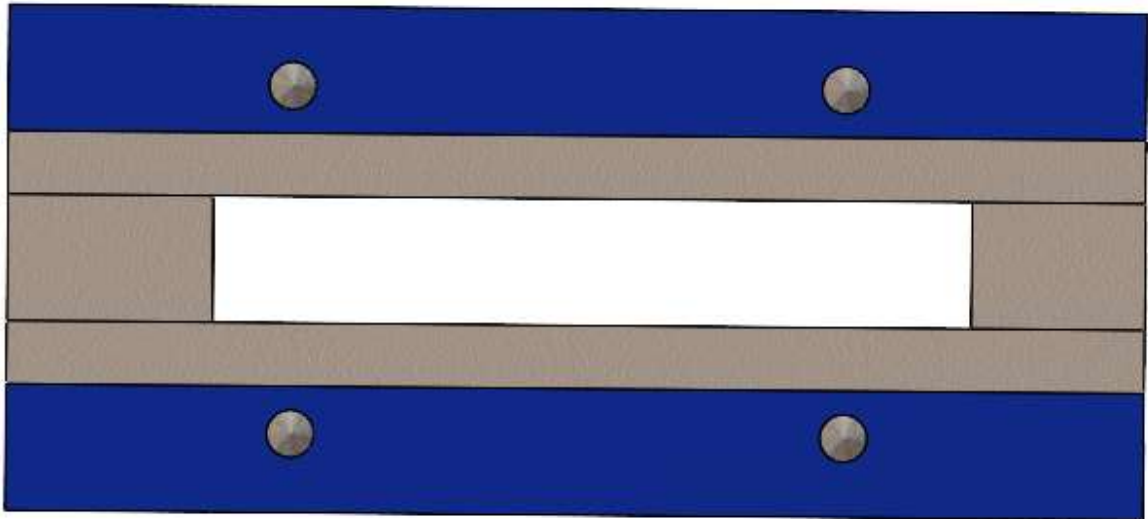
$$Q = S \cdot [2 \cdot \text{tg}(\alpha + \varphi) + 3 \cdot (D_2 - d_2)] L$$

2.3 Fixture Design

2.3.1 Base elements

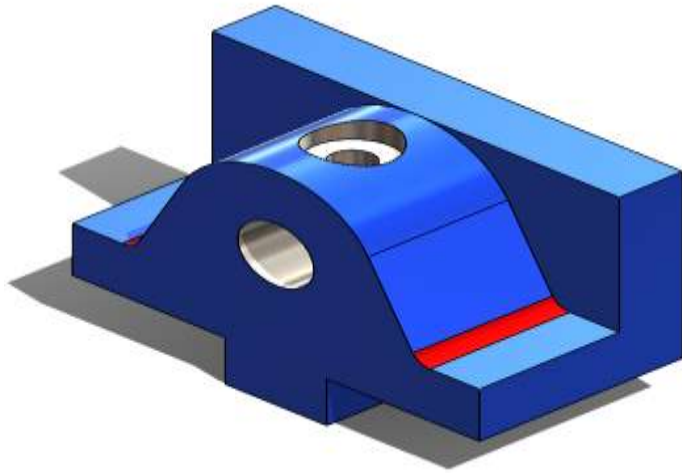
In modular fixture systems, foundational elements typically include plates that feature T-shaped grooves and come in various shapes such as rectangular, square, or round. The optimal choice of plate is the smallest one that can adequately fit the workpiece along with its orientation and clamping components. For a workpiece with dimensions of 230x390mm, a plate measuring 240x400mm is chosen as it closely matches the required size. The

subsequent larger size of plate is nearly double in size and exceeds a weight of 45kg, which makes it less feasible for practical use.



2.3.2 Selection of Locating Elements

To meet the requirements of the locating scheme, the setup needs to incorporate various types of supports to accommodate workpieces with flat, round, and diamond-shaped surfaces. Typical supports in modular fixtures include spherical supports, notched elements, support washers, or plates. Given the small dimensions of the workpiece, positioning these supports can pose a challenge if their total size substantially exceeds that of the workpiece. Consequently, it is advantageous to combine several functions into a single component. In this arrangement, the component serves both as a support and a guide for pins. Maintaining precise tolerances for the distances between the axes of the pins is crucial, and mounting pins directly onto the threaded areas of the plate, such as studs, may not achieve the necessary accuracy since these areas lack centering capabilities.



Once the designs for the locating elements are completed, their placement on the plate needs to be strategically planned. The use of a two-pin locating scheme can complicate modular fixture design due to the non-standard distances between hole centers and the unchanging pitch of the groove grid.

For example, one approach involves securing one plate with a stud that aligns with a threaded hole on the plate, while positioning another plate parallel to it. This setup necessitates the alignment of the coordinate systems between the part, the device, and the machine, along with necessary adjustments to the CNC system.

On the other hand, a simpler design opts for a layout where plates are arranged perpendicularly and attached directly to the main plate using bolts. This straightforward arrangement is preferred for its ease of implementation and is selected for further development.

Top of Form



2.3.3 Clamping elements

The clamping system will utilize L-shaped clamps, in line with the project specifications. At the heart of this system is a lever mechanism: a strap clamp seated on a fixed screw exerts force upon the workpiece. This force is engaged by rotating nut 1 along the axis of bolt 6, situated in the T-groove of the plate. Nut 1 is designed to be tall for ease of manipulation and is equipped with a spherical end, which, in combination with conical surfaces on the thrust washer, aids in correcting any alignment discrepancies.





2.3.4 Mount of the fixture on the CNC- machine

The placement of the fixture on the CNC machine is determined by the configuration of the machine's table. For this operation, an EC-1600ZT vertical milling machine is used, as depicted in Fig. 4.

Top of Form

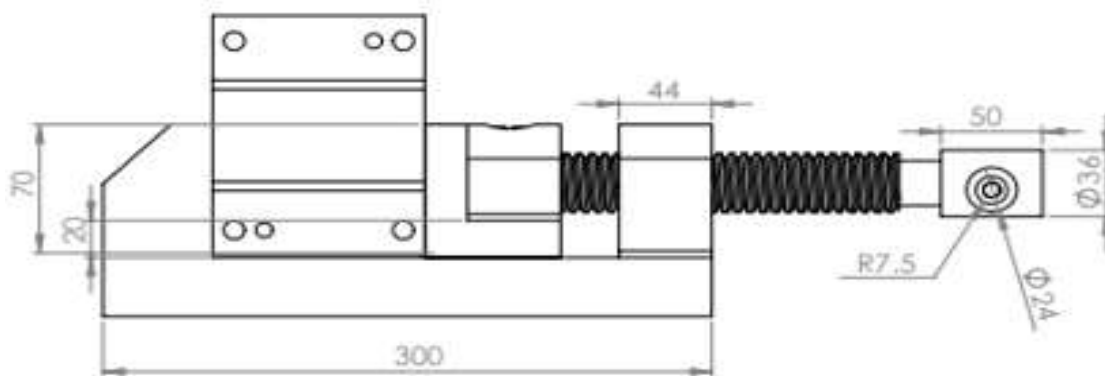


Figure 4 – Dimensions of the machine ta

A critical consideration in this setup is the discrepancy between the dimensions of the modular fixture system and the connection dimensions of the machine elements.

Consequently, the creation of a specially designed transition key, as shown in Fig. 5, is required.

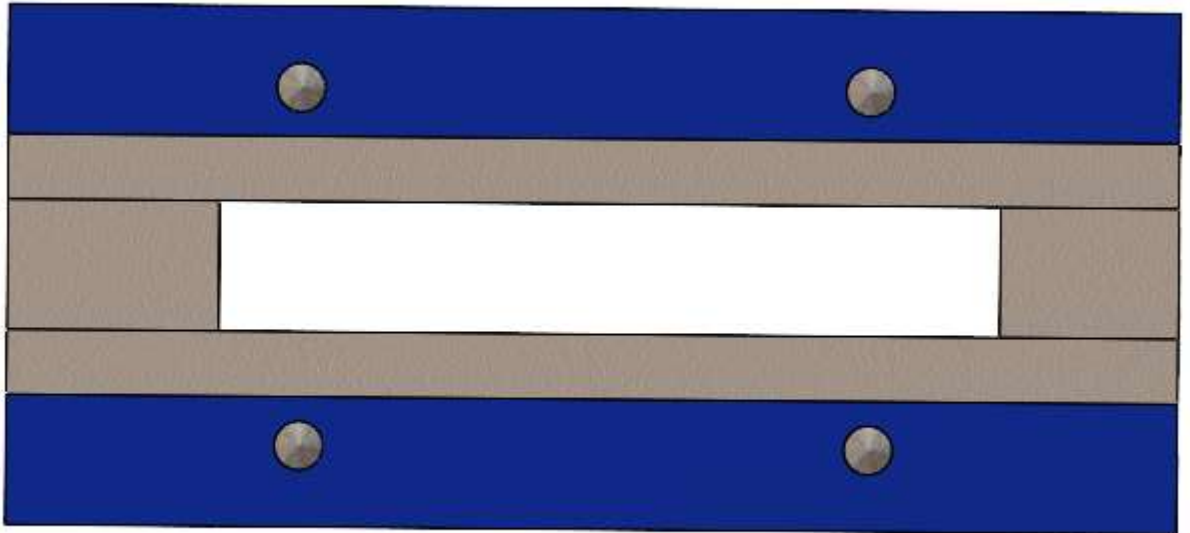


Figure 5 - Diagram of locating the device

By assembling all structural components, we complete the design of the fixture device, as shown in Fig. 6.

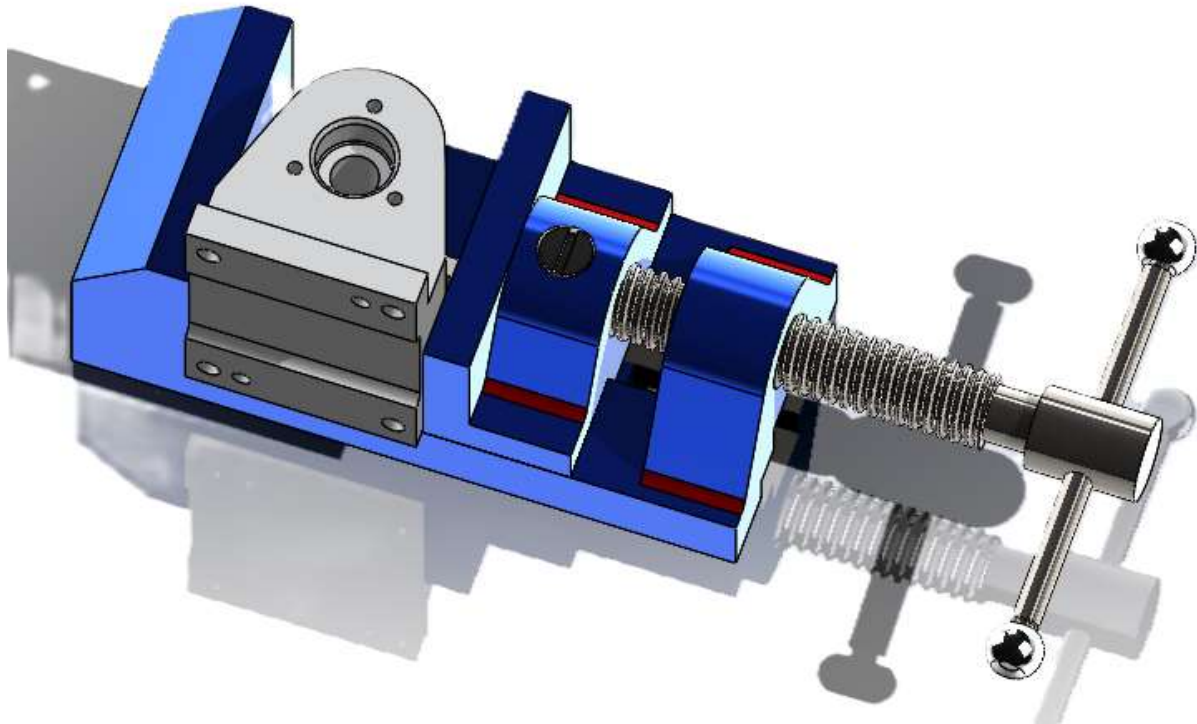


Figure 6 - General view of the fixture design

The visual portion of this coursework encompasses a detailed assembly drawing of the fixture, complete with its full specifications.

CHAPTER 3

3.1 Process flog for assembling a product using parts and fixtures

1. Part Preparation:

- Raw materials are received and inspected for quality.
- Parts are cut, molded, or formed according to specifications.
- Parts undergo surface treatment such as painting, coating, or plating if required.

2. Assembly Line Setup:

- Fixtures are prepared and set up on the assembly line.
- Workstations are arranged in sequence according to the assembly process.

3. Component Integration:

- Components are placed into fixtures for assembly.
- Fixtures aid in positioning and holding components securely during assembly.

4. Sub-Assembly:

- Sub-components are assembled together at designated workstations.
- Fixtures ensure proper alignment and fit during sub-assembly processes.

5. Final Assembly:

- Sub-assemblies are brought together for final assembly.
- Fixtures aid in aligning and joining components accurately.

6. Testing and Inspection:

- Finished products undergo testing and inspection for quality control.
- Fixtures may be used for holding products during testing procedures.

7. Packaging and Shipping:

- Finished products are packaged according to customer requirements.
- Fixtures may be used for holding products during packaging.

8. Quality Assurance:

- Throughout the process, quality checks are conducted at each stage to ensure adherence to standards.
- Fixtures may include measurement gauges or tools for quality inspection.

9. Maintenance and Calibration:

- Regular maintenance of fixtures is conducted to ensure proper functionality.

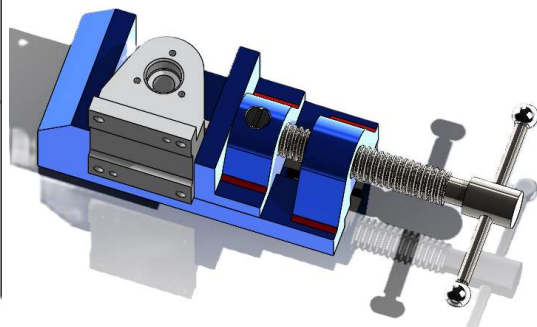
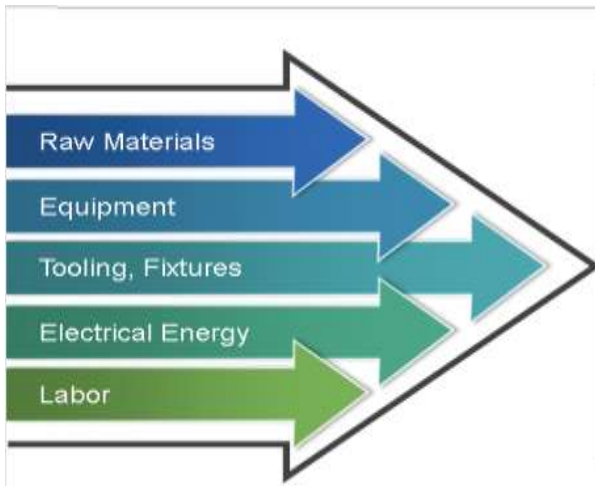
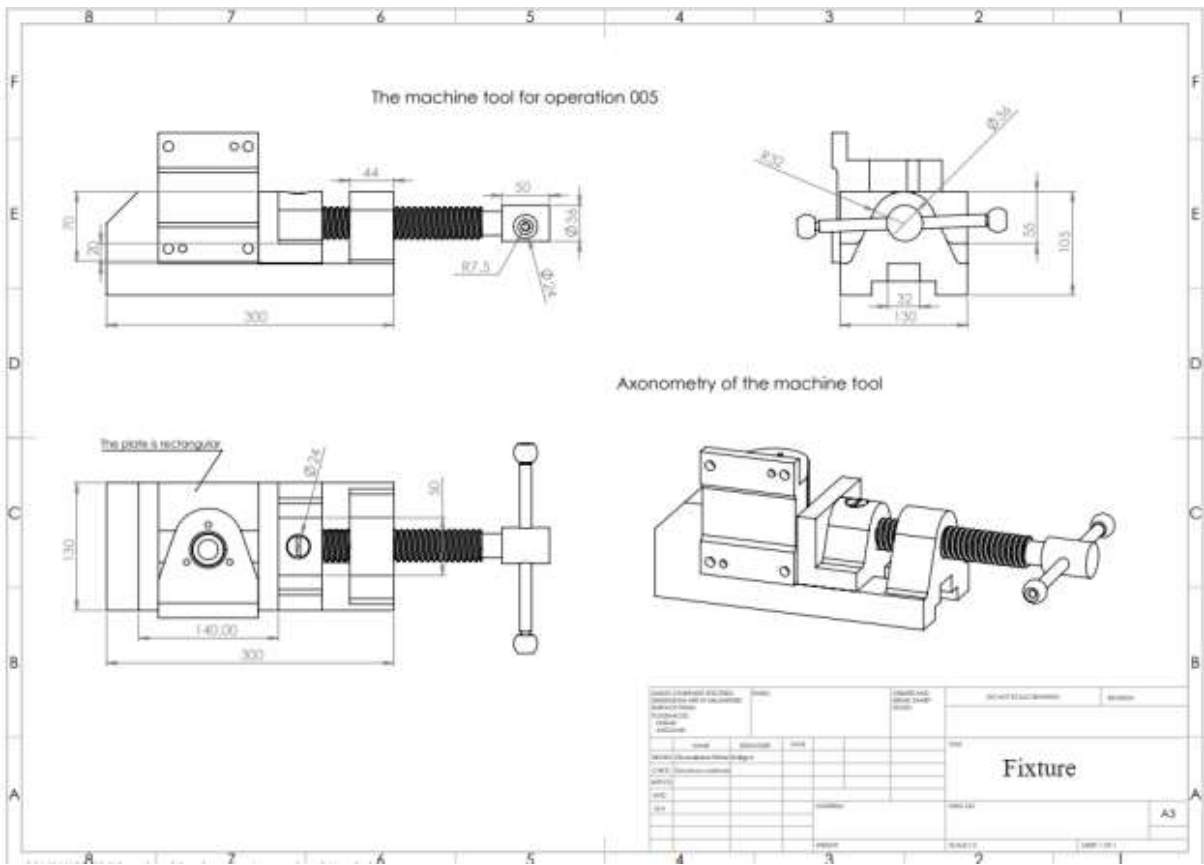
- Fixtures may require calibration to maintain accuracy in assembly processes.

10. Continuous Improvement:

- Feedback from testing, inspection, and maintenance is used for continuous improvement of the manufacturing process.
- Fixtures may be modified or upgraded based on feedback to enhance efficiency and quality.

This process flow diagram illustrates how parts and fixtures are integrated into the manufacturing process to ensure efficient assembly and quality control.

3.2 Fixture and process flow diagram

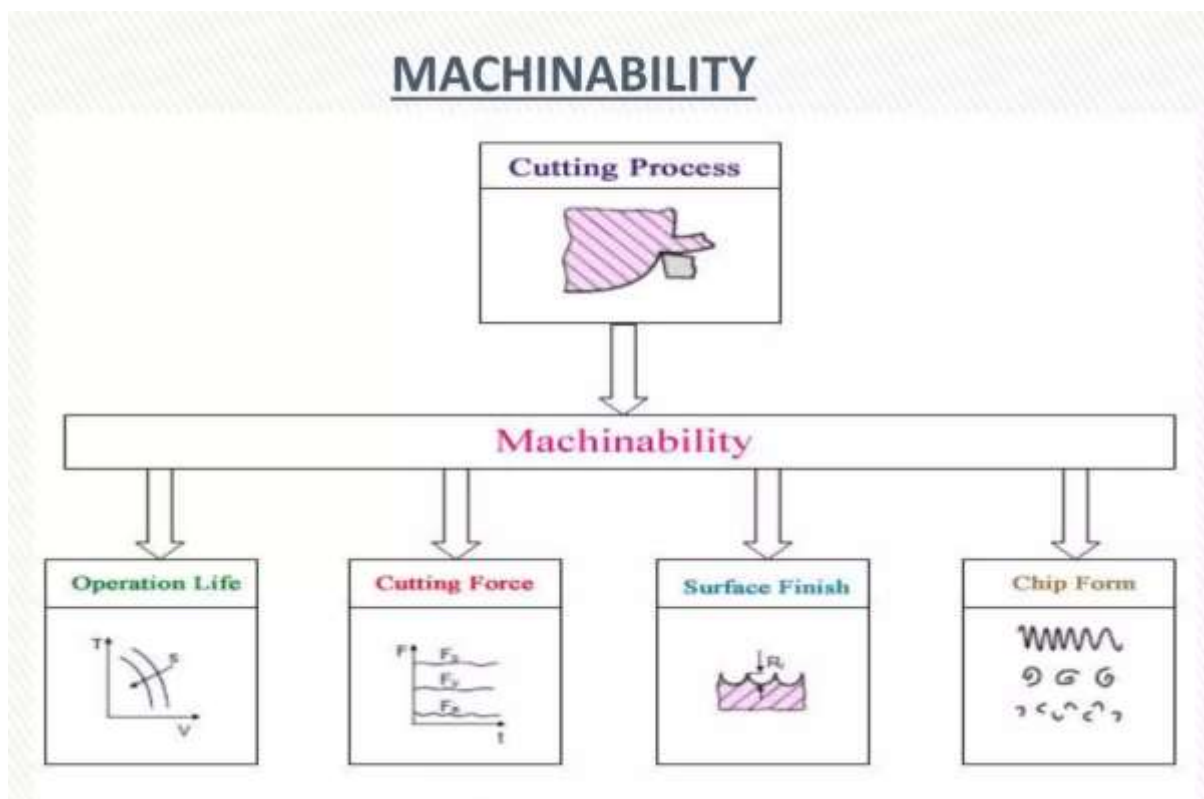


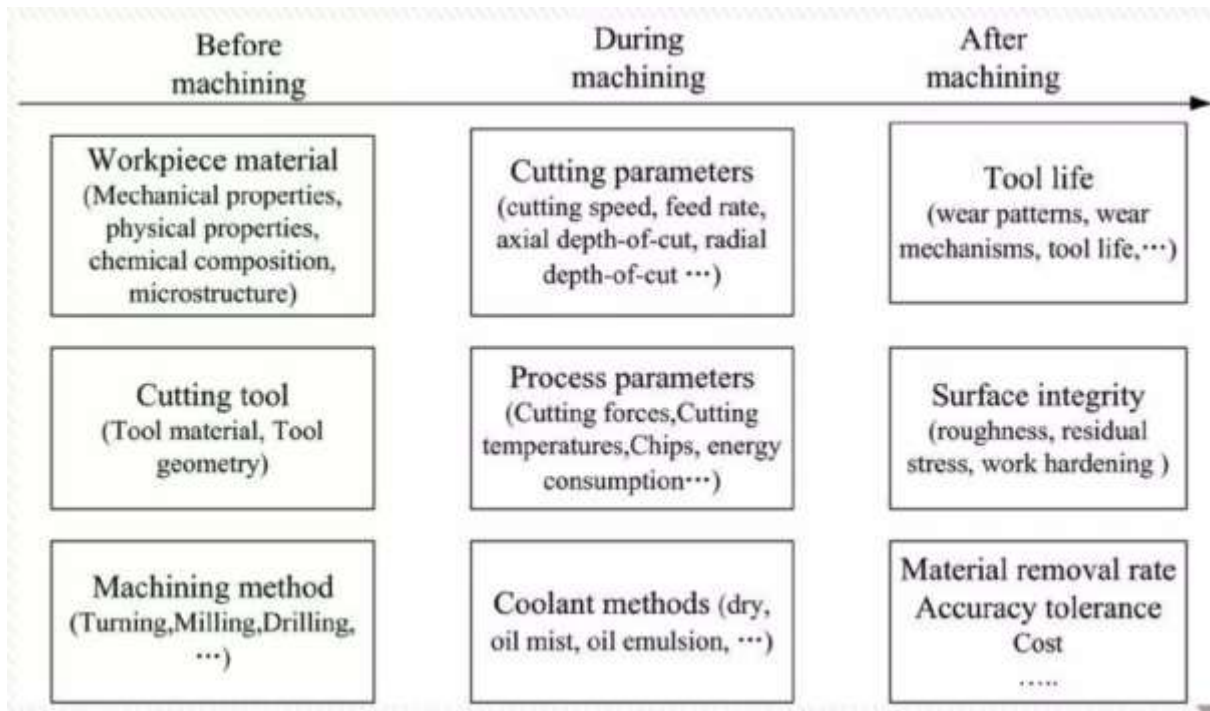
CHAPTER 4

4.1 Machinability

Machinability is the ease with which a given material may be worked with a cutting tool. The machinability of a material is usually defined in terms of four factors:

- Surface finish
- Tool life.
- Force and power required.
- The level of difficulty in chip control. Thus, good machinability indicates good surface finish and surface integrity, a long tool life, low force and power requirements and desired chip control in the cutting zone.





4.1.1 Machinability index

Because of the complex nature of cutting operations, it is difficult to establish relationships that quantitatively define the machinability of a particular material. The machinability rating of a material attempts to quantify the machinability of various materials.

$$K_M = V_{60} / V_{60R}$$

where V_{60} is the cutting speed for the target material that ensures tool life of 60 min, V_{60R} is the same for the reference material.

- Reference materials are selected for each group of work materials (ferrous and non-ferrous) among the most popular and widely used brands.

*/ If $K_M > 1$, the machinability of the target material is better than that of the reference material, and vice versa.

* Note that this system can be misleading because the index is different for different machining processes.

4.1.2 Machinability Rating Example

The reference material for steels, AISI 1112 steel has an index of 1. Machining of this steel at cutting speed of 0.5 m/s gives tool life of 60 min.

Therefore, $V_{60R} = 0.5$ m/s.

For the austenitic 302 SS steel

The machinability index is $K_m = 0.23/0.5 = 0.46$ (tool life of 60 min is reached at 0.23 m/s).

For AISI 1045 steel

The machinability index is $K_m = 0.36/0.5 = 0.72$. (tool life of 60 min is reached at 0.36 m/s).

So, we can rate these steels in a descending order of machinability:

AISI 1112 > AISI 1045 > 302 SS

Note that Tool life cannot be considered as the only criteria for judging machinability as it is dependent on many factors other than cutting velocity. Keeping all such factors and limitations in view, Machinability can be tentatively defined as "ability of being machined" and more reasonably as "ease of machining".

4.2 Cast iron description and classification

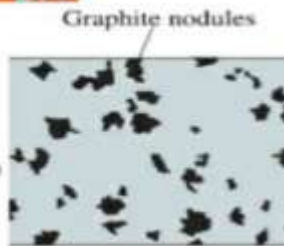
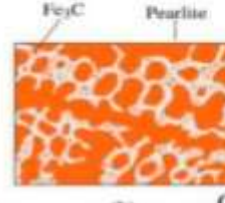
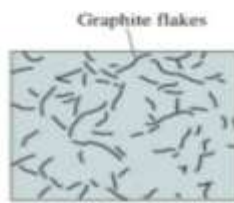
To provide a comprehensive description and classification of cast iron, it is essential to consider its metallurgical properties, classification, and microstructural characteristics. Cast iron is a versatile material with various types such as gray, ductile, malleable, compacted graphite, and white cast iron ("Basic Metallurgy of Cast Iron", 1998). The microstructure of cast iron, particularly the graphite morphologies, plays a crucial role in its properties (Velichko et al., 2007). The classification of cast iron can be based on graphite grain morphology, and neural network approaches have been proposed for this purpose (Pattan et al., 2010). Additionally, the characterization of cast iron microstructure through statistical fluctuation and fractal analyses of ultrasonic backscattered signals has been explored (Moura et al., 2011; Moura et al., 2011).

Overall, the comprehensive understanding of cast iron involves the consideration of its metallurgical, microstructural, and mechanical properties, as well as its classification based on various characteristics. The synthesis of these references provides a multidimensional view of cast iron, encompassing its material properties, microstructural features, and classification methodologies.

Classification of Cast iron,

- Depending on chemical composition, cooling rate, types and amount of inoculants that are used we can have

- Gray iron
- White iron
- Malleable iron
- Ductile iron
- Compacted graphite iron



4.3 Machinability of cast iron

The machinability of cast iron is influenced by various factors such as microstructure, alloying elements, and heat treatments. Alloying nodular cast iron with Ni and Cu has been reported to improve machinability by reducing cutting forces and surface roughness (Yiğit et al., 2008). Additionally, the microstructure of ductile cast iron plays a significant role in its machinability, with properties such as mechanical strength, fatigue and wear resistance, and machinability being comparable to some types of steels (Marques et al., 2019). Furthermore, the Si content in ductile iron has been found to influence its machinability, with variations in machinability observed along the cross-section of nodular cast irons due to differences in microstructure and mechanical properties (Xavier et al., 2022).

Heat treatments also impact the machinability of cast iron. For instance, the effect of different heat treatments on the weldability of high strength ductile cast iron has been investigated, with a focus on assessing the mechanical properties of welded joints and structural modifications induced by thermal cycles (Gouveia et al., 2017). Moreover, the machinability of austempered spheroidal graphite cast iron made by continuous casting and sand mold methods has been studied, highlighting the influence of casting methods on machinability (Ikuta et al., 2016; Ikuta et al., 2016).

In addition to microstructure and heat treatments, the influence of alloying elements on the machinability of cast iron has been explored. By controlling the chemical composition, it is possible to obtain high-vanadium cast iron with high strength properties, hardness, and abrasion resistance (Kawalec & Kozana, 2014). Furthermore, the resistance of castings to abrasive wear has been linked to the abrasive hardness ratio of the cast iron (Kopyciński et al., 2013).

It is important to note that the inherent properties of cast iron, such as its damping capacity and dimensional stability, make it a suitable material for machine tool frames, effectively dampening vibrations and ensuring stability during machining operations (Boral et al., 2018). Furthermore, the use of alternative materials, such as polymer concrete, for machine tool beds has been explored, highlighting the potential for improving the dynamic characteristics of the bed compared to traditional cast iron beds (Bruni et al., 2008).

In conclusion, the machinability of cast iron is a complex interplay of microstructure, alloying elements, heat treatments, and material properties. Understanding these factors is

crucial for optimizing the machinability of cast iron and enhancing its performance in various applications.

In figure 4.3.1 you can see the machinability of cast iron in comparison with other metals.

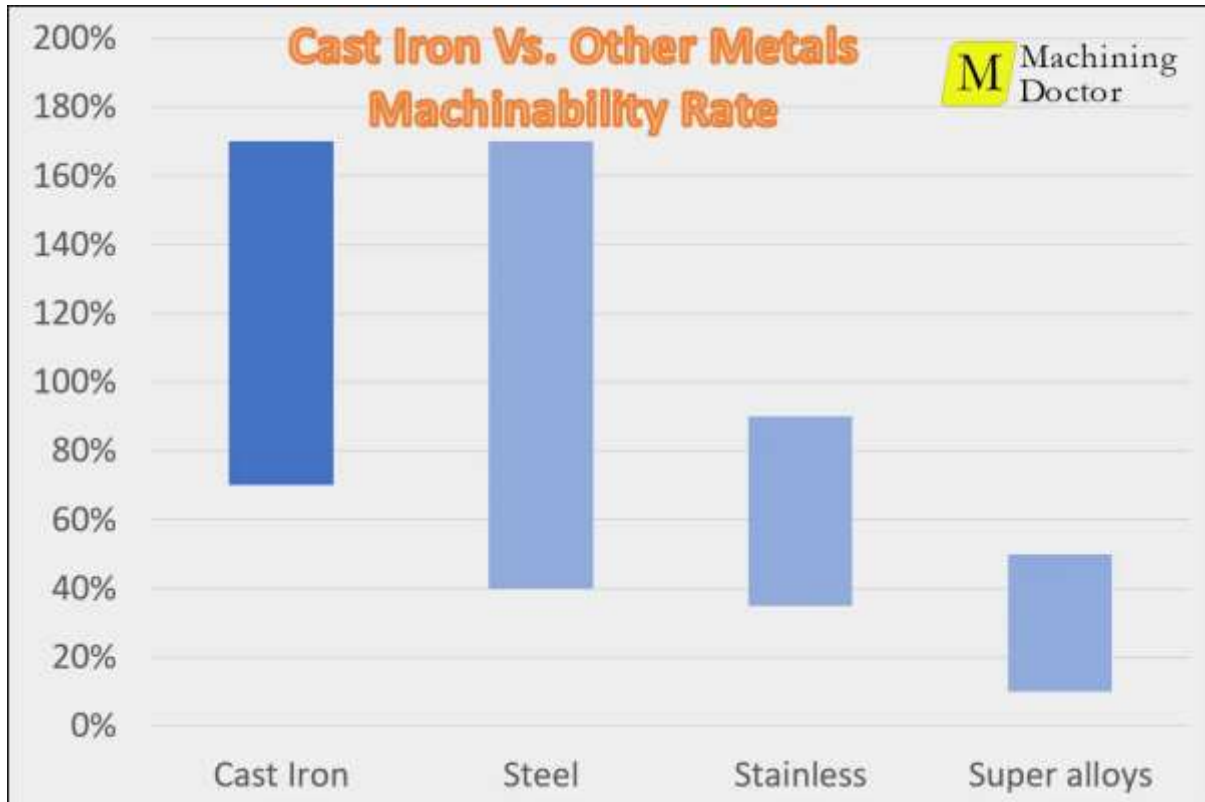


Fig 4.3.1

Figure 4.3.2 shows the machinability percentage of different types of cast iron

Material	Condition	ISCAR Mat. Group [®]	Machinability %
Grey Cast Iron (GCI)	Ferritic	15	130
	Pearlitic	16	100
Nodular Cast Iron (NCI)	Ferritic-pearlitic	17	75
	Pearlitic	18	70
Malleable Cast Iron (MCI)	Ferritic	19	115
	Pearlitic	20	93
Compacted Graphite Iron		~17	80
Austempered Ductile Iron (ADI)	Soft	~10	80
	Hardened	41	35
Ni-resist Austenitic CI			90
Chilled Cast Iron	HB 400...440	40	50
Hardened Cast Iron	HB 550...600	41	25

[®]ISCAR material group is in accordance with VDI 3323 standard

Fig 4.3.2

4.4 Difficulties and problems in machining cast iron

Machining cast iron presents several challenges and difficulties due to its poor machinability, high hardness, and the occurrence of spontaneous disintegration during the machining process (Yanda et al., 2011). The high-aluminum cast iron, despite its advantages, has not been widely used in the industry due to these encountered difficulties during machining (Gilewski et al., 2021). Additionally, the fatigue strength of machined and shot peened grey cast iron can be problematic to identify, especially in terms of inducing beneficial surface residual stresses (Lundberg et al., 2014). Furthermore, the bending fatigue resistance of machined cast irons, including grey cast iron, can be improved to certain degrees by shot peening (Ahmad et al., 2016).

The use of conventional materials such as cast iron for structural components is least preferred due to properties such as chemical resistance, workability, ease of production, stiffness, and damping (Rangasamy et al., 2015). Moreover, the dynamic properties of hybrid constructions compared to cast iron bodies can affect the machining process (Kępczak & Pawłowski, 2021). It is also noted that many materials have the ability to replace conventional cast iron, such as mild steel weldments, granite, ceramics, concrete, ferrocement, polymers, epoxy granite, and composites (Abuthakeer, 2011).

In terms of specific types of cast iron, the machinability of austempered spheroidal graphite cast iron made by different casting methods was investigated, highlighting the importance of the casting method in determining machinability (Ikuta et al., 2016). Additionally, aluminum-alloyed cast iron has been studied for its wear resistance, heat resistance, and damping properties, indicating the potential for improving these properties through alloying (Takamori et al., 2002). Furthermore, the structure of the casting alloy, which includes the FeAl phase, is related to high-aluminum cast iron, indicating the influence of alloy composition on the properties of cast iron (Kopyciński et al., 2013).

In conclusion, machining cast iron presents challenges related to its poor machinability, high hardness, and the occurrence of spontaneous disintegration. The choice of casting method and alloy composition also significantly influences the machinability and properties of cast iron. Additionally, the use of alternative materials and hybrid constructions can impact the dynamic properties and machining process of cast iron.

The rigidity of cast iron can be seen in fig 4.4.1



Fig 4.4.1

4.5 Economic implications and benefits of machinability of cast iron

The machinability of cast iron has significant economic implications and benefits. Cast iron, particularly ductile cast iron (DCI), possesses properties comparable to some steels, including mechanical strength, fatigue and wear resistance, and machinability (Marques et al., 2019). This suggests that cast iron can be a cost-effective alternative to steel in various applications. Additionally, the use of cast iron in machine tool structures has been shown to increase damping capacity, which can lead to improved performance and reduced maintenance costs (Möhring et al., 2015). Furthermore, the economic considerations for using cast iron in machine tool frames are highlighted by the fact that steel systems are much thinner compared to cast-iron ones, indicating potential cost savings (Boral et al., 2018).

The economic benefits of cast iron are also evident in its machinability. Studies have shown that proper process cooling can lead to economically viable machining of iron-carbon alloys, including cast iron (Reiter et al., 2018). Moreover, the excellent machinability of gray iron, a common type of cast iron, contributes to its widespread use as a cast material due to its low cost and outstanding castability (Xue et al., 2018). This indicates that the machinability of cast iron can lead to cost savings in manufacturing processes.

Furthermore, the economic profile of modern foundry processes is changing due to continuous improvement in the physical and mechanical properties of casting alloys, allowing for precise casting with a smooth surface that does not require extensive machining, thereby

increasing productivity and reducing costs (Kukartsev & Tynchenko, 2020). Additionally, the use of cast iron in machine tool beds has been a subject of research, with efforts to minimize drawbacks while maximizing advantages, indicating the economic significance of utilizing cast iron in such applications (Kępczak et al., 2015).

In conclusion, the economic implications and benefits of the machinability of cast iron are evident in its cost-effectiveness as an alternative to steel, its excellent machinability leading to cost savings in manufacturing processes, and its role in improving the economic profile of modern foundry processes.

4.6 Solutions to difficulties in machining cast iron

To address the difficulties encountered during machining of cast iron, several solutions have been proposed in the literature. High-aluminum cast iron, despite its advantages, has not been widely used in the industry due to the challenges faced during machining (Gilewski et al., 2021). The high carbon content in cast iron, approximately 3%, poses a major problem during welding, making it difficult to work with (Marques et al., 2019). Additionally, the large concentrations of carbon and other influencing elements can negatively interfere with the welding process of ductile cast irons (Gouveia et al., 2017). Furthermore, the inherent problems such as chattering detected in cast iron structures of advanced machine tools affect the tool life, machining integrity, and surface quality of the workpiece and geometric accuracy (Selvakumar & Mohanram, 2013).

Heat treatment has been found to reduce the pearlitic phase within the matrix of the cast iron, leading to increased machinability and ductility, as well as reduced hardness and wear resistance when compared to non-heat treated samples ("undefined", 2020). Moreover, the brittleness and susceptibility to fracture of gray cast iron can lead to problems like inaccuracy and jitter when processing workpieces, highlighting the need for optimization of the mechanical properties of machine tools (Chuang, 2023).

Alternative materials have been suggested to replace cast iron in machine tool construction, indicating a shift towards the application of mineral casting instead of cast iron in the construction of machine tools (Kępczak & Pawłowski, 2021). Silicon nitride-based ceramics have also been identified as having enough resistance to withstand the impacts inherent to the machining of gray cast iron, compacted graphite iron, and Ti-6Al-4V (Souza et al., 2008).

In conclusion, the difficulties in machining cast iron have prompted research into various solutions, including heat treatment, alternative materials, and the application of ceramics. These approaches aim to address the challenges posed by the microstructure and high carbon content of cast iron, as well as its brittleness and susceptibility to fracture.

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