

**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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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 the Part "Bushing" _____

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 _____

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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

Head of the department

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«__» _____ 20__ p.

ASSIGNMENT
for the diploma project to the student

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(full name)

1. Topic of the diploma project Manufacturing Process Planning for the Part
"Bushing" _____

project supervisor Associate professor Anatolii SUBIN _____ ,
(full name, academic degree, academic title)

approved by the University Order dated «__» _____ 202__ p. № _____

2. The deadline for the student to submit a diploma project «16» 06 2024

3. Initial data for the project _____ draw of the detail, production volume _____
5000\year, steel 45 as material _____

4. The content of the explanatory note, a list of tasks to be developed _____

perform standard tasks of designing the operational technological process of manufacturing parts " Busing "; to design 2 fixtures for realization of technological process; to determine the cost calculations; create a set of technological documentation; investigate Surface Treatment and Chrome plating

5. A list of graphic and illustrative material Detail and blank draws; technological process explanation draws, CNC operational draws, fixtures draws; investigation task draw; in total numbers of draws should no less then 5

6. Consultants for chapters of the project

Chapter	Surname, initials, and position of consultant	Signature, date		
		Issued the task	Accepted the task	the task
Economical	Anatolii SUBIN			

7. Issue date of the assignment

«15» 04 2024

CALENDAR PLAN

No	Stages of the diploma project implementation	The deadline for the stages of the diploma project	Notes
1	Technological section	1 week	
2	Technological section	2 week	
3	Design section	3 week	
4	Design section	4 week	
5	Other sections	5 week	
6	Formalizing of the project sections	6 week	

Student

EMIR CAN YAŞA

Supervisor

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ABSTRACT

Diploma Project on "Manufacturing Process Planning for the part “Bushing” on CNC Machine Platforms"

The Diploma project comprises both textual and graphical components. The graphical portion is rendered on four A1 sheets and includes 3-D models and detailed drawings of parts and blanks, schematics for the technological transitions of operation 005 in the manufacturing process of the "bushing," and assembly drawings for the devices used in operations 005.

The explanatory note is divided into two sections: technological and design. It also encompasses:

- 34 figures

- 6 tables

At the conclusion of the course work, there is a list of references and appendices. These include the operational technological process and sketch maps.

This paper offers a comprehensive examination of machining and milling processes, delving into the fundamental principles and methodologies that are vital to these essential manufacturing techniques. Beginning with an overview, the paper highlights the processes and benefits of chrome plating, discussing its role in enhancing surface hardness, reducing friction, and increasing corrosion resistance in machined parts.

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CHAPTER 1: Surface Treatment and Chrome plating

1. Surface Treatment

Surface treatments involve applying different processes directly to a workpiece's surface, typically a few microns thick. These processes alter the surface properties, making them distinct from the material's interior. Surface treatments are vital for improving the performance and durability of components in various industries. By adjusting surface characteristics like hardness and corrosion resistance, these treatments enhance the functionality and lifespan of engineering parts, meeting the demands of modern applications.

1.1. Applications of Surface Treatments

Surface treatments find application in various domains, serving crucial purposes such as corrosion prevention, wear resistance, aesthetic enhancement, hardness improvement, and facilitation of weldability. These treatments are instrumental in extending the lifespan and improving the performance of components across industries. Whether it's protecting metal structures from rusting, increasing the durability of machine parts subjected to friction, enhancing the visual appeal of consumer products, or ensuring the weldability of materials in fabrication processes, surface treatments play a pivotal role in meeting diverse engineering requirements.

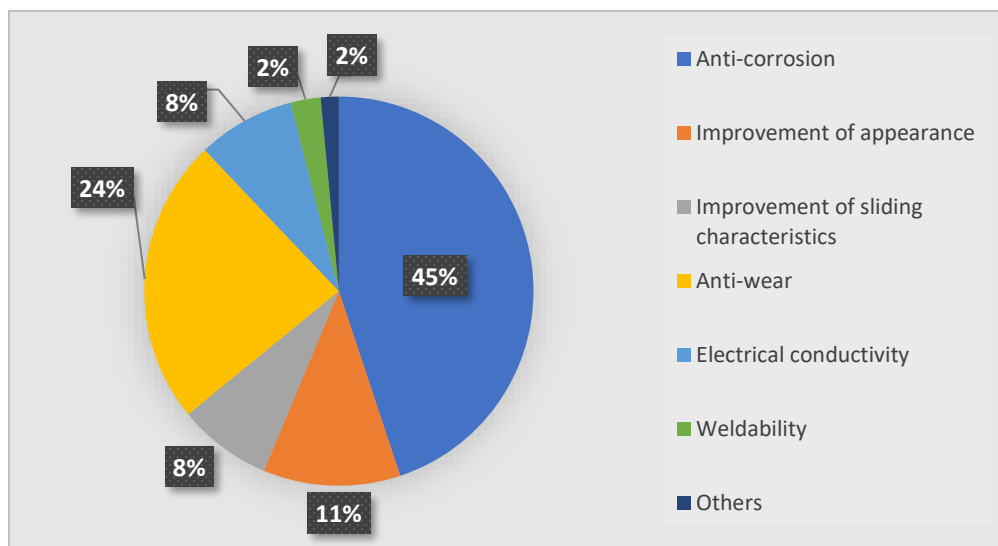


Fig.1.1. Chart of Surface Treatment Applications

1.2. Classification of Surface Treatment Processes

The classification of surface treatment processes is crucial for understanding and selecting the most suitable method based on the specific needs of each application. Surface treatment processes can be grouped into four main categories: metallic coatings, conversion treatments, diffusion thermochemical treatments, and structural transformation treatments. The details of each category are outlined in Table 1.1., facilitating their comparative study and practical application in various industrial fields.

Table 1.1. Classification of surface treatment processes

Metallic Coating	Wet Deposition	<ul style="list-style-type: none"> ➤ Electrolytic deposition ➤ Chemical deposition ➤ Molten metal dip
	Dry Deposition	<ul style="list-style-type: none"> ➤ Thermal Spray ➤ Vapor phase ➤ Energy Beam ➤ Metallic cladding
Conversion Processing	Electrolytic	<ul style="list-style-type: none"> ➤ Anodization ➤ Sulphuration
	Chemical	<ul style="list-style-type: none"> ➤ Phosphitylation ➤ Chromatization
Thermochemical diffusion	Diffusion of non-metallic elements	<ul style="list-style-type: none"> ➤ Cementation ➤ Nitration ➤ Carbonitriding
	Diffusion of metallic elements	<ul style="list-style-type: none"> ➤ Chromization ➤ Aluminization
Structural transformation	Thermal route	➤ Melting and surface quenching
	Mechanical route	➤ Shot blasting, burnishing

1.3. Surface Treatment Mechanisms

- Coatings: The coating material reacts minimally or not at all with the substrate.
- Chemical conversion treatments: The coating material reacts superficially with the substrate.
- Thermochemical treatments with diffusion: The coating material diffuses into the substrate.

- Surface treatments with structural transformation: The metallurgical structure of the substrate is modified.

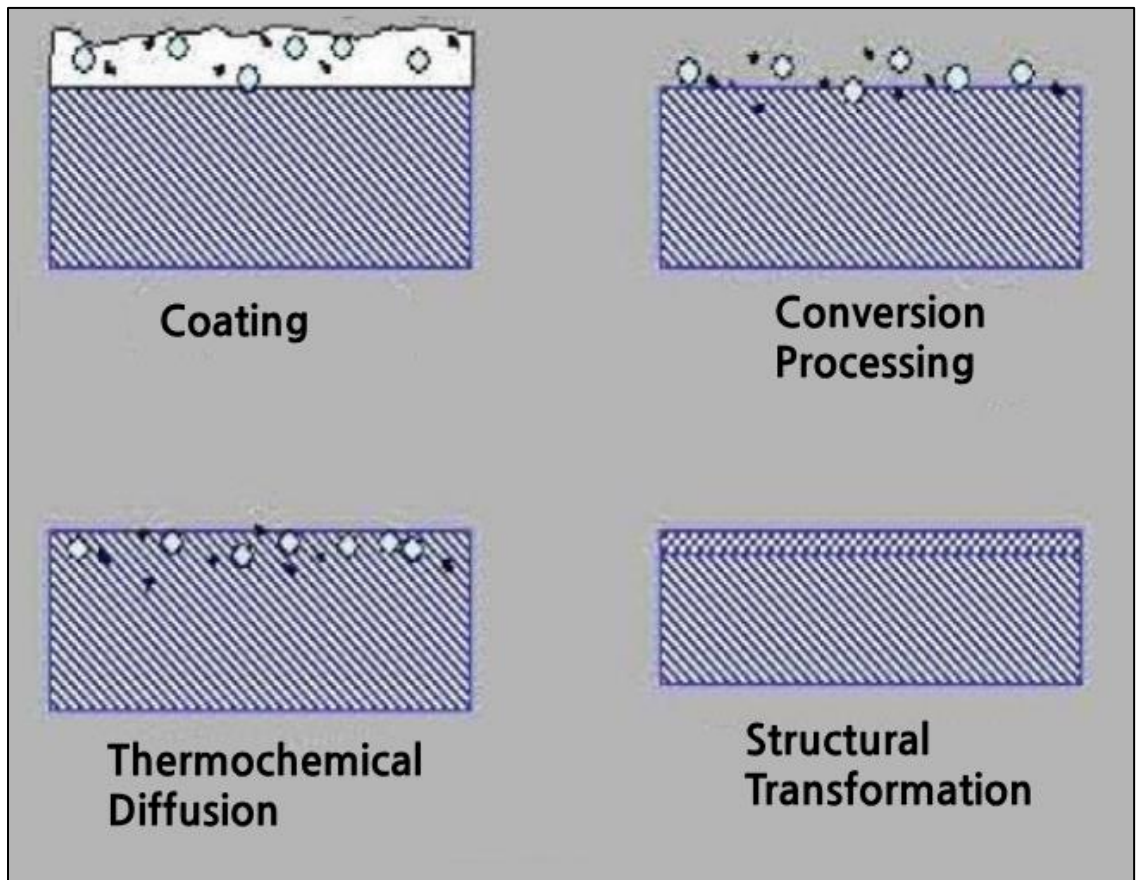


Fig.1.2. Mechanisms of Surface Treatments

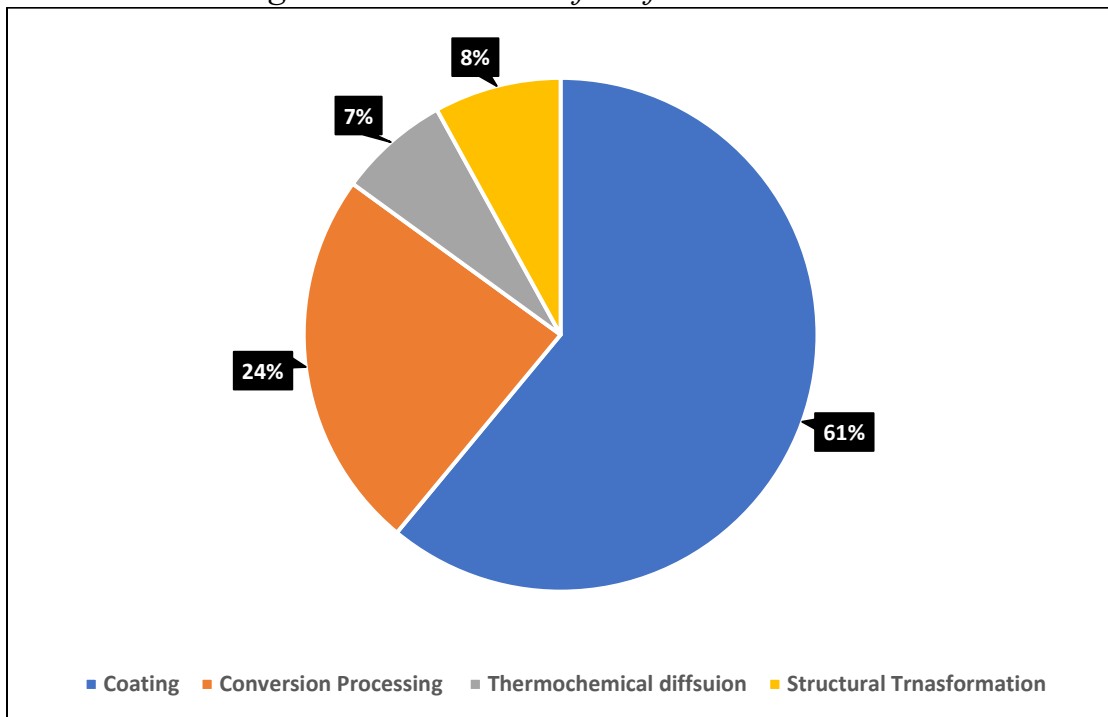


Fig.1.3. Chart of Usage percentage

1.4. Surface Cleaning

Before any treatment, surface cleaning is a crucial phase aimed at removing impurities present on the surface of the parts. This includes two distinct operations:

- Degreasing: Removes greasy substances through mechanical, chemical, or electrolytic actions. This operation is essential to ensure that no oily residues interfere with subsequent treatment processes.
- Deoxidizing: Removes all traces of corrosion and oxide that cling to the surface of the parts. This can be achieved through mechanical methods (such as sandblasting or shot blasting), chemical treatments, or electrolytic processes.

2. Chromium and Chrome-plating

2.1. Chromium

2.1.1. Definition

Chromium is a chemical element, metallic, with the symbol Cr, atomic number 24, and atomic mass of 51.996 u.m.a. It belongs to group 6 (or VI b) of the periodic table. This element is a hard transition metal with a steel-silver color. It resists corrosion and tarnishing. It often substitutes for iron (very similar ionic radii: Fe (III) = 0.067 nm, Cr (III) = 0.061 nm, Cr (VI) = 0.044 nm). The traces of chrome found in these minerals are often responsible for their colors: the green of emerald or the red of ruby (Alloway, 1995).

2.1.2. Structure of Chromium

Chromium is a grayish-white metal that can achieve a beautiful polish. Its crystal structure is body-centered cubic (edge length 2.8 angstroms). Chromium melts at a very high temperature (1800°C). The coefficient of linear expansion for chromium is $\alpha = 8 \times 10^{-6}$.

In its normal electrolytic deposition state, the hardness of chromium is very high, about 1000 HV, which corresponds to approximately 70 HRC, and by extrapolation to 800 HB. Under the influence of heat treatments starting from 400°C, the hardness of the chromium deposits decreases, regardless of the deposition method used, until it reaches about 200 HV for a heat treatment at 1200°C.

2.1.3. Structures and Properties of Chromium Carbides:

2.1.3.1. Preparation of Chromium Carbides:

Chromium carbides have been observed since 1893, when MOISSAN prepared Cr₃C₂ and "Cr₄C" in an electric furnace. Chromium carbides can be produced by heating a mixture of Cr₂O₃ and carbon in a hydrogen atmosphere. Below 1600°C, layers of chromium carbonyl form. The metal can react with methane at 600-800°C.

2.1.3.2. Properties of Chromium Carbides:

The evaluation of the potential uses of various materials in the varying states to which they can be brought by treatments is determined by determining a number of quantities related to the various properties of the metal. The most common, if not the most important, are related, on the one hand, to strength, i.e., the resistance to deformation, and, on the other hand, to ductility, i.e., the ability to deform without breaking. These two qualities are somewhat interdependent.

- **Hardness:**

Among the most commonly determined quantities, we first mention hardness, which is expressed as resistance to indentation. The hardness of chromium carbide varies depending on the quality of the deposited chromium, for example, by electrolysis, the value being (1500-1800) HV.

- **Wear:**

Wear is caused by material removal from a surface in contact and in relative motion with another surface. Composition, microstructure, surface topography, presence or absence of lubricant or other media, load, contact speed, and temperature are determining factors for wear rate. Chromium carbide has excellent resistance to adhesive wear, abrasive wear, and erosive wear. In general, the average lifespan of chromium carbide-coated parts is multiplied by 5 to 10 times. The wear protection layers obtained are particularly suitable for high-temperature applications and have proven themselves in the chemical industry as well as in aviation.

- **Friction:**

Chromium carbide has a very low coefficient of friction, making it an excellent material for friction in industrial uses, especially dry friction. Chromium carbide maintains wear resistance by friction at temperatures up to 482°C.

- Corrosion Resistance:

The corrosion resistance of chromium carbides is generally very good. Its ability to protect against corrosion is significantly enhanced by a nickel underlayer. Practically, chromium carbides are distinguished by their very high chemical and thermal stability. They resist all chemicals (except hydrochloric acid), even at high temperatures. They are non-corrosive up to 800°C.

2.2. Chrome Plating

2.2.1 Definition of Chrome Plating

Chrome plating is an electrolysis coating process used to deposit metallic chrome on surfaces to impart the properties of this metal.

2.2.2 Types of Chrome Plating

This well-known treatment is carried out for two significant applications: Decorative Chrome Plating and Hard Chrome Plating, where the deposited layer essentially differs in thickness.

- Decorative Chrome Plating is performed on surfaces typically coated beforehand with a layer of nickel (or possibly layers of copper and nickel). Its primary purpose is to give the coating the brightness characteristics of chrome. The resistance to tarnishing of this metal, combined with its hardness, allows this decorative layer, on the order of micrometers, to maintain a shiny appearance for many years. The shiny chromes of vintage cars (still visible today) and current motorcycles testify to this.

- Hard Chrome Plating differs from the former in that its thickness is greater (from a few micrometers to a few tenths of a millimeter). This coating provides the material on which it is applied with a good coefficient of friction and ensures good properties of wear and corrosion resistance. It is prominently visible, for example, on the cylinders of mechanical equipment (lifting devices or construction machinery, etc.). This type of treatment is the preferred coating in the mechanical field for parts in rotation or translation that need to resist wear and have good friction qualities, and for areas where adhesion could be a disadvantage (plastics processing, rolling mill cylinders, etc.).

2.2.3. Hard Chrome plating

2.2.3.1. Objective

The objective of this surface treatment process is to utilize the fundamental characteristics of chrome deposits, namely:

- High hardness;
- Wear resistance;
- Low coefficient of friction;
- Good corrosion resistance.

2.2.3.2. Essential characteristics

- Microhardness: Generally, the microhardness of hard chrome deposits is around 1,000 HV 0.1. This microhardness depends on a number of factors, as will be discussed later, and can vary from 800 to 1,200 HV. For deposits made from hexavalent chromium, this microhardness significantly decreases with treatment temperature, reaching values of about 300 HV 0.1 at 700 °C.

- Cracking: Hard chrome deposits are typically micro-cracked: the number and size of the microcracks largely depend on the nature of the catalysts used, the condition of the substrate, and the form of the current used to make the deposit. Figure II, 7 illustrates the appearance of the chrome deposit (thickness 70 µm) obtained with standard solutions. Photographs a and b show the surface appearance fresh out of the bath at different magnifications, and c presents this surface after polishing and slight etching: the cracking is clearly visible.

The rate of cracking must be quantified on a polished cross-section of the deposit (Figure II, 7d). It is determined by the linear density (number of cracks intercepting a segment of a determined length and parallel to the substrate): it is expressed as the number of cracks per unit length. This rate of cracking is influenced by:

- Nature of the Bath: The nature of the catalyst in the chrome plating bath plays a crucial role in the tendency towards fissuring. Baths using organic catalysts tend to produce approximately ten times more micro fissures compared to those using sulfate ions, which are considered standard baths. This difference may be attributed to variations in the deposition mechanisms and the dynamics of ions within the bath.

- Bath Temperature: The temperature of the bath also significantly influences the formation of cracks. Higher temperatures can increase the deposition rate,

which alters the structure and cohesion of the deposit. Precise temperature management is essential to control the rate and severity of fissuring.

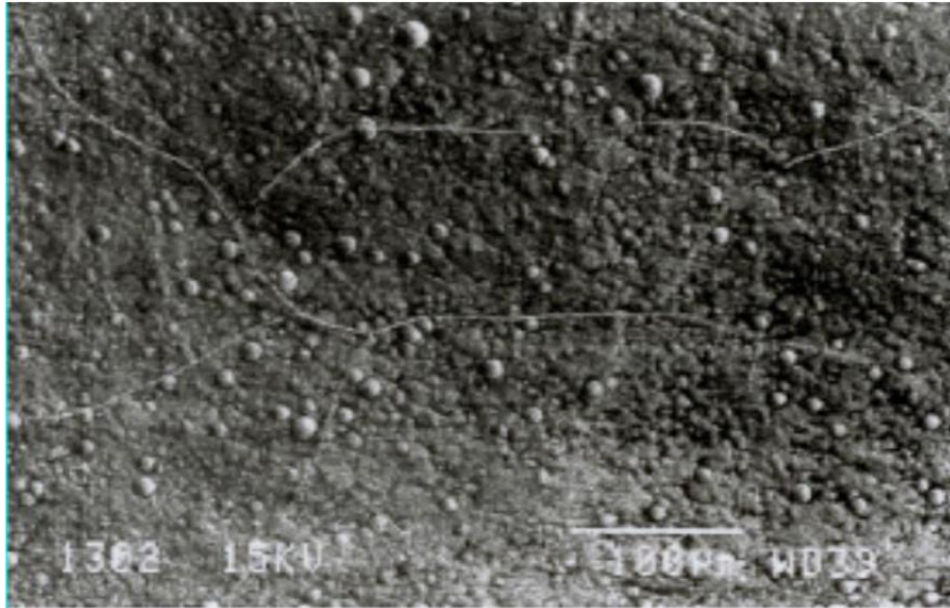
Development of Fissuring: Research has visualized the development of fissuring in situ. It has been observed that fissuring occurs discontinuously during electroplating. Initially, the cracks help to release internal stresses in the deposit. As deposition continues, the current density increases at the edges of the cracks, accelerating deposition in these areas and potentially leading to the temporary closure of the cracks. However, new cracks can form and reproduce the cycle.

2.2.3.3. Residual Stresses

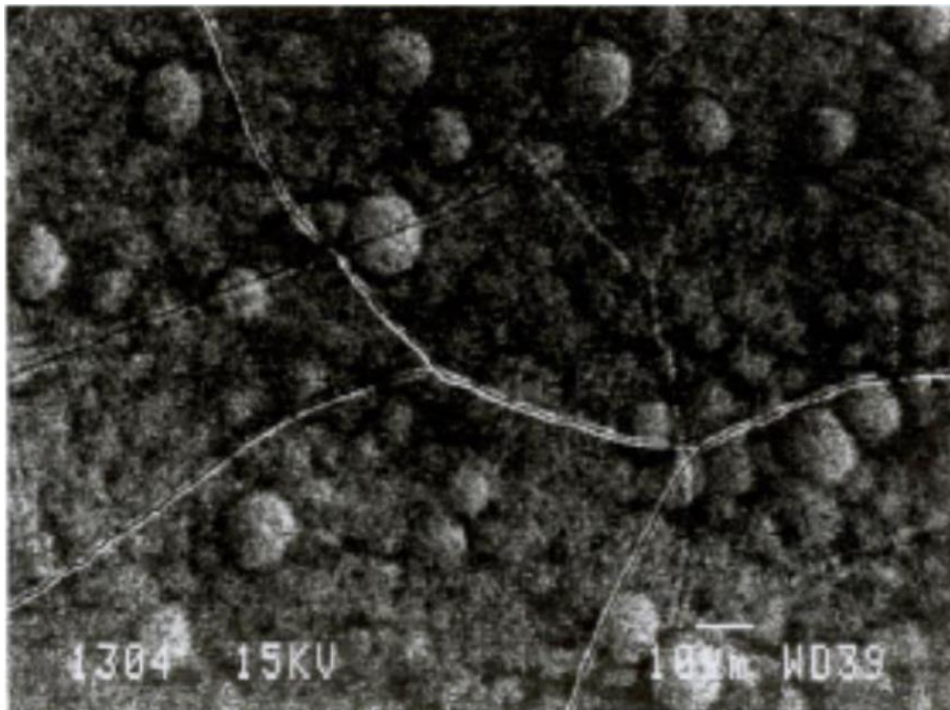
The mechanisms of residual stress formation are still poorly understood, but their development appears to be related to the presence of hydrogen within the deposit. Two models have been proposed, though they have not yet been experimentally verified.

The first model hypothesizes that these stresses may be directly linked to the presence of hydrogen trapped during electrolysis, which would later diffuse and cause the deposit to contract. Since this contraction is constrained by the substrate, it would lead to the emergence of tensile residual stresses.

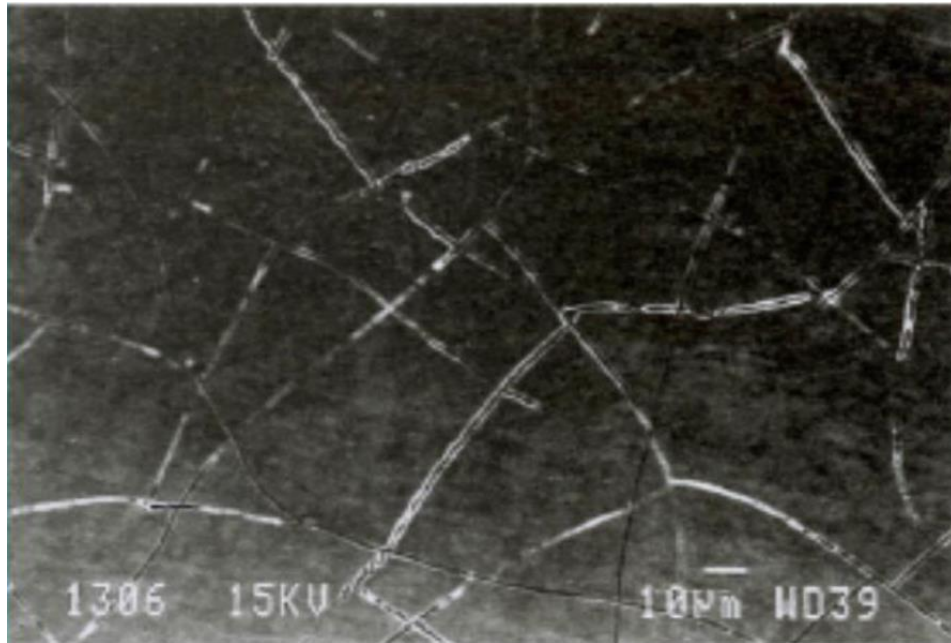
The second proposed model involves the formation of hexagonal structured chromium hydrides during deposition (a possibility due to the simultaneous presence of nascent atomic hydrogen and metallic chromium), which would then transform into cubic centered chromium of a smaller size than the hexagonal structure, thereby causing tensile stresses.



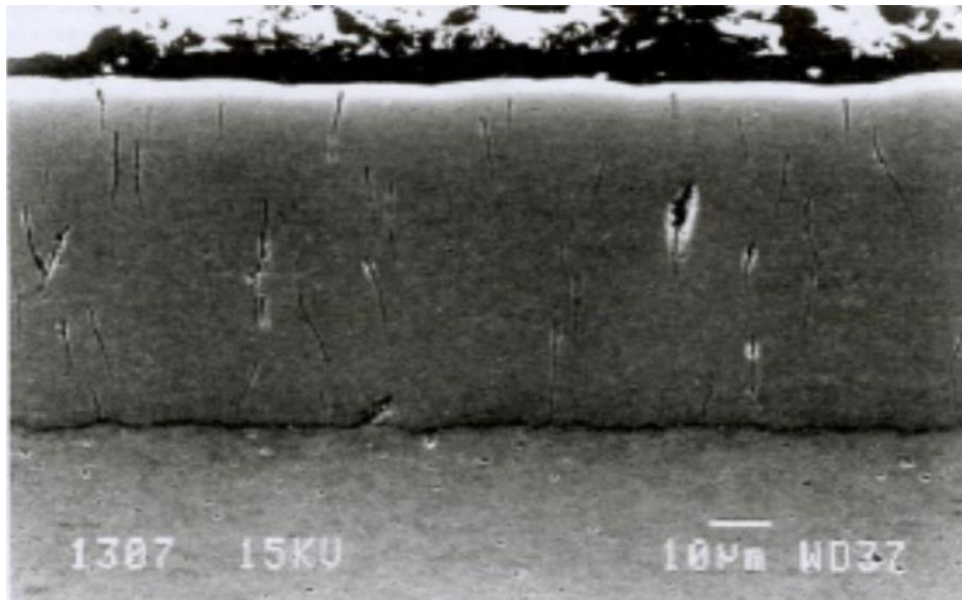
Surface appearance when leaving the bath (apparent cracking)
“a” chromium deposit (70 μm) obtained in standard chrome plating solution



“b” deposit under the same conditions as “a” but at higher magnification



“c” Surface appearance of a chrome deposit (standard) after polishing and light etching



“c” surface appearance of a chrome deposit (standard) after polishing and light etching

Fig.1.4. Hard Chrome plating: highlighting of cracking

CHAPTER 2: Manufacturing Process Plan

2.1. General analysis of the part

2.1.1. Geometry analysis

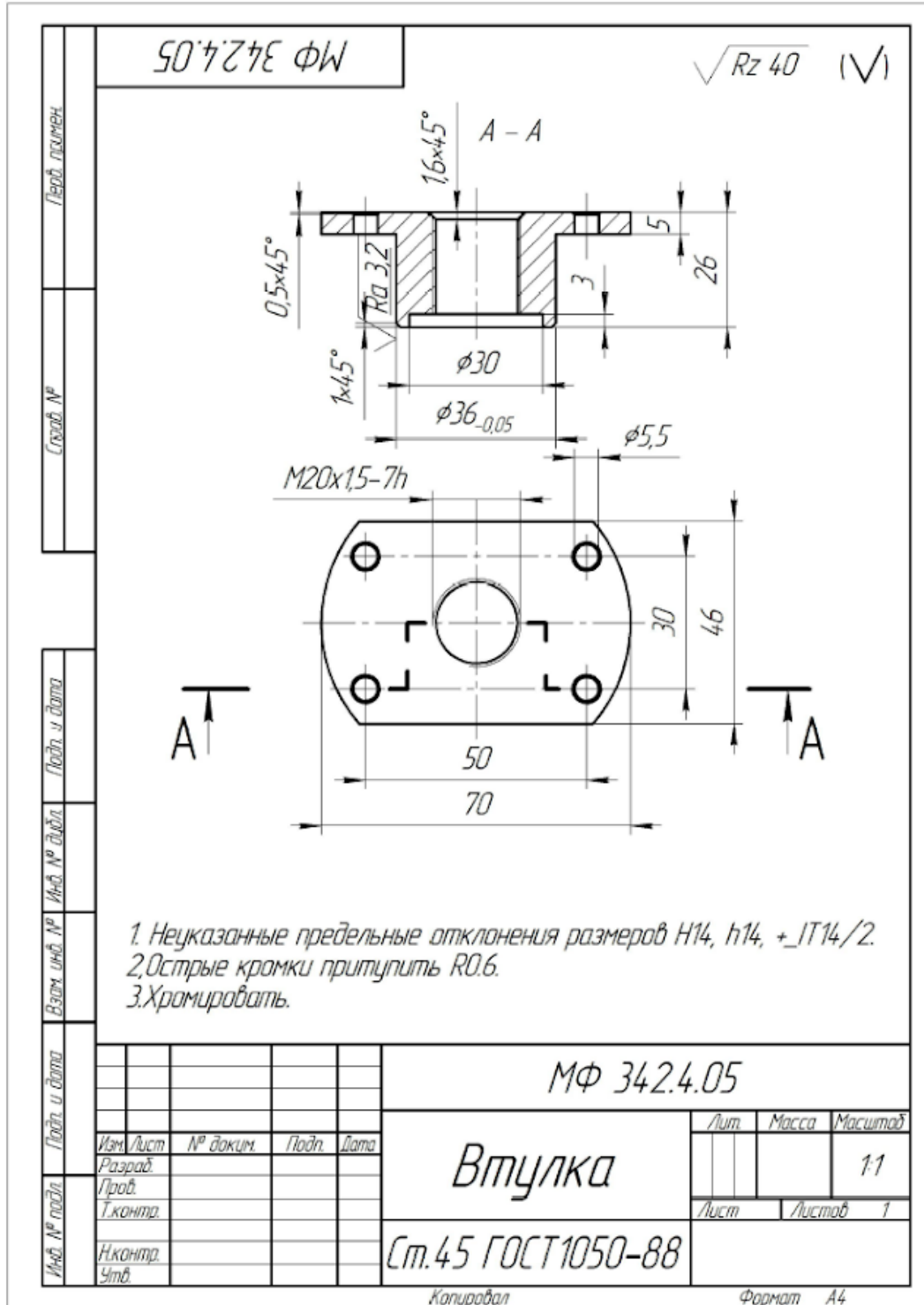


Fig.1. Initial variant drawing

Overall, the surfaces on the part have moderate tolerances, requiring standard machining practices. However, special attention is needed for the M20x1.5 H7 hole. Tight tolerances for this hole are crucial to ensure proper shaft alignment, verticality, and ultimately, the stability of the mechanism it houses.

2.1.2. Part’s working condition in the assembly

The Bushing’s primary function is to ensure rigid shaft retention, preventing any unintended movement. To achieve this, the M20 H7 hole is specifically designed to facilitate smooth shaft rotation while maintaining stability. Additionally, the 5.5 holes serve as attachment points for securely fixing the Bushing onto the platform, ensuring proper alignment within the assembly.

2.1.3. Material analysis

According to the stated information on the drawing sheet, we are safe to say that the material chosen to manufacture the Jaw; “Steel 45 ГОСТ 1050–88” (DIN 1.0503), is a suitable choice, which criteria are stated on Table.1.

Table.1. Chemical composition and mechanical properties of C45

Chemical Composition				
C	Si	Mn	P	Cr
0.42 – 0.5	≤ 0.4	0.5 – 0.8	≤ 0.035	≤ 0.4
Mechanical Properties				
Tensile Strength (MPa)	Yield Strength (MPa)	Elongation (%)	Impact Energy (J)	Hardness (HB)
≥532Mpa	≥280Mpa	≥32%	≥60J	160-200HBW

2.1.4. Type of production determination

As per instructions, we will determine the type of production based on the part weight (Fig.2), as well as Production Volume required. In accordance with the table below (Table.2).

Table.2. Production type catalog

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

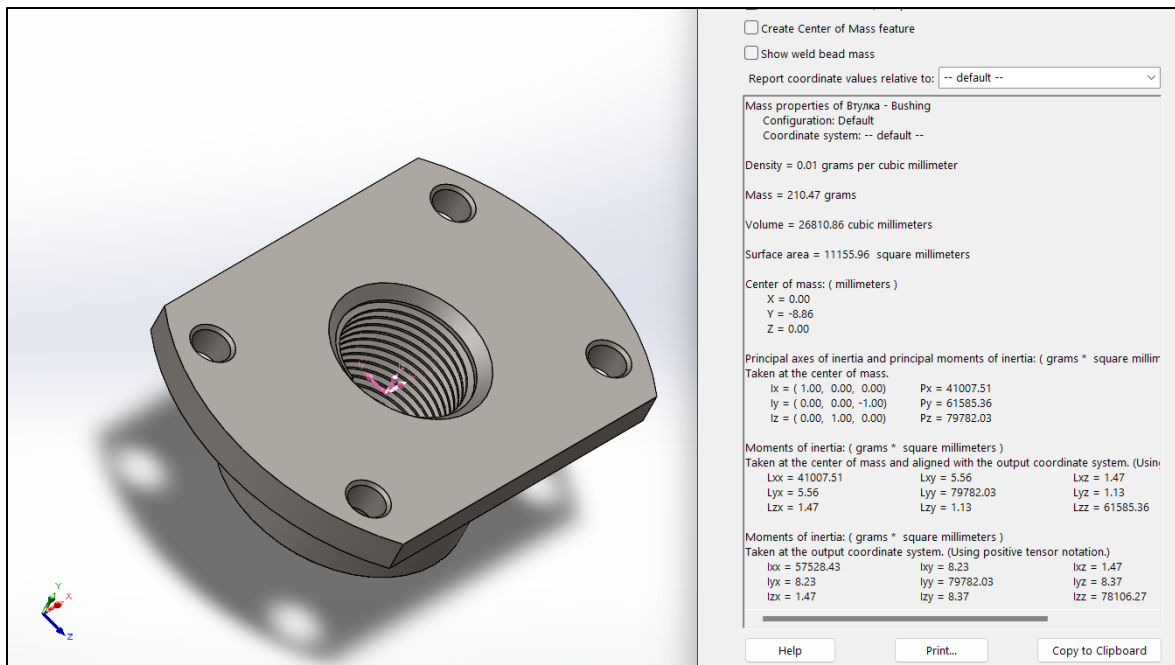
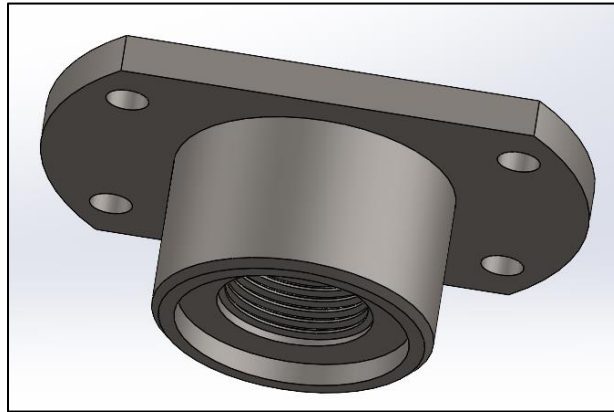


Fig.2. Mass properties of the part

So, the data we now have is: $m = 0.210$ grams and production quantity per annum: 5000

Conclusion: According to the data as well as the table, we conclude that all further calculations and technological decisions will be based on the Medium-batch production type.

2.1.5. The 3D model of the part



2.2. Selection of the base process and Blank design

2.2.1. Selection of the base process

Having provided the necessary information regarding the part Bushing:

- Drawing of the part
- Component Material Steel 45
- Production volume per annum (5000)

We can now choose the Process with the help of The Solidification processes' chart in Fig.3

	Cast iron	Carbon steel	Alloy steel	Stainless steel	Aluminum and alloys	Copper and alloys	Zinc and alloys	Magnesium and alloys	Titanium and alloys	Nickel and alloys	Refractory metals	Thermoplastics	Thermosets
Sand casting	Normal practice	Normal practice	Normal practice	Normal practice	Normal practice	Normal practice	Normal practice	Normal practice	Normal practice	Normal practice	Normal practice	Normal practice	Normal practice
Investment casting	Normal practice	Normal practice	Normal practice	Normal practice	Normal practice	Normal practice	Normal practice	Normal practice	Normal practice	Normal practice	Normal practice	Normal practice	Normal practice
Die casting	Normal practice	Normal practice	Normal practice	Normal practice	Normal practice	Normal practice	Normal practice	Normal practice	Normal practice	Normal practice	Normal practice	Normal practice	Normal practice
Injection molding	Normal practice	Normal practice	Normal practice	Normal practice	Normal practice	Normal practice	Normal practice	Normal practice	Normal practice	Normal practice	Normal practice	Normal practice	Normal practice
Structural foam molding	Normal practice	Normal practice	Normal practice	Normal practice	Normal practice	Normal practice	Normal practice	Normal practice	Normal practice	Normal practice	Normal practice	Normal practice	Normal practice
Blow molding (ext.)	Normal practice	Normal practice	Normal practice	Normal practice	Normal practice	Normal practice	Normal practice	Normal practice	Normal practice	Normal practice	Normal practice	Normal practice	Normal practice
Blow molding (inj.)	Normal practice	Normal practice	Normal practice	Normal practice	Normal practice	Normal practice	Normal practice	Normal practice	Normal practice	Normal practice	Normal practice	Normal practice	Normal practice
Rotational molding	Normal practice	Normal practice	Normal practice	Normal practice	Normal practice	Normal practice	Normal practice	Normal practice	Normal practice	Normal practice	Normal practice	Normal practice	Normal practice

Normal practice
 Not applicable
 Less common

Solidification processes

Fig.3. Solidification processes

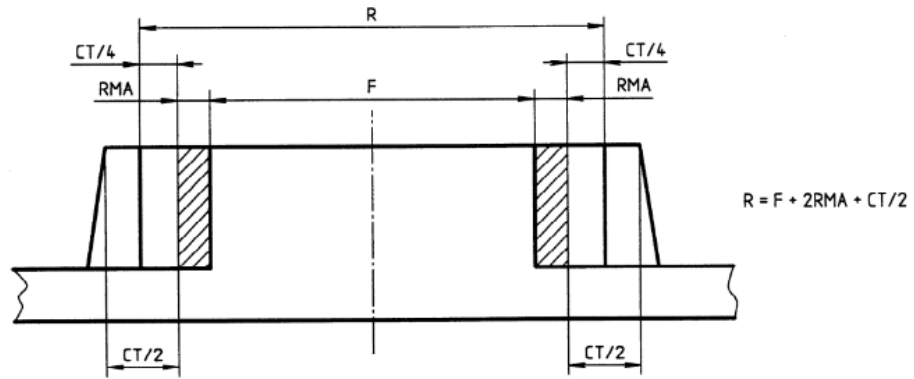
According to the Geometry of the part as well as as the chat above, we choose the Sand Casting as our base process moving on.

2.2.2. Casting Tolerance and Required Machining Allowance calculations

To select the required machining allowance (RMA) grade, we can refer to Table B.1 in [ISO 8062]. This table recommends grade F for sand casting machine-molded with Steel. Based on Table 1 in the same reference, and considering the part's largest dimension of 70mm (as per drawing), the required machining allowance for RMA grade F is 1mm.

To estimate the casting tolerance (CT) grade for long production runs, we can refer to Table A1 in [ISO 8062]. This table suggests CT grade 10 for sand casting with Steel.

The selection of RMA and CT grades, along with their locations on the part, are further illustrated in the sketches presented in Fig.4.



R = Raw casting basic dimension

F = Dimension after final machining

RMA = Required machining allowance

CT = Casting tolerance

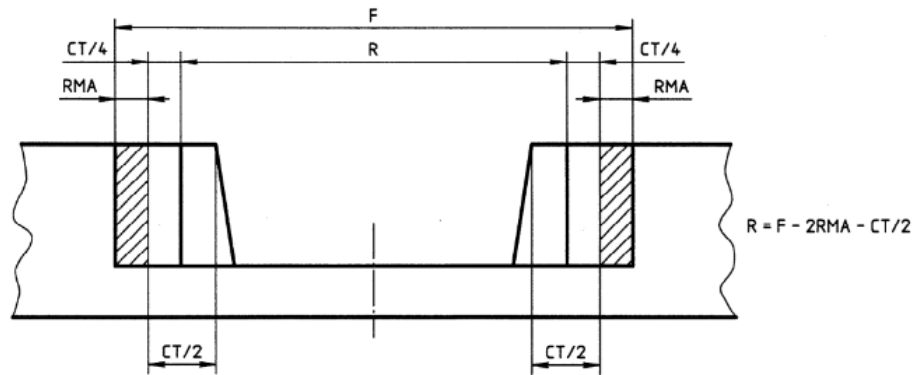


Fig.4. CT an RMA illustration

Table.3. CT and RMA Tolerances

Dimensio n	RM A	Min limit of size for external features (or max for internal features)	CT	Raw Casting Dimension
∅70	1	72	3.2	73.6±1.6
46	1	48	2.8	49.4±1.4
∅36	1	38	2.6	39.3±1.3
26	1	28	2.6	29.3±1.3

∅20	1	18	2.4	16.8±1.2
5	1	7	2	8.0±1.0

Effective casting design is crucial for producing high-quality parts. Here are the key considerations we implemented for the sand-casted bushing:

- The workpiece is positioned to minimize its height within the mold. This reduces the distance molten metal travels, minimizing the risk of solidification issues like shrinkage porosity.
- The parting line, where the mold separates, coincides with the plane of symmetry. This simplifies mold design and core placement.
- Sharp corners in the casting design are avoided. Instead, radii of 0.5-5mm are used. This improves casting integrity by reducing stress concentration points that could lead to cracking.
- A draft angle of 2° is applied to all walls perpendicular to the parting line. This facilitates easier removal of the cast part from the mold after solidification.
- The machining allowance (RMA) is added only to surfaces that will require secondary machining processes. This minimizes material waste and optimizes casting efficiency.
- The main hole of the bushing is formed using cores. This allows for the creation of this feature during the casting process itself.
- Small features like additional holes are created using secondary processes like drilling or machining after casting. This is because small features are more challenging to achieve consistently and precisely during casting.

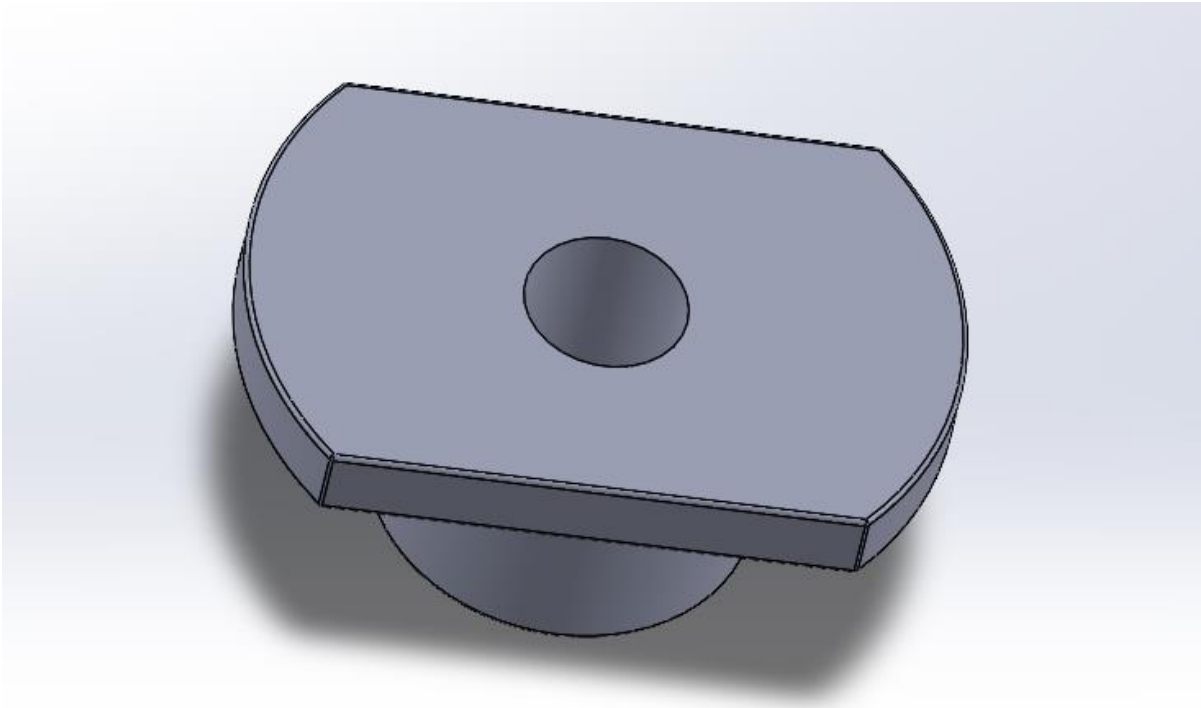


Fig.5. 3D Model of the Casting Blank

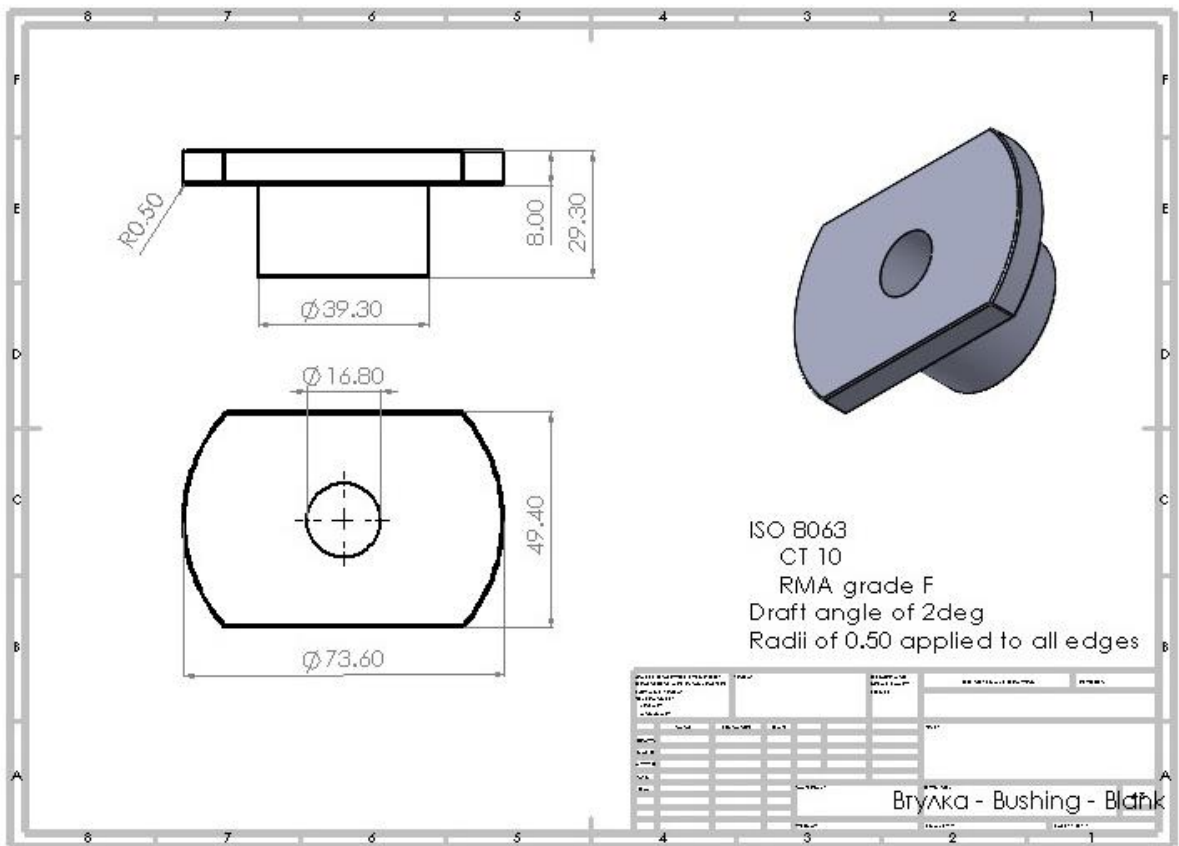


Fig.6. Technical 2D drawing of the Blank

2.3. Locating Scheme selection

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

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

2.3.1. Choosing General Manufacturing Datum (GMD)

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

The initial data to justify the choice of GMD are the working drawing of the part. To solve the problems of the first stage, it is necessary to classify the surfaces of the part for their intended purpose. The design of any part can be represented as a set of four types of surfaces:

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

For further analysis let's classify surfaces of a given part according to their purpose:

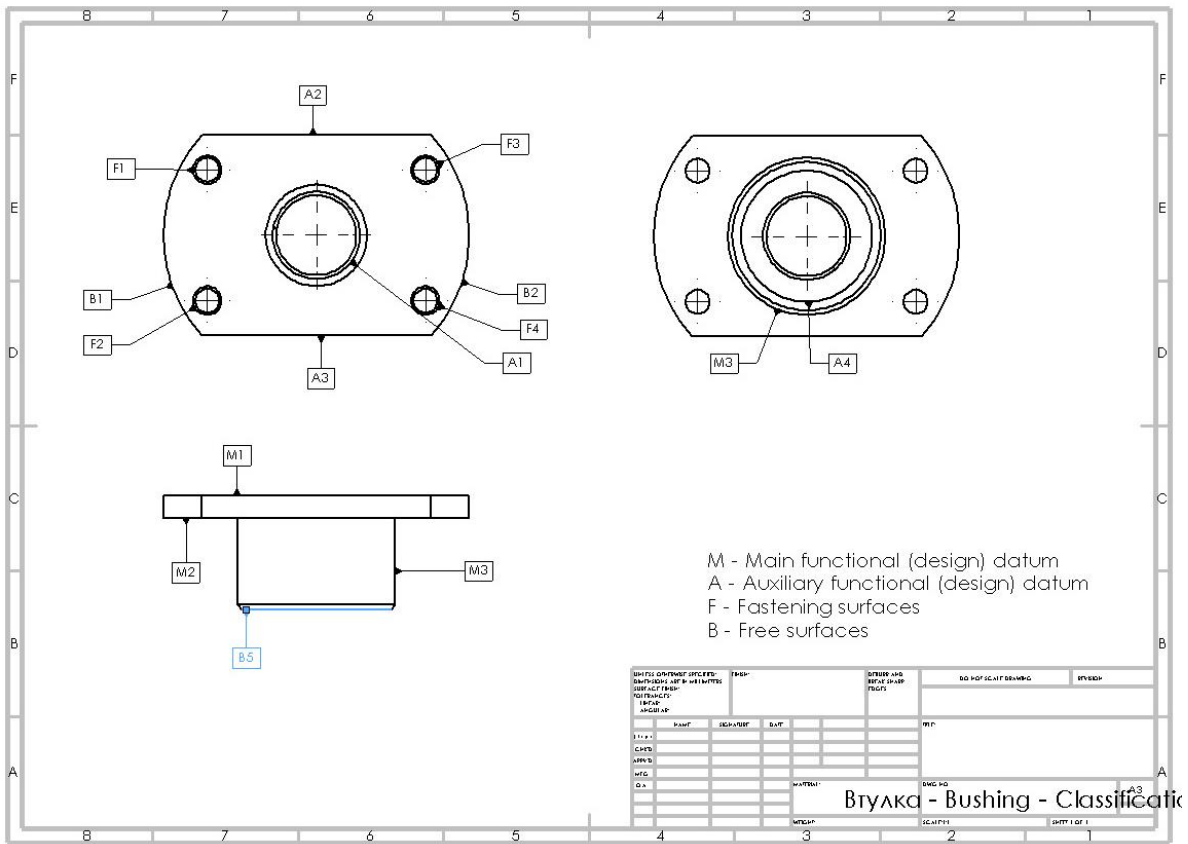


Fig. 7. Surfaces Classification

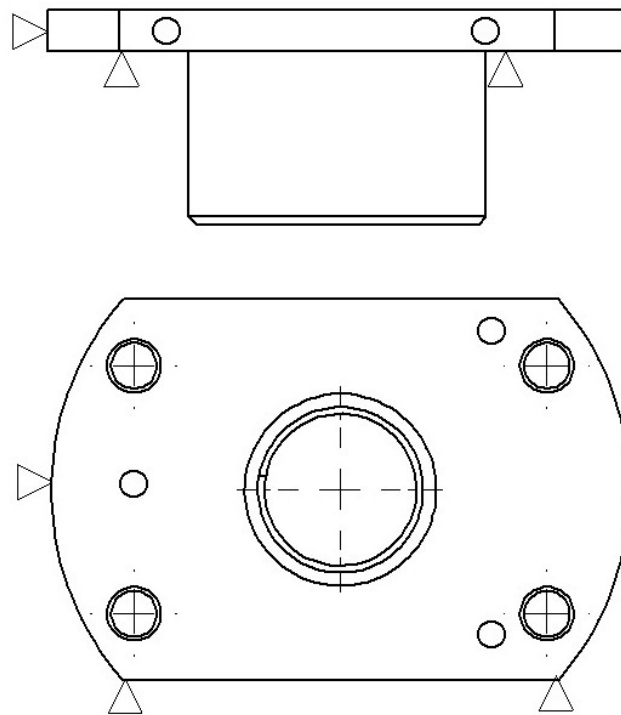


Fig. 8. GMD Locating scheme

The formula for the locating scheme presented in Fig.8 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.

This scheme is implemented using: a plane, round head and diamond head locating pins. In this case, the "Bushing" is sufficiently oriented, which allows processing its surfaces with the specified requirements for the spatial position. In our case GMD remains unchanged.

$$GMD = Const$$

2.3.2. Choosing MD for the first manufacturing operation

When choosing datum surfaces for the first manufacturing operations it is necessary to ensure openness for processing of all surfaces of GMD and to choose machines that can carry out consecutive processing of GMD surfaces for achievement of the set quality characteristics. Otherwise, it is necessary to take into account that the full set of the GMD has to be processed during next first technological operations.

Let's consider possible locating schemes for the first manufacturing operations as well as their advantages and disadvantages. For this purpose, we will use the following recommendations:

- for MD select surfaces that aren't supposed to be processed according to the drawing
- if all surfaces of the workpiece have to be processed, then as MD we take the surfaces that have the lowest allowance, if the allowances are uniform, it is necessary to choose surfaces on which defects are not allowed;
- choose as MD surfaces for which it is necessary to provide a uniform allowance for the next stages of processing;
- if there are several possible schemes of basing, then as MD we accept the option with the shortest dimensional chain.

The first variant is presented in Fig.9.1.

Advantages:

- Easy to implement.
- Ensures the correct placement of untreated surfaces related to the treated ones.

Disadvantages:

- Blocks processing the workpiece from 2 sides (as it is cylindrical).
- Does not ensure the alignment of the perpendicularity of the main hole.

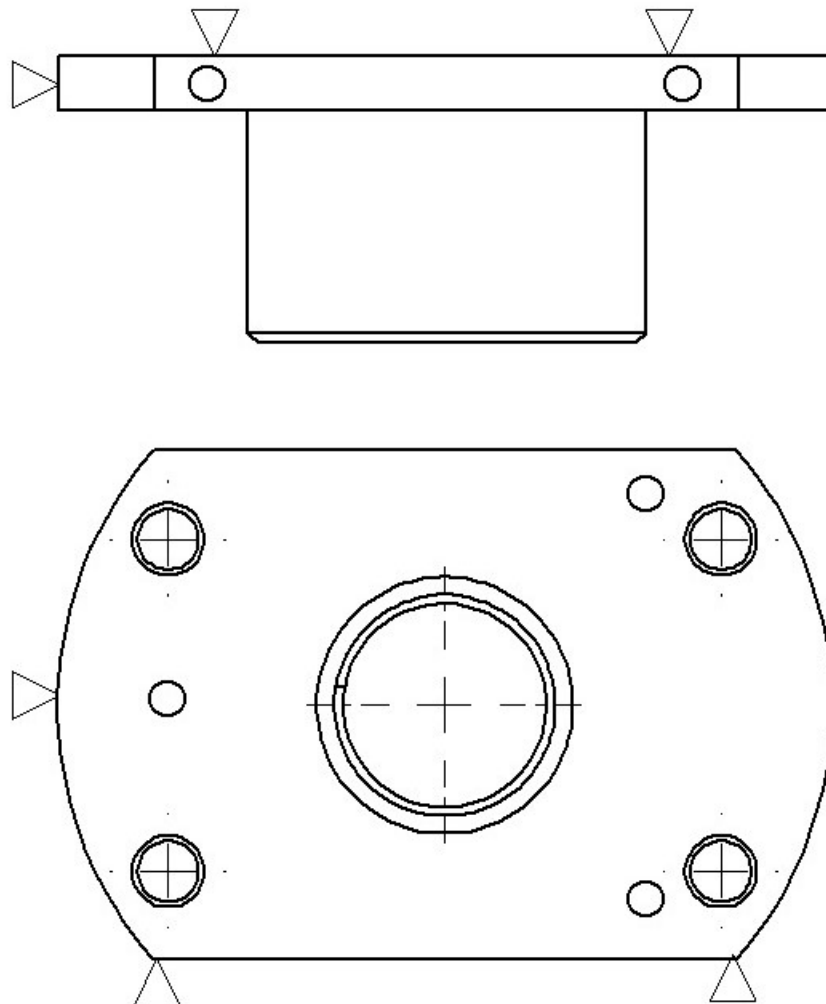


Fig.9.1. Locating scheme for first manufacturing operation MD

The second variant is presented in Fig.9.2.

Advantages:

- Provides perpendicularity of the untreated side plane to a datum surface.
- Uniform allowance for further processing of the hole used for locating.

Disadvantages:

- The correct placement of untreated surfaces relative to the processed ones is not ensured.
- Blocks processing the workpiece from one side.

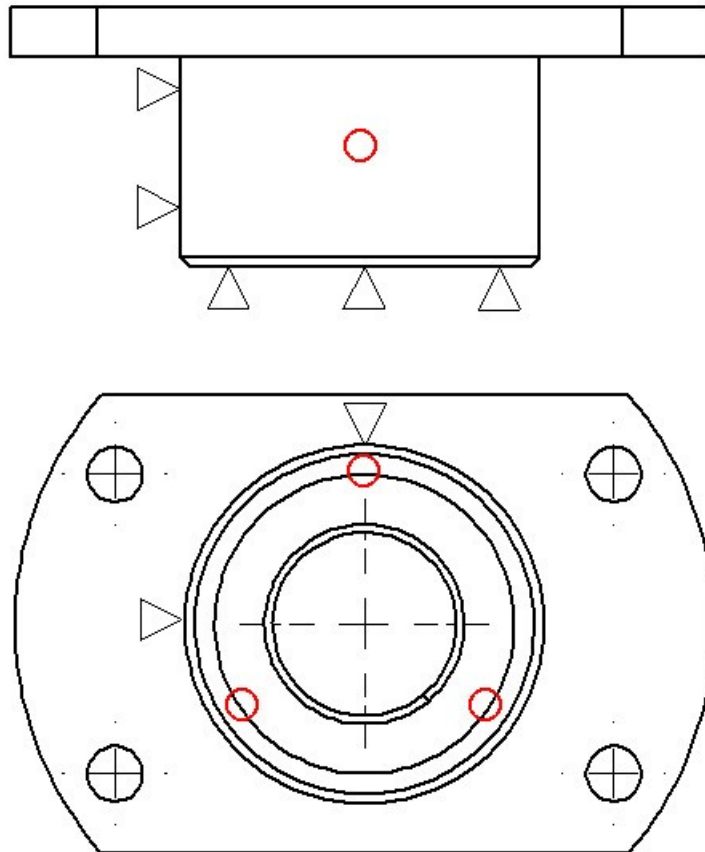


Fig.9.2. Locating scheme for second manufacturing operation MD

Conclusion: The second locating scheme (Fig.9.2) is easy to implement, and provides the correct spatial position of the untreated surfaces relative to the processed surfaces. The given scheme allows processing several additional surfaces besides the general manufacturing datum during the first manufacturing operation. Therefore, we will use the second variant of locating scheme for processing general manufacturing datum.

CHAPTER 3: Design Section

3.1. Design of the typical surfaces processing routes

The design of a part can be broken down into fundamental geometric shapes that work together to achieve the part's overall function. Common elements include cylindrical or conical surfaces (both internal and external), flat planes, and specialized shapes like screw threads or involute gears.

The type of surface directly influences the selection of cutting tools used during machining. Different tools provide varying levels of precision for each surface. Consequently, the machining process involves a specific sequence of operations to achieve the desired final geometry and accuracy for each surface.

This rewrite clarifies the connection between geometric shapes in part design and the corresponding machining processes needed to create them. It also highlights the role of surface type in tool selection and the importance of a defined machining sequence.

The first step in designing a process plan for machining is developing machining routes for individual surfaces. This initial plan focuses on creating a sequence of operations that achieves the desired dimensional accuracy, shape, and quality for each surface on the part. However, this initial plan doesn't consider how precisely these surfaces are positioned relative to each other.

Relative position accuracy refers to how accurately different surfaces are located in relation to one another. This crucial aspect is addressed later in the process planning stage by defining locating schemes. These schemes specify how the part will be positioned and secured during machining. Additionally, the overall machining process is divided into stages: roughing, finishing, and final operations. Each stage uses specific tools and techniques to progressively achieve the desired surface quality.

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.10, selected typical machining sequences as well as achieved accuracy and roughness of working surfaces are given in Table.4. The surfaces classification is given in Fig.11.

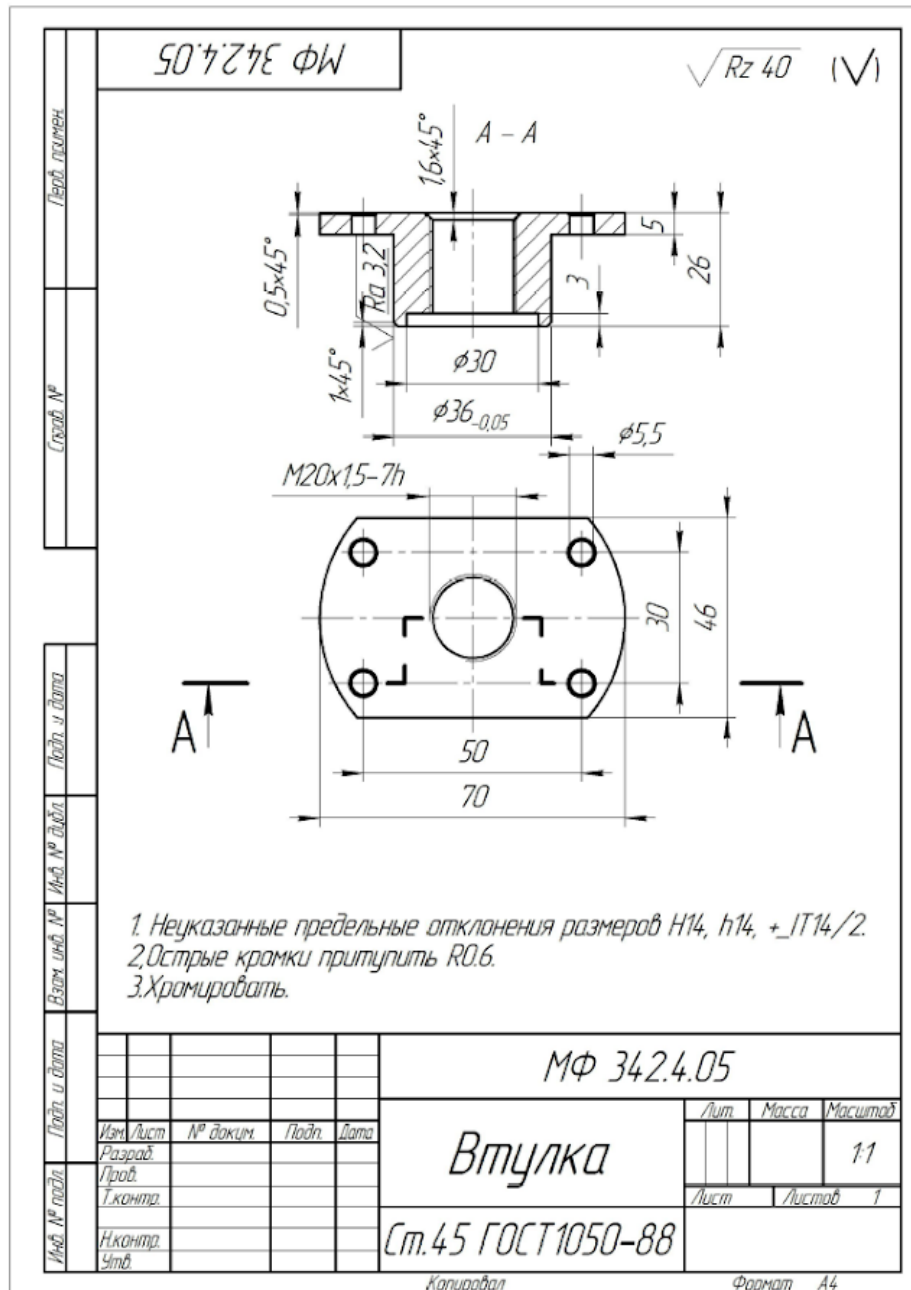


Fig.10. The part "Bushing"

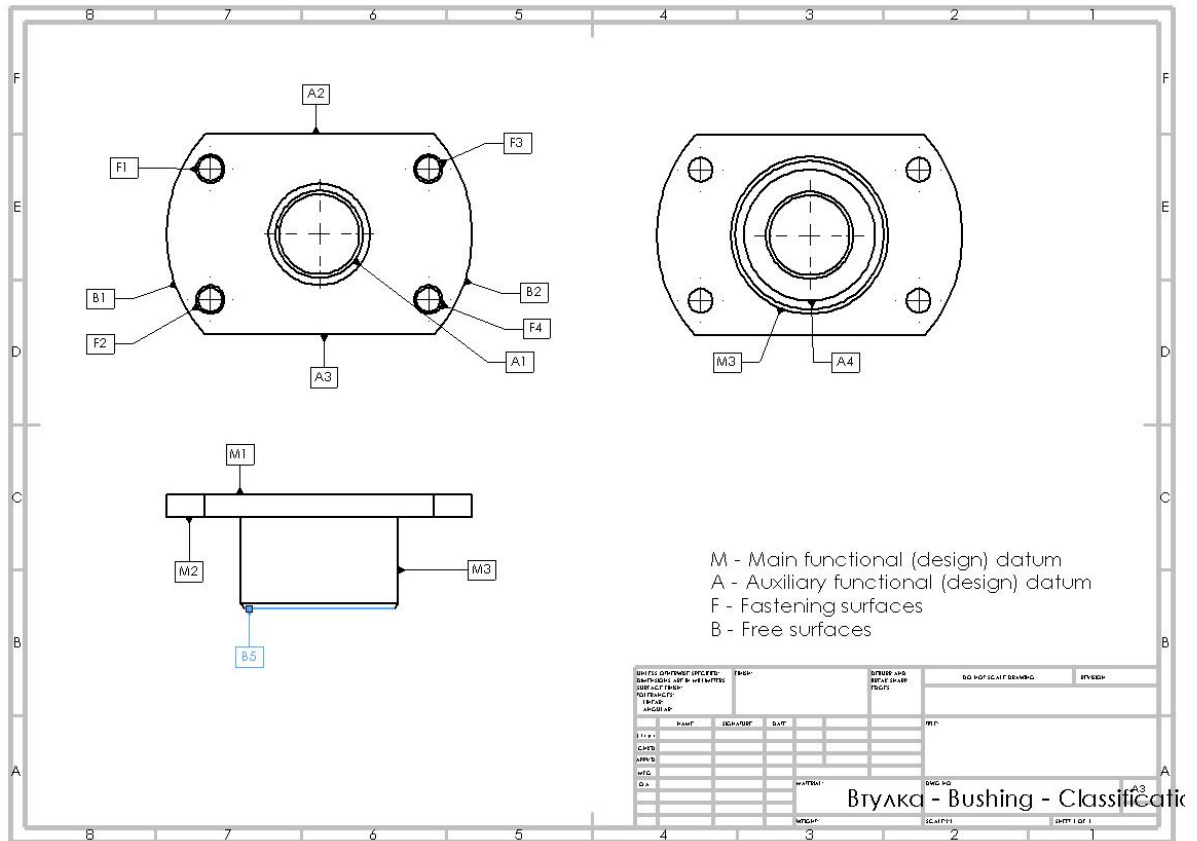


Fig.11. Surfaces Classification

Table.4. Machining Sequences

Surfaces	IT	Ra	Maching sequence	IT	Ra
	According to Drawing			After machinging	
1	2	3	4	5	6
M1	14	-	Rough Milling Finish Milling	14	-
M2	14	-	Rough Milling Finish Milling	14	-
A2	14	-	Rough Milling Finish Milling	14	-
A3	14	-	Rough Milling Finish Milling	14	-
M3	14	3.2	Rough Turn\Milling Finish Turn\Milling	14	6.3 3.2
A1	7h	-	Centering	7h	-

			Boring Reaming Tapping Countersinking		
A4	14	-	Centering Counterboring Reaming	7	-
F1, F2, F3, F4	14	10	Centering Drilling Countersinking	-	10

3.2. Design of the operational manufacturing process plan

We will develop a possible variant of the manufacturing process plan based on: analysis of working conditions and technical requirements to the part, type of production, geometry of the workpiece, and surfaces processing routes, while considering the following recommendations:

- Surfaces that are datums for subsequent stages of processing should be processed first.
- Each subsequent manufacturing step or operation must improve the quality characteristics of the treated surfaces. If not, revisit processing datum surfaces (e.g., after heat treatment).
- Separate roughing from finishing with time or aging, especially for critical, large, or high-value parts.
- Process surfaces early to detect defects where they're not allowed.
- During roughing, prioritize surfaces with the highest allowance and those most critical. Finish critical surfaces last.
- Process surfaces with minimal impact on overall stiffness first.
- Achieve precise relative positioning by processing surfaces in one installation.
- Avoid tool changes during finishing of precise, critical surfaces.
- Process fastening surfaces after finishing related surfaces, typically in the 3rd stage.

005 Multipurpose

Machine:

A. Install, Secure, Remove

Position 1 (Refer to Manufacturing Datum)

005.01 Rough Milling of the Surface M1

005.02 Finish Milling of the Surface M1

005.03 Rough Side Milling of the surfaces A2 and A3

005.04 Finish Side Milling of the surfaces A2 and A3

005.05 Centering of the holes F1, F2, F3 and F4

005.06 Drilling of the holes F1, F2, F3 and F4

005.07 Countersinking of the holes F1, F2, F3 and F4

005.08 Centering of the main hole A1

005.09 Boring of the main hole A1

005.10 Reaming of the main hole A1

005.11 Tapping of the main hole A1

005.12 Countersinking of the main hole A1

Position 2 (Refer to Manufacturing Datum)

005.13 Rough Milling and Turn\Milling of the Surfaces M2 and M3 respectively

005.14 Finish Milling and Turn\Milling of the Surfaces M2 and M3 respectively

005.15 Centering of the hole A4

005.16 Counterboring of the hole A4

005.17 Reaming of the hole A4

3.4. Machine and Tooling Selection

3.4.1. Machine Selection

Machine selection is crucial for efficient, high-quality manufacturing. Each process (turning, milling, etc.) requires specialized machines. For example, turning often uses lathes for workpiece rotation and cutting tool control.

Machine size matters. Machines unable to handle the workpiece dimensions at any stage are usually discounted, with exceptions for limited options.

Power is another factor. Machines lacking the minimum power for cutting are eliminated. However, a machine with significantly higher power might be considered if it offers a crucial high spindle speed for specific operations.

Machine capability analysis ensures the machine can meet quality standards. This includes dimensional/geometric tolerances and desired surface finish, which impacts the final product's functionality.

Batch size is important. Machines that can't handle the production volume efficiently are not ideal. Automated loading/unloading machines might be necessary for high-volume production.

Considering these factors, we can safely denounce that “Haas UMC-500” is more than capable of fulfilling all requirements.

Table.5. Specs sheet of the Haas UMC-500 Machine

Feature	Specification
Machine Type	5-Axis Universal Machining Center
Table	Integrated 400 mm diameter 2-axis trunnion rotary table
Travel (X, Y, Z)	610 x 406 x 406 mm (24" x 16" x 16")
Spindle Taper	40-Taper
Spindle Speed	8,100 rpm (15,000 rpm optional)
Spindle Motor	30 hp Vector Drive
Maximum Tool Diameter (adjacent empty)	127 mm (5.0 in)
Maximum Tool Length (from gage line)	305 mm (12 in)

Maximum Tool Weight	5.4 kg (12 lb)
Chip Conveyor	Belt-type
Coolant	Through-spindle coolant
Control	Haas Next Generation Control
Control Features	Large remote jog handle with touchscreen display, CNC control cabinet cooler, control touchscreen, media display M-Code (M130), HaasConnect (remote monitoring), early power-failure detection module, Ethernet interface, WiFi connection for the Haas Control, Safe Run, rigid tapping, dynamic work offsets and tool center point control, standard program memory (1 GB), second home position, internal high-voltage isolated transformer, power surge protection, broken tool detection
Weight	4,536 kg (10,000 lb)
Dimensions (L x W x H)	3.05 x 2.08 x 2.44 m (10' x 6.8' x 8') (approx.)



Fig.12. The CNC Machine Haas UMC-500

3.4.2. Tooling Selection and Cutting Conditions

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 out 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 steps

005.03 Rough Side Milling of the surfaces A2 and A3

005.04 Finish Side Milling of the surfaces A2 and A3

Allowance = 2.6

Radial Cut width = 10

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

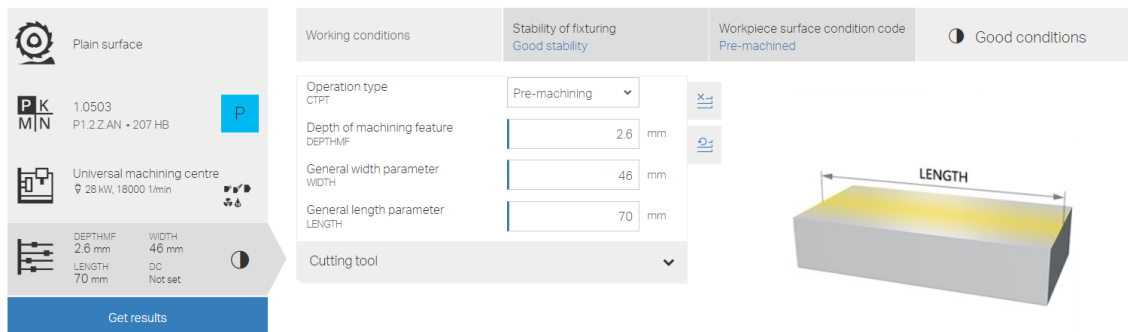


Fig.13. Initial Data

After applying the initial data, consider the results of analysis: recommended cutting tool and cutting conditions

PLAIN SURFACE

FACE MILLING / INDEXABLE

CUTTING DATA

VC [m/min]
CUTTING SPEED
1 301

FZ [mm]
FEED PER TOOTH
0.8

N [1/min]
SPINDLE SPEED
1390

VFM [mm/min]
FEED SPEED AT MACHINED DIAMETER
1 6670

AE [mm]
WORKING ENGAGEMENT
46

AP [mm]
DEPTH OF CUT
1.3

NOPAE [NOPae]
NUMBER OF PASSES IN AE DIRECTION
1

NOPAP [NOPap]
NUMBER OF PASSES IN AP DIRECTION
2

PPC [kW]
CUTTING POWER
16.7

MMC [Nm]
CUTTING TORQUE
115

HEX [mm]
MAXIMUM CHIP THICKNESS
0.26

QQ [cm³/min]
MATERIAL REMOVAL RATE
399

Fig.14. Recommended Cutting Tool and Cutting Data

3.5. Machining Simulation

In this section, I'll detail the computer-aided machining (CAM) simulation I performed using Fusion 360 software to validate the machining plan for the part "Bushing". This plan, outlined in the "Design of the operational manufacturing process plan" section, defines the sequence of operations for creating the bushing.

3.5.1. Simulation Purpose

The CAM simulation aims to virtually replicate the entire machining process, based on the established plan. This allows me to:

Verify Toolpaths: Visually analyze the tool movement for each operation, ensuring there are no collisions between the tool and the workpiece or other tools.

Estimate Machining Times: Obtain estimations for the machining time required for each operation, aiding in production planning and scheduling.

Identify Optimization Opportunities: Analyze the simulation to potentially identify areas where the process can be optimized for increased efficiency.

3.5.1. Simulation Setup

I utilized Fusion 360's CAM module to create the virtual simulation. This involved:

Importing the Bushing Model: The digital model of the bushing, designed earlier in the project, was imported into the CAM software.

Tool Selection: Appropriate cutting tools were selected based on the operation type (milling, drilling, etc.) and the desired surface finish requirements defined in the manufacturing process plan.

3.5.2. Simulation Results and Documentation

The CAM simulation will generate detailed results for each machining step. These include:

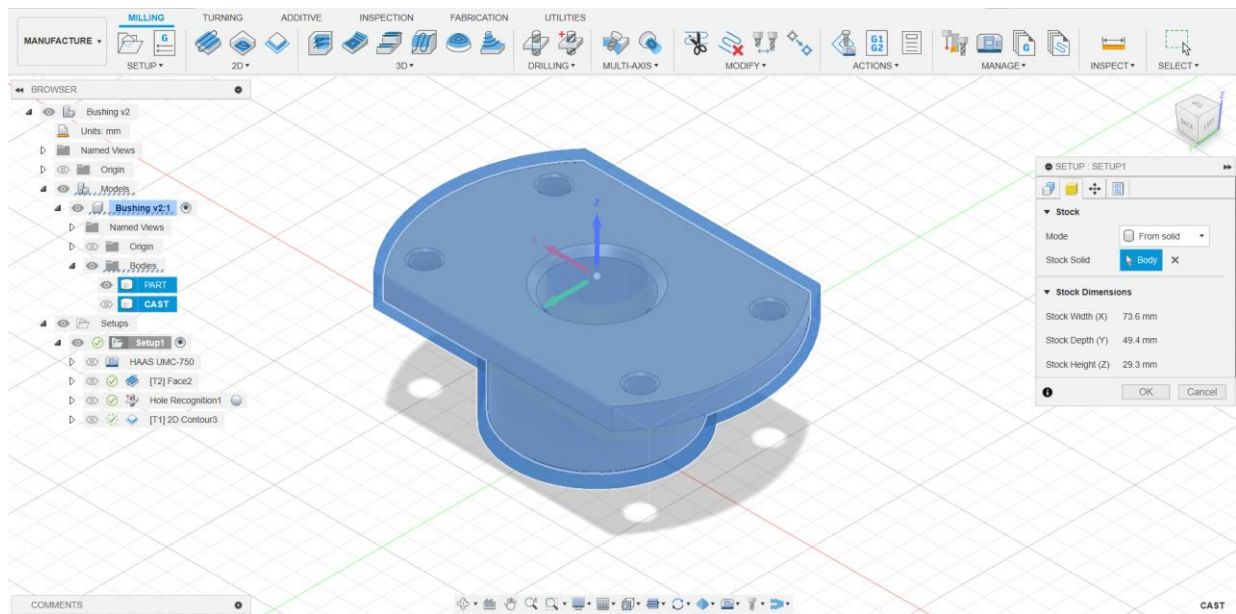
Visualizations: Screenshots capturing the toolpath for each operation will be included in this section, clearly labeled with the corresponding operation number (e.g., 005.01 Rough Milling of Surface M1). These visualizations will allow for a

clear understanding of the tool movements and potential interactions with the workpiece.

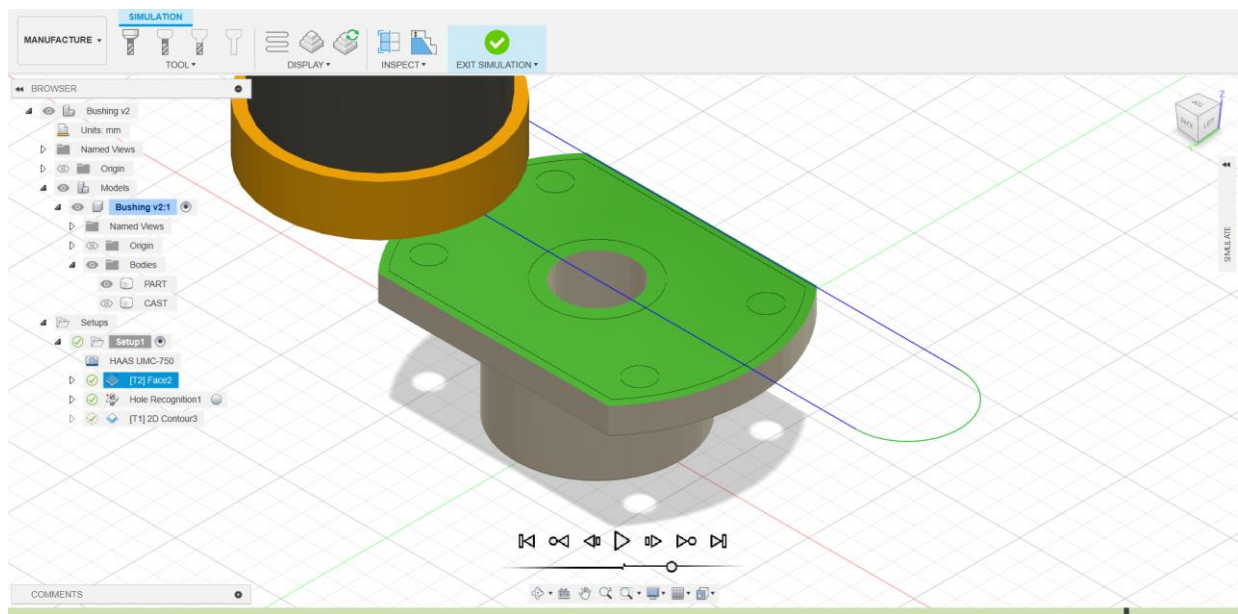
G-code Generation: The simulation will generate G-code, which is a set of coded instructions for the CNC machine to follow during the actual machining process. This G-code will be attached to the project documentation in the "Annexes" section for reference and potential customization.

3.5.2.1. Visualizations

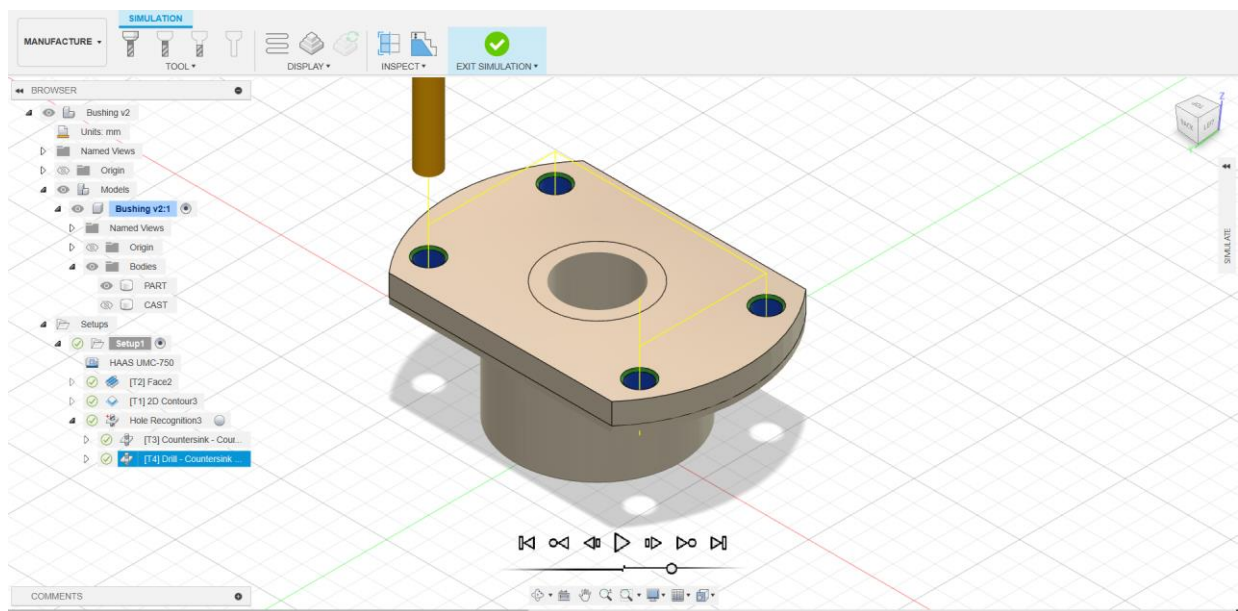
1. Setup of the First position



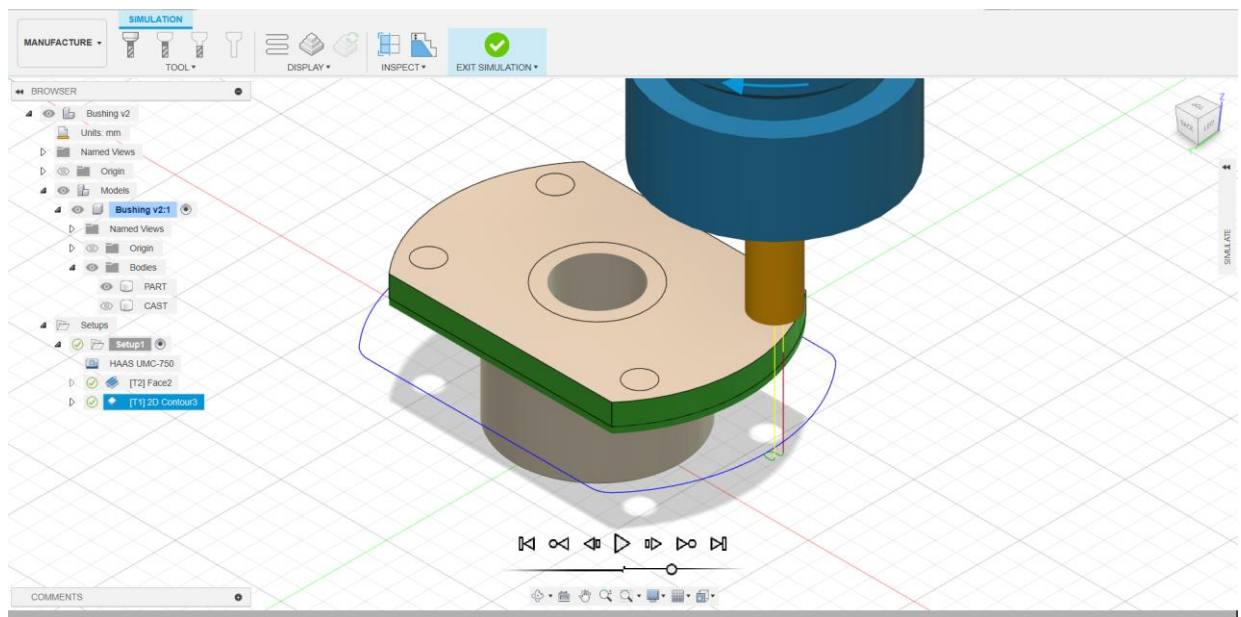
2. Face Milling M1 "005.01"



3. Drilling and Countersinking F1, F2, F3 and F4 “005.05 – 005.07”

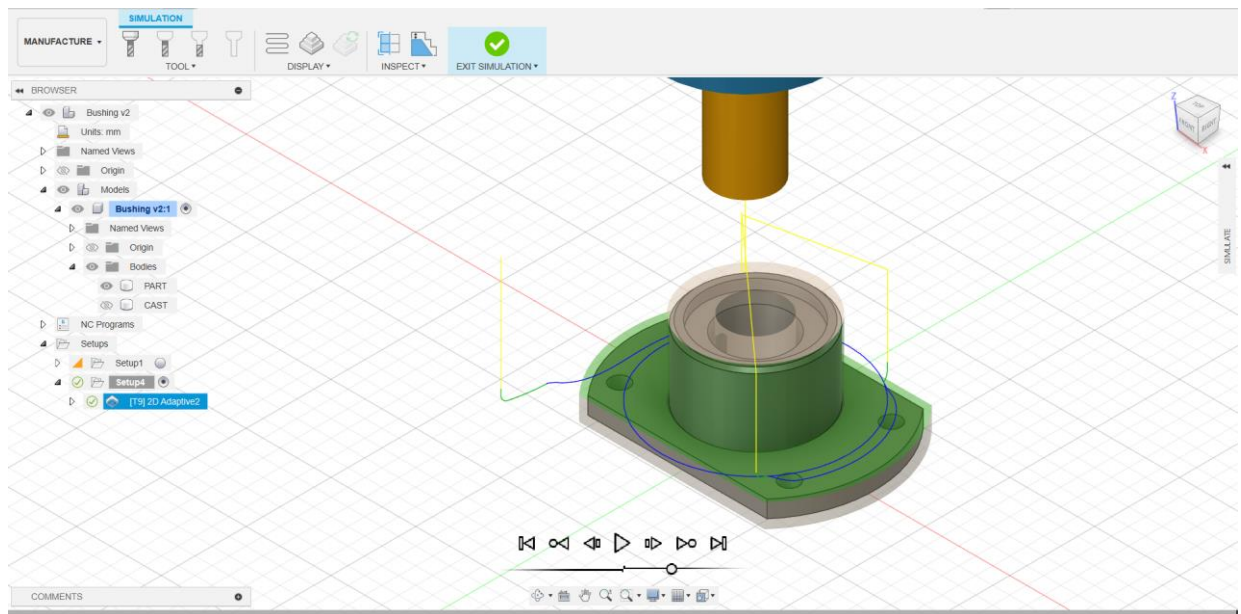


4. Contour Milling A2 and A3 “005.03”

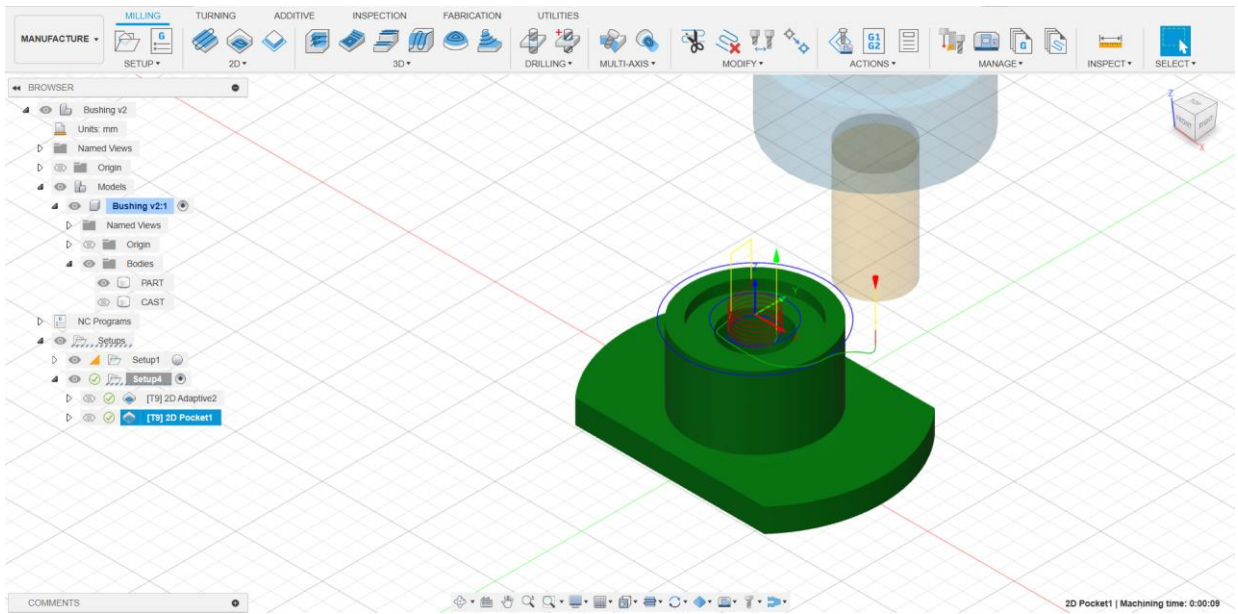


5. Reaming and Countersinking Hole A1 “005.10 & 005.12”

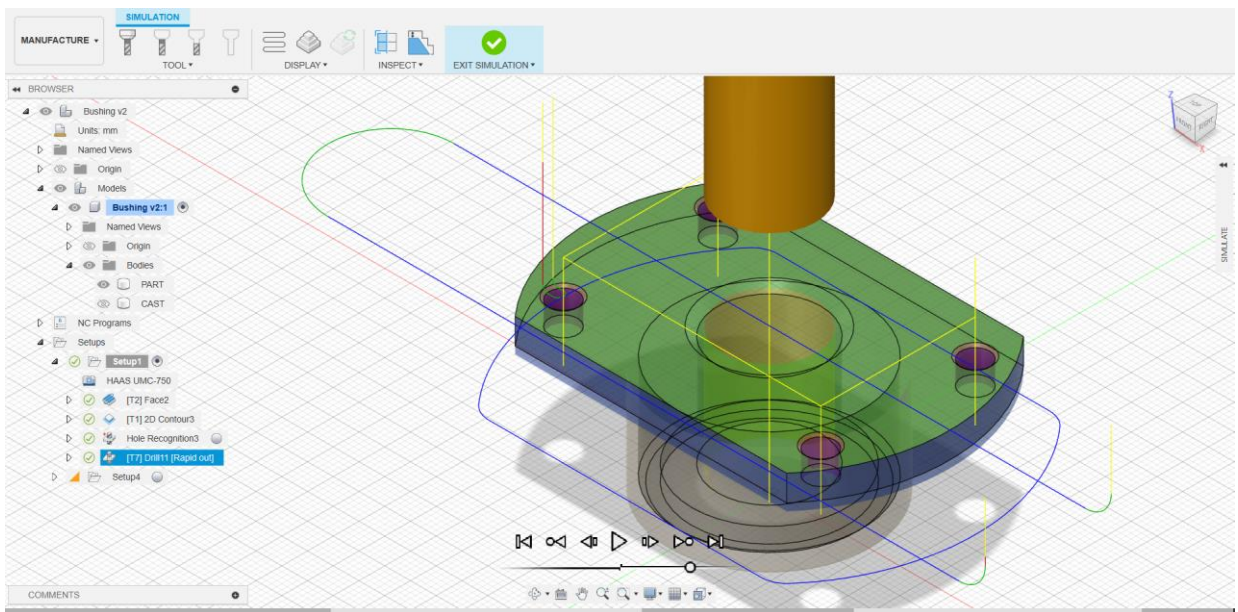
6. Milling M2 and M3 “005.13 – 005.14”



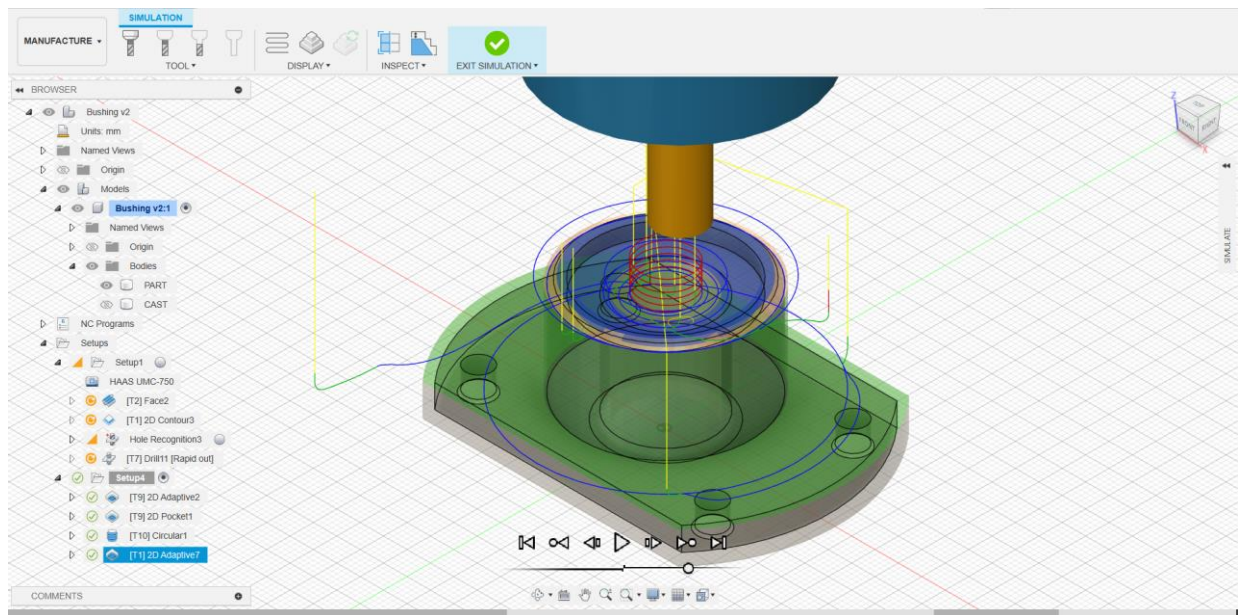
7. Counterboring and Reaming hole A4 “005.15 – 005.17”



3.5.2.2. First Position Toolpaths



3.5.3.3. Second Position Toolpaths



CHAPTER 4: Fixture Design

4.1. Purpose of the Fixture

This project focuses on designing a fixture for the machining of a carbon steel 45 bushing, which features a large central hole and small corner holes. The primary goal of this fixture is to ensure the precise and repeatable machining of this part, maintaining high levels of dimensional accuracy and alignment. The customized fixture design aims to improve the manufacturing process by enhancing productivity and ensuring the quality of the machined parts.

The purpose of this report is to detail the design process and specifications of the fixture, targeting the machining requirements of a part with complex features. It provides a comprehensive overview of the fixture design, including conceptualization, engineering drawings, and manufacturing considerations. This document is intended as a reference, offering necessary information to support the evaluation, approval, and implementation phases of the project.

4.2. Possible Fixture designs and solutions

The manufacturing process of the carbon steel 45 bushing necessitates two distinct positions in the machining sequence, each chosen based on the specific requirements of the locating datum. To accommodate these requirements, two different fixture designs have been identified as optimal solutions for the sequential operations.

1. Table Vise for First Manufacturing Operations:

The initial stage of machining calls for the use of a table vise. This fixture is selected for its capability to securely hold the bushing part in place, providing the necessary support and stability for precision machining of the large central hole and preliminary shaping. The design and functionality of the table vise are tailored to ensure accessibility and accuracy during these critical first operations.

2. Table Chuck for Second Manufacturing Operations:

Following the initial machining steps, the manufacturing process transitions to operations that require a different fixture setup. A table chuck is chosen for these subsequent operations due to its ability to offer precise positioning and enhanced grip for machining the small corner holes and completing the final contours of the bushing. The table chuck's design facilitates accurate

alignment and rotation capabilities, crucial for the detailed machining tasks in this phase.

Detailed drawings and images of these fixture designs will be provided in the following figures, illustrating their specific applications in the machining sequence of the bushing part. Each fixture has been carefully selected to optimize the manufacturing process, ensuring that each operation is conducted with the highest level of precision and efficiency.

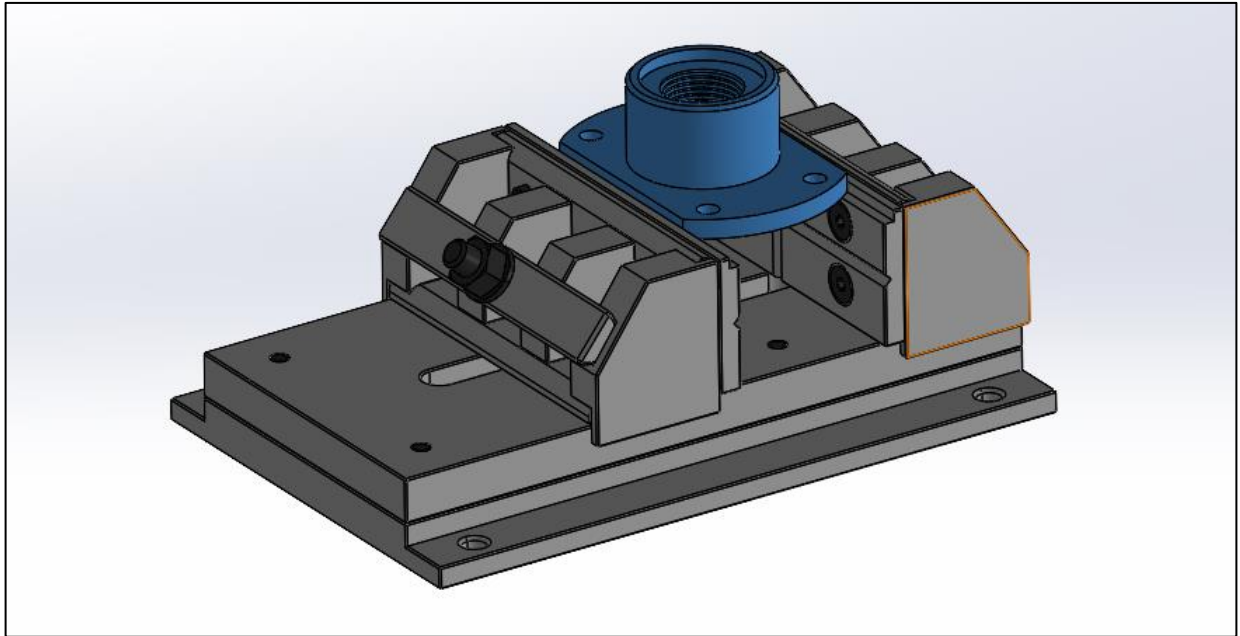


Fig.19. Vise 3D

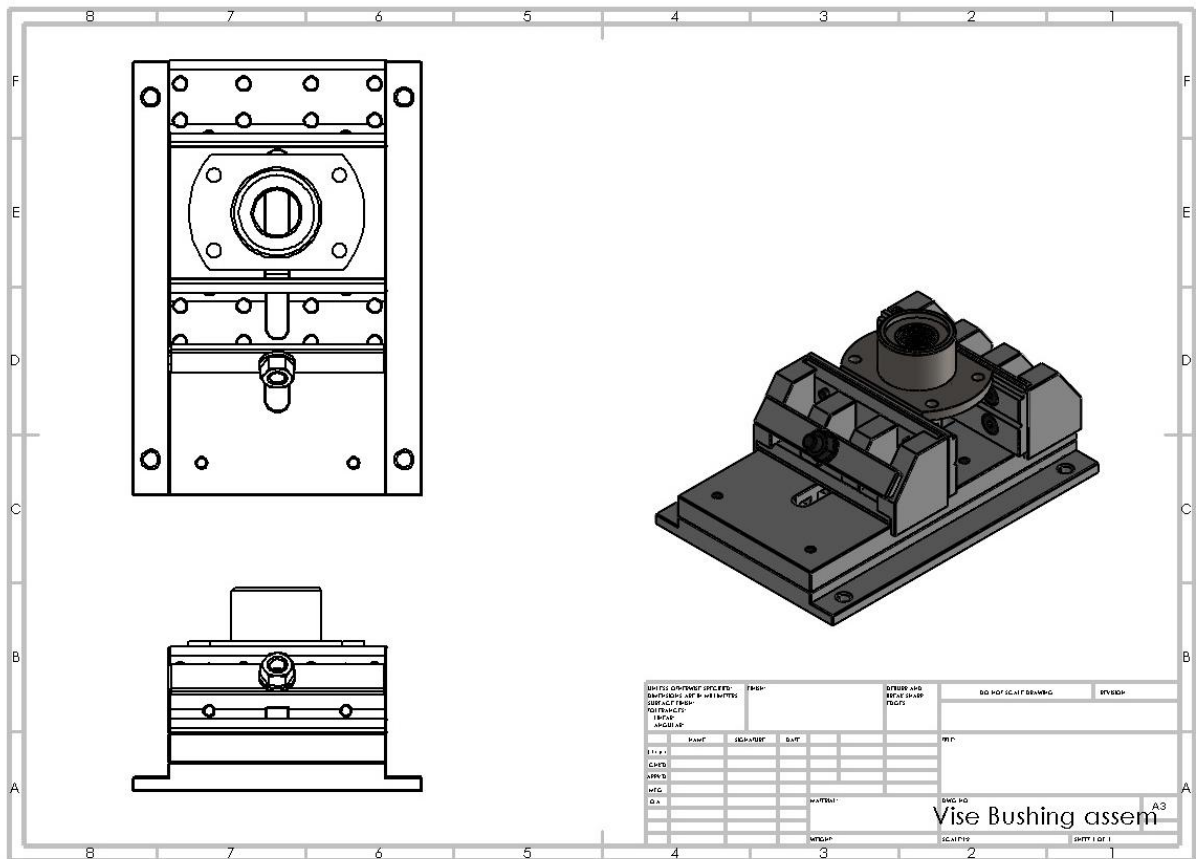


Fig.20. Drawing of the Vise

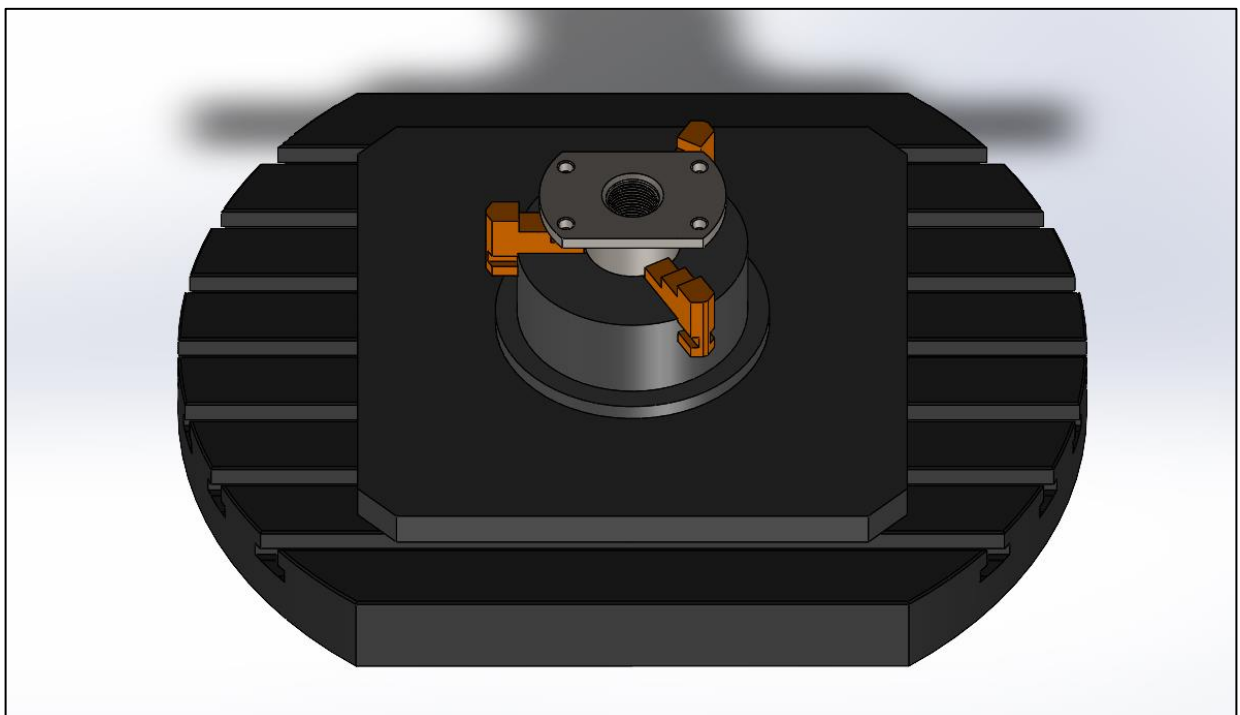


Fig.21. Table Chuck 3D

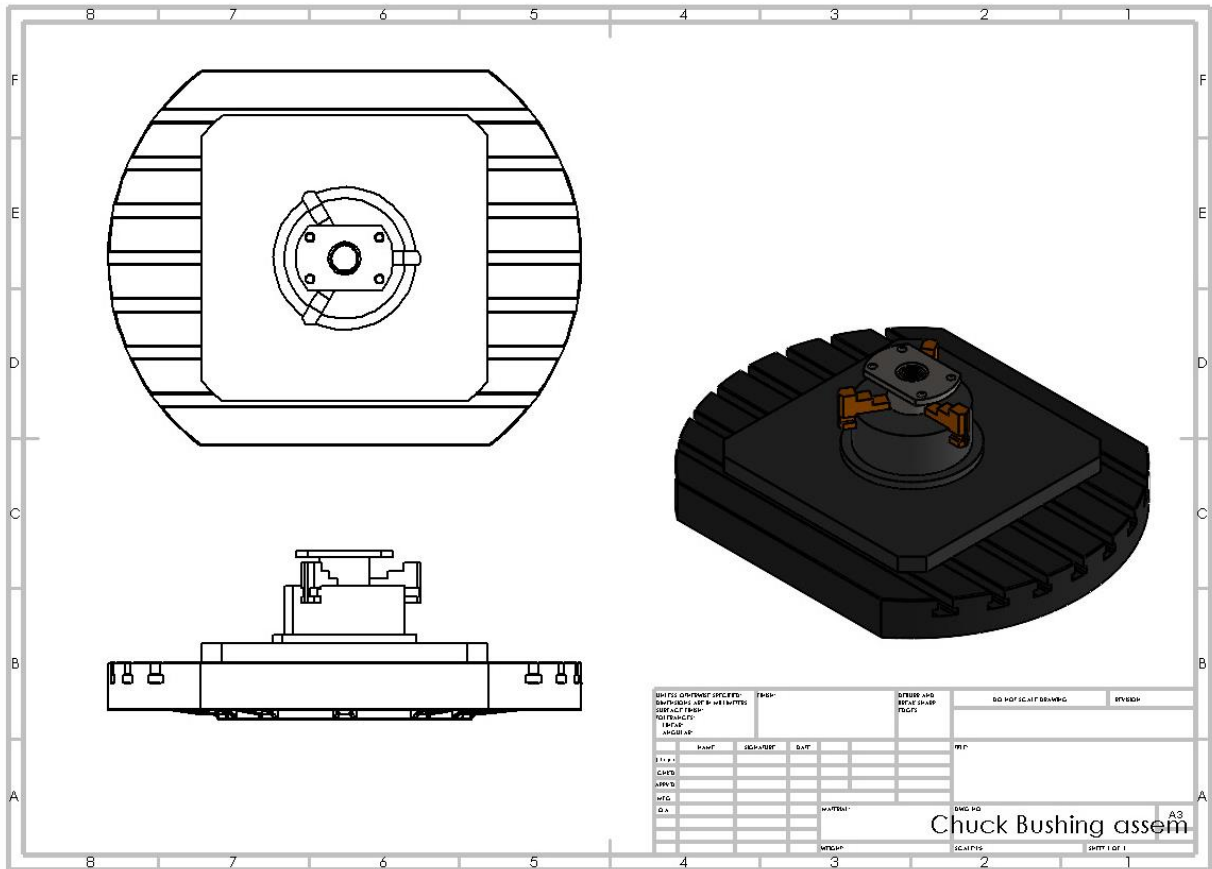


Fig.22. Drawing of the Table Chuck

4.3. Clamping Force calculation

4.3.1. Vise Fixture

Calculating the clamping force is essential for machining operations because theoretical projections often fall short in accounting for real-world variables, such as material inconsistencies and machining dynamics. These calculations ensure that the fixture applies sufficient force to hold the workpiece securely without causing deformation. To achieve accurate and practical results, we employ the method detailed below, which considers the actual cutting forces, the coefficient of friction between the workpiece and the fixture, and other operational parameters.

To calculate the necessary clamping force for a fixture, use the equation below:

$$\text{Clamping Force} = \frac{\text{Cutting Force}}{\text{Coefficient of Friction}}$$

To determine the cutting force, apply:

$$\text{Cutting Force} = \frac{4.5 \times k \times f \times d \times b}{\text{Cutting Speed}}$$

Where:

- k: for the material constant
- f: the feed rate
- d: the depth of the cut
- b: the width of the cut

The cutting speed can be calculated using:

$$\text{Cutting Speed} = \frac{\pi \times \text{Tool diameter} \times \text{Spindle speed}}{60,000}$$

For an example, assuming a cutting speed of 0.942 (units will vary based on input parameters) and plugging in the values into the cutting force formula yields:

$$\text{Cutting Force} = \frac{4.5 \times k \times f \times d \times b}{\text{Cutting Speed}}$$

After calculating the cutting force, divide this by the coefficient of friction (assumed here to be 0.3) to find the clamping force. Consequently:

$$\text{Cutting Force} = \frac{4.5 \times k \times f \times d \times b}{\text{Cutting Speed}}$$

Given a cutting force of 4299.36 N in our example, the resulting clamping force would be 14331.2 N

4.3.2. Chuck Fixture

Understanding the necessary clamping force for chuck fixtures is critical in machining operations, as it directly influences the stability and precision of the workpiece during machining. While theoretical projections provide a baseline, real-world variables like material variations and operational conditions necessitate precise calculations. These ensure that the chuck applies adequate force to securely grip the workpiece without risking deformation or slippage. By employing the method outlined below, which accounts for factors such as workpiece material strength, chucking efficiency, and workpiece dimensions, we can determine the optimal clamping force required for successful machining.

In order to calculate the necessary Clamping force for the chuck, we use the following Formula:

$$\text{Clamping Force} = \frac{\text{Chucking Pressure}}{\text{Effective Gripping Diameter}}$$

To determine the Chucking pressure, we use:

$$\text{Chucking Pressure} = \frac{(WMS \times FoS)}{\text{Chucking Efficiency}}$$

To determine Effective Gripping Diameter, we use:

$$\begin{aligned} \text{Effective Gripping Diameter} \\ = \frac{(\text{Workpiece Diameter} - \text{Chuck Jaw Depth})}{2} \end{aligned}$$

Where;

- WMS – Workpiece Material Strength: The maximum allowable stress the workpiece material can withstand.
- FoS – Factor of Safety: A multiplier to ensure the clamping force is sufficient for the application.
- Chucking Efficiency: The efficiency of the chucking system, often assumed to be around 0.7 to 0.9.
- Chuck Jaw Depth: The depth to which the chuck jaws penetrate into the workpiece material.

Based the aforementioned data of our Workpiece, as well as assuming a Factor of Safety of 1.5 and Chucking Efficiency of 0.8, we can safely calculate the Clamping Force as follows:

$$\text{Clamping Force} = \frac{\text{Chucking Pressure}}{\text{Effective Gripping Diameter}} = \frac{570\text{MPa} \times 1.5 / 0.8}{(36\text{mm} - 15\text{mm}) / 2}$$

The Clamping force will total to the amount of: 11222.81 N

CHAPTER 5: Economical Section

5.1. Cost Estimation

In order to estimate the casting cost, we could utilize an online application called “Cost Estimator” that can be found through [“https://www.custompartnet.com/”](https://www.custompartnet.com/).

The one disadvantage of this tool, is that it requires various calculations and detailed measurements that we simply can not having without actually having this part on hand for visual study. In addition to that, all Units on this tool are imperial, therefore conversions to Metric units have been done to adjust to this obstacle, below are the final Cost estimations.

The screenshot shows the 'Sand Casting' section of the 'Cost Estimator' application. It includes a 'Part Information' section with input fields for Quantity (5000), Material (Aluminum C443.0, Casting), Envelope X-Y-Z dimensions (3.93 x 2.36 x 1.37), Projected area (2.319 in² or 25% of envelope), Volume (1.630 in³ or 12.83% of envelope), and Feature count (< 10 features). Below this is a 'Cores' table with one core (A) having a quantity of 1, length of 1.10, and width of 0.6. The 'Process Parameters' section is currently empty. The 'Cost' section shows a total cost of \$7,115 (\$1.423 per part), broken down into Material (\$1,740), Production (\$4,209), and Tooling (\$1,166).

Core	Quantity per part	Length (in)	Width (in)	Proj. area (in²)	Volume (in³)	Feature count
A	1	1.10	0.6			< 10 features

Material:	\$1,740 (\$0.348 per part)
Production:	\$4,209 (\$0.842 per part)
Tooling:	\$1,166 (\$0.233 per part)
Total:	\$7,115 (\$1.423 per part)

Fig.15. Sand Casting Cost Estimation

 **Stock Information**

Part quantity:

Defect rate (%):

Run quantity: 5155


Material: Steel - Medium carbon: 1040

Workpiece:

LxWxH (in): x x

Weight (lb):

Fig.16. Stock Information for Machining cost estimation

 **Cost**

Material: \$0 (\$0.000 per part)

Production: \$42,284 (\$8.457 per part)

Tooling: \$500 (\$0.100 per part)

Total: **\$42,784 (\$8.557 per part)**

[Feedback/Report a bug](#)

Fig.17. Cost Estimation for Machining Sequences

Overall, the tally cost of producing 5000 parts will be the sum of sand-casting costs and machining costs, as following:

$$C_T = C_c + C_m = 7,115 + 42,784 = \$49,899$$

C_T : Total Cost ; C_c : Cost of Casting ; C_m : Cost of Machining

Which accords to roughly: ~\$9.97 per part.

5.2. Time Estimation

After simulating and estimating the cost of the Machining, we come up with a rough Time estimation per part, as illustrated below.

Due to Difficulties estimating Casting time we will leave that for a foundry to give us a quote, which can be done at a later date.

Production

Machine type:

Machine:

Idle operation
Face milling
Drilling
Reaming
Tapping
Chamfer milling
Idle operation
Counterboring
Chamfer milling

Operation:

Type:

Time (min):

Totals: Cut time (min): 6.65 Idle time (min): 2.55 Cycle time (min): 9.20

Fig.18. Time Estimation

The Time estimation for Machining per part will amount to the following:

The Cut Time for a total of 6.65 min

The Idle Tie for a total of 2.55 min

Therefore, the Cycle Time will be 9.20 min.

REFERENCES

- Custompartnet : <https://www.custompartnet.com>
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ANNEX

POST PROCESS “G CODE”

In this annex, I have included the complete G code sequences necessary for the manufacturing of the "Bushing" workpiece. Each sequence corresponds to a specific operation in the manufacturing process. To make the best use of space while maintaining readability, I have formatted the G code in a three-column layout on each page, using a smaller font. This format allows for easy reference and does not unnecessarily extend the length of the document. The G code for each operation is presented consecutively, detailing the precise steps to be followed during production.

G CODE

%	(Face2)	N90 G0 Z5.
O00005	N25 T2 M6	N95 G1 Z3.4 F333.33
(Using high feed G1 F650. instead of G0.)	N30 S5000 M3	N100 G18 G3 X61.31 Z-1.6 I-5. K0. F1000.
(Machine)	N35 G17 G90 G94	N105 G1 X-61.31
(vendor: HAAS)	N40 G54	N110 G17 G2 Y0.1 I0. J12.238
(model: UMC-750)	N45 G53 G0 X-736.6 Y-203.2	N115 G1 X61.31
(description: Haas UMC-750 Classic legacy design)	N50 M11	N120 G18 G2 X66.31 Z3.4 I0. K5.
(T2 D=50. CR=0. - ZMIN=-1.6 - face mill)	N55 M13	N60 G0 B0. C0.
N10 G90 G94 G17	N65 M10	N125 G0 Z15.
N15 G21	N70 M12	N130 M5
N20 G53 G0 Z0.	N75 M8	N135 M9
	N80 G1 X66.31 Y- 24.375 F650.	N140 G53 G0 Z0.
	N85 G0 G43 Z15. H2	N145 G53 G0 X-736.6 Y-203.2

N150 M11	N35 G17 G90 G94	N135 G2 X30.151 Y26.286 I0. J-5.
N155 M13	N40 G54	N140 Y-26.286 I- 30.151 J-26.286
N160 G0 B0. C0.	N45 G53 G0 X-736.6 Y-203.2	N145 X26.382 Y-28. I-3.769 J3.286
N165 M30	N50 M11	N150 G1 X-26.382
%	N55 M13	N155 G2 X-30.151 Y- 26.286 I0. J5.
%	N60 G0 B0. C0.	N160 X-40. Y0. I30.151 J26.286
O00010	N65 M10	N165 G3 X-41. Y1. I- 1. J0.
(Using high feed G1 F650. instead of G0.)	N70 M12	N170 G1 X-42.
(Machine)	N75 M8	N175 G18 G3 X-43. Z-15.6 I0. K1.
(vendor: HAAS)	N80 G1 X-43. Y-1. F650.	N180 G0 Z15.
(model: UMC-750)	N85 G0 G43 Z15. H1	N185 M5
(description: Haas UMC-750 Classic legacy design)	N90 G0 Z5.	N190 M9
(T1 D=10. CR=0. - ZMIN=-16.6 - flat end mill)	N95 G1 Z1. F540.06	N195 G53 G0 Z0.
N10 G90 G94 G17	N100 Z-15.6	N200 G53 G0 X-736.6 Y-203.2
N15 G21	N105 G18 G2 X-42. Z-16.6 I1. K0. F1620.19	N205 M11
N20 G53 G0 Z0.	N110 G1 X-41.	N210 M13
(2D Contour3)	N115 G17 G3 X-40. Y0. I0. J1.	N215 G0 B0. C0.
N25 T1 M6	N120 G2 X-30.151 Y26.286 I40. J0.	N220 M30
N30 S4851 M3	N125 X-26.382 Y28. I3.769 J-3.286	
	N130 G1 X26.382	

	N40 G54	(Drill - Countersink Drill)
%	N45 G53 G0 X-736.6	
%	Y-203.2	N145 M1
O00015	N50 M11	N150 T4 M6
(Using high feed G1	N55 M13	N155 S5000 M3
F650. instead of G0.)	N60 G0 B0. C0.	N160 G17 G90 G94
(Machine)	N65 M10	N165 G54
(vendor: HAAS)	N70 M12	N170 G53 G0 X-736.6
(model: UMC-750)	N75 M8	Y-203.2
(description: Haas	N80 G1 X-25. Y15.	N175 M11
UMC-750 Classic	F650.	N180 M13
legacy design)	N85 G0 G43 Z15. H3	N185 G0 B0. C0.
(T3 D=7.938 CR=0.	N90 T4	N190 M10
TAPER=90deg -	N95 G0 Z5.	N195 M12
ZMIN=-4.85 - spot	N100 G98 G81 X-25.	N200 M8
drill)	Y15. Z-4.85 R3.4	N205 G1 X-25. Y15.
(T4 D=5.5 CR=0.	F333.33	F650.
TAPER=118deg -	N105 Y-15.	N210 G0 G43 Z15. H4
ZMIN=-13.252 - drill)	N110 X25.	N215 T3
N10 G90 G94 G17	N115 Y15.	N220 G0 Z5.
N15 G21	N120 G80	N225 G98 G73 X-25.
N20 G53 G0 Z0.	N125 G0 Z15.	Y15. Z-13.252 R3.4
(Countersink -	N130 M9	Q1.375 F1000.
Countersink Drill)	N135 M5	N230 Y-15.
N25 T3 M6	N140 G53 G0 Z0.	N235 X25.
N30 S5000 M3		N240 Y15.
N35 G17 G90 G94		

N245 G80	N10 G90 G94 G17	N110 M5
N250 G0 Z15.	N15 G21	N115 M9
	N20 G53 G0 Z0.	N120 G53 G0 Z0.
N255 M5		N125 G53 G0 X-736.6 Y-203.2
N260 M9	(Drill11)	N130 M11
N265 G53 G0 Z0.	N25 T7 M6	N135 M13
N270 G53 G0 X-736.6 Y-203.2	N30 S1617 M3	N140 G0 B0. C0.
N275 M11	N35 G17 G90 G94	N145 M30
N280 M13	N40 G54	
N285 G0 B0. C0.	N45 G53 G0 X-736.6 Y-203.2	%
N290 M30	N50 M11	%
	N55 M13	O00030
%	N60 G0 B0. C0.	(Using high feed G1 F650. instead of G0.)
%	N65 M10	(T9 D=18. CR=0. - ZMIN=-22.2 - flat end mill)
O00020	N70 M12	N10 G90 G94 G17
(Using high feed G1 F650. instead of G0.)	N75 M8	N15 G21
(Machine)	N80 G1 X0. Y0. F650.	N20 G53 G0 Z0.
(vendor: HAAS)	N85 G0 G43 Z15. H7	
(model: UMC-750)	N90 G0 Z5.	
(description: Haas UMC-750 Classic legacy design)	N95 G98 G81 X0. Y0. Z-31.2 R1.8 F436.59	(2D Adaptive2)
(T7 D=18. CR=0. TAPER=118deg - ZMIN=-31.2 - drill)	N100 G80	N25 T9 M6
	N105 G0 Z15.	N30 S6930 M3
		N35 G17 G90 G94

N40 G54	N125 X-36.644 Y- 37.323 Z-21.93	N200 X-32.935 Y- 24.016
N45 M8		
N50 G1 X-36.856 Y- 38.149 F650.	N130 X-36.608 Y- 37.182 Z-22.011	N205 X-32.83 Y- 23.908
N55 G0 G43 Z15. H9	N135 X-36.571 Y- 37.035 Z-22.078	N210 X-32.728 Y- 23.799
N60 G0 Z5.	N140 X-36.531 Y- 36.882 Z-22.131	N215 X-32.628 Y- 23.687
N65 Z-18.6		
N70 G1 Z-20.4 F3200.29	N145 X-36.491 Y- 36.726 Z-22.169	N220 X-32.529 Y- 23.574
N75 X-36.854 Y- 38.141 Z-20.566	N150 X-36.45 Y- 36.566 Z-22.192	N225 X-32.433 Y- 23.459
N80 X-36.848 Y- 38.119 Z-20.731	N155 X-36.409 Y- 36.405 Z-22.2	N230 X-32.339 Y- 23.342
N85 X-36.839 Y- 38.082 Z-20.893	N160 G3 X-35. Y- 26.606 I-44.516 J11.403	N235 X-32.247 Y- 23.223
N90 X-36.826 Y- 38.031 Z-21.05	N165 G1 Y-26.408	N240 X-32.157 Y- 23.103
N95 X-36.809 Y- 37.966 Z-21.202	N170 X-34.957 Y- 26.215	N245 X-32.069 Y- 22.982
N100 X-36.789 Y- 37.888 Z-21.348	N175 X-34.873 Y- 26.037	N250 X-31.977 Y- 22.851
N105 X-36.766 Y- 37.797 Z-21.485	N180 X-33.903 Y- 24.788	N255 X-31.883 Y- 22.711
N110 X-36.739 Y- 37.694 Z-21.613	N185 X-33.261 Y- 24.326	N260 X-31.789 Y- 22.567
N115 X-36.71 Y-37.58 Z-21.73	N190 X-33.15 Y- 24.225	N265 X-31.696 Y- 22.42
N120 X-36.678 Y- 37.456 Z-21.836	N195 X-33.041 Y- 24.121	N270 X-31.604 Y- 22.268

N275 X-31.513 Y- 22.112	N350 X-30.302 Y- 19.204	N425 X-29.491 Y- 13.482
N280 X-31.422 Y- 21.952	N355 X-30.233 Y- 18.955	N430 X-29.47 Y- 12.757
N285 X-31.333 Y- 21.787	N360 X-30.158 Y- 18.669	N435 X-29.46 Y- 11.968
N290 X-31.245 Y- 21.618	N365 X-30.086 Y- 18.374	N440 X-29.463 Y- 11.102
N295 X-31.158 Y- 21.445	N370 X-30.017 Y- 18.069	N445 X-29.494 Y- 9.521
N300 X-31.072 Y- 21.267	N375 X-29.951 Y- 17.755	N450 X-29.541 Y-7.94
N305 X-30.988 Y- 21.084	N380 X-29.889 Y- 17.429	N455 X-29.596 Y- 6.359
N310 X-30.905 Y- 20.896	N385 X-29.829 Y- 17.092	N460 X-29.637 Y- 4.779
N315 X-30.823 Y- 20.704	N390 X-29.774 Y- 16.743	N465 X-29.65 Y-3.197
N320 X-30.743 Y- 20.506	N395 X-29.722 Y- 16.381	N470 X-29.628 Y- 1.616
N325 X-30.665 Y- 20.303	N400 X-29.674 Y- 16.005	N475 X-29.553 Y- 0.036
N330 X-30.588 Y- 20.095	N405 X-29.631 Y- 15.614	N480 X-29.425 Y1.54
N335 X-30.514 Y- 19.881	N410 X-29.593 Y- 15.207	N485 X-29.23 Y3.109
N340 X-30.441 Y- 19.661	N415 X-29.56 Y- 14.778	N490 X-29.1 Y3.889
N345 X-30.37 Y- 19.436	N420 X-29.522 Y- 14.153	N495 X-28.781 Y5.539
		N500 X-28.418 Y7.078
		N505 X-27.967 Y8.594

N510 X-27.451 Y10.089	N585 X-21.045 Y17.681	N660 X-11.871 Y24.787
N515 X-26.849 Y11.551	N590 X-20.969 Y17.777	N665 X-11.332 Y25.05
N520 X-26.179 Y12.983	N595 X-20.505 Y18.301	N670 X-10.792 Y25.268
N525 X-25.803 Y13.679	N600 X-19.966 Y18.86	N675 X-10.253 Y25.476
N530 X-25.706 Y13.851	N605 X-18.886 Y19.94	N680 X-9.713 Y25.679
N535 X-25.509 Y14.194	N610 X-18.337 Y20.471	N685 X-9.173 Y25.88
N540 X-24.353 Y15.273	N615 X-17.807 Y20.945	N690 X-8.634 Y26.076
N545 X-24.263 Y15.313	N620 X-17.726 Y21.009	N695 X-8.094 Y26.267
N550 X-22.814 Y15.946	N625 X-17.268 Y21.368	N700 X-7.677 Y26.397
N555 X-22.798 Y15.951	N630 X-16.188 Y22.176	N705 X-7.015 Y26.562
N560 X-22.53 Y16.055	N635 X-15.649 Y22.577	N710 X-6.475 Y26.688
N565 X-22.282 Y16.2	N640 X-14.795 Y23.164	N715 X-5.337 Y26.935
N570 X-22.06 Y16.382	N645 X-14.569 Y23.316	N720 X-4.856 Y27.039
N575 X-21.87 Y16.598	N650 X-14.03 Y23.62	N725 X-4.317 Y27.145
N580 X-21.39 Y17.239	N655 X-12.411 Y24.503	N730 X-3.777 Y27.224

N735 X-3.238 Y27.291	N845 X12.411 Y24.503	N925 X29.092 Y7.787
N740 X-2.158 Y27.37	N850 X14.03 Y23.62	N930 X29.481 Y6.254
N745 X-1.079 Y27.447	N855 X14.569 Y23.316	N935 X29.784 Y4.702
N750 X0. Y27.498	N860 X15.948 Y22.542	N940 X30.003 Y3.136
N755 X1.079 Y27.447	N865 X17.492 Y21.879	N945 X30.135 Y1.56
N760 X2.158 Y27.37	N870 X18.982 Y21.348	N950 X30.184 Y-0.02
N765 X3.238 Y27.291	N875 X20.368 Y20.587	N955 X30.147 Y-1.601
N770 X3.777 Y27.224	N880 X21.653 Y19.666	N960 X30.028 Y-3.178
N775 X4.317 Y27.145	N885 X22.846 Y18.627	N965 X29.925 Y-3.962
N780 X4.856 Y27.039	N890 X23.937 Y17.483	N970 X29.879 Y-4.255
N785 X5.936 Y26.805	N895 X24.943 Y16.263	N975 X29.6 Y-5.912
N790 X6.475 Y26.688	N900 X25.851 Y14.968	N980 X29.256 Y-7.455
N795 X7.015 Y26.562	N905 X26.676 Y13.618	N985 X28.83 Y-8.978
N800 X7.677 Y26.397	N910 X27.408 Y12.217	N990 X28.323 Y-10.476
N805 X8.094 Y26.267	N915 X28.057 Y10.775	N995 X27.739 Y-11.946
N810 X8.634 Y26.076	N920 X28.616 Y9.295	N1000 X27.077 Y-13.382
N815 X9.173 Y25.88		N1005 X26.709 Y-14.082
N820 X9.713 Y25.679		N1010 X26.266 Y-14.737
N825 X10.253 Y25.476		
N830 X10.792 Y25.268		
N835 X11.332 Y25.05		
N840 X11.885 Y24.78		

N1015 X25.059 Y- 15.759	N1090 X17.268 Y- 21.368	N1165 X7.677 Y- 26.397
N1020 X23.652 Y- 16.481	N1095 X16.188 Y- 22.176	N1170 X7.015 Y- 26.562
N1025 X22.167 Y- 17.023	N1100 X15.649 Y- 22.577	N1175 X6.475 Y- 26.688
N1030 X21.972 Y- 17.076	N1105 X14.795 Y- 23.164	N1180 X5.337 Y- 26.935
N1035 X21.703 Y- 17.172	N1110 X14.569 Y- 23.316	N1185 X4.856 Y- 27.039
N1040 X21.453 Y- 17.31	N1115 X14.03 Y- 23.62	N1190 X4.317 Y- 27.145
N1045 X21.228 Y- 17.486	N1120 X12.411 Y- 24.503	N1195 X3.777 Y- 27.224
N1050 X21.034 Y- 17.695	N1125 X11.871 Y- 24.787	N1200 X3.238 Y- 27.291
N1055 X20.969 Y- 17.777	N1130 X11.332 Y- 25.05	N1205 X2.158 Y- 27.37
N1060 X20.505 Y- 18.301	N1135 X10.792 Y- 25.268	N1210 X1.079 Y- 27.447
N1065 X19.966 Y- 18.86	N1140 X10.253 Y- 25.476	N1215 X0. Y-27.498
N1070 X18.886 Y- 19.94	N1145 X9.713 Y- 25.679	N1220 X-1.079 Y- 27.447
N1075 X18.337 Y- 20.471	N1150 X9.173 Y- 25.88	N1225 X-2.158 Y- 27.37
N1080 X17.807 Y- 20.945	N1155 X8.634 Y- 26.076	N1230 X-3.238 Y- 27.291
N1085 X17.726 Y- 21.009	N1160 X8.094 Y- 26.267	N1235 X-3.777 Y- 27.224

N1240 X-4.317 Y-27.145	N1315 X-14.03 Y-23.62	N1390 X-22.196 Y-16.161
N1245 X-4.856 Y-27.039	N1320 X-14.569 Y-23.316	N1395 X-22.596 Y-15.622
N1250 X-5.936 Y-26.805	N1325 X-14.795 Y-23.164	N1400 X-23.203 Y-14.737
N1255 X-6.475 Y-26.688	N1330 X-15.649 Y-22.577	N1405 X-23.33 Y-14.545
N1260 X-7.015 Y-26.562	N1335 X-16.307 Y-22.087	N1410 X-23.632 Y-14.006
N1265 X-7.677 Y-26.397	N1340 X-17.268 Y-21.368	N1415 X-24.515 Y-12.39
N1270 X-8.094 Y-26.267	N1345 X-17.726 Y-21.009	N1420 X-24.798 Y-11.852
N1275 X-8.634 Y-26.076	N1350 X-17.807 Y-20.945	N1425 X-25.059 Y-11.313
N1280 X-9.173 Y-25.88	N1355 X-18.347 Y-20.462	N1430 X-25.275 Y-10.774
N1285 X-9.713 Y-25.679	N1360 X-18.894 Y-19.932	N1435 X-25.483 Y-10.235
N1290 X-10.253 Y-25.476	N1365 X-19.971 Y-18.855	N1440 X-25.685 Y-9.697
N1295 X-10.792 Y-25.268	N1370 X-20.505 Y-18.301	N1445 X-25.901 Y-9.117
N1300 X-11.332 Y-25.05	N1375 X-20.969 Y-17.777	N1450 X-26.081 Y-8.619
N1305 X-11.885 Y-24.78	N1380 X-21.045 Y-17.681	N1455 X-26.271 Y-8.081
N1310 X-12.411 Y-24.503	N1385 X-21.39 Y-17.239	N1460 X-26.43 Y-7.542

N1465 X-26.565 Y-7.003	N1540 X-27.041 Y4.848	N1615 X-23.33 Y14.545
N1470 X-26.69 Y-6.464	N1545 X-26.807 Y5.926	N1620 X-23.203 Y14.737
N1475 X-26.981 Y-5.128	N1550 X-26.69 Y6.464	N1625 X-22.664 Y15.524
N1480 X-27.041 Y-4.848	N1555 X-26.565 Y7.003	N1630 G3 X-22.398 Y16.256 I-1.519 J0.966
N1485 X-27.146 Y-4.31	N1560 X-26.43 Y7.542	N1635 G1 X-22.376 Y16.421 Z-22.192
N1490 X-27.225 Y-3.771	N1565 X-26.271 Y8.081	N1640 X-22.355 Y16.584 Z-22.169
N1495 X-27.291 Y-3.232	N1570 X-26.081 Y8.619	N1645 X-22.334 Y16.744 Z-22.131
N1500 X-27.37 Y-2.155	N1575 X-25.886 Y9.158	N1650 X-22.313 Y16.901 Z-22.078
N1505 X-27.447 Y-1.077	N1580 X-25.685 Y9.697	N1655 X-22.294 Y17.052 Z-22.011
N1510 X-27.498 Y0.	N1585 X-25.483 Y10.235	N1660 X-22.275 Y17.196 Z-21.93
N1515 X-27.447 Y1.077	N1590 X-25.275 Y10.774	N1665 X-22.257 Y17.332 Z-21.836
N1520 X-27.37 Y2.155	N1595 X-25.059 Y11.313	N1670 X-22.24 Y17.458 Z-21.73
N1525 X-27.291 Y3.232	N1600 X-24.798 Y11.852	N1675 X-22.225 Y17.575 Z-21.613
N1530 X-27.225 Y3.771	N1605 X-24.515 Y12.39	N1680 X-22.211 Y17.68 Z-21.485
N1535 X-27.146 Y4.31	N1610 X-23.632 Y14.006	N1685 X-22.199 Y17.773 Z-21.348

N1690 X-22.189 Y17.854 Z-21.202	N1770 X13.458 Y25.222 Z-21.485	N1845 X17.268 Y21.368
N1695 X-22.18 Y17.92 Z-21.05	N1775 X13.503 Y25.126 Z-21.613	N1850 X17.726 Y21.009
N1700 X-22.173 Y17.973 Z-20.893	N1780 X13.553 Y25.019 Z-21.73	N1855 X17.807 Y20.945
N1705 X-22.168 Y18.01 Z-20.731	N1785 X13.607 Y24.903 Z-21.836	N1860 X18.347 Y20.462
N1710 X-22.165 Y18.033 Z-20.566	N1790 X13.666 Y24.779 Z-21.93	N1865 X18.894 Y19.932
N1715 X-22.164 Y18.041 Z-20.4	N1795 X13.728 Y24.648 Z-22.011	N1870 X19.971 Y18.855
N1720 G0 Z5.	N1800 X13.792 Y24.51 Z-22.078	N1875 X20.505 Y18.301
N1725 G1 X13.303 Y25.551 F650.	N1805 X13.859 Y24.368 Z-22.131	N1880 X20.969 Y17.777
N1730 G0 Z-18.6	N1810 X13.928 Y24.221 Z-22.169	N1885 X21.045 Y17.681
N1735 G1 Z-20.4 F3200.29	N1815 X13.999 Y24.072 Z-22.192	N1890 X21.39 Y17.239
N1740 X13.306 Y25.544 Z-20.566	N1820 X14.069 Y23.922 Z-22.2	N1895 X22.196 Y16.161
N1745 X13.316 Y25.523 Z-20.731	N1825 G3 X14.569 Y23.316 I1.432 J0.674	N1900 X22.596 Y15.622
N1750 X13.332 Y25.488 Z-20.893	N1830 G1 X14.795 Y23.164	N1905 X23.203 Y14.737
N1755 X13.355 Y25.441 Z-21.05	N1835 X15.649 Y22.577	N1910 X23.33 Y14.545
N1760 X13.383 Y25.38 Z-21.202	N1840 X16.307 Y22.087	N1915 X23.632 Y14.006
N1765 X13.418 Y25.307 Z-21.348		

N1920 X24.515 Y12.39	N2000 X27.291 Y3.232	N2080 X25.886 Y- 9.158
N1925 X24.798 Y11.852	N2005 X27.37 Y2.155	N2085 X25.685 Y- 9.697
N1930 X25.059 Y11.313	N2010 X27.447 Y1.077	N2090 X25.483 Y- 10.235
N1935 X25.275 Y10.774	N2015 X27.498 Y0.	N2095 X25.275 Y- 10.774
N1940 X25.483 Y10.235	N2020 X27.447 Y- 1.077	N2100 X25.059 Y- 11.313
N1945 X25.685 Y9.697	N2025 X27.37 Y- 2.155	N2105 X24.798 Y- 11.852
N1950 X25.901 Y9.117	N2030 X27.291 Y- 3.232	N2110 X24.515 Y- 12.39
N1955 X26.081 Y8.619	N2035 X27.225 Y- 3.771	N2115 X23.632 Y- 14.006
N1960 X26.271 Y8.081	N2040 X27.146 Y- 4.31	N2120 X23.33 Y- 14.545
N1965 X26.43 Y7.542	N2045 X27.041 Y- 4.848	N2125 X23.203 Y- 14.737
N1970 X26.565 Y7.003	N2050 X26.807 Y- 5.926	N2130 X22.596 Y- 15.622
N1975 X26.69 Y6.464	N2055 X26.69 Y- 6.464	N2135 X22.124 Y- 16.258
N1980 X26.981 Y5.128	N2060 X26.565 Y- 7.003	N2140 X21.39 Y- 17.239
N1985 X27.041 Y4.848	N2065 X26.43 Y- 7.542	N2145 X21.034 Y- 17.695
N1990 X27.146 Y4.31	N2070 X26.271 Y- 8.081	N2150 G3 X20.718 Y- 18.407 I1.449 J-1.068
N1995 X27.225 Y3.771	N2075 X26.081 Y- 8.619	

N2155 G1 X20.686 Y- 18.57 Z-22.192	N2230 X20.365 Y- 20.164 Z-20.566	N2310 X-22.662 Y17.821 Z-21.93
N2160 X20.653 Y- 18.731 Z-22.169	N2235 X20.363 Y- 20.172 Z-20.4	N2315 X-22.638 Y17.678 Z-22.011
N2165 X20.621 Y- 18.89 Z-22.131	N2240 G0 Z5.	N2320 X-22.612 Y17.528 Z-22.078
N2170 X20.59 Y- 19.045 Z-22.078	N2245 G1 X-22.803 Y18.662 F650.	N2325 X-22.586 Y17.372 Z-22.131
N2175 X20.56 Y- 19.194 Z-22.011	N2250 G0 Z-18.6	N2330 X-22.559 Y17.213 Z-22.169
N2180 X20.531 Y- 19.336 Z-21.93	N2255 G1 Z-20.4 F3200.29	N2335 X-22.532 Y17.05 Z-22.192
N2185 X20.504 Y- 19.47 Z-21.836	N2260 X-22.802 Y18.654 Z-20.566	N2340 X-22.505 Y16.887 Z-22.2
N2190 X20.479 Y- 19.596 Z-21.73	N2265 X-22.798 Y18.631 Z-20.731	N2345 G3 X-22.292 Y16.131 I3.595 J0.604
N2195 X20.456 Y- 19.711 Z-21.613	N2270 X-22.792 Y18.594 Z-20.893	N2350 G1 X-22.281 Y16.107
N2200 X20.435 Y- 19.815 Z-21.485	N2275 X-22.783 Y18.542 Z-21.05	N2355 X-22.256 Y16.098
N2205 X20.416 Y- 19.907 Z-21.348	N2280 X-22.772 Y18.476 Z-21.202	N2360 X-22.233 Y16.111
N2210 X20.4 Y- 19.987 Z-21.202	N2285 X-22.758 Y18.396 Z-21.348	N2365 G3 X-21.941 Y16.833 I-1.482 J1.021
N2215 X20.387 Y- 20.052 Z-21.05	N2290 X-22.743 Y18.303 Z-21.485	N2370 G1 X-21.913 Y16.997 Z-22.192
N2220 X20.377 Y- 20.104 Z-20.893	N2295 X-22.725 Y18.198 Z-21.613	N2375 X-21.886 Y17.16 Z-22.169
N2225 X20.369 Y- 20.142 Z-20.731	N2300 X-22.706 Y18.082 Z-21.73	N2380 X-21.859 Y17.319 Z-22.131
	N2305 X-22.684 Y17.956 Z-21.836	

N2385 X-21.833
Y17.475 Z-22.078

N2390 X-21.808
Y17.625 Z-22.011

N2395 X-21.784
Y17.768 Z-21.93

N2400 X-21.761
Y17.903 Z-21.836

N2405 X-21.74
Y18.029 Z-21.73

N2410 X-21.72
Y18.145 Z-21.613

N2415 X-21.702
Y18.25 Z-21.485

N2420 X-21.687
Y18.343 Z-21.348

N2425 X-21.673
Y18.422 Z-21.202

N2430 X-21.662
Y18.489 Z-21.05

N2435 X-21.654
Y18.541 Z-20.893

N2440 X-21.647
Y18.578 Z-20.731

N2445 X-21.643
Y18.601 Z-20.566

N2450 X-21.642
Y18.608 Z-20.4

N2455 G0 Z15.

N2460 M5

N2465 M9

N2470 G53 G0 Z0.

N2475 G53 G0 X0.
Y0.

N2480 M30

%

%

O00035

(Using high feed G1
F650. instead of G0.)

(T1 D=10. CR=0. -
ZMIN=-4.2 - flat end
mill)

N10 G90 G94 G17

N15 G21

N20 G53 G0 Z0.

(2D Adaptive7)

N25 T1 M6

N30 S1940 M3

N35 G17 G90 G94

N40 G54

N45 M8

N50 G1 X1.841
Y0.066 F650.

N55 G0 G43 Z15. H1

N60 G0 Z5.

N65 Z-2.2

N70 G1 Z-3.2 F181.73

N75 X1.834 Y0.063
Z-3.321

N80 X1.814 Y0.055
Z-3.439

N85 X1.78 Y0.042 Z-
3.555

N90 X1.734 Y0.023
Z-3.665

N95 X1.676 Y0. Z-
3.768

N100 X1.607 Y-0.027
Z-3.863

N105 X1.528 Y-0.059
Z-3.949

N110 X1.439 Y-0.094
Z-4.023

N115 X1.343 Y-0.132
Z-4.085

N120 X1.241 Y-0.173
Z-4.135

N125 X1.134 Y-0.216
Z-4.171

N130 X1.024 Y-0.26
Z-4.193

N135 X0.912 Y-0.304
Z-4.2
N140 G3 X-3.949 Y-
2.878 I9.449 J-23.717
N145 G1 X-4.036 Y-
2.942
N150 X-4.063 Y-3.09
N155 X-4.067 Y-3.24
N160 X-4.048 Y-3.388
N165 X-4.017 Y-3.535
N170 X-3.978 Y-3.68
N175 X-3.926 Y-3.821
N180 X-3.864 Y-3.957
N185 X-3.78 Y-4.12
N190 X-3.691 Y-4.273
N195 X-3.608 Y-4.399
N200 X-3.511 Y-4.529
N205 X-3.384 Y-4.681
N210 X-3.222 Y-4.857
N215 X-3.072 Y-5.002
N220 X-2.944 Y-5.115
N225 X-2.781 Y-5.243
N230 X-2.576 Y-5.388
N235 X-2.319 Y-5.55
N240 X-2.152 Y-5.643

N245 X-1.957 Y-5.74
N250 X-1.715 Y-5.844
N255 X-1.417 Y-5.954
N260 X-1.168 Y-6.031
N265 X-0.946 Y-6.087
N270 X-0.676 Y-6.141
N275 X-0.345 Y-6.189
N280 X-0.047 Y-6.217
N285 X0.192 Y-6.226
N290 X0.481 Y-6.222
N295 X0.831 Y-6.199
N300 X1.143 Y-6.163
N305 X1.39 Y-6.12
N310 X1.686 Y-6.054
N315 X2.04 Y-5.954
N320 X2.335 Y-5.854
N325 X2.579 Y-5.757
N330 X2.867 Y-5.624
N335 X3.209 Y-5.445
N340 X3.462 Y-5.294
N345 X3.691 Y-5.142
N350 X3.958 Y-4.943
N355 X4.269 Y-4.684
N360 X4.465 Y-4.504

N365 X4.666 Y-4.297
N370 X4.897 Y-4.035
N375 X5.148 Y-3.717
N380 X5.293 Y-3.513
N385 X5.454 Y-3.257
N390 X5.634 Y-2.938
N395 X5.8 Y-2.602
N400 X5.904 Y-2.361
N405 X6.014 Y-2.064
N410 X6.128 Y-1.697
N415 X6.212 Y-1.369
N420 X6.266 Y-1.1
N425 X6.314 Y-0.771
N430 X6.352 Y-0.369
N435 X6.364 Y-0.073
N440 X6.361 Y0.215
N445 X6.338 Y0.562
N450 X6.289 Y0.984
N455 X6.247 Y1.23
N460 X6.181 Y1.524
N465 X6.083 Y1.876
N470 X5.958 Y2.245
N475 X5.862 Y2.488
N480 X5.73 Y2.775

N485 X5.552 Y3.115	N605 X-1.218 Y6.253	N725 X-6.317 Y0.807
N490 X5.375 Y3.415	N610 X-1.511 Y6.188	N730 X-6.355 Y0.409
N495 X5.223 Y3.643	N615 X-1.861 Y6.09	N735 X-6.369 Y0.096
N500 X5.025 Y3.909	N620 X-2.236 Y5.964	N740 X-6.364 Y-0.419
N505 X4.769 Y4.219	N625 X-2.478 Y5.869	N745 X-6.319 Y-1.162
N510 X4.562 Y4.443	N630 X-2.764 Y5.738	N750 X-6.257 Y-1.709
N515 X4.357 Y4.644	N635 X-3.103 Y5.561	N755 X-6.176 Y-2.188
N520 X4.097 Y4.874	N640 X-3.408 Y5.381	N760 X-6.083 Y-2.612
N525 X3.765 Y5.137	N645 X-3.635 Y5.23	N765 X-5.977 Y-2.992
N530 X3.556 Y5.285	N650 X-3.9 Y5.034	N770 X-5.857 Y-3.352
N535 X3.302 Y5.446	N655 X-4.209 Y4.779	N775 X-5.722 Y-3.696
N540 X2.985 Y5.625	N660 X-4.438 Y4.569	N780 X-5.575 Y-4.018
N545 X2.632 Y5.8	N665 X-4.638 Y4.365	N785 X-5.418 Y-4.32
N550 X2.393 Y5.903	N670 X-4.867 Y4.106	N790 X-5.247 Y-4.611
N555 X2.098 Y6.013	N675 X-5.129 Y3.776	N795 X-5.059 Y-4.896
N560 X1.733 Y6.128	N680 X-5.281 Y3.563	N800 X-4.86 Y-5.164
N565 X1.391 Y6.215	N685 X-5.441 Y3.311	N805 X-4.652 Y-5.417
N570 X1.123 Y6.27	N690 X-5.62 Y2.995	N810 X-4.429 Y-5.66
N575 X0.797 Y6.318	N695 X-5.797 Y2.639	N815 X-4.19 Y-5.896
N580 X0.396 Y6.356	N700 X-5.901 Y2.401	N820 X-3.938 Y-6.119
N585 X0.089 Y6.369	N705 X-6.01 Y2.107	N825 X-3.678 Y-6.326
N590 X-0.197 Y6.366	N710 X-6.125 Y1.744	N830 X-3.407 Y-6.52
N595 X-0.543 Y6.344	N715 X-6.214 Y1.398	N835 X-3.119 Y-6.704
N600 X-0.963 Y6.296	N720 X-6.268 Y1.132	N840 X-2.818 Y-6.874

N845 X-2.511 Y-7.028	N965 X5.793 Y-5.286	N1065 X7.548 Y2.293
N850 X-2.196 Y-7.165	N970 X6.057 Y-4.989	N1070 X7.417 Y2.688
N855 X-1.868 Y-7.288	N975 X6.309 Y-4.673	N1075 X7.266 Y3.073
N860 X-1.528 Y-7.396	N980 X6.546 Y-4.342	N1080 X7.099 Y3.444
N865 X-1.183 Y-7.486	N985 X6.762 Y-4.005	N1085 X6.911 Y3.808
N870 X-0.834 Y-7.557	N990 X6.961 Y-3.656	N1090 X6.699 Y4.171
N875 X-0.478 Y-7.61	N995 X7.145 Y-3.288	N1095 X6.473 Y4.515
N880 X-0.112 Y-7.646	N1000 X7.309 Y-2.915	N1100 X6.232 Y4.843
N885 X0.258 Y-7.663	N1005 X7.45 Y-2.538	N1105 X5.971 Y5.161
N890 X0.625 Y-7.66	N1010 X7.573 Y-2.152	N1110 X5.689 Y5.47
N895 X0.995 Y-7.638	N1015 X7.679 Y-1.748	N1115 X5.398 Y5.759
N900 X1.374 Y-7.595	N1020 X7.761 Y-1.349	N1120 X5.094 Y6.03
N905 X1.749 Y-7.533	N1025 X7.822 Y-0.951	N1125 X4.77 Y6.289
N910 X2.118 Y-7.452	N1030 X7.862 Y-0.544	N1130 X4.432 Y6.532
N915 X2.485 Y-7.351	N1035 X7.881 Y-0.128	N1135 X4.088 Y6.753
N920 X2.859 Y-7.226	N1040 X7.879 Y0.279	N1140 X3.733 Y6.956
N925 X3.22 Y-7.085	N1045 X7.855 Y0.683	N1145 X3.36 Y7.143
N930 X3.571 Y-6.926	N1050 X7.81 Y1.093	N1150 X2.98 Y7.31
N935 X3.917 Y-6.746	N1055 X7.742 Y1.502	N1155 X2.598 Y7.455
N940 X4.264 Y-6.543	N1060 X7.655 Y1.9	N1160 X2.208 Y7.58
N945 X4.592 Y-6.327		N1165 X1.801 Y7.686
N950 X4.907 Y-6.094		N1170 X1.396 Y7.77
N955 X5.215 Y-5.842		N1175 X0.993 Y7.832
N960 X5.514 Y-5.569		N1180 X0.584 Y7.873

N1185 X0.165 Y7.893	N1270 X-6.022 Y5.106	N1345 X-7.953 Y- 1.373
N1190 X-0.246 Y7.891	N1275 X-6.282 Y4.783	N1350 X-7.9 Y-1.862
N1195 X-0.653 Y7.868	N1280 X-6.526 Y4.445	N1355 X-7.823 Y- 2.339
N1200 X-1.065 Y7.823	N1285 X-6.747 Y4.1	N1360 X-7.723 Y- 2.802
N1205 X-1.477 Y7.756	N1290 X-6.951 Y3.745	N1365 X-7.601 Y- 3.253
N1210 X-1.877 Y7.669	N1295 X-7.139 Y3.373	N1370 X-7.458 Y-3.69
N1215 X-2.272 Y7.561	N1300 X-7.306 Y2.993	N1375 X-7.294 Y- 4.112
N1220 X-2.668 Y7.431	N1305 X-7.459 Y2.592	N1380 X-7.111 Y-4.52
N1225 X-3.055 Y7.28	N1310 X-7.593 Y2.173	N1385 X-6.909 Y- 4.913
N1230 X-3.428 Y7.112	N1315 X-7.719 Y1.695	N1390 X-6.689 Y- 5.292
N1235 X-3.793 Y6.925	N1320 X-7.825 Y1.191	N1395 X-6.451 Y- 5.656
N1240 X-4.156 Y6.713	N1325 X-7.904 Y0.676	N1400 X-6.196 Y- 6.005
N1245 X-4.502 Y6.486	N1330 X-7.957 Y0.155	N1405 X-5.924 Y-6.34
N1250 X-4.831 Y6.245	N1335 X-7.983 Y- 0.362	N1410 X-5.635 Y- 6.659
N1255 X-5.15 Y5.985	N1340 X-7.981 Y- 0.872	N1415 X-5.33 Y-6.962
N1260 X-5.461 Y5.703		N1420 X-5.01 Y-7.249
N1265 X-5.75 Y5.411		N1425 X-4.675 Y- 7.519

N1430 X-4.326 Y-7.771	N1510 X2.503 Y-8.984	N1590 X7.344 Y-5.944
N1435 X-3.963 Y-8.006	N1515 X2.952 Y-8.862	N1595 X7.635 Y-5.545
N1440 X-3.588 Y-8.221	N1520 X3.396 Y-8.717	N1600 X8.126 Y-4.795
N1445 X-3.2 Y-8.418	N1525 X3.834 Y-8.549	N1605 X8.364 Y-4.386
N1450 X-2.801 Y-8.594	N1530 X4.265 Y-8.356	N1610 X8.582 Y-3.963
N1455 X-2.391 Y-8.75	N1535 X4.686 Y-8.14	N1615 X8.689 Y-3.724
N1460 X-1.973 Y-8.885	N1540 X5.096 Y-7.903	N1620 X8.715 Y-3.663
N1465 X-1.546 Y-8.999	N1545 X5.496 Y-7.643	N1625 G3 X8.13 Y-2.376 Z-4. I-0.937 J0.35
N1470 X-1.111 Y-9.09	N1550 X5.882 Y-7.361	N1630 X6.912 Y-2.813 I-0.351 J-0.936
N1475 X-0.669 Y-9.159	N1555 X6.254 Y-7.059	N1635 G1 X5.981 Y-4.429
N1480 X-0.223 Y-9.205	N1560 X6.611 Y-6.737	N1640 G3 X6.231 Y-5.716 I0.866 J-0.499
N1485 X0.228 Y-9.228	N1565 X6.952 Y-6.396	N1645 X7.635 Y-5.545 Z-4.2 I0.616 J0.788
N1490 X0.682 Y-9.227	N1570 X7.176 Y-6.146	N1650 G1 X7.943 Y-5.122
N1495 X1.138 Y-9.203	N1575 X7.22 Y-6.096	N1655 X8.057 Y-4.946
N1500 X1.594 Y-9.154	N1580 X7.262 Y-6.046	
N1505 X2.049 Y-9.081	N1585 X7.304 Y-5.994	

N1660 X8.243 Y-4.614	N1750 X9.111 Y2.548	N1870 X2.248 Y9.183
N1665 X8.543 Y-4.071	N1755 X9.028 Y2.848	N1875 X1.948 Y9.25
N1670 X8.555 Y-4.047	N1760 X8.929 Y3.147	N1880 X1.049 Y9.398
N1675 X8.681 Y-3.747	N1765 X8.681 Y3.747	N1885 X0.749 Y9.424
N1680 X8.805 Y-3.447	N1770 X8.555 Y4.047	N1890 X0.15 Y9.471
N1685 X8.929 Y-3.147	N1775 X8.543 Y4.071	N1895 X-0.15
N1690 X9.028 Y-2.848	N1780 X8.226 Y4.646	N1900 X-0.749 Y9.424
N1695 X9.111 Y-2.548	N1785 X8.057 Y4.946	N1905 X-1.049 Y9.398
N1700 X9.183 Y-2.248	N1790 X7.943 Y5.122	N1910 X-1.948 Y9.25
N1705 X9.25 Y-1.948	N1795 X7.344 Y5.944	N1915 X-2.248 Y9.183
N1710 X9.398 Y-1.049	N1800 X7.184 Y6.145	N1920 X-2.548 Y9.111
N1715 X9.424 Y-0.749	N1805 X7.044 Y6.306	N1925 X-2.848 Y9.028
N1720 X9.471 Y-0.15	N1810 X6.306 Y7.044	N1930 X-3.147 Y8.929
N1725 Y0.15	N1815 X6.145 Y7.184	N1935 X-3.747 Y8.681
N1730 X9.424 Y0.749	N1820 X5.944 Y7.344	N1940 X-4.047 Y8.555
N1735 X9.398 Y1.049	N1825 X5.122 Y7.943	N1945 X-4.071 Y8.543
N1740 X9.25 Y1.948	N1830 X4.946 Y8.057	N1950 X-4.646 Y8.226
N1745 X9.183 Y2.248	N1835 X4.614 Y8.243	N1955 X-4.946 Y8.057
	N1840 X4.071 Y8.543	
	N1845 X4.047 Y8.555	
	N1850 X3.747 Y8.681	
	N1855 X3.147 Y8.929	
	N1860 X2.848 Y9.028	
	N1865 X2.548 Y9.111	

N1960 X-5.122 Y7.943	N2035 X-9.111 Y2.548	N2120 X-8.226 Y- 4.646
N1965 X-5.944 Y7.344	N2040 X-9.183 Y2.248	N2125 X-8.057 Y- 4.946
N1970 X-6.145 Y7.184	N2045 X-9.25 Y1.948	N2130 X-7.943 Y- 5.122
N1975 X-6.306 Y7.044	N2050 X-9.398 Y1.049	N2135 X-7.344 Y- 5.944
N1980 X-7.044 Y6.306	N2055 X-9.424 Y0.749	N2140 X-7.184 Y- 6.145
N1985 X-7.184 Y6.145	N2060 X-9.471 Y0.15	N2145 X-7.044 Y- 6.306
N1990 X-7.344 Y5.944	N2065 Y-0.15	N2150 X-6.306 Y- 7.044
N1995 X-7.943 Y5.122	N2070 X-9.424 Y- 0.749	N2155 X-6.145 Y- 7.184
N2000 X-8.057 Y4.946	N2075 X-9.398 Y- 1.049	N2160 X-5.944 Y- 7.344
N2005 X-8.243 Y4.614	N2080 X-9.25 Y-1.948	N2165 X-5.122 Y- 7.943
N2010 X-8.543 Y4.071	N2085 X-9.183 Y- 2.248	N2170 X-4.946 Y- 8.057
N2015 X-8.555 Y4.047	N2090 X-9.111 Y- 2.548	N2175 X-4.614 Y- 8.243
N2020 X-8.681 Y3.747	N2095 X-9.028 Y- 2.848	N2180 X-4.071 Y- 8.543
N2025 X-8.929 Y3.147	N2100 X-8.929 Y- 3.147	N2185 X-4.047 Y- 8.555
N2030 X-9.028 Y2.848	N2105 X-8.681 Y- 3.747	N2190 X-3.747 Y- 8.681
	N2110 X-8.555 Y- 4.047	
	N2115 X-8.543 Y- 4.071	

N2195 X-3.147 Y-8.929	N2280 X4.047 Y-8.555	N2355 X7.42 Y-4.792 Z-4.085
N2200 X-2.848 Y-9.028	N2285 X4.071 Y-8.543	N2360 X7.405 Y-4.689 Z-4.023
N2205 X-2.548 Y-9.111	N2290 X4.646 Y-8.226	N2365 X7.391 Y-4.595 Z-3.949
N2210 X-2.248 Y-9.183	N2295 X4.946 Y-8.057	N2370 X7.378 Y-4.511 Z-3.863
N2215 X-1.948 Y-9.25	N2300 X5.122 Y-7.943	N2375 X7.367 Y-4.437 Z-3.768
N2220 X-1.049 Y-9.398	N2305 X5.944 Y-7.344	N2380 X7.358 Y-4.376 Z-3.665
N2225 X-0.749 Y-9.424	N2310 X6.145 Y-7.184	N2385 X7.351 Y-4.327 Z-3.555
N2230 X-0.15 Y-9.471	N2315 X6.306 Y-7.044	N2390 X7.345 Y-4.291 Z-3.439
N2235 X0.15	N2320 X7.044 Y-6.306	N2395 X7.342 Y-4.27 Z-3.321
N2240 X0.749 Y-9.424	N2325 X7.184 Y-6.145	N2400 X7.341 Y-4.262 Z-3.2
N2245 X1.049 Y-9.398	N2330 X7.304 Y-5.994	N2405 G0 Z15.
N2250 X1.948 Y-9.25	N2335 G3 X7.489 Y-5.251 I-0.804 J0.594	N2410 M5
N2255 X2.248 Y-9.183	N2340 G1 X7.471 Y-5.132 Z-4.193	N2415 M9
N2260 X2.548 Y-9.111	N2345 X7.454 Y-5.015 Z-4.171	N2420 G53 G0 Z0.
N2265 X2.848 Y-9.028	N2350 X7.437 Y-4.901 Z-4.135	N2425 G53 G0 X0. Y0.
N2270 X3.147 Y-8.929		N2430 M30
N2275 X3.747 Y-8.681		

%	N80 G17 G3 X0. Y-18. I-1.2 J0.
%	
O00040	N85 G2 Y18. I0. J18.
(Using high feed G1 F650. instead of G0.)	N90 Y-18. I0. J-18.
(T10 D=12. CR=0. TAPER=45deg - ZMIN=-2.7 - chamfer mill)	N95 G3 X-1.2 Y-19.2 I0. J-1.2
N10 G90 G94 G17	N100 G1 Y-19.8
N15 G21	N105 G19 G2 Y-21. Z-1.5 J0. K1.2
N20 G53 G0 Z0.	N110 G0 Z15.
(Circular1)	N115 M5
N25 T10 M6	N120 M9
N30 S5000 M3	N125 G53 G0 Z0.
N35 G17 G90 G94	N130 G53 G0 X0. Y0.
N40 G54	N135 M30
N45 M8	%
N50 G1 X1.2 Y-21. F650.	
N55 G0 G43 Z15. H10	
N60 G0 Z-0.7	
N65 G1 Z-1.5 F1000.	
N70 G19 G3 Y-19.8 Z-2.7 J1.2 K0.	
N75 G1 Y-19.2	