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**Department of Mechanical Engineering**

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## **Senior Design Project Report**

### **Ultrasound Drying**

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Degree of Bachelor of Science in Mechanical Engineering**

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## Abstract:

With the massive influx in electricity prices within the Kingdom of Saudi Arabia, many people are becoming affected. In an attempt to mediate this issue, small home appliances were tackled to figure out a way to cut costs through applying an engineering solution. The concept of ultrasound was incorporated in both drying and ironing appliances to replace the conventional heat source of energy that was initially used to them. Incorporating ultrasound energy proved to be an effective means of completing the tasks initially done by the heat version of the appliances. Through testing, it was shown that ultrasound does have an effect with drying and ironing with different types of materials. Although the application of this is effective, it doesn't necessarily change the characteristics of the materials drying, for example nylon still dries faster than cotton in ultrasound drying as well, however the rate of drying is much more efficient. The application of ultrasound drying will drastically impact the prices of these applications because of the cheaper manufacturing methods used, the reduction in power necessary to dry, and neglecting components included in normal dryers and irons that were implemented as safety measures against heat generation.

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# Chapter 1 Introduction

## 1.1 Project Definition

The foundation of all technology share one common trait; they were created as a means to innovate and improve. With the industrial era coming to an end, and people's consciousness and awareness on the issues that matter, global warming and the economy, the motivation to innovate has never been more apparent. In the case of Saudi Arabia, their goal of Vision 2030 has set the foundation and criteria of all future endeavors in Saudi, which includes technology. Although these criteria include large scale projects, we thought it was necessary to shift the focus to a much smaller and more accessible scale that the general public are more exposed to. Two household appliance that are used hand in hand regularly are dryers and clothing irons. Although convenient, certain issues are present that many might not be aware of when it comes to these devices. Financially, clothes dryers cost consumers around \$9 billion in electricity bills. Practically, the devices operate on suboptimal levels of efficiency due to their reliance on generating heat to operate. The introduction of heat energy in any appliance creates an extra layer of complexity due to the safety hazards that are present, the materials ability to withstand heat energy, and the excessive power needed to generate the heat. The proposed project aims to replace this layer with an alternative energy source to complete the same actions; ultrasound energy.

Ultrasound is classified as mechanical energy, a form of energy whose mechanics operate differently than that of heat energy. Through alterations done to the geometry of the components, the acoustics would allow for the ultrasound to travel in a manner that drastically improves the efficiency of the operation. This will also be requiring much less energy to achieve the same results as those found with appliances that rely on heat. In the case of drying and ironing, exposing the clothes to ultrasound energy would affect it at a molecular level. Rather than breaking the hydrogen bonds left behind from the drying phases, it would instead create microscopic channels through cavitation to allow for the hydrogen atoms to escape. This process requires much less energy to achieve than the conventional heating method. Eliminating the need to generate heat opens up a plethora of opportunities from design and material selection options.

This project aims to design and manufacture an ultrasound emitting device primarily for the use with different cloth types to both dry and straighten out creases that exists when clothes are damp. The device will initially be tested on wet fabrics, where a large energy saving is

expected. The components will be subjected to long exposure to the ultrasounds and the effect on them will be studied. Moreover, various different designs will be made on the actual prototype that test the initial concepts of ironing that exist today and showing where alterations can be made to facilitate the new ultrasound operation.

## 1.2 Objectives:

- 1) To design an energy efficient iron that uses ultrasound waves.
- 2) To allow for ease of use for consumers.
- 3) To find an alternative means to heat generated household items.
- 4) To increase overall efficiency of the drying and ironing.
- 5) To drastically decrease ironing and drying time.
- 6) To be user friendly without fear of hazards occurring with use.

## 1.3 Project specifications

The components required to build the ultrasound iron consists of those needed to generate the actual ultrasound waves. The two primary components are the ultrasound transducers and ultrasound generator. While the transducers will be housed within the actual 3D printed casing, it will be connected to the generator with wires. A power source is also to be included to supply the device with the energy necessary to operate.

## 1.4 Applications

The primary application for this device would be for commercial use. People would be able to use them in their households to replace their conventional irons. Businesses can also benefit from the device as it will operate at a much higher efficiency than their current means of ironing and drying.

# Chapter 2: Literature Review

## 2.1 Project background

Ultrasound waves are a form of soundwaves that possess frequencies higher than the audible threshold that human beings can hear. When taking a look at ultrasound waves from a physical standpoint, they possess the same characteristics as normal sound waves, however they differ from a frequency standpoint as ultrasound waves exist from 20kilohertz up to several

gigahertz. Harald Lutz and R Soldner mention their book, Manual of Diagnostic Ultrasound, "Ultrasound is the term used to describe sound of frequencies above 20 000 Hertz (Hz), beyond the range of human hearing. Frequencies of 1–30 megahertz (MHz)"(Lutz, 1995) The range in which ultrasound is generated are present in this scale, hence humanly reaching these numbers are not possible.

### 2.1.1 Transducers

Transducers are devices that operate through the process of transduction, which is the process of converting one form of energy to another. (Agarwal, 2005) In various applications, signals are needed to transfer their forms of energy for them to be use. This usually comes in the form of electric signals being converted into physical energy such as force and torque. In this case of ultrasound, the transducer devices change the electric energy supplied into ultrasound waves.

### 2.1.2 Piezoelectric crystals

Piezoelectric crystals or materials are able to convert mechanical pressure into electrical voltage on their surface. (Lutz, 1995). This form of conversion is created through piezoelectricity, a form of generating sound waves into mechanical energy. This is achieved through components known as piezoelectric crystals, which are crystals that allow for the movement of electricity through them when they experience mechanical stress, such as through squeezing. (Woodford, 2017). They then continue "The piezoelectric crystal, therefore, serves as a transducer, which converts electrical energy into mechanical energy and vice versa."(Lutz, 1995). It's through these means that the mechanical energy experienced by the crystals are able to convert these physical quantities into electric potential; also known as transducers. In the case of our project, the electric potential the transducers will be experiencing are from a different electrical output allowing for them to transform into a mechanical property; ultrasound waves.

The velocity of said sound ultrasound waves would serve as the primary means in which the project will operate. The authors mention "The velocity of sound depends on the density and compressibility of the medium. In pure water, it is 1492 m/s (20 °C), for example. The relationship between frequency (f), velocity (c) and wavelength ( $\lambda$ ) is given by the relationship" (Buzea, 2007) This relationship generates the equation

$$\lambda = \frac{c}{f}$$

(Eq 2.1)

Through comprehension of the means of travel and understanding the impact the velocity in which the sound waves operate, its effect on different materials can be studied. Different chemical structures of materials react differently to the velocity of the waves that they are exposed to. These waves affect the materials on a microscopic scale, creating deviations within the chemical structures. Cristina Buzea; Ivan Pacheco & Kevin Robbie mention in their book "Nanomaterials & Nanoparticles: Sources & Toxicity" that " Nanostructure deals with objects and structure that are in the 1-100nm range. In many materials, atoms or molecules, agglomerate together to form objects at the nanoscale. This causes many interesting electrical, magnetic, optical and mechanical properties. (Buzea, 2007). It's through these agglomerated structures that affect the speed of the waves travelling through them, while simultaneously altering some of their properties. Three types of materials, with respect to their chemical structures, can be analyzed and to see the impact that ultrasound waves have on said structures; these include viscoelastic materials, cellulosic material and soft tissue.

### 2.1.3 Viscoelastic Materials

Viscoelastic materials refer to materials who possess both elastic and viscous components within them, taking time heavily into consideration when tackling the stress/strain aspect. In the Princeton University's publication by JFV Vincent "The Basic of Elasticity and Viscoelasticity" they mention "When material is deformed (stretched, perhaps), energy (usually referred to as strain energy) is stored in the deformation of its bonds, and it is this energy that brings the material back to its original shape. (Vincent, 1982) Taking this factor into consideration, they continue "it is dissipated in a number of ways, such as heat and sound" (Vincent, 1982). Mechanical energy has a direct impact on this type of material. This is further confirmed through Meyers and Chawla publication "Mechanical Behavior of Materials" stating that "Purely elastic materials do not dissipate energy (heat) when a load is applied, then removed" (Meyers, 1999) They continue "Since viscosity is the resistance to thermally activated plastic deformation will lose energy through a loading cycle" (Meyers, 1999) The influence of energy in viscoelastic material paves the way for the means in which mechanical energy can have an effect on such a

medium, and further shed light on the effect of ultrasound waves on different materials. Considering the classification of ultrasound being mechanical energy, and the viscoelastic material's ability to alter mechanical energy into thermal energy deduces that subjecting a viscoelastic material to this energy would result in some heat generated.

### 2.1.4 Cellulous Materials

Cellulose material, or cellulose fibers, are materials that are manufactured from plants that are processed into a pulp and then extruded in the same ways that synthetic fibers like polyester or nylon are made. (Enciclopedia) Figure 2.2 shows the crystalline structure of cellulose materials. When taking a look at cellulose materials on a microscopic level, the bonds are aligned in a manner that allow for ultrasound waves to alter them. Carcel JA, Garcia-Perez JV, Riera E, Mulet A mention in their book "Influence of high intensity ultrasound on drying kinetics of persimmon" that "A series of alternative compressions and expansions can be produced when ultrasonic waves travel through the material" (Carcel, 2007) they continue "alternating stress can be higher than surface tension of the moisture inside the capillaries of the material and can create microscopic channels".(Carcel, 2007) Therefore, mechanical energy can deviate the shape of cellulose structure, aligning them in a manner that overlaps with the ultrasound waves.

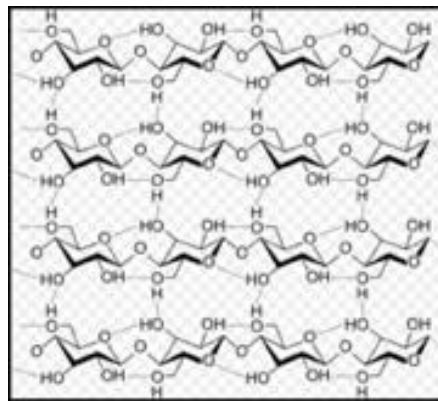


Figure 2.1 cellulose-based fabrics chemical composition

### 2.1.5 Soft Tissue

Soft tissue are those that surround and support the organs of the body. Soft tissue includes a chemical composition of this type of tissue located with the extracellular matrix are the collagen, elastic and ground substances. (skinner, 2006) The combination of these chemical compositions creates transparency for the ultrasound waves when passing through.

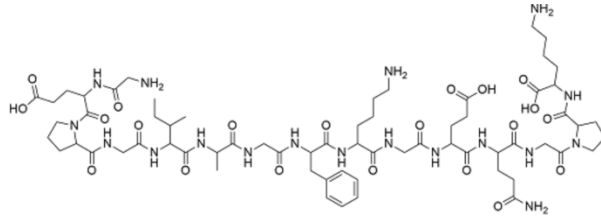


Figure 2.2 Collagen Chemical Structure

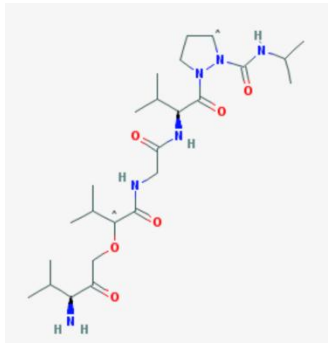


Figure 2.3 Elastic Chemical Structure

Since ultrasound is used in various forms of modern medicine, various studies were conducted on the medium on the soft tissue. Harald Lutz and R Soldner discuss "Bone absorbs ultrasound much more than soft tissue, so that, in general, ultrasound is suitable for examining only the surfaces of bones." Through this, we can understand that the chemical composition of the collagen, elastic and the jell like ground substance allow for ultrasound waves to pass through relatively easily, unlike hard tissues such as bones, where they absorb the majority of the ultrasound" (Lutz, 1995) They continue "In soft tissue, attenuation by absorption is approximately 0.5 decibels (dB) per centimeter of tissue and per megahertz" (Lutz, 1995) which helps clarify the next point they discuss " In this connection, it should be noted that the reflected ultrasound echoes also have to pass back out through the same tissue to be detected." (Lutz, 1995) This correlation is why ultrasound methods are used for soft tissue rather than bone tissue.

Since the chemical structure of the soft tissue allows for ease of transport through it, it can pass back relatively easily through it once more to allow for an analysis of the picture generated. Through understanding the mechanical impact ultrasound waves have on materials, and the means in which they alter the chemical structure of the components, excluding soft tissue, the results of this alteration can be manipulated to serve various different real-world purposes.

### 2.1.6 Commercial Irons

Commercial electric irons are used widely by consumers everywhere. Ironing occurs through loosening the bonds between the long-chain polymer molecules in the fibers of a material and is done by using the heat from an ironing plate, the fibers are stretched and the fabric maintains its new shape when cool. (*DU FERA REPASSER*) Irons are made of several components listed in table 1.1.

Table 2.1 List of components of commercial electric irons

Element	Definition
Sole Plate	Thick triangular shaped slab of iron that forms the base. Chromium plated to avoid corrosion.
Pressure Plate	Known as top plate, usually made up of thin sheet of steel.
Heating Element	Present between the sole plate and pressure plate, The heating element consists of nichrome wire wound around a sheet of mica
Sheet of Mica	Mica is a very good insulating material. Besides that mica can also withstand very high temperatures.
Cover Plate	Made of thin sheet of iron. It is placed on top of the base plate and it covers all the internal parts of the iron.
Handle	The handle is attached to the cover plate with the aid of screws. Studs can also be used for this purpose
The pilot lamp	Its housed in the cover plate of the electric iron. A shunt resistance is provided across the pilot lamp which assists in providing a voltage drop. The shunt is designed to provide a voltage drop of 2-5 volts.
Thermostat	Uses a bimetallic strip to operate the switch which is connected in series with the resistance (or) heating element.
Capacitor	Frequent making and breaking of circuit damages the contact points and it may also result in interference with radio reception; capacitors stops this from

### 2.1.7 Creases

Heat and water cause wrinkles, otherwise known as creases. Heat breaks the bonds holding polymers in place within the fibers of a fabric. When the bonds are broken, the fibers are less rigid, with respect to each other, so they can shift into new positions. As the fabric cools, new bonds form, locking the fibers into a new shape. (Marie, 2016)

Water plays an important role in the creation of creases in cellulose-based fabrics, such as cotton, linen, and rayon. The polymers in these fabrics are linked by hydrogen bonds, which are the same bonds that hold together molecules of water. Absorbent fabrics allow water molecules to penetrate the areas between the polymer chains permitting the formation of new hydrogen bonds. The new shape becomes locked in as the water evaporates. Steam ironing works well on removing these wrinkles. (Marie, 2016)

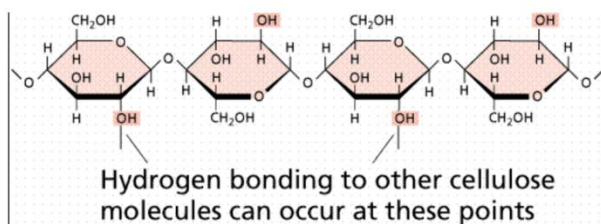
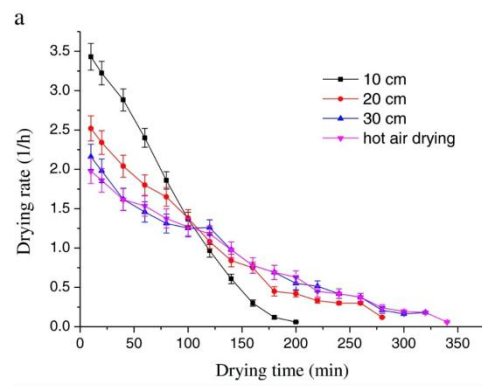
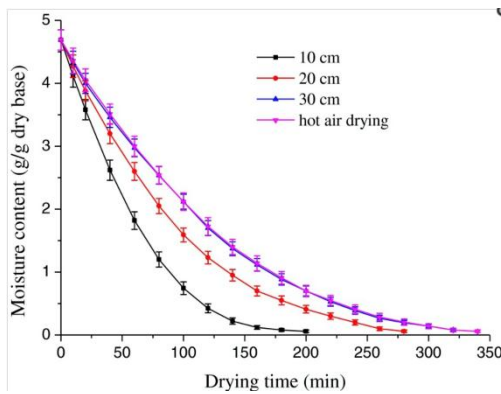


Figure 2.4 Location of hydrogen bonds connection in cellulose molecules.

## 2.2 Previous work

Through comprehension of the dynamic microscopic effect ultrasound waves have on various types of materials, appropriate manipulation and harnessing of these occurrences can help with the application of them in real world scenarios. One such research conducted by Yunhong Liu, Yue Sun, Shuai Miao, Fang Li and Denglin Luo titled "Drying characteristics of ultrasound assisted hot air drying of Flos Lonicerate" tested the means in which Ultrasound waves would work on drying a Chinese herb known as Flos Lonicerate. They explain in their research "acoustic energy produces oscillating velocities and microstreaming at the interfaces which may break the bonding of water molecules and product surface and minimize diffusion boundary layer thickness" (Puig et al.2012). This confirms the science mentioned either on the means in which mechanical energy work on a microscopic level with the molecule systems, in

the case of water it can break the bonding through the mechanical energy. They continue "A series of alternative compressions and expansions can be produced when ultrasonic waves travel through the material, and this alternating stress can be higher than surface tension of the moisture inside the capillaries of the material and can create microscopic channels which may improve water removal" (Mulet et al. 2003). The physics behind ultrasound waves allow for the alternating stresses to occur based on the moisture content of the material. When something is wet and H<sub>2</sub>O particles bond with the structure of the material, ultrasound waves can be altered to reach a point in which its higher than that of the surface tension of the moisture within said material, this change in stress creates infinitesimal channels within the bonding structure of the material. Adding to this point they mention "acoustic waves may produce cavitation which may be beneficial for the removal of strongly attached moisture" (Mulet et al. 2003) This proves effective where the moisture might be significantly stronger in some respect where the microscopic channels may not be as efficient in that sense. The results of this experiment are stated in the figures bellow



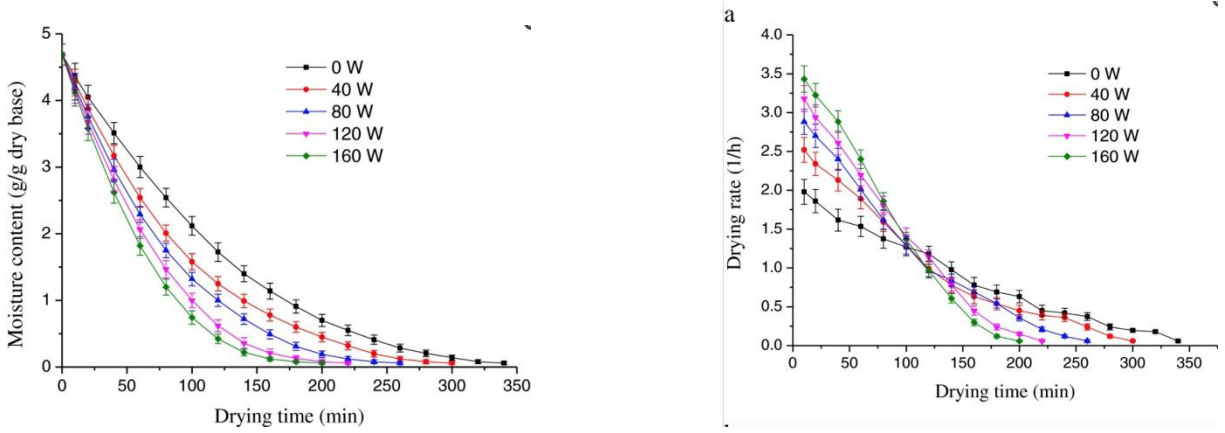


Figure 2.5 Graphs generated from experiment indicating drying curves through adjustment of various variables and wavelengths

Figure 2.5 shows some of the data gathered during the course of this experiment. The results proved ultrasounds ability to dry in this specific circumstance. Ultrasound had a large influence on the drying rate showing an inversely proportional relationship between the ultrasonic radiation distance, and drying rate of HAD. The HAD decrease with the increase in ultrasonic radiation. This was proven to be because of attenuation as they state " the influence of ultrasound on drying rate of HAD decreases with the increase in ultrasonic radiation distance because of energy attenuation" (Liu, 2014) As seen in the curves generated, the effects of ultrasonic radiation distance and ultrasonic power on drying rate decrease with the reduction of sample's moisture content during drying process. (Liu, 2014)

Another study conducted by Chang Peng, Ayyoub M. Momen and Saeed Moghaddam from the department of Mechanical and Aerospace Engineering at the University of Florida titled "An energy-efficient method for direct-contact ultrasonic cloth drying" aimed to include a binary modulating signal to the power supply of the transducers used for the direct-contact drying of different fabrics. The authors initially state that " In 2013, clothes dryers accounted for about 6% of the annual residential electricity use in the United States, costing consumers about \$9 billion" (Peng, 2017) pointing to an excess need of energy consumption that can be mediated through different forms of drying mediums. Rather than looking at the base mechanics of ultrasound waves, the experiment aimed to adjust the transducer's effect. The experiment managed to pinpoint two key findings. The first is that drying using a modulating signal consists of nonlinear and linear regimes (Peng, 2017). The second is that drying time for fabrics depends on fabric types and duty cycle and modulating frequencies. (Peng, 2017). They also found that a "critical duty cycle" in which drying time does not change, hence needing to alter the type of transducers

related to such endeavors. (Peng, 2017). Based on table 2.2, the different energy factor, EF, values of the fabrics were listed with their corresponding values based on which transducer was used.

Table 2.2 Energy factor (EF) for different Fabrics on transducer A and B.

Fabric	EF <sub>100-20%</sub> (lb/kWh)	
	Transducer A	Transducer B
F-1	0.27	2.79
F-2	0.05	0.36
F-3	0.06	0.70
F-4	0.18	4.12

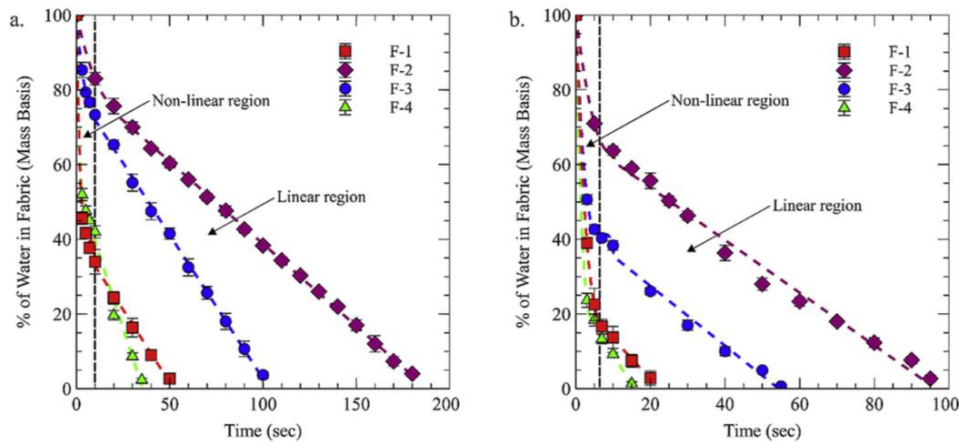


Figure 2.6 Drying characteristics of different fabrics on (a) transducer A and (b) transducer B. The fabric size was fixed at 44 mm<sup>2</sup> and the water mass was 10 mg.

Figure 2.6 shows the effect the different transducers had on both the non-linear region and linear region for different transducers. Transducer B was used on burst mode while transducer A was used in continuous mode. The findings showed that the repeatedly vibrating fabrics detached from the transducers surface before returning to the initial region; falling back on the surface. (Peng, 2017) This finding helped show how that the using the transducer in burst mode instead of continuous mode was much more energy efficient.

### 2.3 Comparative Study

A research conducted by Ayyoub M. Momen for the U.S Department of Energy created an ultrasound clothes dryer which aimed to find a suitable piezoelectric transducer for drying,

to identify the best driving signal for the experiment and to show the pros and cons of such technology. (Momen, 2016) They mention early on in the research study that "Ultrasonic dryers are projected to save up to \$900 million in consumer utility savings over 10 years" (Momen, 2016) this sets up the scene for the premise of the project and validating the need to conduct it. The background of the project discussed how conventional dryers operated. Dryers that operate on the premise of evaporation have to overcome the latent heat of evaporations, meaning that they'd require between 3.21-3.51 lbwater/kWh, coincidentally 2453–2257 kJ/kgw. (Momen, 2016) Taking into consideration the wasted energy present in conventional dryers, it was concluded that a theoretical maximum efficiency of 54%-66% exists.

Adopting the concept of mechanical energy, ultrasound, to this cycle means that certain parameters and equations would replace existing ones. First, the driving force and the resisting force would need to be addressed. Considering how heating and evaporation would be replaced with mechanical energy, the mechanical energy would act as the driving force for the water, hence concluding that the driving factor of the process would be the inertia of water. This would need to satisfy the equation 2.2.

$$F_{vib} \sim m_{drop} A \omega^2 \quad (\text{Eq 2.2})$$

Vibrating force  $F_{vib}$  based on the mass of the water droplet, area and angular frequency

Considering the waters tendency to adhere to the edges of the vessel its contained in, in this case the dryer, would result in an upward force being exerted on the water leading to meniscuses occurring turning upward. When the adhesion of the water on the walls is stronger than the cohesive forces between the molecules within the water leads to capillary action. Capillary action would in turn serve as the resistive force within this mean of drying clothes hence satisfying the equation 2.3. (Momen, 2016)

$$F_{Cap} \sim \sigma \pi d \cos \theta \quad (\text{Eq 2.3})$$

Based on the exposure to the waves, the theoretical residual moisture content, RMC, of each kind of fabric after being exposed to the vibration can be calculated based on the different angular frequencies the waves possess satisfying the equation  $\omega = 2\pi f$ . (Momen, 2016) These can be seen in figure 2.7

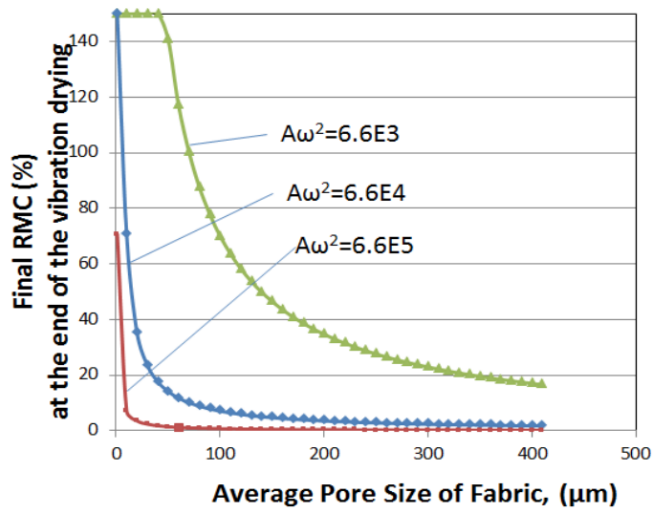


Figure 2.7 Angular frequencies of waves based on pore size of fabrics used.

Through the application of these altered concepts to the drying method and developing a prototype, the research addressed some significant findings. First, since the fabrics would be exposed to the new driving and resistive forces, the trajectory of the fabrics based on the new forces were graphed along with piezo crystals frequencies as seen in figure 2.8

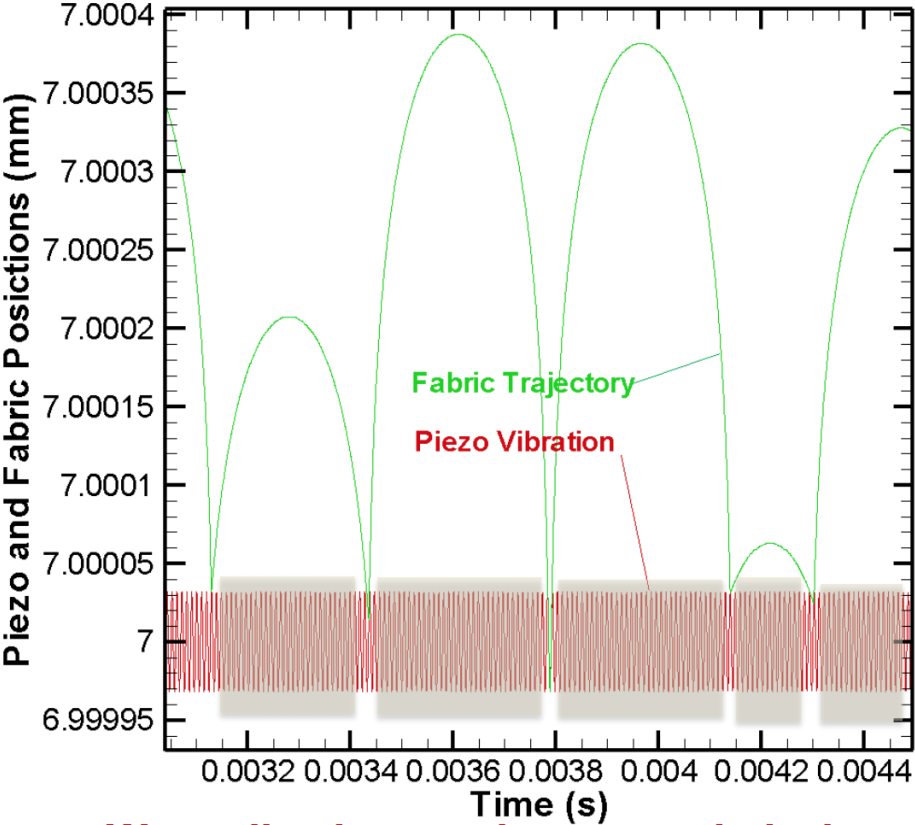


Figure 2.8 Graph of Piezo & Fabric Positions (mm) Vs Time (s)

Considering the large gap between the piezo crystals and fabric trajectories, it was concluded that power is not needed when they are mechanically decoupled. (Momen, 2016) Based on the behavior of the graph, it was also concluded that the acceleration of the fabric was much larger (Momen, 2016)

## Chapter 3: System Design

### 3.1: Design Constraints

Various different constraints were faced during the process of this study. Although the constraints vary in nature, the most apparent one was the lack of research conducted on this specific application of ultrasound waves. Although studies have been done on different other applications of it, the fact that this specific application, ironing, is a deviation from the more commercial drying method, the lack of direct information on the topic served as one of the more apparent constraints. This was mediated through combining the logic behind modern ironing and ultrasound drying, and systematically applying them together in order to reach a conclusion on the functionality of the prototype.

In the previous section of this study, an in-depth analysis was included on the means in which two forms of ironing function; steam and heat ironing. Heat ironing requires pressure, but the steam ironing does not. In turn, due to the lack of experimentation done on the matter, two different schematics were conducted on solid works to show two different variations of the ultrasound iron prototype, one resembling a heat iron that requires pressure, and the second resembling a steam iron which would function by releasing the waves on stationary fabrics. The components needed for the construction of the prototype can be seen in table 3.1.

Table 3.1 components

Part	Information	Functionality	Dimension	Cost
40KHz 60W Ultrasonic Cleaning Transducer Code: BJC-4060T- 49HN PZT-8 15 pieces	The component possesses a frequency of 40Khz with a capacity of 3800pd and a resistance factor of 10-22 Ohms.	This component will serve as the primary transformer for the conversion of electricity into ultrasound waves	55mm length, 350g per piece	Each piece costs 26.25Sar  Total: 398 SAR
1200W Ultrasonic Generator Code: BJU201242711 1 piece	The ultrasound generator is the basis of the project, functioning at a working current of 4.5A and a working voltage of 200V-240V and possessing a frequency of up to 40Khz.	Generating the ultrasound required to be induced by the transducer for the operation.	300 mm long, 360mm wide, and 160mm high.	1,050.04 Sar
60W 220V Ultrasonic Generator Circuit Code: BJU201241648	The circuit possesses a frequency of 40Khz, operating with transducers that work up to 60W.	The generator will serve as the lifeline of the other components since it will provide functionality	300g per piece	120 Sar

### 3.1.1 Constraints:

With the device being a new concept in design, there are various different constraints that are present within its design cycle, as well as with varying result types. These constraints range from.

- Environmental
- Economical
- Material Based
- Design
- Social

The analysis of each individual constraint will be elaborated on, as well as showing techniques used to mediate the issues these constraints presented.

#### 3.1.1.1. Environmental

The premise of the project is to function on both drying and ironing, the various different moisture contents could affect the overall results. The environmental issues that comes into play is the quality of the water used during the washing process that may very well affect the overall moisture content and drying time. Water types with altered biological and radiological characteristics may play a role in deviating the results of the drying and ironing efficiency.

Parameter		Gulf Standard
pH	-	6.5-8.5
Conductivity	( $\mu$ S/cm)	-
Alkalinity	(mg/L)	-
TDS	(mg/L)	1000
Hardness	(mg/L)	500
Chloride	(mg/L)	250
Sulfate	(mg/L)	500
Sodium	(mg/L)	200
Iron	( $\mu$ g/L)	300
Lead	( $\mu$ g/L)	10
Nickel	( $\mu$ g/L)	20
Chromium	( $\mu$ g/L)	50

Figure 3.1 Gulf Standard Chemical Parameters for Domestic Waters

Since the project will be conducted in Saudi Arabia in the Gulf region, the domestic water follows the Gulf Standard chemical parameters of the water supplies. The deviation in the parameters specified in figure 3.1 may potentially alter the results. Therefore, countries following different standards based on their domestic waters may not have the same results, leading to this constraint being present.

#### 3.1.1.2 Economical

Considering one of the main aims of the project is to be as cost efficient as possible, creating the prototype should follow suit. However, due to the lack of certain components being found within the country, they had to be special ordered from vendors in Beijing. Due to this, the price of certain components was pricy, and when compared to the manufacturing of conventional irons could be mistakenly considered cheaper. Considering this is a prototype to test the hypothesis, the overall price and design will be optimized upon proving the validity of the theory.

#### 3.1.1.3. Material Based

This constraint is split into two parts, material used with the creation of the prototype, and material used with testing the prototype. With the overall creation, many materials were excluded, such as metals, so cheaper material can be used because of the lack of heat being generated. However, the constraint is present with the lack of information on whether force and pressure are going to be necessary with the ironing and drying procedures. If the need for more excessive pressure and force are required, the material might not be able to support it, hence the need to test and alter the prototype based on the results. With the material used for testing, we are limited to cellulous material to test the functionality of the prototype. This is because of the lack of time to expand, as well as the lack of excessive ultrasound generation to tackle tougher material such as leather.

#### 3.1.1.4. Unoptimized Design

The design of the of the prototype draws its inspiration from the conventional heat iron designs that exist. Optimization of the design however is not possible due to the lack of understanding of the functionality of the concept. Barrowing the design from conventional heat

and steam irons are the initial steps to check whether the application of ultrasound in this instance is viable, and if so if it requires the same type of operations for it to function. The design is not optimized primarily because it aims to answer the functionality question before going into optimization.

### 3.1.1.5 Social

Comfortability breeds contempt, meaning that new concepts that challenge what people are used to are usually met with criticism. Social constraints include a lack of trust and acceptance for the new technology. However, due to the innovative revolution that has become more apparent in today's time will allow for people to be more inclined to understand and apply the concept.

### 3.1.2 Design Methodology

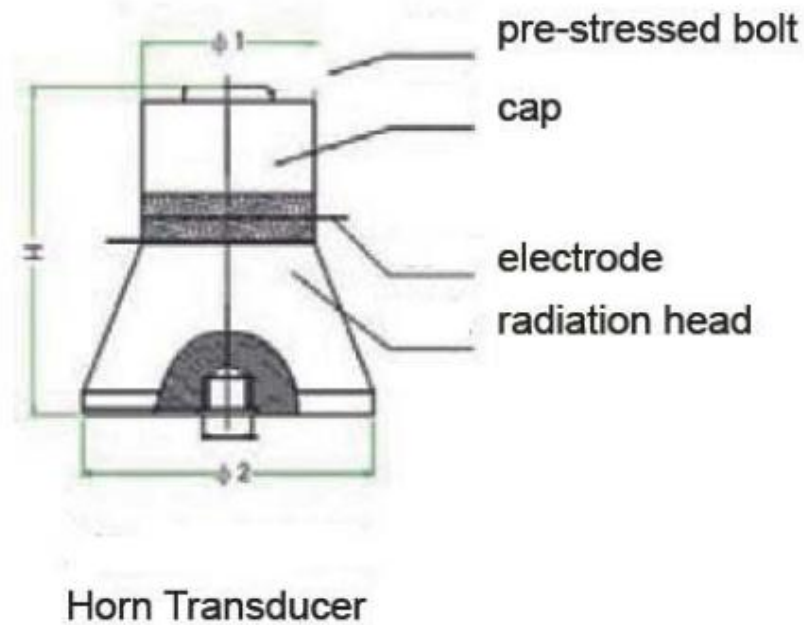
As mentioned earlier, the overall concept of this form of application is relatively new, however the predeceasing means of ironing served as a starting point for the design. With the different iterations of irons that have been manufactured and optimized, they are currently at a state in which their functionality has reached peak performance. The prototype aims to follow the optimized design of these irons, and then upon proving the functionality of the hypothesis will begin the optimization of said design. Therefore, the design was built to tackle the follow criteria.

- Functionality
- User Friendly
- Cheap
- Unique Manufacturing

The components would be included within the overall iron casing, each individual component mentioned in table 3.1 will be analyzed in the following section.

### 3.1.3. Transducers

The transducers will serve as the point of exposure in which the fabrics will be experiencing the ultrasound. The electrical energy it receives will be subsequently transformed into ultrasound energy. The horn transducer has a cylindrical geometry at its surface area, with the angle reduction reaching 90 degrees when reaching the surface.



*Figure 3.2 Horn Transducer*

Figure 3.2 shows a visual representation of the transducer with the components within it. The dimensions of the transducer are as follows.

- L= 55mm
- W= 350g

### 3.1.4: Ultrasound Generator:

The ultrasound generator is what will induce the energy to the transducers for the effect to take place. The generator used in this study was chosen with a lack of optimization in mind in order to test the theory in a real-world application before coming work on optimization. The generator will be located outside of the actual casing of the iron, connecting it to the transducer using wires.

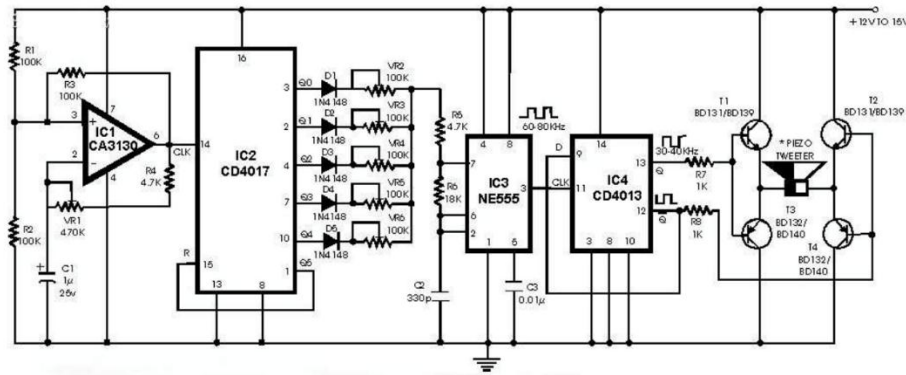


Figure 3.3 Electric Schematic of Ultrasound Generator

The manner in which the device operates can be understood from the schematic of the generator in figure 3.3. The IC amplifier through the input would then allow for the amplification of the energy and movement of it to the alignment of resistors. This will allow for different varying input of different ultrasound energies, up to 1800W, to cater to the number of transducers that are to be included within the final casing through an analog control found on the casing of the generator. The inclusion of a Piezo Tweeter within will lead to the energy supplied to be transformed into high audio frequencies; ultrasound.

#### The dimensions & Specifications

- Length = 300mm
- Width = 360mm
- Height = 160mm
- Working current: 4.5A
- Working voltage: 200V-240V/50HZ, 100V-120V./60HZ
- Frequency: from 20khz to 40khz (such as 20khz, 25khz, 28khz,30khz,33khz 40khz)

#### 3.1.5. Circuit Board

The circuit board will be the bed in which the transducers will be wired on to. The circuit board will allow for the wiring to be done in order to connect the transducers with the ultrasound

generator. The circuit board used in the prototype will be located within the actual casing of the iron because of its direct attachment with the transducers.

#### The dimensions & Specifications

<b>Frequency</b>	<b>40 KHz.28khz.25khz</b>
<b>Power</b>	60w
<b>Drive transducer</b>	One 50w transducer or one 60w transducer
<b>Power Supply</b>	Input: 200V~230V AC
<b>Weight</b>	300g/pcs

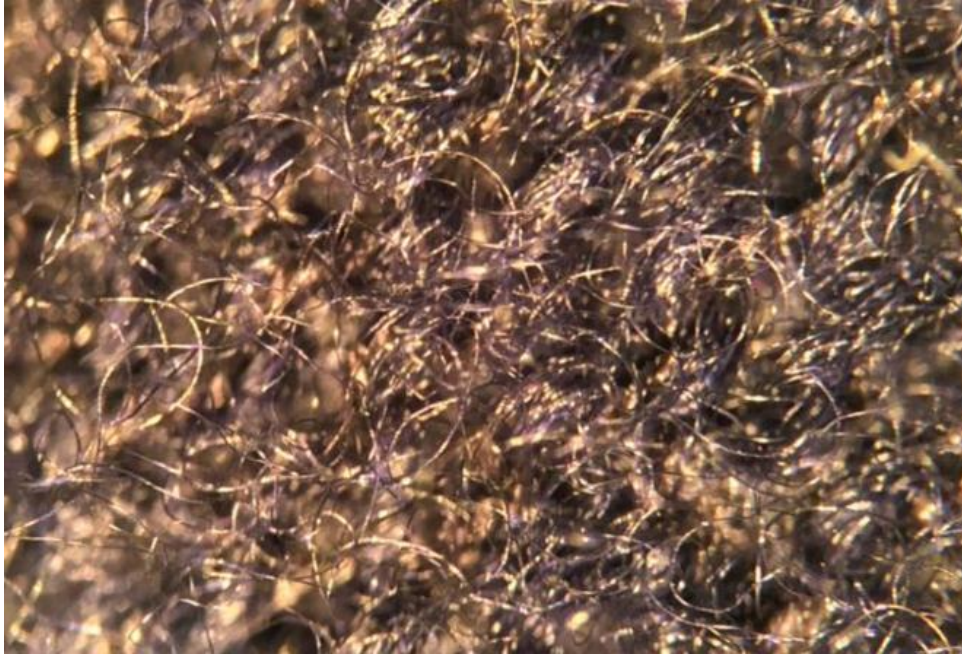
### 3.1.6 Microscopic Sampling of Materials

Different materials were chosen to test the prototype which are included in the table below. The materials were looked at under a microscope to gather visual data on their alignment, and to grasp a better understanding during the testing phase on the effect of the apparatus on them.

Type	Material
Swim shorts	100% Nylon
Sweater	65% Wool, 25% Silk, 10% Cashmere
Polo shirt	100% Cotton
T shirt	100% Cotton

Figure 3.4 Material types

The figures below show the microscopic weavings of each material respectively. Figure 3.5 shows the 100% Cotton sweater material, figure 3.6 shows the 100% cotton material, and figure 3.7 the 100% nylon swim shorts.



*Figure 3.4 20x Cotton Sweater*



*Figure 3.5 20x Wool T shirt*



*Figure 3.6 20x Nylon Swim shorts*

## 3.2 Engineering Standards

The components used within the development of the prototype are required to follow a certain engineering standard to be considered eligible for both manufacturing and commercial use.

### 3.2.1. IEEE 1452 Smart Transducer Standard

IEEE 1451 is a set of smart transducer interface standards developed by the Institute of Electrical and Electronics Engineers (IEEE) Instrumentation and Measurement Society's Sensor Technology Technical Committee describing a set of open, common, network-independent communication interfaces for connecting transducers (sensors or actuators) to microprocessors, instrumentation systems, and control/field networks. (Wobschall, 2007)

Table 3.2 Basic TEDS IEEE Standards

	<b>Bit Length</b>	<b>Allowable Range</b>
<b>Manufacturer ID</b>	14	17 – 16381
<b>Model Number</b>	15	0-32767
<b>Version Letter</b>	5	A-Z (data type Chr5)
<b>Version Number</b>	6	0-63
<b>Serial Number</b>	24	0-16777215

### 3.2.2. ISP/TC 61 Plastic Standards

The International Organization for Standardization is a standards-making body, similar to IEC or International Electrotechnical Commission. ISO works with National Committees in different countries in preparing and maintaining standards. ISO is the largest developer and publisher of international standards in the world.

### 3.3 Theory & Theoretical Calculations

Throughout the course of the project, there were calculations involved that would indicate the amount of power necessary for each transducer through calculating the peak voltages provided by the kingdom. Also, the resistance was calculated both in parallel and in series in order to see how much each transducer would be experiencing to ensure that they are able to withstand this. However, the lack of certain data meant that we would need to rely on the experimental procedure to see how much time was required to dry the fabrics that were to be exposed to the transducers.

#### **Theoretical Current Required.**

When assuming a maximum case, we will take the maximum voltage at 220 V, however this is an exaggeration due to the inability to know how much is being provided by the wall plug.

$P_{\max}$  = Ideal Maximum Power

$I_{\max}$  = Maximum Current.

$R_{\max}$  = Maximum Resistance

$V_{\max}$  = Maximum Voltage

$P_{\max} = 1800 \text{ W}, V_{\max} = 220\text{V}$

$$I_{\max} = \frac{P_{\max}}{V_{\max}} = \frac{1800}{220} = 8.1 \text{ A}$$

$$R_{\max} = \frac{V}{I} = \frac{220}{8.1} = 27.16 \Omega$$

$$\text{Current in parallel connection} = \frac{I_{\max}}{N} = \frac{8.1}{8} = 1.0125 \text{ A}$$

From gathering information from the website

Current (A)	Resistance of Transducers ( $\Omega$ )
6-6.5	10 - 20

$I_{\text{real}}$  for 8 transducers = 1.2 A from generator reading.

$V_{\text{real}} = 1.2 (0.15) = 0.18 \text{ V}$  which is the voltage provided to system from wall plug.

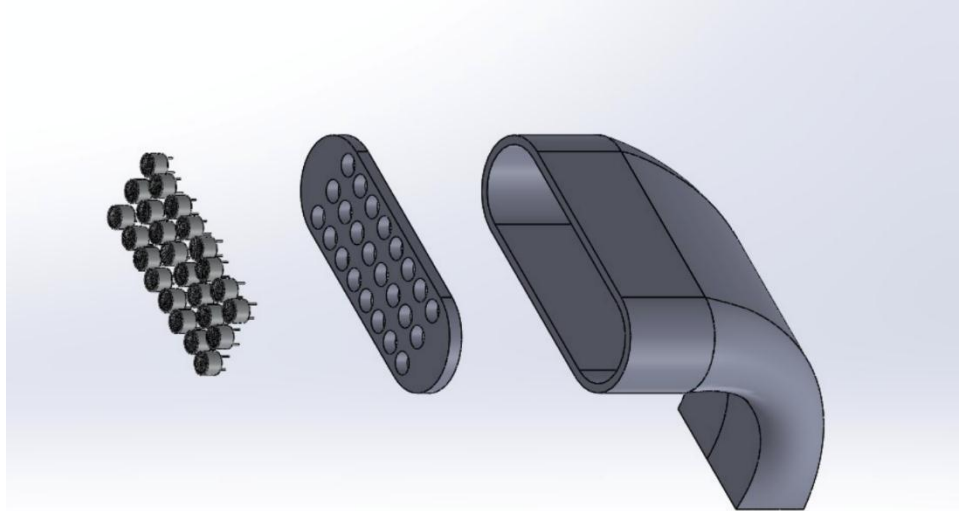
$I_{\text{parallel}}$  for 8 transducers =  $\frac{1.2}{8} = 0.15$  per transducer

### 3.4 Product Subsystems and selection of Components

As mentioned earlier, two designs for the prototype were created using SolidWorks to show the Ultrasound version of already established Iron designs.

#### 3.4.1 Steam Iron Version

This particular design aims to mimic the functionality of the steam iron which mounts the piece of clothing onto a stand to straighten it, and then applying the steamer onto it to begin the process of ironing. The design had different alterations towards the dimensions to compensate for the transducers that are to be implemented within it, allowing for the shirt to be exposed to the ultrasound.



*Figure 3.7 Curved Version of Ultrasound Iron*

As seen from the side view in figure 3.8, the design can be easily held and moved freely by the user so as to have absolute control of where the ultrasound will be exposed to. This design however does not include any pressure to be induced onto the actual piece of clothing. Figure. 3.8 shows the 2D version of the design. Since this particular part of the head was on as one piece, it can easily be 3D printed. The space within leaves enough room for the circuit board to be attached.

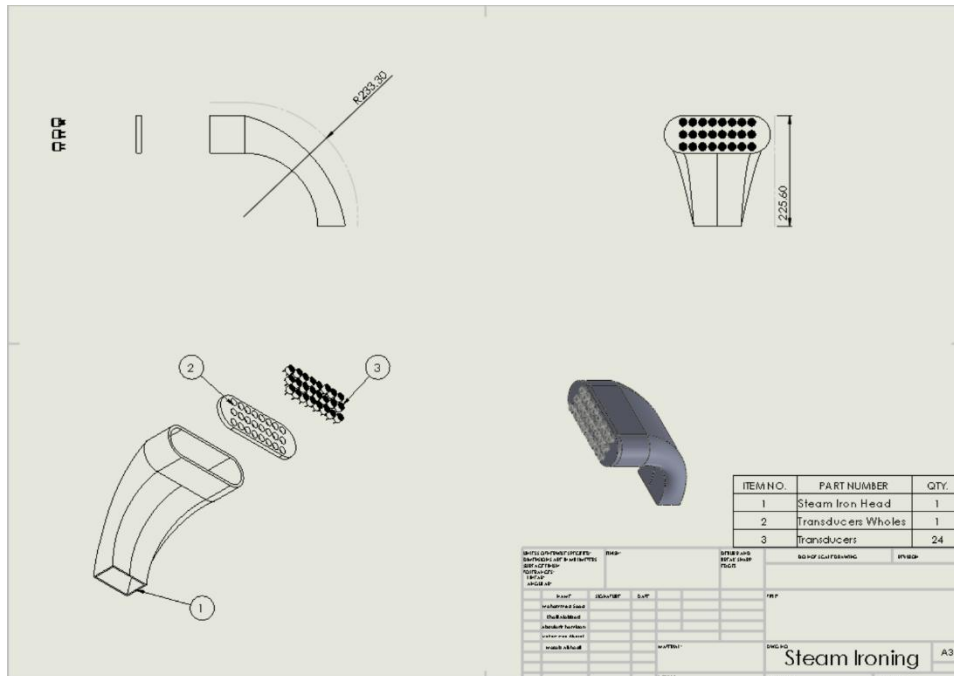
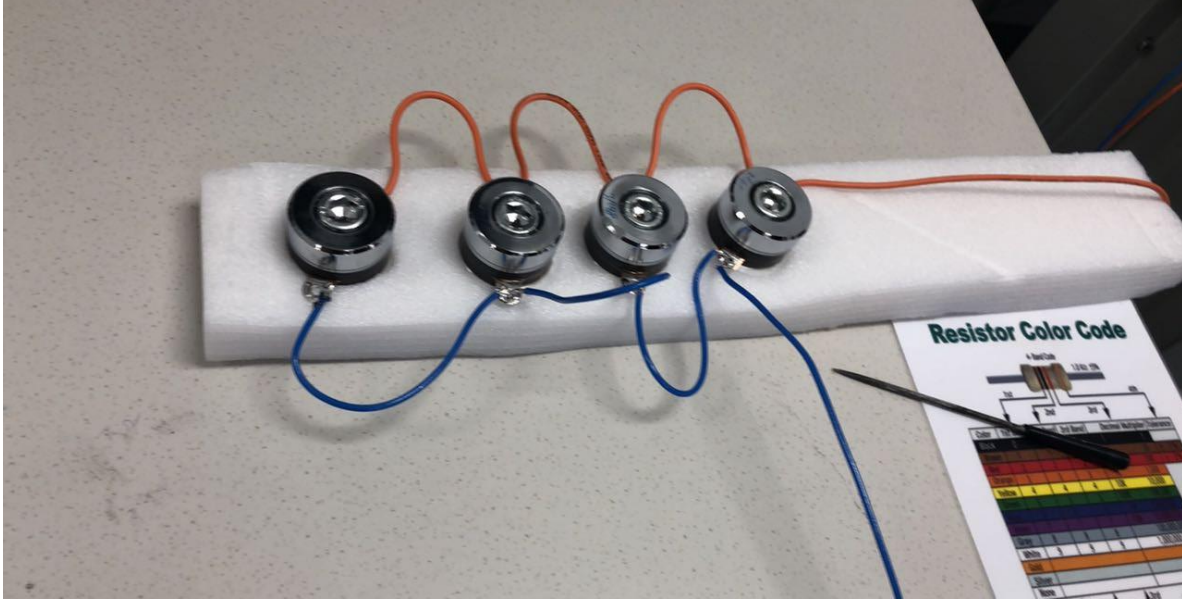


Figure 3.8 2D Drawing of design

### 3.4.2 Pressure Clothes Iron

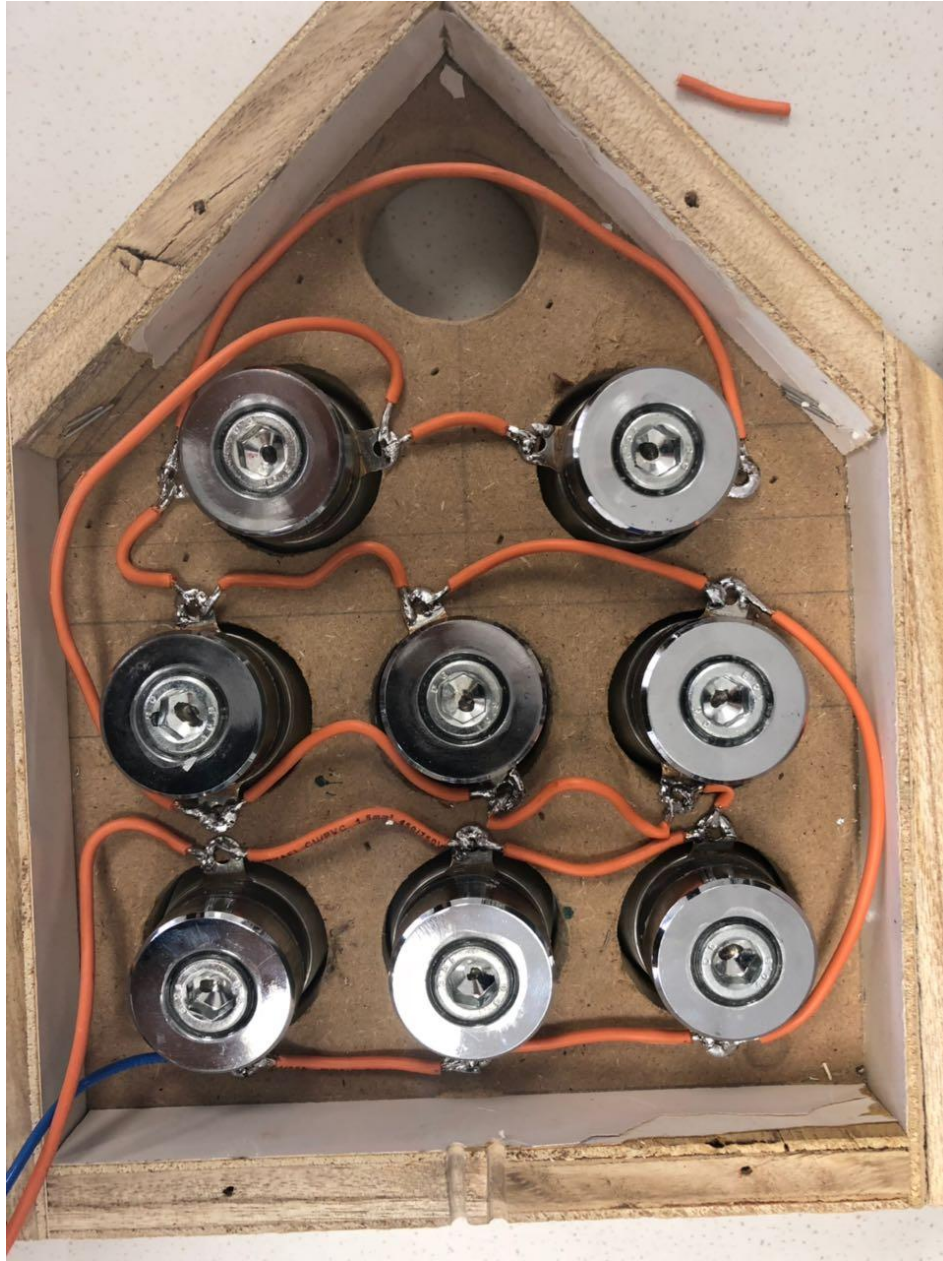
The design in figure 3.9 takes on the more conventional Iron with the inclusion of the transducers. This design aims to deduce whether or not pressure would be required within the ironing process. Since ironing works in two manors, steam and pressure, it was necessary to include a design that tackles the pressure design. The dimensions within the case are to in compose the transducers that are to be included, while having openings at the bottom of the plate in order to make room for the transducers to release the ultrasound waves onto the piece of clothing.





*Figure 3.10 Transducers on Styrofoam stand*

Upon testing their functionality, they were placed on the second prototype casing in parallel so the testing would be conducted.



*Figure 3.11 Transducers connected in parallel on wood prototype.*

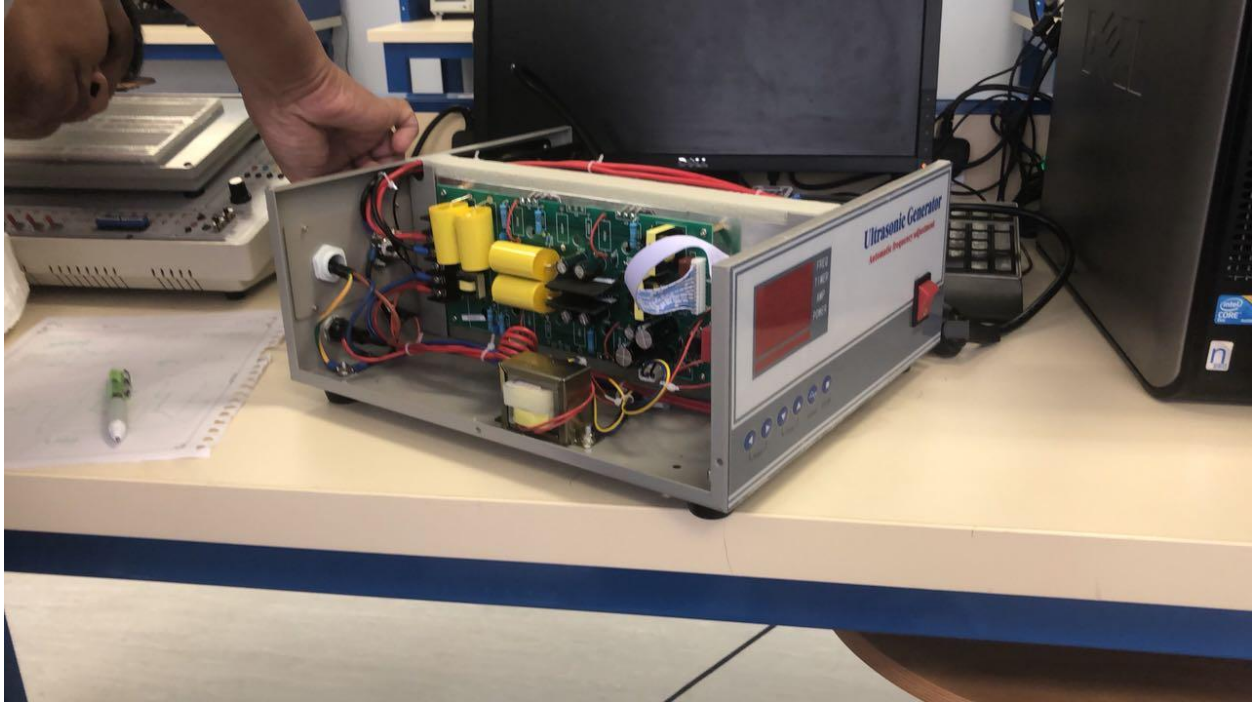
After testing, they were attached to a 3D printed casing when their functionality was confirmed.



*Figure 3.12: 3D printed casing*

### 3.5.2: Generator

The generator was opened up initially to figure out the wiring configuration in order to select the proper wires to incorporate. Through following the wire plan, two different colored wires, blue and orange, were attached. The blue wire indicated the positive terminal and the orange the negative.



*Figure 3.13 Generator Components*

### 3.5.3 Wiring & Soldering

The parts of the prototype were soldered together using a soldering iron, and the wires used were both stranded wires at  $(1 \times 1.5) \text{ mm}^2$ . These wires were used so they could withstand up to 400 V, and withstand temperature up to  $105^\circ \text{C}$  dry condition.

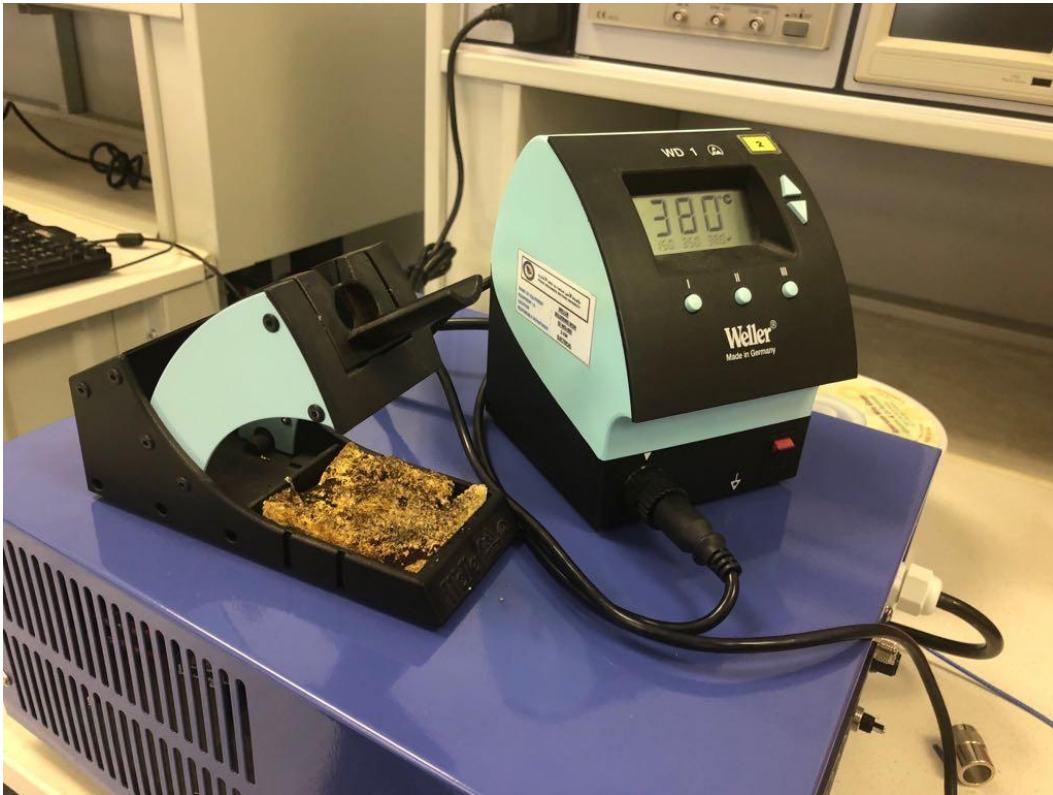
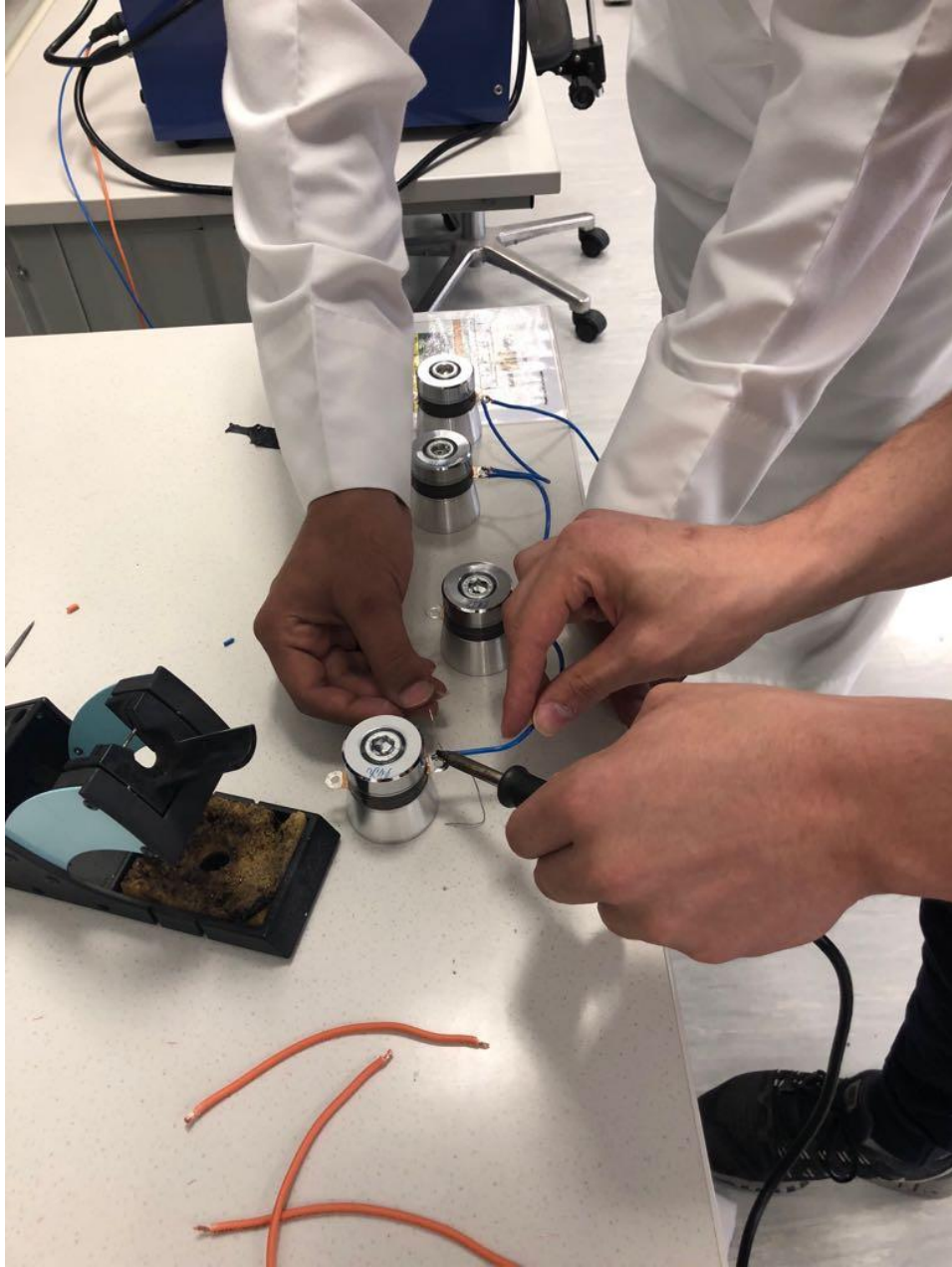


Figure 3.14 Soldering Iron



*Figure 3.15 Soldering wires onto transducers*

## Chapter 4: System Testing and Analysis

### 4.1 Experimental Setup, Sensors and data acquisition system

#### 4.1.1 Digital Scale

The digital scale's purpose was to check the weight of the fabrics before and after being submerged in water. Upon exposing the fabrics to the prototype for a set time limit, the fabrics would be remeasured each time to check for the change in weight. The digital scale would allow for more accurate results when compared to the normal ones due to the fact that it eliminates many human errors when it comes to these respects.

#### **Specifications:**

Functions Lifting capacity, max.: 250 kg/551,1 lbs. & 320 kg/705,5 lbs.

Weight range: 0-250 kg/0-551,1

Item No. 113461

lbs. Item No. 11346: 0-320 kg/0-705,5 lbs.

Display type: LCD Display resolution:

Item No. 113461: 0-1 kg/0-2,2 lbs.

Item No. 11346: up to 200 kg/440 lbs. = 0.1 kg/0,22 lbs. : up to 320 kg/705,5 lbs. = 0.2 kg/0,44 lbs.

Display interval/ accuracy: +/- 0,1%

Weight and Materials Weight: 0,7 kg/15,4 lbs.

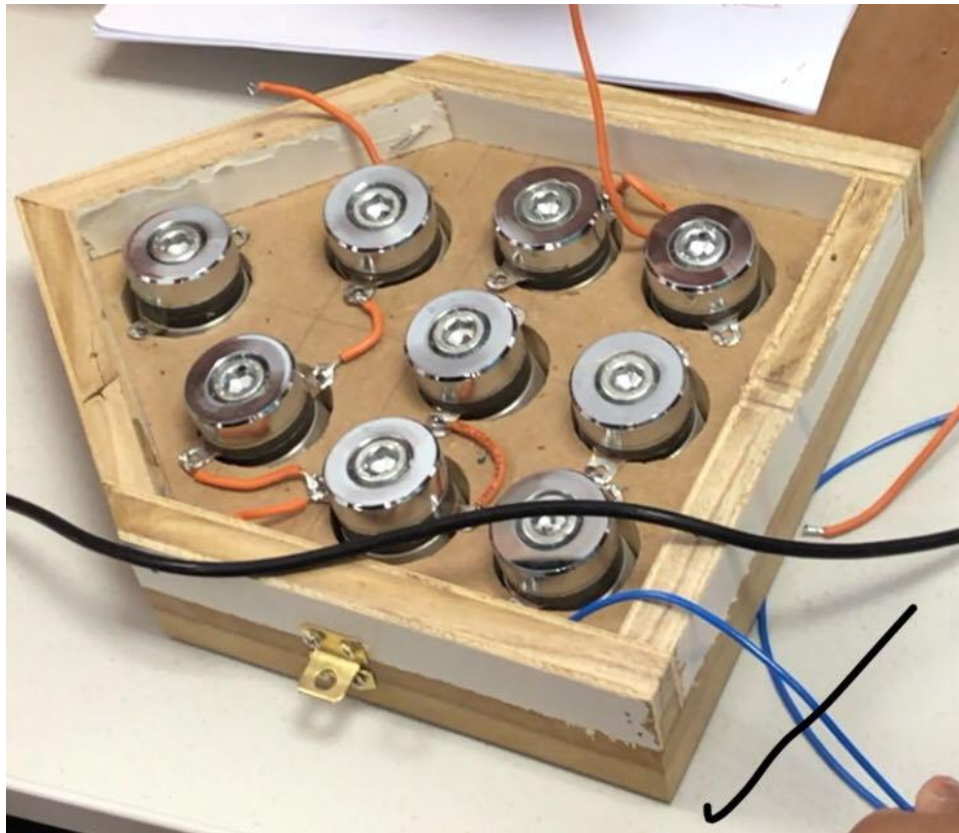
### 4.2 Results, analysis and discussion

#### 4.2.1 Goals

In this experiment, our main goal was to decrease the weight of the fabrics after they have been submerged in water, when exposing them to the ultrasound waves. Considering the fact that the fabrics weights would change upon being submerged in water, the change in weight would indicated the fabrics were getting dry.

### 4.2.2 Experiment Methodology

1. Measuring Device: In this case the digital scale, it would measure the weights of the fabrics after every attempt to dry from the prototype. This would be placed directly next to the prototype to immediately measure the change in weight the fabrics experienced.
2. Transducers: These devices are what will exert the ultrasound waves on the materials. Through these waves, the drying process will begin.
3. Power control: Located on the generator, this allows for the adjustment to the power level of the prototype. It would be used to increase or decrease the amount of power being exerted on the materials.



*Figure 4.1 Prototype of the material*

### 4.2.3 Weight of Material

Initially, the fabrics were cut into smaller pieces, and their weights were taken. This was done so we would compare the weight of the fabrics before drying with the weight of the fabrics after drying. Table 4.1 includes a list of the materials used with their weights, as well as their weight upon submerging them in water.

Table 4.1 weight of materials

Fabric Type	Weight (g)	Weight + H <sub>2</sub> O (g)
100% Cotton T shirt	33	57
80% Nylon Swim shorts	28	52
40% Silk 60% Cotton Sweater	29	53

These would serve as the basis of the experiment since through the drying process, we would be attempting to reach the initial weight of the shirt which would indicate full drying.

#### 4.2.4 System Testing

**Procedure:**

First, you set up the experiment by cutting the fabrics into the ideal sizes for the testing phase. Water is then poured onto these fabrics, note the weight of the fabric before and after putting water on them. Upon wetting the fabrics, the materials are placed under the prototype. Set the generator to maximum power. The material is then left under the prototype for 10 minute increments. After the 10 minutes are completed, weigh the fabric again, and note the weight after being placed under the prototype. Repeat these steps 4-5 times until enough readings are gathered.

#### 4.2.5 Drying Rates

Table 4.2 shows the drying rate for the 100 % cotton shirt in 80-minute time frames. The shirt did in fact start drying considering the fact that the weight was gradually decreasing as time went on. Every 10 minutes, the shirt was weighed again, and then put back under the prototype.

Table 4.2 Drying Rate of 100% Cotton Shirt

100% cotton	
Time (m)	Weight (g)
10	58
20	56
30	54
40	52
50	52
60	50
70	49
80	46

The graph for the drying rate of the 100% cotton shirt can be seen in figure 4.1. We can see from the gradual decline of the curve that the shirt is in fact drying through the decrease in weight. The increments in which its reducing is by 2.

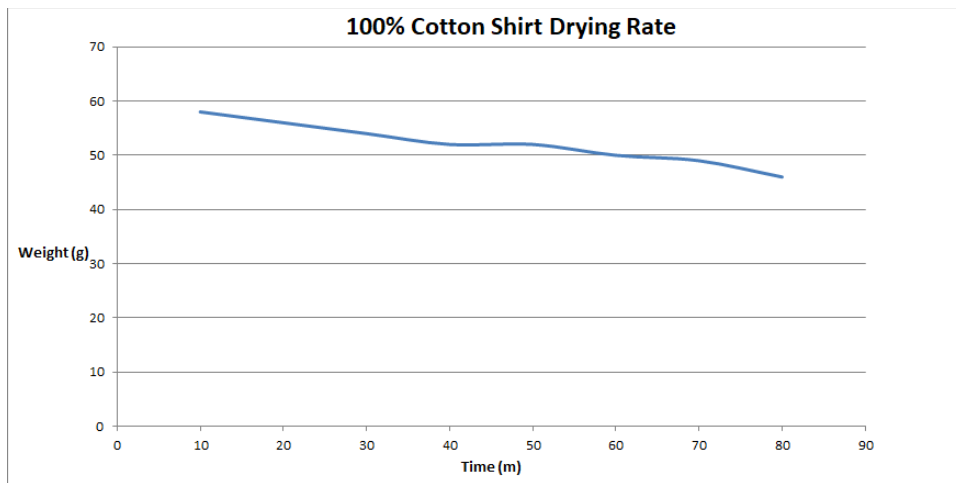


Figure 4.2 Graph showing drying rate of the 100% Cotton Shirt

Next, we take a look at table 4.3 which shows the drying rate of the 100% Nylon Swim shorts that were used in the experiment. The increments varied with this type of material when compared to the cotton shirt that was used in the previous part of the experiment.

Table 4.3 100% Nylon Drying Rate

100% Nylon	
Time (m)	Weight (g)
10	52
20	49
30	45
40	43
50	41
60	37
70	35
80	32

Corresponding with the data, a graph was generated to better illustrate the findings which can be seen in figure 4.3

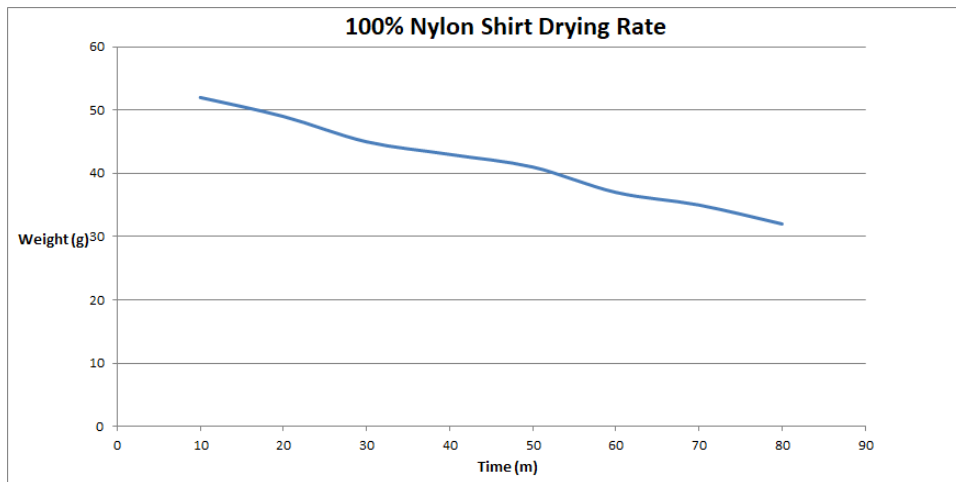


Figure 4.3 Graph of Drying Rate of 100% Nylon Swim shorts

The last material that was tested was the 60% silk and 40% cotton sweater. The data can be seen in table 4.4 showing the drying rate of this material.

Table 4.4 60% silk and 40% Cotton Sweater.

60% Silk, 40% Cotton	
Time (m)	Weight (g)
10	53
20	51
30	49
40	46
50	44
60	41
70	39
80	37

The graph corresponding with the data can be seen in figure 4.4

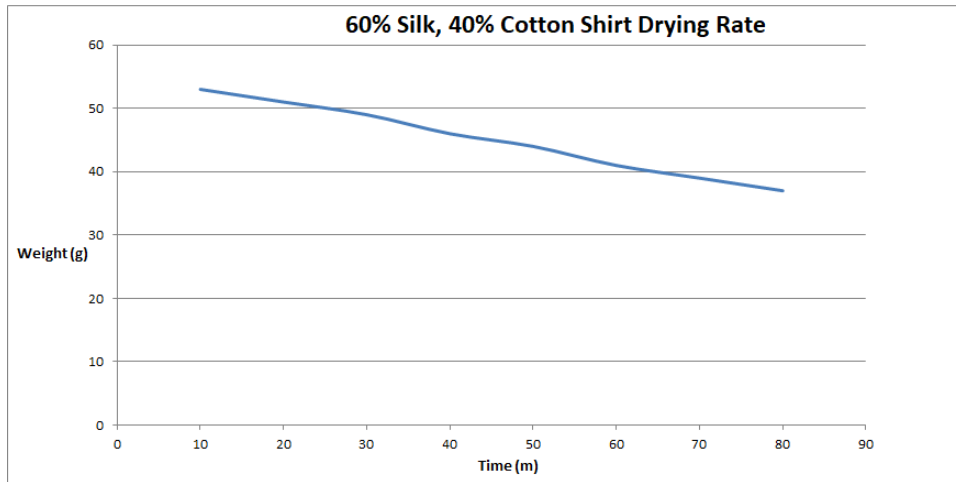


Figure 4.4 Graph for 60% and 40% Cotton shirt Drying rate

Figure 4.5 shows the curves simultaneously included in one graph

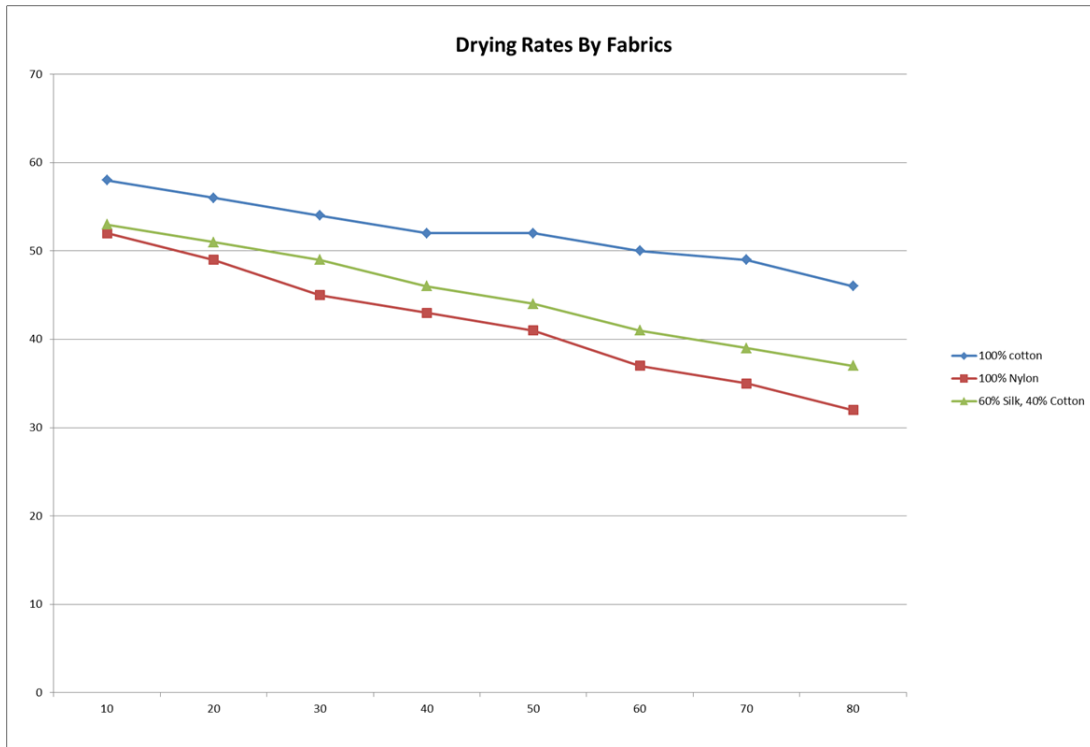


Figure 4.5 shows the curves simultaneously included in one graph

#### 4.2.6 Analysis

The results showed interesting results, primarily through confirming the capabilities of ultrasound when it comes to drying. The effect of ultrasound on drying said materials differed from one to another but this was primarily due to the type of material. When taking a look at the cotton shirt, the drying rate was occurring in increments of 2g every 10 minutes. When compared to the other materials however we notice that it's the slowest. The nylon material from the swim short's weight was decreasing at a faster rate. The it was increasing in increments of 3-4 every 10 minutes. The explanation for this is that nylon dries much faster than cotton, hence why it's used in swim shorts. The exposure to ultrasound with drying doesn't change this, it still dries at a faster rate than cotton. Finally, when taking a look at the 60% silk and 40% cotton sweater, dries faster than the cotton but slower than the nylon. The weight was decreasing at a rate or 2-3g every 10 minute. This is due to the combination of materials within it considering the fact that the majority of the material in the sweater was the silk. Silk dries at a faster rate than cotton, but the inclusion of the cotton hindered the drying rate slightly. It still dried faster however than the 100% cotton material.

## Chapter 5: Project Management

### 5.1 Project Plan

Completing the project proved to be challenging considering the fact that we had to compress the amount of time to complete the project in a 2-month period. As such, tasks were delegated accordingly based on each group members individual strengths. Each group member contributed equally to the completion of their respective tasks, and if anyone experienced any difficulties completing their tasks, the group members helped them get over the difficulties they experienced.

Table 5.1 Gant Chart

	Start Date	Days to complete
<b>Framework of Project</b>		
5 page research on topic	2/Oct/18	1
Draft of Solid Works Drawings	2/Sep/18	1
Check availability of components.	2/Nov/18	3
Checking facilities (3D Printing/Warehouses	13/Feb/18	3
<b>Assembling Parts/Cost Estimation Plan</b>		
Ordering Transducers	16/Feb/18	14
Altering Solid Works Schematics	14/Feb/18	2
Creating Cost Estimation Plan	16/Feb/18	1
Finding Proper Equations	17/Feb/18	2
<b>First Prototype Framework minus Transducers</b>		
3D Printing From Fablab	18/Feb/18	3
Starting Work on Literature Review	19/Feb/18	2
Finding Power Supply	20/Feb/18	3
Confirming Power output requirements	21/Feb/18	2
<b>Constructing first functional Prototype</b>		
Take components to electrician for assembly	3/Feb/18	5
Starting Work on Introduction	3/Feb/18	2
Testing functionality of first prototype	3/Aug/18	1
Fixing any issues that may arise from first functional prototype	3/Sep/18	2

<b>Constructing first functional Prototype</b>		
Take components to electrician for assembly	3/Feb/18	5
Starting Work on Introduction	3/Feb/18	2
Testing functionality of first prototype	3/Aug/18	1
Fixing any issues that may arise from first functional prototype	3/Sep/18	2
<b>Testing material on succesful prototype</b>		
Purchasing Measuring Equipment	1/Mar/18	2
Starting Work on Introduction	3/Feb/18	2
Testing functionality of first prototype	3/Aug/18	1
Fixing any issues that may arise from first functional prototype	3/Sep/18	2
<b>Testing material on succesful prototype</b>		
Purchasing Measuring Equipment	1/Mar/18	2
Starting Work on Introduction	3/Feb/18	2
Gathering different fabrics to test on prototype	3/Apr/18	1
<b>Gathering Data from prototype</b>		
Testing Materials	3/Jul/18	7
Discussing Data and finding correlations	14/Mar/18	3
Testing Data against commercial iron	15/Mar/18	4
Begin work on chapter 3	15/Mar/18	2
<b>Working on Remaining Chapters</b>		
Work on chapter 4	16/Mar/18	2
Chapter 5	18/Mar/18	2
Chapter 6	20/Mar/18	2
Chapter 7	22/Mar/18	2
<b>Begin work on presentation</b>		
Assembling Chapters in Powerpoint	24/Mar/18	1
Giving each group specefic slides to study	25/Mar/18	1
Completing Presentation	26/Mar/18	2
Practice Presentation	28/Mar/18	3

## 5.2 Contribution of Team

Table 5.2 Group Contribution Table

<b>Task</b>	<b>Assigned</b>	<b>Contribution</b>
<b>Introduction</b>	Mohammad Yousif	<b>50%</b>
		<b>50%</b>
<b>Literature Review</b>	Khalil Alabbasi	<b>100%</b>
<b>Calculations</b>	Khalil Alabbasi	<b>40%</b>
	Mohammad Al-Otaibi	<b>60%</b>
<b>SolidWorks Model</b>	Mohammad Al-Otaibi	<b>100%</b>
<b>Acquiring Parts</b>	Abdulaziz Al-Homaidan	<b>100%</b>
<b>Assembling Prototype</b>	Abdulaziz Al-Homaidan	<b>100%</b>
<b>Testing Prototype</b>	All	<b>100%</b>
<b>Chapter 3</b>	Khalil Al-Abbasi	<b>50%</b>
	Abdulaziz Al-Homaidan	<b>50%</b>
<b>Chapter 4</b>	Mohammad Yousif	<b>50%</b>
	Mosab Al-Khaldi	<b>50%</b>
<b>Chapter 5</b>	Mohammad Yousif	<b>50%</b>
	Mosab Al-Khaldi	<b>50%</b>
<b>Chapter 6</b>	Mosab Al-Khaldi	<b>100%</b>
<b>Chapter 7</b>	All	<b>100%</b>
<b>Mid Presentation</b>	Mosab Al-Khaldi	<b>50%</b>
	Mohammad Al-Otaibi	<b>50%</b>
<b>Editing</b>	All	<b>100%</b>

## 5.3 Project Execution Monitoring

In order to facilitate the many tasks we needed to complete in order to complete the project on time, we constructed a schedule on the important tasks. These included meeting with group members and important dates correlating with the project.

Table 5.3 Table of activities

<b>Time</b>	<b>Activities</b>
<b>Two times a week</b>	<b>Assessment class</b>
<b>Two times a week</b>	<b>Meeting with group members</b>
<b>Weekly</b>	<b>Meeting with advisors</b>
<b>Sunday, April 15</b>	<b>Assembling Prototype</b>
<b>Monday, April 2nd</b>	<b>Mid Presentation Video Recording</b>
<b>Monday, April 23</b>	<b>Testing Prototype</b>
<b>Thursday, May 3rd</b>	<b>Final presentation</b>

## 5.4 Challenges and decision making

As with any project, many challenges were faced but were thankfully overcome thanks to the contribution of the group members. These included.

1. Acquiring parts for the prototype.
2. Calculations
3. Assembly

### 5.4.1 Material and Equipment Sourcing

The parts to assemble our prototype proved to be difficult to come across. This resulted in us having to contact various different vendors in different countries in order to source the parts. Many of the parts were difficult to come across in the local market, which is why we decided to purchase them internationally.

#### International Vendors

One of the most important parts of our prototype were the transducers. Finding these transducers proved to be a difficult task primarily due to the lack of vendors in the Middle East that provide them. We checked in Al-Khobar, Bahrain and Dubai and none of the shops offered transducers. We resorted to purchasing it from website based in Beijing, China. In order to accelerate the shipping process, we decided to order the parts to one of the group members family company. This is because when dealing with a company, the vendor would prioritize the order.

## Generator Power

The generator we needed for the project required a certain amount of power, 1800KW, had to be custom made. For an application such as ours, we required a lot of power and corresponding transducers to match these specifications. Finding such a generator that incorporates such power was difficult to come across in both in the Middle East as well as overseas. Through interactions with the vendor, we managed to come to a deal that they design a custom generator the facilitate the power output we needed.

- **Transducers**

The transducers proved to be a challenging barrier to overcome considering the fact that no vendors in Saudi provided them, as well as the specific type we required. The transducers are the backbone of the prototype, and as such meant that they had to be come in the perfect form; both with dimensions and power. Through completing the comparative study, we found the idea transducers that were similar to an experiment done by General Electric. We special ordered these transducers from the online vendor and gave them the specific of what we required.

### 5.4.2 Design Problems

Some of the issues we faced when it came to the design were both not having an optimized design for any type of iron other than heat, and not having the proper dimensions for the transducers so that we would incorporate it onto our 3D design. These problems required critical thinking in order to solve them, because there were no direct ways to overcome them. We managed to create similar transducers from the scarce information we had, and well as borrowing a design from an already optimized heat iron.

### 5.4.3 Report Writing and Documents

Writing the report was divided between the group members to incorporate each of their individual strengths. However, to make up for their shortcomings, we made sure one group member read another group member's chapter in order to ensure the writing and editing were up to standards. This editing technique helped ensure the quality of the writing was ideal, and that every group member would contribute equally.

## 5.5 Project Bill of Materials and Budget

Table 5.4 Bill of Materials

Component	Price	Total
<b>part: 40KHz 60W Ultrasonic Cleaning Transducer</b>	\$7	\$112
<b>12800W Ultrasonic Generator</b>	\$280	\$280
<b>60W 220V ultrasonic Generator Circuit</b>	\$32	\$32

Total: \$424 => 1,590.11 SR

## Chapter 6: Project Analysis

### 6.1 Lifelong Learning

With every difficulty faced, a lesson learned. This was the case with our project due to the abundance of issues that surfaced throughout our time completing it. However, these issues were not without their lessons. The issues faced such as heavy time constraints, project design issues, disagreements and calculation issues, the group managed to overcome these circumstances and learned valuable lessons in the process. Although some of the skills picked up were technical, there were a lot of skills that do not exactly correlate with engineering specifically, but with education and life as a whole. Some of these skills include critical thinking, time management, the ability to work with a team, the ability to delegate the proper task and software related skills.

#### 6.1.1 Critical thinking

One of the more unique skill so be picked up throughout the course of the project was the ability to apply critical thinking to almost all aspects of the project. This came to light when we realized there was no blueprint to success when it came to creating and applying a new concept. Everything had to be done from scratch, using only certain tools as resources. This required the team to develop and apply a “think outside the box” mentality. When faced with a problem, we decided to consider other variables that we wouldn’t have otherwise considered, and it brought into perspective some interesting results. Naturally, this skill was implemented throughout the entire course of the project, and as such became a valuable lesson and experience the team needed to experience.

#### 6.1.2 Time Management

Upon starting the project, we had a very limited time to complete the various different tasks assigned to us, and many for these tasks took priority over some of our daily routines. This required a high level of time management in order to incorporate every task within our limited time frame. The group was able to delegate the tasks properly, and to work effectively enough to ensure that these tasks are completed on time. This is a valuable skill that many people struggle with even in the workplace, however we were fortunate enough to experience it first hand and to apply in such an effective manner.

### 6.1.3 Learning to use tools

The project required us to assemble and put together the different parts in order to create the prototype. Although many of us were not familiar with many of the tools used, we managed to learn how to use each one in an effective manner. Some of these tools included the soldering iron, 3D printers as well as software tools such as SolidWorks. Although we were familiar with these tools, we've never actually used them in practice. Being able to apply this knowledge and use them in the manner that we did proved to be beneficial to our overall knowledge.

## 6.2 Impact of Engineering solutions

Engineers serve a large purpose in this world considering the fact that their work impacts the quality of life of any society. Our project had a large impact on the economy, safety and innovation.

### 6.2.1 Economic

Previously stated in the report was the amount of consumption dryers and irons have on the economy, costing around \$90 million per year. Through implementing this new means of drying it would cut a lot of costs that come with drying rather than paying more for the same results. This is a huge impact because people are now more conscious about their spending, and many would disregard certain things because of how much it would cost them. Through implementing this project, we managed to tackle this problem, and work on improving the economy by allowing people to save on the process rather than spend more. This is also applicable to manufacturers considering the fact that to develop this technology it would cost them much less. This in turn means they can manufacture more for cheaper, and have a large impact on the sales.

### 6.2.2 Safety

Any piece of equipment that generates heat is a safety hazard in some respect. With normal irons and dryers, the amount of heat generated is excessive, and it could lead to many people getting injured in the process if not used properly. Our project aimed to tackle this issue and provide a safer alternative to using these heat generated equipment by replacing them with ones that rely on ultrasound. Ultrasound does not possess any immediate threat to people's wellbeing, and using them in these applications means that people would not be exposing themselves to devices that generate excessive heat.

### 6.2.3 Innovation

Saudi Arabia has not begun creating incentives to innovate in the various different scientific fields, which created an opportunity for us to develop something that aligns with the country's future goals. Through bringing in a new perspective on an application everyone is familiar with, drying, we managed to innovate the process. By applying these new concepts, as well as using the new means of development and manufacturing to serve our purpose, we have aligned our vision with that of the country managed to innovate in that respect. Being able to innovate in this respect paves the way for others to apply the same manner of thinking in other fields, and would lead to the creation of new technologies and means of accomplishing things through innovative means.

### 6.3 Contemporary Issues Addressed

Taking a look at some of the contemporary issues facing the GCC and Saudi Arabia as a whole is the lack of research conducted on the subject of Ultrasound. Although ultrasound is an application that is regularly used worldwide, there isn't much research done when it comes to safety regarding exposure to ultrasound waves. This lack of research can prove to be problematic considering the fact that many people might be discouraged from using the device out of fear for their health. Through applying more research, the country can break the stigma behind the use of these devices, and either support or refute these claims in order for people to have clarity of mind when using the devices.

## Chapter 7 Conclusions and Future Recommendations

### 7.1 Conclusion

Gone are the times of mills and steel. Through the development of human knowledge and technology, the world has seen the light of innovation like never before in the past. For every application in today's time is a more optimal means to accomplish the task. This innovation has taken a lifetime to develop. Throughout the course of history, many cultures portrayed science is the work of evil, but with enlightenment that has all changed. The world has developed beyond measure, which means that the time to innovate and develop is now. The opportunities provided for the people, both through the ease of acquiring knowledge and the encouragement from governments. Every aspect of the world can be improved, and with the wealth of knowledge available, has become much more accessible for all. However, our time is also costlier, meaning that incentive is created to tackle this issue to help the world. Through this ideology, the idea of the project was developed by combining it with the new criteria set by the world to innovate.

The many crises and issues the world has experienced fuel our desire to accomplish this project because we felt responsible to help the world develop. When seeing issues around the world that include global warming and financial crises, gave us incentive to tackle them one by one. The group members were all motivated by these facts, and we felt that applying our creative minds and engineering skills could serve a larger purpose in the grand scheme of things. With the crisis that hit Saudi Arabia and the development of the new vision 2030, paved the way for us to begin development of a new concept that could align with the same goals as the country. One of the predominant goals of the vision 2030 is to reduce energy consumption. However, reducing energy consumption would mean that people would need to reduce the use of certain equipment they have come to depend on. Rather than encouraging them to stop, we decided to tackle this issue by developing a new piece of technology that would allow them to continuously use their equipment, while also saving energy.

Translating an economical issue into an engineering issue however proved to be a difficult task. Because engineering relies on creation through applying the laws of Physics, taking into consideration saving proved to be a barrier that required a certain way of thinking to overcome. The normal applications that people were used to could not be optimized in a manner that would serve their excessive use while also saving money. This required the introduction of a new application that was able to perform the same task; hence the introduction of ultrasound.

However, the lack of research on the matter required the team to assemble the right information in order to tackle the application.

From a design standpoint, there were no optimized designs for any irons except the heat iron. This led to the team studying why heat irons were done in this shape, and why they were designed in that manner. Through understanding the combination of heat and pressure to both dry and remove creases, the team decided to incorporate the same design in order to test whether or not the pressure would be required for this application. Through confirming the need for pressure, the team went along with this design. Due to the project aiming to prove the concept that ultrasound does in fact dry clothes, the next step would have been to optimize the design to in compensate the new form of energy; however, the time constraints led to this objective not being achieved.

Upon confirming the need for pressure so the application can work, the next issue that came was which type of material would we choose in order to ensure the prototype would be able to withstand the weight. Taking a look at the normal iron's materials, we noticed that there were many parts that were there to serve the purpose of maintaining the heat that was being generated. This meant that we would be able to disregard these parts, and replace the overall casing with that of more brittle material. The need for strong materials such as steel became unnecessary, and as such was replaced with plastic. However, when excessive force is implemented, the device may break. Taking a look at the tensile properties of plastics for ABS plastics, we have deduced that the ultimate tensile strength is at 40 Mpa which is a force that would not be applied with such an application.

Moreover, we decided to take a look at that power requirements that would be required in order for the prototype to work. This created a barrier for the project considering the fact that our only source of reference was the amount of heat necessary to dry clothes. Considering the fact that there was no way to convert the temperature required into an acoustic equivalence, we had to rely on trial and error. The parts used were made to facilitate the standard amount of voltage provided by the Kingdom. The number of transducers used was excessive in order to see whether or not the theory was applicable. This resulted in a large prototype that would incorporate all the transducers, and for it to be optimized at a later date.

Through our experimentation, we concluded that using the transducers on burst mode would be much more reliable than using them continuously. This is because the time between

bursts allowed the ultrasound to penetrate through the chemical bonds of the fabrics at a higher efficiency. This was based on another study conducted that confirmed this theory, and we applied the same theory to our transducers in order to see if the results matched.

Considering the fact that we were attempting to confirm the theory, it was important to apply an assembly model that was simply rather than one that was overcomplicated. This is primarily because with assembly there were a lot of times in which we had to remove and add transducers, as well as to change their alignment from parallel to series. The wiring also had to be adjusted multiple times which resulted in us created a dummy case initially for the testing phase that would allow for ease opening and reassembly.

## 7.2 Future Recommendations

Since the project was a proof of concept, there is a wide variety of improvements that can be made to the project in order to optimize it. Through confirming the theory, the next step would be to optimize the project in a manner that doesn't require excessive materials, and precise dimensions. One such example is adjusting the geometry of the prototype that facilitates the ultrasound in a more accurate manner. Because our prototype borrowed the optimized design of the heat iron, applying a design that facilitates ultrasound would be an exceptional improvement to the project.

Another improvement that can be made is the inclusion of a sensor on the prototype that can detect the kind of fabric that it is drying. This would allow for the prototype to adjust the power level of the transducers according to the material. This would lead to a more accessible application that would not require a lot of interaction from the user. Since most devices are not being converted to smart forms of the, this would be an interesting addition to the prototype that would further enhance its capabilities.

Furthermore, different iterations of the device can be made based on different applications of the ultrasound. For example, it is possible to figure out a way to incorporate the ultrasound drying without direct contact from the transducers and the fabric. This would resemble the steam iron, and would allow for a different type of testing to occur to test the optimization of the design

In conclusion, the beauty of engineering can be seen through the different ways to accomplish different tasks. The ultrasound drying method is one such example of this due to incorporating a completely new means of drying into an application that was solemnly built

around heat generation. With the direction the Kingdom is currently heading in with the new-found appreciation for technology, innovation and economic awareness, this product could help serve all these purposes and show that with any application, there is always a better more effective way to accomplish the task. Targeting the consumer market rather than focusing on the big companies also helps spread the awareness on the matter to them, and to help them adapt to the new way of life the Kingdom is providing.

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