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

The defense allowed:
Acting head of the department
Oleksandr Okhrimenko
_____

Diploma project
Level of higher education – first (bachelor)
Program subject area – 131 "Applied Mechanics"
Educational Program "Manufacturing Engineering"

Topic: «Manufacturing Process Planning for the Part "Bearing Support"»

Developed by:
Student of the IV year of study, group MT-93
Abdultawaab Suleiman Hassan _____

Supervisor:
Ph.D, associate professor Volodymyr Korenkov _____

Reviewer:
Ph.D, associate professor Kholavik Olga _____

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

Kyiv-2023

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ASSIGNMENT

for the student's diploma project
Abdultawaab Suleiman Hassan

1. Topic of the project: Manufacturing Process Planning for the Part "Bearing Support". Supervisor: Volodymyr Korenkov, Ph.D.
approved by the University Order of «__» _____
2. Deadline for submission of the project «15» June 2023
3. Initial data for the project
- Drawing of a part " Bearing Support"
- Annual production output: 30000 part
- Material: Cast Iron
4. Content of the text part (explanatory note):
- Chapter 1 Calculation of workpiece deformations
- Chapter 2 Manufacturing process planning
- Chapter 3 Fixture design
- Chapter 4 Economic calculations
5. List of the graphic material (indicating mandatory drawings, posters, presentations, etc.)
- Presentation of the overview on the topic: Manufacturing Process Planning for the Part "Bearing Support" - 1 drawing Al
- Drawing of a part and a blank - 1 drawing Al
- Manufacturing operation presentation - 1-2 drawings Al

- Drawing of fixtures - 1-2 drawings Al
- Presentation of the project - 5-10 PowerPoint slides

6. Date of the task issue_«26» may 2023

Time schedule

No	The stage of the diploma project execution	Deadline	Notes
1	Chapter 1. Calculation of workpiece deformations	16.05.23	completed
2	Chapter 2. Manufacturing process planning	1.06.23	completed
3	Chapter 3. Fixture design	5.06.23	completed
4	Chapter 4. Economic calculations	10.06.23	completed
5	Presentation of the project	15.06.23	completed

Student
Abdultawaab Suleiman Hassan _____

Supervisor
Volodymyr Korenkov _____

ABSTRACT

Bachelor's thesis on the topic “Manufacturing Process Planning for the Part "Bearing Support"”. It consists of 104 sheets of A4 format and contains 48 figures and 4 tables.

The purpose of this work is to develop the process of manufacturing the "Bearing Support" part. The first chapter is devoted to calculation of workpiece deformations. The sequence of the production process was developed, including the selection of CNC machines, cutting tools, cutting conditions, etc. For two specific production processes, the fixture was selected and the corresponding settings were developed. Economic calculations for the first plant have been carried out.

The graphic part consists of 6 sheets of Al format, as follows:

1. Calculation of workpiece deformations
2. Drawings and 3D models of the "Bearing Support" part and blank
3. Manufacturing operation presentation
4. Fixture setup for the 1st manufacturing operation
5. Fixture setup for the last manufacturing operation
6. Results of CNC code development

TABLE OF CONTENT

INTRODUCTION

Manufacturing engineering is a dynamic and multidisciplinary field that lies at the heart of modern production processes.

It blends the principles of engineering with the intricacies of manufacturing to optimize the creation of products across various industries. Engineering play a crucial role in developing efficient and cost-effective production systems, designing innovative manufacturing processes, and ensuring the highest quality standards. Their expertise encompasses everything from analyzing and improving production workflows to implementing cutting-edge technologies like automation and robotics. With a focus on efficiency, sustainability, and collaboration, manufacturing engineering is at the forefront of shaping the future of manufacturing.

Manufacturing engineering plays a pivotal role in the modern industrial landscape, driving innovation, efficiency, and sustainability in the production of goods. With the continuous advancement of technology and the increasing demand for high-quality products, manufacturing processes have become more complex and intricate than ever before.

This thesis aims to explore the realm of manufacturing engineering and its significant impact on enhancing manufacturing efficiency and sustainability. By delving into various aspects of manufacturing engineering, including manufacturing process planning, advanced fixtures, milling operations, materials selection and cost calculations, this project seeks to shed light on the key principles and practices that can revolutionize the manufacturing industry and pave the way for a more sustainable and productive future. Through a comprehensive analysis of relevant case studies and empirical data, I have prepared a full manufacturing guideline to creating my assigned part and have also done this in the most cost and time efficient manner.

CHAPTER 1: Calculation of workpiece deformations

1.1 Advanced fixtures simulations - introduction

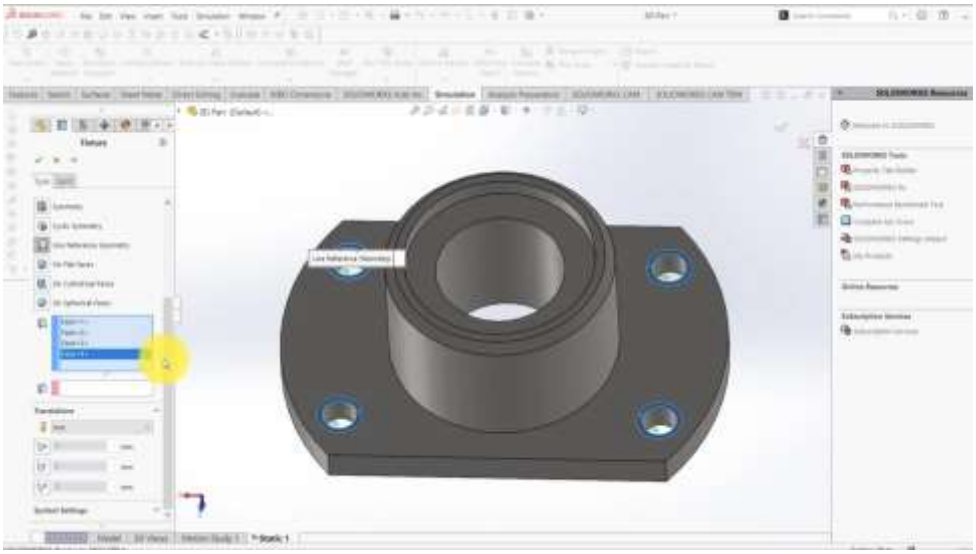
Advanced fixtures simulation refers to the process of using sophisticated computer-aided tools and techniques to simulate and optimize the design and performance of fixtures in manufacturing processes. Fixtures play a critical role in securely holding and positioning workpieces during various machining operations, ensuring accurate and repeatable production.

The application of advanced simulation techniques allows manufacturing engineers to virtually model and evaluate the behavior of fixtures, enabling them to identify potential issues, optimize designs, and improve overall productivity.

Through advanced fixtures simulation, engineers can create virtual prototypes of fixtures and assess their performance under different operating conditions. They can analyze factors such as clamping forces, stress distribution, deflection, and stability, ensuring that the fixture design meets the required specifications and tolerances. By simulating various scenarios, engineers can identify potential interferences, collisions, or structural weaknesses, allowing for necessary adjustments and improvements before the physical manufacturing phase.

One of the key advantages of advanced fixtures simulation is the ability to optimize the fixture design and operation to enhance manufacturing efficiency. By simulating different strategies, engineers can identify optimal clamping positions, determine the appropriate number and arrangement of clamps, and optimize the distribution of forces to minimize workpiece distortion and maximize machining accuracy. This iterative process of simulation and optimization helps reduce setup time, minimize scrap rates, and improve overall production throughput.

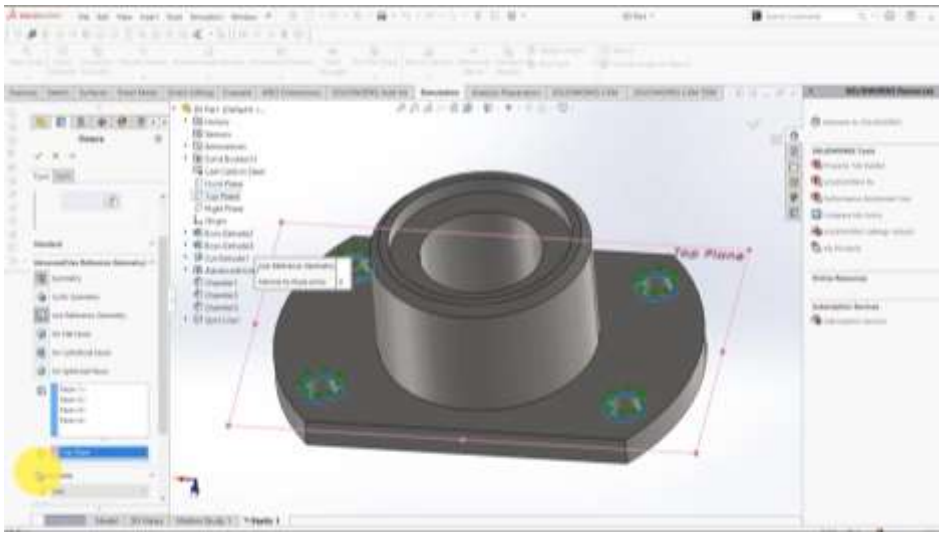
1.2 Using reference geometry to simulate bolt head



For the beginning step, I went to the fixtures tab and used reference geometry to select circular points on the top view face of the drawing to simulate the presence of the head of the bolt that would be used to hold down the part. I left the radial, circumferential and axial fixture options deactivated (used to specify an amount by which we are displacing)

1.3 Top plane selection

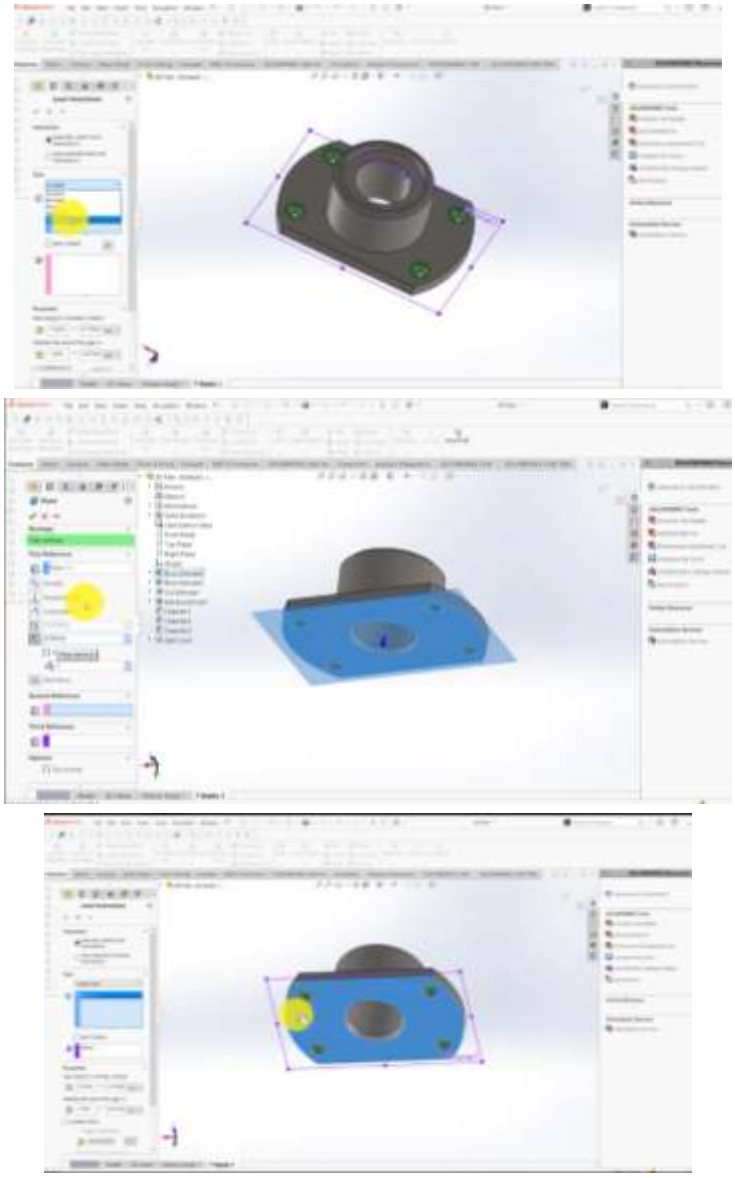
For the next step, due to using reference geometry for my simulation, I



selected the top plane and specified that I did not want any translations in the Z direction simulating the presence of the bolt head not allowing the selected faces to shift upwards.

1.4 Virtual wall setup

For the next step, I created a virtual wall, to do this, I first created another plane using references in the features tab and used the base of the model as my reference point.



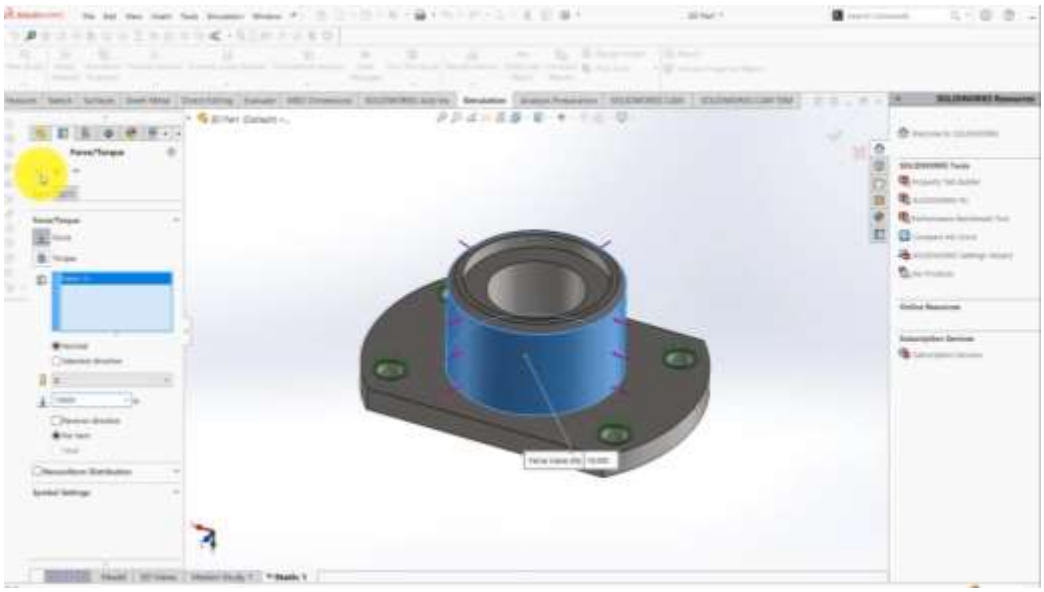
I then used connections and local interactions to implement the virtual wall on the newly created plane.

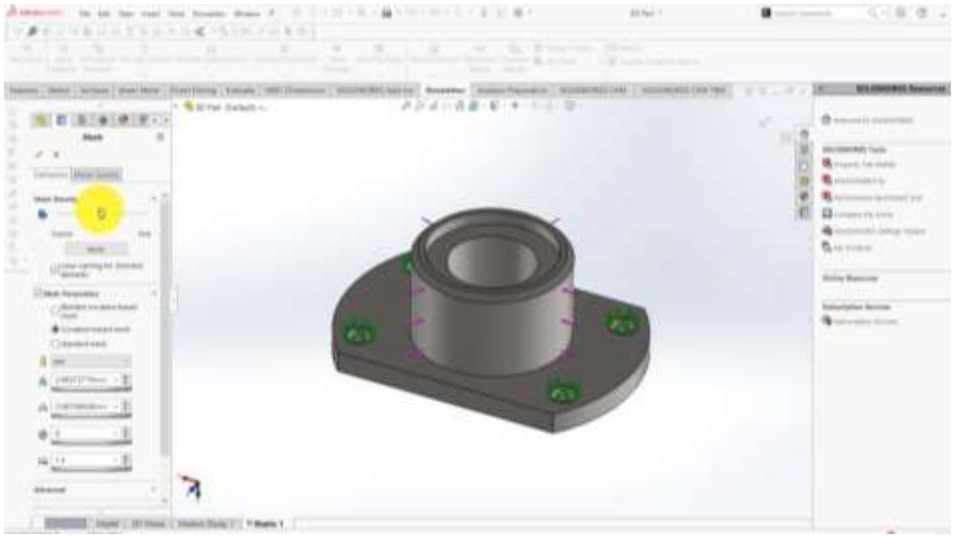
After that, I selected the bottom face of my model as my ground to indicate to the system that there is something on that plane area that will not allow our geometry to move beyond it. This basically means that we are not allowing the model move beyond that wall.

1.5 Force Simulation

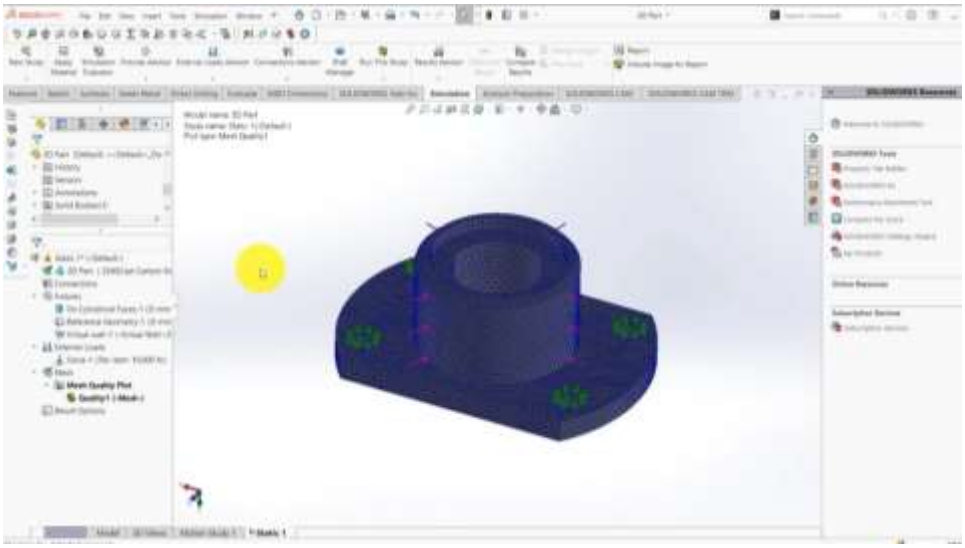
For the next step, I simulated the force acting on the model and selected a plane on which said force would act. I then input a value for said force.

As you can see, the split faces simulating the head of the bolts can now be clearly seen.



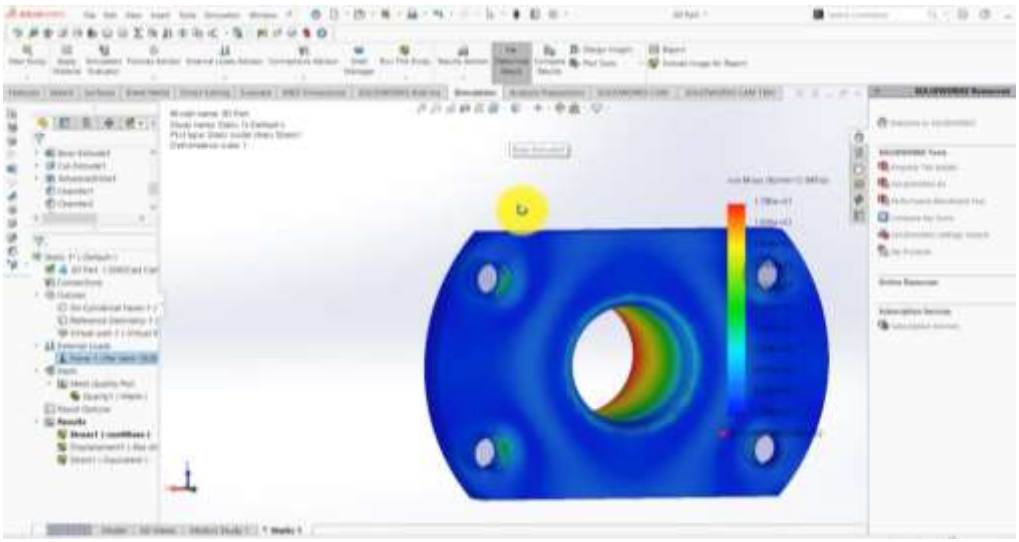


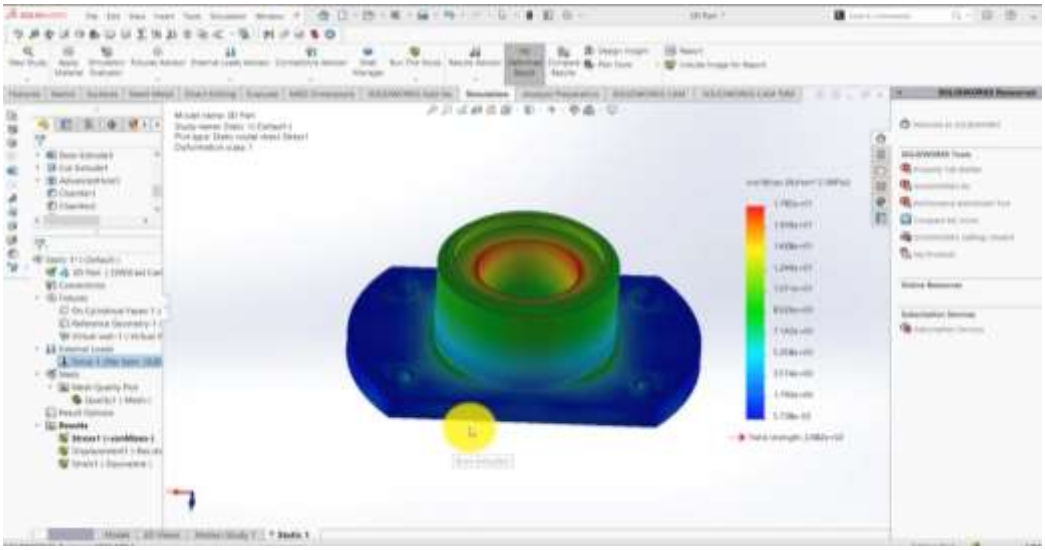
After that I proceeded to created a curvature based mesh and set parameters to increase the accuracy of the simulation. I selected the curvature-based mesh option and set the mesh density to the highest level in the direction of “Fine”.



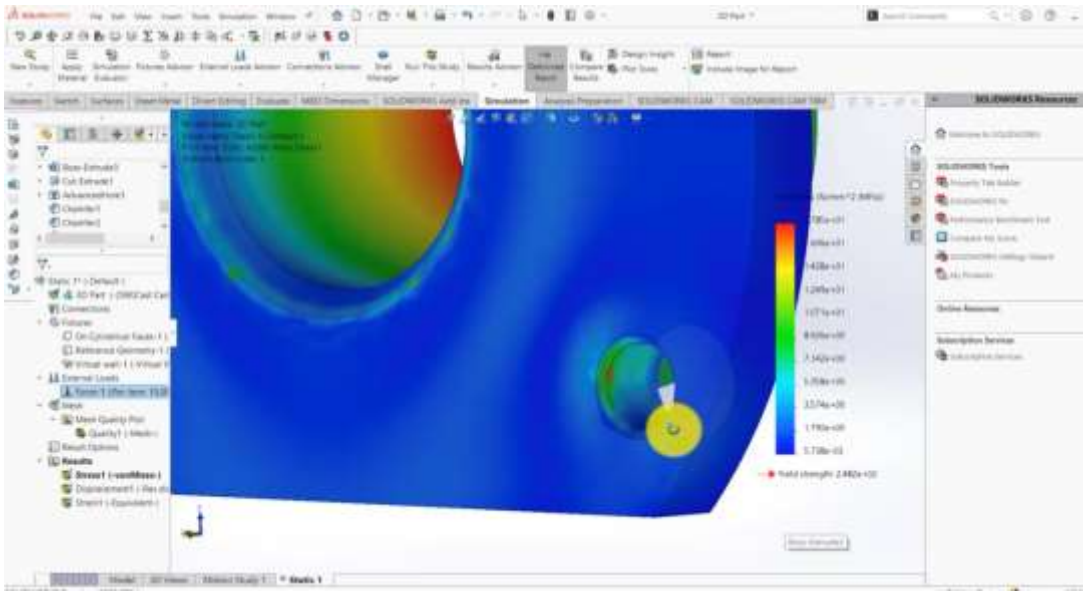
These were the results.

1.6 Stress Results

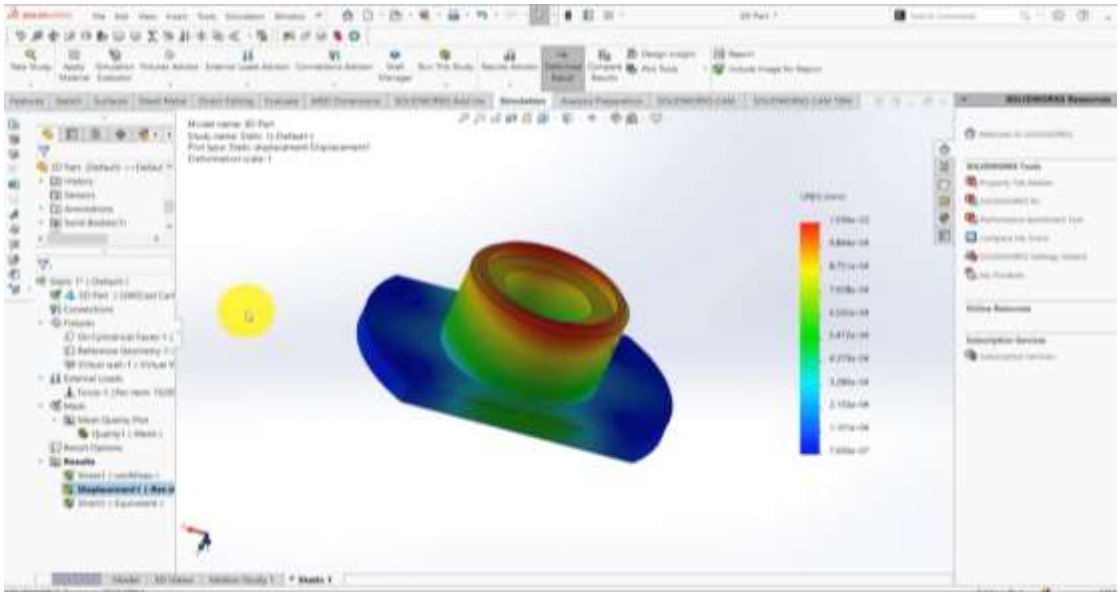


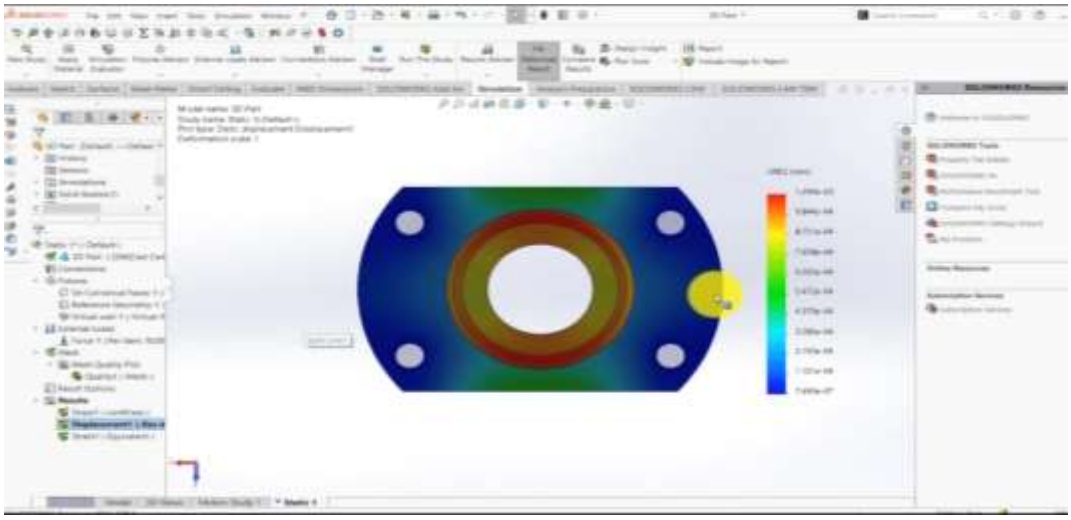


As indicated in the above diagrams, the stress is focused mostly in the inner centre of the model. There is also minor stress in the area where the screws would be placed. The simulation took 11 minutes to run. A force of 10000N was applied to achieve the results



1.6 Displacement Results





For the final step, we look at the displacement levels on the model, as we can see from the images above, we have most displacement taking place on the top part of the model due to it not being fixed on any points and having force applied to it.

CHAPTER 2. Manufacturing process planning

2.1 DFM / DFMA Analysis

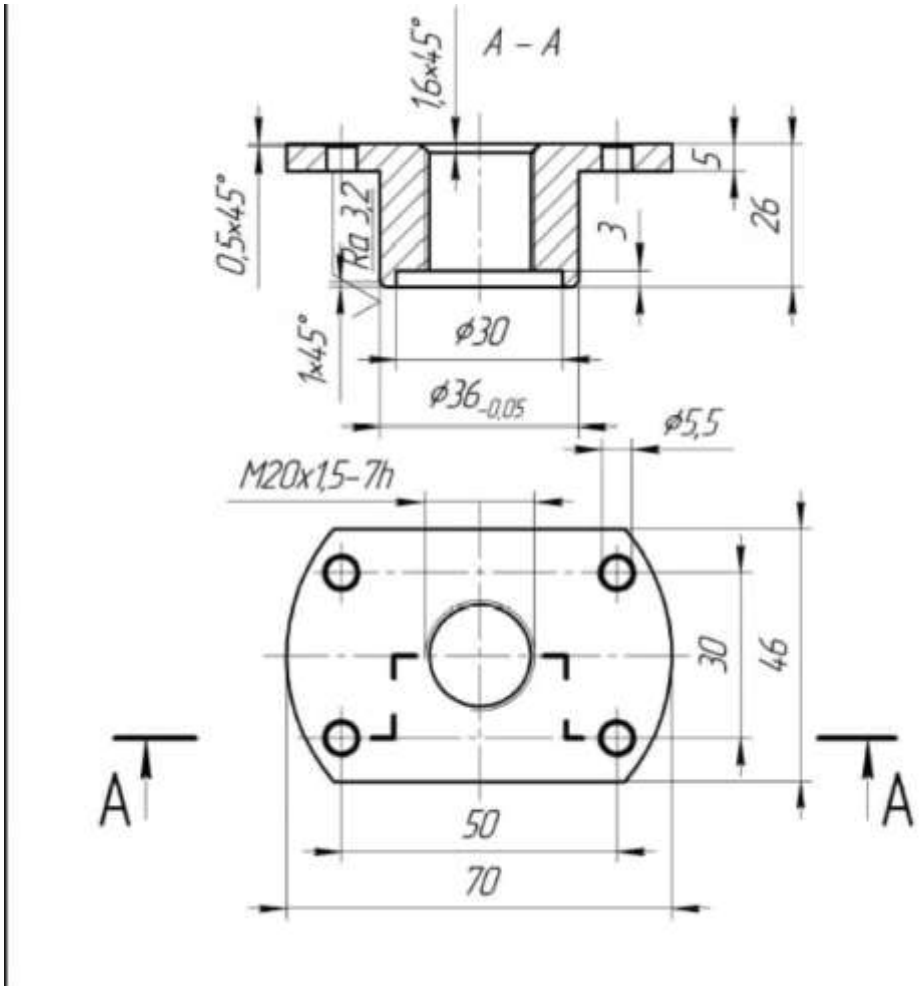


Fig. 1.1: 2D drawing of part

Although there are a few surfaces that are subject to higher criteria, the requirements for the accuracy and quality of the part's surfaces are generally not very high.

Special attention must be taken when manufacturing hole M20x1.5 H7 to ensure alignment and verticality of the shaft, thus ensuring the stability of the hole mechanism.

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

This housing is designed to hold the shaft together in a rigid way and avoid its displacement in any unwanted direction.

The bearing will be held in the M20 H7 hole and holes ⋅ 5.5 will be used to fix the housing on the platform.

2.2 Analysis of the material

This part is made of High-quality structural carbon steel grade 45. It has the following chemical composition:

It has tensile Strength of $\sigma_в$= 600 MPa; HB 10^{-1} = 229 MPa; density ρ = 7,8 g/cm3.

From the information above we can conclude that this part is used for applications including very high strength, extreme hardness and resistance to wear, and moderate ductility.

The drawing of the part has a sufficient number of types, and sections, which provide a complete understanding of the design features of the part.

2.3 Determining the type of production

For educational purposes, we will use analog methods of designation of production type based on the weight of a part and production volume.

Part weight m=0.202 kg (Fig. 1.2) Production volume Np =20000

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

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

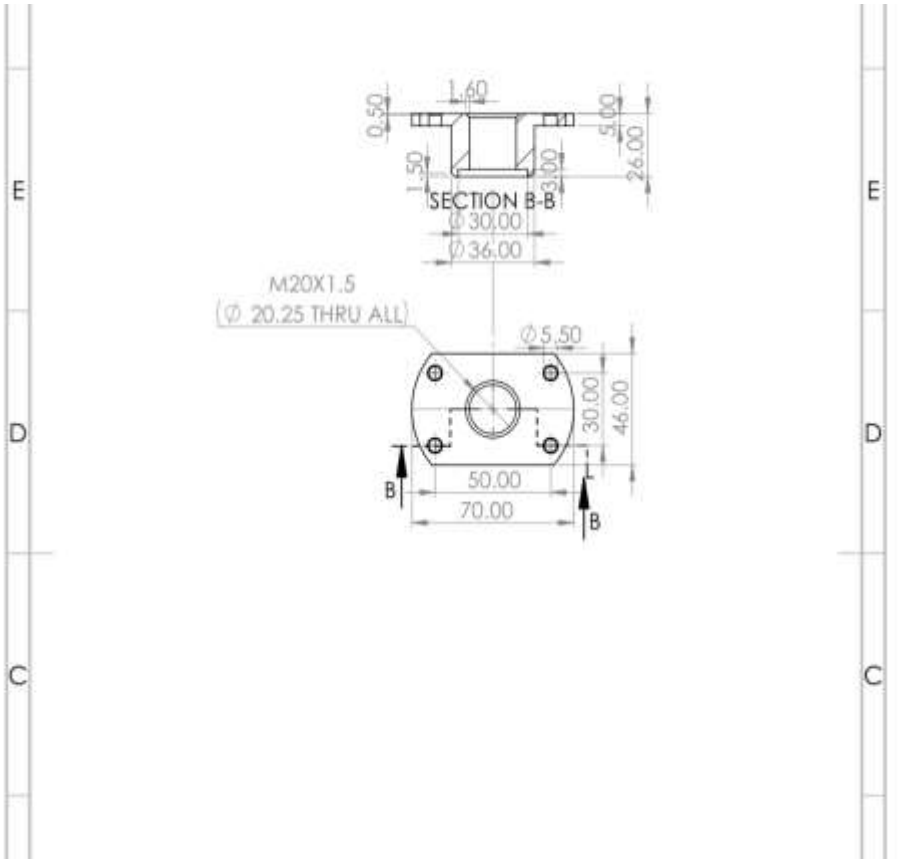
Table 1.1 – Estimation of the production type

Chemical composition in % for grade 45 (45)

C	Si	Mn	Ni	S	P	Cr	Cu	As
0.42 - 0.5	0.17 - 0.37	0.5 - 0.8	max 0.3	max 0.04	max 0.035	max 0.25	max 0.3	max 0.08

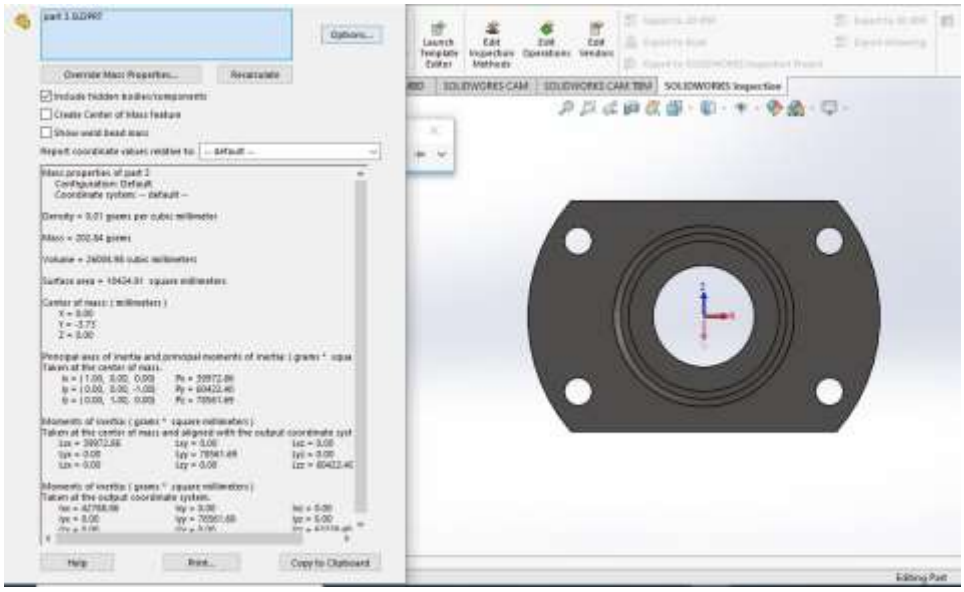
Fig. 1.2 – Characteristics of the part 'Housing' and its 3-D model

Conclusion: According to the information above we will consequently conduct all additional calculations and make technological decisions for the medium-volume manufacturing type, which is medium batch.

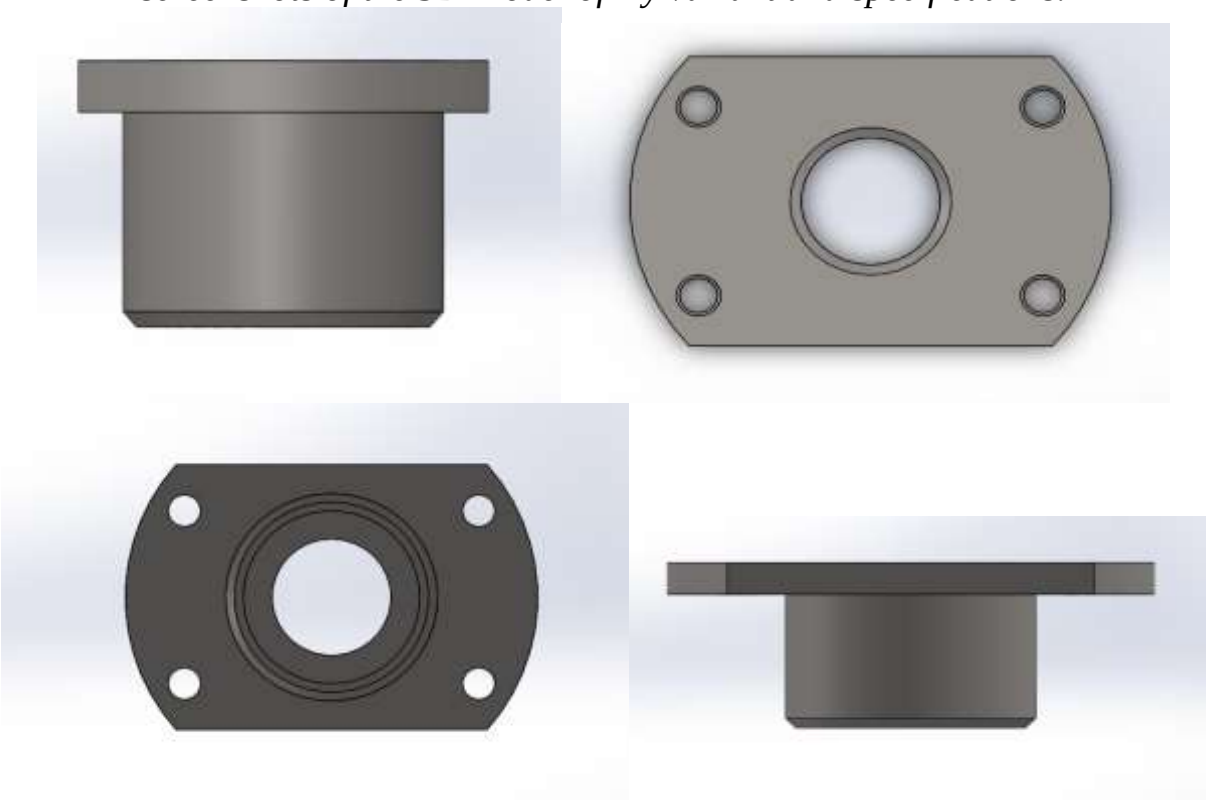


2D Modelling: Above is a 2D sketch of my variant

3D Model: Attached below are screenshots of 3D Model of my variant and



screenshots of the 3D Model of my variant and specifications.



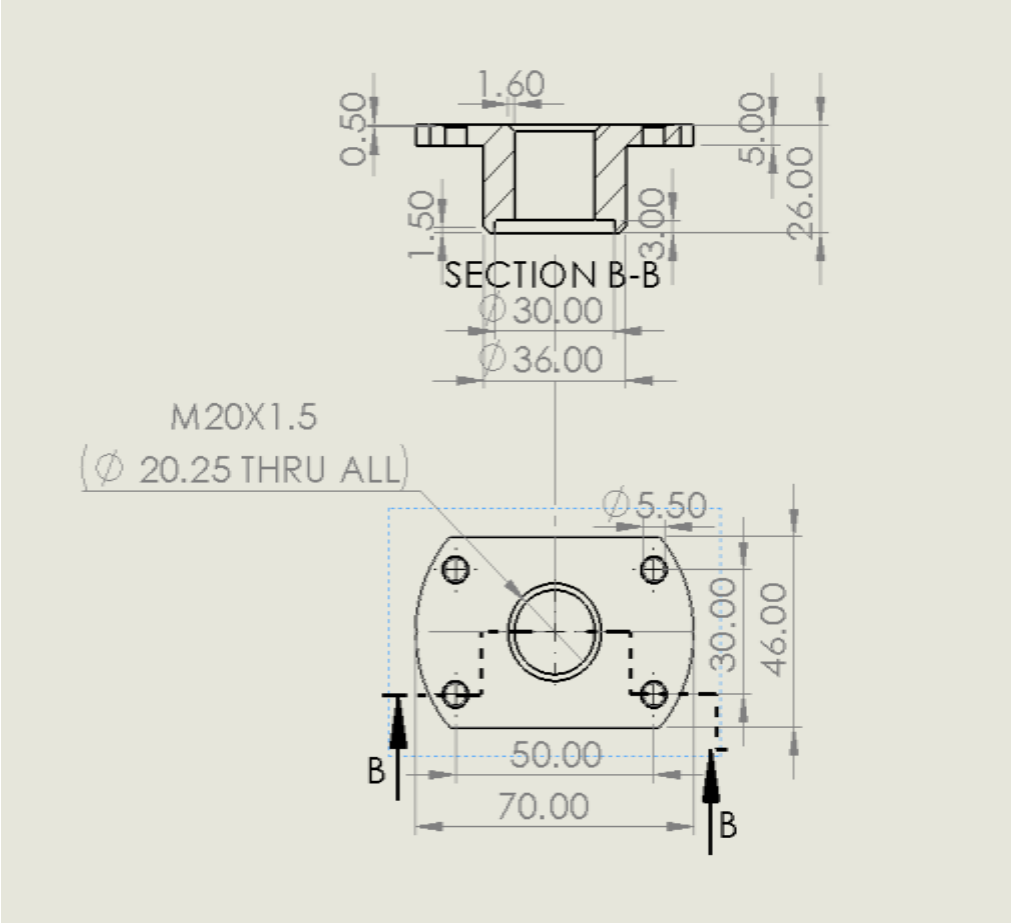
2.4 Selection of the base process and design of the blank

Initial data for the selection primary and secondary manufacturing processes:

drawing of a part;

material of a part – Grey Iron;

Annual output – 20000 pcs.



Considering the material and geometrical shape of a part, as the base process the sand casting could be selected.

To estimate the required machining allowance (RMA) grade we will use Table B.1 [2]. For the sand casting process and Grey Iron the recommended RMA grade is F. Required machining allowance according to the F grade and the largest dimension of a part 70mm (see drawing) is 2 mm according to the table 1 [2].

1 To estimate casting tolerance (CT) grade we will use table A1 (for long series) [2]. For the sand casting process and the Grey Iron the CT 11 could be applied. The results of estimation of casting tolerances are presented in Table 1.

The sketches of RMA and CT location are presented in Fig. 1.3

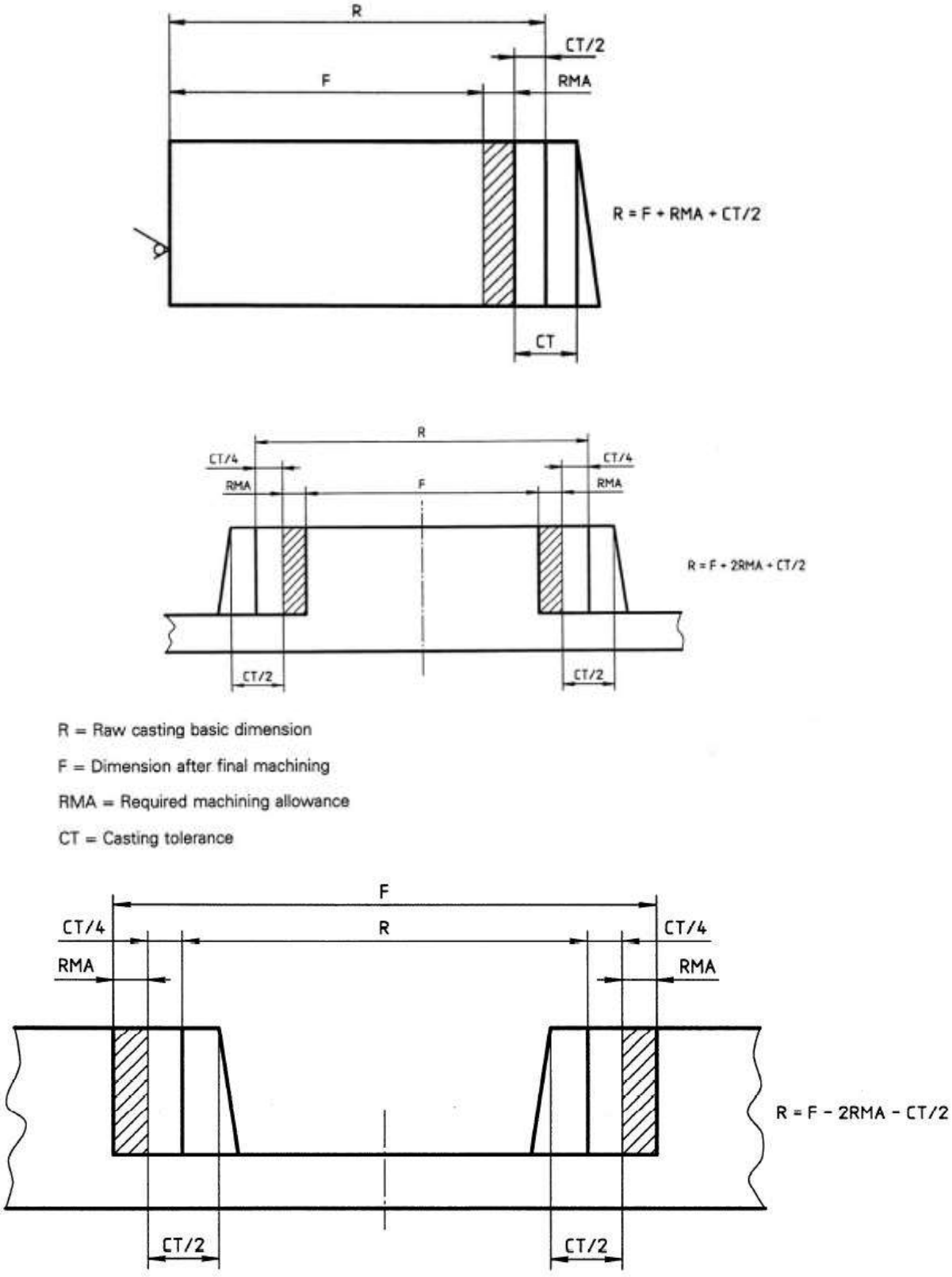


Fig. .1.3 Sketches for determining Raw casting basic dimension

Table 2 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
26	1	30	3.6	31.8±1.8
5	1	8	2.8	9.4±1.4
46	1	50	4	52±2
36	1	40	3.6	41.8±1.8
30	1	26	3.6	24.2±1.8
20	1	16	3	14.5±1.5

During the casting design we considered the following recommendations:

a workpiece is positioned in the way that allows for the lowest possible height in the mold;

the parting line is in the plane of symmetry;

radii of 2-5 mm were applied to all edges;

a draft angle of 2° was applied to all walls, that are perpendicular to the defined parting plane, thus facilitating removing the part from the mould;

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

the 2 centre holes and a main pocket of the part will be obtained using cores;

all small features of the part (for example, small holes) will be obtained by a secondary process. The workpiece design is presented in Fig. 1.4

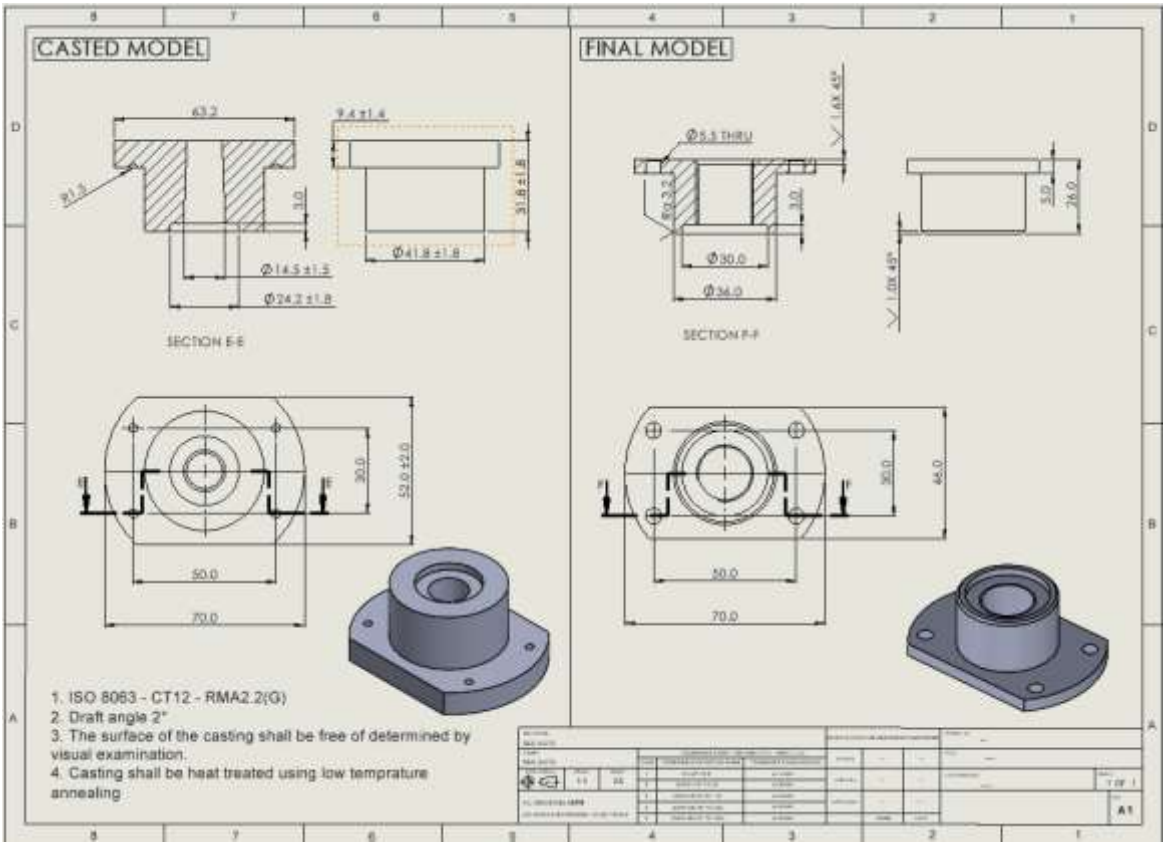


Fig 1.4- Drawing of part and blank (casting)

2.5. Locating scheme selection

When it comes to designing a product, selecting the appropriate location scheme is crucial to ensuring its functionality and effectiveness. The location scheme determines how different components or parts of the product or system are organised and positioned in relation to each other.

In the context of the specific part below, choosing the right location scheme can impact its performance and efficiency. It is important to consider factors such as the size and shape of the part, its intended use, and any other components it interacts with.

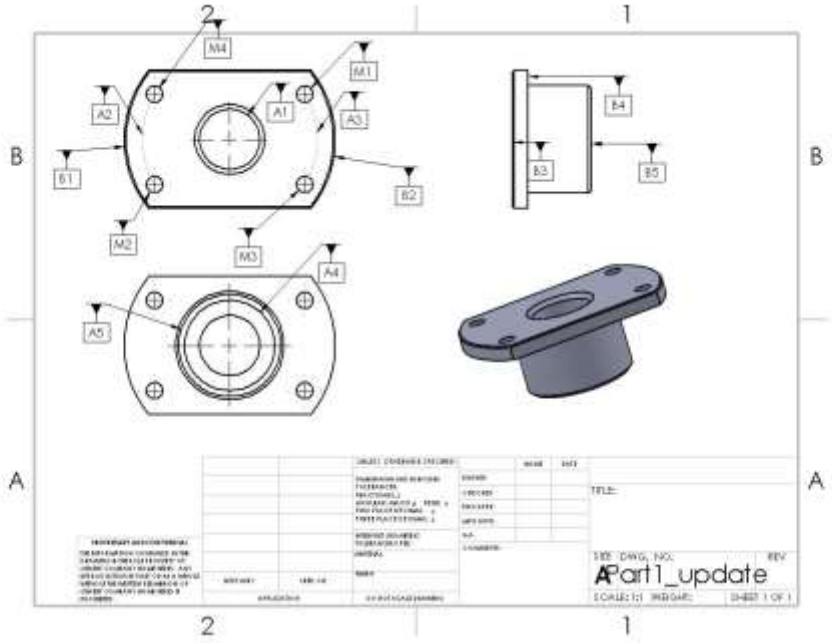
.

General Manufacturing Datum

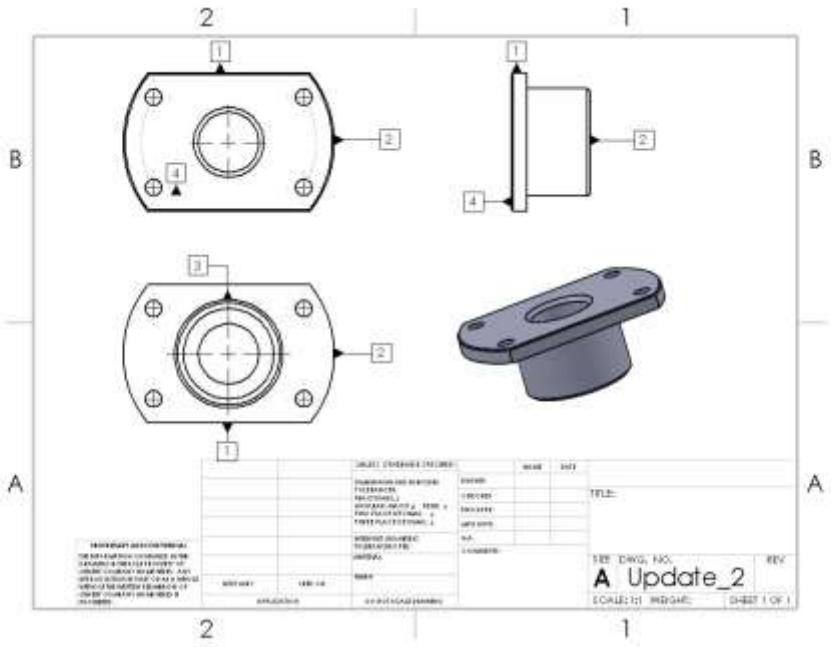
A General Manufacturing Datum (GMD) is a group of datum surfaces that can be utilised for carrying out most, if not all, of the manufacturing procedures. The selection of the appropriate GMD is based on the details outlined in the part's engineering drawing.

In order to effectively choose the GMD, it is essential to categorise the surfaces of the part based on their intended function. The part design can be viewed as a collection of four distinct surface types.

Main functional (design) datum M
Auxiliary functional (design) datum A
Fastening surfaces F
Free surfaces B



As mentioned in the lecture, the fourth locating scheme is an ideal choice due to its ease of implementation and ability to accurately position untreated surfaces relative to processed ones. Moreover, this scheme enables the processing of multiple additional surfaces, besides the general manufacturing datum, during the initial manufacturing operation. Thus, we have decided to use the fourth variant of the locating scheme to process the general manufacturing datum.



2.6. Design of the typical surfaces processing routes

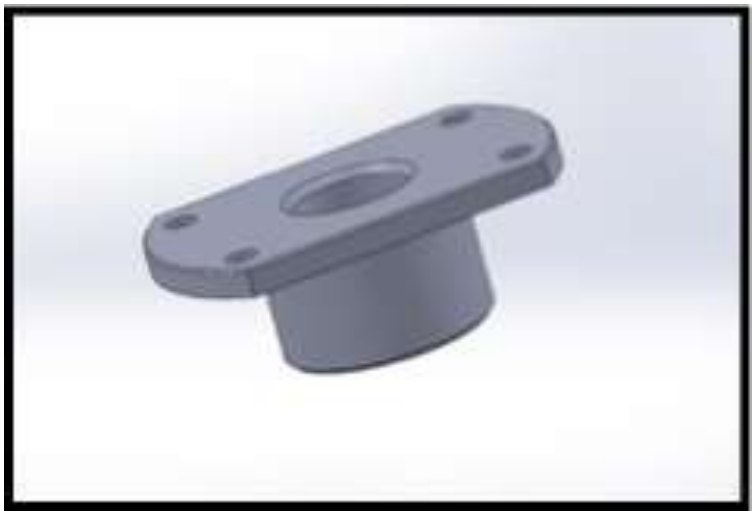


Figure 1.5: The specific part

The design of the typical surfaces processing routes is an important aspect of the manufacturing process for many components and parts. Surface finish and quality can affect the performance, durability, and aesthetics of a part, and it is important to select the right processing routes to achieve the desired finish.

Processing routes can vary depending on the material being processed, the shape and size of the part, and the desired finish quality. For example, a part made of aluminium may require a different processing route than a part made of steel, and a flat surface may require a different processing route than a curved surface.

Typical surface processing routes may include operations such as milling, drilling, turning, grinding, polishing, and electroplating, among others. These operations can be performed manually or using CNC machines, and they can

be performed using a variety of cutting tools, abrasives, and polishing compounds.

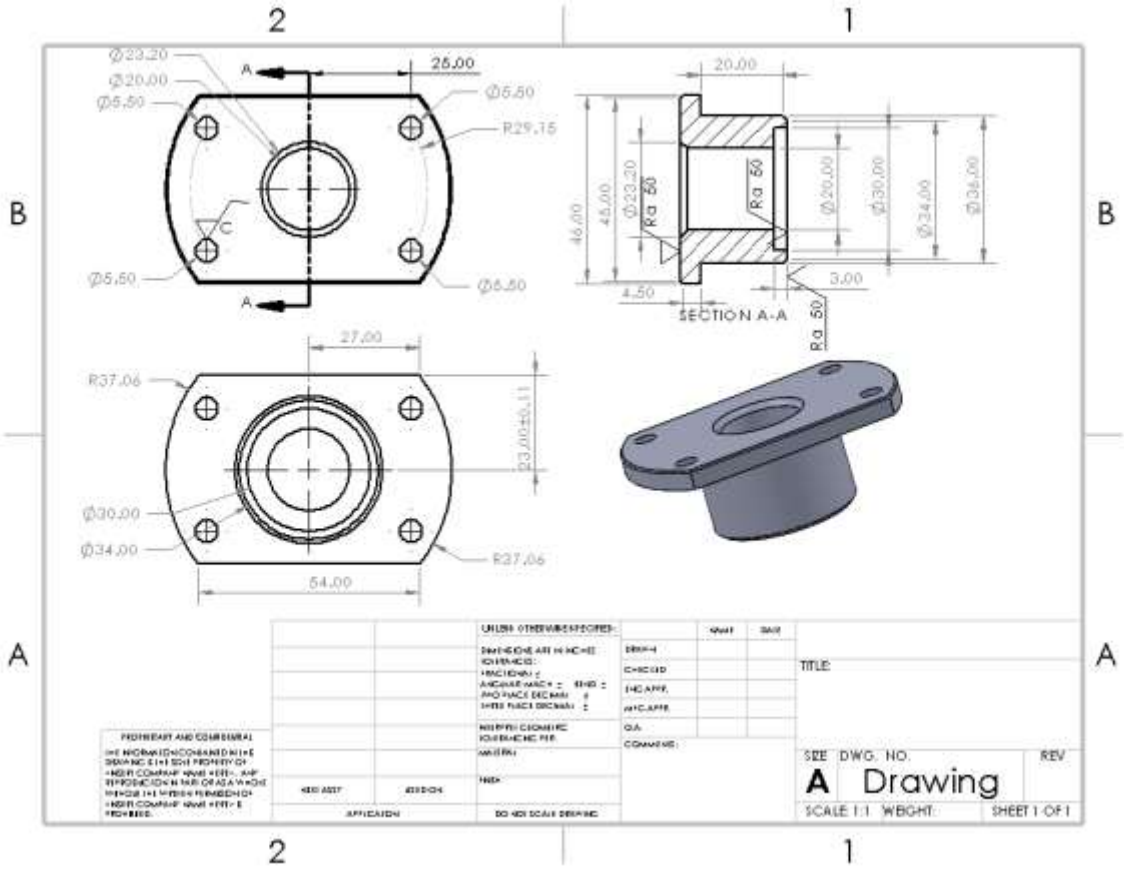
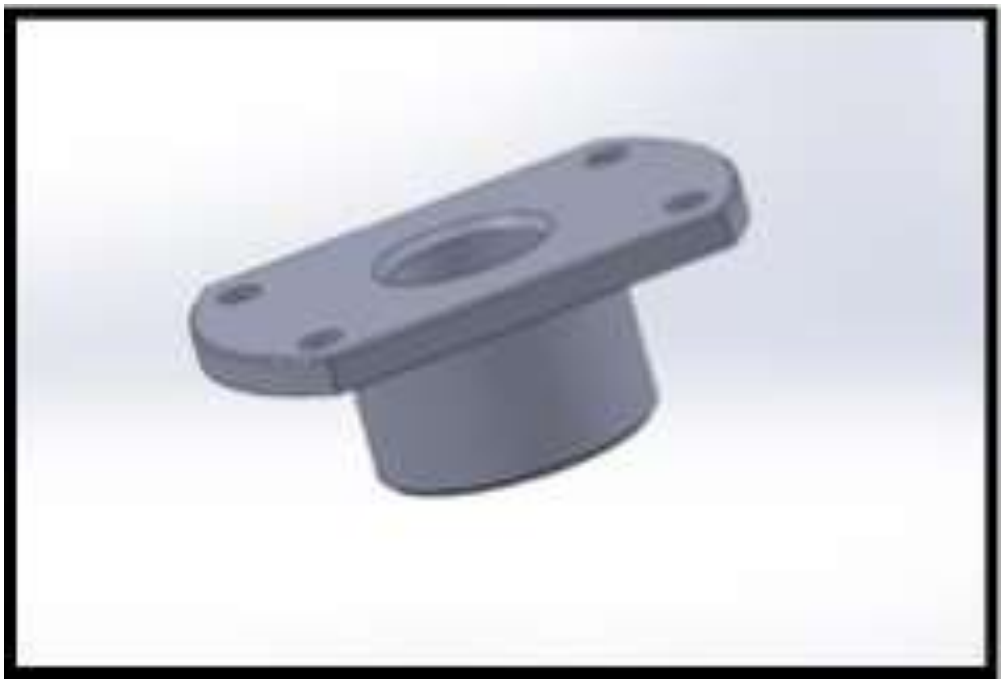


Figure 1,6: Drawing of a part

Table I: Processing routes for surfaces of a part

Surfaces	IT	Ra	Machining	IT	Ra
	According to the drawing		Sequence	After machining	
1	2	3	4	5	6
M1,M2,M3,M4	14	2,5	Centering Drilling	9	2,5
A4	7	0,63	Rough Boring Final Boring	12	6,3
A2,A3	14	5	Rough milling Finish milling	14	6,3 5
A5	14	10	Chambering	14	10
A1	7H		Centering Drilling Countersinking Threading	7H	

2.6. Design of manufacturing process plan



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

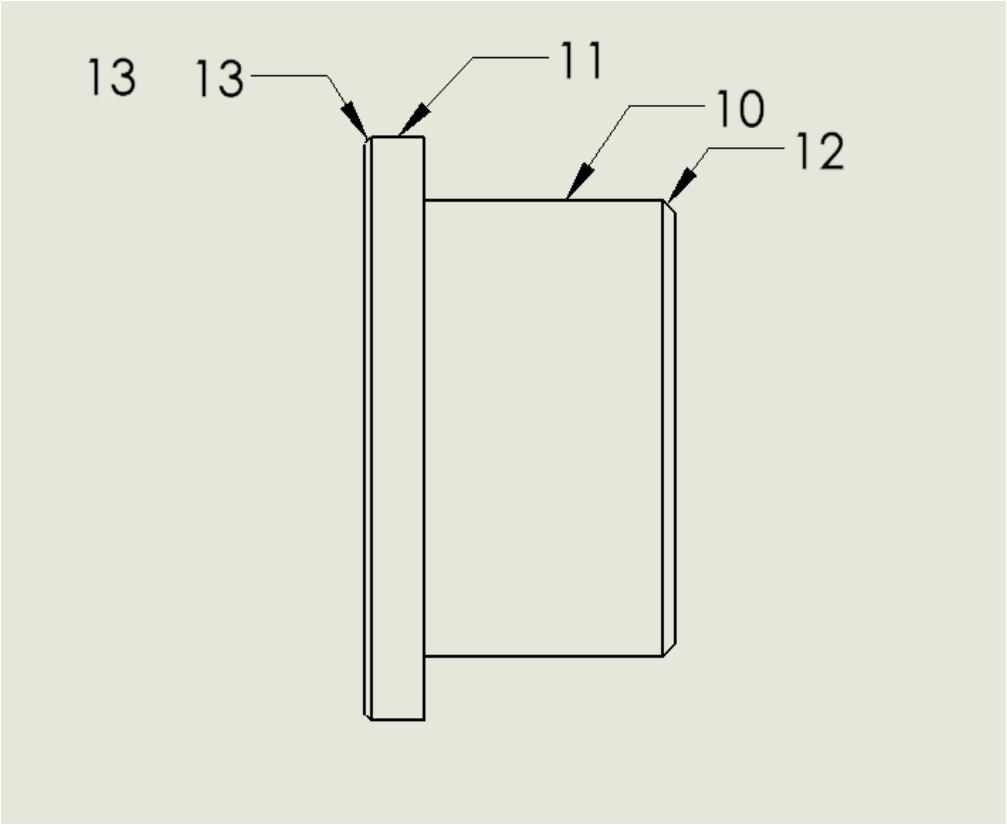
005 Multipurpose

Position 1

Turning operations with right side

05.01 Rough turning the surface 10 and 11 05.02 Finish turning surface 10 and 11 Diameters are 36mm and 46mm

05.03 simultaneously make chamfers 12 and 13 ration 1:1

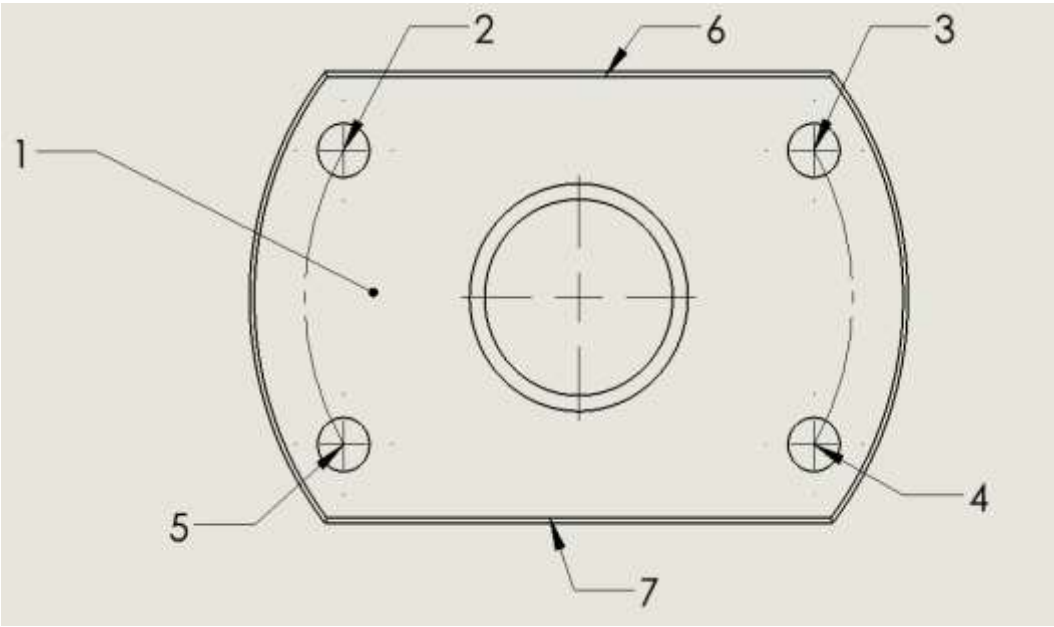


Position 2

Face milling operations – Top surface

05.04 Rough surface milling for face 1 05.05 Finish surface milling for face 1 05.06 Cut the edges straightly surfaces are 6 and 7. The dimension with centre point straightly 23mm

05.07 Mark the centre points for hole number 2,3,4 and 5. 05.08 Drill the holes with diameter 5.5mm 05.09 Make the chamber simultaneously with ratio 1:1 with 1mm for outer line



Position 3

Turn the workpiece 180 degrees for back surface

05.10 Finish surface milling for face 23 05.11 Make the centre for boring 05.12 Rough boring for hole 21 with 20mm diameter 05.13 Finish boring with hole depth 3mm 05.14 Make the centre point again for hole(24) 05.15 Rough Boring for hole number 24 05.16 Finish boring with 20mm dimeter and 25mm depth of the hole. 05.17 Tapper the hole 05.14 Make the chamber simultaneously with ratio 1:1 with 1mm for line 22

2.7 Manufacturing equipment

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

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

Power/Force analysis

After having calculated the power requirements for all operations, those machines that cannot meet the maximum power requirement can be discounted. The exception of this is if there are no other machines available. In this case, reducing feeds and speeds and/or the depth of cut can reduce the power required. On the other hand, those machines with a far greater power output than required can also be discounted. The only exception of this is if such a machine has a higher spindle speed required by one or more operations.

Capability analysis

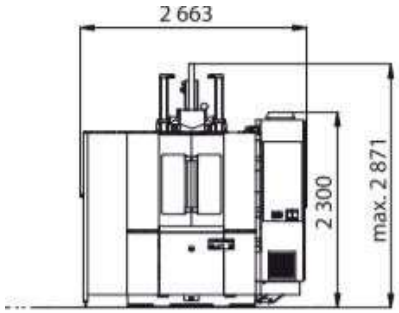
The factors considered in the capability analysis are the dimensional and geometric accuracy and the surface finish required.

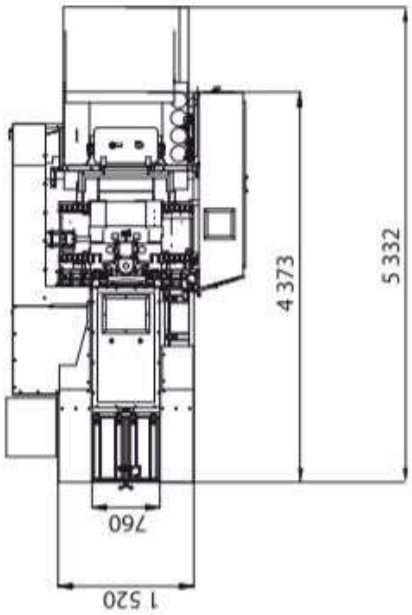
Operational analysis

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

Considering all mentioned requirements and limitations as well as process plan, developed in the previous chapter, the preliminary selected machine is the horizontal machining centre is TAJMAC-ZPSH500.

The horizontal machining centre in the H 500 version (see general technical data in fig. 8.1) is a highly productive machine for the complex chip machining of parts from the steel, grey cast iron and soft metal alloys clamped on the rotary table. It enables to perform the milling operations in three mutually perpendicular X, Y, Z coordinate axes and in the rotary B axis. It also enables to perform the drilling, boring, reaming and thread cutting operations as well as the usage of the screw die heads without aligning bushin the Z axis.





Travels			
X-axis (column)		560 mm	
Y-axis (spindle head)		560 mm	
Z-axis (table)		560 mm	
Max. working feed		50 m/min	
Rapid traverse		50 m/min	
Acceleration		5 m/sec²	
Spindle			
Tool interface	ISO 40	ISO 40	HSK-A63
Maximum speed	10 000 rpm	15 000 rpm*	18 000 rpm*
Continuous output S1 / overload S6 – 40 %	20/30 kW	25/31 kW	25/31 kW
Torque S1 / overloading S6 – 40 %	76/115 Nm	159/197 Nm	159/197 Nm
Transmission type	belt drive	electrospindle	
Rotary table with pallet			
Pallet dimensions		500 × 500 mm	
Range of turning		360 °	
Pallet max. load		300 kg	
Workpiece max. size (dia × height)		ø 600 × 750 mm	
Pallet change time		10 sec	
Measuring accuracy (VDI/DGQ 3441)		**direct / indirect**	
Positioning accuracy (P)		0.008/0.010 mm	
Repeatability (Ps max.)		0.005/0.006 mm	
NC table positioning accuracy (P)		6/22 arc sec	
Distances			
Spindle nose to rotary table axis		130 – 690 mm	
Spindle axis to pallet clamping surface		50 – 610 mm	
Working pallet to floor		1 010 mm	
Tool magazine			
Number of tool pots in magazine		45	
Tool interchange time		3.5 sec	
Tool maximum diameter:			
– fully occupied magazine		70 / 90 mm	
– without adjacent tools		125 mm	
Tool maximum length		300 mm	
Tool maximum weight		7 kg	

2.8 Cutting Tools and Cutting Conditions Selection

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

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

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

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

Selection of tooling – If single-piece tooling is being used, then a suitable tool holder should be selected before fully defining the tool geometry and material. If insert- type tooling is being used then the following steps should be followed:

Select clamping system;
Select tool holder type and size;
Select insert shape;
Select insert size;
Determine tool edge radius;
Select insert type;
Select tool material.

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

Radial cutting width= 24mm

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

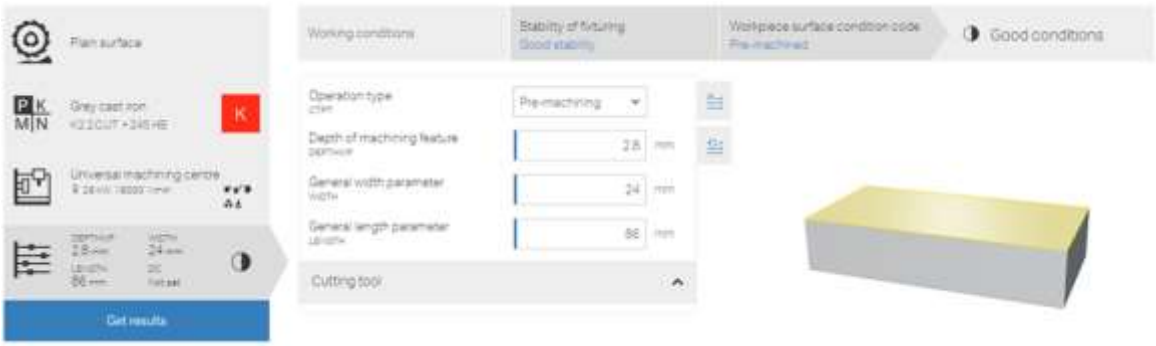


Fig.8.2 Initial Data for tooling selection (screenshot)

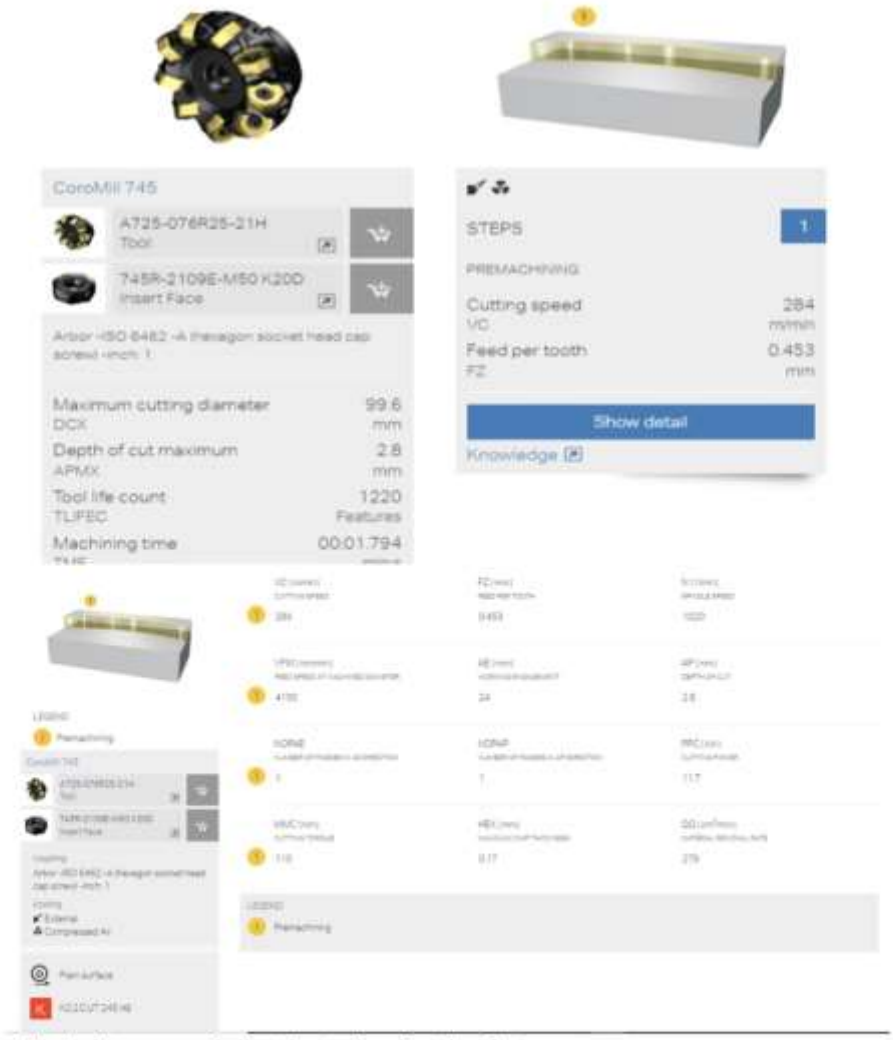


Fig.8.3 Recommended cutting tool and cutting data.

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

2.9 Development of NC PROGRAM

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N120 T3 M6
N130 G0 G90 G54 X25. Y-15.S1000 M3
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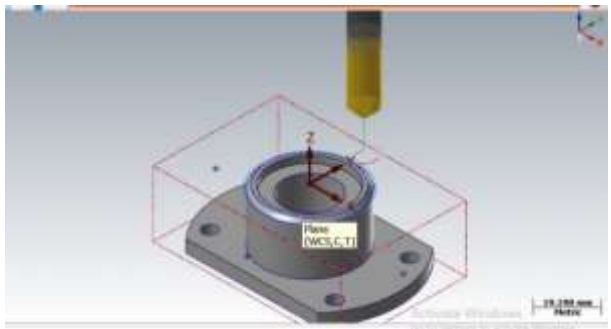

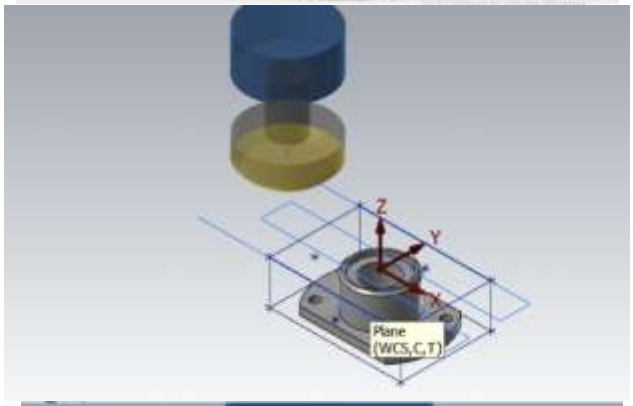

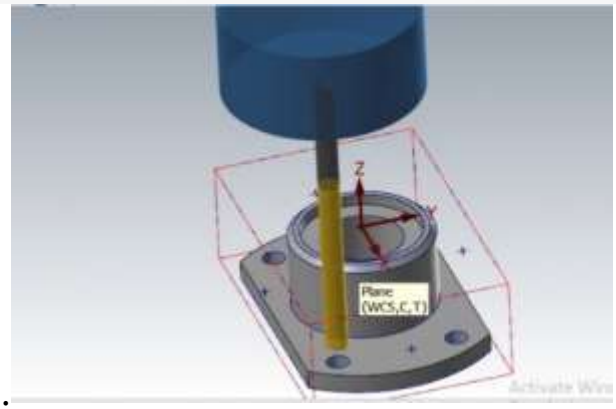

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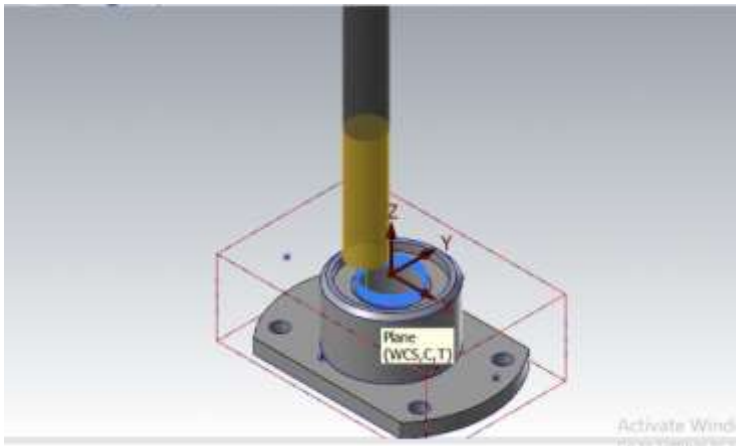


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N190 X-61.5
N200 Y-8.333
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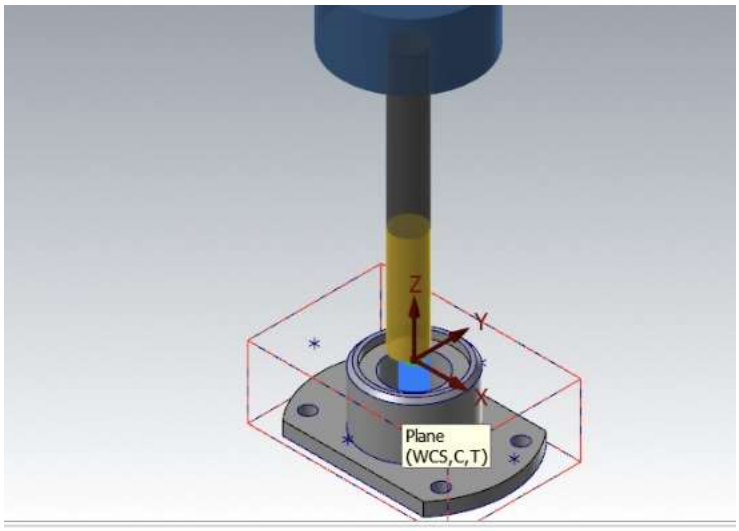


CHAPTER 3: FIXTURE DESIGN

3.1. Introduction

This project aims to design a fixture specifically tailored for machining a part that features a large central hole and small corner holes. The fixture's primary objective is to ensure precise and repeatable machining operations, maintaining dimensional accuracy and alignment. By developing a customised fixture, the project aims to optimise the manufacturing process, enhance productivity, and deliver high-quality parts.

The purpose of this report is to document the design process and specifications for the fixture intended for machining a part with a large central hole and small corner holes. The report aims to provide a comprehensive understanding of the fixture design, including its conceptualisation, engineering drawings, and considerations for manufacturing. Additionally, it serves as a reference for stakeholders involved in the project, providing the necessary information to evaluate, approve, and proceed with the fabrication and assembly of the fixture.

3.2 Part analysis

Critical Features

The part to be machined for this project exhibits several critical features that must be carefully addressed in the fixture design. These features include:

Large Central Hole:

The part contains a large central hole with a diameter of 0.5 mm. The fixture design must ensure precise positioning and stability of the part during the machining process to achieve accurate and consistent results. The fixture should securely hold the part without introducing any deformation or misalignment during the machining operations.

Small Corner Holes:

In addition to the central hole, the part features small corner holes with diameters of 1 mm and 1.6 mm. These holes require precise positioning and alignment to achieve the desired dimensional accuracy. The fixture should provide adequate support and clamping mechanisms to securely hold the part and ensure accurate hole positioning during the machining process.

Chamber Operations:

The part also requires chamber operations with chamber depths ranging from 0.5 mm to 1.6 mm. These operations involve removing material within specific dimensions and depths, necessitating a fixture design that provides stability and accurate positioning for precise machining of the chambers. The fixture should allow for easy access to the chambers and secure clamping to prevent any part movement or misalignment during the machining process.

Challenges and considerations

Part Stability: Ensuring the stability of the part during machining operations is crucial, particularly due to the presence of the large central hole and small corner holes. The fixture design should provide secure clamping and support to prevent any unwanted movement or vibrations that could lead to inaccuracies or damage.

Hole Alignment: Achieving precise alignment of the small corner holes with respect to the larger central hole is essential for maintaining dimensional accuracy. The fixture design must account for the hole positions and provide mechanisms for accurate alignment during the machining process.

Accessibility: The presence of the small corner holes may introduce challenges in terms of accessibility for tooling and machining operations. The fixture design should allow sufficient clearance and unobstructed access to these areas to enable efficient machining without compromising the stability of the part.

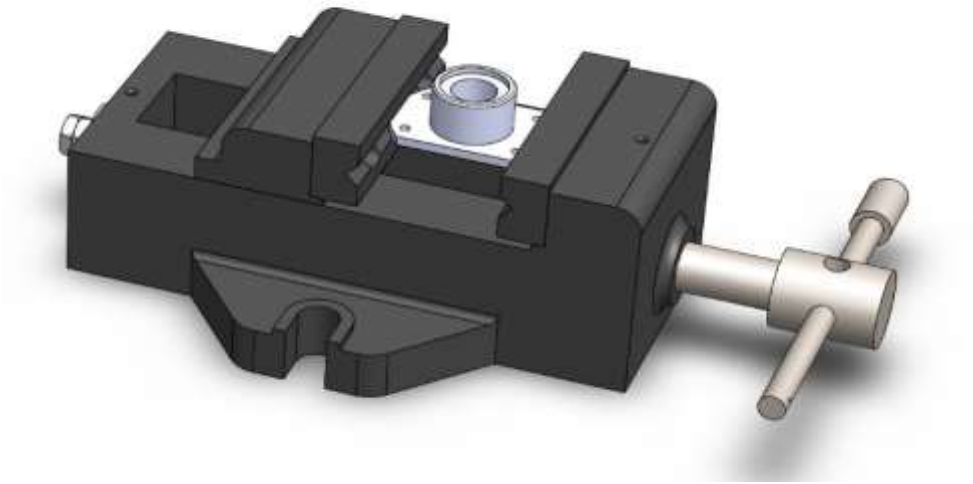
Tolerances and Accuracy: The dimensional tolerances required for the large central hole, small corner holes, and chamber operations are critical. The fixture design must ensure that these tolerances can be consistently achieved, accounting for potential variations in the part and the machining process.

Chip Evacuation: Efficient chip evacuation is essential to maintain a clean machining environment and prevent chip buildup or interference with the machining operations. The fixture design should consider appropriate chip evacuation mechanisms to ensure uninterrupted machining and prevent chip accumulation that could affect accuracy or damage the part.

Fixture Repeatability: The fixture design should enable repeatability in terms of accurately positioning and securing the part for consistent machining operations. It should allow for easy and reliable setup and removal of the part, ensuring that the same alignment and stability can be achieved in subsequent machining operations.

Material Compatibility: Considerations should be given to the material of the fixture itself, ensuring its compatibility with the part material and the machining processes involved. The fixture design should address any potential material interactions or restrictions to ensure optimal performance and longevity

3.3 Design fixture



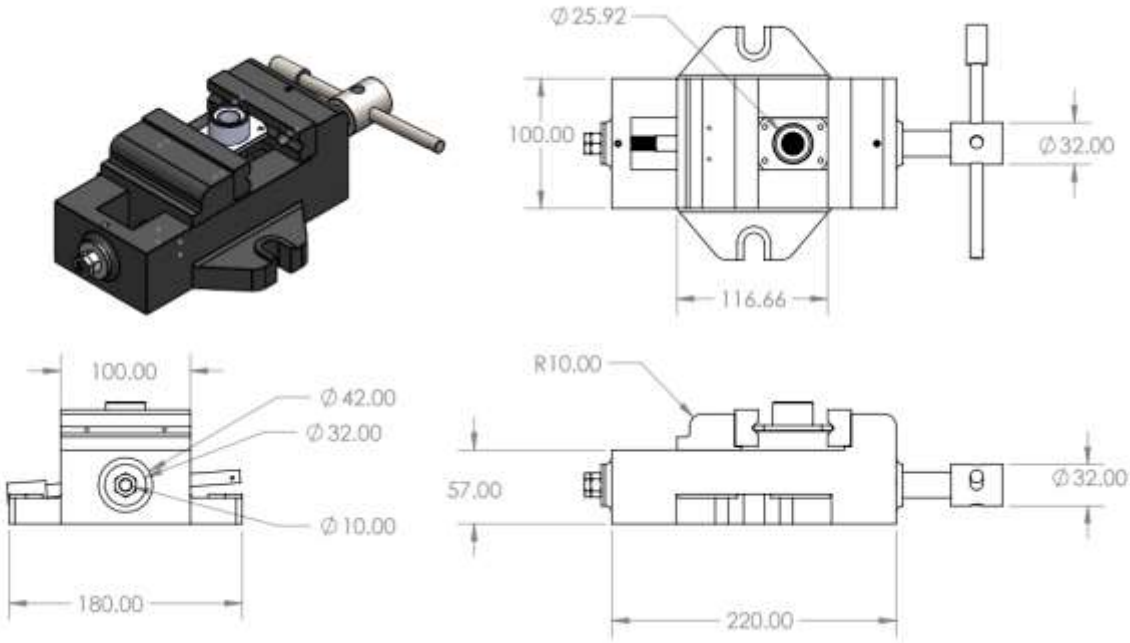


Figure III : Fixture vise drawing

The V-shaped fixture cut vise, ingeniously devised for this particular project, presents an exemplary solution for securely grasping intricate curved

shapes, particularly at the two critical corners of the workpiece. Its distinctive V shape delivers impeccable clamping efficacy by establishing multiple contact points along the curved profiles, effectively thwarting any slippage during the machining process. By conforming to the contours of the curved components, this vise enhances alignment, ensuring utmost precision in positioning.

One of the remarkable advantages of this vise's design lies in its ability to enhance stability. The evenly distributed clamping force it exerts prevents any deformation or distortion, thereby preserving the integrity and dimensional accuracy of the delicate curved parts. The vise's remarkable versatility shines through its capability to accommodate a wide range of curved shapes, making it a go-to solution for various applications across diverse industries.

Fixture Exploded View

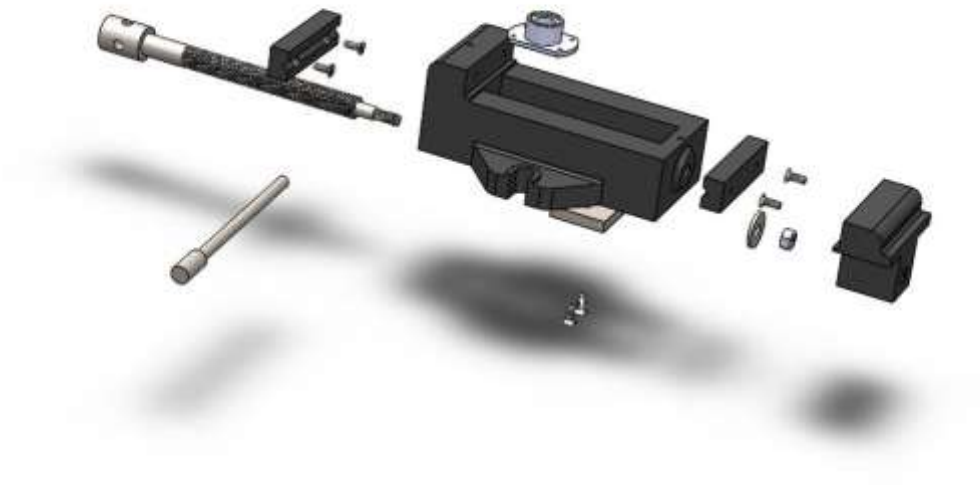


Figure IV: Fixture Exploded View

The exploded view of the fixture design provides a comprehensive visual representation of its intricate components and their precise arrangement.

This detailed illustration showcases the various elements of the fixture, such as clamping mechanisms, supports, and adjustable features, in a meticulously disassembled state.

Each component is strategically positioned to reveal its function and relationship with the others, offering a clear understanding of how the fixture operates and how its parts interact.

The exploded view not only serves as a valuable reference for assembly and disassembly but also aids in troubleshooting and maintenance, as it highlights the specific connections and fasteners involved.

By deconstructing the fixture into its constituent parts, the exploded view provides engineers, technicians, and operators with a comprehensive guide, enabling them to grasp the design intricacies and ensure the optimal functionality of the fixture.

Moveable Jaw

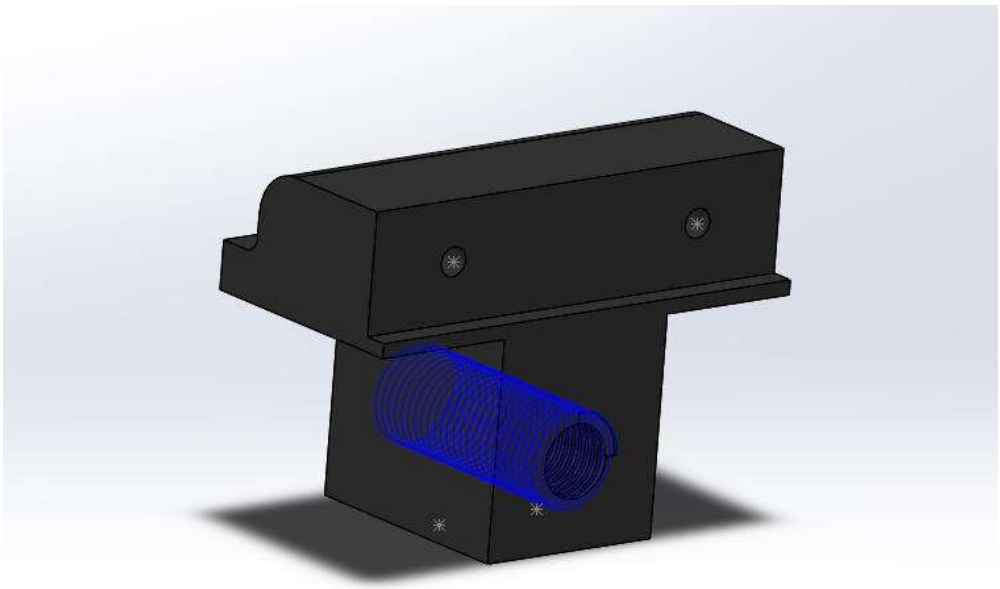


Figure V: Moveable Jaw

The movable jaw in this fixture design plays a crucial role in providing versatility and adaptability to securely hold a wide range of workpieces. Crafted with precision, the movable jaw offers adjustable positioning, allowing for the accommodation of various sizes and shapes of components. Its robust construction ensures durability and long-term reliability.

One notable feature of the movable jaw is the presence of large screw holes that facilitate its movement. These strategically placed screw holes serve as anchor points for the insertion of screws or bolts, enabling the jaw to be easily adjusted and locked into the desired position. The size of these screw holes allows for the use of larger fasteners, providing increased stability and strength when clamping the workpiece.

The large screw holes also contribute to the overall flexibility of the fixture. By having multiple holes along the jaw, it offers multiple options for securing the workpiece, allowing for precise and customized clamping configurations. This adaptability is particularly advantageous when working with irregularly shaped or asymmetrical components, as it enables the jaw to be positioned optimally for secure and stable holding.

Furthermore, the design of the large screw holes ensures a secure grip and prevents any unwanted movement or slippage during machining operations. The increased diameter of the holes allows for a larger contact area between the fastener and the jaw, distributing the clamping force evenly and effectively. This enhanced stability is vital for maintaining the integrity and dimensional accuracy of the workpiece throughout the machining process.

3.4. Evaluation 4.1 Calculation of the required clamping force

Let's assume that the material being clamped is steel, and we want to apply a clamping pressure of 10 MPa (megapascals) or 10 N/mm2. The coefficient of friction between the jaws and the material is typically around 0.4.

First, let's calculate the area of the contact surface:

Area of the contact surface = Length × Width = 70mm × 46mm = 3220 mm2

Now, we can calculate the clamping force: Clamping force = Area of contact surface × Clamping pressure = 3220 mm2 × 10 N/mm2 = 32,200 N

Therefore, the clamping force for the V-shaped jaws with a length of 70mm and a width of 46mm, assuming a clamping pressure of 10 MPa and a coefficient of friction of 0.4, would be approximately 32,200 Newtons.

4. CHAPTER 4. Economic Calculations

4.1 Cost estimation for each machining process

All cost calculations within this work will be performed using on-line Cost Estimator custompartnet.com, available at the web-site: https://www.custompartnet.com/estimate/machining/.

First, we need to specify part quantity – it is the order quantity (or yield quantity), that is the number of parts required from the developed manufacturing process to fill a buyer's total (or annual) order or to be used in a subsequent process. It should be taken into account, that due to the defect rates that are inherent to many manufacturing processes, in most cases a larger production quantity or run quantity must be manufactured to yield the desired order quantity.

In our case annual order is 3200 parts.

Assuming our defect rate for the process is 0.37%. This would be the estimated percentage of the production quantity of parts that are predicted to be defective. These parts nay either be disposed of or recycled for environmental protection.

With the defect rate in mind, the run quantity will be 3,212 parts, which is the total number of parts to be manufactured with the estimated incomplete or defective parts added.

The workpiece is determined to be a casting, so it will be a pre-fabricated part so we will select that option on the site.

The dimensions of the workpiece are 70mm (2.76 in) x 46mm (1.81 in) x 26mm (1.02 in) and weight 0.202 kg (0.01

Fig. 4.2 Stock Information

For the beginning, we will enter the stock information for the part (Fig 4.2) for the material, I have selected medium steel carbon and the workpiece will be prefabricated part. The weight of the part is 0.01lb. The dimensions are as follows:

LENGTH = 70 mm (2.76 inches)

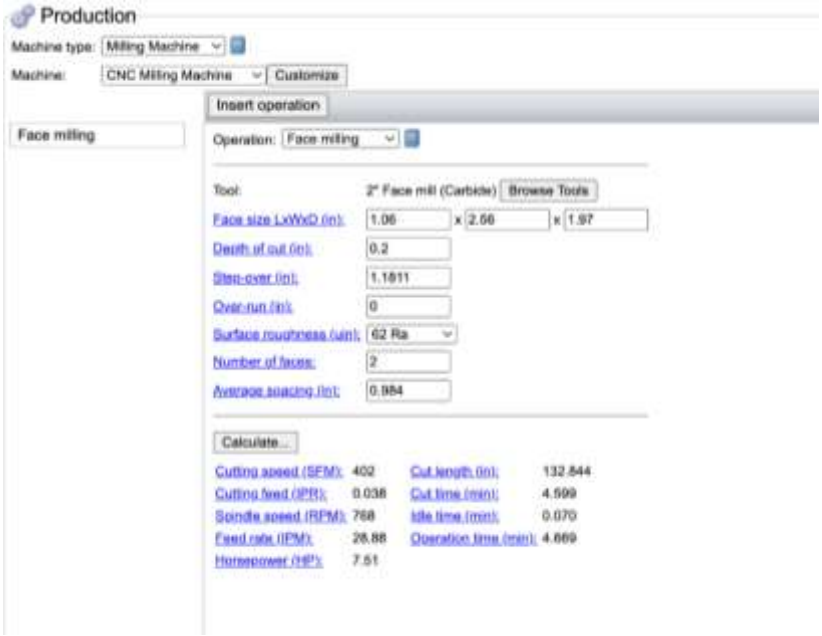
WIDTH = 46 mm (1.81 inches)

HEIGHT = 26 mm (1.02 inches)

The processes for the operations will be indicated below along with screenshots of the parameters used and the estimated machining time for these processes:

Rough Milling for 1 plane: 1.06 in x 2.56 in x 1.97 in with depth of cut 0.2 inches.

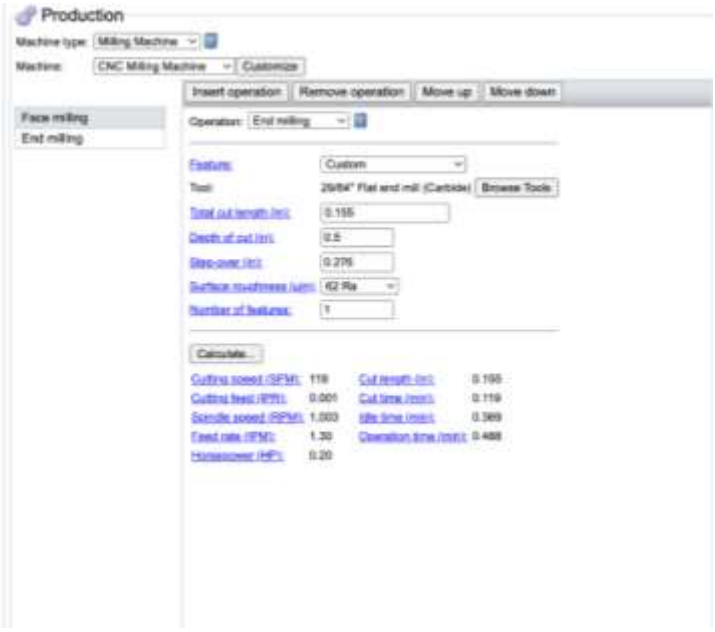
Cutting tool is a face mill Ø50mm with 6 teeth.



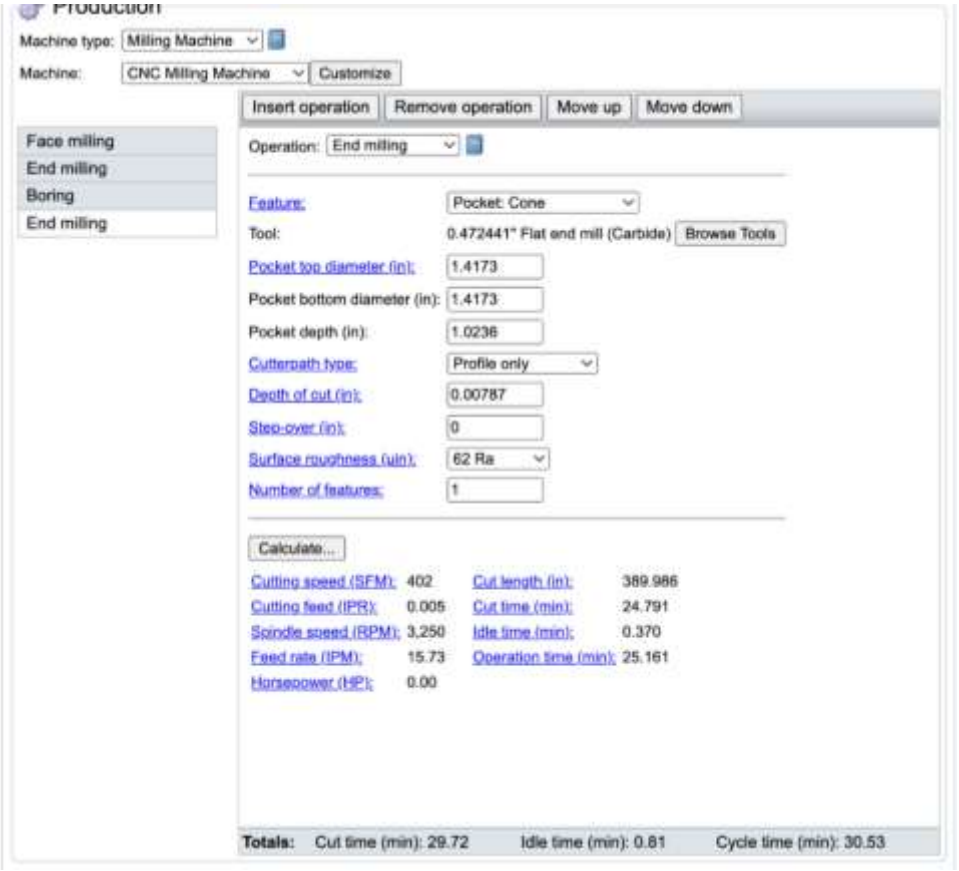
2. Surface milling for 1 plane: dimension

with centre point straightly 23mm

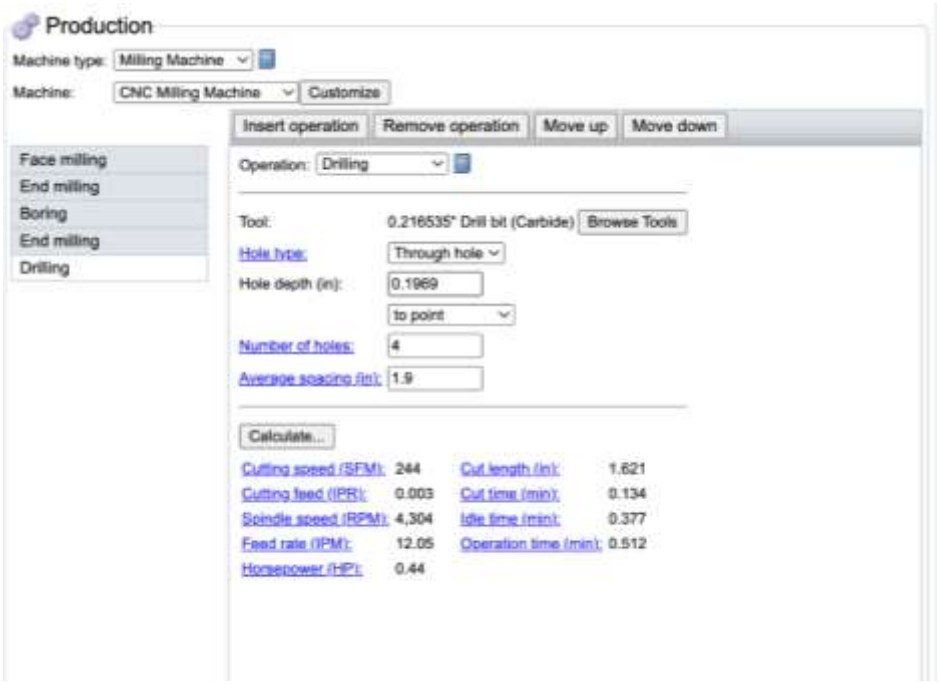
3. End milling: End milling 1 plane, finishing walls of the model 12mm



Operating time presented below.



4. Drilling: Drill 4 holes Ø5.5mm diameter, depth of cut 5mm. Average spacing between holes: 50mm. Operating time presented below



5. Chamfering: Chamfer milling with LxW: 1mm (0.059 in), Operating time presented below

4.3 Total Cost Summary

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14. Jig and Fixture Design Manual by Erik Karl Henriksen.

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ANNEX NC Codes

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N140 G43 H2 Z30. M8
N150 Z10.
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N190 G3 X-24. Y0. I0. J-24.
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N260 Z-.398 F636.6
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N330 G2 X-3.6 Y27.6 I0. J3.6
N340 G1 Y31.2
N350 X3.6
N360 Z-.597 F636.6
N370 Y27.6 F1273.2
N380 G2 X0. Y24. I-3.6 J0.
N390 G3 X-24. Y0. I0. J-24.
N400 X0. Y-24. I24. J0.
N410 X24. Y0. I0. J24.
N420 X0. Y24. I-24. J0.
N430 G2 X-3.6 Y27.6 I0. J3.6
N440 G1 Y31.2
N450 X3.6
N460 Z-.796 F636.6

N470 Y27.6 F1273.2
N480 G2 X0. Y24. I-3.6 J0.
N490 G3 X-24. Y0. I0. J-24.
N500 X0. Y-24. I24. J0.
N510 X24. Y0. I0. J24.
N520 X0. Y24. I-24. J0.
N530 G2 X-3.6 Y27.6 I0. J3.6
N540 G1 Y31.2
N550 X3.6
N560 Z-.995 F636.6
N570 Y27.6 F1273.2
N580 G2 X0. Y24. I-3.6 J0.
N590 G3 X-24. Y0. I0. J-24.
N600 X0. Y-24. I24. J0.
N610 X24. Y0. I0. J24.
N620 X0. Y24. I-24. J0.
N630 G2 X-3.6 Y27.6 I0. J3.6
N640 G1 Y31.2
N650 X3.6
N660 Z-1.194 F636.6
N670 Y27.6 F1273.2
N680 G2 X0. Y24. I-3.6 J0.
N690 G3 X-24. Y0. I0. J-24.
N700 X0. Y-24. I24. J0.
N710 X24. Y0. I0. J24.
N720 X0. Y24. I-24. J0.
N730 G2 X-3.6 Y27.6 I0. J3.6
N740 G1 Y31.2
N750 X3.6
N760 Z-1.394 F636.6
N770 Y27.6 F1273.2
N780 G2 X0. Y24. I-3.6 J0.
N790 G3 X-24. Y0. I0. J-24.
N800 X0. Y-24. I24. J0.
N810 X24. Y0. I0. J24.
N820 X0. Y24. I-24. J0.
N830 G2 X-3.6 Y27.6 I0. J3.6

N840 G1 Y31.2
N850 X3.6
N860 Z-1.593 F636.6
N870 Y27.6 F1273.2
N880 G2 X0. Y24. I-3.6 J0.
N890 G3 X-24. Y0. I0. J-24.
N900 X0. Y-24. I24. J0.
N910 X24. Y0. I0. J24.
N920 X0. Y24. I-24. J0.
N930 G2 X-3.6 Y27.6 I0. J3.6
N940 G1 Y31.2
N950 X3.6
N960 Z-1.792 F636.6
N970 Y27.6 F1273.2
N980 G2 X0. Y24. I-3.6 J0.
N990 G3 X-24. Y0. I0. J-24.
N1000 X0. Y-24. I24. J0.
N1010 X24. Y0. I0. J24.
N1020 X0. Y24. I-24. J0.
N1030 G2 X-3.6 Y27.6 I0. J3.6
N1040 G1 Y31.2
N1050 X3.6
N1060 Z-1.991 F636.6
N1070 Y27.6 F1273.2
N1080 G2 X0. Y24. I-3.6 J0.
N1090 G3 X-24. Y0. I0. J-24.
N1100 X0. Y-24. I24. J0.
N1110 X24. Y0. I0. J24.
N1120 X0. Y24. I-24. J0.
N1130 G2 X-3.6 Y27.6 I0. J3.6
N1140 G1 Y31.2
N1150 X3.6
N1160 Z-2.19 F636.6
N1170 Y27.6 F1273.2
N1180 G2 X0. Y24. I-3.6 J0.
N1190 G3 X-24. Y0. I0. J-24.
N1200 X0. Y-24. I24. J0.

N1210 X24. Y0. I0. J24.
N1220 X0. Y24. I-24. J0.
N1230 G2 X-3.6 Y27.6 I0. J3.6
N1240 G1 Y31.2
N1250 X3.6
N1260 Z-2.389 F636.6
N1270 Y27.6 F1273.2
N1280 G2 X0. Y24. I-3.6 J0.
N1290 G3 X-24. Y0. I0. J-24.
N1300 X0. Y-24. I24. J0.
N1310 X24. Y0. I0. J24.
N1320 X0. Y24. I-24. J0.
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N1340 G1 Y31.2
N1350 X3.6
N1360 Z-2.588 F636.6
N1370 Y27.6 F1273.2
N1380 G2 X0. Y24. I-3.6 J0.
N1390 G3 X-24. Y0. I0. J-24.
N1400 X0. Y-24. I24. J0.
N1410 X24. Y0. I0. J24.
N1420 X0. Y24. I-24. J0.
N1430 G2 X-3.6 Y27.6 I0. J3.6
N1440 G1 Y31.2
N1450 X3.6
N1460 Z-2.787 F636.6
N1470 Y27.6 F1273.2
N1480 G2 X0. Y24. I-3.6 J0.
N1490 G3 X-24. Y0. I0. J-24.
N1500 X0. Y-24. I24. J0.
N1510 X24. Y0. I0. J24.
N1520 X0. Y24. I-24. J0.
N1530 G2 X-3.6 Y27.6 I0. J3.6
N1540 G1 Y31.2
N1550 X3.6
N1560 Z-2.986 F636.6
N1570 Y27.6 F1273.2

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N1590 G3 X-24. Y0. I0. J-24.
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N1610 X24. Y0. I0. J24.
N1620 X0. Y24. I-24. J0.
N1630 G2 X-3.6 Y27.6 I0. J3.6
N1640 G1 Y31.2
N1650 X3.6
N1660 Z-3.185 F636.6
N1670 Y27.6 F1273.2
N1680 G2 X0. Y24. I-3.6 J0.
N1690 G3 X-24. Y0. I0. J-24.
N1700 X0. Y-24. I24. J0.
N1710 X24. Y0. I0. J24.
N1720 X0. Y24. I-24. J0.
N1730 G2 X-3.6 Y27.6 I0. J3.6
N1740 G1 Y31.2
N1750 X3.6
N1760 Z-3.384 F636.6
N1770 Y27.6 F1273.2
N1780 G2 X0. Y24. I-3.6 J0.
N1790 G3 X-24. Y0. I0. J-24.
N1800 X0. Y-24. I24. J0.
N1810 X24. Y0. I0. J24.
N1820 X0. Y24. I-24. J0.
N1830 G2 X-3.6 Y27.6 I0. J3.6
N1840 G1 Y31.2
N1850 X3.6
N1860 Z-3.583 F636.6
N1870 Y27.6 F1273.2
N1880 G2 X0. Y24. I-3.6 J0.
N1890 G3 X-24. Y0. I0. J-24.
N1900 X0. Y-24. I24. J0.
N1910 X24. Y0. I0. J24.
N1920 X0. Y24. I-24. J0.
N1930 G2 X-3.6 Y27.6 I0. J3.6
N1940 G1 Y31.2

N1950 X3.6
N1960 Z-3.782 F636.6
N1970 Y27.6 F1273.2
N1980 G2 X0. Y24. I-3.6 J0.
N1990 G3 X-24. Y0. I0. J-24.
N2000 X0. Y-24. I24. J0.
N2010 X24. Y0. I0. J24.
N2020 X0. Y24. I-24. J0.
N2030 G2 X-3.6 Y27.6 I0. J3.6
N2040 G1 Y31.2
N2050 X3.6
N2060 Z-3.981 F636.6
N2070 Y27.6 F1273.2
N2080 G2 X0. Y24. I-3.6 J0.
N2090 G3 X-24. Y0. I0. J-24.
N2100 X0. Y-24. I24. J0.
N2110 X24. Y0. I0. J24.
N2120 X0. Y24. I-24. J0.
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N2140 G1 Y31.2
N2150 X3.6
N2160 Z-4.181 F636.6
N2170 Y27.6 F1273.2
N2180 G2 X0. Y24. I-3.6 J0.
N2190 G3 X-24. Y0. I0. J-24.
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N2210 X24. Y0. I0. J24.
N2220 X0. Y24. I-24. J0.
N2230 G2 X-3.6 Y27.6 I0. J3.6
N2240 G1 Y31.2
N2250 X3.6
N2260 Z-4.38 F636.6
N2270 Y27.6 F1273.2
N2280 G2 X0. Y24. I-3.6 J0.
N2290 G3 X-24. Y0. I0. J-24.
N2300 X0. Y-24. I24. J0.
N2310 X24. Y0. I0. J24.

N2320 X0. Y24. I-24. J0.
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N2340 G1 Y31.2
N2350 X3.6
N2360 Z-4.579 F636.6
N2370 Y27.6 F1273.2
N2380 G2 X0. Y24. I-3.6 J0.
N2390 G3 X-24. Y0. I0. J-24.
N2400 X0. Y-24. I24. J0.
N2410 X24. Y0. I0. J24.
N2420 X0. Y24. I-24. J0.
N2430 G2 X-3.6 Y27.6 I0. J3.6
N2440 G1 Y31.2
N2450 X3.6
N2460 Z-4.778 F636.6
N2470 Y27.6 F1273.2
N2480 G2 X0. Y24. I-3.6 J0.
N2490 G3 X-24. Y0. I0. J-24.
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N2510 X24. Y0. I0. J24.
N2520 X0. Y24. I-24. J0.
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N2540 G1 Y31.2
N2550 X3.6
N2560 Z-4.977 F636.6
N2570 Y27.6 F1273.2
N2580 G2 X0. Y24. I-3.6 J0.
N2590 G3 X-24. Y0. I0. J-24.
N2600 X0. Y-24. I24. J0.
N2610 X24. Y0. I0. J24.
N2620 X0. Y24. I-24. J0.
N2630 G2 X-3.6 Y27.6 I0. J3.6
N2640 G1 Y31.2
N2650 X3.6
N2660 Z-5.176 F636.6
N2670 Y27.6 F1273.2
N2680 G2 X0. Y24. I-3.6 J0.

N2690 G3 X-24. Y0. I0. J-24.
N2700 X0. Y-24. I24. J0.
N2710 X24. Y0. I0. J24.
N2720 X0. Y24. I-24. J0.
N2730 G2 X-3.6 Y27.6 I0. J3.6
N2740 G1 Y31.2
N2750 X3.6
N2760 Z-5.375 F636.6
N2770 Y27.6 F1273.2
N2780 G2 X0. Y24. I-3.6 J0.
N2790 G3 X-24. Y0. I0. J-24.
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N2810 X24. Y0. I0. J24.
N2820 X0. Y24. I-24. J0.
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N2840 G1 Y31.2
N2850 X3.6
N2860 Z-5.574 F636.6
N2870 Y27.6 F1273.2
N2880 G2 X0. Y24. I-3.6 J0.
N2890 G3 X-24. Y0. I0. J-24.
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N2910 X24. Y0. I0. J24.
N2920 X0. Y24. I-24. J0.
N2930 G2 X-3.6 Y27.6 I0. J3.6
N2940 G1 Y31.2
N2950 X3.6
N2960 Z-5.773 F636.6
N2970 Y27.6 F1273.2
N2980 G2 X0. Y24. I-3.6 J0.
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N3000 X0. Y-24. I24. J0.
N3010 X24. Y0. I0. J24.
N3020 X0. Y24. I-24. J0.
N3030 G2 X-3.6 Y27.6 I0. J3.6
N3040 G1 Y31.2
N3050 X3.6

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N3100 X0. Y-24. I24. J0.
N3110 X24. Y0. I0. J24.
N3120 X0. Y24. I-24. J0.
N3130 G2 X-3.6 Y27.6 I0. J3.6
N3140 G1 Y31.2
N3150 X3.6
N3160 Z-6.171 F636.6
N3170 Y27.6 F1273.2
N3180 G2 X0. Y24. I-3.6 J0.
N3190 G3 X-24. Y0. I0. J-24.
N3200 X0. Y-24. I24. J0.
N3210 X24. Y0. I0. J24.
N3220 X0. Y24. I-24. J0.
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N3240 G1 Y31.2
N3250 X3.6
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N3270 Y27.6 F1273.2
N3280 G2 X0. Y24. I-3.6 J0.
N3290 G3 X-24. Y0. I0. J-24.
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N3320 X0. Y24. I-24. J0.
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N3360 Z-6.569 F636.6
N3370 Y27.6 F1273.2
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N3390 G3 X-24. Y0. I0. J-24.
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N3410 X24. Y0. I0. J24.
N3420 X0. Y24. I-24. J0.
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N3520 X0. Y24. I-24. J0.
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N3610 X24. Y0. I0. J24.
N3620 X0. Y24. I-24. J0.
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N3650 X3.6
N3660 Z-7.167 F636.6
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N3690 G3 X-24. Y0. I0. J-24.
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N3710 X24. Y0. I0. J24.
N3720 X0. Y24. I-24. J0.
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N3740 G1 Y31.2
N3750 X3.6
N3760 Z-7.366 F636.6
N3770 Y27.6 F1273.2
N3780 G2 X0. Y24. I-3.6 J0.
N3790 G3 X-24. Y0. I0. J-24.

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N3810 X24. Y0. I0. J24.
N3820 X0. Y24. I-24. J0.
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N3840 G1 Y31.2
N3850 X3.6
N3860 Z-7.565 F636.6
N3870 Y27.6 F1273.2
N3880 G2 X0. Y24. I-3.6 J0.
N3890 G3 X-24. Y0. I0. J-24.
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N3910 X24. Y0. I0. J24.
N3920 X0. Y24. I-24. J0.
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N3940 G1 Y31.2
N3950 X3.6
N3960 Z-7.764 F636.6
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N4040 G1 Y31.2
N4050 X3.6
N4060 Z-7.963 F636.6
N4070 Y27.6 F1273.2
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N4090 G3 X-24. Y0. I0. J-24.
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N4110 X24. Y0. I0. J24.
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N4150 X3.6
N4160 Z-8.162 F636.6

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N4240 G1 Y31.2
N4250 X3.6
N4260 Z-8.361 F636.6
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N4340 G1 Y31.2
N4350 X3.6
N4360 Z-8.56 F636.6
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N4410 X24. Y0. I0. J24.
N4420 X0. Y24. I-24. J0.
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N4440 G1 Y31.2
N4450 X3.6
N4460 Z-8.759 F636.6
N4470 Y27.6 F1273.2
N4480 G2 X0. Y24. I-3.6 J0.
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N4550 X3.6
N4560 Z-8.958 F636.6
N4570 Y27.6 F1273.2
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N4610 X24. Y0. I0. J24.
N4620 X0. Y24. I-24. J0.
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N4660 Z-9.157 F636.6
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N4740 G1 Y31.2
N4750 X3.6
N4760 Z-9.356 F636.6
N4770 Y27.6 F1273.2
N4780 G2 X0. Y24. I-3.6 J0.
N4790 G3 X-24. Y0. I0. J-24.
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N4810 X24. Y0. I0. J24.
N4820 X0. Y24. I-24. J0.
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N4850 X3.6
N4860 Z-9.556 F636.6
N4870 Y27.6 F1273.2
N4880 G2 X0. Y24. I-3.6 J0.
N4890 G3 X-24. Y0. I0. J-24.
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N4960 Z-9.755 F636.6
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N4980 G2 X0. Y24. I-3.6 J0.
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N5010 X24. Y0. I0. J24.
N5020 X0. Y24. I-24. J0.
N5030 G2 X-3.6 Y27.6 I0. J3.6
N5040 G1 Y31.2
N5050 X3.6
N5060 Z-9.954 F636.6
N5070 Y27.6 F1273.2
N5080 G2 X0. Y24. I-3.6 J0.
N5090 G3 X-24. Y0. I0. J-24.
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N5140 G1 Y31.2
N5150 X3.6
N5160 Z-10.153 F636.6
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N5220 X0. Y24. I-24. J0.
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N5250 X3.6
N5260 Z-10.352 F636.6
N5270 Y27.6 F1273.2

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N5320 X0. Y24. I-24. J0.
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N5350 X3.6
N5360 Z-10.551 F636.6
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N5410 X24. Y0. I0. J24.
N5420 X0. Y24. I-24. J0.
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N5450 X3.6
N5460 Z-10.75 F636.6
N5470 Y27.6 F1273.2
N5480 G2 X0. Y24. I-3.6 J0.
N5490 G3 X-24. Y0. I0. J-24.
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N5510 X24. Y0. I0. J24.
N5520 X0. Y24. I-24. J0.
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N5540 G1 Y31.2
N5550 X3.6
N5560 Z-10.949 F636.6
N5570 Y27.6 F1273.2
N5580 G2 X0. Y24. I-3.6 J0.
N5590 G3 X-24. Y0. I0. J-24.
N5600 X0. Y-24. I24. J0.
N5610 X24. Y0. I0. J24.
N5620 X0. Y24. I-24. J0.
N5630 G2 X-3.6 Y27.6 I0. J3.6
N5640 G1 Y31.2

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N5660 Z-11.148 F636.6
N5670 Y27.6 F1273.2
N5680 G2 X0. Y24. I-3.6 J0.
N5690 G3 X-24. Y0. I0. J-24.
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N5710 X24. Y0. I0. J24.
N5720 X0. Y24. I-24. J0.
N5730 G2 X-3.6 Y27.6 I0. J3.6
N5740 G1 Y31.2
N5750 X3.6
N5760 Z-11.347 F636.6
N5770 Y27.6 F1273.2
N5780 G2 X0. Y24. I-3.6 J0.
N5790 G3 X-24. Y0. I0. J-24.
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N5810 X24. Y0. I0. J24.
N5820 X0. Y24. I-24. J0.
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N5840 G1 Y31.2
N5850 X3.6
N5860 Z-11.546 F636.6
N5870 Y27.6 F1273.2
N5880 G2 X0. Y24. I-3.6 J0.
N5890 G3 X-24. Y0. I0. J-24.
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N5910 X24. Y0. I0. J24.
N5920 X0. Y24. I-24. J0.
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N5940 G1 Y31.2
N5950 X3.6
N5960 Z-11.745 F636.6
N5970 Y27.6 F1273.2
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N6010 X24. Y0. I0. J24.

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N6050 X3.6
N6060 Z-11.944 F636.6
N6070 Y27.6 F1273.2
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N6220 X0. Y24. I-24. J0.
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N6250 X3.6
N6260 Z-12.343 F636.6
N6270 Y27.6 F1273.2
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N6310 X24. Y0. I0. J24.
N6320 X0. Y24. I-24. J0.
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N6350 X3.6
N6360 Z-12.542 F636.6
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N6420 X0. Y24. I-24. J0.
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N6450 X3.6
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N6520 X0. Y24. I-24. J0.
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N6570 Y27.6 F1273.2
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N6610 X24. Y0. I0. J24.
N6620 X0. Y24. I-24. J0.
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N6650 X3.6
N6660 Z-13.139 F636.6
N6670 Y27.6 F1273.2
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N6710 X24. Y0. I0. J24.
N6720 X0. Y24. I-24. J0.
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N6740 G1 Y31.2
N6750 X3.6

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N6820 X0. Y24. I-24. J0.
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N6840 G1 Y31.2
N6850 X3.6
N6860 Z-13.537 F636.6
N6870 Y27.6 F1273.2
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N6910 X24. Y0. I0. J24.
N6920 X0. Y24. I-24. J0.
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N6940 G1 Y31.2
N6950 X3.6
N6960 Z-13.736 F636.6
N6970 Y27.6 F1273.2
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N7050 X3.6
N7060 Z-13.935 F636.6
N7070 Y27.6 F1273.2
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N7150 X3.6
N7160 Z-14.134 F636.6
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N7220 X0. Y24. I-24. J0.
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N7240 G1 Y31.2
N7250 X3.6
N7260 Z-14.333 F636.6
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N7320 X0. Y24. I-24. J0.
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N7340 G1 Y31.2
N7350 X3.6
N7360 Z-14.532 F636.6
N7370 Y27.6 F1273.2
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N7390 G3 X-24. Y0. I0. J-24.
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N7410 X24. Y0. I0. J24.
N7420 X0. Y24. I-24. J0.
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N7440 G1 Y31.2
N7450 X3.6
N7460 Z-14.731 F636.6
N7470 Y27.6 F1273.2
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N7490 G3 X-24. Y0. I0. J-24.

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N7540 G1 Y31.2
N7550 X3.6
N7560 Z-14.931 F636.6
N7570 Y27.6 F1273.2
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N7590 G3 X-24. Y0. I0. J-24.
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N7610 X24. Y0. I0. J24.
N7620 X0. Y24. I-24. J0.
N7630 G2 X-3.6 Y27.6 I0. J3.6
N7640 G1 Y31.2
N7650 X3.6
N7660 Z-15.13 F636.6
N7670 Y27.6 F1273.2
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N7690 G3 X-24. Y0. I0. J-24.
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N7710 X24. Y0. I0. J24.
N7720 X0. Y24. I-24. J0.
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N7740 G1 Y31.2
N7750 X3.6
N7760 Z-15.329 F636.6
N7770 Y27.6 F1273.2
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N7810 X24. Y0. I0. J24.
N7820 X0. Y24. I-24. J0.
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N7840 G1 Y31.2
N7850 X3.6
N7860 Z-15.528 F636.6

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N7910 X24. Y0. I0. J24.
N7920 X0. Y24. I-24. J0.
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N7940 G1 Y31.2
N7950 X3.6
N7960 Z-15.727 F636.6
N7970 Y27.6 F1273.2
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N8010 X24. Y0. I0. J24.
N8020 X0. Y24. I-24. J0.
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N8040 G1 Y31.2
N8050 X3.6
N8060 Z-15.926 F636.6
N8070 Y27.6 F1273.2
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N8090 G3 X-24. Y0. I0. J-24.
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N8120 X0. Y24. I-24. J0.
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N8140 G1 Y31.2
N8150 X3.6
N8160 Z-16.125 F636.6
N8170 Y27.6 F1273.2
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N8220 X0. Y24. I-24. J0.
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N8260 Z-16.324 F636.6
N8270 Y27.6 F1273.2
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N8290 G3 X-24. Y0. I0. J-24.
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N8310 X24. Y0. I0. J24.
N8320 X0. Y24. I-24. J0.
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N8340 G1 Y31.2
N8350 X3.6
N8360 Z-16.523 F636.6
N8370 Y27.6 F1273.2
N8380 G2 X0. Y24. I-3.6 J0.
N8390 G3 X-24. Y0. I0. J-24.
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N8410 X24. Y0. I0. J24.
N8420 X0. Y24. I-24. J0.
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N8440 G1 Y31.2
N8450 X3.6
N8460 Z-16.722 F636.6
N8470 Y27.6 F1273.2
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N8510 X24. Y0. I0. J24.
N8520 X0. Y24. I-24. J0.
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N8540 G1 Y31.2
N8550 X3.6
N8560 Z-16.921 F636.6
N8570 Y27.6 F1273.2
N8580 G2 X0. Y24. I-3.6 J0.
N8590 G3 X-24. Y0. I0. J-24.
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N8610 X24. Y0. I0. J24.
N8620 X0. Y24. I-24. J0.
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N8640 G1 Y31.2
N8650 X3.6
N8660 Z-17.12 F636.6
N8670 Y27.6 F1273.2
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N8690 G3 X-24. Y0. I0. J-24.
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N8710 X24. Y0. I0. J24.
N8720 X0. Y24. I-24. J0.
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N8740 G1 Y31.2
N8750 X3.6
N8760 Z-17.319 F636.6
N8770 Y27.6 F1273.2
N8780 G2 X0. Y24. I-3.6 J0.
N8790 G3 X-24. Y0. I0. J-24.
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N8810 X24. Y0. I0. J24.
N8820 X0. Y24. I-24. J0.
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N8840 G1 Y31.2
N8850 X3.6
N8860 Z-17.519 F636.6
N8870 Y27.6 F1273.2
N8880 G2 X0. Y24. I-3.6 J0.
N8890 G3 X-24. Y0. I0. J-24.
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N8910 X24. Y0. I0. J24.
N8920 X0. Y24. I-24. J0.
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N8940 G1 Y31.2
N8950 X3.6
N8960 Z-17.718 F636.6
N8970 Y27.6 F1273.2

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N9010 X24. Y0. I0. J24.
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N9040 G1 Y31.2
N9050 X3.6
N9060 Z-17.917 F636.6
N9070 Y27.6 F1273.2
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N9090 G3 X-24. Y0. I0. J-24.
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N9110 X24. Y0. I0. J24.
N9120 X0. Y24. I-24. J0.
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N9140 G1 Y31.2
N9150 X3.6
N9160 Z-18.116 F636.6
N9170 Y27.6 F1273.2
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N9220 X0. Y24. I-24. J0.
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N9240 G1 Y31.2
N9250 X3.6
N9260 Z-18.315 F636.6
N9270 Y27.6 F1273.2
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N9290 G3 X-24. Y0. I0. J-24.
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N9310 X24. Y0. I0. J24.
N9320 X0. Y24. I-24. J0.
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N9340 G1 Y31.2

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N9410 X24. Y0. I0. J24.
N9420 X0. Y24. I-24. J0.
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N9440 G1 Y31.2
N9450 X3.6
N9460 Z-18.713 F636.6
N9470 Y27.6 F1273.2
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N9510 X24. Y0. I0. J24.
N9520 X0. Y24. I-24. J0.
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N9540 G1 Y31.2
N9550 X3.6
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N9570 Y27.6 F1273.2
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N9610 X24. Y0. I0. J24.
N9620 X0. Y24. I-24. J0.
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N9650 X3.6
N9660 Z-19.111 F636.6
N9670 Y27.6 F1273.2
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N9690 G3 X-24. Y0. I0. J-24.
N9700 X0. Y-24. I24. J0.
N9710 X24. Y0. I0. J24.

N9720 X0. Y24. I-24. J0.
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N9740 G1 Y31.2
N9750 X3.6
N9760 Z-19.31 F636.6
N9770 Y27.6 F1273.2
N9780 G2 X0. Y24. I-3.6 J0.
N9790 G3 X-24. Y0. I0. J-24.
N9800 X0. Y-24. I24. J0.
N9810 X24. Y0. I0. J24.
N9820 X0. Y24. I-24. J0.
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N9840 G1 Y31.2
N9850 X3.6
N9860 Z-19.509 F636.6
N9870 Y27.6 F1273.2
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N9890 G3 X-24. Y0. I0. J-24.
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N9910 X24. Y0. I0. J24.
N9920 X0. Y24. I-24. J0.
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N9940 G1 Y31.2
N9950 X3.6
N9960 Z-19.708 F636.6
N9970 Y27.6 F1273.2
N9980 G2 X0. Y24. I-3.6 J0.
N9990 G3 X-24. Y0. I0. J-24.
N100 X0. Y-24. I24. J0.
N110 X24. Y0. I0. J24.
N120 X0. Y24. I-24. J0.
N130 G2 X-3.6 Y27.6 I0. J3.6
N140 G1 Y31.2
N150 X3.6
N160 Z-19.907 F636.6
N170 Y27.6 F1273.2
N180 G2 X0. Y24. I-3.6 J0.

N190 G3 X-24. Y0. I0. J-24.
N200 X0. Y-24. I24. J0.
N210 X24. Y0. I0. J24.
N220 X0. Y24. I-24. J0.
N230 G2 X-3.6 Y27.6 I0. J3.6
N240 G1 Y31.2
N250 X3.6
N260 Z-20.106 F636.6
N270 Y27.6 F1273.2
N280 G2 X0. Y24. I-3.6 J0.
N290 G3 X-24. Y0. I0. J-24.
N300 X0. Y-24. I24. J0.
N310 X24. Y0. I0. J24.
N320 X0. Y24. I-24. J0.
N330 G2 X-3.6 Y27.6 I0. J3.6
N340 G1 Y31.2
N350 X3.6
N360 Z-20.306 F636.6
N370 Y27.6 F1273.2
N380 G2 X0. Y24. I-3.6 J0.
N390 G3 X-24. Y0. I0. J-24.
N400 X0. Y-24. I24. J0.
N410 X24. Y0. I0. J24.
N420 X0. Y24. I-24. J0.
N430 G2 X-3.6 Y27.6 I0. J3.6
N440 G1 Y31.2
N450 X3.6
N460 Z-20.505 F636.6
N470 Y27.6 F1273.2
N480 G2 X0. Y24. I-3.6 J0.
N490 G3 X-24. Y0. I0. J-24.
N500 X0. Y-24. I24. J0.
N510 X24. Y0. I0. J24.
N520 X0. Y24. I-24. J0.
N530 G2 X-3.6 Y27.6 I0. J3.6
N540 G1 Y31.2
N550 X3.6

N560 Z-20.704 F636.6
N570 Y27.6 F1273.2
N580 G2 X0. Y24. I-3.6 J0.
N590 G3 X-24. Y0. I0. J-24.
N600 X0. Y-24. I24. J0.
N610 X24. Y0. I0. J24.
N620 X0. Y24. I-24. J0.
N630 G2 X-3.6 Y27.6 I0. J3.6
N640 G1 Y31.2
N650 X3.6
N660 Z-20.903 F636.6
N670 Y27.6 F1273.2
N680 G2 X0. Y24. I-3.6 J0.
N690 G3 X-24. Y0. I0. J-24.
N700 X0. Y-24. I24. J0.
N710 X24. Y0. I0. J24.
N720 X0. Y24. I-24. J0.
N730 G2 X-3.6 Y27.6 I0. J3.6
N740 G1 Y31.2
N750 X3.6
N760 Z-21.102 F636.6
N770 Y27.6 F1273.2
N780 G2 X0. Y24. I-3.6 J0.
N790 G3 X-24. Y0. I0. J-24.
N800 X0. Y-24. I24. J0.
N810 X24. Y0. I0. J24.
N820 X0. Y24. I-24. J0.
N830 G2 X-3.6 Y27.6 I0. J3.6
N840 G1 Y31.2
N850 X3.6
N860 Z-21.301 F636.6
N870 Y27.6 F1273.2
N880 G2 X0. Y24. I-3.6 J0.
N890 G3 X-24. Y0. I0. J-24.
N900 X0. Y-24. I24. J0.
N910 X24. Y0. I0. J24.
N920 X0. Y24. I-24. J0.

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N930 G2 X-3.6 Y27.6 I0. J3.6
N940 G1 Y31.2
N950 X3.6
N960 Z-21.5 F636.6
N970 Y27.6 F1273.2
N980 G2 X0. Y24. I-3.6 J0.
N990 G3 X-24. Y0. I0. J-24.
N1000 X0. Y-24. I24. J0.
N1010 X24. Y0. I0. J24.
N1020 X0. Y24. I-24. J0.
N1030 G2 X-3.6 Y27.6 I0. J3.6
N1040 G1 Y31.2
N1050 G0 Z30.
N1060 Y-1.755
N1070 Z10.
N1080 G1 Z-.199 F636.6
N1090 Y.525 F1273.2
N1100 G2 X0. Y4.125 I3.6 J0.
N1110 X4.125 Y0. I0. J-4.125
N1120 X0. Y-4.125 I-4.125 J0.
N1130 X-4.125 Y0. I0. J4.125
N1140 X0. Y4.125 I4.125 J0.
N1150 X3.6 Y.525 I0. J-3.6
N1160 G1 Y-1.755
N1170 X-3.6
N1180 Z-.398 F636.6
N1190 Y.525 F1273.2
N1200 G2 X0. Y4.125 I3.6 J0.
N1210 X4.125 Y0. I0. J-4.125
N1220 X0. Y-4.125 I-4.125 J0.
N1230 X-4.125 Y0. I0. J4.125
N1240 X0. Y4.125 I4.125 J0.
N1250 X3.6 Y.525 I0. J-3.6
N1260 G1 Y-1.755
N1270 X-3.6
N1280 Z-.597 F636.6
N1290 Y.525 F1273.2
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N1320 X0. Y-4.125 I-4.125 J0.
N1330 X-4.125 Y0. I0. J4.125
N1340 X0. Y4.125 I4.125 J0.
N1350 X3.6 Y.525 I0. J-3.6
N1360 G1 Y-1.755
N1370 X-3.6
N1380 Z-.796 F636.6
N1390 Y.525 F1273.2
N1400 G2 X0. Y4.125 I3.6 J0.
N1410 X4.125 Y0. I0. J-4.125
N1420 X0. Y-4.125 I-4.125 J0.
N1430 X-4.125 Y0. I0. J4.125
N1440 X0. Y4.125 I4.125 J0.
N1450 X3.6 Y.525 I0. J-3.6
N1460 G1 Y-1.755
N1470 X-3.6
N1480 Z-.995 F636.6
N1490 Y.525 F1273.2
N1500 G2 X0. Y4.125 I3.6 J0.
N1510 X4.125 Y0. I0. J-4.125
N1520 X0. Y-4.125 I-4.125 J0.
N1530 X-4.125 Y0. I0. J4.125
N1540 X0. Y4.125 I4.125 J0.
N1550 X3.6 Y.525 I0. J-3.6
N1560 G1 Y-1.755
N1570 X-3.6
N1580 Z-1.194 F636.6
N1590 Y.525 F1273.2
N1600 G2 X0. Y4.125 I3.6 J0.
N1610 X4.125 Y0. I0. J-4.125
N1620 X0. Y-4.125 I-4.125 J0.
N1630 X-4.125 Y0. I0. J4.125
N1640 X0. Y4.125 I4.125 J0.
N1650 X3.6 Y.525 I0. J-3.6
N1660 G1 Y-1.755

N1670 X-3.6
N1680 Z-1.394 F636.6
N1690 Y.525 F1273.2
N1700 G2 X0. Y4.125 I3.6 J0.
N1710 X4.125 Y0. I0. J-4.125
N1720 X0. Y-4.125 I-4.125 J0.
N1730 X-4.125 Y0. I0. J4.125
N1740 X0. Y4.125 I4.125 J0.
N1750 X3.6 Y.525 I0. J-3.6
N1760 G1 Y-1.755
N1770 X-3.6
N1780 Z-1.593 F636.6
N1790 Y.525 F1273.2
N1800 G2 X0. Y4.125 I3.6 J0.
N1810 X4.125 Y0. I0. J-4.125
N1820 X0. Y-4.125 I-4.125 J0.
N1830 X-4.125 Y0. I0. J4.125
N1840 X0. Y4.125 I4.125 J0.
N1850 X3.6 Y.525 I0. J-3.6
N1860 G1 Y-1.755
N1870 X-3.6
N1880 Z-1.792 F636.6
N1890 Y.525 F1273.2
N1900 G2 X0. Y4.125 I3.6 J0.
N1910 X4.125 Y0. I0. J-4.125
N1920 X0. Y-4.125 I-4.125 J0.
N1930 X-4.125 Y0. I0. J4.125
N1940 X0. Y4.125 I4.125 J0.
N1950 X3.6 Y.525 I0. J-3.6
N1960 G1 Y-1.755
N1970 X-3.6
N1980 Z-1.991 F636.6
N1990 Y.525 F1273.2
N2000 G2 X0. Y4.125 I3.6 J0.
N2010 X4.125 Y0. I0. J-4.125
N2020 X0. Y-4.125 I-4.125 J0.
N2030 X-4.125 Y0. I0. J4.125

N2040 X0. Y4.125 I4.125 J0.
N2050 X3.6 Y.525 I0. J-3.6
N2060 G1 Y-1.755
N2070 X-3.6
N2080 Z-2.19 F636.6
N2090 Y.525 F1273.2
N2100 G2 X0. Y4.125 I3.6 J0.
N2110 X4.125 Y0. I0. J-4.125
N2120 X0. Y-4.125 I-4.125 J0.
N2130 X-4.125 Y0. I0. J4.125
N2140 X0. Y4.125 I4.125 J0.
N2150 X3.6 Y.525 I0. J-3.6
N2160 G1 Y-1.755
N2170 X-3.6
N2180 Z-2.389 F636.6
N2190 Y.525 F1273.2
N2200 G2 X0. Y4.125 I3.6 J0.
N2210 X4.125 Y0. I0. J-4.125
N2220 X0. Y-4.125 I-4.125 J0.
N2230 X-4.125 Y0. I0. J4.125
N2240 X0. Y4.125 I4.125 J0.
N2250 X3.6 Y.525 I0. J-3.6
N2260 G1 Y-1.755
N2270 X-3.6
N2280 Z-2.588 F636.6
N2290 Y.525 F1273.2
N2300 G2 X0. Y4.125 I3.6 J0.
N2310 X4.125 Y0. I0. J-4.125
N2320 X0. Y-4.125 I-4.125 J0.
N2330 X-4.125 Y0. I0. J4.125
N2340 X0. Y4.125 I4.125 J0.
N2350 X3.6 Y.525 I0. J-3.6
N2360 G1 Y-1.755
N2370 X-3.6
N2380 Z-2.787 F636.6
N2390 Y.525 F1273.2
N2400 G2 X0. Y4.125 I3.6 J0.

N2410 X4.125 Y0. I0. J-4.125
N2420 X0. Y-4.125 I-4.125 J0.
N2430 X-4.125 Y0. I0. J4.125
N2440 X0. Y4.125 I4.125 J0.
N2450 X3.6 Y.525 I0. J-3.6
N2460 G1 Y-1.755
N2470 X-3.6
N2480 Z-2.986 F636.6
N2490 Y.525 F1273.2
N2500 G2 X0. Y4.125 I3.6 J0.
N2510 X4.125 Y0. I0. J-4.125
N2520 X0. Y-4.125 I-4.125 J0.
N2530 X-4.125 Y0. I0. J4.125
N2540 X0. Y4.125 I4.125 J0.
N2550 X3.6 Y.525 I0. J-3.6
N2560 G1 Y-1.755
N2570 X-3.6
N2580 Z-3.185 F636.6
N2590 Y.525 F1273.2
N2600 G2 X0. Y4.125 I3.6 J0.
N2610 X4.125 Y0. I0. J-4.125
N2620 X0. Y-4.125 I-4.125 J0.
N2630 X-4.125 Y0. I0. J4.125
N2640 X0. Y4.125 I4.125 J0.
N2650 X3.6 Y.525 I0. J-3.6
N2660 G1 Y-1.755
N2670 X-3.6
N2680 Z-3.384 F636.6
N2690 Y.525 F1273.2
N2700 G2 X0. Y4.125 I3.6 J0.
N2710 X4.125 Y0. I0. J-4.125
N2720 X0. Y-4.125 I-4.125 J0.
N2730 X-4.125 Y0. I0. J4.125
N2740 X0. Y4.125 I4.125 J0.
N2750 X3.6 Y.525 I0. J-3.6
N2760 G1 Y-1.755
N2770 X-3.6

N2780 Z-3.583 F636.6
N2790 Y.525 F1273.2
N2800 G2 X0. Y4.125 I3.6 J0.
N2810 X4.125 Y0. I0. J-4.125
N2820 X0. Y-4.125 I-4.125 J0.
N2830 X-4.125 Y0. I0. J4.125
N2840 X0. Y4.125 I4.125 J0.
N2850 X3.6 Y.525 I0. J-3.6
N2860 G1 Y-1.755
N2870 X-3.6
N2880 Z-3.782 F636.6
N2890 Y.525 F1273.2
N2900 G2 X0. Y4.125 I3.6 J0.
N2910 X4.125 Y0. I0. J-4.125
N2920 X0. Y-4.125 I-4.125 J0.
N2930 X-4.125 Y0. I0. J4.125
N2940 X0. Y4.125 I4.125 J0.
N2950 X3.6 Y.525 I0. J-3.6
N2960 G1 Y-1.755
N2970 X-3.6
N2980 Z-3.981 F636.6
N2990 Y.525 F1273.2
N3000 G2 X0. Y4.125 I3.6 J0.
N3010 X4.125 Y0. I0. J-4.125
N3020 X0. Y-4.125 I-4.125 J0.
N3030 X-4.125 Y0. I0. J4.125
N3040 X0. Y4.125 I4.125 J0.
N3050 X3.6 Y.525 I0. J-3.6
N3060 G1 Y-1.755
N3070 X-3.6
N3080 Z-4.181 F636.6
N3090 Y.525 F1273.2
N3100 G2 X0. Y4.125 I3.6 J0.
N3110 X4.125 Y0. I0. J-4.125
N3120 X0. Y-4.125 I-4.125 J0.
N3130 X-4.125 Y0. I0. J4.125
N3140 X0. Y4.125 I4.125 J0.

N3150 X3.6 Y.525 I0. J-3.6
N3160 G1 Y-1.755
N3170 X-3.6
N3180 Z-4.38 F636.6
N3190 Y.525 F1273.2
N3200 G2 X0. Y4.125 I3.6 J0.
N3210 X4.125 Y0. I0. J-4.125
N3220 X0. Y-4.125 I-4.125 J0.
N3230 X-4.125 Y0. I0. J4.125
N3240 X0. Y4.125 I4.125 J0.
N3250 X3.6 Y.525 I0. J-3.6
N3260 G1 Y-1.755
N3270 X-3.6
N3280 Z-4.579 F636.6
N3290 Y.525 F1273.2
N3300 G2 X0. Y4.125 I3.6 J0.
N3310 X4.125 Y0. I0. J-4.125
N3320 X0. Y-4.125 I-4.125 J0.
N3330 X-4.125 Y0. I0. J4.125
N3340 X0. Y4.125 I4.125 J0.
N3350 X3.6 Y.525 I0. J-3.6
N3360 G1 Y-1.755
N3370 X-3.6
N3380 Z-4.778 F636.6
N3390 Y.525 F1273.2
N3400 G2 X0. Y4.125 I3.6 J0.
N3410 X4.125 Y0. I0. J-4.125
N3420 X0. Y-4.125 I-4.125 J0.
N3430 X-4.125 Y0. I0. J4.125
N3440 X0. Y4.125 I4.125 J0.
N3450 X3.6 Y.525 I0. J-3.6
N3460 G1 Y-1.755
N3470 X-3.6
N3480 Z-4.977 F636.6
N3490 Y.525 F1273.2
N3500 G2 X0. Y4.125 I3.6 J0.
N3510 X4.125 Y0. I0. J-4.125

N3520 X0. Y-4.125 I-4.125 J0.
N3530 X-4.125 Y0. I0. J4.125
N3540 X0. Y4.125 I4.125 J0.
N3550 X3.6 Y.525 I0. J-3.6
N3560 G1 Y-1.755
N3570 X-3.6
N3580 Z-5.176 F636.6
N3590 Y.525 F1273.2
N3600 G2 X0. Y4.125 I3.6 J0.
N3610 X4.125 Y0. I0. J-4.125
N3620 X0. Y-4.125 I-4.125 J0.
N3630 X-4.125 Y0. I0. J4.125
N3640 X0. Y4.125 I4.125 J0.
N3650 X3.6 Y.525 I0. J-3.6
N3660 G1 Y-1.755
N3670 X-3.6
N3680 Z-5.375 F636.6
N3690 Y.525 F1273.2
N3700 G2 X0. Y4.125 I3.6 J0.
N3710 X4.125 Y0. I0. J-4.125
N3720 X0. Y-4.125 I-4.125 J0.
N3730 X-4.125 Y0. I0. J4.125
N3740 X0. Y4.125 I4.125 J0.
N3750 X3.6 Y.525 I0. J-3.6
N3760 G1 Y-1.755
N3770 X-3.6
N3780 Z-5.574 F636.6
N3790 Y.525 F1273.2
N3800 G2 X0. Y4.125 I3.6 J0.
N3810 X4.125 Y0. I0. J-4.125
N3820 X0. Y-4.125 I-4.125 J0.
N3830 X-4.125 Y0. I0. J4.125
N3840 X0. Y4.125 I4.125 J0.
N3850 X3.6 Y.525 I0. J-3.6
N3860 G1 Y-1.755
N3870 X-3.6
N3880 Z-5.773 F636.6

N3890 Y.525 F1273.2
N3900 G2 X0. Y4.125 I3.6 J0.
N3910 X4.125 Y0. I0. J-4.125
N3920 X0. Y-4.125 I-4.125 J0.
N3930 X-4.125 Y0. I0. J4.125
N3940 X0. Y4.125 I4.125 J0.
N3950 X3.6 Y.525 I0. J-3.6
N3960 G1 Y-1.755
N3970 X-3.6
N3980 Z-5.972 F636.6
N3990 Y.525 F1273.2
N4000 G2 X0. Y4.125 I3.6 J0.
N4010 X4.125 Y0. I0. J-4.125
N4020 X0. Y-4.125 I-4.125 J0.
N4030 X-4.125 Y0. I0. J4.125
N4040 X0. Y4.125 I4.125 J0.
N4050 X3.6 Y.525 I0. J-3.6
N4060 G1 Y-1.755
N4070 X-3.6
N4080 Z-6.171 F636.6
N4090 Y.525 F1273.2
N4100 G2 X0. Y4.125 I3.6 J0.
N4110 X4.125 Y0. I0. J-4.125
N4120 X0. Y-4.125 I-4.125 J0.
N4130 X-4.125 Y0. I0. J4.125
N4140 X0. Y4.125 I4.125 J0.
N4150 X3.6 Y.525 I0. J-3.6
N4160 G1 Y-1.755
N4170 X-3.6
N4180 Z-6.37 F636.6
N4190 Y.525 F1273.2
N4200 G2 X0. Y4.125 I3.6 J0.
N4210 X4.125 Y0. I0. J-4.125
N4220 X0. Y-4.125 I-4.125 J0.
N4230 X-4.125 Y0. I0. J4.125
N4240 X0. Y4.125 I4.125 J0.
N4250 X3.6 Y.525 I0. J-3.6

N4260 G1 Y-1.755
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N4280 Z-6.569 F636.6
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N4330 X-4.125 Y0. I0. J4.125
N4340 X0. Y4.125 I4.125 J0.
N4350 X3.6 Y.525 I0. J-3.6
N4360 G1 Y-1.755
N4370 X-3.6
N4380 Z-6.769 F636.6
N4390 Y.525 F1273.2
N4400 G2 X0. Y4.125 I3.6 J0.
N4410 X4.125 Y0. I0. J-4.125
N4420 X0. Y-4.125 I-4.125 J0.
N4430 X-4.125 Y0. I0. J4.125
N4440 X0. Y4.125 I4.125 J0.
N4450 X3.6 Y.525 I0. J-3.6
N4460 G1 Y-1.755
N4470 X-3.6
N4480 Z-6.968 F636.6
N4490 Y.525 F1273.2
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N4510 X4.125 Y0. I0. J-4.125
N4520 X0. Y-4.125 I-4.125 J0.
N4530 X-4.125 Y0. I0. J4.125
N4540 X0. Y4.125 I4.125 J0.
N4550 X3.6 Y.525 I0. J-3.6
N4560 G1 Y-1.755
N4570 X-3.6
N4580 Z-7.167 F636.6
N4590 Y.525 F1273.2
N4600 G2 X0. Y4.125 I3.6 J0.
N4610 X4.125 Y0. I0. J-4.125
N4620 X0. Y-4.125 I-4.125 J0.

N4630 X-4.125 Y0. I0. J4.125
N4640 X0. Y4.125 I4.125 J0.
N4650 X3.6 Y.525 I0. J-3.6
N4660 G1 Y-1.755
N4670 X-3.6
N4680 Z-7.366 F636.6
N4690 Y.525 F1273.2
N4700 G2 X0. Y4.125 I3.6 J0.
N4710 X4.125 Y0. I0. J-4.125
N4720 X0. Y-4.125 I-4.125 J0.
N4730 X-4.125 Y0. I0. J4.125
N4740 X0. Y4.125 I4.125 J0.
N4750 X3.6 Y.525 I0. J-3.6
N4760 G1 Y-1.755
N4770 X-3.6
N4780 Z-7.565 F636.6
N4790 Y.525 F1273.2
N4800 G2 X0. Y4.125 I3.6 J0.
N4810 X4.125 Y0. I0. J-4.125
N4820 X0. Y-4.125 I-4.125 J0.
N4830 X-4.125 Y0. I0. J4.125
N4840 X0. Y4.125 I4.125 J0.
N4850 X3.6 Y.525 I0. J-3.6
N4860 G1 Y-1.755
N4870 X-3.6
N4880 Z-7.764 F636.6
N4890 Y.525 F1273.2
N4900 G2 X0. Y4.125 I3.6 J0.
N4910 X4.125 Y0. I0. J-4.125
N4920 X0. Y-4.125 I-4.125 J0.
N4930 X-4.125 Y0. I0. J4.125
N4940 X0. Y4.125 I4.125 J0.
N4950 X3.6 Y.525 I0. J-3.6
N4960 G1 Y-1.755
N4970 X-3.6
N4980 Z-7.963 F636.6
N4990 Y.525 F1273.2

N5000 G2 X0. Y4.125 I3.6 J0.
N5010 X4.125 Y0. I0. J-4.125
N5020 X0. Y-4.125 I-4.125 J0.
N5030 X-4.125 Y0. I0. J4.125
N5040 X0. Y4.125 I4.125 J0.
N5050 X3.6 Y.525 I0. J-3.6
N5060 G1 Y-1.755
N5070 X-3.6
N5080 Z-8.162 F636.6
N5090 Y.525 F1273.2
N5100 G2 X0. Y4.125 I3.6 J0.
N5110 X4.125 Y0. I0. J-4.125
N5120 X0. Y-4.125 I-4.125 J0.
N5130 X-4.125 Y0. I0. J4.125
N5140 X0. Y4.125 I4.125 J0.
N5150 X3.6 Y.525 I0. J-3.6
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N9770 X-3.6
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N9970 X-3.6
N9980 Z-17.917 F636.6
N9990 Y.525 F1273.2
N100 G2 X0. Y4.125 I3.6 J0.
N110 X4.125 Y0. I0. J-4.125
N120 X0. Y-4.125 I-4.125 J0.
N130 X-4.125 Y0. I0. J4.125
N140 X0. Y4.125 I4.125 J0.
N150 X3.6 Y.525 I0. J-3.6
N160 G1 Y-1.755
N170 X-3.6
N180 Z-18.116 F636.6
N190 Y.525 F1273.2
N200 G2 X0. Y4.125 I3.6 J0.
N210 X4.125 Y0. I0. J-4.125
N220 X0. Y-4.125 I-4.125 J0.
N230 X-4.125 Y0. I0. J4.125
N240 X0. Y4.125 I4.125 J0.
N250 X3.6 Y.525 I0. J-3.6
N260 G1 Y-1.755
N270 X-3.6

N280 Z-18.315 F636.6
N290 Y.525 F1273.2
N300 G2 X0. Y4.125 I3.6 J0.
N310 X4.125 Y0. I0. J-4.125
N320 X0. Y-4.125 I-4.125 J0.
N330 X-4.125 Y0. I0. J4.125
N340 X0. Y4.125 I4.125 J0.
N350 X3.6 Y.525 I0. J-3.6
N360 G1 Y-1.755
N370 X-3.6
N380 Z-18.514 F636.6
N390 Y.525 F1273.2
N400 G2 X0. Y4.125 I3.6 J0.
N410 X4.125 Y0. I0. J-4.125
N420 X0. Y-4.125 I-4.125 J0.
N430 X-4.125 Y0. I0. J4.125
N440 X0. Y4.125 I4.125 J0.
N450 X3.6 Y.525 I0. J-3.6
N460 G1 Y-1.755
N470 X-3.6
N480 Z-18.713 F636.6
N490 Y.525 F1273.2
N500 G2 X0. Y4.125 I3.6 J0.
N510 X4.125 Y0. I0. J-4.125
N520 X0. Y-4.125 I-4.125 J0.
N530 X-4.125 Y0. I0. J4.125
N540 X0. Y4.125 I4.125 J0.
N550 X3.6 Y.525 I0. J-3.6
N560 G1 Y-1.755
N570 X-3.6
N580 Z-18.912 F636.6
N590 Y.525 F1273.2
N600 G2 X0. Y4.125 I3.6 J0.
N610 X4.125 Y0. I0. J-4.125
N620 X0. Y-4.125 I-4.125 J0.
N630 X-4.125 Y0. I0. J4.125
N640 X0. Y4.125 I4.125 J0.

N650 X3.6 Y.525 I0. J-3.6
N660 G1 Y-1.755
N670 X-3.6
N680 Z-19.111 F636.6
N690 Y.525 F1273.2
N700 G2 X0. Y4.125 I3.6 J0.
N710 X4.125 Y0. I0. J-4.125
N720 X0. Y-4.125 I-4.125 J0.
N730 X-4.125 Y0. I0. J4.125
N740 X0. Y4.125 I4.125 J0.
N750 X3.6 Y.525 I0. J-3.6
N760 G1 Y-1.755
N770 X-3.6
N780 Z-19.31 F636.6
N790 Y.525 F1273.2
N800 G2 X0. Y4.125 I3.6 J0.
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N820 X0. Y-4.125 I-4.125 J0.
N830 X-4.125 Y0. I0. J4.125
N840 X0. Y4.125 I4.125 J0.
N850 X3.6 Y.525 I0. J-3.6
N860 G1 Y-1.755
N870 X-3.6
N880 Z-19.509 F636.6
N890 Y.525 F1273.2
N900 G2 X0. Y4.125 I3.6 J0.
N910 X4.125 Y0. I0. J-4.125
N920 X0. Y-4.125 I-4.125 J0.
N930 X-4.125 Y0. I0. J4.125
N940 X0. Y4.125 I4.125 J0.
N950 X3.6 Y.525 I0. J-3.6
N960 G1 Y-1.755
N970 X-3.6
N980 Z-19.708 F636.6
N990 Y.525 F1273.2
N1000 G2 X0. Y4.125 I3.6 J0.
N1010 X4.125 Y0. I0. J-4.125

N1020 X0. Y-4.125 I-4.125 J0.
N1030 X-4.125 Y0. I0. J4.125
N1040 X0. Y4.125 I4.125 J0.
N1050 X3.6 Y.525 I0. J-3.6
N1060 G1 Y-1.755
N1070 X-3.6
N1080 Z-19.907 F636.6
N1090 Y.525 F1273.2
N1100 G2 X0. Y4.125 I3.6 J0.
N1110 X4.125 Y0. I0. J-4.125
N1120 X0. Y-4.125 I-4.125 J0.
N1130 X-4.125 Y0. I0. J4.125
N1140 X0. Y4.125 I4.125 J0.
N1150 X3.6 Y.525 I0. J-3.6
N1160 G1 Y-1.755
N1170 X-3.6
N1180 Z-20.106 F636.6
N1190 Y.525 F1273.2
N1200 G2 X0. Y4.125 I3.6 J0.
N1210 X4.125 Y0. I0. J-4.125
N1220 X0. Y-4.125 I-4.125 J0.
N1230 X-4.125 Y0. I0. J4.125
N1240 X0. Y4.125 I4.125 J0.
N1250 X3.6 Y.525 I0. J-3.6
N1260 G1 Y-1.755
N1270 X-3.6
N1280 Z-20.306 F636.6
N1290 Y.525 F1273.2
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N1310 X4.125 Y0. I0. J-4.125
N1320 X0. Y-4.125 I-4.125 J0.
N1330 X-4.125 Y0. I0. J4.125
N1340 X0. Y4.125 I4.125 J0.
N1350 X3.6 Y.525 I0. J-3.6
N1360 G1 Y-1.755
N1370 X-3.6
N1380 Z-20.505 F636.6

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N1460 G1 Y-1.755
N1470 X-3.6
N1480 Z-20.704 F636.6
N1490 Y.525 F1273.2
N1500 G2 X0. Y4.125 I3.6 J0.
N1510 X4.125 Y0. I0. J-4.125
N1520 X0. Y-4.125 I-4.125 J0.
N1530 X-4.125 Y0. I0. J4.125
N1540 X0. Y4.125 I4.125 J0.
N1550 X3.6 Y.525 I0. J-3.6
N1560 G1 Y-1.755
N1570 X-3.6
N1580 Z-20.903 F636.6
N1590 Y.525 F1273.2
N1600 G2 X0. Y4.125 I3.6 J0.
N1610 X4.125 Y0. I0. J-4.125
N1620 X0. Y-4.125 I-4.125 J0.
N1630 X-4.125 Y0. I0. J4.125
N1640 X0. Y4.125 I4.125 J0.
N1650 X3.6 Y.525 I0. J-3.6
N1660 G1 Y-1.755
N1670 X-3.6
N1680 Z-21.102 F636.6
N1690 Y.525 F1273.2
N1700 G2 X0. Y4.125 I3.6 J0.
N1710 X4.125 Y0. I0. J-4.125
N1720 X0. Y-4.125 I-4.125 J0.
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N1740 X0. Y4.125 I4.125 J0.
N1750 X3.6 Y.525 I0. J-3.6

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N1760 G1 Y-1.755
N1770 X-3.6
N1780 Z-21.301 F636.6
N1790 Y.525 F1273.2
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N1810 X4.125 Y0. I0. J-4.125
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N1830 X-4.125 Y0. I0. J4.125
N1840 X0. Y4.125 I4.125 J0.
N1850 X3.6 Y.525 I0. J-3.6
N1860 G1 Y-1.755
N1870 X-3.6
N1880 Z-21.5 F636.6
N1890 Y.525 F1273.2
N1900 G2 X0. Y4.125 I3.6 J0.
N1910 X4.125 Y0. I0. J-4.125
N1920 X0. Y-4.125 I-4.125 J0.
N1930 X-4.125 Y0. I0. J4.125
N1940 X0. Y4.125 I4.125 J0.
N1950 X3.6 Y.525 I0. J-3.6
N1960 G1 Y-1.755
N1970 G0 Z30.
N1980 M5
N1990 G91 G28 Z0. M9
N2000 G28 X0. Y0. A0.
N2010 M30
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