

# Introduction to Capstone Design

## MENG 411

### Name of Project:

Design and manufacturing of cutting machine for metallurgical testing

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## **ABSTRACT**

In this world, each metal has its own particular component and properties, but with the cutting processes, the properties and phases will change and might lose them. In expansion, our project is to design and manufacture a high precision cutting machine for metallurgy test which creates a solution for changing metal characteristics and properties during the cutting process. This machine will offer assistance to numerous students in the workshop of our university, if they want to keep the specimen properties unaltered during cutting, with having low material removal rates, while also providing a safe cutting process.

The project objectives are to design for safety, cost, assembly, high performance, less impact on the environment. We faced some constraints during design such as economic, environmental, availability, reliability, manufacturability, and safety.

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## LIST OF SYMBOLS and ABBREVIATIONS

ISO: International Organization for Standardization.

ASTM: American Society for Testing and Materials.

OSHA: The Occupational Safety and Health Administration

ASME: American Society of Mechanical Engineers.

ASM: American society for metals.

NDT: Non-Destructive test.

DT: Destructive Test.

D: Hose inner diameter.

L: Total hose length.

$\rho$ : Coolant density  $\nu$ : Coolant viscosity

$g$ : Gravitational acceleration

$Q$ : Coolant flow rate

$A$ : Cross-sectional area of the hose

$V$ : Velocity of the coolant

$Re$ : Reynolds number

$f$ : Friction factor of the pipe

$h_1$ : Hose losses

$h_p$ : pump head

$W$ : Watt

# CHAPTER 1 – INTRODUCTION

## 1.1. Detailed definition of the project

Throughout human life it has always been manufacturing and processing. People today underestimate production because they do not know the difficulties of manufacturing and the methods people used to use. For example, many products we use now are easier to manufacture than before. Therefore, the work for craftsmen is decreasing. Thus, manufacturing becomes standardized and easier. However, before the actual start of manufacturing era, few mechanical devices were handmade by highly skilled artisans. This did not only lead to a shortage of goods, but also was very over the average price of such devices.

To maximize the level of efficiency of the properties of the materials that we use in the manufacturing industry we should be able to examine the properties inside, Especially metals and alloys. Since the Individual pure metals may possess useful properties such as good electrical conductivity, high strength, and hardness, or heat and corrosion resistance. Commercial metal alloys are a homogeneous mixture of a metal element formed by the combination of at least one other element (metal, nonmetal). The material obtained becomes a material with metal character. Alloys exhibit properties different from the properties of metals entering the mixture. Examples of the most common alloys are bronze (copper-tin), brass (copper-zinc), solder (tin-lead). Alloys are widely used to manufacture materials with physical properties required by applications.

Checking during manufacture and processing of the final properties of the alloys is difficult. However, they require testing and research of the regime in which it is applied under the name of metallurgical testing. Metallurgical tests focus on measuring the properties of metals along with mechanical tests and chemical analysis. Metallography is often used to determine material type, grade or grain size and provide certification for new material or mixed batches, microstructure analysis and failure analysis. Metallurgical testing can verify that the metal you have received is in

fact the metal you were promised by your supplier. Developing a high precision cutting machine for metallurgical test samples to examine the microstructure and properties of the sample with minimal changes will help us move forward. Overheating parts is an issue that can change the microstructure of the sample. Our aim is to minimize this issue by applying a cooling system to prevent overheating when cutting alloy samples.

## **1.2. Significance of the Project**

Metallurgical testing is considered one of the most significant tests for the identification of the material condition and makeup. It is also used to extract metals from their ores, refining them, and preparing them for final use. Abrasive wet cutting is the most appropriate method for cutting materials since it provides the least damage in relation to the time used for the process, therefore manufacturing a wet abrasive cutting machine will allow us to do important tests on the metal to provide important information about the structure and properties of metal and alloy samples. The use of the standard metal cutting machine increases the metal temperature, which may change the microstructure and the properties of the metal and this will end up affecting the surface finish of the metal. The cooling system in the wet abrasive cutting machine will help decrease the rate of the microstructure changes due to overheating during the cutting process.

### 1.3. Detailed project objectives

The aim of this project to design a high precision cutting machine that fixates on cutting metal while adding fluid to prevent raising the temperature of the metal with less error and less material waste with consistent product quality. The project will have different objectives such as:

- Literature review and background studies.
- Designing the components and the machine.
- Numerical analysis of the data.
- Conduct testing on the materials.
- Communicate the result of research and analysis of data.

### 1.4. Detailed project constraints

In each project, there are common limitations, which are scope, time and quality. The most imperatives of this extent are financial, security, manufacturability, accessibility, time and productivity.

1. **COST:** Our primary goal is to balance between project cost and quality. There will be no unnecessary costs in our project. However, high precision cutting machine for metallurgy test that can work at high performance is our goal. So that, We will have a budget of approximately 750 \$. We will make it cheaper and more durable compare with other similar projects.
2. **TIME:** This project is very important for all team members to graduate. Before starting the project, we made the necessary plans with a meeting every week and we will make. The entire project will take 2 terms, approximately 10 months. However, we aim to finish it about 1 month ago in order to perform the necessary tests and controls. The first term is the theoretical part of the project. In the second term, we will order the necessary materials and make the project assembly.

3. **Availability of materials:** Material supply is very important for the project to progress. Some supplies can be difficult to obtain as Cyprus is an island. For this, we are going to get some supplies from Turkey.
4. **Manufacturability:** Manufacturing and assembly will be done in the university workshop.
5. **Effectiveness:** Generally, higher efficiency and productivity are aimed for a high precision cutting machine for metallurgy test than the average cutting force.
6. **Efficiency:** The proficiency of our extend is critical since our project is high exactness cutting machine for metallurgy. The materials, components and engine are exceptionally quality and progressed to create the project is exceptionally proficiently.
7. **Safety:** Our project, which could be a high accuracy-cutting machine, is exceptionally perilous, so we should pay consideration to safety, especially within the university workshop, since there is a portion we are going create within the workshop.

## 1.5. Report Organization

This report has 5 chapters, and every chapter is divided into subsections. Firstly, chapter one will introduce the project and its detailed definition, significance, objectives, and constraints, then in chapter two we will give the background information of the project with concurrent solutions, its comparisons, and engineering standards. After that, in chapter three we will discuss the design and analysis which includes the proposed design, engineering standard followed during the design, design calculation, and the cost analysis, onto chapter four which will be about the project's manufacturing process selection and detailed manufacturing process, subsequently, chapter five which will be on the product testing plan which includes the verification plan of the objectives of the project and the verification of the engineering standards, afterwards chapter 6 will discuss the results gained from the testing procedure and explain the engineering standards used in testing plus the constraints faced during it, lastly, chapter 7 will conclude the report with a conclusion summary and future additions to the project. At the end of the report the appendix and the references will be added.

# CHAPTER 2 - LITERATURE REVIEW

## 2.1. Background information

### 2.1.1 Metallurgical testing

Metallurgical testing which is also known as metallurgical evaluation, examination, or analysis is a series of inspections and examinations to verify the properties of the metal prior to bending, shaping, or any other form of physical tampering, it's also used to determine if the metal can be used for the needed application or not.

Metallurgical testing usually uses microscopy to provide vital details about the structure and properties of the metal or the alloy sample and it's done to the following core properties:

- Tensile Strength
- Hardness
- Elasticity
- Grain size
- Surface contamination

Metallurgical testing can be one of 2 types: Destructive and Non-destructive.

#### 2.1.1.1 Destructive testing (DT)

In this method of testing the sample is destroyed in the process and can't be used after. In tests such as:

- Bend test
- Impact test
- Tensile test

### **2.1.1.2 Non-Destructive testing (NDT)**

As the name suggests in this method the sample is not destroyed during the test and can be used after. In tests such as:

- Visual testing
- Ultrasonic testing
- Radiographic testing

### **2.1.2 Abrasive cutting**

Abrasive cutting is the most widely used method of sectioning materials for microscopic examination and other material investigations. The cutting procedure can be done with either abrasive cutting wheels made from metals or with diamond cutting wheels. The first step in preparing a specimen for metallographic or microstructural analysis is to locate the area of interest, and then to flat and cut close to the area of interest and minimize microstructure damage. What you don't want to happen is to have a plastically deformed metal or heat affected areas or any damage to the secondary phases (graphite flakes, nodules, or grain pull-out).

### **2.1.3 Cooling**

Cutting fluids are a prerequisite for wet abrasive cutting and serve as cooling, flushing, lubrication, corrosion protection, and bacteria prevention media. The ideal fluid for abrasive cutting removes the cutting swarf and degraded abrasive blade material. And it needs to have a high flash point because of the high temperature produced by the cutting procedure.

Paying attention to the position of the workpiece and choice of cutting mode can increase the fluid efficiency and to be directed to the cutting zone. The best placement for the fluid dispenser is perpendicular to the cut-off wheel.



## 2.2. Concurrent solutions

### 2.2.1 Laser cutting machine

Laser cutting is a non-contact process that uses a laser to cut materials and provides high quality, dimensionally accurate cuts. The process is performed by directing the laser beam from a processing head to the workpiece. A focused laser beam ensures cutting under high accuracy and repeatability on a wide variety of material types. The high energy density at the focal point of the laser beam causes the material to melt, burn, and evaporate. By blowing an active or neutral process gas, for example, oxygen, nitrogen, or argon, with a gas, the molten material is expelled, blown off and an edge with a high-quality finishing surface is obtained.

High alloy steel, stainless steel; precious and non-ferrous metals: Gold, silver, titanium, platinum, aluminum; tungsten and molybdenum; ceramics such as aluminum oxide, zirconium oxide, and aluminum nitride; carbide, polycrystalline diamond, and boron nitride; crystals such as sapphires and rubies; Semiconductors such as silicon are among many kinds of materials that can be cut with laser cutting.

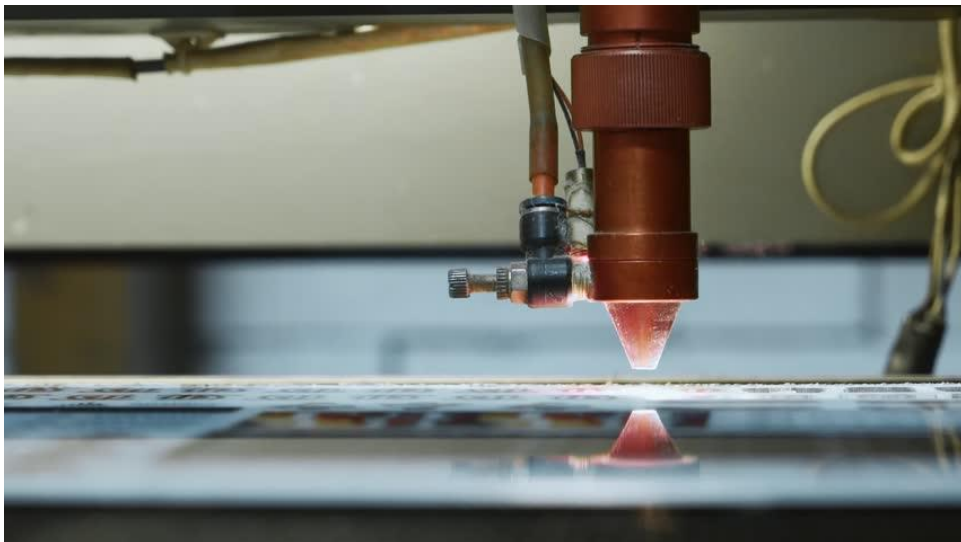


Figure 1: Laser cutting machine

### 2.2.2 Water jet-cutting machine

The water jet is a "non-cutting tool" abrasive-backed, water-based manufacturing tool that is used to cut all materials in the world with a precise tolerance (0.1 mm) regardless of the hardness level, regardless of the hardness and softness. It has the capacity to cut almost any type of material. The small sand grains in the water jet reach the cutting edge, which transfers the maximum power to the material to be cut, by progressing gradually until they reach the "spray nozzle", which has a very high strength, together with the enormous pressurized water of about 6000 bars. It is not the water that does the work here, but the abrasive grains of sand in it. After cutting, the particle size of the abrasive grit grains cannot be reused for a second cut as it has turned into powder. With the day-to-day development of water jet technology, its use may increase even more, especially in industrial material cutting and processing.

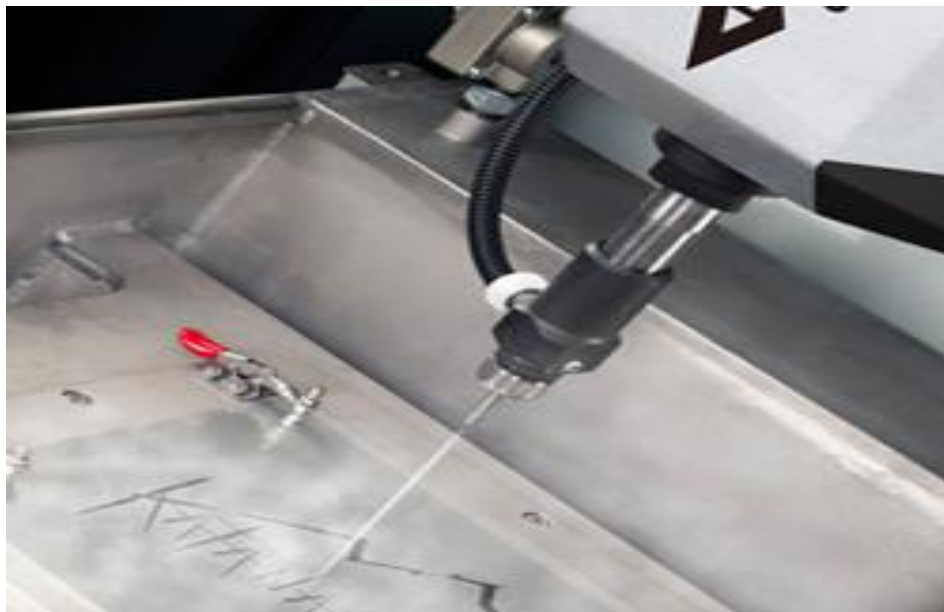


Figure 2: Water jet cutting machine

### **2.2.3 High precision cutting machine**

Cutting can be done using methods such as a hand saw, lathe chainsaw. The most ideal cutting method is to use a water-cooled rotating disc. These are called metallographic sectioning discs. There is a suitable cutting disc for every material. These discs contain abrasive materials such as Sic, diamond dust, and therefore these discs are called abrasive cutting discs.

Coolant should be used to reduce the heat accumulation during the cutting process. The coolant used can consist of oil and oil mixtures that do not corrode the sample. This liquid removes both the excess heat and the particles detached from the part from the cutting zone.

There is another cutting disc. This is called a diamond cutting disc. They are diamond cutting discs produced by applying super abrasive grains such as industrial diamonds to the cutting surfaces of steel discs. Diamond discs are used in cutting processes of especially natural stones such as marble, artificial stones, brick, cremite, asphalt and concrete.



Figure 3: High Precision Cut Off Machine

### 2.2.4 Plasma cutting machine

Plasma cutting is the application of hot and accelerated plasma to the surface to be cut, thanks to a material with high electrical conductivity. With this cutting technique, materials such as aluminum, steel, sheet metal, and copper can be cut very sharply and smoothly. Plasma Cutting Devices have found a place in many areas of the industry, from large industrial companies to hobby workshops, thanks to its high speed and precise cutting, and low operating cost. The plasma cutting method can be applied to all types of conductive metals such as steel, stainless steel, and aluminum alloys. Compared to alloyed materials, it is possible to cut on unalloyed steels faster and with thicker sections. Although it is possible to use various gases in the plasma cutting method, the most common plasma gas is compressed air. Since compressed air can be used in almost every workshop, there is no need for flammable gas and pressurized oxygen in the plasma cutting method.



Figure 4: Plasma-Cutting Machine

### 2.2.5 Flame cutting

The metal is first heated with a flame so that it reaches the ignition temperature lower than the melting point. Fuel gas e.g. It can be methane, acetylene, or propane. Then oxygen is supplied to the preheated area; Oxygen reacts with metal to form iron oxide and generates exothermic heat. The cutting process continues with the exothermic reaction. As soon as the metal burns, the liquid turns into iron oxide and flows away from the cutting area. Some of the iron oxide remains on the work surface and forms a hard slag, which can be removed by sharpening. Fuel type and nozzle

choices can speed up the flame cutting process and reduce labor costs. While the oxygen jet determines the speed of a cut, the gas used in preheating also affects the start time of the cut. The choice of gas used in the process depends on whether the operation is manual or mechanical, the type of work done, and the type of material. For example, acetylene is ideal for thin sheet metal and curved cuts with its flame temperature of 3160 degrees Celsius. However, acetylene is more expensive than other gases and does not generate much heat. Therefore, it is not suitable for cutting large metal plates. When cutting small parts, the heat generated by the cutting torch and preheating accumulates inside the workpiece. The smaller the cut piece, the greater the risk of softening. When using an oxygen source for cutting plates of 30 mm or more, the distance between the two cuts must be wide enough to prevent loss of hardness in the whole component. Oxygen cutting generates more heat than any other cutting method, raising the temperature of the workpieces. The quality of the final cut surface; It can be perfectly level with a sharp top edge, square / flat cut surface, and a sharp dross free bottom edge.

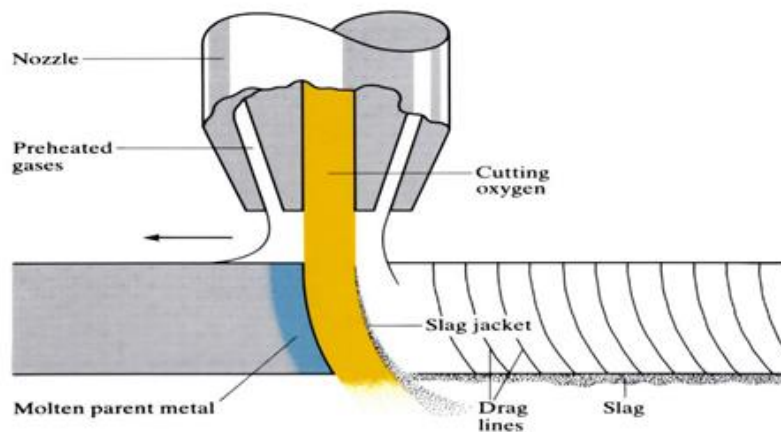


Figure 5: Flame cutting

### 2.3. Comparisons of the concurrent solution

Table 1: Comparison of the Concurrent Solutions

Machines	Advantages	Disadvantages
<b>Laser cutting machine</b>	<ul style="list-style-type: none"> <li>• Cuts wide range of materials like (wood, plastic, ceramic, rubber and certain metals)</li> <li>• Provides higher precision</li> <li>• Very low risks and noise</li> </ul>	<ul style="list-style-type: none"> <li>• High cost</li> <li>• Difficult to manufacture</li> <li>• Low efficiency</li> </ul>
<b>Water jet cutting machine</b>	<ul style="list-style-type: none"> <li>• Cuts through thicker sheets and has almost no material restrictions</li> <li>• Doesn't require heat</li> </ul>	<ul style="list-style-type: none"> <li>• Can pose problems for small parts, which might get deformed</li> <li>• Increasing its performance induces high costs</li> <li>• Difficult to manufacture</li> <li>• High risk and noise</li> </ul>
<b>High precision Cutting machine</b>	<ul style="list-style-type: none"> <li>• Fair cost due to its efficiency</li> <li>• Simple design</li> <li>• Low risks</li> <li>• Minimal burn</li> <li>• Produces a clean-cut surface finish</li> </ul>	<ul style="list-style-type: none"> <li>• Thin-wheel abrasive cutting is not recommended for large diameters</li> <li>• Very high noises</li> </ul>
<b>Plasma cutting machine</b>	<ul style="list-style-type: none"> <li>• Fast cutting speed</li> <li>• Narrow cutting slots</li> <li>• Low noise</li> </ul>	<ul style="list-style-type: none"> <li>• Cannot cut thick materials</li> <li>• Difficult to manufacture</li> <li>• Generate harmful gases and arc light</li> </ul>

Machines	Advantages	Disadvantages
<b>Flame cutting</b>	<ul style="list-style-type: none"> <li>• Cut very thick plates</li> <li>• low cost</li> </ul>	<ul style="list-style-type: none"> <li>• Requires long preheating so the cutting speed is low</li> <li>• The accuracy is not high especially when cutting thin plates</li> </ul>

Table 2: PUGH’s Matrix signs and their meaning.

Sign	Meaning
+	Better
-	Worse
S	Same
++	Much better
--	Much worse

In this table, the team compared three different concepts using a very simple Pugh’s matrix to determine that the concept

Table 3: PUGH's Matrix

Concept	Aluminum	Steel	Stainless steel
Cost	--	++	+
Reliability	S	+	+
Weight	++	-	S
Environment friendly	S	S	S
Stability	+	++	+
Sustainability	++	+	+
Score	3	5	4

We used steel and stainless steel in manufacturing our project, the reason being that they got better scores in our PUGH's matrix.



## **2.4. Engineering standards of the concurrent solutions**

- 1-ISO 12100:2010, Safety of machinery — General principles for design — Risk assessment and risk reduction.
- 2- ISO 13850, Safety of machinery — Emergency stop function — Principles for design.
- 3- ISO 13855:2010, Safety of machinery — positioning of safeguards with respect to the approach speeds of parts of the human body.
- 4- ISO/TR 11688-1, Acoustics — Recommended practice for the design of low-noise machinery and equipment — Part 1: Planning.
- 5- B31T-2018 Standard Toughness Requirements for Piping.
- 6- A112.6.3-2019 Floor and Trench Drains.
- 7- B89.7.2-2014(R2019) Dimensional Measurement Planning.
- 8- ISO 299:1987 for T-slots and corresponding bolts.

## **CHAPTER 3 -DESIGN and ANALYSIS**

### **3.1. Proposed/Selected design**

The high precision cutting machine aims to cut the metal with high precision, ensuring maximum surface quality. During this cutting process, it removes fewer chips than normal cutting machines. The cutting machine in the project phase has a direct connection with the electric motor on a mechanism so that it can rotate at 2800 rpm. A precision abrasive disc will be used when cutting metal. In addition, a liquid cooling system will be used against the high temperatures that will occur during the metal cutting process. It will be pumped from the liquid tank in the table with the help of a submersible pump and sent to the hoses to cool the disc and metal. It will then be filtered and circulated through a funnel to the liquid tank. The metal will be connected to the vise on the T-slot plate. The machine has a protective cover for safety. In addition, the cover will be supported by a hydraulic piston. Control of the cutting disc will be done manually from outside with a mechanical arm. Finally, the design of the cutting machine was made in order to cut longer metal parts as well.

#### **3.1.1 Material Selection of Designed Parts**

Mainly, a material have been selected for designed parts (Ferritic stainless steel).

##### **3.1.1.1 Ferritic Stainless Steel**

Ferritic stainless steels are low carbon stainless steels containing 11 to 30% chromium (Cr). The main alloying element in this group is chromium (Cr), followed by molybdenum (Mo). The ferrite group is completely magnetic. The most used type is grade 430. They are similar in structure to mild steels but have high corrosion resistance. Added from 11% to 30% chromium (Cr) and a small number of austenitic elements such as carbon (C), nitrogen (N), nickel (Ni). The ferritic group has low impact resistance and weldability. A low value of these properties means high brittleness of the material.

Therefore, their use as a machine tool is limited, especially for welded assemblies and thick sections. They are not as easy to form as austenitic steels. Ferrite grades have low thermal expansion, high thermal permeability, and high creep resistance. Some areas of use for this group; Such as car chassis and exhaust parts, some kitchen equipment, hot water tanks, washing machine drums, air conditioning ducts, barbecue grills. Their resistance to atmospheric corrosion and oxidation is an important advantage. Since the ferrite group contains a low carbon (C) content, it cannot be hardened by heat treatment, it is only used in the annealed state. The medium to the good corrosion resistance of ferritic steels improves in direct proportion to the increase in the chromium (Cr) content in their chemical composition.



Figure 6: Ferritic Stainless Steel

Table 4: Properties of Ferritic Stainless Steel

Elastic modulus	220 GPa at 20 °C	
Tensile strength	550 MPa at 20 °C	
Electrical resistivity	6E-7 - 7.5E-7 $\Omega \cdot m$ at 20 °C	
Coefficient of thermal expansion	9.3E-6 – 1.2E-5 1/K at 20 °C	
Thermal conductivity	11 - 22 W/(m·K) at 20 °C	
Melting point	1375 - 1450 °C	
Specific heat capacity	420 - 586 J/(kg·K) at 20 °C	
Chemical composition %	C	0.080 – 0.20
	Si	1.0
	Mn	1.0 – 1.50
	Cr	11.0 – 27.0

### 3.1.1.2 1050 Aluminum Alloy

Aluminum is in the group of non-ferrous alloys. (non-ferrous (Fe) alloys). Since this alloy is a light metal, it will be the material of most parts in the design. It weighs about one-third of the density of steel (2.71g / cm<sup>3</sup>) and has a melting point of 650 ° C. 1050, excellent cold working properties and conventional methods are used for cold working of this alloy. It is ductile and soft. It is also easy to shape and process. 1050 alloy belongs to the family of wrought alloys that fall under the same ISO standard as 1060 alloy, as they are similar but fall under different ASTM standards.

Table 5: Properties of Aluminum 1050 Alloy

Density	2.71g/cm <sup>3</sup>
Melting Temperature	650 °C
Thermal Expansion	24x10 <sup>-6</sup> /K
Modulus of Elasticity	71 GPa
Thermal Conductivity	222 W/m.K
Electrical Resistivity	0.0282x10 <sup>-6</sup> Ω.m



Figure 7: 1050 Aluminum Alloy Sheet

### 3.1.2 Designed Parts

#### 3.1.2.1 Arm

Manual arm designed in ferritic stainless steel and supported by the motor support part to actuate the motor base.

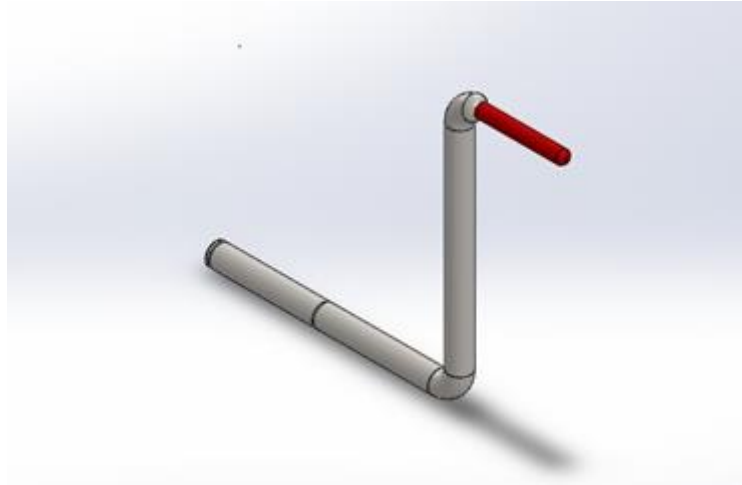


Figure 8: Arm

#### 3.1.2.2 Motor Support

Motor support part designed to make the motor run more stable and to make a more precise cut. Minimum vibration is aimed at this part.

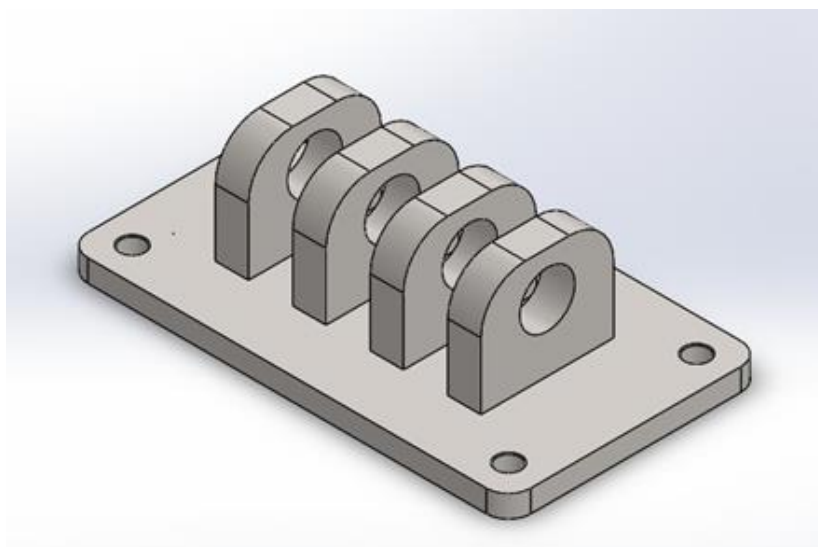


Figure 9: Motor Support

### 3.1.2.3 Motor Base

It is the main carrier designed from ferritic stainless steel on which the motor is positioned. There are also two bearing housings inside. It aims to work in harmony with the engine support to minimize the vibrations coming from the engine. Finally, it moves to return the arm and motor to their original position.

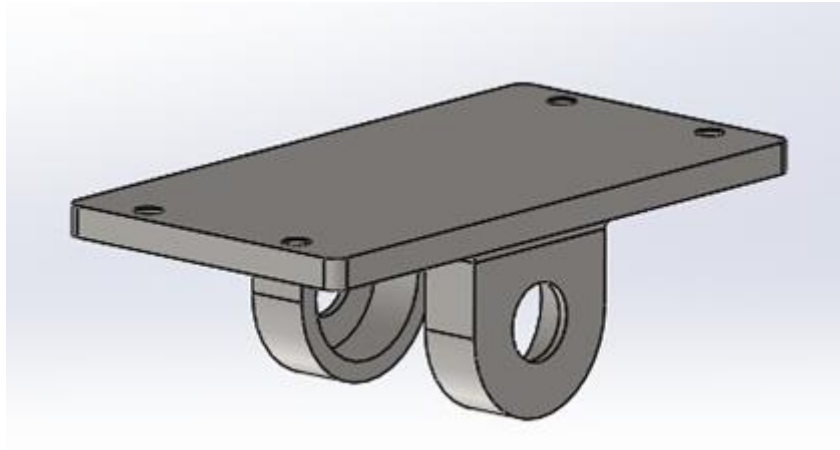


Figure 10: Motor Base

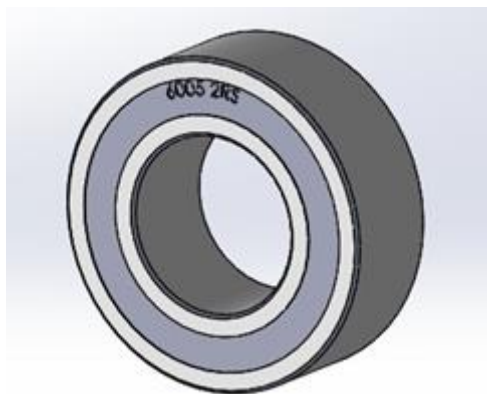


Figure 11: 6005 2RS bearing

### 3.1.2.4 Base

The stainless steel base is designed to protect and secure the assembly of the T-plate and engine support. An inclined surface is preferred to circulate the flow of coolant.

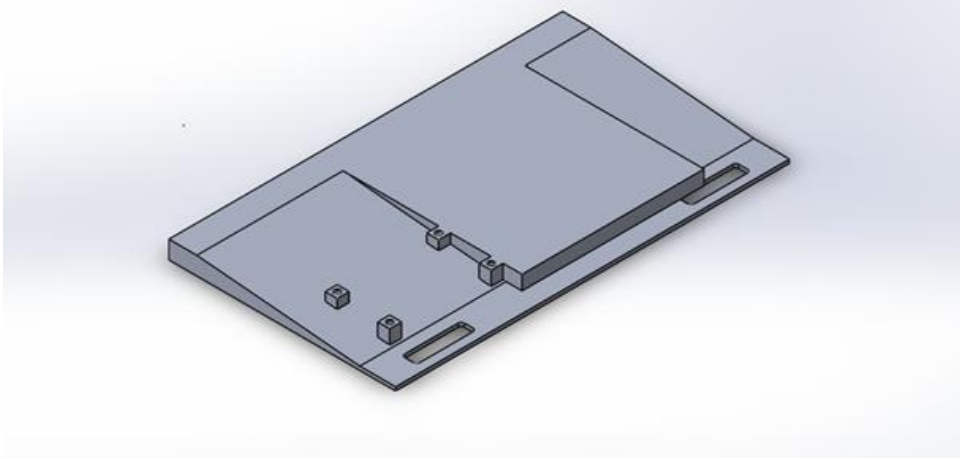


Figure 12: Base

### 3.1.2.5 Disc Cover

This cover is made to protect the motor from chips ejecting from the cutting disc.

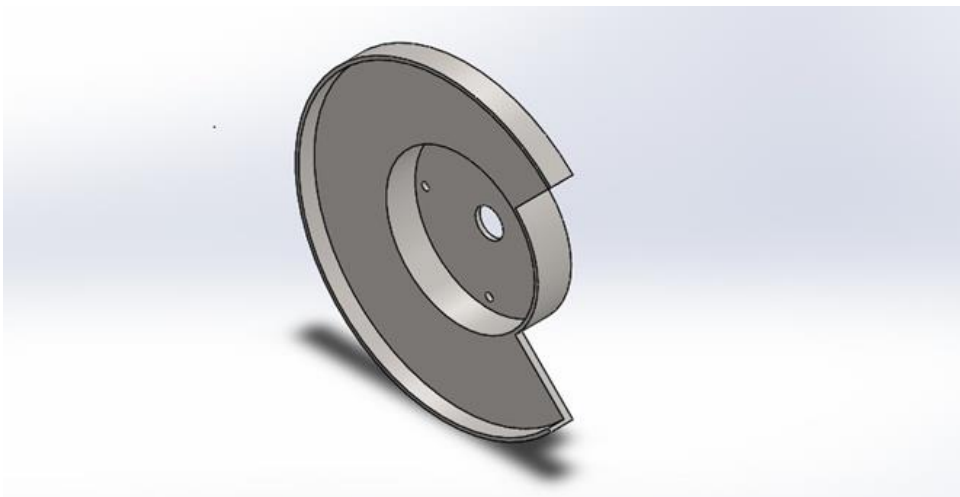


Figure 13: Disc Cover



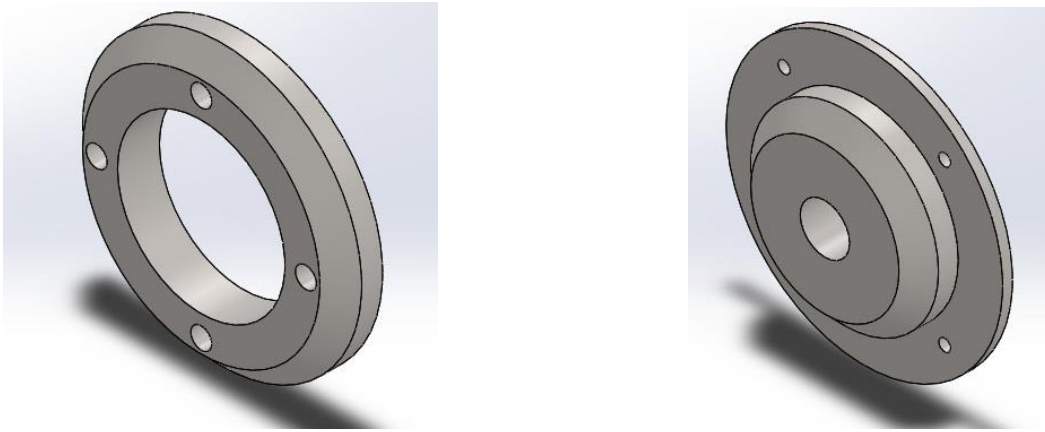


Figure 14: Disc Stabilizers

### 3.1.2.6 Basic Assembly

An assembly with a disc, motor, disc cover, arm, motor support, and the motor base was designed to perform the preliminary test.

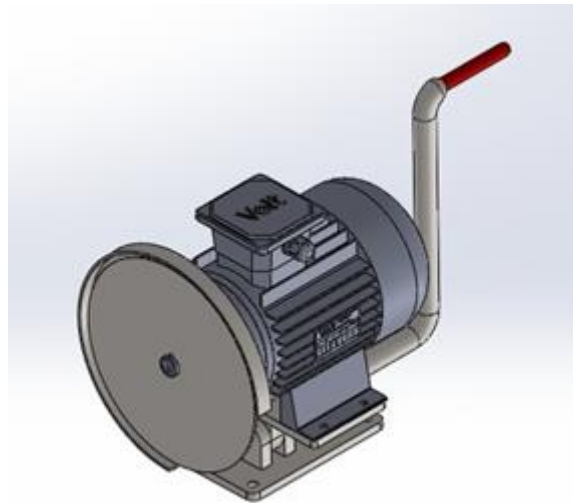


Figure 15: Basic Assembly

### 3.1.2.7 Bottom Housing

It is the lowest part of the assembly. There are filter openings to allow the flow of coolants.

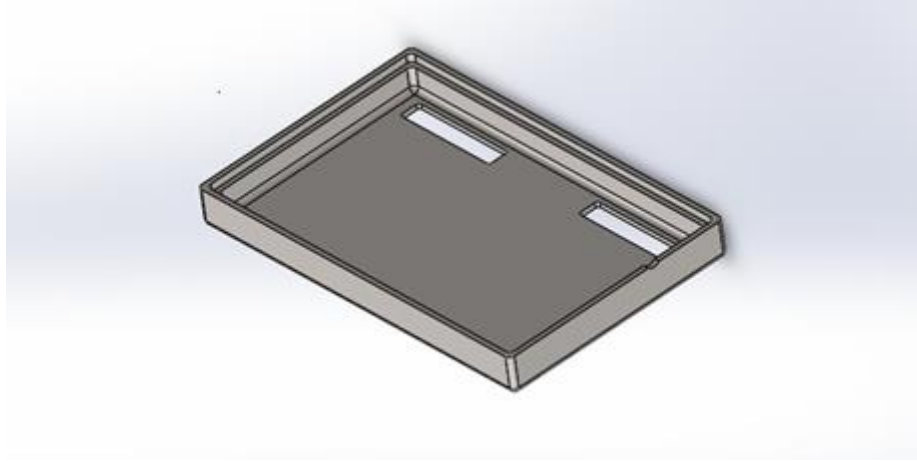


Figure 16: Bottom Housing

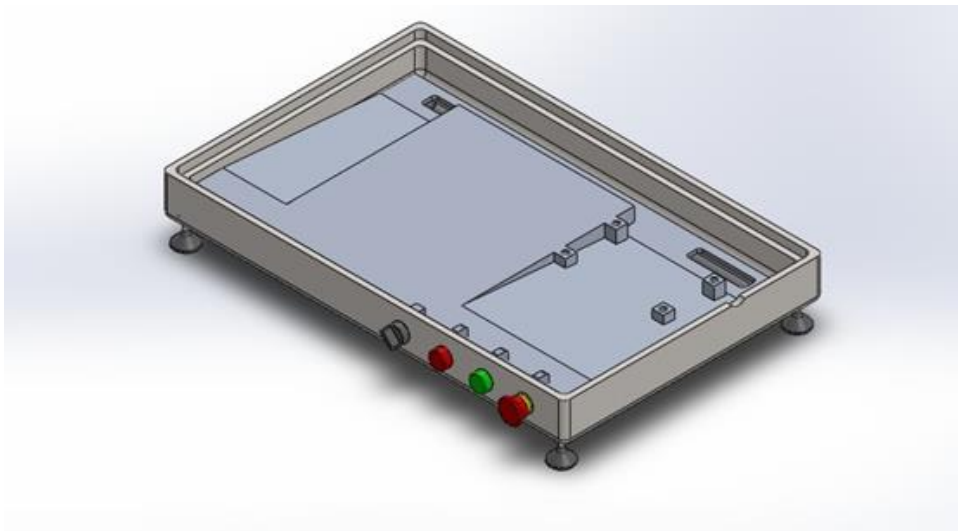


Figure 17: Assembly of the Base, Bottom Housing and Buttons

### 3.1.2.8 Buttons and Switch

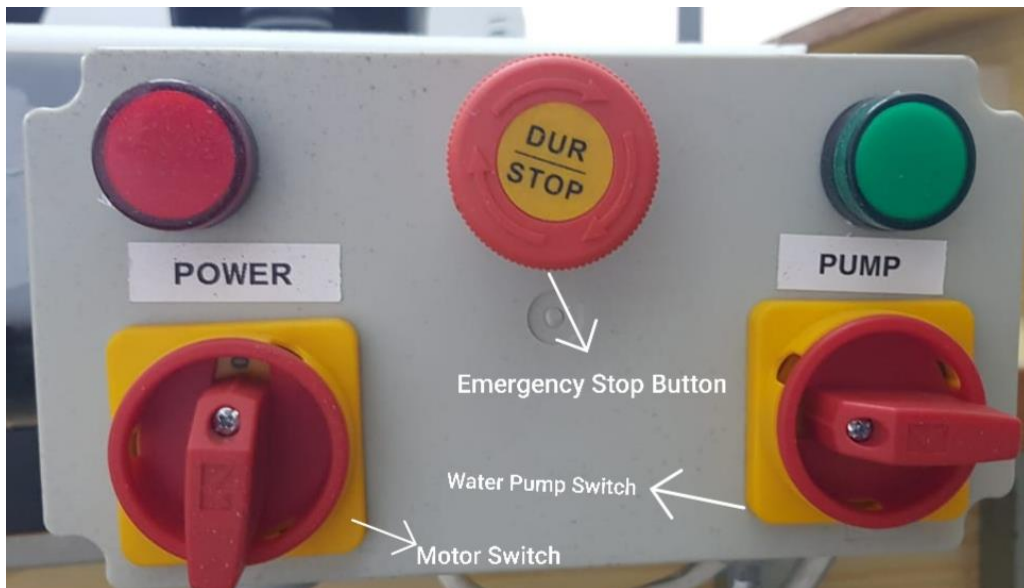


Figure 18: Electric Controlling Box

### 3.1.2.9 Hydraulic Piston

When the top cover is opened, it is placed on both sides to prevent the cover from closing due to safety conditions.



Figure 19: Hydraulic Piston

### 3.1.2.10 Upper Housing

It is designed with two windows, front and left sides of which are covered with glass, for the visibility of the cutting processes, to ensure safety and security in the closed environment. Also, a small space is left on the left side to cut longer pieces.

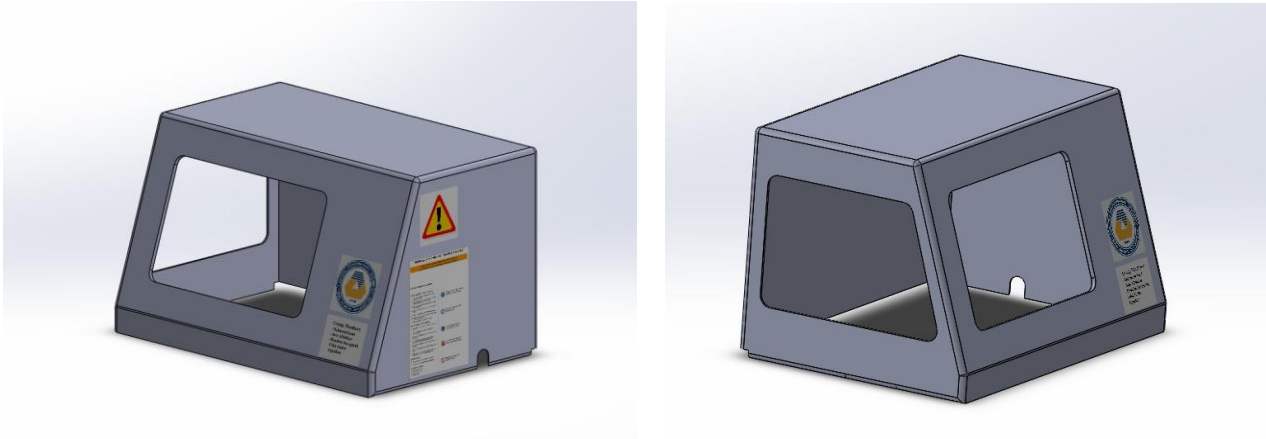


Figure 20: Upper Housing

### 3.1.2.11 Fluid Tank

It is where the coolant is stored.

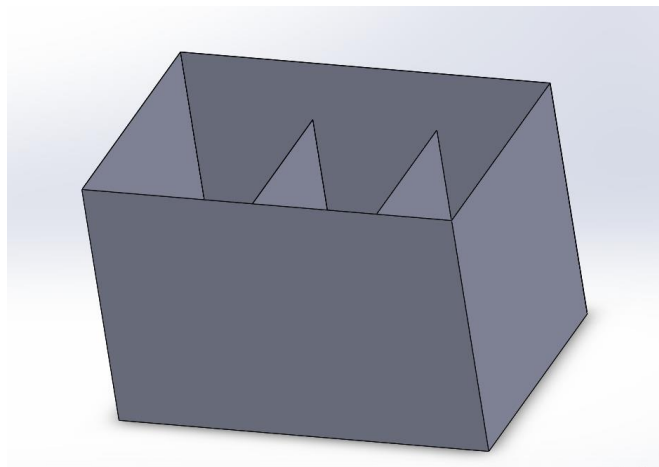
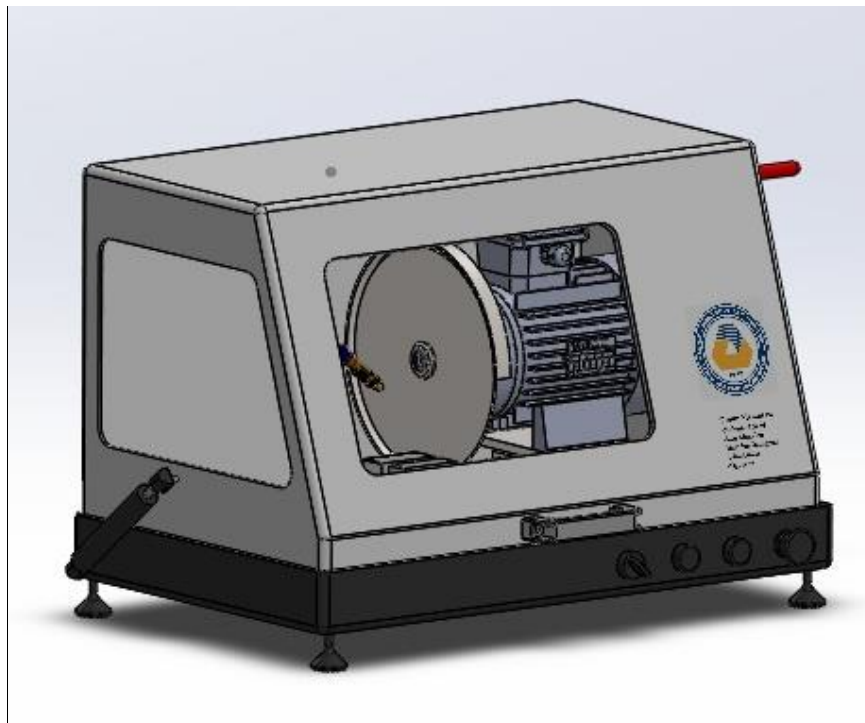
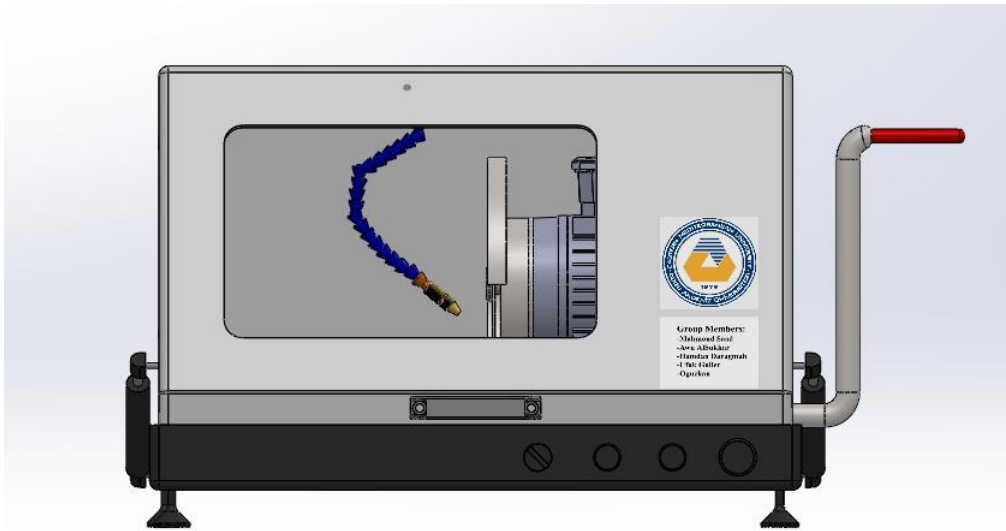


Figure 21: Fluid Tank

### 3.1.2.12 Assembly of the Machine



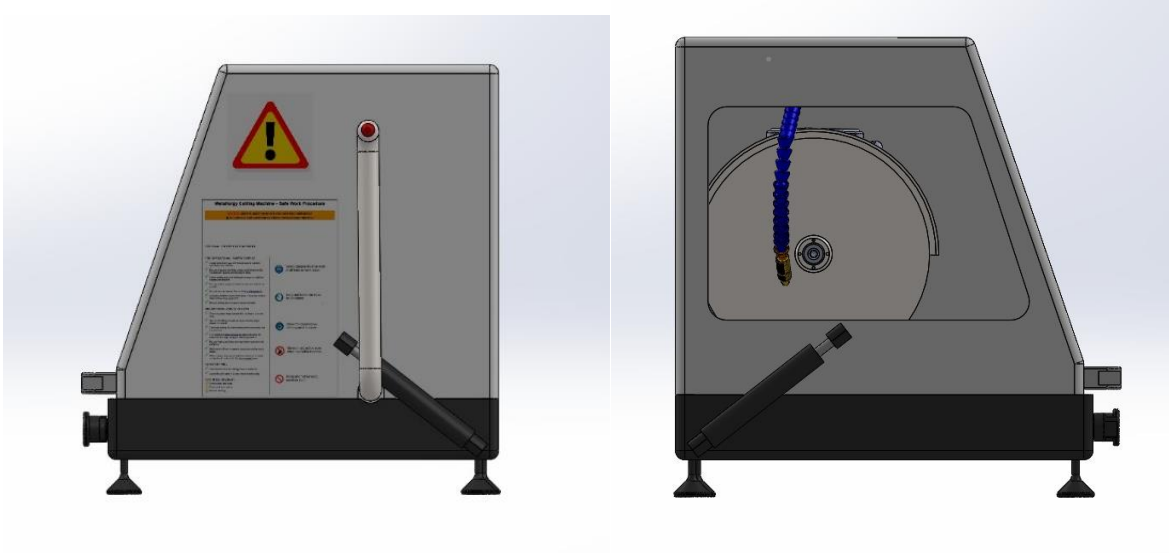


Figure 22: Assembly of the Machine

### 3.1.2.13 Render of the Modelling

Rendering has been done to show how the machine will look like. So we can see the machine more realistically.



Figure 23: Render of the modelling

### 3.1.3 Electric Motor

The motor is stainless steel waterproof. The motor rpm range should be between 2800-2880 to avoid breaking the cutting wheel, and the voltage of the motor should be between 200-250 volt to satisfy the design requirements.

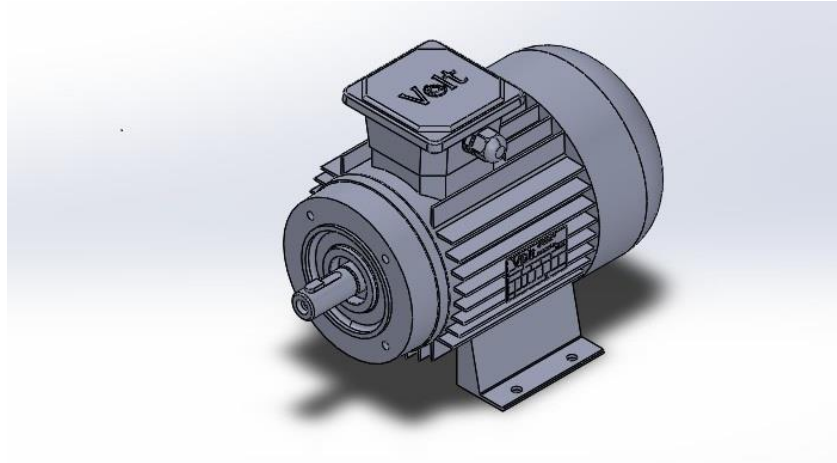


Figure 24: Electric Motor

Table 6: The Specifications of the Electric Motor

Power (kW)	Voltage (V)	Current (A)	Speed (rpm)	Efficiency (%)
2.2	220	13.67	2800	77

### 3.1.4 Cutting Wheel

Cutting wheel is used to cut various materials, cut or divide to desired dimensions. It is easier, more practical, and useful than guillotine shears, saw, and flame cutting processes. Cutting wheel is produced with or without reinforcement. The severity of the cutting process determines the reinforcement requirement. Cutting wheel is divided into two. Cutting wheel without Reinforcement, this type of cut stones are used only in cutting machines. In the cutting machines, the stones are securely fixed, they are equipped with protective equipment and the cutting plane is

under control. Reinforced Cut-off wheels, reinforced cut-wheel use special durable materials or glass fiber. The purpose of the reinforcement is to prevent breaking with the effect of flexible forces arising from side pressure and to ensure high peripheral speeds thanks to its resistance to higher centrifugal forces. All portable cutting machines, pendulum machines, hand-operated cutters require the use of reinforced cutting discs. 75 and 500 mm cut-off wheels. diameter, flat stones. Thicknesses vary according to stone diameter, grain size ,and structure, but a maximum 6 mm. maybe.



Figure 25: Cutting Wheel

### 3.1.5 Submersible Pump

The submersible pump is the name given to one of the pump types that work in the liquid or medium to be treated. A small submersible pump is a good choice for a cooling system as it is inexpensive and does not consume a lot of power and is easy to install. The submersible pump transports the coolant from the reservoir under the machine and pumps it to the cutting wheel. Since the submersible pump is in direct contact with the liquid, the motor is equipped according to some technical specifications. One of these technical features is its waterproof housing. It is also filled with oil that will prevent any liquid that may cause a short circuit from entering and protect it from



damage. Thanks to the submersible pump oil, leakage of liquid is prevented and possible dangers are prevented to a great extent. Connection points are designed to be air and watertight. Impermeability feature has been gained with the isolated work. We can say that one of the features that make submersible pumps so useful and advantageous is that they are designed to operate without exposure to external factors.



Figure 26: Submersible Pump

### 3.1.6 T-slot plate

Vice and clamps are attached to the T-slot table. This table will allow the use of different types of vices and clamps depending on the shape of the sample.

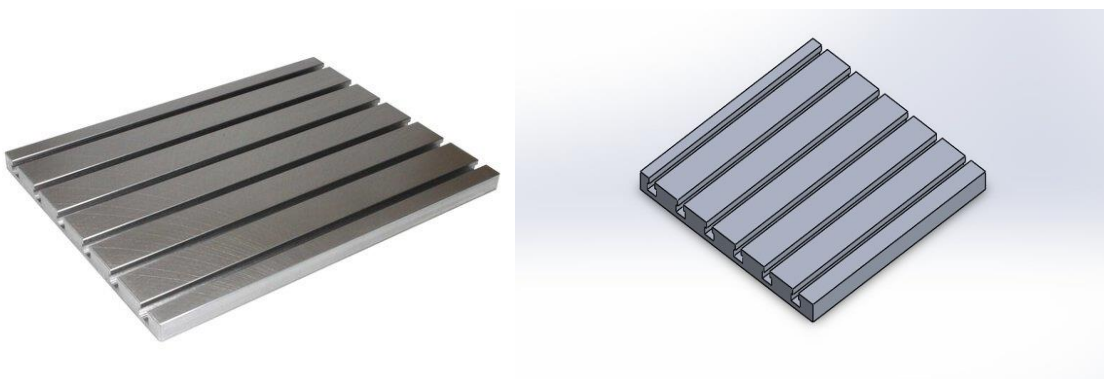


Figure 27: T-slot Plate

Table 7: Table Specifications

L	B	H	H1	H2	D	A	C	Weight
200 mm	200 mm	20 mm	6.5 mm	8 mm	50 mm	10 mm	16 mm	6.20 kg

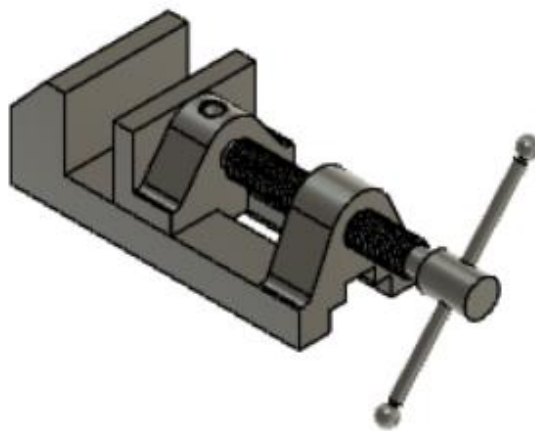


Figure 28: Vice

### 3.2. Engineering Standards

The design of this project complies with ISO (International Organization for Standardization) standards, including:

- ISO/TR 230-8:2010 Vibration.
- ISO 229:1973 for Speeds and feeds.
- ISO 299:1987 for T-slots and corresponding bolts.
- ISO 230-10:2016 Determination of the measuring performance of probing systems of numerically controlled machine tools.
- ISO/TR 230-11:2018 Measuring instruments suitable for machine tool geometry tests.
- CE compliant for EU.

It provides important information for the proposed design, which simplifies the process.

### 3.3. Design calculations, simulations and analysis

#### 3.3.1 Calculation

The coolant pump is selected depending on the calculation shown below:

##### Givens:

Hose inner diameter ( $D$ ) = 0.0125 m

Total hose length ( $L$ ) = 1.5 m

Coolant density ( $\rho$ ) = 890 kg/m<sup>3</sup>

Coolant viscosity ( $\nu$ ) =  $1 \times 10^{-5}$  m<sup>2</sup>/s

Gravitational acceleration ( $g$ ) = 9.81 m/s<sup>2</sup>

##### Assumptions:

Coolant flow rate ( $Q$ ) =  $2 \times 10^{-4}$  m<sup>3</sup>/s

##### Calculating the cross-sectional area of the hose:

$$A = \frac{\pi}{4} \times D^2 = \frac{\pi}{4} \times (0.0125 \text{ m})^2 = 1.227 \times 10^{-4} \text{ m}^2$$

##### Velocity of the coolant:

$$Q = A \times V$$

$$V = \frac{Q}{A} = \frac{2 \times 10^{-4} \text{ m}^3/\text{s}}{1.227 \times 10^{-4} \text{ m}^2} = 1.63 \text{ m/s}$$

##### Reynolds number:

$$Re = \frac{V \times D}{\nu} = \frac{(1.63 \frac{m}{s}) \times (0.0125 m)}{1 \times 10^{-5} m^2/s} = 2037.5$$

**Friction factor:**

$$f = \frac{64}{Re} = \frac{64}{2037.5} = 0.0314$$

**Head losses:**

$$h_l = f \times \frac{L}{D} \times \frac{V^2}{2 \times g} = (0.0314) \times \frac{(1.5 m)}{(0.0125 m)} \times \frac{(1.63 \frac{m}{s})^2}{2 \times (9.81 m/s^2)} = 0.51 m$$

**Using Bernoulli equation between the coolant tank and the hose outlet, we get:**

$$h_p = h_l + \frac{V^2}{2 \times g} + \frac{\rho_{outlet}}{\rho \times g}$$

$$= (0.51 m) + \frac{(1.63 m/s)^2}{2 \times (9.81 \frac{m}{s^2})} + \frac{(101325 Pa)}{(890 \frac{kg}{m^3}) \times (9.81 \frac{m}{s^2})} = 12.25 m$$

**Pump power:**

$$(W) = h_p \times \rho \times g \times Q = (12.25 m) \times (890 \frac{kg}{m^3}) \times (9.81 \frac{m}{s^2}) \times (2 \times 10^{-4} \frac{m^3}{s})$$

$$= 21.4 W$$

The electric motor is selected depending on the calculation shown below:

**Assumptions:**

$$N = 2800 \text{ rpm}$$

$$\text{Torque} = 5.6 \text{ lb.ft.}$$

**Electric motor power:**

$$H_p = \frac{\text{Torque} \times N}{5252} = \frac{(5.6 \text{ lb.ft}) \times (2800 \text{ rpm})}{5252} = 3 \text{ hp} = 2.2 \text{ kW}$$

### Calculations for cutting machine

**The sample is made of aluminum with cylindrical shape**

Motor speed(N) = 2800 rpm

Disk diameter = 300 mm

Disk thickness = 1.5 mm

Sample diameter = 50 mm

Chip thickness ( $t_0$ ) = 0.25mm

Aluminum density ( $\rho$ ) = 0.0027 g/mm<sup>3</sup>

Aluminum thermal conductivity (k) = 0.22 J/s.mm

Aluminum specific heat energy (U) = 0.7 N.m/mm<sup>3</sup>

Aluminum specific heat capacity (C) = 0.921096 J/g.c

diagonal of aluminum specimen= 32.14

### Cutting speed

$$v = N \times 2\pi \times r = 2800 \text{rpm} \times 2\pi \times 150 \text{mm} = 2637600 \text{ mm/min} = 439600 \text{ mm/s}$$

### Material removal rate for aluminum specimen

$$R_{mr} = V \times f \times d = 439600 \text{ mm/s} \times 32.14 \text{ mm} \times 3 \text{ mm/s} = 42386232 \text{ mm}^3/\text{s}$$

### Thermal diffusivity

$$K = k / \rho.C = \frac{0.22 \frac{\text{J}}{\text{s.mm}}}{0.0027 \frac{\text{g}}{\text{mm}^3} \times 0.921096 \frac{\text{J}}{\text{g.c}}} = 88.46 \frac{\text{mm}^2}{\text{s}}$$

### Mean Temperature Rise at The Tool–Chip Interface

$$(\Delta T) = \frac{0.4U}{\rho c} \times \left( \frac{Vt_c}{K} \right)^{0.333} = \frac{0.4 \times 0.7 \text{ N} \cdot \frac{\text{m}}{\text{mm}^3}}{0.0027 \frac{\text{g}}{\text{mm}^3} \times 0.921096 \frac{\text{J}}{\text{g.c}}} \times \left( \frac{36651.9 \frac{\text{mm}}{\text{s}} \times 0.25 \text{ mm}}{88.46 \frac{\text{mm}^2}{\text{s}}} \right)^{0.333} = 527.9 \text{ } ^\circ\text{C}$$

### Measure Cutting Disc Performance

#### Assumption:

Cutting discs diameter before cutting = 115.00 mm.

Final diameter = 110.00 mm.

Cut-off = 30 times

Stainless steel rod diameter = 12mm diameter

Cutting discs consume area =  $\pi.(115/2).(115/2) - \pi.(110/2).(110/2) = \pi.(3306.25 - 3025) = 883.125 \text{ mm}^2$

Work-piece consume area =  $\pi.(12/2).(12/2).30 = 3391.2 \text{ mm}^2$

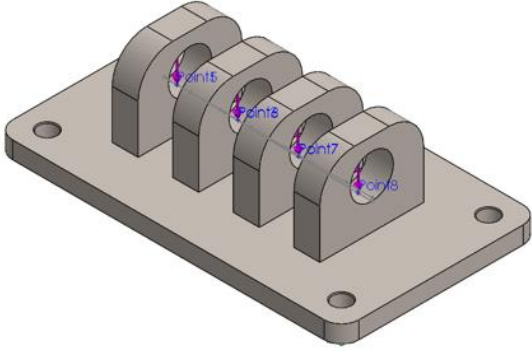
G.Ratio =  $3391.2 \text{ mm}^2 / 883.125 \text{ mm}^2 = 3.84$

### 3.3.2 Analysis results and simulations

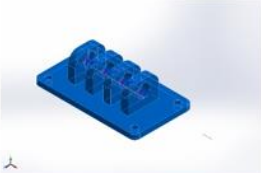
A simulation was implemented using FFE-plus solver to guarantee the effect obtained from static loading on censorious designed fragments. Loads of the parts were estimated starting with the motor base up until the structure of the machine. According to the analysis below, the parts designed should be placed below the yield strength of the material (ferritic stainless steel). Therefore, no mechanical failure would appear from the loads that are applied on expected surfaces and are fixed

exactly as they are supposed to be fixed. The following tables display detailed information about the parts:

### Motor support Model Information



**Model name:** Motor support  
**Current Configuration:** Default

Solid Bodies		
Document Name and Reference	Treated As	Volumetric Properties
Fillet2 	Solid Body	<b>Mass:</b> 2.7987 kg <b>Volume:</b> 0.000358808 m <sup>3</sup> <b>Density:</b> 7,800 kg/m <sup>3</sup> <b>Weight:</b> 27.4273 N

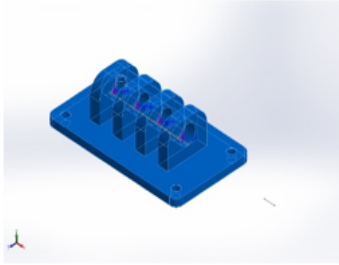
### Units

<b>Unit system:</b>	SI (MKS)
<b>Length/Displacement</b>	mm
<b>Temperature</b>	Kelvin
<b>Angular velocity</b>	Rad/sec
<b>Pressure/Stress</b>	N/m <sup>2</sup>

## Study Properties

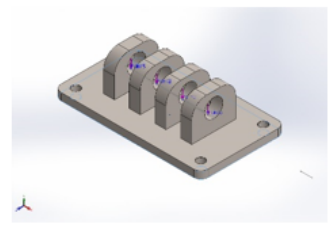
<b>Study name</b>	Pillow block
<b>Analysis type</b>	Static
<b>Mesh type</b>	Solid Mesh
<b>Thermal Effect:</b>	On
<b>Thermal option</b>	Include temperature loads
<b>Zero strain temperature</b>	298 Kelvin
<b>Include fluid pressure effects from SOLIDWORKS Flow Simulation</b>	Off
<b>Solver type</b>	FFEPlus
<b>Inplane Effect:</b>	Off
<b>Soft Spring:</b>	Off
<b>Inertial Relief:</b>	Off
<b>Incompatible bonding options</b>	Automatic
<b>Large displacement</b>	Off
<b>Compute free body forces</b>	On
<b>Friction</b>	Off
<b>Use Adaptive Method:</b>	Off

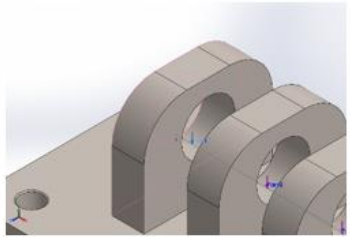
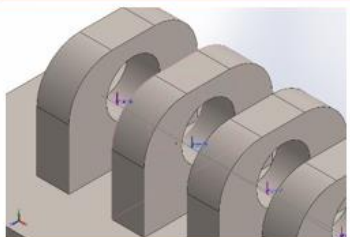
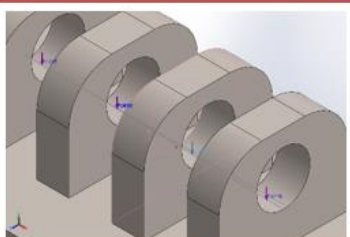
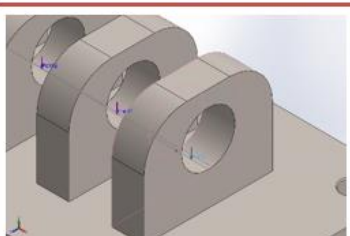
## Material Properties

Model Reference	Properties	Components
	<p><b>Name:</b> Stainless Steel (ferritic)  <b>Model type:</b> Linear Elastic Isotropic  <b>Default failure criterion:</b> Unknown  <b>Yield strength:</b> 1.72339e+08 N/m<sup>2</sup>  <b>Tensile strength:</b> 5.13613e+08 N/m<sup>2</sup>  <b>Elastic modulus:</b> 2e+11 N/m<sup>2</sup>  <b>Poisson's ratio:</b> 0.28  <b>Mass density:</b> 7,800 kg/m<sup>3</sup>  <b>Shear modulus:</b> 7.7e+10 N/m<sup>2</sup>  <b>Thermal expansion coefficient:</b> 1.1e-05 /Kelvin</p>	Motor support



## Loads and Fixtures

Fixture name	Fixture Image	Fixture Details		
Fixed-3		<b>Entities:</b> 1 face(s) <b>Type:</b> Fixed Geometry		
Resultant Forces				
Components	X	Y	Z	Resultant
Reaction force(N)	0.000307526	97.9999	-0.00104927	97.9999
Reaction Moment(N.m)	0	0	0	0

Load name	Load Image	Load Details
Force-1		<b>Reference:</b> Face< 1 > <b>Type:</b> Apply force <b>Values:</b> -24.5, ---, --- N
Force-2		<b>Reference:</b> Face< 1 > <b>Type:</b> Apply force <b>Values:</b> -24.5, ---, --- N
Force-3		<b>Reference:</b> Face< 1 > <b>Type:</b> Apply force <b>Values:</b> -24.5, ---, --- N
Force-4		<b>Reference:</b> Face< 1 > <b>Type:</b> Apply force <b>Values:</b> -24.5, ---, --- N

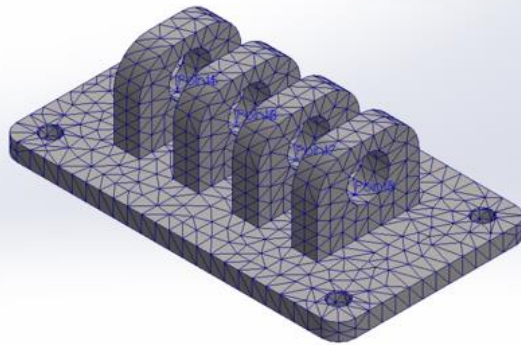
### Mesh information

Mesh type	Solid Mesh
Mesher Used:	Standard mesh
Automatic Transition:	Off
Include Mesh Auto Loops:	Off
Jacobian points for High quality mesh	16 Points
Element Size	8.17397 mm
Tolerance	0.408699 mm
Mesh Quality	High

### Mesh information - Details

Total Nodes	11350
Total Elements	6349
Maximum Aspect Ratio	14
% of elements with Aspect Ratio < 3	95.5
% of elements with Aspect Ratio > 10	0.173
% of distorted elements(Jacobian)	0
Time to complete mesh(hh:mm:ss):	00:00:01

Model name: 01\_09\_V2.0015  
Study name: Pillow block(-Default-)  
Mesh type: Solid Mesh



## Resultant Forces

### Reaction forces

Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N	0.000307526	97.9999	-0.00104927	97.9999

### Reaction Moments

Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N.m	0	0	0	0

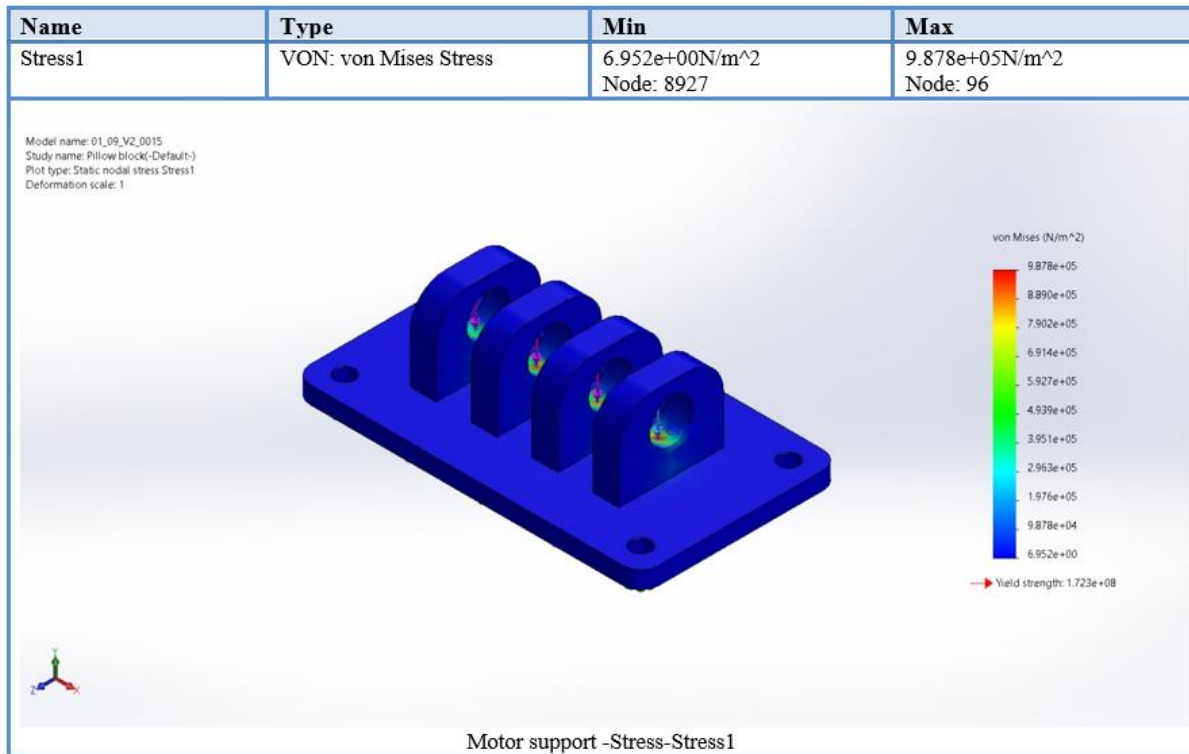
### Free body forces

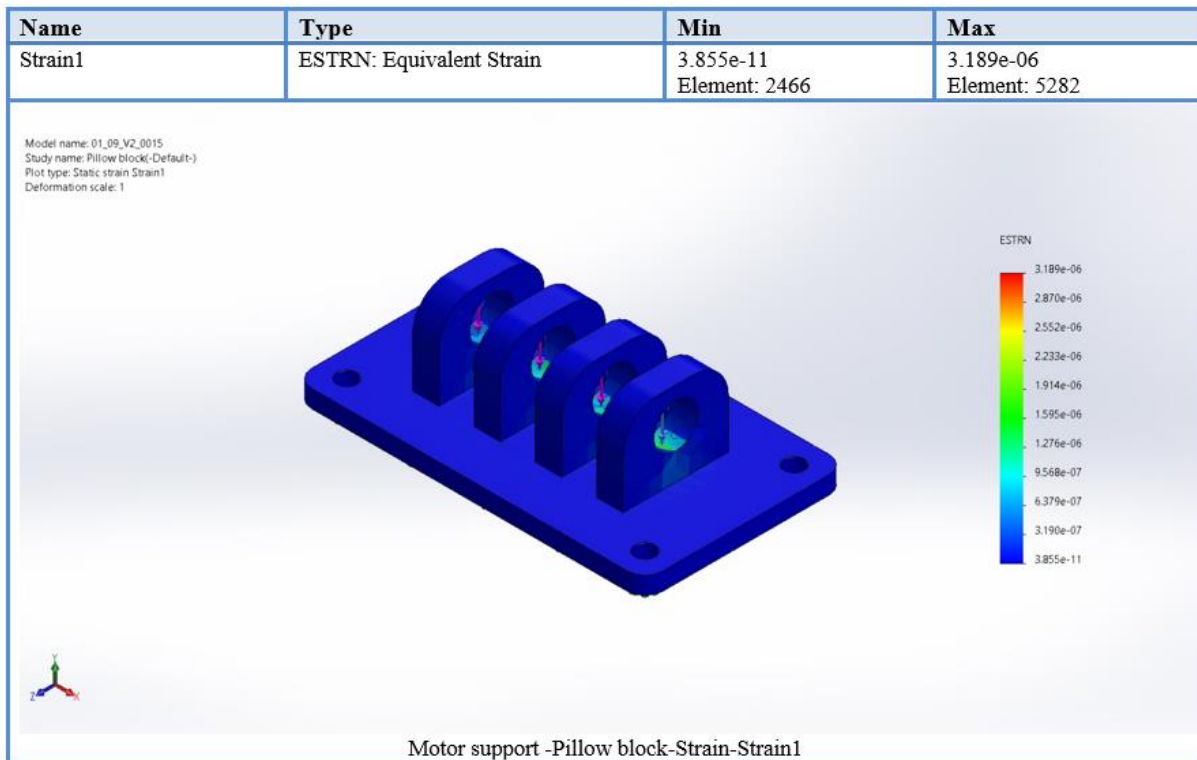
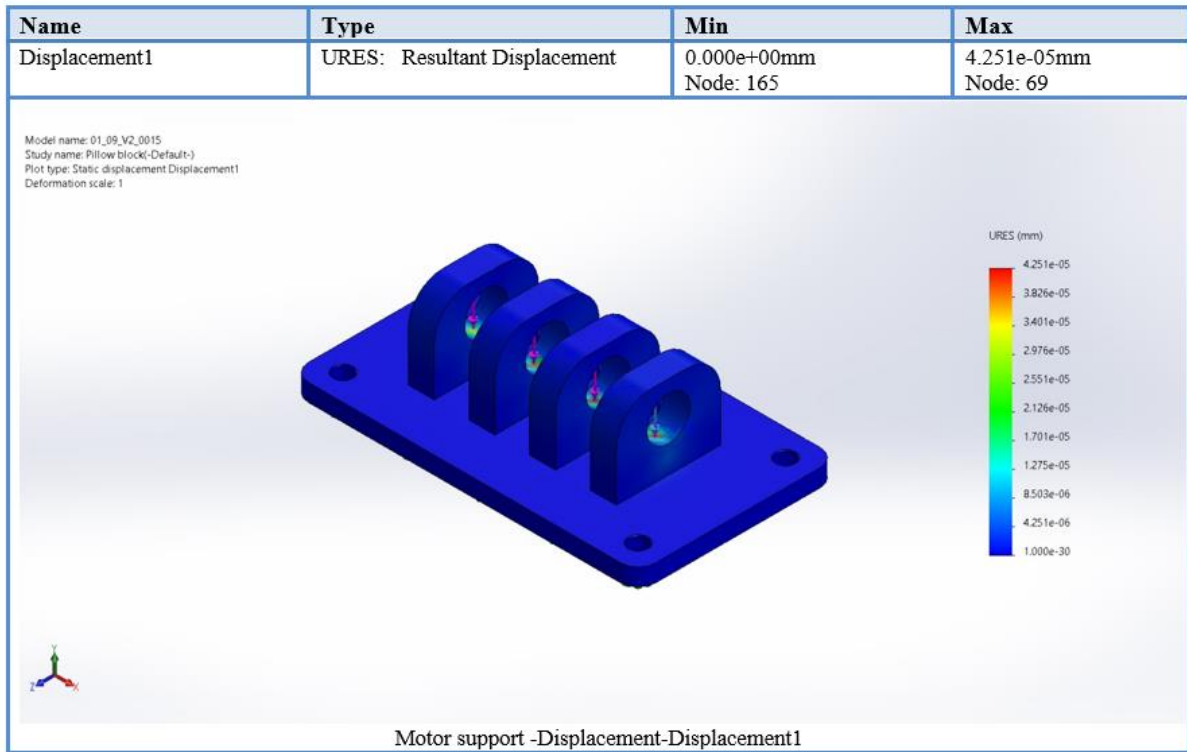
Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N	0.000725678	0.0050838	-0.00249495	0.00570932

### Free body moments

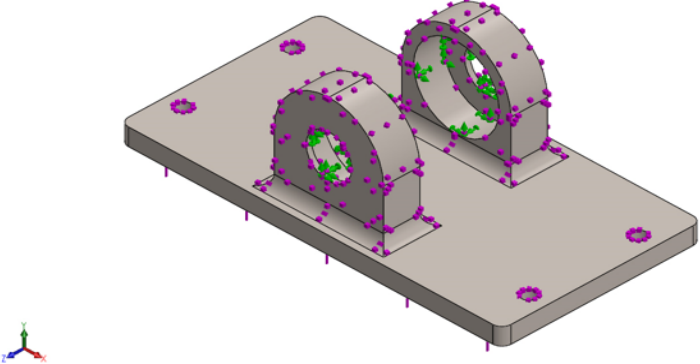
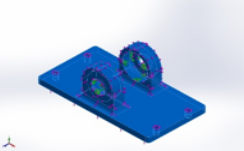
Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N.m	0	0	0	1e-33

## Study Results





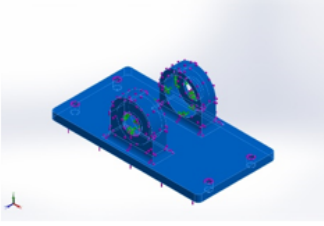
## Motor Base Model Information

		
<p><b>Model name:</b> Motor base  <b>Current Configuration:</b> Default</p>		
Solid Bodies		
Document Name and Reference	Treated As	Volumetric Properties
Fillet3 	Solid Body	<b>Mass:</b> 2.32453 kg <b>Volume:</b> 0.000298016 m <sup>3</sup> <b>Density:</b> 7,800.02 kg/m <sup>3</sup> <b>Weight:</b> 22.7804 N

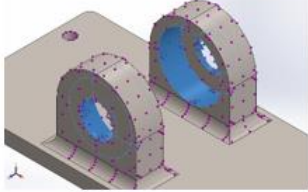
## Study Properties

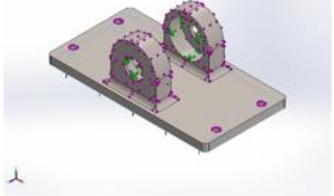
<b>Study name</b>	Static 1
<b>Analysis type</b>	Static
<b>Mesh type</b>	Solid Mesh
<b>Thermal Effect:</b>	On
<b>Thermal option</b>	Include temperature loads
<b>Zero strain temperature</b>	298 Kelvin
<b>Include fluid pressure effects from SOLIDWORKS Flow Simulation</b>	Off
<b>Solver type</b>	FFEPlus
<b>Inplane Effect:</b>	Off
<b>Soft Spring:</b>	Off
<b>Inertial Relief:</b>	Off
<b>Incompatible bonding options</b>	Automatic
<b>Large displacement</b>	Off
<b>Compute free body forces</b>	On
<b>Friction</b>	Off
<b>Use Adaptive Method:</b>	Off

### Material Properties

Model Reference	Properties	Components
	<p><b>Name:</b> Stainless Steel (ferritic)</p> <p><b>Model type:</b> Linear Elastic Isotropic</p> <p><b>Default failure criterion:</b> Unknown</p> <p><b>Yield strength:</b> 1.72339e+08 N/m<sup>2</sup></p> <p><b>Tensile strength:</b> 5.13613e+08 N/m<sup>2</sup></p> <p><b>Elastic modulus:</b> 2e+11 N/m<sup>2</sup></p> <p><b>Poisson's ratio:</b> 0.28</p> <p><b>Mass density:</b> 7,800 kg/m<sup>3</sup></p> <p><b>Shear modulus:</b> 7.7e+10 N/m<sup>2</sup></p> <p><b>Thermal expansion coefficient:</b> 1.1e-05 /Kelvin</p>	Motor base

### Loads and Fixtures

Fixture name	Fixture Image	Fixture Details		
Fixed-1		<p><b>Entities:</b> 4 face(s)</p> <p><b>Type:</b> Fixed Geometry</p>		
<b>Resultant Forces</b>				
<b>Components</b>	<b>X</b>	<b>Y</b>	<b>Z</b>	<b>Resultant</b>
<b>Reaction force(N)</b>	-0.000524288	-98.1009	-0.000509985	98.1009
<b>Reaction Moment(N.m)</b>	0	0	0	0

Load name	Load Image	Load Details
Force-1		<p><b>Entities:</b> 1 face(s)</p> <p><b>Type:</b> Apply normal force</p> <p><b>Value:</b> 98.1 N</p>

## Resultant Forces

### Reaction forces

Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N	-0.000524288	-98.1009	-0.000509985	98.1009

### Reaction Moments

Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N.m	0	0	0	0

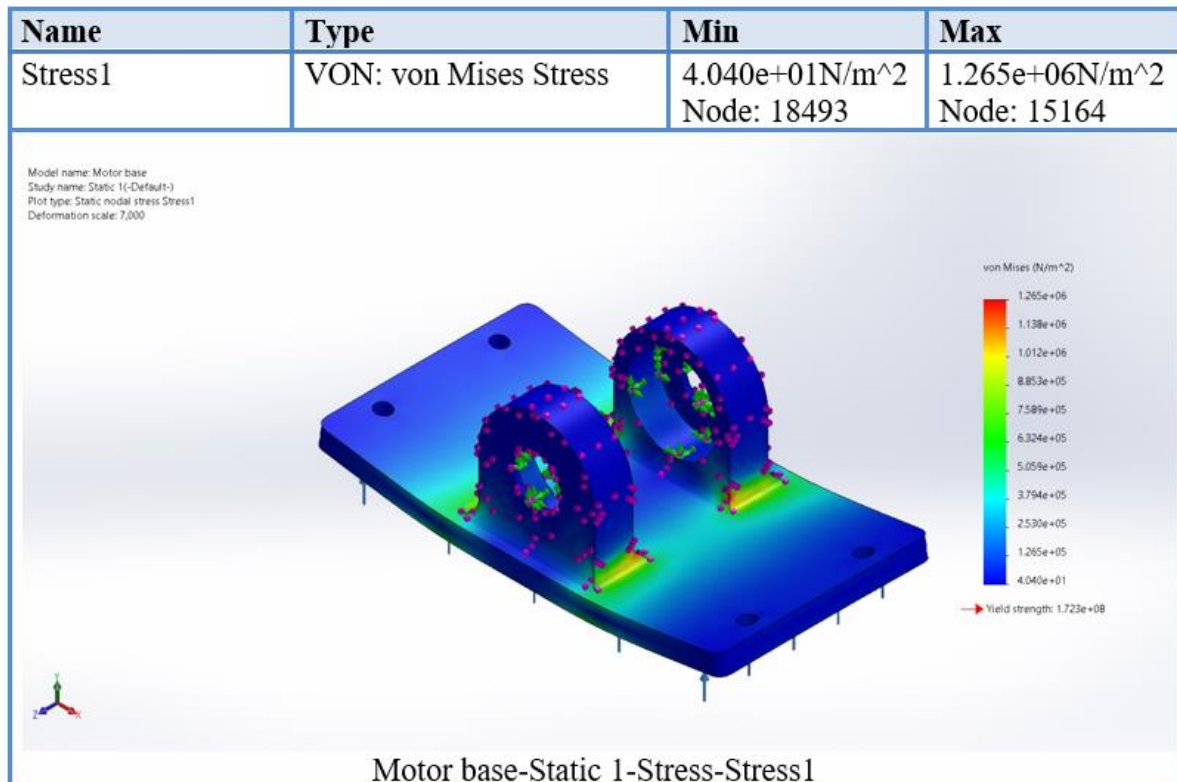
### Free body forces

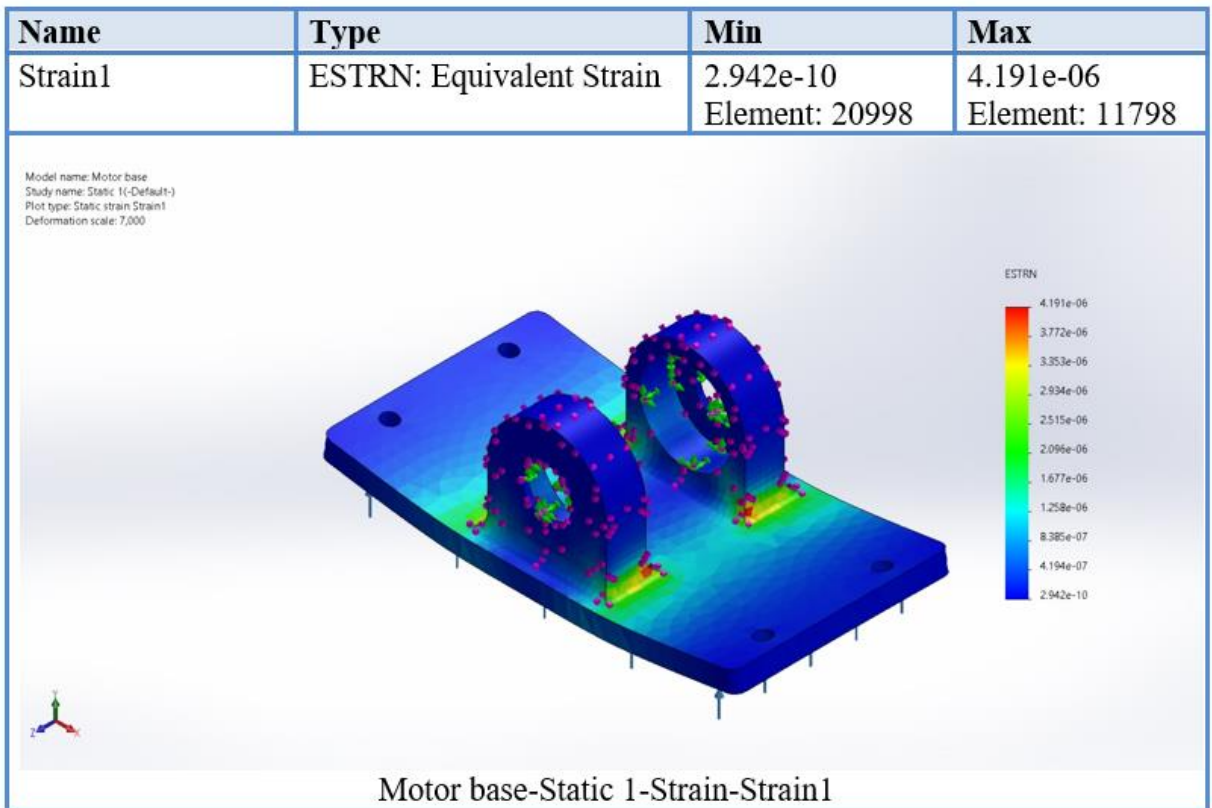
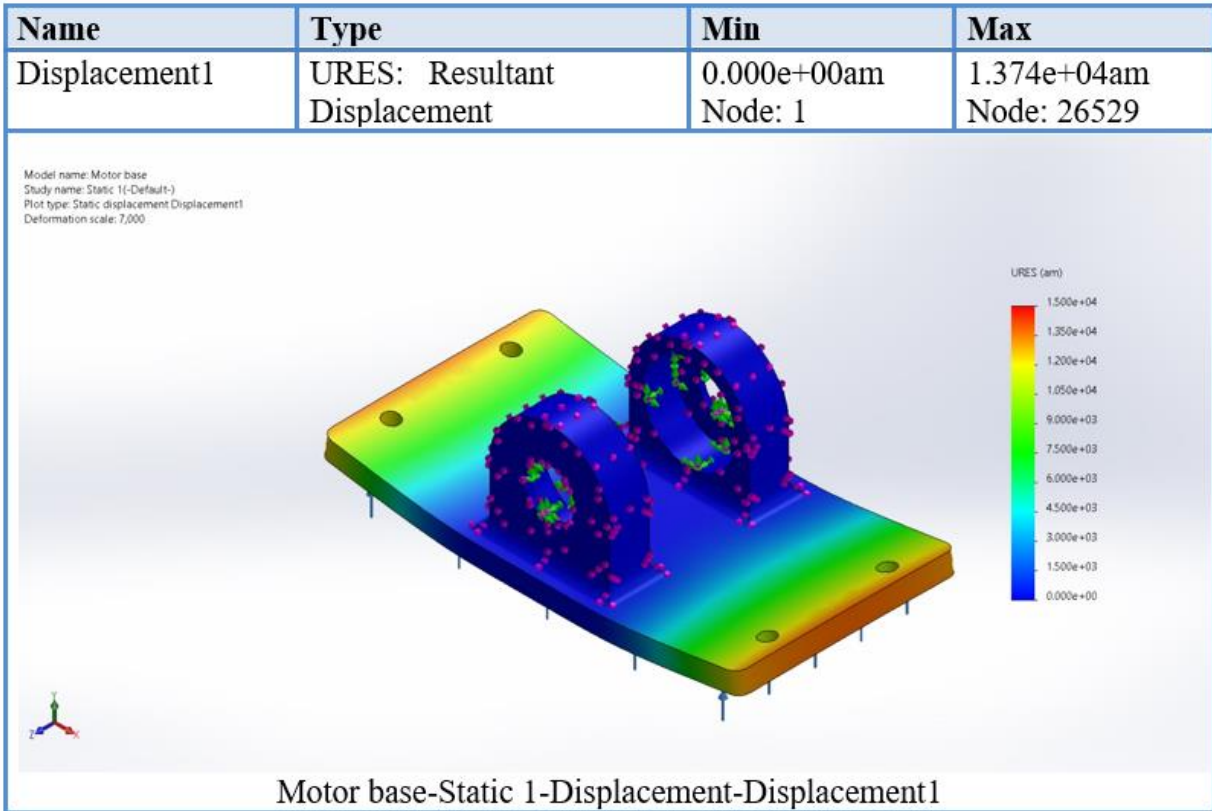
Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N	-0.000791798	-0.00117388	0.000444198	0.001484

### Free body moments

Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N.m	0	0	0	1e-33

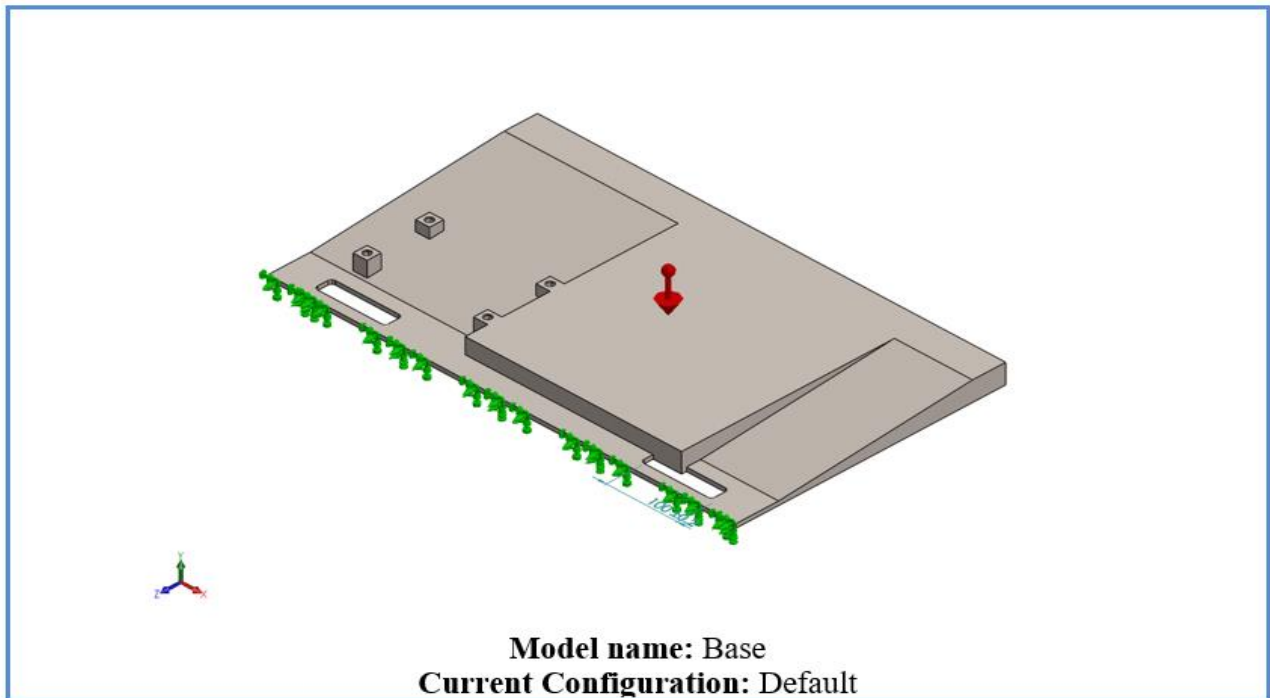
## Study Results

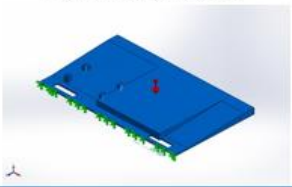






## Base Model Information

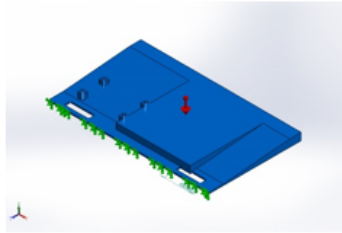


Solid Bodies		
Document Name and Reference	Treated As	Volumetric Properties
Boss-Extrude4 	Solid Body	<b>Mass:</b> 43.6915 kg <b>Volume:</b> 0.00560147 m <sup>3</sup> <b>Density:</b> 7,800 kg/m <sup>3</sup> <b>Weight:</b> 428.176 N

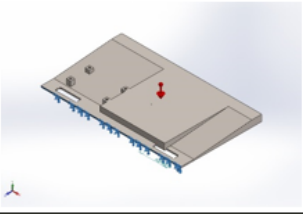
### Study Properties

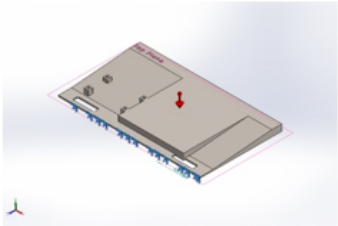
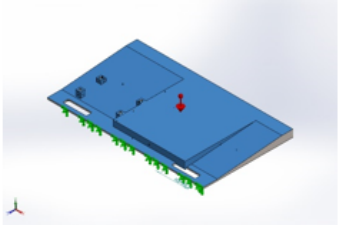
<b>Study name</b>	Static 5
<b>Analysis type</b>	Static
<b>Mesh type</b>	Solid Mesh
<b>Thermal Effect:</b>	On
<b>Thermal option</b>	Include temperature loads
<b>Zero strain temperature</b>	298 Kelvin
<b>Include fluid pressure effects from SOLIDWORKS Flow Simulation</b>	Off
<b>Solver type</b>	FFEPlus
<b>Inplane Effect:</b>	Off
<b>Soft Spring:</b>	Off
<b>Inertial Relief:</b>	Off
<b>Incompatible bonding options</b>	Automatic
<b>Large displacement</b>	Off
<b>Compute free body forces</b>	On
<b>Friction</b>	Off
<b>Use Adaptive Method:</b>	Off

### Material Properties

Model Reference	Properties	Components
	<p><b>Name:</b> Stainless Steel (ferritic)</p> <p><b>Model type:</b> Linear Elastic Isotropic</p> <p><b>Default failure criterion:</b> Unknown</p> <p><b>Yield strength:</b> 1.72339e+08 N/m<sup>2</sup></p> <p><b>Tensile strength:</b> 5.13613e+08 N/m<sup>2</sup></p> <p><b>Elastic modulus:</b> 2e+11 N/m<sup>2</sup></p> <p><b>Poisson's ratio:</b> 0.28</p> <p><b>Mass density:</b> 7,800 kg/m<sup>3</sup></p> <p><b>Shear modulus:</b> 7.7e+10 N/m<sup>2</sup></p> <p><b>Thermal expansion coefficient:</b> 1.1e-05 /Kelvin</p>	Base

### Loads and Fixtures

Fixture name	Fixture Image	Fixture Details		
Fixed-1		<b>Entities:</b> 2 face(s) <b>Type:</b> Fixed Geometry		
<b>Resultant Forces</b>				
<b>Components</b>	<b>X</b>	<b>Y</b>	<b>Z</b>	<b>Resultant</b>
<b>Reaction force(N)</b>	-0.000359579	574.248	-0.000168017	574.248
<b>Reaction Moment(N.m)</b>	0	0	0	0

Load name	Load Image	Load Details
Gravity-1		<b>Reference:</b> Top Plane <b>Values:</b> 0 0 -9.81 <b>Units:</b> m/s <sup>2</sup>
Distributed Mass-1		<b>Entities:</b> 25 face(s) <b>Type:</b> Displacement (Direct transfer) <b>Coordinate System:</b> Global Cartesian coordinates <b>Translation Values:</b> ---, ---, --- mm <b>Rotation Values:</b> ---, ---, --- deg <b>Reference coordinates:</b> 0 0 0 mm <b>Remote Mass:</b> 15 kg <b>Moment of Inertia:</b> 0,0,0,0,0,0 kg.m <sup>2</sup> <b>Components transferred:</b> NA

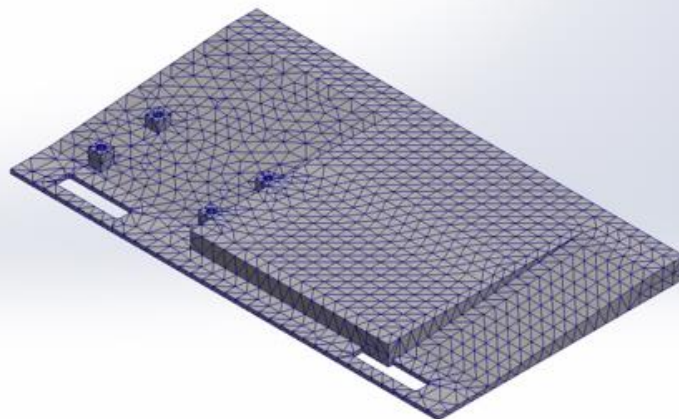
### Mesh information

<b>Mesh type</b>	Solid Mesh
<b>Mesher Used:</b>	Standard mesh
<b>Automatic Transition:</b>	Off
<b>Include Mesh Auto Loops:</b>	Off
<b>Jacobian points for High quality mesh</b>	16 Points
<b>Element Size</b>	17.7627 mm
<b>Tolerance</b>	0.888135 mm
<b>Mesh Quality</b>	High

### Mesh information - Details

<b>Total Nodes</b>	17990
<b>Total Elements</b>	9972
<b>Maximum Aspect Ratio</b>	11.654
<b>% of elements with Aspect Ratio &lt; 3</b>	89.5
<b>% of elements with Aspect Ratio &gt; 10</b>	0.0501
<b>% of distorted elements(Jacobian)</b>	0
<b>Time to complete mesh(hh:mm:ss):</b>	00:00:01

Model name: 01\_09\_V2\_0013  
Study name: Static 5(-Default-)  
Mesh type: Solid Mesh



## Resultant Forces

### Reaction forces

Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N	-0.000359579	574.248	-0.000168017	574.248

### Reaction Moments

Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N.m	0	0	0	0

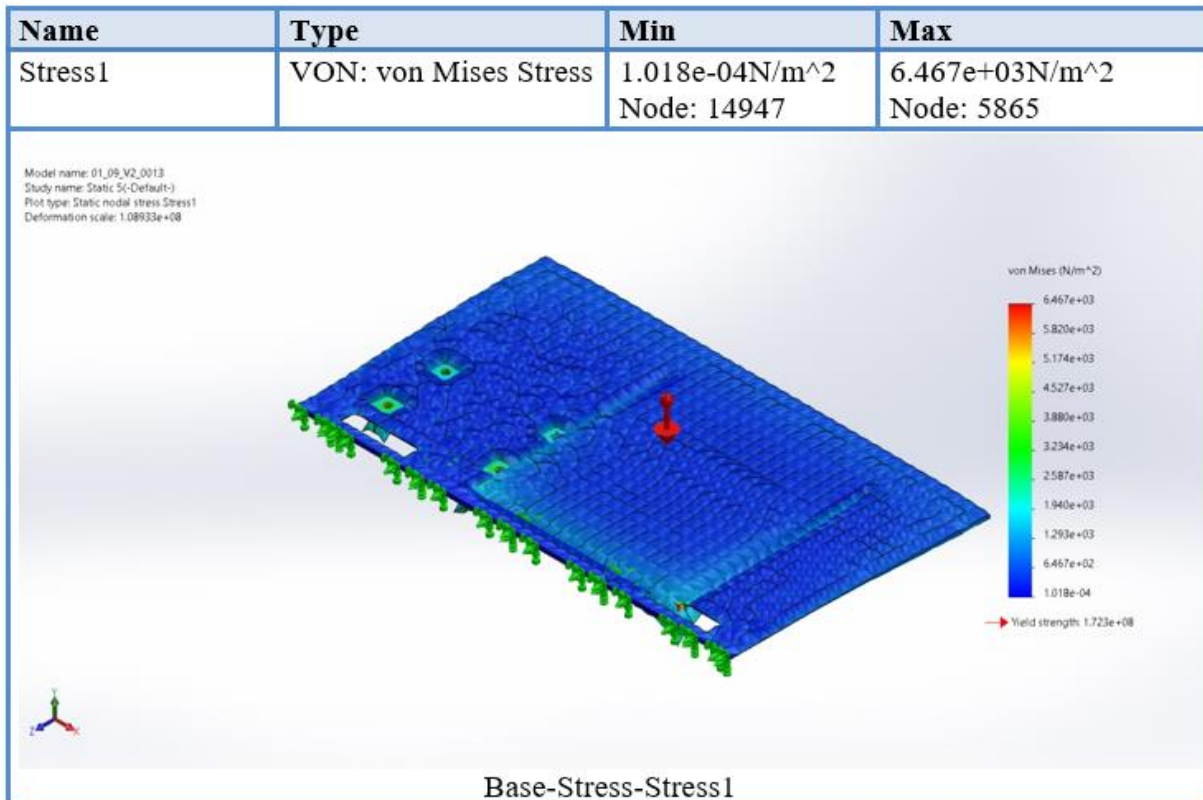
### Free body forces

Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N	0.000192664	342.006	-0.00124088	342.006

### Free body moments

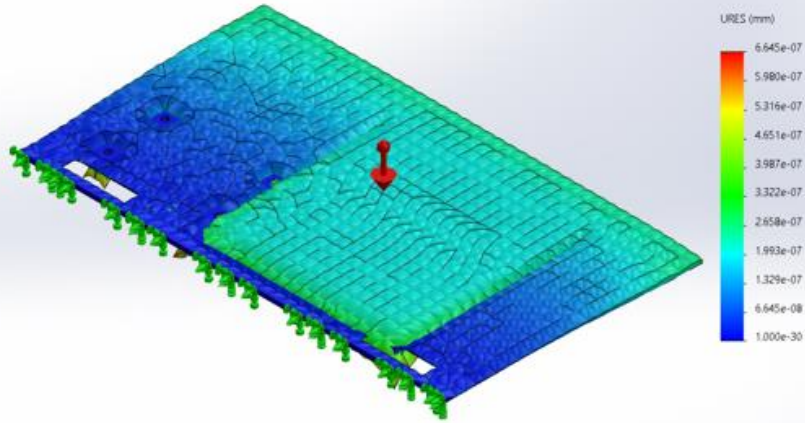
Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N.m	0	0	0	1e-33

## Study Results



Name	Type	Min	Max
Displacement1	URES: Resultant Displacement	0.000e+00mm Node: 4	6.645e-07mm Node: 1524

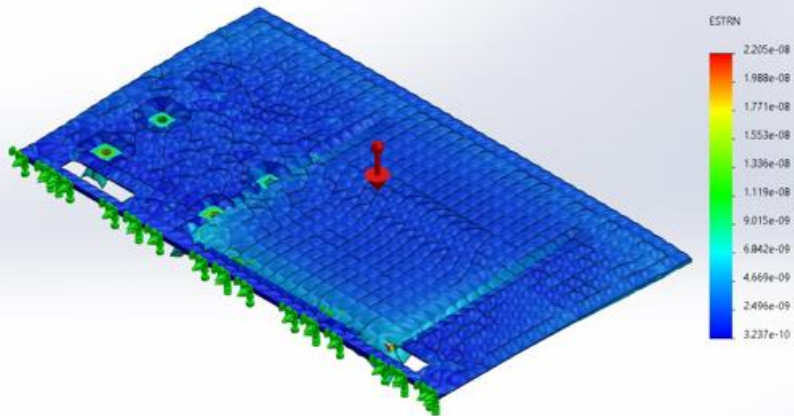
Model name: 01\_09\_V2\_0013  
 Study name: Static 5(-Default-)  
 Plot type: Static displacement Displacement1  
 Deformation scale: 1.08933e+08



Base -Static 5-Displacement-Displacement1

Name	Type	Min	Max
Strain1	ESTRN: Equivalent Strain	3.237e-10 Element: 976	2.205e-08 Element: 3876

Model name: 01\_09\_V2\_0013  
 Study name: Static 5(-Default-)  
 Plot type: Static strain Strain1  
 Deformation scale: 1.08933e+08

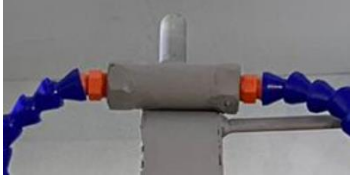
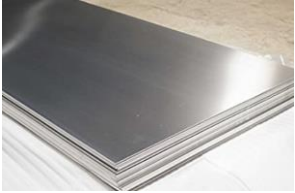
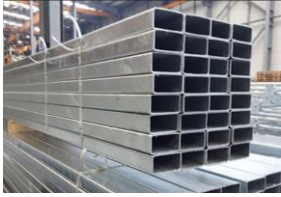




Base -Static 5-Strain-Strain1

### Structure Model Information



### 3.4. Cost analysis

Table 8: Bill of Materials

Bill of Materials					
Item No	Part Name	Quantity	Cost (USD)	Source	Picture
1	1/2" Bsp Female 4 Hole Manifold	1	5.88	www.amazon.com	
2	Steel sheets	3	22.5	Local market	
3	Steel Profile	3 meters	12 / meter	Local market	
4	12.5mm (0.5 inch) Green PVC	1	1.2	www.aliexpress.co m	
5	Washing machine pump	1	11.5	www.aliexpress.co m	

Item No	Part Name	Quantity	Cost (USD)	Source	Picture
6	Flexible Water Oil Coolant Pipe	2	6.4	www.aliexpress.com	
7	Emergency Stop Push Button	1	2.7	www.aliexpress.com	
8	On/Off Rotary Selector Switch	3	7.1	www.aliexpress.com	
9	STEEL T-SLOT PLATE 2020	1	56	www.worldofclamping.com/T-slot-plate-2020	
10	Bench Vise	1	30	www.amazon.com	



Item No	Part Name	Quantity	Cost (USD)	Source	Picture
11	Electric motor	1	200	www.metallorgraphic.com	
12	Gas spring hinge	2	3.5	Aliexpress.com	
13	Transparent plastic glass for windows	2	12	Local markets in Famagusta	
14	PGN 6005-2RS Sealed Ball Bearing	2	9.95	www.amazon.com	
15	Rubber mold	5	6	https://www.shop.metkon.com/	

Item No	Part Name	Quantity	Cost (USD)	Source	Picture
16	Keller's Reagent	1	25	<a href="http://www.gunduzkimya.com.tr/urun/kellers-reagent/">www.gunduzkimya.com.tr/urun/kellers-reagent/</a>	
17	Rubber Mold Release	2	3.125	Local markets in Turkey	
18	Alumina powder	1	105	<a href="https://www.makelekt ronik.com.tr/">https://www.makelekt ronik.com.tr/</a>	
19	Cutting Disc	2	17	<a href="https://www.makelekt ronik.com.tr/">https://www.makelekt ronik.com.tr/</a>	

Additional costs : 1) For transportation 60 USD

2) Electrical wiring 55 USD

3) For paint 24 USD

Total cost: 835 USD

## CHAPTER 4 – MANUFACTURING PLAN

### 4.1. Manufacturing Process Selection

Manufacturing process planning can be described as the systemic determination of comprehensive methods for having economic and competitive manufacturing for the pieces or the parts used, from its initial phases (raw material form) to finish phases (desired form). In addition, to determine the appropriate sequence of processing operations based on the geometrical features, sizes, tolerances. To achieve our target, which is a high precision cutting machine, we have selected the materials and components for manufacturing. Mostly we used steel sheet metal for manufacturing process.

#### 4.1.1. Manufacturing process

Manufacturing process is a critical step in manufacturing, this section identifies the parts and the method utilized for doing the project.

##### 4.1.1.1. The machine

For this machine, we have applied some manufacturing processes such as welding, drilling, bending, grinding and cutting in order to achieve the desired shape. The machine parts are divided into 7 manufacturing parts. we will describe the methods used and its needed materials.

For all machine's parts almost the same methods were used, Steel sheets and steel profile were used for creating the parts. Steel was chosen in order to make the project economic and durable. For cutting and assembling methods, The Criteria matrix were applied as shown in the following tables, for illustrating the criteria considered when comparing the available assembly methods.

Table 9: Criteria matrix for cutting process

<b>Legend</b> 1→ worst 10→ Best	<b>priority</b>	<b>Importance</b>	<b>Cutting with portable Electric Saw</b>	<b>Gas Cutting</b>
strength	4	4	5	8
Safe	1	10	8	4
Accuracy	2	9	8	5
Cost effectiveness	3	7	7	4
Weighted total			<u>221</u>	145



Figure 29: Cutting with portable Electric Saw

Table 10: Criteria matrix for sheet cutting process

<b>Legend</b> 1→ worst 10→ Best	<b>priority</b>	<b>Importance</b>	<b>Cutting Straight Lines with an Electric Saw</b>	<b>Tin Snips for Thin Sheets</b>
strength	4	7	10	6
Safe	1	10	6	8
Reliability	2	8	9	6
Cost	3	6	5	9
Weighted total			<u>232</u>	224

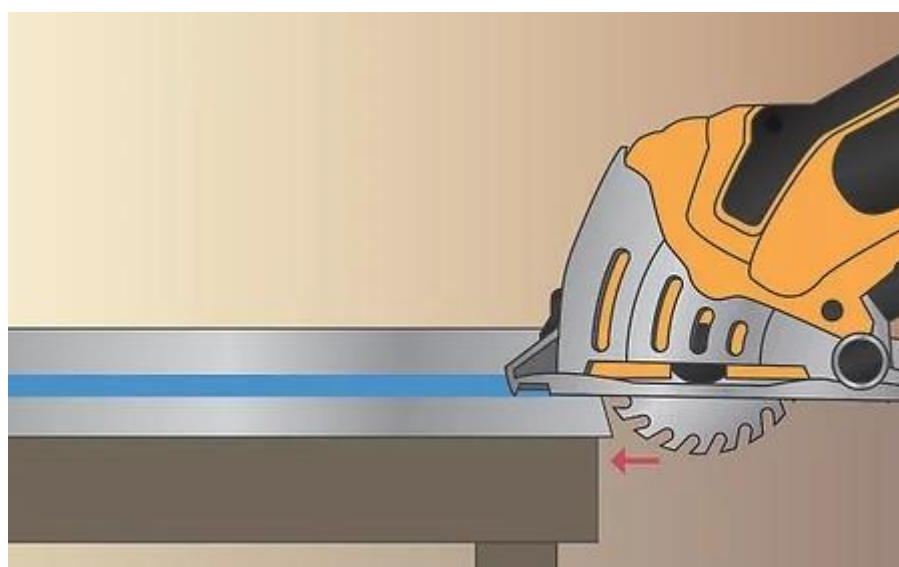


Figure 30: Cutting Straight Lines with an Electric Saw

Table 11: Criteria matrix for welding process

Legend	priority	Importance	Shield metal arc Welding	Geometric Fasteners
1→ worst				
10→ Best				
strength	1	10	10	4
Reliability	2	8	6	8
Cost	3	6	4	8
Weighted total			<u>172</u>	152

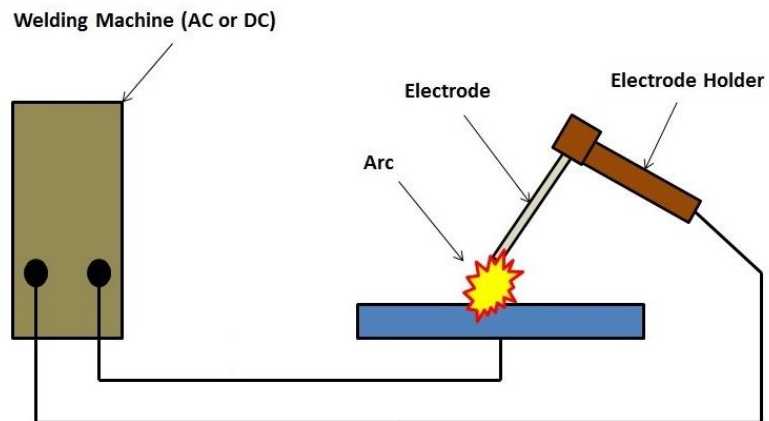


Figure 31: Shield metal arc Welding

After performing criteria matrix for the available alternatives, Shield metal arc Welding was the best to be chosen.

All the processes above were applied to the Upper housing, bottom housing, motor's base and support, and for the Disc cover. Furthermore, for the Arm inside the machine, bending process were applied to get the final shape. In addition, drilling process were applied to create the holes needed for the project.

#### 4.1.1.2. The tank

Cutting, welding and drilling processes were applied, for doing to outer perimeter and for the inner partitions



Figure 32: Cooling Tank

## 4.2. Detailed manufacturing process

### 4.2.1. Detailed dimensions of the machine

the machine dimensions are  $76 \times 60 \times 67$ . As mentioned before there are multiple parts that need either manufacturing or assembling. The dimensions of the upper and bottom housing  $76 \times 60 \times 55$ ,  $76 \times 60 \times 8$  in millimeters respectively, the arm will be mounted on the motor base and it will handle moving the motor with a diameter of 25 mm, lastly, the disc will be fixed by the disc cover with a radius of 135mm. manufacturing process of the machine cabinet4

#### 4.2.1.1. Bottom housing

Bottom housing is made of metal profile and steel sheet. For the base used a metal profile with cross-sectional area of ( ), we cut it into four parts with endings corners of 45° degree so we can assemble them orthogonally. We assembled the parts using shield metal arc welding, also we added more metal profile to the base to support it more, then we assembled the motor with its base and support together with the T-slot table.



Figure 33: Bottom housing during manufacturing



Figure 34: Bottom housing after manufacturing

#### 4.2.1.2. Upper housing

The steel sheet were shaped to the desired shapes using straight cutting machine, then it were joined by the means of shield metal arc welding. After we finished, we used the portable cutting machine for making the two windows, then painting it as shown in the following figures





Figure 35 : Upper housing during manufacturing

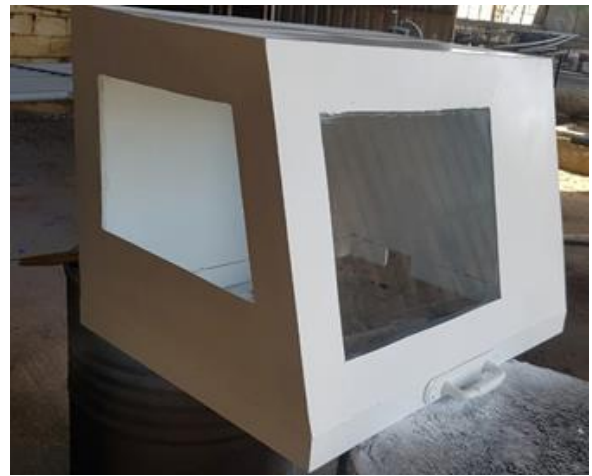


Figure 36 : Upper housing after manufacturing

#### 4.2.1.3. Motor base & Support

For both pieces, steel alloy and mild flat steel were used, in order to fix the motor.

We cut the mild flat steel to needed measurements, then we create the base and the support, then assembled the two parts together using the steel alloy with the bearing and the spring.



Figure 37 : Motor base & Support during manufacturing



Figure 38: Motor base & Support after manufacturing

#### 4.2.1.4. Disc stabilizer and outer cover

We assembled the disc stabilizers and the outer cover, the disc stabilizers used to stabilize the disc due to their larger size and precise grinding usually they come in pairs. The disc cover's main job is to prevent chips from the cutting disc to reach the motor, and it is made out of steel sheet metal. For the cover we created it using steel sheet, then welded it to the desired shape, finally we assembled both parts to the motor as the following figure ( )

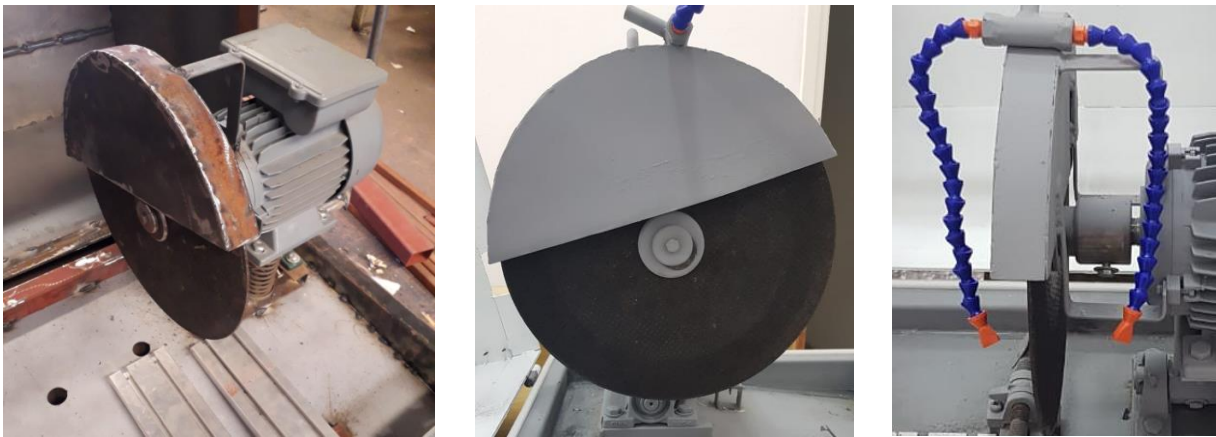


Figure 39: Manufacturing of Disc stabilizer and outer cover

#### 4.2.1.5. Arm

The arm is a very important part, it is linked to many other parts and its job to handle their weight, also for controlling the movement with avoiding any crash, so we used steel alloy as the material in the arm part because it is considered a hard material. We used turning machine for manufacturing the arm then we used bending machine to create the bend corner, lastly we welded it with the steel alloy which from the motor base.



Figure 40: Manufacturing of Arm

#### 4.2.2. Cooling tank

For cooling tank, it is made of galvanized steel since it can resist corrosion, the tank contains of three partitions from inside and as shown in figure ( ), to prevent metal chips from coming to the motor side, since the water discharge is from the farthest side. We used cutting and welding and drilling processes in order to create it. Its connected to washing machine pump and then by hoses to the machine as a loop, the tank dimensions is 30 mm × 20 mm × 20 mm, the partitions high is 17 mm.



Figure 41: Manufacturing of tank

## CHAPTER 5 – PRDODUCT TESTING PLAN

### 5.1. Verification plan of the objectives of the project

Our cutting machine is mainly used to study the microstructure of metals and metal alloys and to compare results with other material after being cut. For our testing procedure, we headed to the manufacturing lab and the workshop of the mechanical department of EMU.

As when it comes to the testing procedure itself, it'll be as follows:

- Prepare the machine by placing the cutting disc and making sure the coolant tank is filled.
- Start by placing your specimen in the vise and tighten it fully.
- Turn on the coolant motor and start the cutting process.
- Prepare second specimen and cut using a portable electrical cutting machine.
- Using abrasive paper or a rotating disk to remove the damaged surface layers from both specimens.
- Spraying mold release inside the plastic molds.
- 
- Remove the scratches that occurred during the grinding stage by polishing the specimens.
- Use a reagent to etch the specimens.
- Preform microscopy to examine for microstructure, defects, cracks other defects.

Compare the results of both specimens

## **5.2. Verification plan of the applied engineering standards**

### **ISO 13849**

Safety of machinery -- Safety-related parts of control systems.

### **ISO 4413**

Hydraulic fluid power -- general rules and safety requirements for systems and their components

### **ISO 9355**

Ergonomic requirements for the design of displays and control actuators.

### **ASTM (F2971)**

Practice for Reporting Data for Test Specimens Prepared.

### **ASTM (F3122)**

Evaluating Mechanical Properties of Metal Materials

## **CHAPTER 6 - RESULTS and DISCUSSIONS**

### **6.1. The Results**

After the analysis of the project, which design and production pictures were drawn, the production phase was started. Produced parts were combined with the help of Shield metal arc welding and turned into a whole. Some parts of the machine are combined with detachable parts. Removable elements are preferred due to ease of maintenance. Sealing materials are used in the necessary parts of the machine. Cooling fluids are positioned towards the cut piece with the help of flexible hoses. Cooling liquid flushes the wheel to avoid damaging the sample with frictional heat. Therefore, the material removal rate (MRR) is less; it introduces the least amount of damage in relation to the time used for the process. The coolant also removes debris from the cutting area. The combination of cutting machine, clamping tools, cut-off wheel, cooling liquid, and a set of parameters including cutting mode, feed speed, and rotational speed, all together, determines the quality of the cut.

Aluminum, steel alloy, iron profile were used in our tests with the cutting machine. Our purpose in doing this cut test is to look at the material removal rate after cutting the materials. For this process, the mass of each specimen was measured before cutting. After the cutting process, the mass of each of the specimens were measured again. Thus, the first part of our testing was carried out successfully.

For the main test of our project, same specimens were used in a second cutting process using portable electrical cutting machine. After that, sample preparation procedure by using the plastic molds and by applying cold mounting, then a grinding procedure is performed as well. Before finally starting the micro scoping analysis, the specimens need to be polished using keller's reagent and alumina powder.



Figure 42: Liquids

Table 12: Testing result for high presser cutting machine

Specimen	Weight before	Weight after
Aluminum Specimen	119g	118g
Steel Alloy	257g	252g
Steel profile	420g	417g



Figure 43: Aluminum Specimen before and after cutting



Figure 44: Steel Alloy before and after cutting



Figure 45: Steel profile before and after cutting



Table 13: Testing result for portable cutting machine

Specimen	Weight before	Weight after
Aluminum Specimen	91g	89g
Steel Alloy	232g	226g
Steel profile	322g	319g

## 6.2. Engineering Standards

Table 14: Testing engineering standards

Standard	Description
ISO 14001:2004	Environmental management systems
OHSAS 18001:2007	Occupational health and safety
ISO 13850	Emergency systems standards
EN IEC 60947-5-5	Emergency stop switch compact, foolproof

### 6.3. The constraints

1. **Cost:** This is the biggest problem we face when making a high precision cutting machine. Since the ingredients were not available from the local market, we had to order from abroad and this created an extra cost.
2. **Time:** Taking too long to deliver the orders placed. In addition, it was difficult to reach the orders given as we are not a company.
3. **Manufacturability:** with the workshop of the university being closed for most of the beginning of the semester we started the work in an off campus workshop then moved back to university.
4. **Availability of Materials:** The coolants we will use and the discs used for cutting are not available in Cyprus. That's why we decided to order the ingredients from Turkey, which might be the closest and cheapest.
5. **Efficiency:** There were occasional problems in the operation of the engine due to the inadequacy of the electrical installation in the school's laboratory.

# **CHAPTER 7 – CONCLUSION AND FUTURE WORKS**

## **7.1 Conclusion**

Manufacturing has been the basis of human production since the beginning of the industrial age. For manufacturing to reach its current level, industrialists had to be able to know the microstructure of the metals they use, and that is our main project objective. By using a cooling liquid and our machine and certain liquids on the cut surface area precision cutting is accomplished which allowed further and more accurate studies to the microstructure. Additionally, with our closed loop cooling liquid system where the liquid used for cutting is stored back to the tank we accomplished the highest efficiency possible.

The report discussed the difference in results from using our machine with the cooling liquid compared with the dry cutting with the cut-off saw, and as explained before in our results the cooling liquid with our machine provides smoother cutting with a less removal rate (MRR).

As for the microscopic analysis performed on the specimens, by doing the sample preparation procedure and the polishing procedure better and smoother surfaces were achieved which improved the results and information gained from the microscopic analysis.

Finally, the project has achieved its objectives, higher safety, more efficient cost, easier assembly and higher performance. Therefore, this machine will offer major assistance to numerous future students in the workshop of our university.

## **7.2 FUTURE WORKS**

Manufacturing a cabinet/stand for tools, blades and extra coolant storage while carrying the machine to make it easier to move and place in different places will be a big addition in the future, and a drawer for extra storage for tools and blades. Additionally a cleaning hose with a holster on the side can be added to improve the cleaning process and make it easier.

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## **APPENDIX A: Electronic Media**

### **A -1: WEBSITE**

This Project is can be followed from the following website:

<http://metallurgicals.website2.me>

### **A – 2: EMAIL ADDRESS**

**The Team can be contacted at [capston\\_gr8@outlook.com](mailto:capston_gr8@outlook.com)**

## APPENDIX B: Constraints

The main constraints on this project are finance, security, manufacturability, accessibility, time and efficiency.

- 1. COST:** Our primary goal is to balance between project cost and quality. There will be no unnecessary costs in our project. However, high precision cutting machine for metallurgy test that can work at high performance is our goal. So that, we will have a budget of approximately 1000 \$. We will make it cheaper and more durable compare with other similar projects.
- 2. TIME:** This project is very important for all team members to graduate. Before starting the project, we made the necessary plans with a meeting every week and we will make. The entire project will take 2 terms, approximately 10 months. However, we aim to finish it about 1 month ago in order to perform the necessary tests and controls. The first term is the theoretical part of the project. In the second term, we will order the necessary materials and make the project assembly.
- 3. Availability of materials:** Material supply is very important for the project to progress. Some supplies can be difficult to obtain as Cyprus is an island. For this, we are going to get some supplies from Turkey .
- 4. Manufacturability:** Manufacturing and assembly will be done in the university workshop.
- 5. Effectiveness:** Generally, higher efficiency and productivity are aimed for a high precision cutting machine for metallurgy test than the average cutting force.
- 6. Efficiency:** The proficiency of our extend is critical since our project is high exactness cutting machine for metallurgy. The materials, components and engine are exceptionally quality and progressed to create the project is exceptionally proficiently.
- 7. Safety:** Our project, which could be a high accuracy cutting machine, is exceptionally perilous, so we should pay consideration to safety, especially within the university workshop, since there's a portion we are going create within the workshop.

## APPENDIX C: Standards

Standards	Definition
ISO 12100	General principles for design
ISO 13850	Safety of machinery — Emergency stop
ISO 13855	Positioning of safeguards with respect to the approach speeds of parts of the human body.
ISO/TR 11688-1	Acoustics — Recommended practice for the design of low-noise machinery and equipment
B31T-2018	Standard Toughness Requirements for Piping
A112.6.3	Floor and Trench Drains
B89.7.2	Dimensional Measurement Planning.
ISO 229	Speeds and feeds.
ISO 299	T-slots and corresponding bolts
ISO 9692-3:2016	Standard Specification for Welding and allied processes
ASTM B209 -14	Standard Specification for Aluminum and Aluminum-Alloy Sheet and Plate

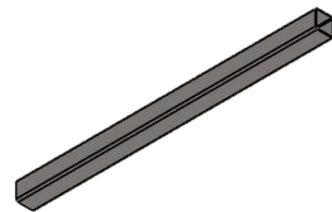
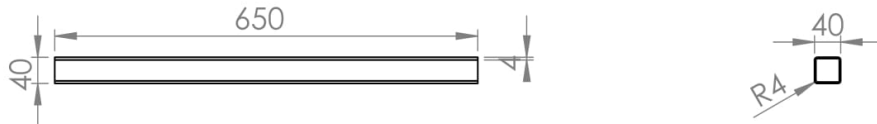
## APPENDIX D: Logbook

Dates	Brief description of the performed work
3/25/2021	Online team meeting for discussing the project ideas, design and development
3/29/2021	Discuss ideas about the project's redesigned development options with the supervisor
3/30/2021	Online team meeting for selecting the items needed for the project
4/5/2021	We gathered to check the local market
4/7/2021	We start ordering the items from online markets
4/12/2021	Upper and bottom housing design
4/14/2021	Upper and bottom housing design selection and starting manufacturing
5/8/2021	Motor base, disc cover and arm design
5/10/2021	Motor base, disc cover and arm design selection and starting manufacturing
5/17/2021	we installed the T-slot table and the vise on the bottom housing
5/18/2021	We started research and rewriting the report
5/19/2021	Cooling tank design
5/21/2021	Cooling tank selection and starting manufacturing , Meeting with the supervisor
5/24/2021	Assembly of electrical wiring for the project
5/25/2021	Painting the project
5/28/2021	starting our testing
5/30/2021	Finalizing the report and submitting it , Meeting with supervisor for getting feedbacks
1/3/2021	Project demonstration and presentation

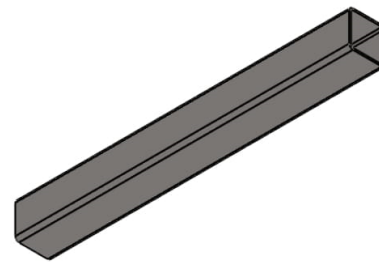
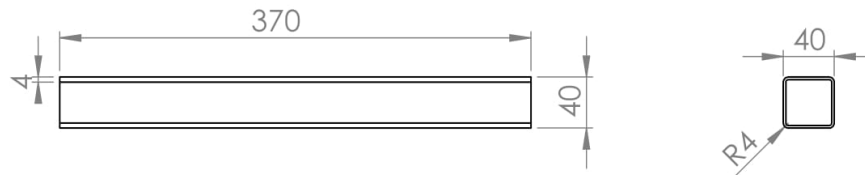
# APPENDIX E: Project Timeline



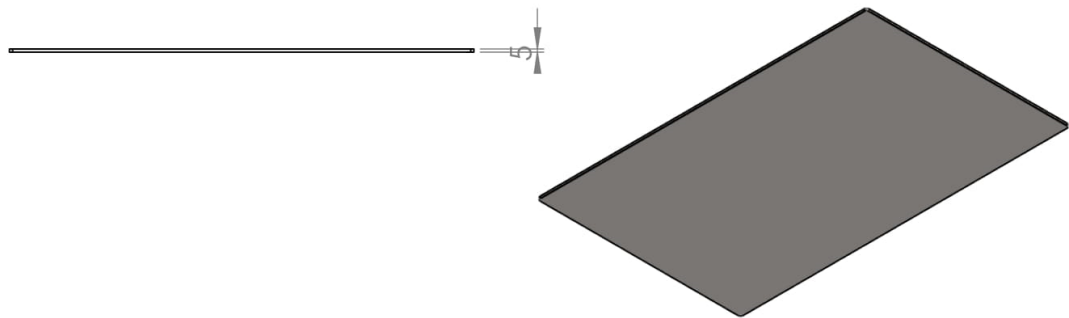
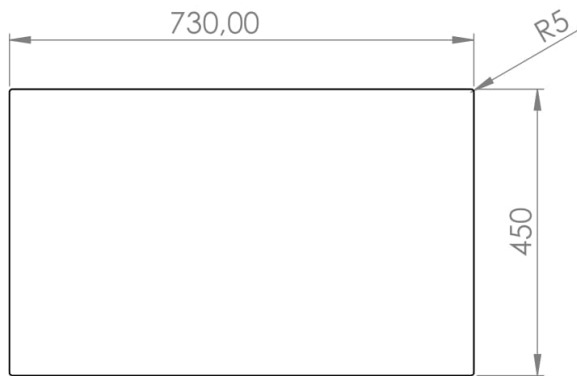
## APPENDIX F: Engineering Drawings



	NAME	SIGN	DATE	Eastern Mediterranean University Mechanical Engineering Department
Drawn By:	GROUP 08		30-DEC-20	
Checked By:	Assist. Prof. Dr. Mohammed Bsher A. Asmael		04-JAN-21	Material: Steel
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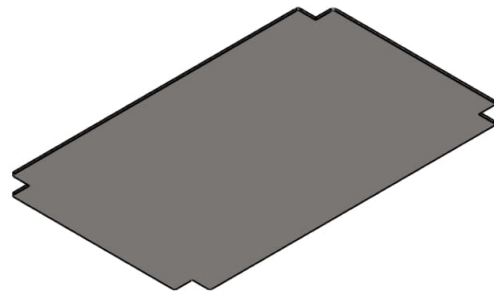
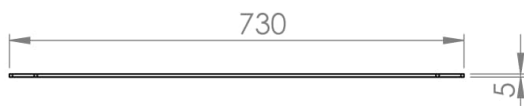
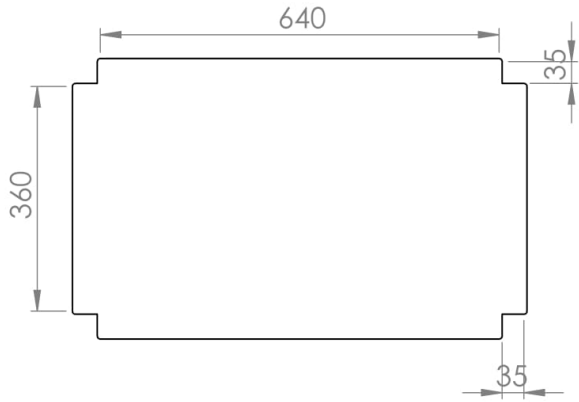


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Drawn By:	GROUP 08		30-DEC-20	
Checked By:	Assist. Prof. Dr. Mohammed Bsher A. Asmael		04-JAN-21	Material: Steel
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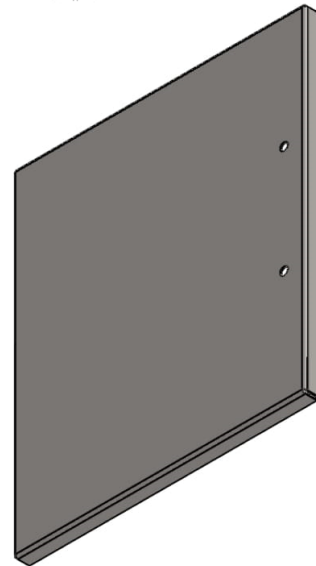
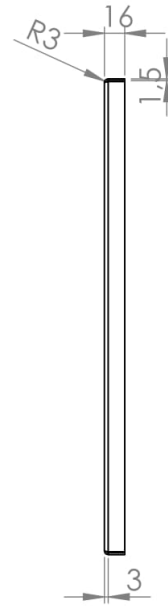
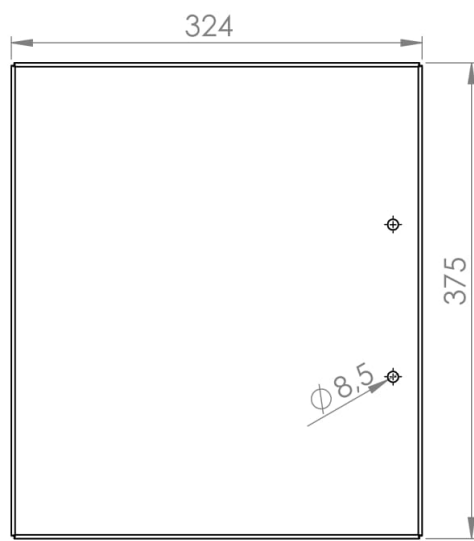


	NAME	SIGN	DATE	Eastern Mediterranean University Mechanical Engineering Department
Drawn By:	GROUP 08		30-DEC-20	
Checked By:	Assist. Prof. Dr. Mohammed Bsher A. Asmael		04-JAN-21	Material: Steel
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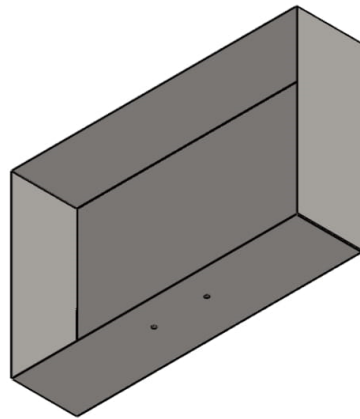
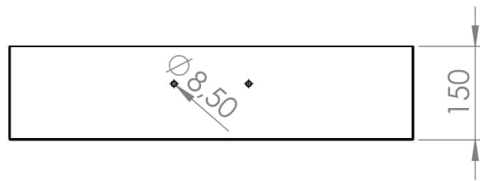
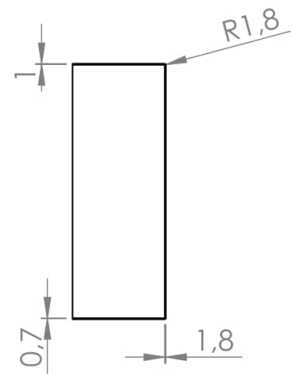




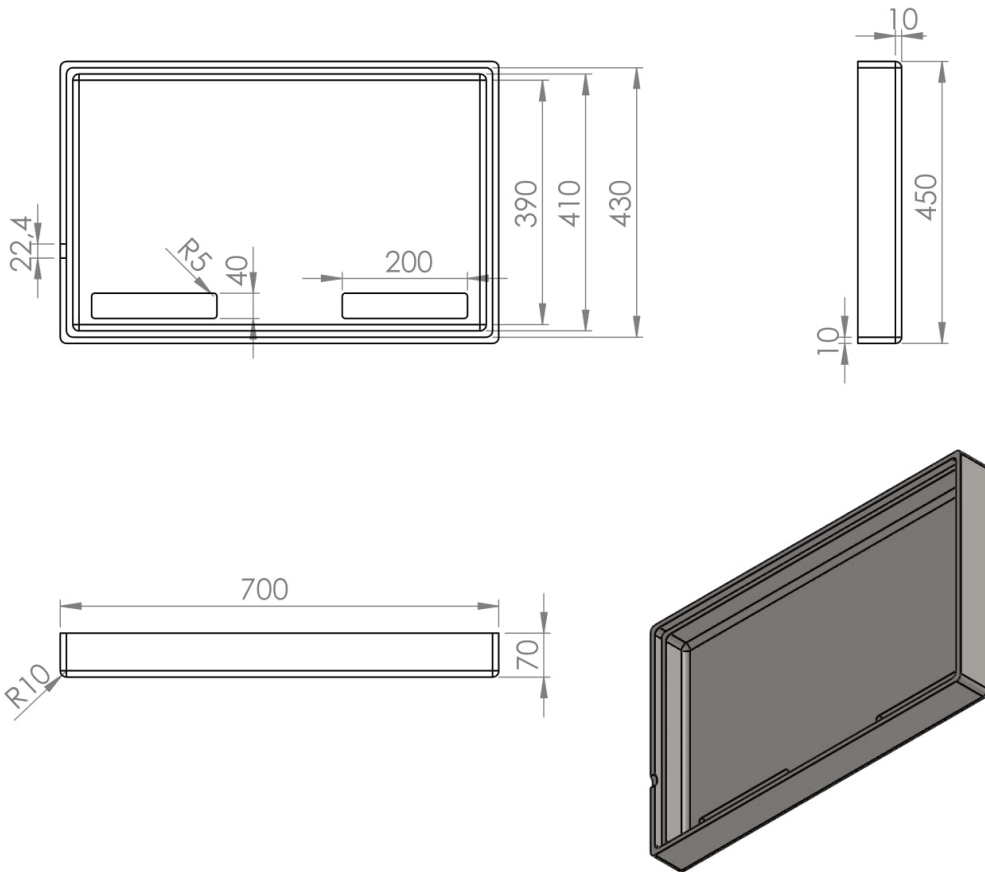
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Drawn By:	GROUP 08		30-DEC-20	
Checked By:	Assist. Prof. Dr. Mohammed Bsher A. Asmael		04-JAN-21	Material: Steel
Scale: 1:1	Title: Bottom sheet plate		Part No.: 04	Dimensions are in millimeters Tolerance 180-9001



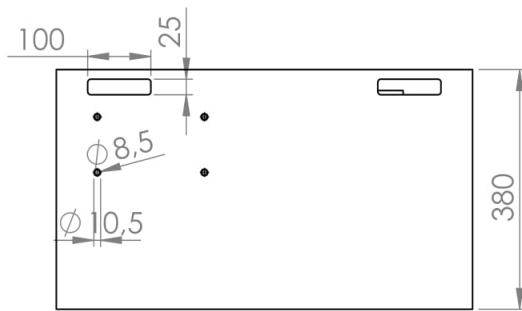
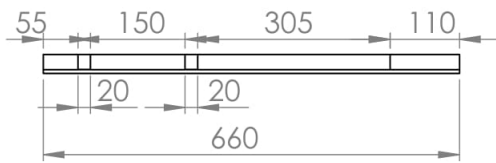
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Drawn By:	GROUP 08		30-DEC-20	
Checked By:	Assist. Prof. Dr. Mohammed Bsher A. Asmael		04-JAN-21	Material: Steel
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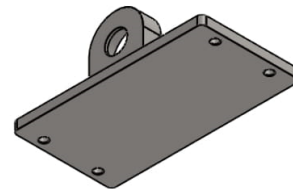
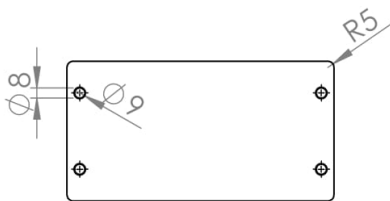
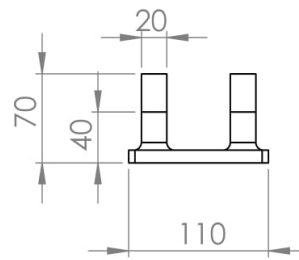
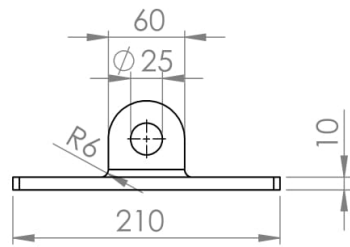
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Checked By:	Assist. Prof. Dr. Mohammed Bsher A. Asmael		04-JAN-21	Material: Steel
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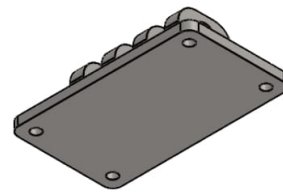
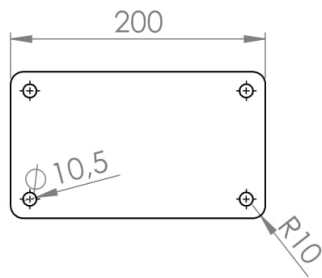
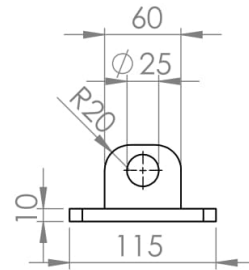
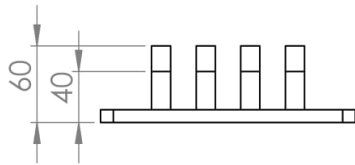
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Checked By:	Assist. Prof. Dr. Mohammed Bsher A. Asmael		04-JAN-21	Material: Aluminum
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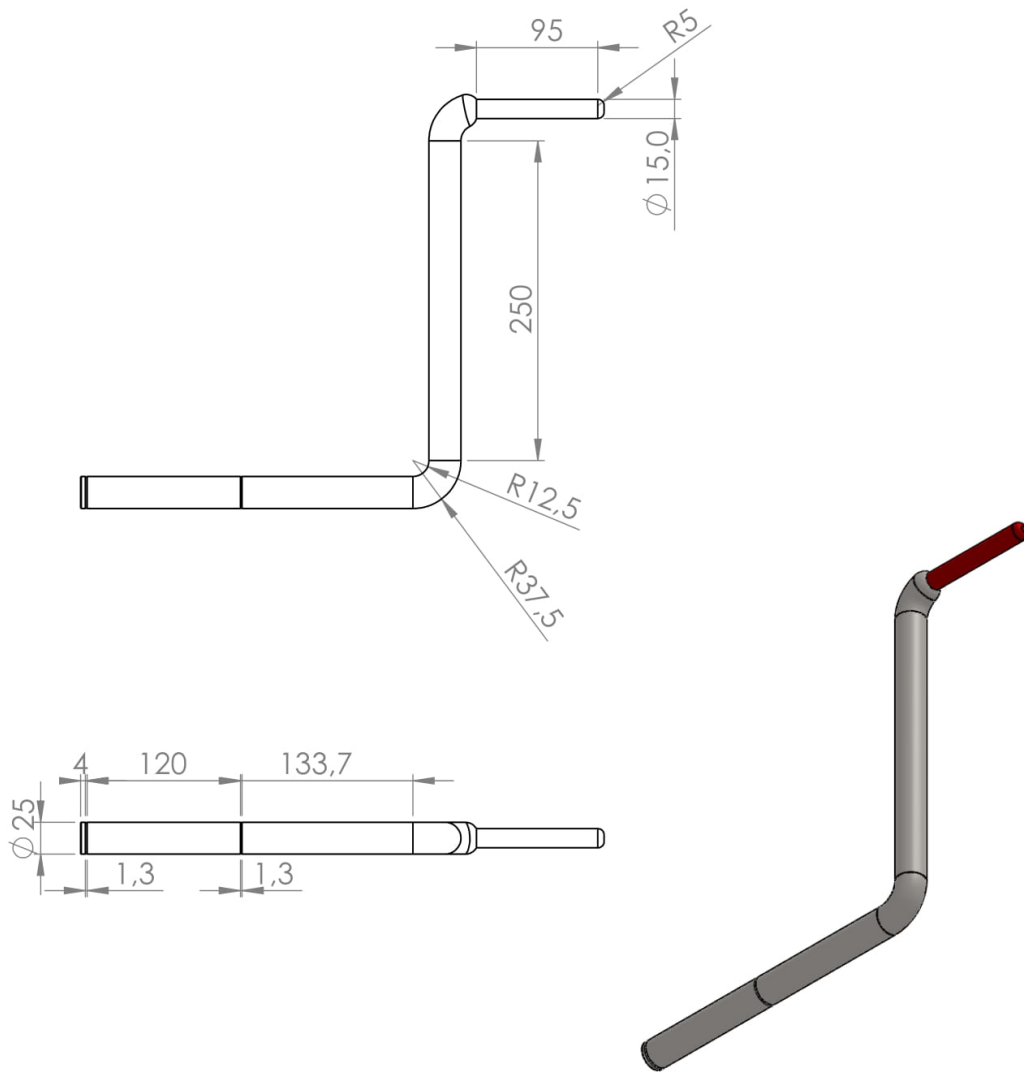
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Drawn By:	GROUP 08		30-DEC-20	
Checked By:	Assist. Prof. Dr. Mohammed Bsher A. Asmael		04-JAN-21	Material: Steel
Scale: 1:1	Title: Base		Part No.: 08	Dimensions are in millimeters Tolerance 180-9001



	NAME	SIGN	DATE	Eastern Mediterranean University Mechanical Engineering Department
Drawn By:	GROUP 08		30-DEC-20	
Checked By:	Assist. Prof. Dr. Mohammed Bsher A. Asmael		04-JAN-21	Material: Steel
Scale: 1:1	Title: Motor base		Part No.: 09	Dimensions are in millimeters Tolerance 180-9001

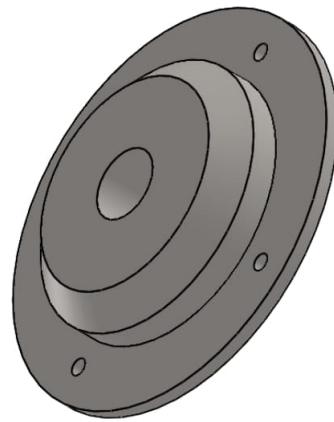
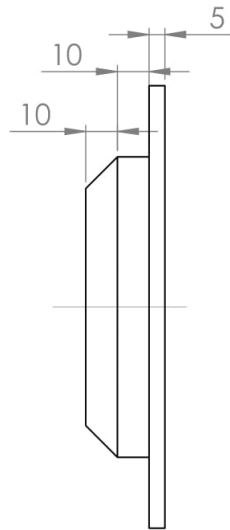
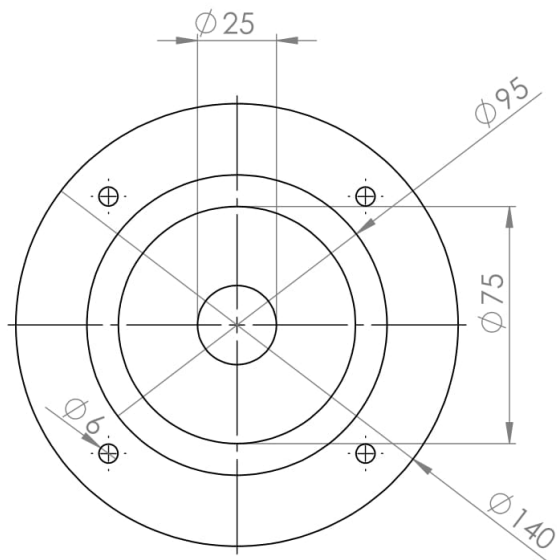


	NAME	SIGN	DATE	Eastern Mediterranean University Mechanical Engineering Department
Drawn By:	GROUP 08		30-DEC-20	
Checked By:	Assist. Prof. Dr. Mohammed Bsher A. Asmael		04-JAN-21	Material: Steel
Scale: 1:1	Title: Motor support		Part No.: 10	Dimensions are in millimeters Tolerance 180-9001

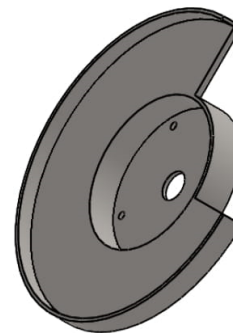
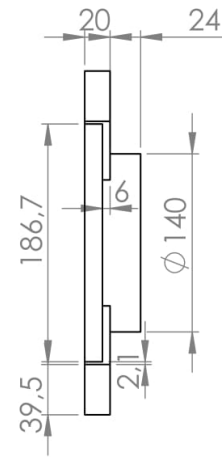
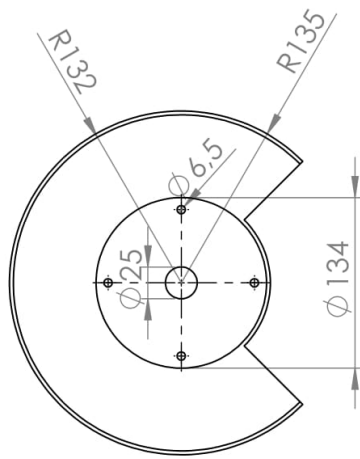


	NAME	SIGN	DATE	Eastern Mediterranean University Mechanical Engineering Department
Drawn By:	GROUP 08		30-DEC-20	
Checked By:	Assist. Prof. Dr. Mohammed Bsher A. Asmael		04-JAN-21	Material: Steel
Scale: 1:1	Title: Arm		Part No.:	Dimensions are in millimeters Tolerance 180-9001

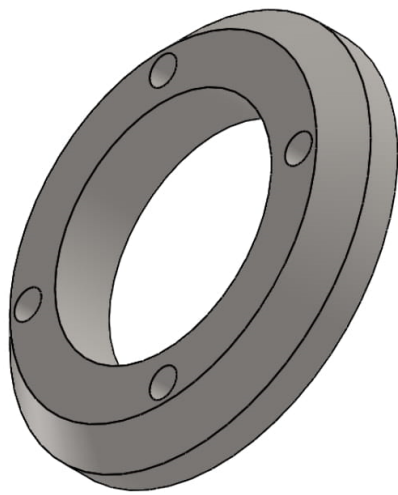
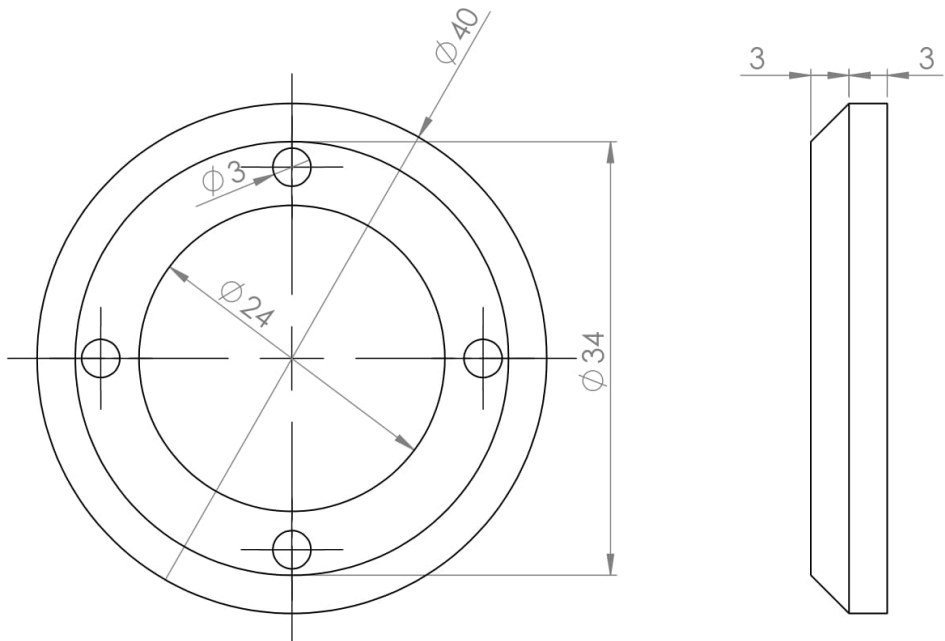




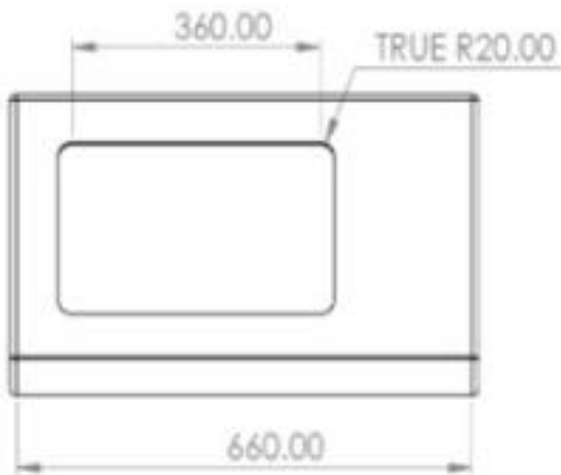
	NAME	SIGN	DATE	Eastern Mediterranean University Mechanical Engineering Department
Drawn By:	GROUP 08		30-DEC-20	
Checked By:	Assist. Prof. Dr. Mohammed Bsher A. Asmael		04-JAN-21	Material: Aluminum
Scale: 1:1	Title: Disc stabilizer 1		Part No.: 12	Dimensions are in millimeters Tolerance 180-9001



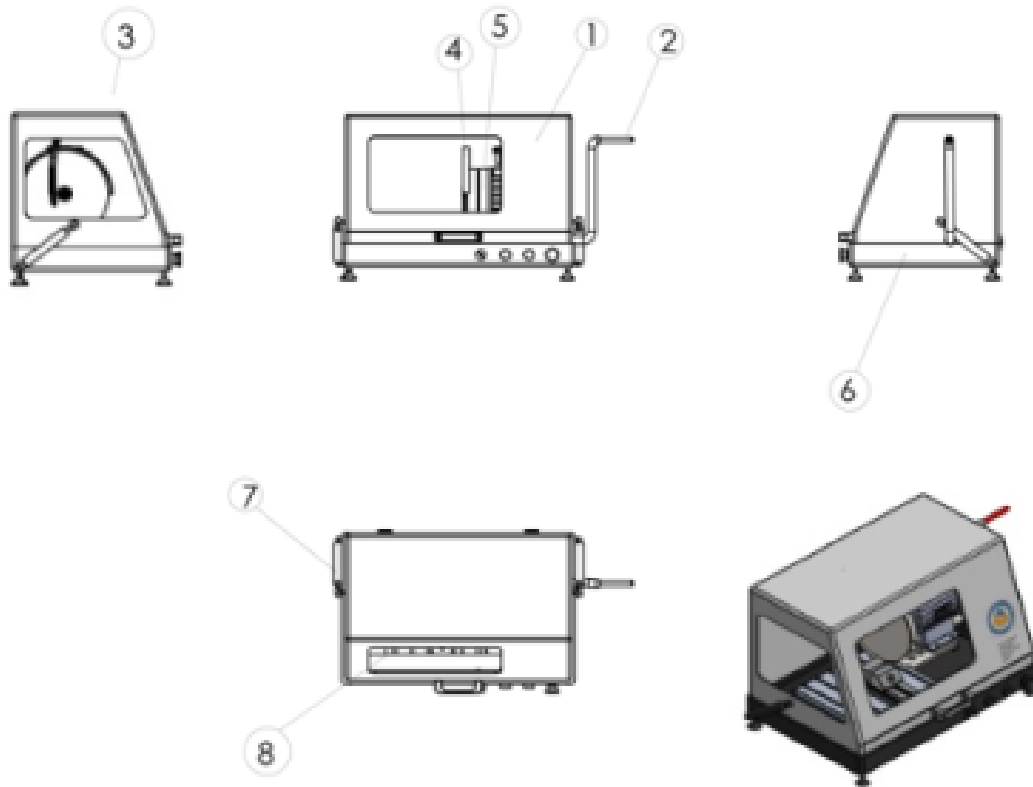
	NAME	SIGN	DATE	Eastern Mediterranean University Mechanical Engineering Department
Drawn By:	GROUP 08		30-DEC-20	
Checked By:	Assist. Prof. Dr. Mohammed Bsher A. Asmael		04-JAN-21	Material: Aluminum
Scale: 1:1	Title: Disc cover		Part No.: 13	Dimensions are in millimeters Tolerance 180-9001



	NAME	SIGN	DATE	Eastern Mediterranean University Mechanical Engineering Department
Drawn By:	GROUP 08		30-DEC-20	
Checked By:	Assist. Prof. Dr. Mohammed Bsher A. Asmael		04-JAN-21	Material: Aluminum
Scale: 1:1	Title: Disc stabilizer 2		Part No.: 14	Dimensions are in millimeters Tolerance 180-9001



	NAME	SIGN	DATE	Eastern Mediterranean University Mechanical Engineering Department
Drawn By:	GROUP 08		30-DEC-20	
Checked By:	Assist. Prof. Dr. Mohammed Bsher A. Asmael		04-JAN-21	Material: <b>Steel</b>
Scale: 1:1	Title: Upper Housing		Part No.: 15	Dimensions are in millimeters Tolerance 180-900



1: Uper housing		2: Arm	
3: Disc		4: Disc cover	
5: Electric motor		6: Base and bottom housing	
7: Hydraulic piston		8: T slot plate	
	NAME	SIGN	DATE
Drawn By:	GROUP 08		30-DEC-20
Checked By:	Assist. Prof. Dr. Mohammed Bahar A. Asmael		04-JAN-21
Scale: 1:1	Title: The cutting machine	Assembly No.: 02	Material: Aluminum and Steel Dimensions are in millimeters Tolerance 180-9001