



**Eastern Mediterranean University**  
**Department of Mechanical Engineering**

**Capstone Team Project**  
**MENG/MECT 411**

**Name of Project: ULTRASONIC PLASTIC WELDING MACHINE**

**Group Members:**

|                 |                       |
|-----------------|-----------------------|
| <i>17000070</i> | <i>EZGİ İŞLEK</i>     |
| <i>16700698</i> | <i>RAMZİ ALSAYYED</i> |
| <i>17701681</i> | <i>MAHMOOD SALEH</i>  |
| <i>17701478</i> | <i>MAHMOUD AQELAH</i> |
| <i>17701823</i> | <i>MAHMOUD JAMAL</i>  |

**Supervisor: Assist. Prof. Dr. Mohammed Asmael**

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## **ABSTRACT**

This project is about converting a manual welding machine to automatic. It is a unique ventilator design that aims to be a self-powered, y-axis moving welding machine. This project also aims to make the machine efficient, easy to use luxury. The approach is to create a low-cost, engineering-efficient welding machine that anyone can use and professionals can easily weld work pieces by choosing ubiquitous and relatively inexpensive material components. All engineering information necessary regarding specific standards and full analysis based on existing engineering designs are included in this project.

The main objective of the report is to analyze, design, test and implement a welding machine by providing all necessary engineering information regarding specific standards and full analysis based on existing engineering designs.

This project includes all steps, part selection and design, backed up with necessary graphical models to make it easy to understand by engineers and users who will use this machine in real time situations. However, some project and design constraints will pose a challenge for the team, such as distance, shipping, connections, part availability, and other factors. In order for this design to be accepted as a real welding machine, the results obtained in the project must meet the required minimum parameters.

# TABLE OF CONTENTS

|  |    |
|--|----|
| ABSTRACT .....   | 2  |
| CHAPTER 1 - INTRODUCTION.....                            | 7  |
| 1.1. Detailed definition of the project .....            | 7  |
| 1.2. Significance of the project .....                   | 7  |
| 1.3. Detailed project objective .....                    | 8  |
| 1.4. Design for safety .....                             | 9  |
| 1.5. Design for cost .....                               | 9  |
| 1.6. Design for assembly .....                           | 9  |
| 1.7. Detailed project constraints .....                  | 9  |
| 1.8. Report organization.....                            | 10 |
| CHAPTER 2 – LITERATURE REVIEW.....                       | 11 |
| 2.1. Background information.....                         | 11 |
| 2.2. Concurrent solutions .....                          | 14 |
| 2.3. Comparison of concurrent solutions .....            | 17 |
| 2.4. Engineering standards of concurrent solutions ..... | 21 |
| CHAPTER 3 – DESIGN AND ANALYSIS .....                    | 22 |
| 3.1. Proposed/Selected Design .....                      | 22 |
| 3.1.1. Machine press .....                               | 23 |
| 3.1.2. Generator .....                                   | 23 |
| 3.1.3. Converter .....                                   | 24 |
| 3.1.4. Booster.....                                      | 25 |
| 3.1.5. Sonotrode/Horn.....                               | 26 |
| 3.1.6. Component support tooling .....                   | 27 |
| 3.1.7. Micro-controller .....                            | 27 |
| 3.1.8. Motor .....                                       | 28 |
| 3.2. Engineering standards .....                         | 28 |
| 3.3. Design calculations .....                           | 31 |
| Mechanism of USMW process .....                          | 33 |

|   |    |
|---|----|
| 3.4. Cost analysis .....  | 37 |
| CHAPTER 4 – MANUFACTURING PLAN .....                              | 39 |
| 4.1. Manufacturing process selection.....                         | 39 |
| 4.2. Detailed manufacturing process.....                          | 40 |
| CHAPTER 5 – PRODUCT TESTING PLAN .....                            | 42 |
| 5.1. Verification plan of the objectives of the project.....      | 42 |
| 5.2. Verification plan of the applied engineering standards ..... | 43 |
| CHAPTER 6 – RESULTS AND DISCUSSIONS.....                          | 44 |
| 6.1. The results .....  | 44 |
| 6.2. The engineering standards .....                              | 45 |
| 6.3. The constraints.....   | 45 |
| CHAPTER 7 – CONCLUSION AND FUTURE WORKS .....                     | 46 |
| 7.1. Conclusion.....  | 46 |
| 7.2. Future works .....   | 47 |
| REFERENCES .....  | 49 |
| APPENDIX A: Electronic media.....                                 | 52 |
| APPENDIX B: Constraints .....                                     | 53 |
| APPENDIX C: Standards.....  | 54 |
| APPENDIX D: Logbook.....  | 55 |
| APPENDIX E: Project timeline.....                                 | 56 |
| APPENDIX F: Engineering drawings.....                             | 57 |

## LIST OF FIGURES

|  |    |
|--|----|
| Figure 1: Laser welding. ....                  | 15 |
| Figure 2: Linear vibration welding. ....       | 15 |
| Figure 3: Spin welding. ....                   | 16 |
| Figure 4: Hot plate welding. ....              | 17 |
| Figure 5: Ultrasonic welding machine. ....     | 17 |
| Figure 6: Proposed design of USW machine. .... | 22 |
| Figure 7: Press machine. ....                  | 23 |
| Figure 8: Generator purpose. ....              | 24 |
| Figure 9: Transducer/converter. ....           | 25 |
| Figure 10: Booster. ....                       | 26 |
| Figure 11: Sonotrode/Horn. ....                | 27 |
| Figure 12: Micro-controller. ....              | 28 |
| Figure 13: USW core parts. ....                | 32 |
| Figure 14: Project poster. ....                | 52 |

## LIST OF TABLES

|   |    |
|---|----|
| Table 1: Criteria matrix for welding process selection.....                               | 20 |
| Table 2: Engineering standards.....   | 28 |
| Table 3: bill of materials.....   | 37 |
| Table 4: Welding parameters for both materials.....                                       | 44 |
| Table 5: Effect of the threshold power level on the joint strength for polyethylene.....  | 44 |
| Table 6: Effect of the threshold power level on the joint strength for polycarbonate..... | 45 |
| Table 7: Project constraints.....   | 53 |
| Table 8: Logbook.....   | 55 |

# **CHAPTER 1 - INTRODUCTION**

## **1.1. Detailed definition of the project**

Welding is one of the most important fabrication processes used in today's manufacturing industries, there are many different forms of welding one of them being Ultrasonic Plastic Welding (USPW). USPW is a mechanical methodology where two thermoplastics are joined by the utilization of ultrasonic vibrations, under medium tension, in which the vibrations are applied corresponding to the interface between the parts. The vibration between parts generates high temperatures by continuous plastic deformation and shearing between surfaces, which causes rapid melting of the plastics and along with the exerted pressure they merge together. There are 3 types of USPW: Spot Welding, Torsional Welding, and Roll Seam Welding. For this project, we are going to use the torsional welding variant of USPW.

Torsional USPW machine mainly consists of 5 parts being the power supply, a press, ultrasonic stack, an anvil, and a controller. Electric power is supplied to the ultrasonic stack which consists of 3 components, a converter/transducer, booster, and a sonotrode/horn. These components function so that the ultrasonic stack could resonate at a controlled ultrasonic frequency which varies from 15khz up to 50khz after that, the controller is used to signal the press to move vertically downwards which allows the ultrasonic stack to induce contact with the two different work pieces to perform the weld, the work pieces on the other hand are supported by the anvil which allows for the frequencies to directly affect the parts.

## **1.2. Significance of the project**

Welding as mentioned before is one of the most important fabrication processes used in today's manufacturing industries, USPW is very crucial in various industries, in the Automotive industry it is used for bonding specific delicate parts such as Inner door panels and door trims, HVAC

staking, central console, front/ Rear bumpers and spoilers [14]. It is also crucial in the packaging industry commonly used to seal containers, blister packs and cartons because of the strong bond it creates. Ultrasonic plastic welding can form a hermetic seal around products containing hazardous materials, or high value products for additional retail security [15]. Recently due to the Covid-19 pandemic the use of USPW has increased exponentially due to its applications in the medical equipment field, mainly for disposable and non-disposable face masks, IV components and plastic textile garments. Many other industries rely on the uses of USPW as well.

USPW is gaining a reputation as the most desired plastic welding method due to many several reasons, power consumption being one since USPW doesn't require high amounts of energy, easy and quick to set up plus being flexible to any changes in the setup along the way, easy to function on, doesn't use any additional materials to perform a weld making it environmentally friendly, as well as it is very reliable, rapid, consistent, and clean.

The current design for this USPW is to be able to utilize energy and time as much as possible while focusing on receiving a constant and reliable outcome without negatively affecting the work piece in the process of welding.

### **1.3. Detailed project objective**

Our aim in this project is to design an ultrasonic welding machine with simply getting a manual welding machine and make it automated welding machine. Our detailed project objectives are as follows. The objective of this project is to design a Welding Machine that will perform all the necessary operations in real-time and move X and Y coordinates. This welding machine will include: Compressor, Base stand, Welding holder, D.A Cylinder, Power source, Tool frame type of robot to coordinate any reference point. This project will also focus on being a converted



manual welding machine that moves in the y-axis, with cheaper, more readily available parts in the market, lightweight and robust design.

#### **1.4. Design for safety**

Error and mistakes are things to expect in designing and manufacturing. In this part of design, we will have a control system to control the amount of power supplied to the machine in order to maintain the safety procedures.

#### **1.5. Design for cost**

The cost of design is considered a bit expensive as you are not creating everything from scratch but you are buying the machine and just upgrading it but it will be really useful as we all know that the traditional welding is harmful and more time consuming and it cuts of a cost price of one worker as it is automated.

#### **1.6. Design for assembly**

Design for assembly also known as DFA, the purpose of this process is to make the product parts easy to assemble. This method mainly concentrates on how many parts we have or to handle also it can consider whether a part of the design is not to be assembled with the other parts. In our design, the parts to be assembled are the welding machine and sensors in order to reduce the cost of assembly.

#### **1.7. Detailed project constraints**

Below are the project constraints:

1. Design: There can be modifications on the welding machine system as in our design.
2. Efficiency: The automated ultrasonic welding machine is built in way to be able to save more time on the welding process itself as you don't need to wait for curing to dry.

3. Maintainability: The automated ultrasonic welding machine is designed in order to avoid any failure in the system or the tools as they are expensive to get or exchange.
4. Reliability: The system is manufactured in which any chance of failures is low.
5. Cost: As long as the assembly and manufacturing doesn't exceed the available budget in cost it is in a satisfactory form.

### **1.8. Report organization**

The following report consists of five chapters, each chapter divided into different subsections. The first chapter being the introduction, which entails five sections which are, the detailed definition of an ultrasonic plastic welding (USPW), the significance of the automated ultrasonic welding machine, the detailed project objectives, the detailed project constraints and finally the structure of the report.

The second chapter, literature review consists of the background of the automated ultrasonic welding machine and the parts of it, the other sections consist of the concurrent solutions, which show the other types of machines used for our same application.

The third chapter, design, and analysis consist of the proposed/selected design, which states why the components that were used were the most compatible to our design. The other sections include the engineering standards used, design calculations and last of all the cost analysis (bill of materials).

The fourth chapter, manufacturing processes contain two sections which are manufacturing processes selection were all the types of manufacturing processes are mentioned and the other section which is the detailed manufacturing processes were the manufacturing processes mentioned in the previous sectioned and mentioned in full detail.

The fifth and last chapter, product testing plan which entails the Verification plan of the objectives of the project as well as the Verification plan of the applied engineering standards.

## **CHAPTER 2 – LITERATURE REVIEW**

### **2.1. Background information**

Welding, method utilized for bringing in metallic parts together mostly along with the function of heat. The method was found out by undergoing a process that turns iron into helpful models. Welding blades were advanced in the first thousand years CE, the most popular being those transported by Arab armories at Damascus, Syria. At that time when it comes to form hard steel the method used was the carburization of iron; it concluded having very brittle steel. The welding method that involves inter layering comparatively soft and hard iron with materials that has high carbon, ensured by hammer forging forming a strong and hard blade.

These days when it comes in developing the iron producing methods, specifically the presentation of iron casting, allowing the jewelers and blacksmith to use welding. Other similar joining methods, for example, mechanical fasteners are being utilized to high end products all the way.

Current combination welding measures are an expanding of the need to get a ceaseless joint on huge iron plates. Riveting had been appeared to have disservices, particularly for an encased compartment like a heater. Gas welding, arc welding, and opposition welding all showed up by the end of the nineteenth century. The primary genuine endeavor to receive welding measures on a larger size was done during World War I. In 1916 the oxyacetylene cycle was all around created, and the welding methods utilized then are as yet utilized. The principle upgrades from

that point forward have been well ensured by safety. Arc welding, utilizing a convenient electrode, was likewise presented at that time, yet the uncovered wires at first utilized delivered fragile welds. An answer was found by wrapping the uncovered wire with asbestos and a laced aluminum wire. The advanced electrode, presented in 1907, comprises of an exposed wire with an unpredictable covering of materials. Arc welding was not all around utilized until the time of World War II, when the earnest requirement for fast methods for development for delivery, power plants, transportation, and designs prodded the vital advancement work.

By the end of the 19<sup>th</sup> century Elihu Thomson came up with an invention called the resistance welding, it was approved way before the arc welding method in cases of seam and spot joining of two sheets. While at the start of the 20<sup>th</sup> century chain production and bar joining or rods undergone by welding were more advanced. Gas process of tungsten inert was introduced in 1940s utilizing a non-convenient tungsten electrode to undergo the fusion welding, eight years later a high-end gas shielded operation using a wire electrode that was utilized in the welding process. Modernly, electron beam and laser welding and more of the solid phase operations for example, diffusion bonding, friction welding and ultrasonic joining have been advanced [1].

The first record for plastic welding was in Germany before World War II, when a shortage of non-ferrous metals (metals without a significant iron content are more malleable) prompted Hitler's chemists to find a material to replace. The production of polyvinyl chloride (PVC) increased dramatically during the 1930s, and it didn't take long for researchers to realize that PVC could easily be molded and heat-treated to create a variety of profiles and it can be welded in a manner very similar to that of metal. The advent of plastic welding began but was initially only used by Germany during the Second World War. During this time, plastic welding

machines were born mainly in the form of a very basic, fuel convection furnace. Infrared (IR) heating began to be used at the beginning of the Second World War when it became clear that it was the fastest way to work with plastics, although the process was much more expensive. After the war, IR welding declined, but during the 1990s IR welding became more popular with the price of equipment used for IR welding machines for plastics dropping.

Ultrasonic welding is a method in which, vibrations with high frequency ultrasonic acoustic are being restrictedly enforced to an object being put together by pressing to form a solid state weld. Ultrasonic welding is utilized mostly in plastics and specifically for joining different materials.

In defining ultrasonic welding, its known as a noisy affair along the usage of high energy sound waves and frequency, it can bring in two materials together. It is generally utilized in companies that specialize in aerospace, automotive and medical. Ultrasonic welding has become the primary method to bond thermoplastics, yet in addition light metals [1].

In 1940<sup>th</sup> ultrasonic was invented, it was used for connecting thermoplastics together then in 1965 it was taken to another level under Seymour Linsley and Robert Soloff. Back then Branson instruments were managed by Robert Soloff. Robert came out with the Sonics and Materials, until this very day he's still considered as the head in the ultrasonic technology. By undergoing experiments, he managed to understand the idea where the sound waves move around rigid plastics while at the same time it will access the joint space of the thermoplastics to be welded. This idea took the industry to another level, where heating plastics to be bonded is no longer compulsory.

Moving forward, Robert then added the fragment of a wasted drill press to the ultrasonic welder and introduced the concept to Ideal Toy Company. The capability to join in thermoplastics together neglecting the utilization of high heat entertained the engineers at the Ideal toy company. They didn't only consider the technology, but they made a deal for manufacturing more. Since then, it was the start of an enormous increase of popularity in plastic toys.

After all, ultrasonic welding made name for itself and it has been considered as one of the most high-end technologies crosswise all companies and industries. Back before the ultrasonic technology was established, customers used to categorize plastic stuff as heavy items. With the development of ultrasonic welding machine, plastics became an essential in our daily life, with benefiting both the end user and the producer in many varieties of different utilizations. This part of high-end technology would not have reached this level of success without the advance of ultrasonic welding technology.

## **2.2. Concurrent solutions**

There are 6 types of plastic welding:

Laser welding is a process used to join together metals or thermoplastics using a laser beam to form a weld. Being such a concentrated heat source, in thin materials laser welding can be carried out at high welding speeds of meters per minute, and in thicker materials can produce narrow, deep welds between square-edged parts. Laser welding operates in two fundamentally different modes: conduction limited welding and keyhole welding. The mode in which the laser beam will interact with the material it is welding will depend on the power density across the beam hitting the work piece.

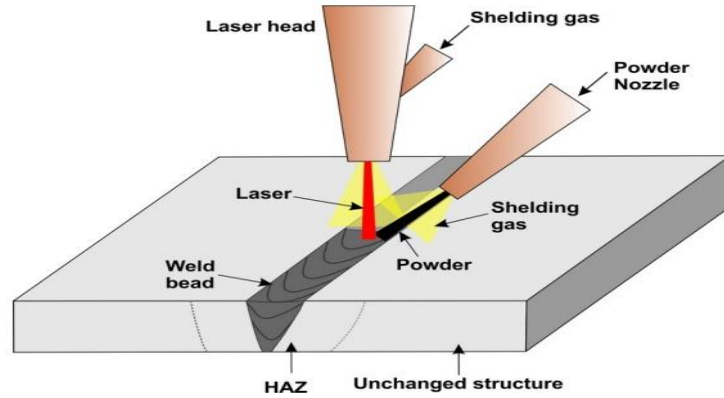


Figure 1: Laser welding.

Linear Vibration Welding is a frictional welding technique capable of producing strong, air-tight welds in thermoplastic parts. In this process, vibration occurs by transverse reciprocating motion controlled electromagnetically by a swing frame assembly containing precision springs, electromagnets and an electromagnetic drive assembly which controls the amplitude and frequency of the vibrating head. Friction is achieved through motion between two parts, one fixed, the other reciprocating at a controlled amplitude and frequency while clamped under pressure. Melt occurs only at the interface of the joint area of the plastic part halves.

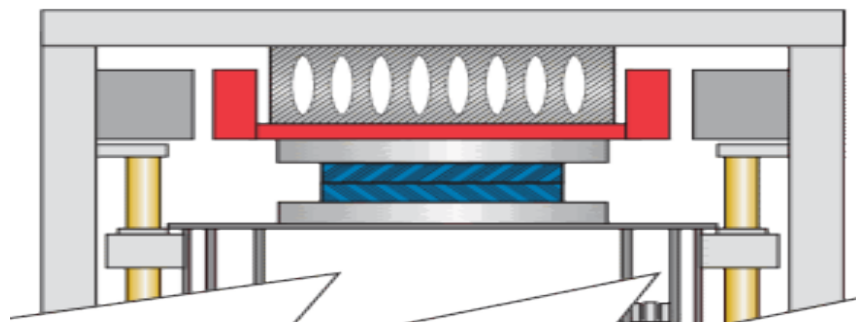
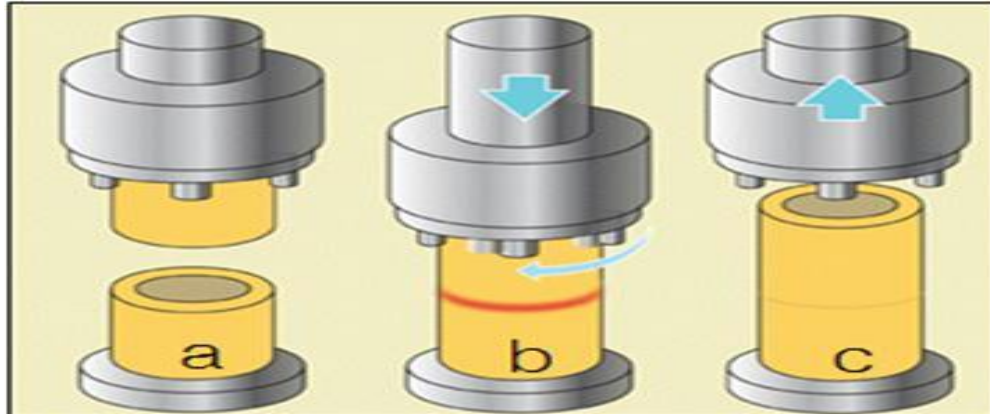


Figure 2: Linear vibration welding.

Orbital vibration welding method also uses friction to generate heat that is applied to the joining pieces. While this method is very useful for welding irregular shapes, it is highly sensitive and cannot be used for all welds.

Spin welding is a form of friction welding used to join thermoplastic parts. The parts to be welded must be round, and in plane with each other. Like all other welding methods this process utilizes heat, time, and pressure to create a weld joint. Heat is generated via internal friction generated between the two parts when rotating and subjected to a load normal to the weld joint. This frictional heat causes the plastic to melt and a bond to be created. Due to this process's high speeds, and high repeat ability it is favored for a high production environment. This process was initially used to weld plastic compasses under a liquid to allow the internal parts of the compass to be filled with the liquid, but it is used in a very wide range of industries and applications.



*Figure 3: Spin welding.*

Hot plate welding uses a heated platen to melt the joining surfaces of the two halves of a thermoplastic part. The part halves are brought into contact with a precisely heated platen for a predetermined period. After the plastic interfaces have melted, the parts are brought together to form a molecular, permanent, and often hermetic bond. A properly designed joint welded under precise process control often equals or exceeds the strength of any other part area.



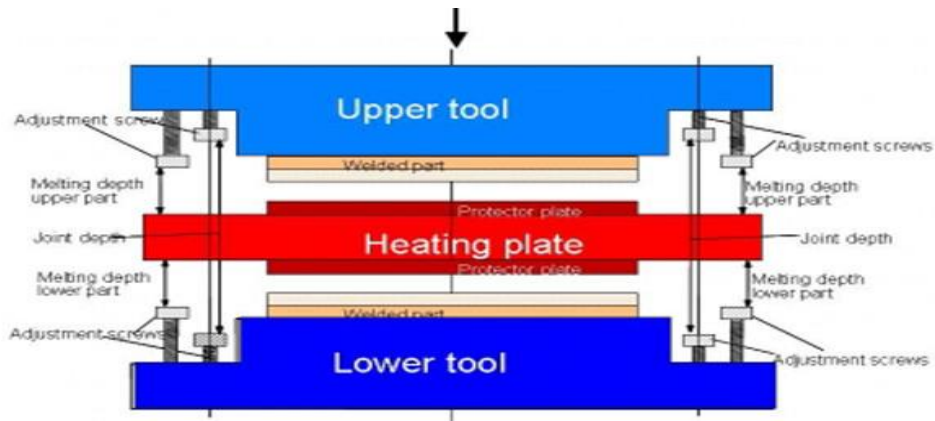


Figure 4: Hot plate welding.

Ultrasonic welding is a solid-state attaching process where frictional like movement occurs between two surfaces due to ultrasonic vibrations. Soft alloys of aluminum, copper, and nickel are usually welding using this type, even though most metals and different combinations can be welded ultrasonically. [1][4]

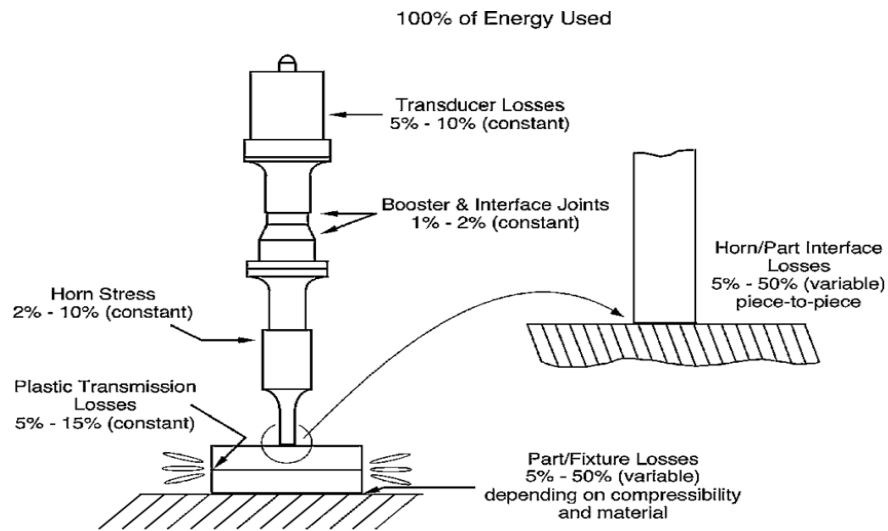


Figure 5: Ultrasonic welding machine.

### 2.3. Comparison of concurrent solutions

In this section, all of the above mentioned types of metal welding will be discussed in depth and a decision matrix will be used to show which type of welding was chosen and why so.

When it comes to laser welding, it is precise while working with exact placing of the energy spot. Moreover, it is capable of welding complicated joint geometry. It also uses low heat

application meaning it will cause minor changes in microstructure. Low thermal distortion. It also has low post weld operation times. Last but not least it is capable of welding up to 500 mm distance and also to inaccessible parts. Now let's talk about some of its disadvantages, to start with its expensive to maintain to welding parts which they depend upon the equipment. Moreover, if filler material is necessary then they are because of the limited amount produced. Relatively this disadvantage is counteracted by the low amount used compared to the welding time and also that there are few post welding operations [15].

Linear friction welding (LFW) is a solid-state joining process which works by oscillating one work piece relative to another while under a large, compressive force. The friction between the oscillating surfaces produces heat, causing the interface material to plasticize. The plasticized material is then expelled from the interface causing the work pieces to shorten (burn-off) in the direction of the compressive force. During the burn-off the interface contaminants, such as oxides and foreign particles, which can affect the properties and possibly the service life of a weld, are expelled into the flash. Once free from contaminants, pure metal to metal contact occurs, resulting in a bond. The LFW process is typically used for joining metals, however, it has been used to join plastics and wood. LFW is particularly effective for joining metals that have good high-temperature properties (compressive yield and shear strength) and low thermal conductivities. This allows the generated heat to remain at the interface causing the interface to rapidly heat and plasticize. This makes titanium alloys particularly suitable for the process, however many similar and dissimilar material combinations have been investigated with varying degrees of success.

The advantages of orbital welding and other automated welding processes are so manifest and apply to so many applications that from an engineering standpoint it is surprising that

manual welding is still widespread. However, there are some disadvantages to the purchasing, setup, maintenance, and operation of orbital and other automated welding machines. Many of these disadvantages are more apparent in smaller projects, where the costs of equipment, training, and setup time may not be worth it. However, in large, repetitive pipe welding projects, orbital welding's advantages quickly outweigh its disadvantages. The key to getting the most out of an orbital welding setup is to choose an experienced orbital welding vendor that offers training classes on specific equipment as well as reliable repair, replacement, and maintenance services.

In spin welding, as the name implies, the heat needed for welding is produced by a spinning movement, combined with applied pressure. This process is only suitable for welding circular parts. If the parts are different lengths, it is better for the shorter one to spin, in order to limit the moving mass volume. The decisive factors for this technology are the geometry of the parts, type of production, and budget available. Because only few mechanical parts are needed, the user can even build the auxiliaries by him. Spin welding is the ideal method for assembling pieces which are circular or which can freely spin on their axis.

Hot-plate welding, like any of the methods which can be selected to join plastic components, has its pros and cons. For instance, there are certain resin and filler combinations which are extremely challenging – if not impractical to hot-plate weld. Additionally, if the hot-plate welding equipment does not offer velocity, distance, and force control, the user will be limited in process control capabilities. Finally, without suitable coating surfaces on the heated tooling, tool wear and plastic material sticking can be problematic. A reasonably well equipped hot-plate welder with well-engineered tooling can provide an excellent solution for assembling plastics.

The last welding process we will discuss is the ultrasonic welding which is a very fast process which takes nothing more than a few seconds. It is a safe process due to it being localized which means that the heat is minimal and quickly drained. It is a very reliable type of welding; you can go through thousands of cycles without the machine breaking down. Contrarily, this type of welding does not weld all thicknesses, works with thin ones. Only lap joints can be welded in this type of process, where the parts are joined while they are on top of each other of a flat plane. It is of very high cost and replacing parts of the machine can be costly. (Positives and negatives of ultrasonic welding, 2019)

Table 1: Criteria matrix for welding process selection.

| Legend               | Priority | Importance (weight) | Laser | LFW | Orbital | Spin | Hot-plate | Ultra-sonic |
|----------------------|----------|---------------------|-------|-----|---------|------|-----------|-------------|
| 1→worst<br>10→best   |          |                     |       |     |         |      |           |             |
| Low cost             | 1        | 10                  | 2     | 2   | 4       | 8    | 3         | 3           |
| Weldability          | 2        | 9                   | 9     | 8   | 8       | 8    | 7         | 10          |
| Flexibility          | 3        | 9                   | 9     | 8   | 8       | 2    | 8         | 10          |
| High production rate | 4        | 8                   | 8     | 8   | 8       | 7    | 7         | 10          |
| Weighted total       |          |                     | 246   | 228 | 248     | 226  | 221       | 290         |

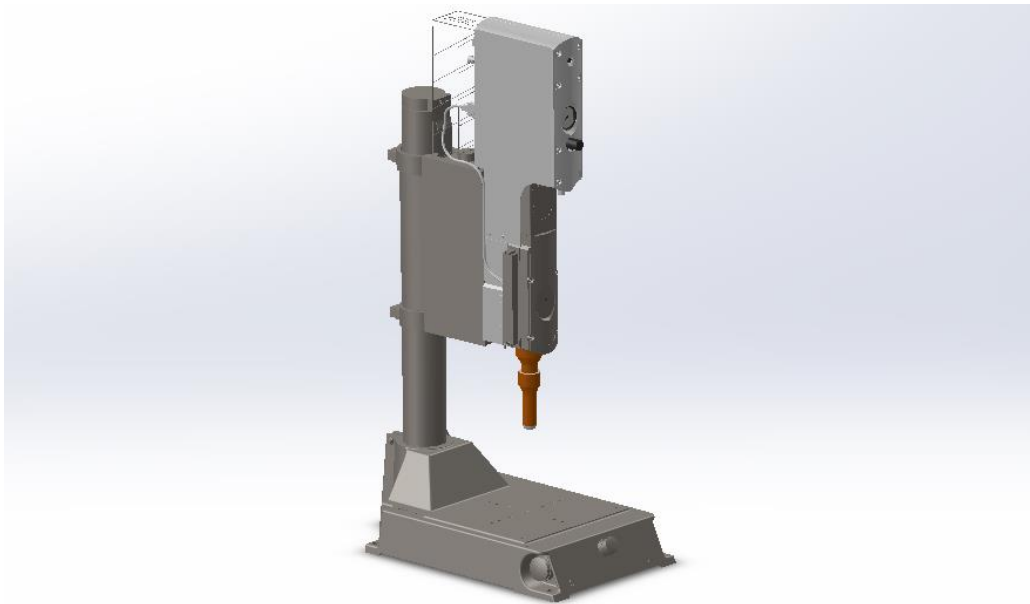
## 2.4. Engineering standards of concurrent solutions

- ISO 17212:2012 provides and describes the usual procedures for the preparation of component surfaces prior to bonding for either laboratory evaluation or the process of construction. It is applicable to metal and plastic surfaces that are commonly encountered.
- ISO 864:1988 This standard is exchanged and modified after the cancelation (ISO 864:1975). Which consist of a technical revision. The nominal diameters of wires are extended to 6, 0 mm, and the tolerances are more subdivided. The nominal diameters of spools, rims and coils are maintained.
- ISO 17212:2004 provides and describes the usual procedures for the preparation of component surfaces prior to bonding for either laboratory evaluation or the process of construction. It is applicable to metal and plastic surfaces that are commonly encountered.
- ISO 24034:2020 Welding consumables Solid wire electrodes, solid wires and rods for fusion welding of titanium and titanium alloys
- The standards mentioned above are related to the concurrent solutions discussed in chapter 2.2 and 2.3 except for the ultrasonic plastic welding.
- G1.2M:1999 and G1.2:1999 are the standards in SI unit for the ultrasonic plastic welding and is used in our application for example
- Amplitude and frequency
- Booster and convertor
- Transducer
- Energy and displacement

## CHAPTER 3 – DESIGN AND ANALYSIS

### 3.1. Proposed/Selected Design

Before we get into the details and design information for our design in this chapter. We should first ask the following questions and answer them throughout our report to know what fits or agrees better with our requirements. **What is my budget? What is the best motor for my project with respect to cost? What speed should the motor run at? Torque? Will the design be easy to assemble and manufacture according to engineering standards? Are the required design parts available in Cyprus? If not, any alternatives? Does the design follow the International Standards?** All these questions will be answered throughout the report and are very important in determining what kind of a design we will produce.



*Figure 6: Proposed design of USW machine.*

### 3.1.1. Machine press

The machine stand is designed to hold the welding system/stack and apply the required force for welding. It mainly consists of a base-plate, to hold the tooling jig, and a pneumatic cylinder to apply the force. The machine has a pressure gauge and regulator for controlling the welding force. It should be noted that a particular gauge pressure set on one piece of ultrasonic welding equipment will not necessarily provide the same welding force as another machine set at the same gauge pressure. Welding force should be calibrated using a load cell so that direct comparison of welding forces can be made from machine to machine. There is also a flow control valve to allow adjustment of the speed at which the welding head approaches the component being welded. Some equipment manufacturers have introduced an electromagnetic force application system in place of the traditional pneumatic cylinder. This gives better control of the approach rate, and can be beneficial when welding small or delicate components.

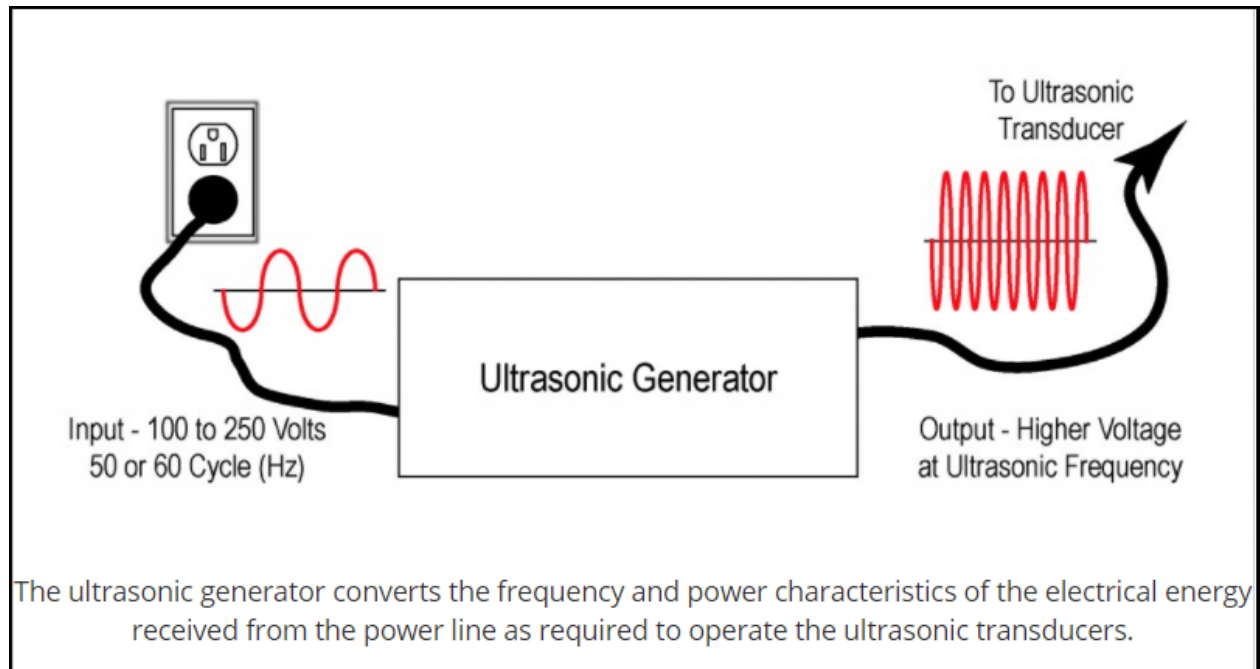


*Figure 7: Press machine.*

### 3.1.2. Generator

In an ultrasonic cleaning system, the device that provides the electrical energy to power the ultrasonic transducers is known as the ultrasonic “generator.” Basically, the ultrasonic generator

converts electrical energy received from the power line into electrical energy with the proper frequency, voltage and amperage to power or “drive” the ultrasonic transducers. In most cases, the power line provides “Alternating Current” or AC at a voltage of 100 to 250 Volts and at a frequency of 50 or 60 Hz depending on location. The power requirements for driving ultrasonic transducers vary but, in general, the ultrasonic generator needs to provide the transducer with a signal at the frequency of intended operation and (usually) at a voltage significantly higher than that delivered from the power line. [16]



*Figure 8: Generator purpose.*

### **3.1.3. Converter**

The transducer, also known as the converter, converts the electrical energy from the generator to the mechanical vibrations used for the welding process. It consists of a number of piezo-electric ceramic discs sandwiched between two metal blocks, usually titanium. Between each of the discs there is a thin metal plate, which forms the electrode. As the sinusoidal electrical signal is fed to the transducer via the electrodes, the discs expand and contract, producing an axial, peak-to-peak



movement of 15 to 20 $\mu$ m. Transducers is delicate devices and should be handled with care. Once the elements are broken, the transducer will not function. [18]



*Figure 9: Transducer/converter.*

#### **3.1.4. Booster**

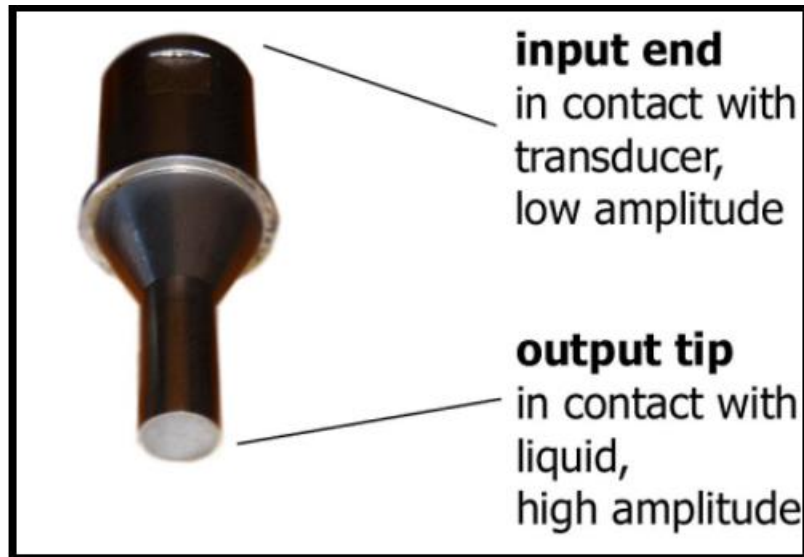
The booster section of the welding stack serves two purposes, primarily to amplify the mechanical vibrations produced at the tip of the transducer and transfer them to the welding horn. Its secondary purpose is to provide a location for mounting the stack on the welding press. The booster expands and contracts as the transducer apply the ultrasonic energy. The booster, like other elements in the welding stack, is a tuned device therefore it must resonate at a specific frequency in order to transfer the ultrasonic energy from the transducer to the welding horn. In order to function successfully, the booster must be either one half of a wavelength of ultrasound in the material from which it is manufactured, or multiples of this length. Normally, it is one half of a wave length. [17]



*Figure 10: Booster.*

### **3.1.5. Sonotrode/Horn**

The sonotrode (also known as the horn) is the “tool” of the ultrasonic welder. It is the component that comes into direct contact and supplies the energy to the metal materials to be welded. A sonotrode is specifically designed for its intended application and will typically be tuned to act as a half-wavelength resonant device that will uniformly supply pressure and vibration to the metal parts to be welded. The sonotrode is mechanically fixed to the booster of the ultrasonic stack. The shape of the sonotrode determines the final amplitude that is experienced at the sonotrode face and, hence, the amplitude that will be used to weld two metal materials. To ensure adequate mechanical coupling and energy transmission between the sonotrode and the uppermost metal material to be welded, the sonotrode face is textured. Typical sonotrode materials are titanium, aluminum, and steel. Titanium materials are favored due to low loss of vibration and high strength; aluminum is often coated with chrome or nickel to reduce wear; and steel is generally used for low-amplitude applications for which hardness is required.[12]



*Figure 11: Sonotrode/Horn.*

### **3.1.6. Component support tooling**

The base of the machine press supports the tooling that supports the components during the welding operation. The support tooling is designed to prevent movement of the lower component while the ultrasound is applied. It is often machined to match the contours of the component surface intimately.

### **3.1.7. Micro-controller**

A microcontroller ( $\mu\text{C}$  or  $\text{uC}$ ) is a solitary chip microcomputer fabricated from VLSI fabrication. A micro controller is also known as embedded controller. Today various types of microcontrollers are available in market with different word lengths such as 4bit, 8bit, 64bit and 128bit microcontrollers. Microcontroller is a compressed micro computer manufactured to control the functions of embedded systems in office machines, robots, home appliances, motor vehicles, and a number of other gadgets. A microcontroller is comprises components like - memory, peripherals and most importantly a processor. Microcontrollers are

basically employed in devices that need a degree of control to be applied by the user of the device.

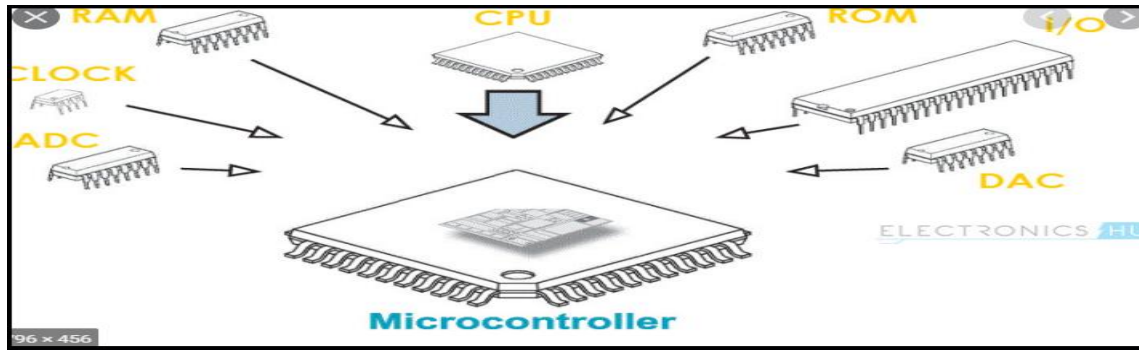


Figure 12: Micro-controller.

### 3.1.8. Motor

An electric motor is an electrical machine that converts electrical energy into mechanical energy. Most electric motors operate through the interaction between the motor's magnetic field and electric current in a wire winding to generate force in the form of rotation of a shaft.

## 3.2. Engineering standards

Table 2: Engineering standards

|          |   |
|----------|---|
| ISO 2553 | Welded, brazed and soldered joints - symbolic representation on drawings (1992)   |
| ISO 2560 | Welding consumables. Covered electrodes for manual metal arc welding of non-alloy and fine grain steels. Classification         |
| ISO 3580 | Covered electrodes for manual arc welding of creep-resisting steels - Code of symbols for identification                        |
| ISO 3581 | Covered electrodes for manual arc welding of stainless and other similar high alloy steels - Code of symbols for identification |
| ISO 3834 | Quality requirements for fusion welding of metallic materials, five parts.  |

|             |  |
|-------------|--|
| ISO 4063    | Welding and allied processes - Nomenclature of processes and reference numbers   |
| ISO 5817    | Welding. Fusion-welded joints in steel, nickel, titanium and their alloys (beam welding excluded). Quality levels for imperfections  |
| ISO 6520-1  | Welding and allied processes — Classification of geometric imperfections in metallic materials — Part 1: Fusion welding  |
| ISO 6520-2  | Welding and allied processes — Classification of geometric imperfections in metallic materials — Part 2: Welding with pressure   |
| ISO 6947    | Welds. Working positions. Definitions of angles of slope and rotation  |
| ISO 9606    | Qualification test of welders — Fusion welding, parts 1 to 5   |
| ISO 9692-1  | Welding and allied processes. Recommendations for joint preparation. Manual metal-arc welding, gas-shielded metal-arc welding, gas welding, TIG welding and beam welding of steels |
| ISO 9692-2  | Welding and allied processes. Joint preparation. Submerged arc welding of steels   |
| ISO 9692-3  | Welding and allied processes. Joint preparation. Part 3: TIG and MIG welding of aluminum and its alloys  |
| ISO 13847   | Petroleum and natural gas industries - Pipeline transportation systems - Welding of pipelines  |
| ISO 13916   | Welding - Guidance on the measurement of preheating temperature, interpass temperature and preheat maintenance temperature   |
| ISO 13918   | Welding - Studs and ceramic ferrules for arc stud welding  |
| ISO 13919-1 | Welding - Electron and laser-beam welded joints - Guidance on quality level for imperfections - Part 1: Steel  |
| ISO 13919-2 | Welding - Electron and laser-beam welded joints - Guidance on quality level for imperfections - Part 2: Aluminum and its weld able alloys  |

|              |  |
|--------------|--|
| ISO 13920    | Welding - General tolerances for welded constructions - Dimensions for lengths and angles - Shape and position                           |
| ISO 14112    | Gas welding equipment - Small kits for gas brazing and welding   |
| ISO 14175    | Welding consumables — Gases and gas mixtures for fusion welding and allied processes. Replaced EN 439:1994 in Europe.                    |
| ISO 14341    | Welding consumables. Wire electrodes and deposits for gas shielded metal arc welding of non alloy and fine grain steels. Classification  |
| ISO 14554    | Resistance welding   |
| ISO 14744    | Electron beam welding, six parts   |
| ISO 15607    | Specification and qualification of welding procedures for metallic materials - General rules   |
| ISO/TR 15608 | Welding - Guidelines for a metallic material grouping system   |
| ISO 15609    | Specification and qualification of welding procedures for metallic materials - Welding procedure specification, five parts.              |
| ISO 15610    | Specification and qualification of welding procedures for metallic materials — Qualification based on tested welding consumables         |
| ISO 15611    | Specification and qualification of welding procedures for metallic materials — Qualification based on previous welding experience        |
| ISO 15612    | Specification and qualification of welding procedures for metallic materials — Qualification by adoption of a standard welding procedure |
| ISO 15613    | Specification and qualification of welding procedures for metallic materials — Qualification based on pre-production welding test        |
| ISO 15614    | Specification and qualification of welding procedures for metallic materials - Welding procedure test, 13 parts.                         |

|              |   |
|--------------|---|
| ISO 15615    | Gas welding equipment. Acetylene manifold systems for welding, cutting and allied processes. Safety requirements in high-pressure devices |
| ISO 15618-1  | Qualification testing of welders for under-water welding. Diver-welders for hyperbaric wet welding  |
| ISO 15618-2  | Qualification testing of welders for under-water welding. Diver-welders and welding operators for hyperbaric dry welding                  |
| ISO 17635    | Non-destructive testing of welds. General rules for metallic materials  |
| ISO 17660-1  | Welding - Welding of reinforcing steel - Part 1: Load-bearing welded joints   |
| ISO 17660-2  | Welding - Welding of reinforcing steel - Part 1: Non-load bearing welded joints   |
| ISO/TR 20172 | Welding — Grouping systems for materials — European materials   |
| ISO/TR 20173 | Welding — Grouping systems for materials — American materials   |
| ISO/TR 20174 | Welding — Grouping systems for materials — Japanese materials   |
| ISO 24394    | Welding for aerospace applications. Qualification test for welders and welding operators. Fusion welding of metallic components           |

### 3.3. Design calculations

Five important core parts that ignites the ultrasonic welding machine which are, generator, convertor, booster, horn/sonotrode and an anvil/base. Generally the generator supply electrical frequency of 20-70 KHz, in which the convertor then converts the electrical energy into

mechanical energy with a similar frequency. The booster carries on the mechanical oscillation towards the horn and amplifies the amplitude ranging between 20-100  $\mu\text{m}$ . As these oscillations reach the horn the welding process starts. In the USMW the transducer, booster and horn vibrate together in resonance. Finally the anvil, it is utilized in holding and positioning the joining parts along the welding process. [10]

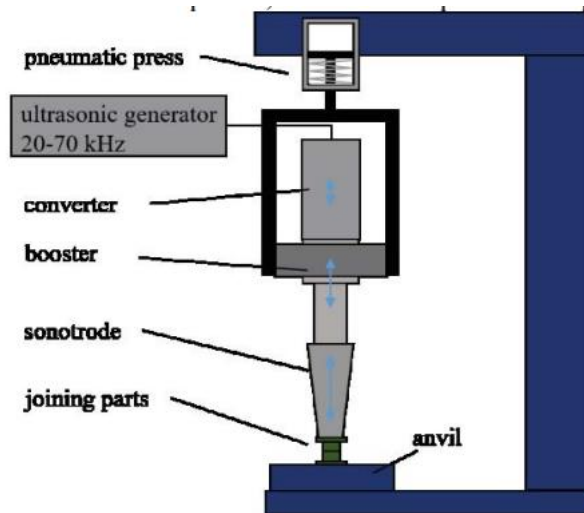


Figure 13: USW core parts.

In order to calculate the maximum power a transducer produces can be expressed as:

$$P = 2\pi f_s E_3^2 \varepsilon_{33}^T k_{eff}^2 Q_m V \quad (1)$$

$P$  = acoustic power delivered (W)

$f_s$  = series resonance frequency (Hz)

$E_3$  = Electric field strength (V/m)

$\varepsilon_{33}^T$  = piezoelectric permittivity at constant stress  $\left( \frac{\text{coulomb}}{\text{m}} = \frac{\text{volt}}{\text{Farad}} \right)$

$k_{eff}$  = electromechanical coupling factor (no unit)



$Q_m = \text{mechanical } Q \text{ (no units)}$

$V = \text{total piezoceramic volume (m}^3\text{)}$

Horn: to get a full wave length of a horn the formula is expressed as  
*standard length of the horn depending on (KHz)* =  $\left(\frac{\text{speed of sound through a material}}{20000}\right)$

### **Mechanism of USMW process**

Despite the fact that the USMW process generally takes seconds, some physical structure are involved in an intricate way. These physical mechanisms are vibrations, heat transfer and heat generation of viscoelastic, squeeze outflow of molten polymer, intermolecular diffusion and cooling. [19]

As an example of a viscoelastic solid utilizing a Voigt-Kelvin model is a thermoplastic in which it is expressed by a damper and a spring linked in parallel

For viscosity, the modulus of Voigt-Kelvin material is expressed by a complex material,  $E^*$

$$E^* = E' + iE'' \quad (2)$$

$E' = \text{storage modulus (MPa)}$

$E'' = \text{loss modulus (MPa)}$

$i = \text{imaginary unit}$

In case that viscoelastic material turned to be a sinusoidal deformation, similarly to the ultrasonic welding case, the calculation of the average energy dissipated can be expressed as

$$Q_{avg} = \frac{\omega \varepsilon_0^2 E''}{2} \quad (3)$$

$\omega$  = circular frequency(Hz)

$\varepsilon_0$  = strain amplitude ( $\mu\varepsilon$ )

As it's shown that the heat generated (energy dissipated) is proportional to the frequency, the strain amplitude and the loss modulus.

With the vibration advances inside the objects, the energy director increases in temperature as the heat generation is surpassing the convection and conduction heat loss. In such cases a regular heat transfer formula may be utilized and maintain the rise rate and distribution of temperature in the energy director and the objects, the 3-D heat conduction formula for a linear behaviors and isotropic materials is,

$$K \left( \frac{\partial^2 T}{\partial x^2} + \frac{\partial^2 T}{\partial y^2} + \frac{\partial^2 T}{\partial z^2} \right) + q = \rho c \frac{\partial T}{\partial t} \quad (4)$$

$K$  = thermal conductivity (w/m-k)

$T$  = temperature (k)

$q$  = internal heat generation ( $w/m^3$ )

$p$  = density ( $\text{kgm}^3$ )

$c$  = specific heat (w/kgk)

$t$  = time (s)

As soon as the energy director temperature overcome the melting temperature, flow starts in the thermoplastic material. Due to the enforced pressure, the molten polymer flow can be expressed as squeeze flow between two plates.

A power law liquid model is expected when it comes to describing the squeeze flow in which,

$$\tau = my^n \quad (5)$$

$\tau$  = shear stress (Pa)

$y$  = shear strain rate

$m, n$  = material parameter

The link among the force, the height of the hole, the width and length of the fluid, properties of fluid are expressed by the following formula

$$\frac{h_0}{h(t)} = \left(1 + \frac{t}{r}\right)^{\frac{n}{2n+3}} \quad (6)$$

$$r = \frac{4n + 2}{2n + 3} \left[ \frac{(2b_0)^{2n+3} wm}{(2h_0 b_0)^{n+1} F(n+2)} \right]^{\frac{1}{n}} \quad (7)$$

$F$  = static force

$2h(t), 2h_0$  = gaps between two plates at time  $t$  and initial time (m)

$2w, 2b_0$  = length and width of the fluid (m)

The above equation illustrates the thickness of the fluid layer through the plates, for instance, if  $h(t)$  the gap is small, it concludes to a greater mechanical resistance due to the increased reduction of the layer thickness. As in mechanics perspective, the fluid interface turn to be more rigid. This usually occur in the final phase of ultrasonic welding.

When the energy director melts, as the polymer flows to cooler surfaces and transfers heat in order to melt further polymer. At instant in the interface a polymer to polymer makes contact where it sets up a polymer diffusion process.

$$\langle l^2 \rangle > \alpha 2D_c t \quad (8)$$

$l$  = minor chain length

$D_c$  = reptation diffusion coefficient

$t$  = time

Once the vibration stops, the USMW process starts the final phase of cooling. Throughout this phase the melted polymer stiffens and obtain its final structure. The crystallization operation for various polymers can be presented by the kinetic equation of Avrami.

$$V_s = 1 - e^{-kt^n} \quad (9)$$

$V_s$  = spherulite volume fraction

$k$  = rate parameter

$n$  = parameter of geometry, mode of growth of spherulites





After maintaining  $V_s$  the final overall crystallinity can be obtained by the following equation.

$$\phi = \phi_s V_s \quad (10)$$

$\phi_s$  = crystallinity within the spherulite

### 3.4. Cost analysis

Table 3: bill of materials

| Item number | Part number | quantity | name   | material  | source  | cost    | picture   |
|-------------|-------------|----------|--|---|---|---------|---|
| 1           | 10          | 1        | 20kHz<br>2000Watt<br>Ultrasonic<br>Generator | various   | Sino Sonics<br>2ND FLOOR. NO.13<br>BUILDING, NO.100<br>DICUI ROAD, WUXI,<br>214072 CHINA<br>Tel:<br>+86-510-84390688<br>Email:<br>wu@sinosonics.com   | \$580   |    |
| 2           | 1           | 1        | 20K<br>2000W-<br>F50-SA-1<br>Transducer      | Cemented<br>Carbide<br>and<br>Aluminum<br>Alloy | Sino Sonics<br>2ND FLOOR. NO.13<br>BUILDING, NO.100<br>DICUI ROAD, WUXI,<br>214072 CHINA<br>Tel:<br>+86-510-84390688<br>Email:<br>wu@sinosonics.com   | \$200   |   |
| 3           | 2           | 1        | Branson TI<br>Green<br>Booster<br>900 Series | various   | Shetal enterprises<br>LL-2, Avani Plaza,<br>Near Satellite Tower,<br>Satellite, Ahmedabad,<br>Gujarat, India-380015<br>Tel: +91-79-26760473<br>Email:<br>ultrasonicweldingparts<br>@gmail.com | \$875   |  |
| 4           | 3           | 1        | Ultra sonic<br>horn                          | Titanium  | Unisonic engineers<br>SonaiIndustrial,Gat<br>No.175, Rupinagar<br>Road, Talwade, Pune -<br>411062, Maharashtra,<br>India<br>Tel: +91-8048725853   | \$205.6 |  |

|    |   |   |                     |            |  |                |   |
|----|---|---|---------------------|------------|--|----------------|---|
| 5  | 4 | 1 | Linear acuator      | various    | RINCO<br>ULTRASONICS<br>Industriestrasse 4<br>CH-8590 Romanshorn<br>Switzerland<br>Tel: +41 71 466 41 00<br>Email:<br>info@rincoultrasonics.com  | \$460          |    |
| 6  | 9 | 1 | Baseplate / anvil   | 4130 steel | Mark-10<br><br>11 Dixon Avenue<br>Copiague, NY 11726<br>USA<br>Tel: 631-842-9200   | \$125          |    |
| 7  | 5 | 1 | 380v DC motor       | various    | Jiangsu Hengkang<br>Mechanical And<br>Electrical Co., Ltd.<br>Bldg. 1, Group 7,<br>Sunying Village, Group<br>6, Xinxing Village,<br>Guomeng Town,<br>Yancheng, Jiangsu,<br>China<br>Email:<br>hengkangjidian@126.<br>Com<br>Tel: 0515-88480808 | \$245          |    |
| 8  | 6 | 2 | ARDUINO NANO 33 BLE | various    | <a href="https://www.arduino.cc/">https://www.arduino.cc/</a>  | \$20.20 /piece |  |
| 10 | 7 |   | Emergency switch    | various    | Mouser electronics<br>Elsenheimerstr. 11<br>80687 Munich<br>Germany<br>Tel:+49 (0)89 520 462<br>110  | \$46.58        |  |

## **CHAPTER 4 – MANUFACTURING PLAN**

### **4.1. Manufacturing process selection**

In this project, we will be working two main systems which have crucial subsystems. These two main systems are the control system and the welding press. Within the welding press we have the pneumatic system that has the welding stack attached to it. At the end of the welding press, we have the base plate. We will be speaking about the crucial parts and any manufactured parts in this project in the section below.

Control system/box: is a portable device that includes a user interface and a microprocessor and control the actions occurring when welding. It helps you control some parameters and gives useful feedback regarding the welding process.

Pneumatic system: we will be using a pneumatic cylinder system which works on the basis of compressed gas/air to produce force and move the piston downwards. Air is let into the cylinder to push the piston down and when air is let out, the piston springs back to its original position.

Transducer: this is the initial part of the welding stack; it receives electrical power from the control system and converts it into mechanical vibrations, hence why it is also known as the converter.

Booster: this is the second part in the formation of the welding stack. This section receives the mechanical vibrations from the transducer and amplifies it to make it more suitable for the welding possible.

Horn: the horn is the last section of the welding stack. It receives the amplified vibrations from the booster and transfers them onto the area to be welded. The vibrations cause friction like movement and shearing that will result in the bondage of the layers of metal.

#### **4.2. Detailed manufacturing process**

Machine press: it is made of strong material so that it can hold the welding system and apply force. It consists of base-plate, to hold the tool.

Generator: The generator/dynamo is made up of stationary magnets (stator) which create a powerful magnetic field, and a rotating magnet (rotor) which distorts and cuts through the magnetic lines of flux of the stator. When the rotor cuts through lines of magnetic flux it makes electricity. [6]

Transducer: In general, ultrasonic transducers are constructed by incorporating one or more piezoelectric vibrators which are electrically connected to pulsing-receiving system. Conventionally, the piezoelectric member is made up of a PZT ceramic, a single crystal, a piezopolymer composite or piezoelectric polymer. [18]

Booster: The Ultrasonic booster is a one half-wavelength long resonant section made of aluminum or titanium. It is mounted between the Ultrasonic converter and the Ultrasonic horn, and modifies the amplitude of vibration applied to the Ultrasonic horn

Sonotrode/Horn: The sonotrode is mechanically fixed to the booster of the ultrasonic stack. The shape of the sonotrode determines the final amplitude that is experienced at the sonotrode face and, hence, the amplitude that will be used to weld two metal materials.



Component support tooling: It is often machined to match the contours of the component surface intimately.

Motor: The rotor assembly is sent to motor assembly. Two end frames are produced and sent to motor assembly. At the final operation, the wound stator assembly, rotor assembly, two end frames, and miscellaneous parts are assembled into a complete motor. The motor is then tested, painted, and packed for shipment. [11]

Micro-controller: A microcontroller is a single chip microcomputer made through VLSI fabrication. A microcontroller also called an embedded controller because the microcontroller and its support circuits are often built into, or embedded in, the devices they control.

## **CHAPTER 5 – PRODUCT TESTING PLAN**

Many precautions and precautions should be taken into account when dealing with our machine. A welding machine error or malfunctions can cause serious problems, malfunction of the work piece and even the health of the user. As mentioned in chapter 2, optimum ergonomics and simple ease of use are crucial to minimizing human error. Strict testing and verification is required to weld the work piece safely and effectively, making it automated moving in the y-axis, not the aforementioned. In this section we test the skill of the welder. [9]

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

As a team, we have conducted rigorous research concerning the different materials and designs we could use for the design of the welding machine. All these were aimed at making a welding machine that would tick off all the objectives of the project. The objective of the project is to make a cheap, reliable, easy to use automatic welding machine. In previous chapters, calculations and comparisons were taken and done to see which products would be best suited for our project to meet its requirements. A motor was chosen instead of a servo motor because higher torque and energy are required for motion. They offer higher torque at lower speeds; this is ideal for our application. The material selection was based on research done by our team, and we also brainstormed ideas from the Institute of Technology on our campus. The microprocessor and rail we selected according to local market specifications will also be in the subsection below, with an in-depth explanation of how the results were verified. Enough when required, just as the development for the device is not limited by the size and state of the machine.

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

This report is made in accordance with the AM Standards for the ISO/ASTM structure of Additive Manufacturing. When manufacturing our EV grinding, shaping, milling, cutting and welding done in manufacturing is carried out following the ISO standards. Turkish standards system will be considered and safety standards like ISO 4001 and Guidelines, will be considered in the workshop.

- For testing the generators ability in providing a stable and steady output we will use a voltmeter so that the machine runs in optimal state to avoid damage in the operating parts.
- An oscilloscope should allow us to measure the frequency of the transducer for it to allow the required frequency to be passed onto the booster
- We can test our own Arduino circuit and code online using Autodesk's 123d circuits. This piece of software let us simulates our schematic
- ANSYS software and Simulink will be used to simulate the project theoretically and to test if the design part such as the motor and some electrical component are working as intended
- To achieve a weld a certain amount of force should be applied to the work pieces using the linear pneumatic actuator to measure that force piezoelectric sensors are used to guarantee that we receive the needed force.

## CHAPTER 6 – RESULTS AND DISCUSSIONS

### 6.1. The results

An open loop control system was determined on polyethylene and polycarbonate (semi crystalline and amorphous) materials. The apparatus utilized for this test is an ultrasonic welding machine. With a maximum power output of 2600 watts and a 0.5 MPa pressure. A 1:1.5 booster was used on both materials.

Table 4: Welding parameters for both materials

| Material      | Vibration amplitude | Trigger pressure | Welding pressure | Holding pressure | Holding time |
|---------------|---------------------|------------------|------------------|------------------|--------------|
| Polyethylene  | 90%                 | 0.207 MPa        | 0.207 MPa        | 0.207 MPa        | 1 s          |
| Polycarbonate | 80%                 | 0.207 MPa        | 0.207 MPa        | 0.207 MPa        | 1 s          |

Both are AWS materials with an energy director. The threshold power level in the polyethylene material was switched from 300 to 600 watts, whereas in polycarbonate, the threshold power level switched from 200 to 400 watts.

Table 5: Effect of the threshold power level on the joint strength for polyethylene

| Threshold power level (watts) | Joint strength (MPa) |
|-------------------------------|----------------------|
| 300                           | 6.2                  |
| 400                           | 6.8                  |
| 600                           | 10.3                 |

Table 6: Effect of the threshold power level on the joint strength for polycarbonate

| Threshold power level<br>(watts) | Joint strength (MPa) |
|----------------------------------|----------------------|
| 200                              | 4.8                  |
| 300                              | 20.7                 |
| 400                              | 24.8                 |

Threshold power level has a strong relation with the strength of the joints. The more threshold power level is used the stronger joints obtained.

Higher mechanical impedance in the joint interface were due to higher power level. In terms of the squeeze flow model, high mechanical impedance shows that the molten polymer layer spreads wider and thinner on the interface. In such circumstances a better diffusion can be accomplished. Thus, joints are stronger.

## **6.2. The engineering standards**

As mentioned in the previous sections, ISO 17212:2004 provides and describes the usual procedures for the preparation of component surfaces prior to bonding for either laboratory evaluation or the process of construction was used. Also, isolated gloves and safety goggles were used to satisfy this standard to maximum level. In addition to that, G1.2M:1999 and G1.2:1999 are the standards in SI unit for the ultrasonic plastic welding which were used in our experiments.

## **6.3. The constraints**

Throughout the project, several constraints were faced:

- Economics: all parts costs were in the range of our financial budget of this project were covered orderly.
- Availability: due to low production of parts for an ultrasonic metal welding, it was complicated as some parts are out of stock or unavailable. We managed to switch to an ultrasonic plastic welding.
- Politics: most of the parts were ordered oversea. We've faced delay in parts arrivals yet, all parts went through the Turkish and the TRNC customs regulations.
- As it's our top priority to ensure safety environment, safety precautions were seriously determined through this project and we were completely aware of safety standards in a workshop.
- Environmental: To ensure safe and clean environment, all waste produced during the project was processed in the correct way.

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

### **7.1. Conclusion**

In this current day and age, welding plays a very important role in nearly everything that is manufactured. There is no place that you would walk in and would not find something that hasn't been welded. The main aim of the ultrasonic welding machine is to weld plastics in an efficient way to improve overall productivity which essentially leads to improvement in economy on a global scale. The main aims of this project was to show reliability and robustness of the system to withstand extreme industrial conditions, increased speed in production level, a higher level of quality, and smaller errors while considering safety factors in this process. These goals have been successfully achieved by implementing a system of control system and a

welding press. A pneumatic system moves the welding stack up and down while the overall machine is controlled by the control system. A simple start button initiates the process and within seconds, the material that requires welding would be welded.

## **7.2. Future works**

The effective and precise joining of plastics is important. For example, the indicator lights in your car, the housing of an electric iron or a dialysis filter are all produced by joining plastics. This can be done through a variety of different processes. Plastics can be joined using adhesive, for instance. Difficult materials can be assembled ultrasonically. Part assemblies are cycled quickly because the energy is transferred to the joint and released as heat occurs very rapidly. It is then confined to the immediate joint area. The rapid dissipation of heat makes this process considerably faster than other methods of assembly. An ultrasonic assembly system's tooling can be quickly changed offering flexibility not found in many other assembly processes. The relatively low-cost investment in ultrasonic equipment along with its long life and reliability make it the ideal choice. Ultrasonic assembly is widely accepted and used in many industries including automotive, medical, electrical, communications, appliance, consumer products, toys, textile, and packaging. It is an economical process that can significantly increase production and lower assembly costs. Ultrasonic welders can be easily integrated into an automation manufacturing environment. 100% all-electric control of the latest equipment provides unprecedented reliability and accuracy to the process. Ultrasonic plastic welding is suitable for virtually all thermoplastics. When planning welds between semi-crystalline plastic pieces of work, it is important to remember that the weld behavior of these plastics differs considerably from that of amorphous plastics. Ultrasonic plastic welding can be used to a limited extent for joining together two different thermoplastics (amorphous plastics). Ultrasonic welding is not

suitable for use with thermo setting plastics. Today ultrasonic welding is used in every industry that processes plastics. Most common uses are in the Automotive, Medical, Textile, Food, Plastics, and Packaging industries.



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# APPENDIX A: Electronic media




## THE DESIGN OF AN ULTRASONIC WELDING MACHINE

### INTRODUCTION

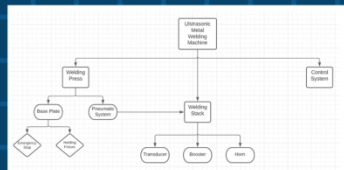
Ultrasonic welding, the intelligent 4.0 ready joining technology, has established itself in modern production. There are many good reasons for that: this sustainable and clean technology requires no additional materials (adhesives) or expensive time-consuming processes such as pre-treatment and drying. The wide range of applications and industries spans from automotive to packaging, and provides the highest quality requirements.

### OBJECTIVE

- Design for safety
- Design for cost
- Design for assembly
- Design for environment
- Design for performance






### BREAKDOWN STRUCTURE

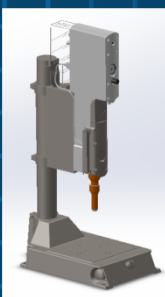


### SYSTEM SPECIFICATION

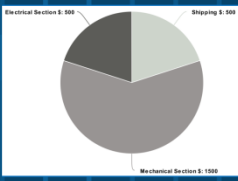
- 20kHz 2000Watt Ultrasonic Generator
- 20K 2000W-F50-SA-1 Transducer
- 380v DC motor
- ARDUINO NANO 33 BLE

### SELECTED DESIGN



### COST ANALYSIS CHART



### FUTURE DEVELOPMENT

Our future aim is to be developing automated ultrasonic welding machines that can be used to replace many other welding processes because of its high accuracy, efficiency and safety measures. This ultimately cuts down the industries costs as you don't really need workers to operate the machine.

### TEAM MEMBERS

Team leader: Mahmoud Aqelah 17701478  
 Mahmood Saleh 17701681  
 Ramzi Al Sayyed 16700698  
 Mahmoud Jamal 17701823  
 Ezgi Islek 17000070

Contact us at: USWM\_grp1@hotmail.com

Figure 14: Project poster.

## APPENDIX B: Constraints

Table 7: Project constraints.

| Constraints       | Yes | No |
|-------------------|-----|----|
| Economic          | X   |    |
| Environmental     | X   |    |
| Reliability       | X   |    |
| Availability      | X   |    |
| Manufacturability | X   |    |
| Ethical           |     | X  |
| Social            | X   |    |
| Political         |     | X  |
| Health & Safety   |     | X  |
| Efficiency        | X   |    |

## **APPENDIX C: Standards**

- ISO 15614-13:2012(en) :Specification and qualification of welding procedures for plastic materials — Welding procedure test
- ISO 9045:1990: Industrial screens and screening.
- ISO 11496:1993 :SEAMLESS AND WELDED STEEL TUBES FOR PRESSURE PURPOSES — ULTRASONIC TESTING OF TUBE ENDS FOR THE DETECTION OF LAMINAR IMPERFECTIONS
- EN IEC 60947-5-5:Emergency stop switch compact, foolproof
- ISO/DIS 17405:NON-DESTRUCTIVE TESTING — ULTRASONIC TESTING — TECHNIQUE OF TESTING CLADDINGS PRODUCED BY WELDING, ROLLING AND EXPLOSION
- IEC 60601-1 & 60601-1-11: requirements for basic safety and essential performance.

## APPENDIX D: Logbook

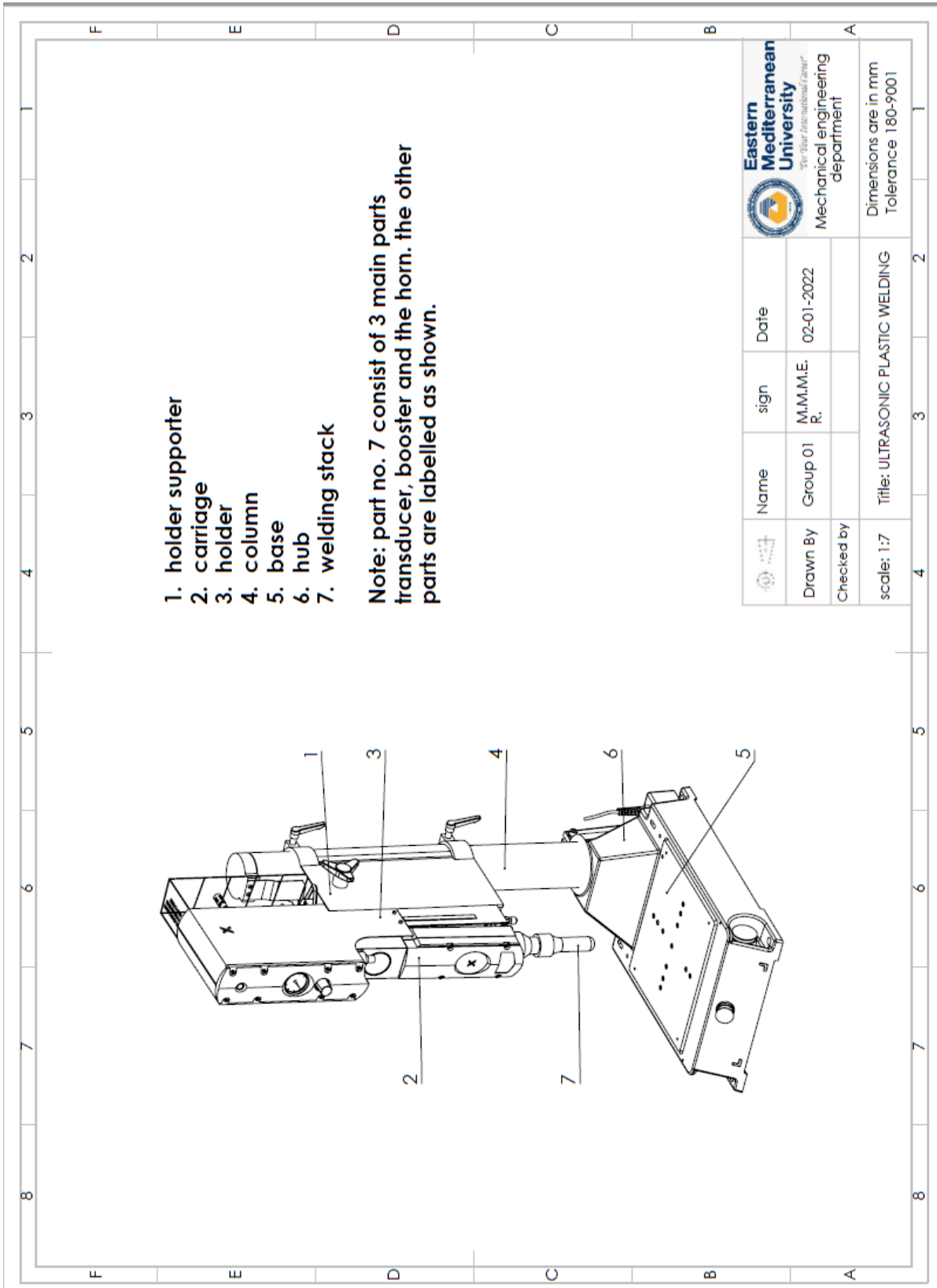
Table 8: Logbook.

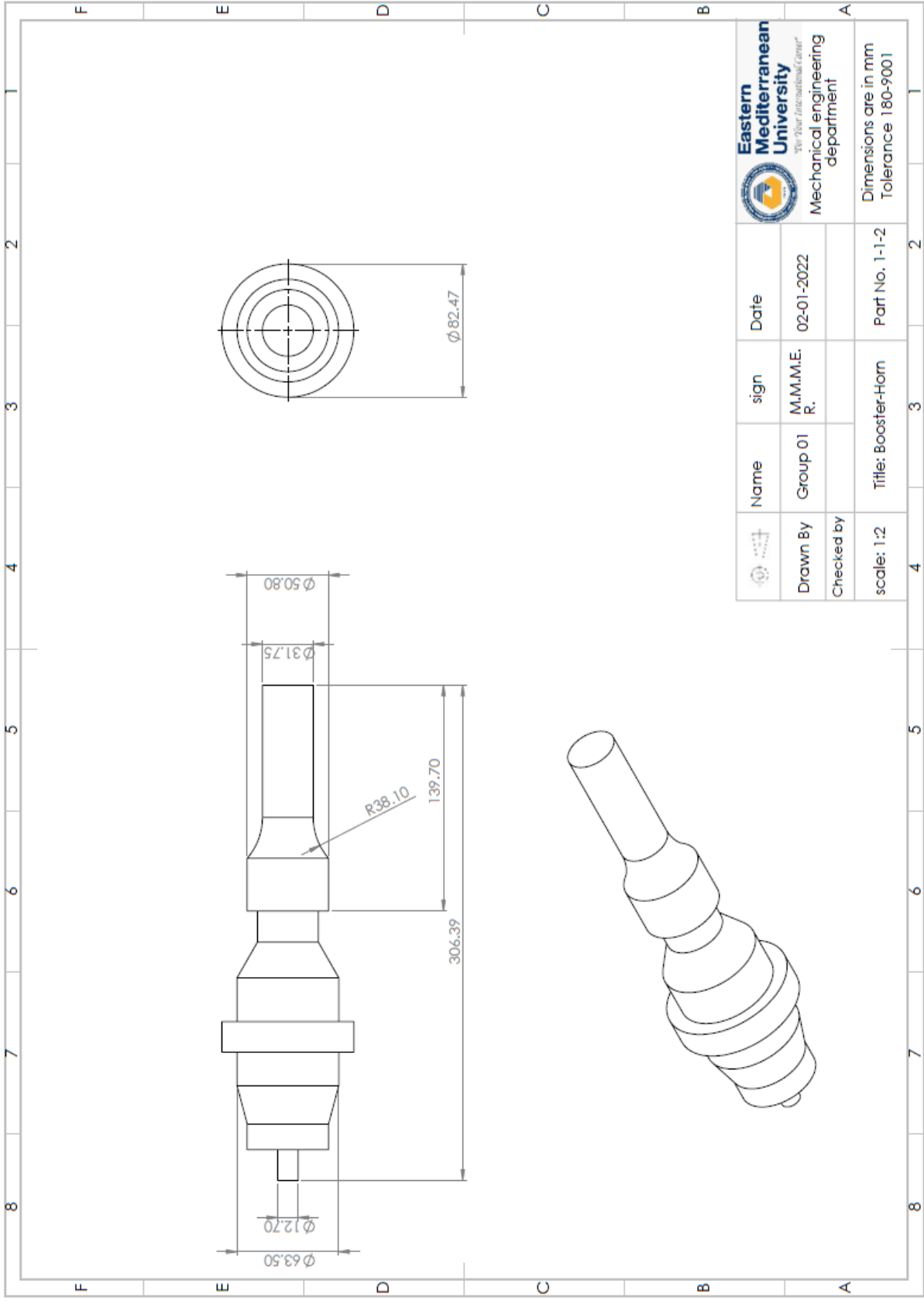
| <b>Date</b> | <b>Brief description of the performed work</b>  |
|-------------|---|
| 07/03/21    | Team members meeting to distribute the work among all of us for chapter 1 and 2       |
| 02/04/21    | Team members meeting to distribute the work among all of us for chapter 3 and 4       |
| 11/05/21    | Team members meeting to distribute the work among all of us for chapter 3 and 4       |
| 21/05/21    | Team members meeting to distribute the work among all of us for chapter 5             |
| 28/05/21    | Team members meeting to distribute the work among all of us for assembling the report |
| 25/10/21    | Required equipment were placed and ordered  |
| 15/12/21    | Pieces and equipment were delivered. Project assembly initiated                       |
| 20/12/21    | Machine was successfully assembled, tests for safety were conducted it.               |
| 25/12/21    | Chapter 6 tests were done, data was obtained and registered.                          |
| 26/12/21    | Chapter 6 theory writing initiated.   |
| 29/12/21    | Chapter 6 and 7 were completed. Report submitted for supervision                      |



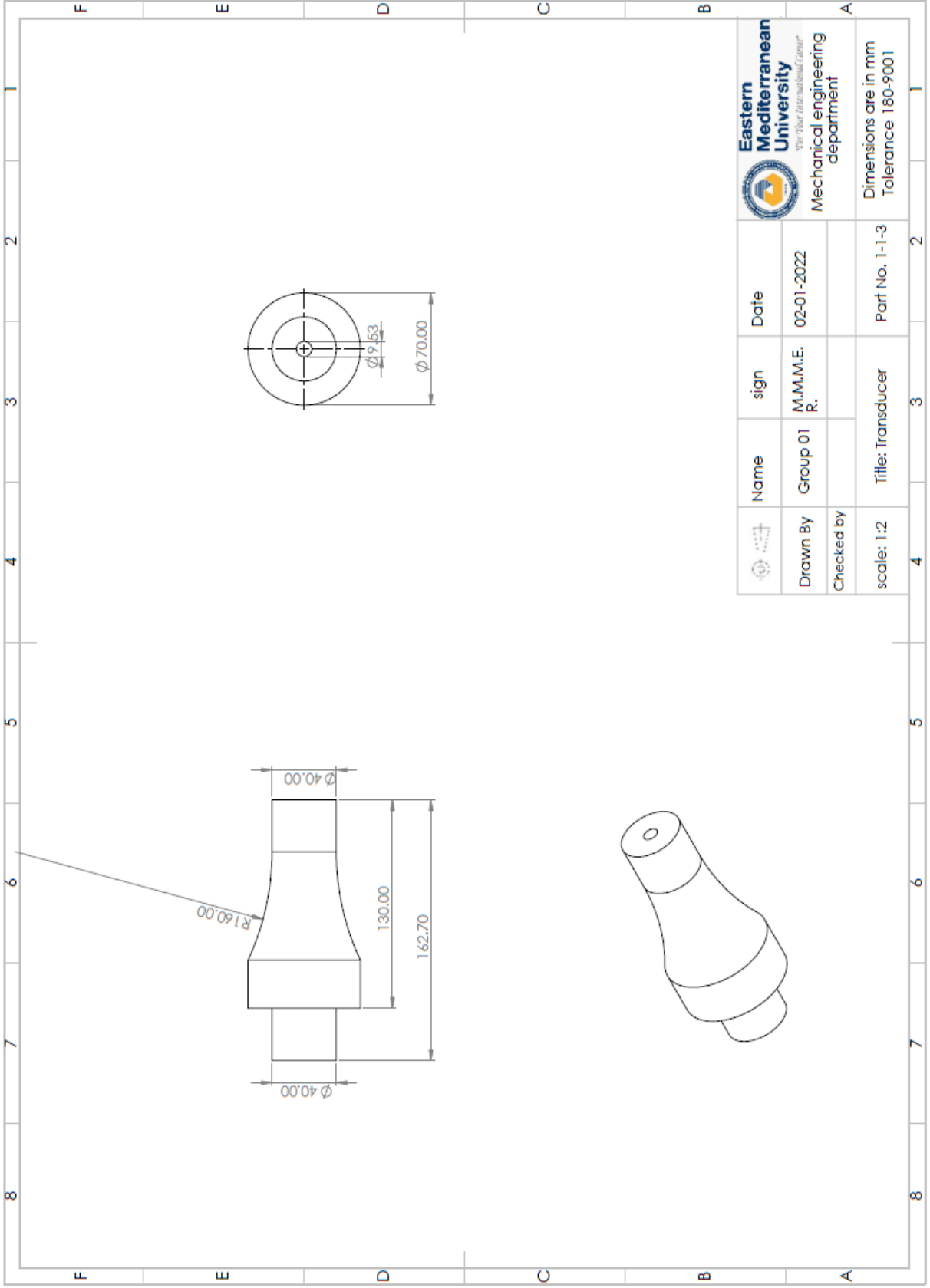


# APPEDNDIX F: Engineering drawings



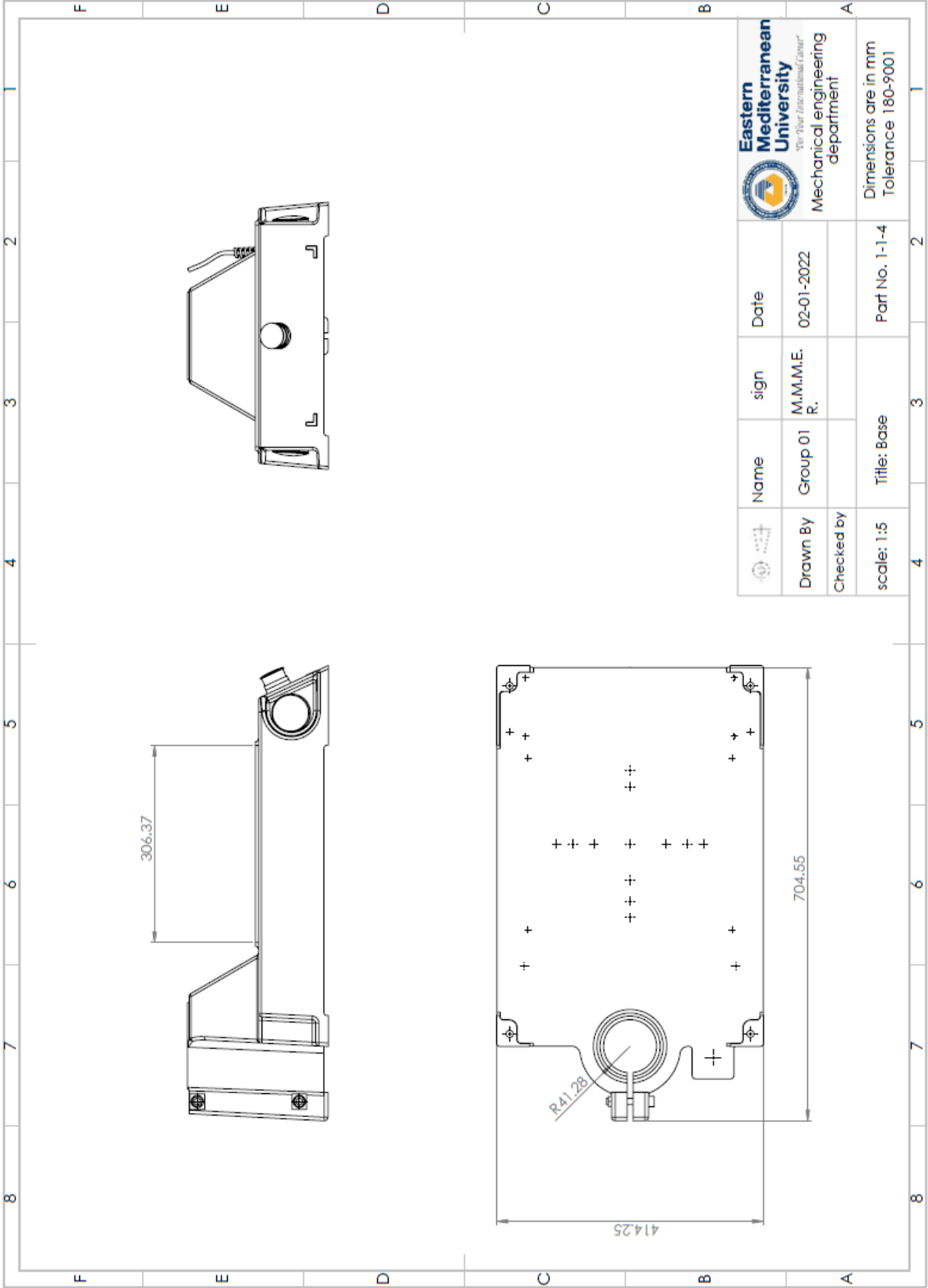


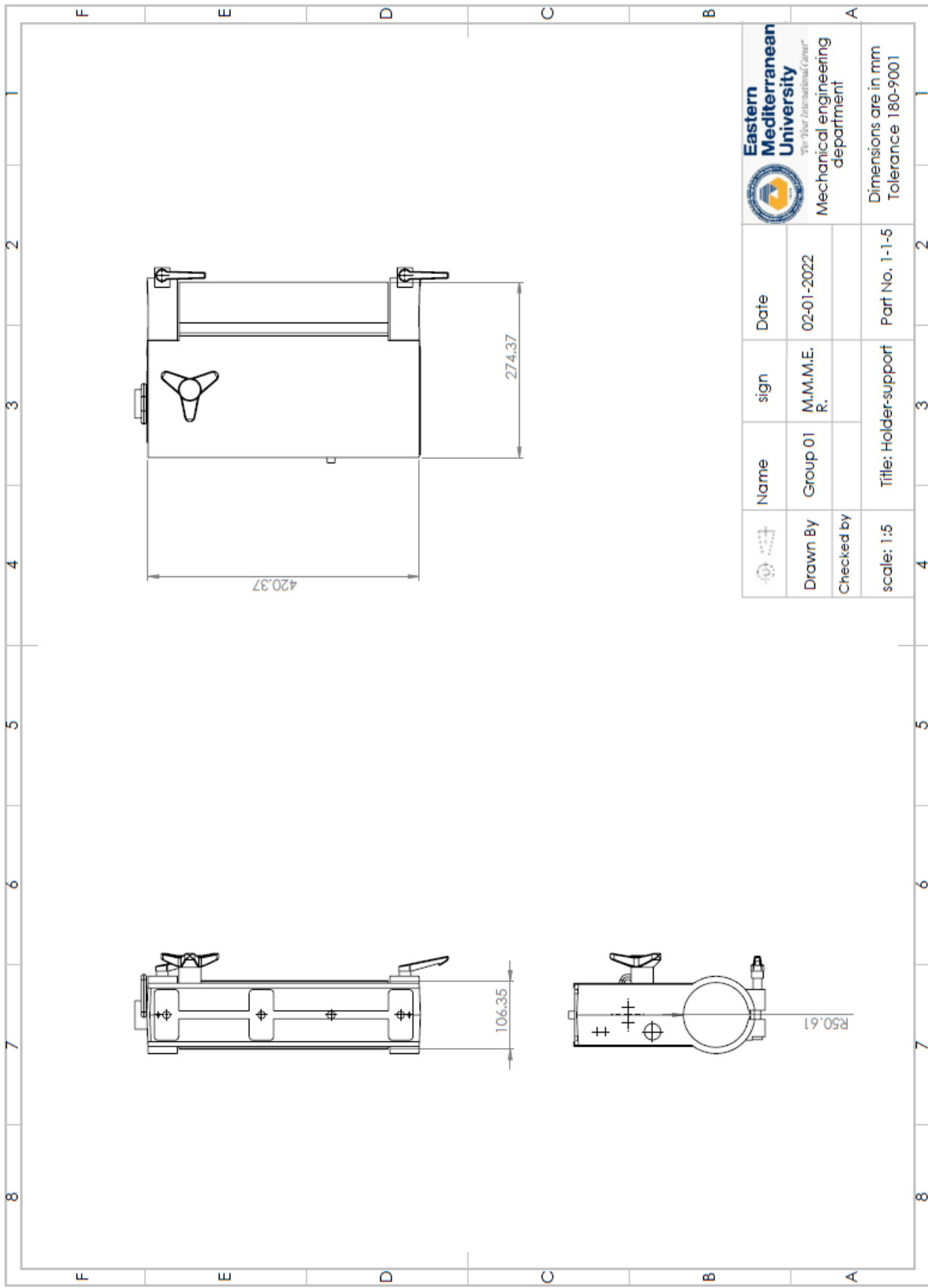
|            |          |  |                |          |            |
|------------|----------|--|----------------|----------|------------|
| Drawn By   | Group 01 | sign                                       | M.M.M.E.<br>R. | Date     | 02-01-2022 |
| Checked by |          | Title:                                     | Booster-Horn   | Part No. | 1-1-2      |
| scale:     | 1:2      | Dimensions are in mm<br>Tolerance 180-9001 |                |          |            |



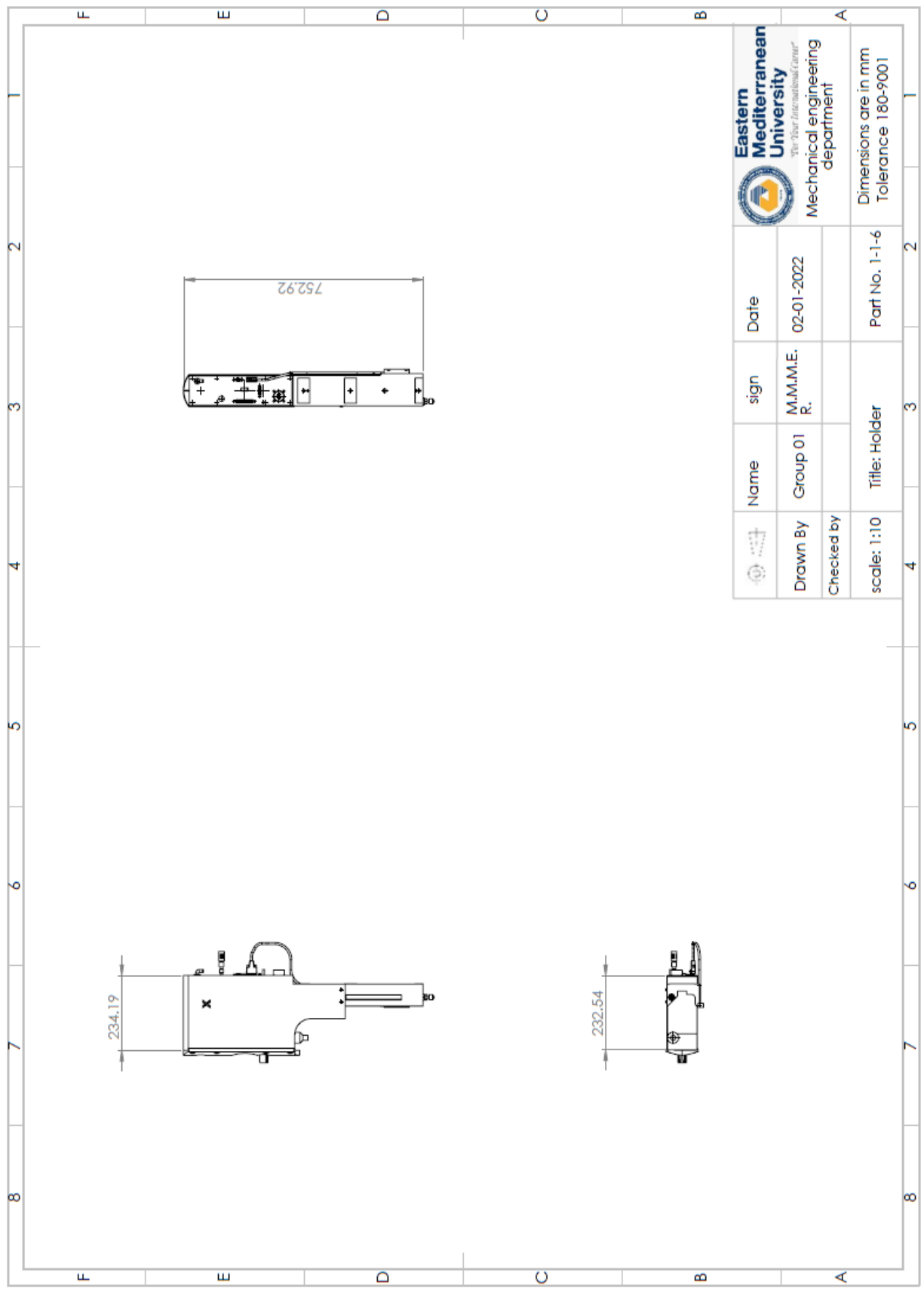
|  |  |                               |  |
|--|--|-------------------------------|--|
|  <b>Eastern Mediterranean University</b><br><small>"Be Your International Partner"</small><br>Mechanical engineering department |  | <b>Date</b><br>02-01-2022     |  |
| <b>Name</b><br>Group 01  |  | <b>sign</b><br>M.M.M.E.<br>R. |  |
| <b>Drawn By</b><br>Checked by  |  | <b>Part No.</b> 1-1-3         |  |
| <b>scale:</b> 1:2  |  | <b>Title:</b> Transducer      |  |



Dimensions are in mm  
Tolerance 180-9001

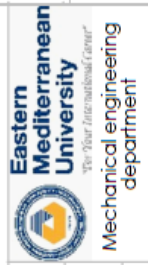
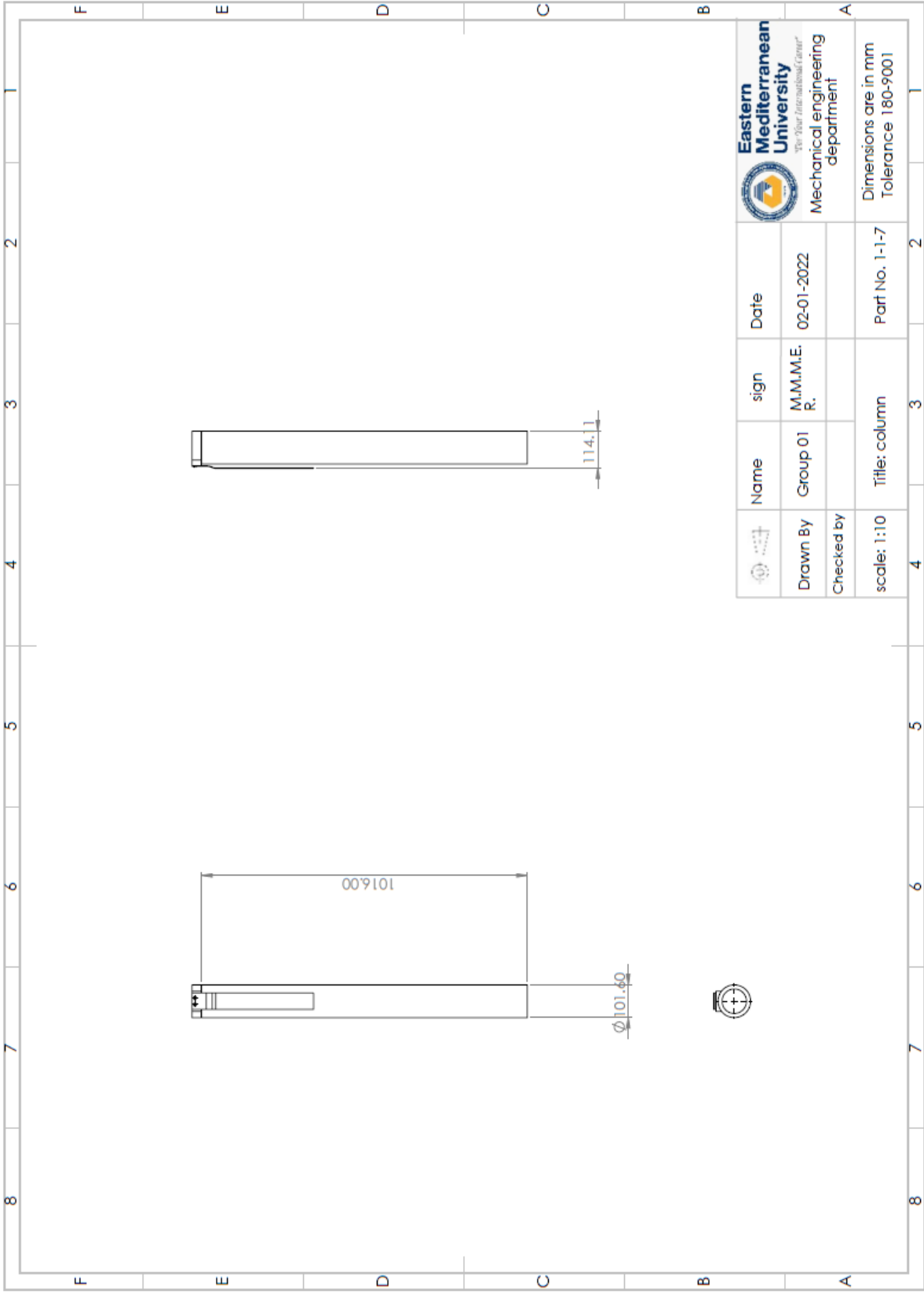




|            |          |        |                |  |            |
|------------|----------|--------|----------------|--|------------|
| Drawn By   | Group 01 | sign   | M.M.M.E.<br>R. | Date                                       | 02-01-2022 |
| Checked by |          | Title: | Holder-support | Part No.                                   | 1-1-5      |
| scale:     | 1:5      |        |                | Dimensions are in mm<br>Tolerance 180-9001 |            |

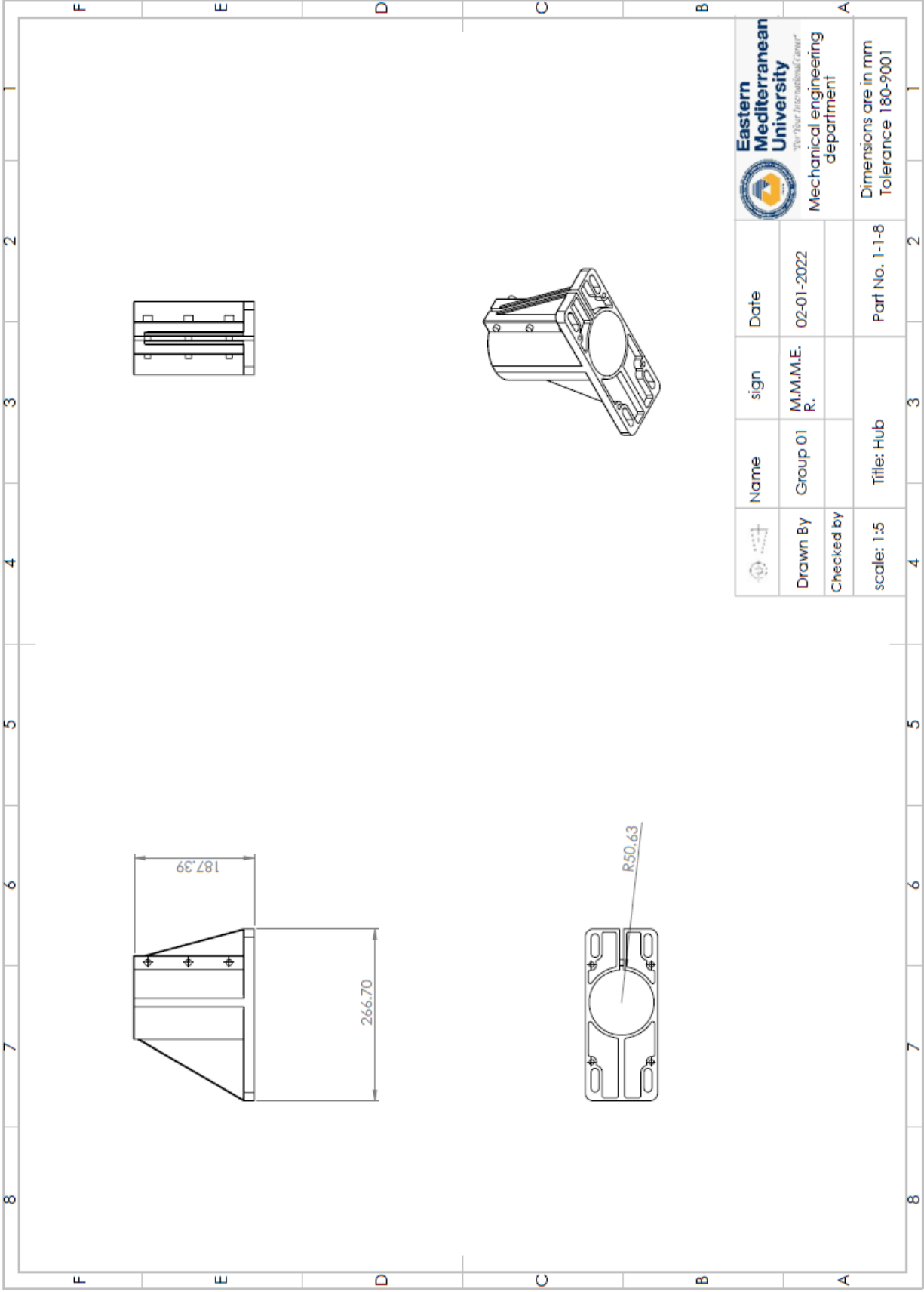





|  |                        |  |                |
|--|------------------------|--|----------------|
|  <b>Eastern Mediterranean University</b><br><small>"Be Your International Partner"</small><br>Mechanical engineering department |                        | Dimensions are in mm<br>Tolerance 180-9001 |                |
|  Name<br>Group 01   | sign<br>M.J.M.E.<br>R. | Date<br>02-01-2022                         | Part No. 1-1-6 |
| Drawn By<br>Checked by   | Title: Holder          | scale: 1:10                                |                |



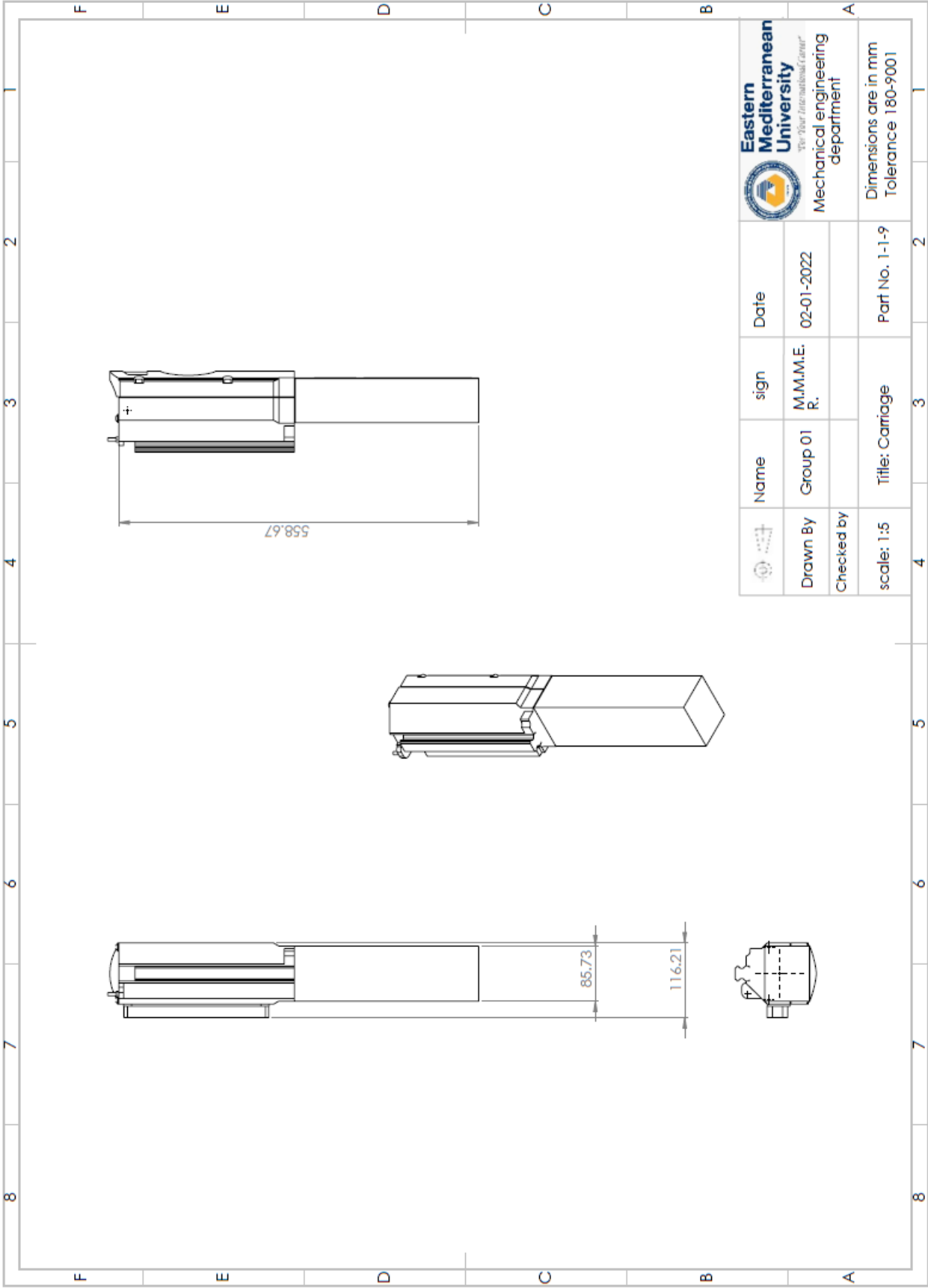
|             |               |      |                |      |  |
|-------------|---------------|------|----------------|------|--|
| Drawn By    | Group 01      | sign | M.M.M.E.<br>R. | Date | 02-01-2022                                 |
| Checked by  |               |      |                |      |  |
| scale: 1:10 | Title: column |      | Part No. 1-1-7 |      | Dimensions are in mm<br>Tolerance 180-9001 |





|   |            |   |                    |
|---|------------|---|--------------------|
|  <b>Eastern Mediterranean University</b><br><small>"Be Your International Partner"</small> |            | Mechanical engineering department<br>Dimensions are in mm<br>Tolerance 180-9001 |                    |
|  Drawn By  | Group 01   | sign<br>M.M.M.E.<br>R.  | Date<br>02-01-2022 |
|  Checked by  | Title: Hub | scale: 1:5  | Part No. 1-1-8     |





**Eastern Mediterranean University**  
 "The Star International Center"  
 Mechanical engineering department

|            |          |                 |                |                |            |
|------------|----------|-----------------|----------------|----------------|------------|
| Drawn By   | Group 01 | sign            | M.M.M.E.<br>R. | Date           | 02-01-2022 |
| Checked by |          | Name            |                |                |            |
| scale: 1:5 |          | Title: Carriage |                | Part No. 1-1-9 |            |

Dimensions are in mm  
 Tolerance 180-9001