Human Powered Dental Mixer (Team I)

Department of Mechanical Engineering

Final Report

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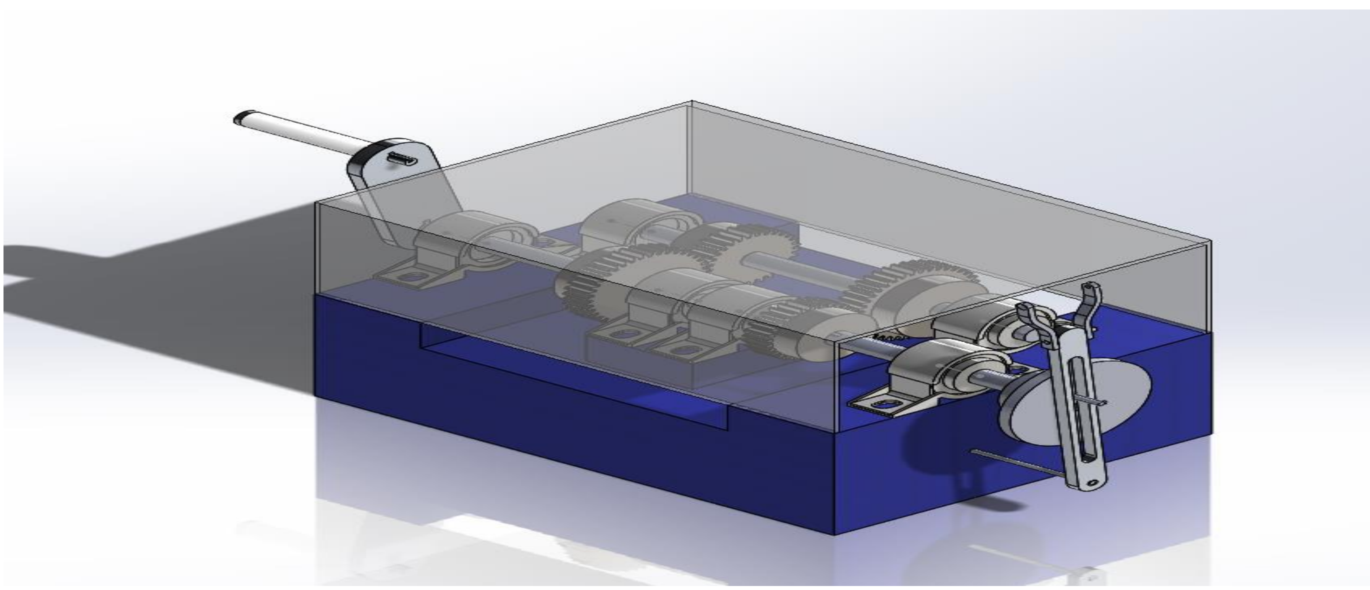
DISCLAIMER

Students prepared this report as part of a university course requirement. While considerable effort has been put into the project, it is not the work of licensed engineers and has not undergone the extensive verification that is common in the profession. The information, data, conclusions, and content of this report should not be relied on or utilized without thorough, independent testing and verification. University faculty members may have been associated with this project as advisors, sponsors, or course instructors, but as such they are not responsible for the accuracy of results or conclusions.

Executive summary

This project is about designing a hand driven dental amalgamator. A dental amalgamator is a device that helps in mixing of dental formulations that are normally found in capsules. Dental hygiene students use this capsule for teeth fillings. There are existing dental amalgamators that can mix the capsule in ten seconds. We seek to make hand powered amalgamator that will be able to make the same mixing in a ten second time interval or more time. This project was motivated by the need of students who work abroad and are unable to use the existing amalgamator. Students are unable to use the existing amalgamator, which operate off of electricity because of the lack of electricity in the area. However, we did not limit our design to the aspect of the power. We checked for other necessities that the customers could have that would improve the device. By the end of the project, we were able to create a hand powered dental amalgamator that has enough power to complete the mixing. The group has tested the device as well as student volunteers to ensure it is operable by a variety of people. The group achieved the goal of getting homogenous liquid that can be used for fillings. Additionally, we achieved several engineering requirements that needed to be met. In the final analysis we came up with a final model that is called a gear amalgamator. This design meets all criterions for the performance as had been required. This was verified by the testing procedure instituted at the end of the project. The project was completed in time and therefore this project can be regarded as having been a success.



Acknowledgment

Our capstone team human powered mixer would like to extend the deepest gratitude to all who contributed toward our success on this project. The group cannot express enough appreciation toward Dr. Sarah Oman for her expert advice in this field. The group would also like to extend their appreciation for the assistance from Dr. David Trevas with his extensive knowledge regarding our gearbox. Lastly we would like to thank K&M Machine Tools for sponsoring us and helping the group in manufacturing some parts.

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1 BACKGROUND

1.1 Introduction

An amalgamator in medical terms can be defined as an apparatus used for trituration, which means shaking a dental capsule to get homogenous liquid that is used for teeth fillings. A dental amalgamator forms the basis for this project. This project is all about the schematics that go with the amalgamator and the efforts that the team has applied to make changes to this device. The changes the team has implemented are informed by a need to have a user-friendlier amalgamator especially for the student users who are finding it hard to cope with the existing dental amalgamator. The team set out with the chief objective of making a hand driven Dental amalgamator. This also doubled up as the client chief concern. The other pressing objective was to make a device that was portable to be moved from one place to another. There are other subsequent minor objectives that were informed by the customer's needs. However, the three objectives listed above were the threshold that the team needed to be able to meet. The rest of them were subject to debate based on the analysis tools. The sponsor of this project was the NAU's Dental Hygiene (DH) Department. The department and the Dental hygiene volunteer students are getting seminars annually in different countries to practice dental work. They are the biggest beneficiary of the project as the device is supposed to be used by their students before it goes to the rest of the world.

1.2 Project Description

The following is the project description from our sponsor "A dental amalgamator is used to mix the components of dental capsules before certain dental procedures and they are usually powered by electricity. When dental hygiene students travel internationally, often times there is no electricity and/or the powered amalgamator are not compatible with international outlets. Collaboration between NAU's Dental Hygiene (DH) Department and NAU Mechanical Engineering Dept. (CHHS and CEFNS) have created this Spring 2017 capstone project for 3-5 mechanical engineering students to create a human powered mixer that can shake a capsule for 10 seconds.''

Two conditions go with the above description. The first condition was the model needed to be human powered. This part of the description is informed by the oversee environment where there is no electricity to carry out the dental mixing. The second condition was on the time factor. A research reveals that existing mixers use ten seconds to mix the dental formulation [1]. This purpose therefore informs the desire to keep the time frame to make the mixing to be a constant for the students. This is for professional efficiency, as the students will come back to the country after their oversea assignment.

1.3 Original System

What is being undertaken in this project is not something entirely new. This is because there is already an existing dental system that is used to make the dental mixing of dental formulations. Our process can therefore be regarded as redesign process of an existing system. The existing system is fondly regarded as the dental amalgamator. There are various types of dental amalgamator that exist. These bleeds are all different to some extent but they all have quite a range of similarities [2]. First of all, they all run on electricity. This is the most basic unifying factor of the amalgamator. This is also the most basic factor that the redesigned model will alter in the amalgamator.

1.3.1 Original System Structure

The original system can be divided into parts, but there are some structures that are generally the same for these devices. One of the common features is the size. Although the devices range in size, most of the devices have the dimension of 7 inches by 10 inches by 9 inches. The other common feature is that most of them have a metallic outer casing [3]. However, there are some that have some plastic outer part. Given that the mixers run on electricity, they all have a chord that is attached to them and runs to a source of power where they can be plugged in. There are two compartments to the existing model. The first compartment is opaque. This is the compartment that holds the motor and all the other parts that are part of the motor system that drives the mixer. The second compartment is visible as it is usually on a glass casing. This compartment contains the two hooks that anchor the dental capsule firmly as a swirling motion.

1.3.2 Original System Operation

The operation process begins with the plug in of the power cable into a socket. The current flows into the mixer to the lower compartment where the motor setup is located. Before switching on the device, the upper compartment is opened and the dental capsule is placed between the two hooks. When the capsule has been hooked, the compartment is then closed. The main reason why this compartment is closed is to avoid any possible accident that may happen if the capsule was to dislodge from the hooks that holds it. After the compartment is closed, the timer that is on the timer screen is set. By convention, a timing of ten seconds is the most commonplace timing scale that is used. The start button is then pressed to start the mixing process. After ten seconds, the device switches itself off. During this time, the dental formulation is usually well mixed. One of the observations that the team cannot overlook is the way that the hooks twirl the capsule. The twirling of the hooks is out of phase with each other. This helps to mix the capsule contents from all the sides of the capsule [4].

1.3.3 Original System Performance

This device works at a voltage of about five units. The task that is performed by the device is quite light given that it has to shake a capsule that weighs 20 grams. As a result, there is not much of a need for excessive force. The chief part of the device is the motor. The motor is connected mechanically to toe hooks and gives them the motion. A high performance characterizes the original system. It is only a device with high performance that can complete a task in ten seconds. Dental amalgamator can be utilized for other purposes other than mixing of the capsule. The time scale that the device has is testimony to this. A motion that has a periodic time of 4,000 revolutions per minute characterizes the performance of the original system. This is a relatively high frequency and is the one that leads to the task being completed in the ten seconds.

1.3.4 Original System Deficiencies

When in ideal environments, the device is effective and efficient. However, in places where the conditions are less than ideal, the device slowly becomes ineffective. One of the less ideal conditions is the lack of electrical power. Without the electricity, this device becomes a useless box [2]. The other deficiency is related to flexibility. This device is made of metallic parts for most of the components. This makes it to be relatively heavy. The other shortfall is the shape. This device is shaped like a cube for the most part. If one is traveling in a bag pack, this device had to be carried with a cardboard, as it is so rugged.

Figure 1.3.4: Original System

2 REQUIREMENTS

The requirements for the device are particular that need to be satisfied for the device to function in the way that it should perform. Parts of the requirements were based on what was specified by the project client and others based on the design necessities. Of essence in the requirements are the necessities that are required by the customers and the design requirements that need to be met.

2.1 Customer Requirements (CRs)

The redesigned model needs to meet the requirements of the customer's needs as well as the design requirements. The first among the design requirements is the ability to use human power to make the device to work. This function is the one that will replace the use of electrical current to drive the device. The second among the design requirements is the ability to carry out the mixing of the dental formula in ten seconds. There are other customer requirements that are a derivative of the student concerns. Weight is also of concern to the students. The current device is too heavy that tires the traveling students easily. The shape is also extremely rugged and this is of concern to the students. The rugged shape makes carrying of the device to be uncomfortable to the carriers. If the size of the device could be reduced, it would be more convenient for customers. Most of the students abroad travel with backpacks, therefore; it would be ideal to have the device small enough to fit in a backpack.

Table 1: Relative Weight of the Customer Requirements

Customer requirement	Weight
Use of human power to power the device	5
Light weight	3
Smaller in size	5
Be durable	4
Speed between 3000 rpm to 4500 rpm	3
Easy to use	4
Transparent compartment	3
Takes 10 seconds to shake	3

2.2 Engineering Requirements (ERs)

One of the engineering requirements is that the device should shake the formulation that is in the capsule for ten seconds. The device that currently exists can shake the formulation for ten seconds. The team does not seek to create any inconvenience in the use of the new device. The dentist should use the same time as he was using before. This is to make sure that the dentist can be able do adequate planning as they do their work. There only difference should be the source of the power that is to be used to make the device to work. The other engineering requirement is that the device should have enough power to shake the capsule thoroughly. The point is not just to shake the capsule for ten seconds but also to make sure that in the ten seconds, the device has produced enough energy to shake the capsule thoroughly. This will only be possible if the mechanism that is made has enough power to shake up the capsule. The mechanism made should therefore be strong enough to provide the power. The final engineering requirement should be the presence of safety through the use of the device. Many times, locally made devices may have shortcomings in regard to the safety aspect.

Table 2: Engineering Requirements

The device should have enough power to shake the capsule thoroughly	3
The mechanism made should therefore be strong enough to provide the power	4
Presence of safety through the use of the device	5
The shaking time of the capsule from 10 to 60 Seconds	3
Quality of the material Used	5
Cost of material used	4
Easy to Maintain	4

2.3 Testing Procedures (TPs)

The device will be tested as description below due to engineering requirements:

1. The device will be tested by shaking the dental capsule at different times to know the minimum time of shaking.
2. The time will start from 10 seconds till 60 seconds till we got homogenous liquid.
3. After 50 Seconds of shaking the filling capsule should produce homogenous liquid.
4. The device will be tested by volunteer student to make sure it's easy to operate.
5. The device will be put in high pressure to make sure is the quality of material of the device is high.

Table 2.3: Testing Procedure

10 Seconds	N/A
15 Seconds	N/A
20 Seconds	N/A
25 Second	N/A
30 Seconds	N/A
35 Seconds	N/A
40 Seconds	N/A
45 Second	N/A
50 Second	Should be success
60 Second	Should be success

2.4 Design Links (DLs)

To insure our design meet with our Engineering Requirement.

2.4.1 Gears and shafts

Gears are made up of steel. Four gears are different in sizes two of them are NSSI 1640. The other two are NSSI 1630. The two different gears were used to insure the change of speeds on the system so the device can be operate on the required speed to shake the capsule.

Shafts are made up of steel. The shafts are 1/2 in diameter to be assembled to the gears. Three shafts were used the first shaft is assembled to the handle crank and to first drive gear which 40 teeth. The second shaft is driven by the first gear. The second gear which 30 teeth are attached to the second shaft and the second gear in this case are driven by the first gear. The third gear, which is 40 teeth it's attached also to the second shaft. Shaft 3, which is assembled to gear 4 which 30 teeth and it's attached to outlet arm and capsule holder.

2.4.2 Inlet

The Inlet power is the part that the user going to let his power in to transfer it to an outlet could reach the purpose. In the Gear Box device we choose the most appropriate material, which is the Aluminum for the hand crank drive and it, has two holes each hole has key lock. The above hole is assembled to the grip by the key lock, and the other one attaching the shaft.

2.4.3 Capsule Holder

This is made of sprig steel therefore making it light in weight. Also, spring steel is tough, hard, resistant and flexible to wear, self-lubrication, chemicals thus suitable for making the casing.

2.4.4 Housing

The Top housing of the device is made of Lexan, which is a polycarbonate, which is light, tough, and resistant to chemicals and stresses from work fatigue. Bottom housing made of wood panted with spray blue color.

2.4.5 Base

The wooden base was assembled with the bearings by the screws to holding the shafts and gears. This base is made of wood and it's about Four parts glowed together, the bottom part is the real base and the other two parts will be on the sides on a high level (as shown on the below figure) higher than the real base to refuse the gears friction. And the fourth part would be the small rectangular on the middle, carrying the bearings.

2.4.6

The outlet assemblies, the outlet is about five parts attached to each other by four screws. Also there is a tall screws stick on the bottom base, to stick the outlet arm to not moving with the shakes

2.5 House of Quality (HoQ)

This section will include the team's house of quality that was made based on the engineering requirements and the customer requirements. The HoQ describing how is important each engineering requirement to the designing procedure.

Table 3: House of Quality

House of Quality (HoQ)

Customer Requirement	Weight	Engineering Requirement		Enough Power (%)	Safety (%)	Quality (%)	Time (s)	Gears (rpm)	Shafts (LB)	Handle (%)	Monitor	Cover Case (%)	Outlet CD (%)	Outlet Arm (%)	Capsule Holder (%)	Wooden Base (%)	Low Profile Mounted Ball Bearings (%)	Screws (%)	Key Looks (%)
1. Use of Human Power	5			9	9	9	3	9	9	9	9	0	9	9	9	0	9	1	9
2. Light weight	3			0	0	3	0	3	3	3	0	3	9	9	9	3	3	9	9
3. Smaller in size	5			0	0	0	0	9	9	9	0	9	9	9	9	9	9	9	9
Durable	4			0	0	0	0	3	3	3	3	3	3	3	3	3	3	3	3
5. Speed BTW 3000 rpm to 4500 rpm	3			0	0	0	0	3	3	1	0	0	3	3	1	0	9	0	0
6. Easy to use	4			9	9	9	3	9	9	9	9	9	9	9	9	9	9	9	9
7. Transparent Compartment	3			0	9	9	0	9	9	9	3	9	9	9	9	9	9	9	9
8. Takes 10s to shake	3			3	0	0	3	3	3	3	9	1	3	3	3	1	3	3	3
Absolute Technical Importance (ATI)				21	27	48	9	48	48	46	33	34	54	54	52	34	54	43	51
Relative Technical Importance (RTI)				10	9	4	11	4	4	5	8	7	1	1	2	7	1	6	3
Target(s)				99%	100%	80%	50s	220rpm	0.3 LB	50%	0	30%	70%	70%	80%	70%	90%	80%	90%
Tolerance(s)				50-100%	50-100%	50-100%	10-60s	100-600rpm	0.1-1LB	50-100%	0	20-30%	50-100%	50-100%	50-100%	50-100%	50-100%	50-100%	50-100%
Testing Procedure (TP#)				3	1,2,3	1,2	4	1,2	1,2	1,2,3	NA	3	1,2	1,2	1	1,2,3	1,2	NA	1
Design Link (DL#)				13	12		14	6	7	8	11	10	2	1	4		3	9	5

Very Weak	0
Weak	1
Medium	3
Strong	9

Approval (print name, sign, and date):

Team member 1: __Mohammad Almutair___________________

Team member 2: ___Majed Bourosli__________________

Team member 3: ___Sultan Alotaibi__________________

Team member 4: _____Minekher Almari_________________

Team member 5: ______Mubarak Alajmi________________

3 EXISTING DESIGNS

This section will include an overview of some appropriate existing designs; some intensive research was performed on each exiting design in order to help the team create an appropriate design eventually.

3.1 Design Research

The Internet was the primary source of information for the existing designs of the dental amalgamator. 'Human Powered Dental Mixer' was the term that the team used to surf through the internet for existing design. There are about two dozen sites that had information on the existing designs. There are not all that many types of amalgamator are in the world. Many of the sites had repeated information that was in other sites as well. There are about five types of amalgamator that the team was able to trace. [4] Two of them seemed to be out-of-date and we therefore settled on three that seemed to make sense to us.

3.2 System Level

The system selections were based on the closeness of the devices to the type of device that the team were seeking to have. The first thing that the team was keen to check was if the system used any power or if it was a manual system. The designs that were selected were all operated manually and they therefore met the needed criterion effectively. The other thing that the team checked was the usefulness of the design in regard to our necessity. Two of the designs that the team did not consider were as big as a Piano. The other thing that the team checked was the potential for speed. The team needed a design that could reach 4000 rpm or could be modified to reach this speed.

3.2.1 Existing Design #1: Mixcap Dental Amalgamator

This design has a basic layout of a PVC pipe. The pipe has a screw on one side and a thread that runs in the PVC pipe. On the other end is held the holder for the capsule. When the screw is turned, it makes the holder to vibrate the capsule and therefore mixes the formulae. The shortcoming of this model is that it cannot be able to reach the 4000-rpm.

Figure 3.2.1: Mix cap Dental Amalgamator

3.2.2 Existing Design #2: Jains Amalgamator

This design is made of a gears cogs system. The gears multiply the power and the spring's offers the return force for the transfer of the force from the amalgamator to the holder of the capsule. A hand is used to move the system and it has to keep moving to make the device to transmit the power. The shortcoming of this device is that it is very large for use by the students as they move.

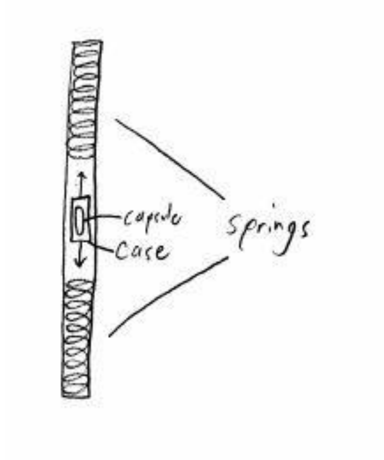


Figure 3.2.2: Jains amalgamator

3.2.3 Existing Design #3: Mortar and pestle

This design is the simplest of all the designs that were researched. This design operates in a tradition of just spilling the content of the capsule into a motor. Then the mixture is ground with a pestle till it is mixed thoroughly. This method however causes a lot of wastage of the capsule content.

3.3 Subsystem Level

The subsystems that were traced in the design held potential for the development of our designs. Sometimes, it takes just some modification of the existing models to come up with a totally new concept that is viable for application.

Subsystem #1: two balls design

3.3.1

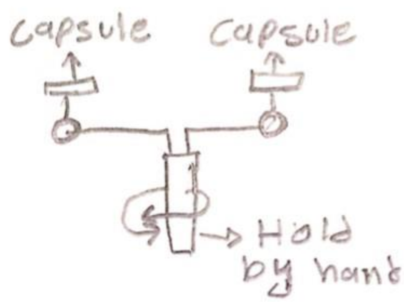


Figure 3.3.1a: two balls design

This design above is basically a hard rod with two connected ropes. The two ropes are attached to the balls. This design works by holding the hard rod and turn right and left by both hands

3.3.2 Subsystem #2 spinning gear design

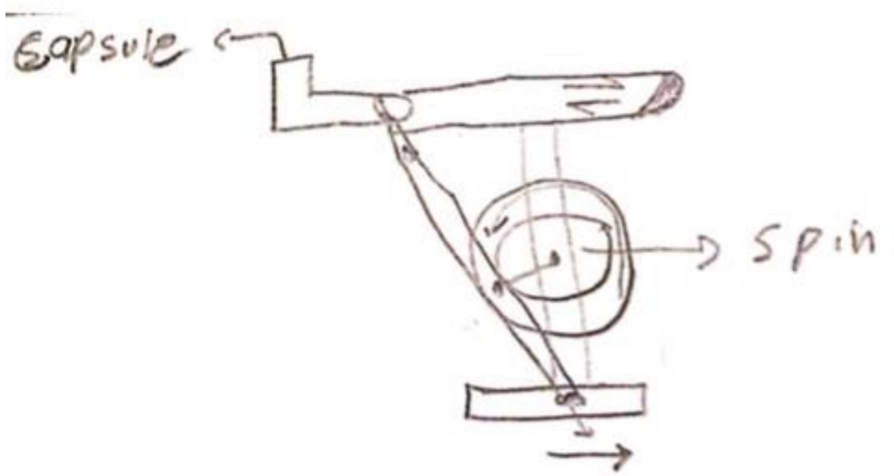


Figure 3.3.1b: two balls design

This concept makes a direct translation of force from one side to the other. A spring inside a box is depressed on one side. As the spring gains it length after the depression, it becomes longer in length. It pushed a holder that is supposed to hold a capsule. As a result, the holder vibrates informed by the compressions and the rare functions of the spring inside the box.

3.3.3 Subsystem #3: Gear mechanics

Gears operate on the principle of speed multiplication. The factors of multiplication are dependent on the diameters of the gears or the number of the teeth that are in the gears that are interacting with each other. The requirements for the device are particulars that need to be satisfied for the device to function in the way that it should perform. Some of the requirement is the ones that were specified by the project client and others based on the design necessities it. Of essence in the requirements are the necessities that are required by the customers and the design requirements that need to be met.

3.4 Functional model

Our functional decomposition consists of the black box and the functional model. The black box is the basic understanding of the operation of the hand powered dental amalgamator. The team seek to make the hand powered dental amalgamator to be as the flow black model shows below. The black box just shows the materials, the energy that is to be used and the signals that will be emitted. The thick line is for the input and the output materials the moderate line is for the energy input and output while the within line is for the signal emission.

3.4.1 Black Box Model

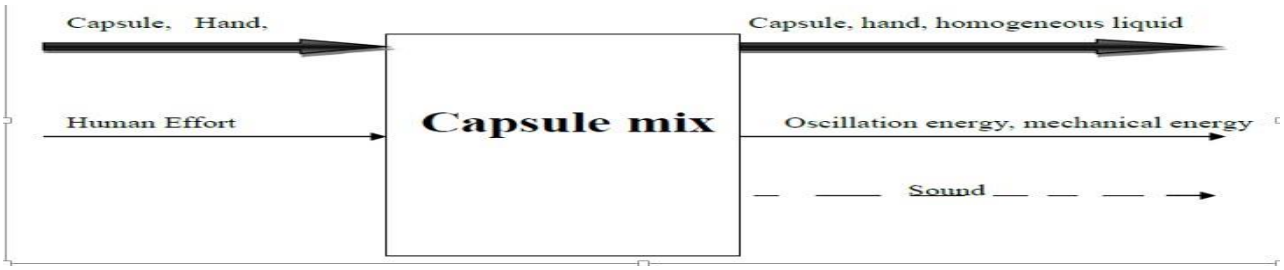


Figure 3.4.1: Black Box Model

The functional model and the black box will be instrumental in defining the processes that needs To be followed in making the designs that will need to be considered. With this understanding the team will choose the designs that are considered for this the hand powered dental amalgamator. This functional model in particular helped out the thinking process, as shown above, the team divided the needs of this project and made what the outcomes that the team need clear. Based on the three primary options that are shown above the team designed the project.

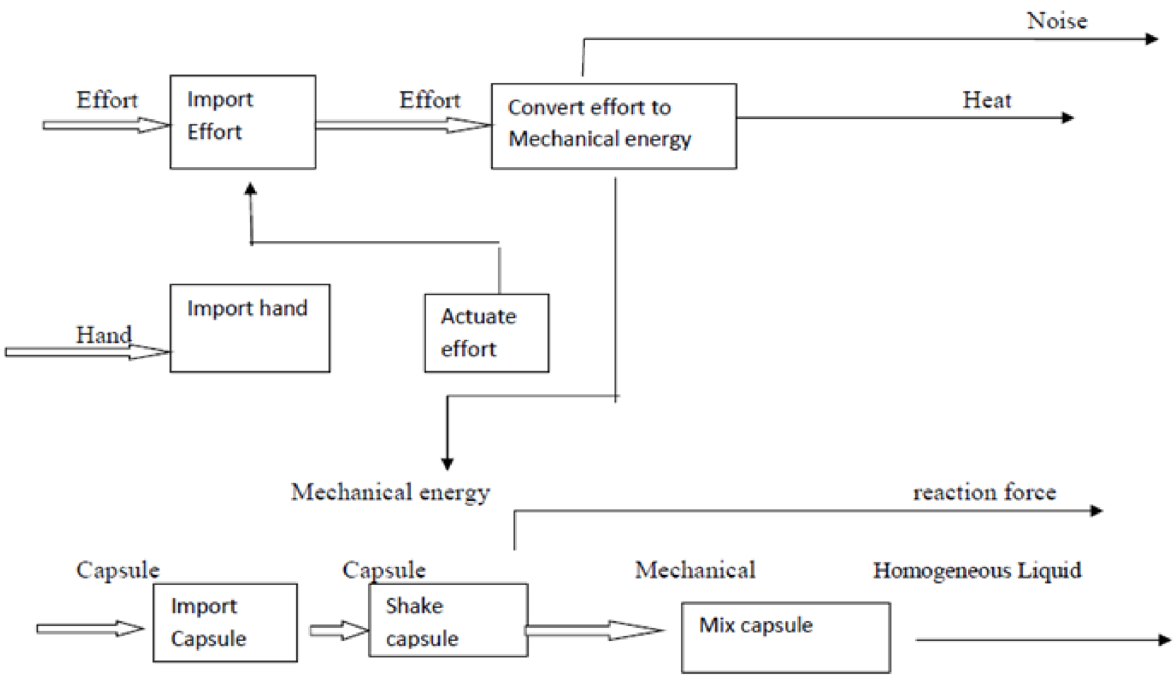


Figure 3.4.2: Functional Model

4 DESIGNS CONSIDERED

This section will include the design that the team came up with, and it is based on the engineering requirements and customer requirements that were set. The team considered about ten designs that have their own advantages and disadvantages.

4.1 Design #1: Resonate box

On two sides of a box, there are springs that are springs that are attached. These springs resonates out of phase with each other. This happens when the handle is displaced downwards with a hand. As the spring gain its mean point, the spring on the other side is displaced downwards. This simple one displacement and the resonance can last for a minute a time over which the capsule could be fine mixed.

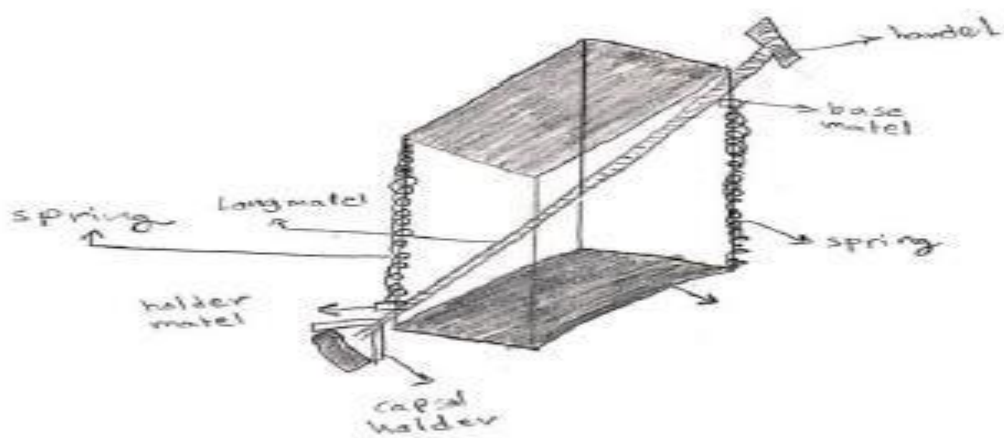


Figure 4.1: Resonate Box

4.2 Design #2: Vibrating Spring

This model has a basic functioning where there is holder that is suspended by springs. The springs are in return attached to a base. What happens is that the prongs are displaced sideways by a hand and then released. As the springs return to the mean point, they surpass it to the opposite direction and there is a continuous vibration until there is no more impetus. The hand could keep on vibrating the capsule.

4.3 *Design #3: Gear* **Amalgamator**

The gear amalgamator utilizes the concept of gears to multiply impetus. This model is driven by hand. The hand has a force that drives the first gear that is normally a very large gear, smaller subsequent gears are driven as a result; their speed is multiplied all the way to the capsule holder.

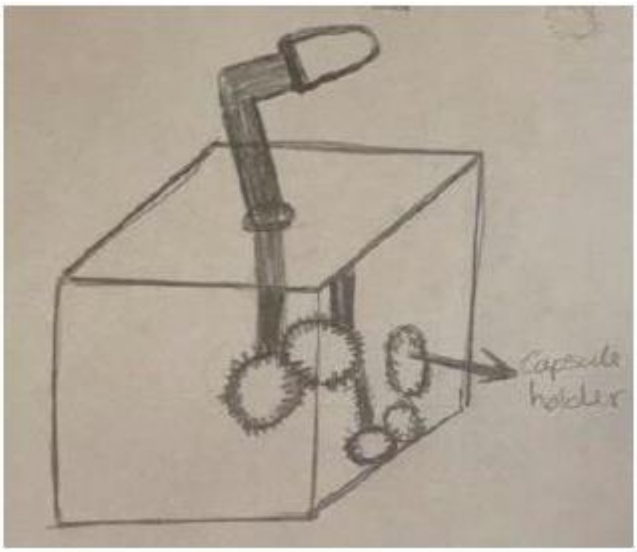


Figure 4.3: Gear Amalgamator

4.4 Design #4: Pipe with spring.

In this design, a pipe contains a spring. On one end, a faucet is pushed downwards and then released to return to the mean point. As the faucet returns to its mean point, it makes the spring to send waves of compressions and rare functions. These waves are successively continuous as the faucet is continuously displaced. The waves hit the capstone holder and make it to vibrate.

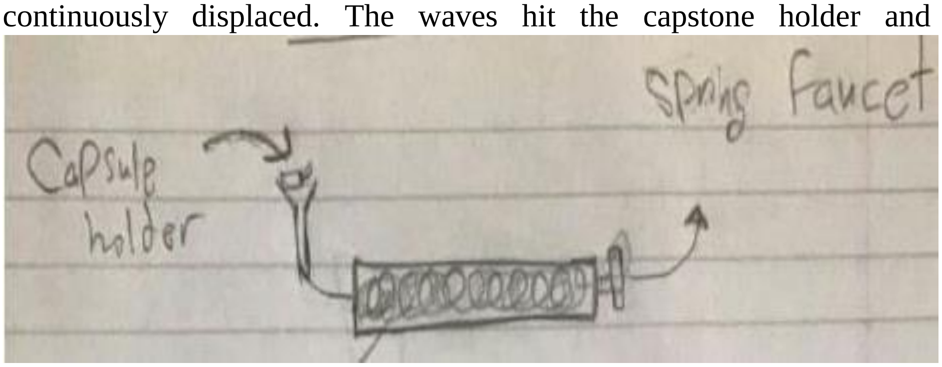


Figure 4.4: Pipe with spring

4.5 Design #5: Bearing.

The bearing works in more or less the same way like the gears would work. There are bearings that have teeth like the ones that are utilized in this model. The gears are lined up so that they drive each other. As the gears drive each other, they become complimentary of the force transition to the capsule holder.

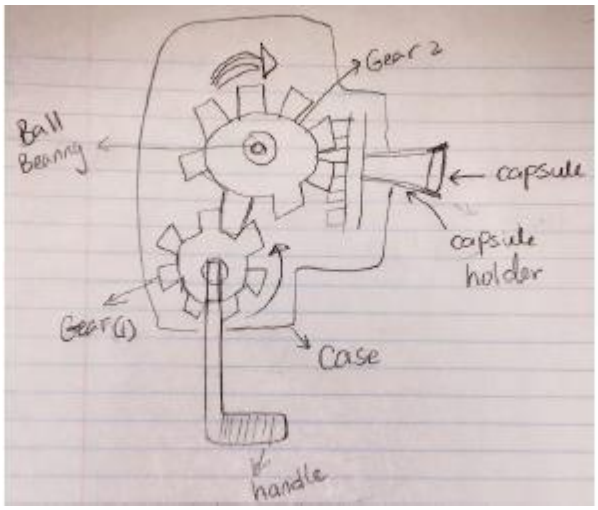


Figure 4.5: Bearing

4.6 Design #6: Solar Powered Model

The solar power can be a great source of energy to drive our amalgamator. The solar panel replaces the cable system that supplied power to the original model.

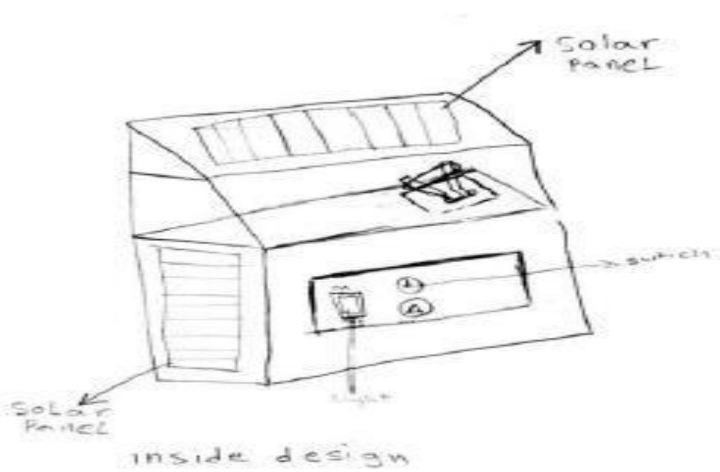


Figure 4.6: Solar Powered Mode

4.7 Design #7: Series gears

These gears are connected in a way that they following each other. In this connection, the gears are all transmitting power to each other. There is a uniform force that is transmitted to the successive gears. The force that starts on one end is the same force that is delivered other end.

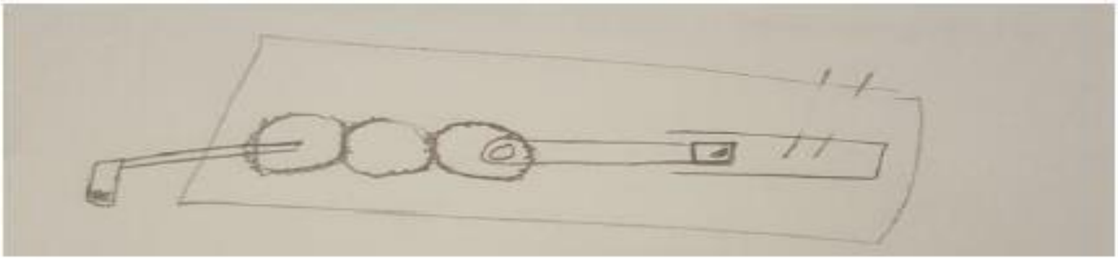


Figure 4.7: Series Gears

4.8 Design #8: Single Pulley

This model was made of a single gear that is attached to an amalgamator. The gear has protrusions on the side that continuously hits the holder as it rotates. There are as many as ten hits that happen to the holder in one revolution and as this happens, the capsule is well mixed.

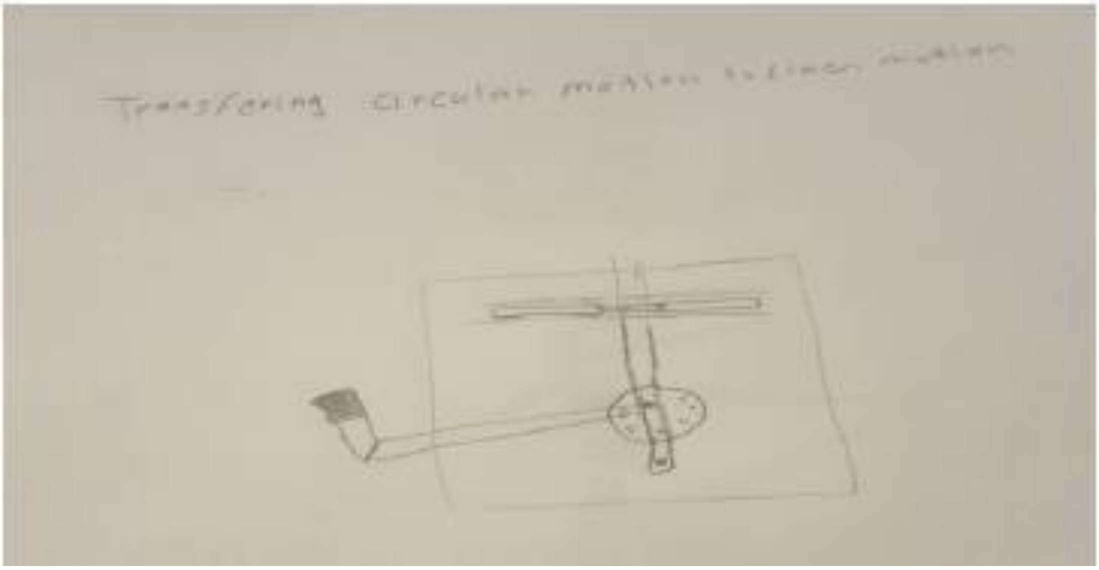


Figure 4.8 Single pulley

4.9 Design #9: Disposable Batteries

Given that the challenge that is major is the lack of electrical energy, this model recommends the use of batteries that are disposable. The batteries can replace the electrified system that does not work anymore due to the lack of electrical power to be used.

4.10 Design #10: Flexible Chorded

This design uses a flexible chord that has a high tensile strength. The chord is fixed on one end, as the other end is free to be vibrated upon a slight displacement downwards. The displacement is done by the use of a hook that is attached at the base of the flexible chord. The hook is pulled downwards and as it makes the return vibration, it makes the capsule that is attached it to mix in the process.

5. DESIGN SELECTED

This section will discuss the process that the team used to evaluate the considered designs, along with the design the team selected on behalf of the other designs. A brief description of the design selected is included. The team used a Pugh chart for the selection process along with a decision matrix to finalize selection.

5.1 Rationale for Design Selection

The ten designs that were made by team all have the same chance of getting chosen. To be able to choose the best among these designs, the team shall use the Pugh Chart and the decision matrix. These two will give the final model that is ideal for development. The team started with the use of the Pugh chart to reduce the options that the team had to a handful that can be sorted out through the decision matrix. There are the top customer needs and the engineering requirements that were synthesized earlier on. These are the ones that will be used to make the final decision on the model that will be choose. Based on the Pugh chart, the gear amalgamator was selected as the final design, and this is because the team thought that it best fits within the criterion that was set before doing the Pugh chart, also the team thought that the vibrating spring and the resonate box designs were good enough, however the team thought that these designs were not entirely applicable due to budget related reasons.

Table 4: Pugh chart

Criterion	Models								
	Resonate box	Sprigged pipe	vibrating spring	Gear triturator	Solar powered model	Series gears	Single pulley	Disposable batteries	Vibration string	Flexible chorded
Use of human power to power the device	+	+	+	+	+	+	+	+	+	+
Safety	+	+	+	+	+	0	+	+	+	0
4500 rpm	+	0	+	+	+	0	0	0	+	0
10 seconds time interval	0	+	0	+	0	0	0	+	0	0
Light weight	+	0	+	+	0	0	0	0	+	+
Speed between 3000 rmp to	+	0	+	0	0	0	0	0	0	0
Total	50	30	50	60	30	10	20	30	40	20

5.2 Design Description

The design that was selected is the Gear Box mixer. This design works on the principle of the gears that are attached on shafts that will transfer the circular motion to semi linear motion. As it is able to multiply the initial torque by a scale that makes it able to meet all the requirements that were outlined as being important for the need that needs to be met. This design works on the principle of gear ratios in the manner that they interact with each other. The driver gear drives the other gears and in the process, as the gears will be rotating on it the capsule holder will be placed on the output and it will move in semi linear motion. The most basic part of the design is the calculations that will be explained more in depth in the next section. The group has researched in different parts of the project on their Individual Analysis as the Gear ratio and the material weight and some of them did some researches about different designs before we settled on our Gearbox design. The device is operated by human power. Therefore, it is designed to employ gears to provide the required power to rotate the components in the Human Powered Dental Mixer. The several components will be run by a combination of gears that will give the desired output.

5.3 Analysis.

5.3.1 Gear Ratio Analysis.

The device is operated by humans. Therefore, it I designed to employ gears to provide the required power to rotate the components in the Human Powered Dental Mixer. The several components will be run by a combination of gears that will give the desired output. To achieve the best gear ratio, a gear train will be used to determine the amount of output kinetic energy.

The device will employ the use of spring to provide the desired kinetic energy and rotate the components of the device. The equations will be used to achieve precise calculations to determine the exact power and time needed to obtain the output. Since the device does not use electrical power, gears coupled with springs will offer the sufficient power to realize the mixing required. The device is human hand operated to initiate the movement and rotations, which will, in turn, provide the required energy to triturate the amalgam and give the capsule needed within the stated time frame. A gear box is considered where systems of gears, with a different number of teeth, are used to change the speed and the motion direction in the components [15].

The gears are connected to the holder of the capsule. The device obtains its initial drive from a spring, which converts the circular motion provided by the human hand to a vertical power, which is fed to the gear system. The sketch is generally a system of springs, spring faucet, the metal casing for the spring, and a Y-shaped metallic frame. When the spring faucet is rotated, the spring tension produces a power in the form of compression to the other side of the case, which is finally connected, to a capsule with the system of gears and the Y-shaped metallic frame. With this connection, the middle placed capsule will triturate by compression power vibration hence mixing is achieved. The following equations will be used to determine a gear ratio of the gear train [15].

If the number of teeth in the driving gear is Na

The number of teeth in the driven gear is Nb

Therefore, the ratio between the first two gears will be [16].

$Gear\ ratio = \frac{Nb}{Na}$ …….. Eq. 1

Therefore, a smaller driver gear shall turn the bigger driven gear and vice versa when the speed is

expected to decrease or increase respectively.
For a system of gears, the ratio can be obtained by the using the equation below
One of the gears may be used as idler gear to increase the distance or change a course of direction. In such a case, the first gear in the box shall remain [16] the driver while the last gear in the box will remain the driven (Frank & Toliyat, 2009). The formula, therefore, remains the same, but the ratio between two adjacent gears will be multiplied by the ration in the next two subsequent gears. The gear ration is the relationship between the input speed to the output speed, and it is typically written as

$Gear\ ration\ =\ Win:\ Wout$ …….. Eq. 2

Therefore,
The system is made up of six gears, namely A, B, C, D, E, and F.
If the number of teeth in gear A, is [16].
The number of teeth in gear B is [16].
The number of teeth in gear C is Nc [16].
The number of teeth gear D is Nd [16].
The number of teeth in gear E is Ne [16].
The number of teeth in gear F is Nf [17].
The driven becomes the driver in the next pair of gears [16].
And hence,

$Gear\ \ Train = \ \frac{Nb}{Na}\ x\frac{Nc}{Nb}\ x\frac{Nd}{Nc}\ x\frac{Ne}{Nd}\ \ x\frac{Nf}{Ne}$ …….. Eq. 3

The number of teeth in each gear is chosen to either increase or decrease the output speed. Since the capsule is expected to mix the amalgam, the last gear is expected to have small number of teeth to increase the speed of trituration.
Since the gears are fixed to a shaft, the shaft experiences a torque.

$T\ in\ W\ in = T\ out\ Wout$…… Eq. 4

$\frac{W\ out}{W\ in} = \frac{R\ in}{R\ out}$ ………. Eq. 5

$\frac{T\ out}{T\ in} = \frac{R\ out}{R\ in}$ ……. Eq. 6

$\frac{T\ out}{T\ in} = \frac{n\ out}{n\ in}$ ………. Eq. 7

Where t is the torque,

W is the angular speed (RPM or rad/sec)
r is the radius of the shaft
n is the number of teeth.
The speed of the shaft can be determined by

$\frac{Speed\ in}{ratio}$ …………… Eq. 8

$Torque\ out\ = Torque\ in\ x\ Gear\ Train$ …… Eq. 9

Results

Gears B, C are on the same shaft, therefore, they rotate in the same direction. Gears D and E are in in the same shaft, but the difference is the number of teeth in each gear. Gear A, D, E rotate in the same direction while gears B, C, and F rotate in the same direction opposite to the gears A, D and E. to achieve the desired speed at the output, the gears are assigned the number of teeth differently according to the speed required between two pairs of gears. Gear A is 30 teeth; [16] gear B is 9 teeth, gear C is 27 teeth, gear D is 9 teeth, gear E is 35 teeth, (Frank & Toliyat, 2009) and gear F is 5 teeth (Lin, Shea, Coultate, & Pears, 2009). Therefore, the gear train is determined as shown below by using equation 2.

$$Gear\ \ Train = \frac{9}{30}\ x\ \frac{9}{27}\ \ x\ \frac{5}{35}$$

Therefore,

$$Gear\ train\ =\ 0.01428357$$

Since gears B and C are on the same shaft, D and E are on the same shaft hence they rotate at the same speed. Therefore, the gear train is determined by the ratios between gear A and B, between gears C and D, and between ratio E and F [17].

To obtain the final speed, the number of revolutions per minute of the shaft holding the gear is divided by the gear train. As it can be noticed, the output speed will be high due to the small value of gear train. Since the last gear has small number of teeth, the output speed is expected to increase [17]. The same can be confirmed by using equation 8, which relates the speed of a shaft to the gear train.

The shaft carrying gear A rotates at 30 revolutions per minute (Lin, Shea, Coultate, & Pears, 2009), [17] the shaft carrying gears B and C rotate at 100 revolutions per minute (Lin, Shea, Coultate, & Pears, 2009), [16] while the shaft carrying gear D and E rotates at 300 revolutions per minute, the shaft with gear F rotates at 2100 rotations per minute [17]. By using the rotations of the shaft, the gear train can also be attained. Additionally, the speed of the shaft can be determined by using the gear train and the speed of the shaft preceding the final shaft by using equation 8[17].

The torque of the shafts is calculated by using equation 9.

The torque of the initial haft was 0.25FtLbs

Therefore, the torque at the final shaft is determined by equation 9.

The output torque is therefore,

Gear	**1**	**2**	**3**	**4**
Number of teeth	40	20	40	20
Ratio	0.74	1.35	0.62	1.625
Gear train	0.2341	0.2341	0.2341	0.2341
Speed (RPM)	30	110	55	220
Shaft	**1**	**2**		**3**
Torque	0.25	0.0585		0.01422

$$=\ 0.25\ FtLbs\ x\ 0.01428357$$

$$=\ 0.003570892\ FtLbs$$

The table below summarizes the data for the analysis of the sketch design

Table 5: Summary of the analysis and parameters of the design of the Human Powered Dental Mixer

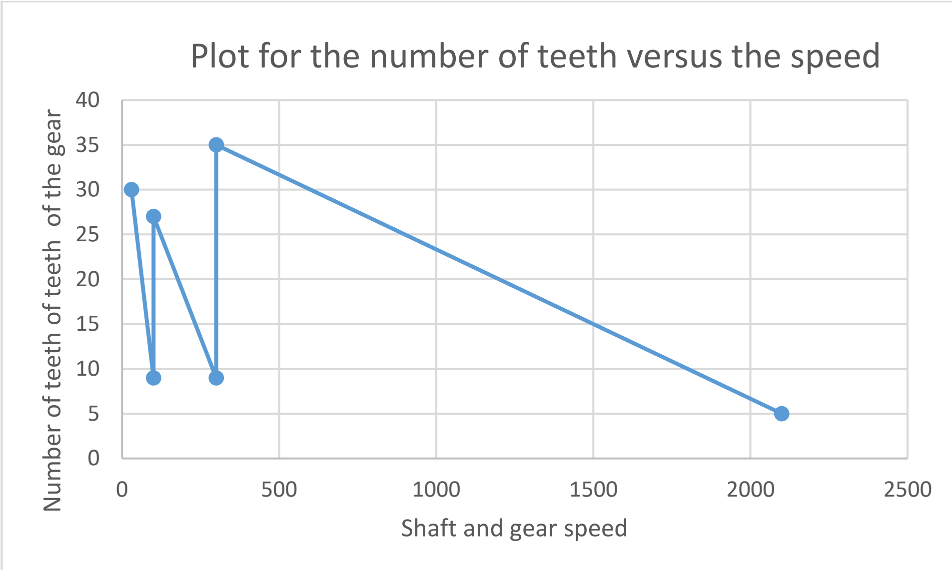


Fig 5.3.1A. Plot for the number of teeth in a gear versus the surface speed of the shaft or the gear

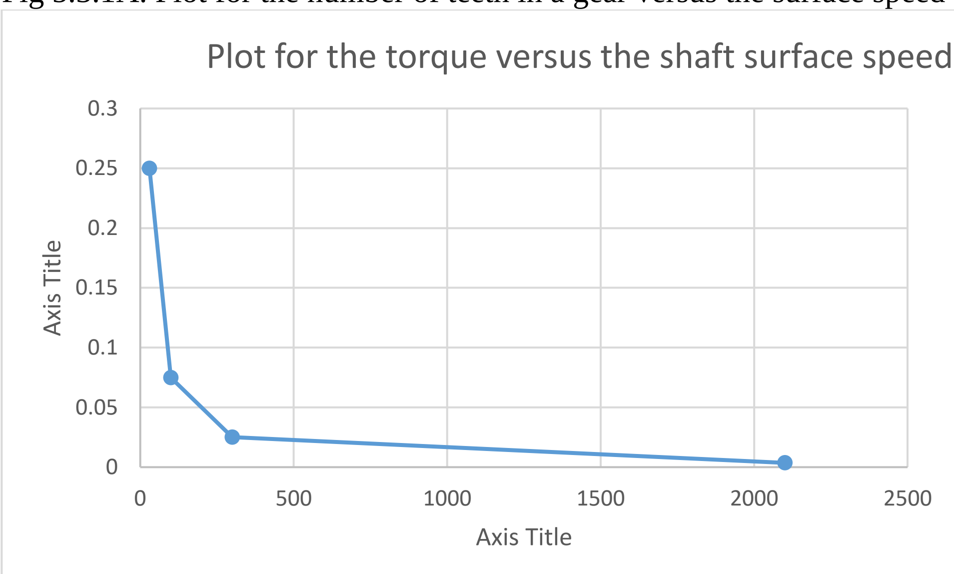


Fig 5.3.1B. Plot for the torque of the shaft versus the shaft surface speed

As it can be seen, the ratios in the gears additionally change the torque right form the input to the output of the system. Torque is a contorting or turning power. Upon reducing the speed by the ratio, the torque in a shaft is diminished by the ratio or the gear trains. Therefore, the torque is expanded by a similar gear proportion or train.
The torque will likewise be influenced by the efficiency of the system. Therefore, it was essential to design a system with high efficiency to utilize the small speed of the initial shaft. One of the principle advantages of a gearbox is it enabled the design of the device making any changes in accordance with the speed and torque of an engine. It is, therefore, essential to install gear motors from providers who offer an extensive range of torque reduction proportions. A wide choice of accessible gear ratios takes into account more chances to choose an exact speed increase or torque reduction for a particular application.
As a result, the objectives of the experiment were met since a Human Powered Dental Mixer that

uses the power of the human hand was successfully designed with the aim of utilizing the force in the human hand to run the capsule. A gear system coupled with spring system was installed in the device, and they derive mechanism gave rise to the components being rotated to the higher speed to achieve mixing at a short time. With the correct utilization of the equations defined above, the values of the surface speed of the shafts were used to attain the final speed. The use of the number of teeth or surface speed of each gear can be used to achieve the output speed required to mix the amalgam. In addition, spring is coupled to the gear system to achieve the return mechanism of the device. The velocity relationship expressed in radii, velocity expressed by the number of gear teeth, the torque expressed regarding radii and the torque in terms of a number of gear teeth were the useful expressions to establish output and torque in the device.

As it can be noted, the device is expected to mix the amalgam in ten seconds. Therefore, the system was designed with the aim of speed increase. Additionally, it was also purposed to design a versatile device that does not require electrical power to run. Therefore, flexibility factors were the ideas at hand throughout the design. The sources of errors in the design of the device were the wear and tear, the backlash of the gear, which reduced the surface speed of the gears. Since the calculations were done with all the factors kept constant, a value of error might have been propagated.

5.3.2 Material Weight Analysis.

5.3.2.1 Gears

The previous model was considered to be heavy by many of the users. To provide a solution to this issue, reviewing the older model with an aim to make it more mobile hence improving mobility was necessary. It was, however, necessary, to do good analysis and make sure the other parameters such as cost and durability were not adversely traded off. The older model had gears made of iron. Though it provides good resistance to wear, deformation and oxidation from air and water, its weight is considerable. An alloy of iron, gray cast iron would provide a substantial reduction in weight due to its density while being also resistant to rust. Seasoning, a process whereby animal fat is cooked into the iron cast is necessary for gray cast iron. The density of gray cast iron is 7.1 g/cm^3 hence provides a good trade off with the other parameters considered, that is durability and cost. Apart from a reduction in weight, the gray cast iron gears provide a less noisy environment during operation.

Gray cast iron has been used extensively to reduce weight while maintaining a high level of durability in the automotive industry. The reason for the high durability lies in gray cast iron ability to withstand tensile and compressive forces. The reduction in density is by 0.7 g/cm^3 making the many gears weight reduced considerable. The decrease in weight of the gears would not only make the mixer easier to carry around but also reduce the effort used during the mixing process which depends on human effort. Consequently, this would increase production due to the minimum effort required.

5.3.2.2 Capsule holder

To further reduce the weight of the manual dental mixer, a plastic capsule would be necessary. This would reduce the weight compared with to a capsule holder made from glass. The plastic that has characteristics that can be utilized to achieve the requirements is Polyamide (nylon).

Table 6: Weight Requirements

Material	Density - ρ - (10^3 kg/m^3)	Tensile Modulus - E - (Gpa)	Tensile Strength - σ - (Gpa)	Specific Modulus - E/ρ -	Specific Strength - σ/ρ -	Maximum Service Temperature (°C)
Nylon 6/6	1.15	2 - 3.6	0.082	2.52	0.071	75 - 100
Polyethylene (HDPE)	0.9 - 1.4	0.18 - 1.6	0.015			
Polypropylene	0.9 - 1.24	1.4	0.033	1.55	0.037	50 - 80
Epoxy	1.25	3.5	0.069	2.8	0.055	80 - 215
Phenolic	1.35	3.0	0.006	2.22	0.004	70 - 120

The low density of glass-filled nylon would reduce the weight compared to the previous model by approximately 1.4 kg/m^3. This significant reduction in the weight, combined with the other advantageous properties of Polyamide such as toughness, hardness, considerable resistance to wear, self-lubrication, good resistance to chemicals and machines, makes it most suited for making of the casing.

5.2.2.3 Cover

To cover the manual dental mixer while working, it was necessary to use a material that was transparent enough for the handler to monitor the process. Though it was heavier than plastic which the next best alternative was, the best trade was for better visibility of glass whose transparency does not get cloudy over time. The density of glass is in the range of 2.4 g/cm^3 to 2.8 g/cm^3, for this case, making the class cover as thin as possible would reduce the weight. The strength of the glass is not of paramount importance to the design provided it is hard enough to resist stresses during the operation. The type of glass chosen should be resistant to scratching externally. Tempered glass provides a good choice for this application as it not brittle, and its density of 2.8 kg/m^3 is relatively low.

5.4 Body of device

The body of the previous device was made of plexus-glass, which has a density of 1410 kg/m^3. The body plexus-glass body would be replaced with Polypropylene, a thermoplastic commonly used in the making of medical equipment due to its properties which are; lightness, toughness, excellent resistance to chemicals and can resist any stresses emanating from work fatigue. Because of aforementioned properties, it is possible to put hinges on the body of the manual dental mixer. By using polypropylene, the density of the body of the device would reduce by 0.2 kg/m^3. This would represent a huge decrease in the weight of the manual dental mixer since the body of the device is of significant volume.

The use of less dense materials in the design of the manual dental mixer compared to its electric predecessor is crucial to the reduction of the weight of the machine. This being a major area of review as pointed out by the personnel who had earlier handled the previous machine; any reduction in the weight of the components is indispensable. The reduction of size will be crucial to weight reduction. Thus the materials chosen for the various elements should be scalable without reducing efficiency.

When looking at the density of materials, the issue of how the various materials are produced comes into play. For components that necessitate the use of metal as the material of choice, metal alloys, mixtures of two metals are commonly preferred. The alloys provide different properties compared to the metals they contain. Thus it is possible to take advantage of the various properties of the parent metals. For example, it is possible to make an alloy of iron that has a lesser density than iron but much harder than iron.

For glass made components, the weight of the glass is a trade off with the how brittle the glass is, tempering though can improve the resistance of the glass to stresses and adverse temperature. Since the manual dental mixture will be subject to constant vibration when in use, it is necessary not to overlook the strength and focus much on reducing the weight. As the strength, transparency, and lightness of the glass improve; the cost of manufacture increases making it unwise to put major focus on reducing the weight in these components. Also, the difference in density of the various glass types is not much.

Plastics are light naturally, thus whenever they can be used as a substitute for glass and metals, it is necessary to do so as long as the reliability of the component is not affected. With recent trends in the plastic industry, it has been possible to produce plastics that can withstand different stresses without deformation and remain lighter considerably.

By making these changes, it will be possible to reduce the weight of the manual dental mixture by 5 % to 10 % compared to its predecessor, the electric mixture. The general idea is to use lesser dense materials of smaller size without compromising on efficiency.

6 PROPOSED DESIGN

The implantation of this device will be fairly complex, as it will require intensive manufacturing techniques. As a plan the team has set to complete the manufacturing process successfully, the team's first step is to have a complete and fully dimensioned CAD design, and this would be the start. After making sure that the CAD design will successfully operate as intended, the team would 3D print the design, and this is to actually investigate how the device physically operates. The step after 3D printing the device is to interact with a machine shop regarding the manufacturing of the device itself. Here, the team will apply any necessary changes to the device in order to make it function as intended. The implementation cost will depend on the manufacturer. Furthermore, the cost of the implementation is dependable on 3D printing the device and ultimately manufacturing the device. Also, the team will manufacture the housing of the gearbox and it will be made out of plastic. The team agreed upon using Aluminum to manufacture the gears and Steel to manufacture the shafts. The estimated manufacturing cost is $800. The table below shows the different parts that the team will manufacture.

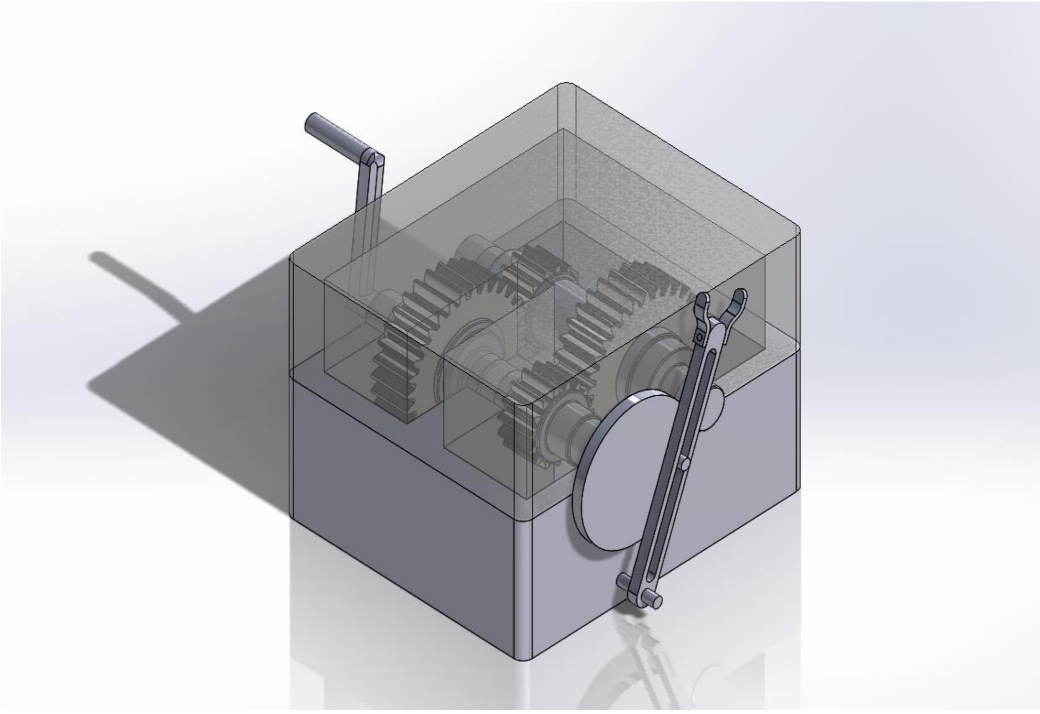


Figure 6.1: First semester Design

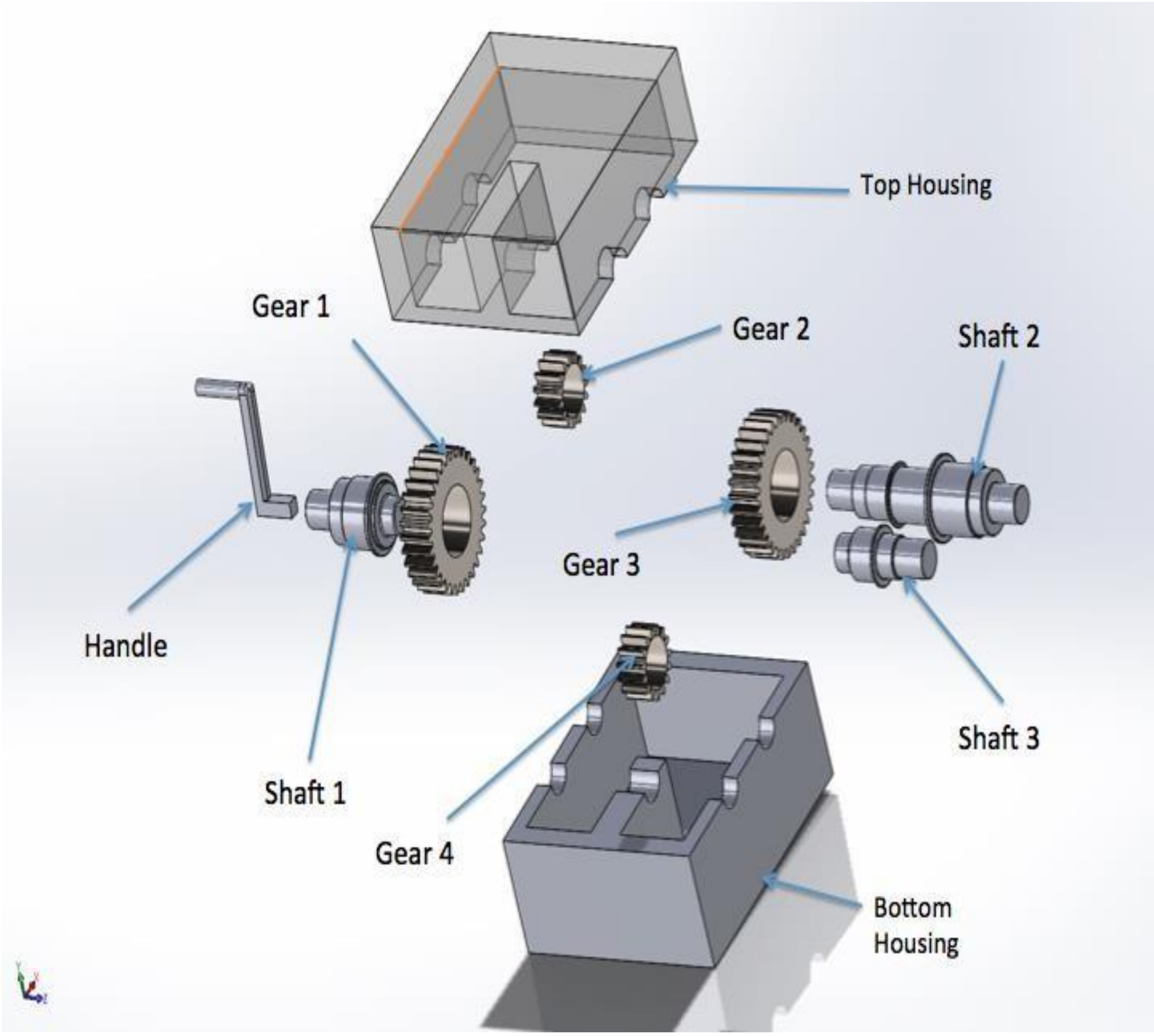


Figure 6.2: CAD Exploded View of the first semester design

7 IMPLEMENTATION

Before finishing up this project all cad parts was designed as the customer and engineering requirements. The cad design was reviewed by the client and they requested some modification such as adding a stop watch to know the required time of shacking exactly. The parts were ordered by the group from several websites such as McMaster and McFadden-Dale Industrial Hardware. The group ordered wrong gear sizes in the beginning and had to reorder for the correct sizes. This is one the reasons why the building procedure was delayed for one week. All the parts were taken to K&M machine shop where they assisted the group in manufacturing.

7.1 Analytic Analyses

7.1.1 Gears and shafts analysis

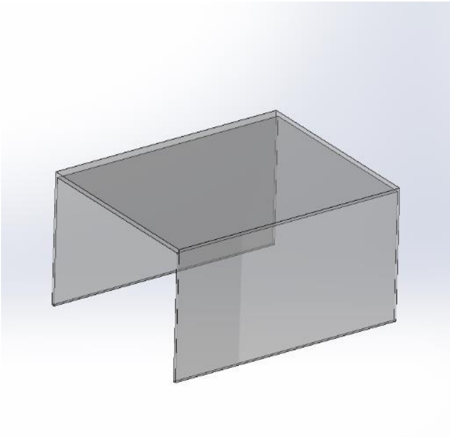
Prior to manufacturing, research was conducted on gears to determine the material and sizes. The group found that the steel is the best material to use for the gears and shafts. Steel is an alloy with a crystalline structure. It is a good electrical and thermal conductor. It has a high strength as well as the elastic module. At both low and high temperatures, steel maintains its good strength. Steel has a good ductility and therefore can be used in most engineering applications. It is easy to use and manufacture. It is resistant to corrosion, which is good factor. Lastly, it can be further strengthened through heat treatment.

Figure 7.1: NSSI640 and NSSI 1630 gears

7.1.2 Housing Material Analysis

Housing is one the important parts of this project. The housing include the base of the device and the cover case. The wooden base was chosen because the wood is a natural material, which is a poor thermal and electrical conductor. It tends to have a high strength on compression. Wood has a high hardness as well as high-temperature strength. Wood is easy to manufacture as it occurs naturally. It is resistant to corrosion, but since it is very hard, it can be used in applications that require metal properties. Wood tends to be low cost and occurs naturally anywhere on the surface of the earth. The cover case is made up of Lexan polycarbonate, which is thin and transparent to ensure good visibility and easy monitoring of the whole process. It is also resistant to scratching, strong, its density Lightweight and stronger than glass

Figure 7.1 B Upper case



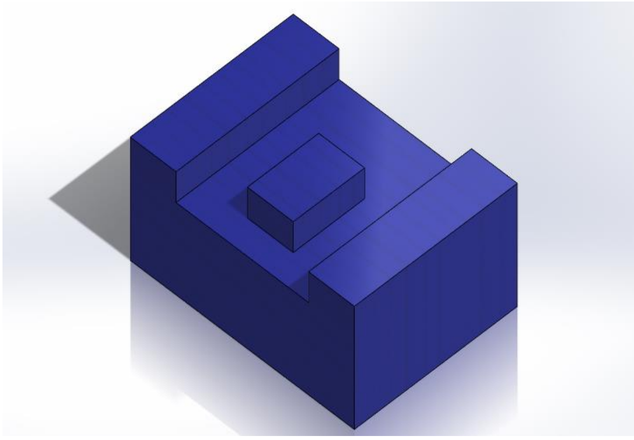


Figure: 7.1b Cover Case

Figure 7.1 C Wooden Bases

Input hand crank and outlet plate is made of aluminum and the grip of the input is made of polymer. As Plastic polymers tend to be organic in nature consisting of long networks or chains comprised of carbon. Most plastic polymers tend to be non-crystalline. However, they may also comprise of the mixtures of both non-crystalline as well as crystalline regions. Polymers possess low rigidity and low densities. Additionally, their mechanical qualities tend to vary significantly. It should also be noted that most plastic polymers are poor conductors of electricity. This is because of the kind of the atomic bonding that they are made up of. Additionally, most plastic polymers tend to be corrosion-resistant even though they cannot be easily used in places where temperatures are high. Lastly, plastic polymers have a good weight to strength ratio. Polymers are also low-cost since their manufacturing is less difficult. Since they are easy to form, they are often preferred in most engineering applications for the input handle and output plate, which is made from Aluminum. This metal has characteristics such as high electrical as well as thermal conductivity. It can be easily deformed as well as cut into different shapes without breaking. Aluminum tends to have a high mechanical strength making it easy to use in applications that require strong materials. Aluminum, like most metals, needs to be reduced from the various chemical compounds and is more costly compared to non-metallic materials after manufacturing. Aluminum is susceptible to corrosion as it reacts with the environment thus reforming the chemical compound. Aluminum is shiny as well as malleable. Aluminum has the above characteristics because it tends to have non-localized electrons.

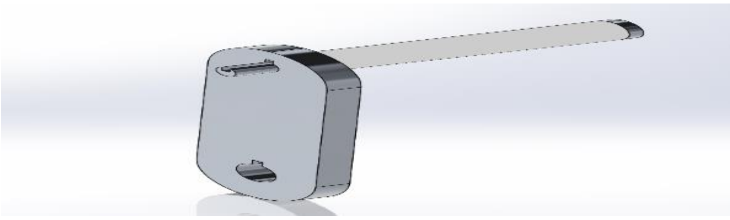


Figure: 7.1 D Handle

7.2 Manufacturing

The gear design has four gears. Two of the gears are spur NSS1640 Gears. These gears have more strength as compared to the other gears of the same size. They also transmit power or force quietly. They are more suitable for applications with high-speed rotations. This is because they tend to produce axial thrust force, which can cope up with the extra forces. They can be combined with many gear teeth of the paired gears. They tend to operate smoothly because of the way that the gear teeth interact. In this case, its teeth tend to cut at an angle, which faces the gear. When the teeth engage, the contact tends to be gradual from the end of a tooth, and this engagement is maintained as the gear rotates. This kind of gear is mainly used during transmissions. The other two gears are NSS1630 spur gears with thirty teeth and is the most commonly used type of gear. In this case, the tooth of the gear contact through rolling. During disengagement as well as engagement sliding may also occur. As this type of gear is used, some noise may be produced. However, at high speeds, the noise may become objectionable. This type of gear is easy to produce. Additionally, this gear is easy to use; as it does not produce any axial thrust forces. It should be noted that there is no minimum number of gear teeth that can be paired in these gears. It consists of two pairs of gears in which case the larger gear is known as the gear while the smaller one is referred to as the pinion.

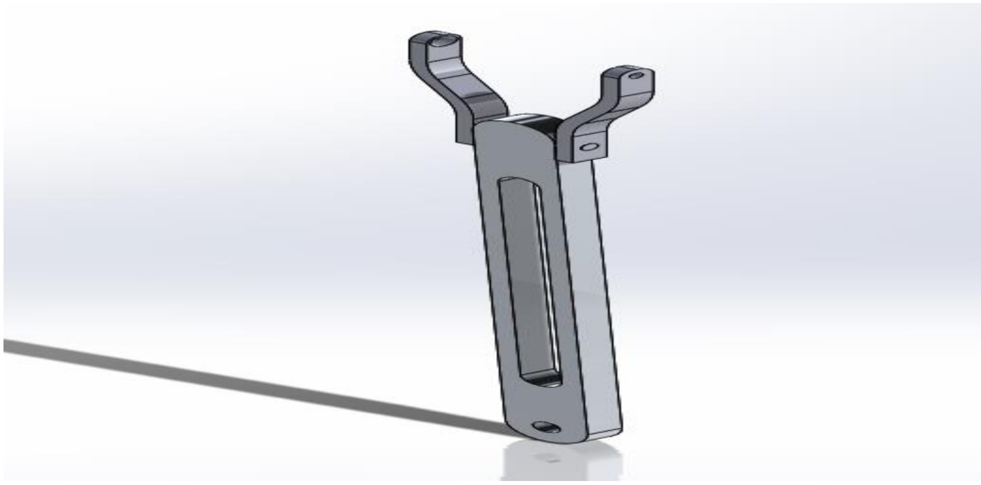


Figure 7.1 F capsule holder

For the shafts they are made up of steel. The shafts are 1/2 in diameter to be assembled to the gears by key-ways that was manufacture at K&M machine shop. Three shafts were used the first shaft is assembled to the handle crank and to first drive gear which 40 teeth. The second shaft is driven by the first gear. The second gear which 30 teeth are attached to the second shaft and the second gear in this case are driven by the first gear. The third gear, which is 40 teeth, is attached also to the second shaft. Shaft 3, which is assembled to gear 4 which 30 teeth and it's attached to outlet arm and capsule holder. The capsule holder was made from spring steel light in weight. Also, spring steel is tough, hard, resistant and flexible to wear, self-lubrication, chemicals thus suitable for making the casing. For the cover case is made from Lexan polycarbonate, which is thin and transparent to ensure good visibility and hence easy monitoring of the whole process. It is also resistant to scratching, not brittle, its density Lightweight, and stronger than glass. The bearings were ordered from McMaster and it was 6 bearings. The bearings were attached to the four gears and both the input and output to create smooth motion of the gear box with less friction to get to the needed speed. The input handle is from aluminum and the grip from polymer. The handle has been manufactured on K&M machine shop and the requested to add key-way so it can be attached directly to the shaft. The output section which the plate and the capsule holder both of them manufacture at the same machine. The group was in intend to make capsule holder from 3D printer at beginning then they figure out it's not that quality of the spring steel. Both cad model and actual device are the same exactly with colors and each small part. The group before start building the device they were intend to build a quality device to be used for long time without any issue. The parts were created in solid-works and the group made an assembly for it before building it to guarantee the device is working and to eliminate any errors.

Table 7: Bill of material

Part	**Quantity**
40 Teeth Gear	2
30 Teeth Gear	2
Steel Shafts	3
Housing	1
Capsule holder	1
Handle	1
Outlet arm	1
Outlet base	1
Low-Profile Mounted Ball Bearings	6
Screws	19

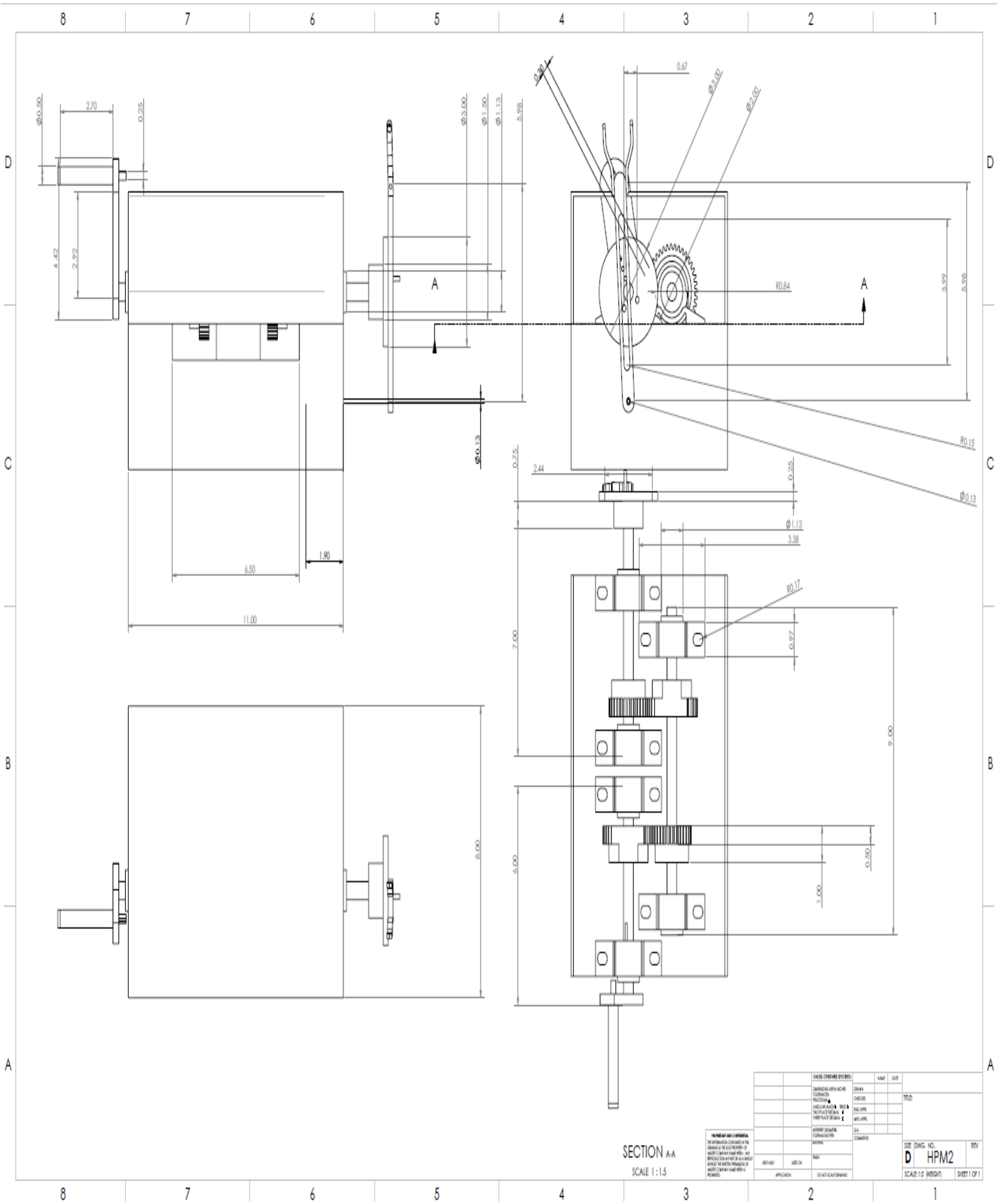


Figure 7.2 Final Design Assembly

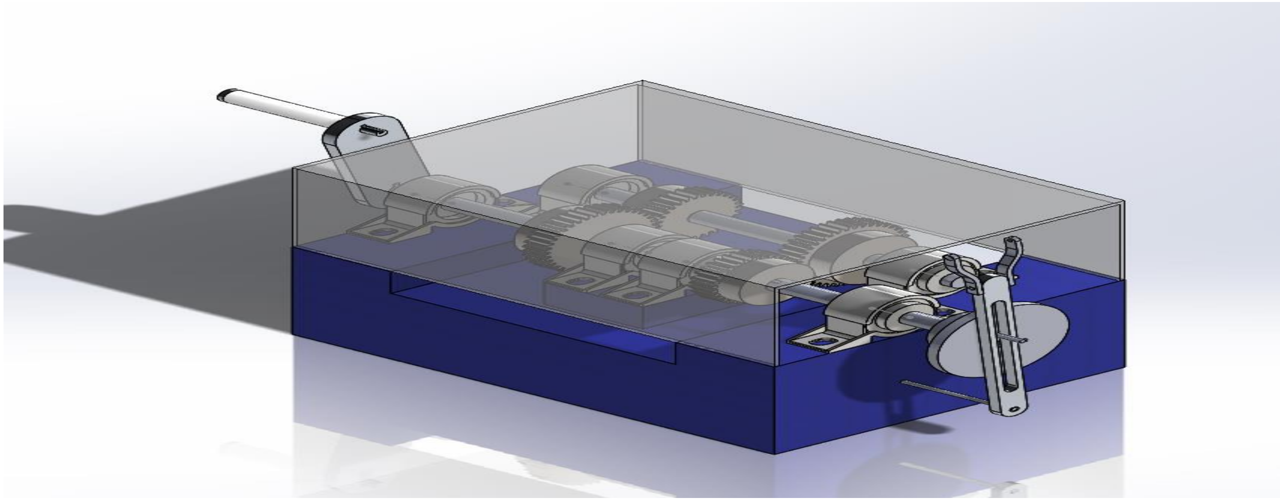


Figure 7.2 b Final cad design

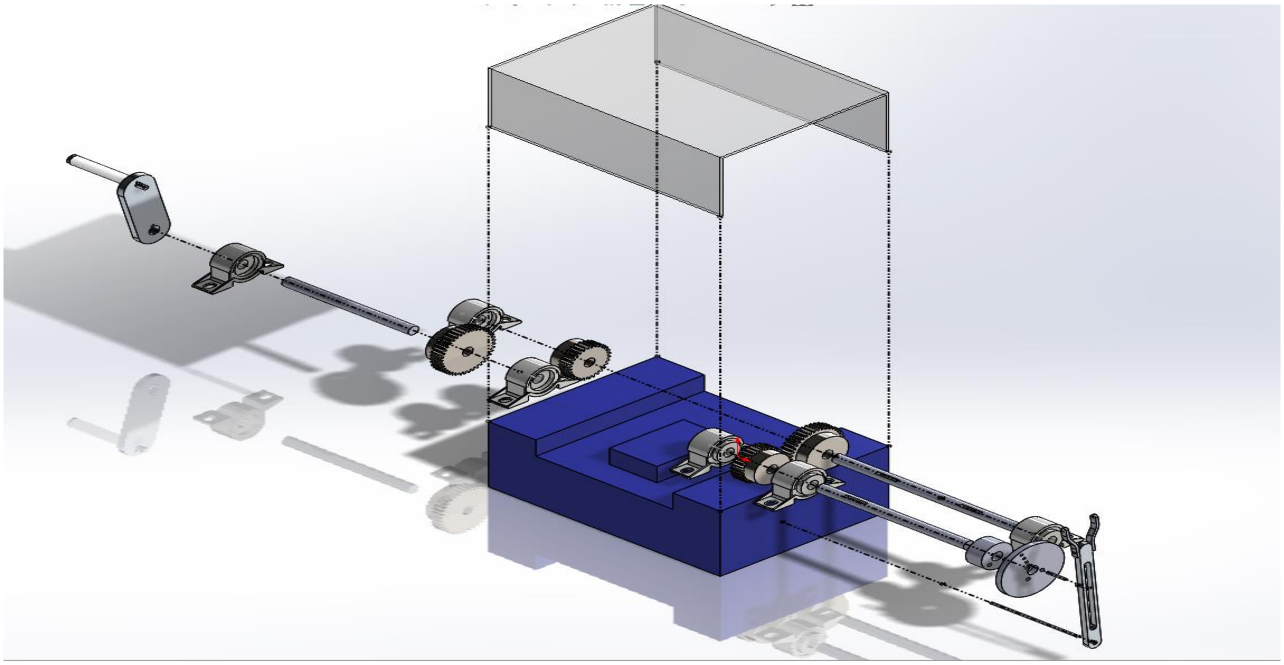


Figure 7.2 c Exploded view of the design

8 Testing

The testing procedure involves the performance evaluation for the device. The team tested the device aligned to the engineering requirements. After building the device the team requested some capsules from the Dental hygiene department. The team was concerned about satisfying the engineering requirements. The device should have enough power to shake the capsule thoroughly to homogeneous liquid and this was satisfied in 50 seconds by human power but in 10 second by attaching drill to the input shaft directly. The second requirement is the long life device. As all the material used is steel, Aluminum, Polymer and plastic case so the device has very quality materials so this requirement has been satisfied. The weight of the whole device is 11lb, which is reasonable to travel with. The safety requirement has been satisfied by the cover case, which has kept the gears out from the hands. The device is easy to operate and can be used two ways, either hand cranking or using the drill directly to the shaft. The mechanism of the device is to shake the capsule thoroughly with enough power, which was succeeded so we reached the homogenous liquid. The tests were conducted by shaking the capsule at different time periods.

Table 10: Time VS Status

10 Seconds	Failed
15 Seconds	Failed
20 Seconds	Failed
25 Second	Failed
30 Seconds	Failed
35 Seconds	Failed
40 Seconds	Failed
45 Second	Failed
50 Second	Successes
60 Second	Successes

Table 9: Requirements due its status

For the unsatisfied requirement 4500 it was not satisfied because the device was working by human power. The team reached the homogenous liquid with no need to reach the speed of 4500 rpm the reason being is that is the time has been increased to 50 S.

Table 9: Requirements due its status

Requirement	Status
The device should have enough power to shake the capsule thoroughly	Satisfied
The device should have enough power to shake the capsule thoroughly	Satisfied
10s to shake the capsule	Ambiguous
Safety	Satisfied
Easy to operation	Satisfied
Stability	Satisfied
4500 rpm	Not satisfied

9 Conclusion

This semester, the second part of the project capstone was undertaken. The major stakeholders that will benefit from the success of this project include the dental hygiene and mechanical engineering departments at NAU, in addition to the dental hygienists around the globe. The team's main objective was to successfully design a human powered dental mixer capsule of mixing a capsule in 10 seconds. During this semester, the team was able to come up with several solutions before coming up with an initial design of the dental mixer. However, several difficulties were met along the way. However, the project capstone done and all the necessary preparations have been met at the end of the second semester. With this regard, it is essential to review the experience of the team during this semester when undertaking the capstone project for the purpose of identifying the successes and challenges met so as to ensure the second semester of the project is undertaken more smoothly. The team was organized in spreading the work with each team member's efficiently. The design manufactured of a dental mixer powered without the use of electricity, and to follow strictly to the design requirements. Under the leadership **of Majed Bourosli** who acts as a project manager, the team was able to properly design the dental mixer. However, there were several challenges met during the second half of the capstone project. Most of these challenges were about the time management as the second half was just two months and the NAU machine shop was closed at the summer time. In this regard, the team was working in K&M machine shop as the got sponsored by them.

9.1 Contributors to Project Success

The team was able to complete the goals and purposes that were stated in the Team Charter. From the Team Charter, the team's main objective was to successfully design and manufacture a dental mixer powered without the use of electricity, and to strictly follow to the design constraints. Also, according to the Team Charter, the team was willing to contribute significantly and manage the project solidly and work hardly to deliver a quality final deliverable. All team members were expected to work productively to gain a decent yet a deserved final grade Project Team Charter 1. With this regard, the team was able to come up with a suitable design that was an improvement to the current dental mixers available on the market. However, the 3 D CAD drawing has been created. For the purpose of ensuring that the team successfully completed the project, there were several ground rules established in the Team Charter.

The five major aspects were mentioned. Firstly, the team was to stay focused on the purpose and goals. Each member was to be focused in group meetings and work hard towards developing our project. Thus, all members were assigned specific tasks to work on based on their expertise. This collaborative effort paid off in the final design. Secondly, there was to be the consideration of different point of views. Team members were to listen to all ideas and point of views of group members and consider them and give each group member opportunity to work. The team manager was instrumental in ensuring that all views put forth by the team members were carefully considered into the realization of the project goals. Thirdly, each team member was to always be respectful. They should respect each other and be friendly with all people involved. Since all the members knew each other prior to the project, it was relatively easy for all of them to get along. Fourthly, each team member was to always be on time for group meetings.

They were expected to show up on time for all group meetings. If not, group members were to warn a specific individual at first time and if the behavior persisted, it would lead to the reduction of the culprit's performance in the group peer evaluation. Needless to say, all group members strictly adhered to this aspect since nobody wanted to be a victim of its repercussions, especially considering the significance of the capstone project for the final grades. Finally, it was expected that there would be the delivery of tasks in a timely manner. It was established that the group due dates were to be before the original due date by at least two days. The aspect was also adhered to closely, and it helped the team to complete the first part of the capstone in a timely manner. Overall, in relation to the contributors to project success, there were several aspects of project performance that proved to be the most positive. The major one was time management.

Based on the guidelines set on the Team Charter, it was easy for the team members to adhere to time restrictions due to the penalties that would befall them. Moreover, since each member had specific tasks to carry out, it was easy to work faster and manger time effectively. There were also numerous tools, methodologies, and practices contributed to the strong aspects of the performance. For instance, the team came up with ten different probable designs that could be used to implement the project. In this way, the team was able to comprehensively compare all of these designs and subsequently choose one of them to be applied. The chosen design was to be fairly cost effective while offering the optimal dental mixer that could be conceived on the provided budget.

9.2 Opportunities/ Areas for Improvement

Although there were several positive aspects of project performance that contributed to the success of the first half of the project, there were needs for improvement. The 3-D CAD model was altered three times due to the change of the gears size and the device size. The group was a little rusty on how to use the solid-works since most of the members haven't used it since 2014 in the ME180 course. The importance of a CAD drawing is to ensure that one gets the visual representation of the actual product and carries out a simulation and stress analysis of the final product.

As for the tools, methodologies, and practices that contributed to the weakness of the performance, it is clear the methodologies selected to conduct the design was not thorough enough to cover aspects of all the manufacturing processes expected. Apart from these aspects, there were certain problems, which the team encountered during the execution of the project. One concern was regarding the financial aspects of the project. There were not sufficient funds available for the project which were necessary to manufacture the device. However, this issues was resolved by K&M machine shop sponsoring the project which is helped with the budget. Secondly, there was an issue with communicating with the client. Mohammad's duties were to contact the client, obtain information regarding the project, and make sure to deliver all requirements that client needs to the group members. Mohammad's responsibilities were to communicate with the client to provide her with the brief information about what the team was doing at this point regarding of the project. The client was unaware of all the mechanical terminology which made it difficult for her to understand.

Lastly, time was an issue because the second semester is only two months. There are certain organizational actions, which can be taken for the purpose of improving the overall team performance. One of them is through the revision of the Team Charter. Since the Team Charter provided the guidelines to be followed by each team member during the second phase of the project, the subsequent problems arose from it as well. However, after the experience gained by the team members, the overall outcome was the device was a success as the capsule has been shaken to homogenous liquid. Under the leadership of Majed Bourosli who acts as a project manager, the team was able to successfully design the dental mixer. However, as seen from this analysis, there were several challenges that were met during the capstone project. It is the reason it has been vital to conduct a comprehensive analysis of the team's experience during the design phase of the project with the aim of recognizing the strengths and weaknesses encountered in a bid to ensure that the overall performance of the how the project is conducted can be improved. There are several specific technical lessons that the team have learned from the execution of the project. Firstly, it is crucial for one to realize that the first idea of a project is not necessarily what will be used. After the comprehensive research, one has to come up with several ideas and analyze them before coming up with a final design. Secondly, it is crucial to utilize time well in order to cater for any technical difficulties that one might face along the way. Overall, regardless of the challenges faced, the first section of the project capstone has been successful. The key details of the expected dental mixer have already been discussed among the group members and approved.

10 Appendix

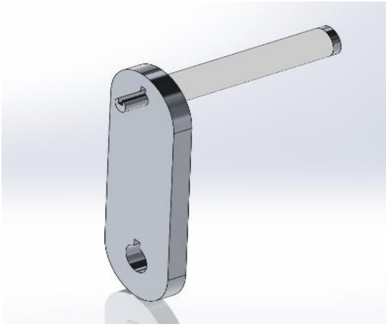


Figure 10.1: HANDLE CRANK

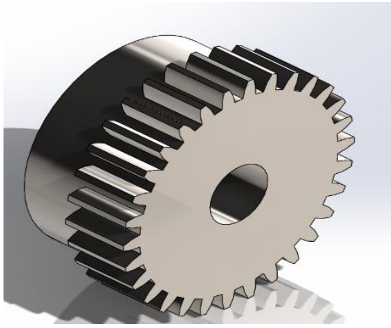


Figure 10.2: Gear 30

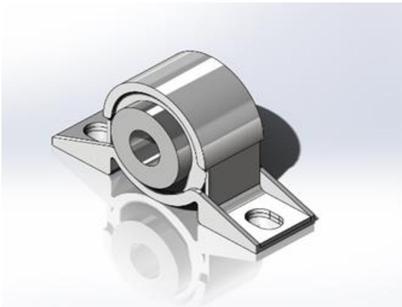


Figure 10.3: Bearing

Figure 10.4: one of the small's shafts

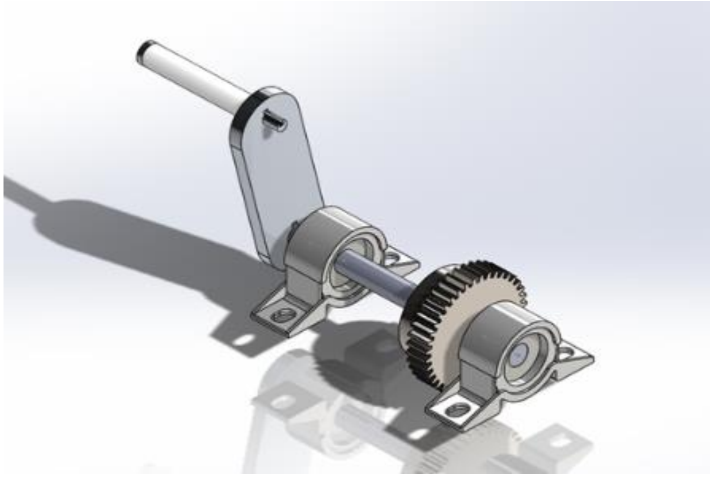


Figure 10.5: The 1st Shaft

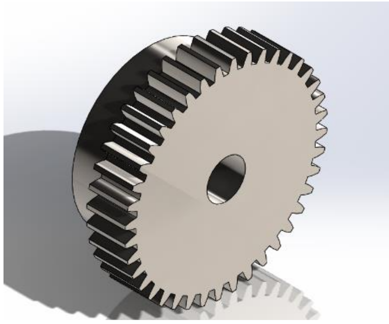


Figure 10.6: Gear 40 Teeth

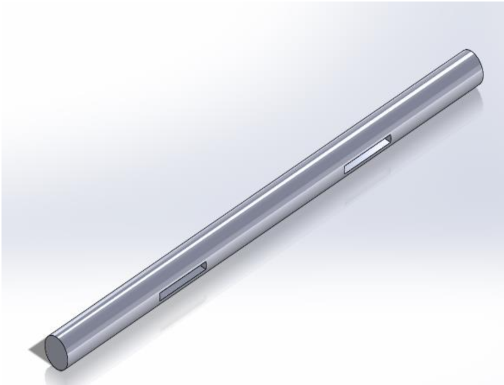


Figure 10.7: The Tall Shaft

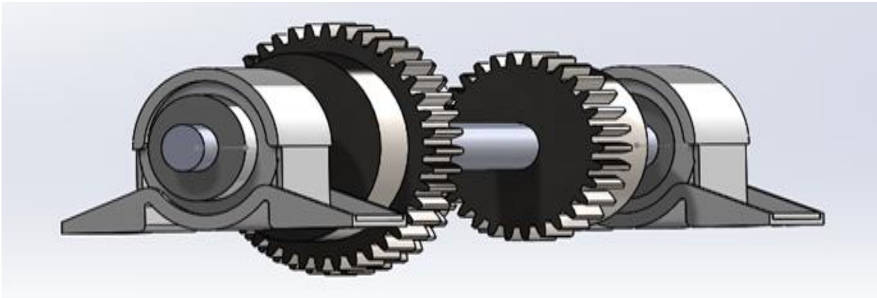


Figure 10.8: The 2nd Shaft

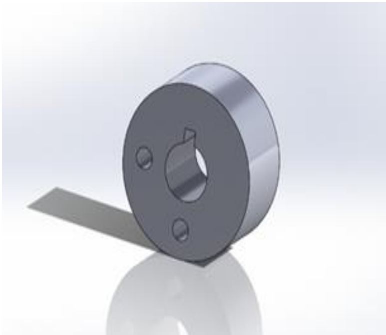


Figure 10.9: Outlet base

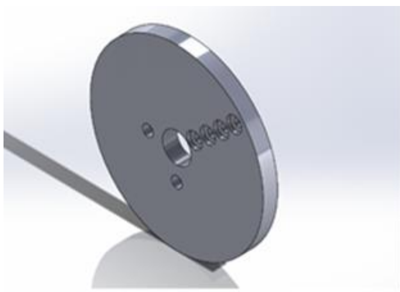


Figure 11 CD outlet

Figure 10.10: CD outlet

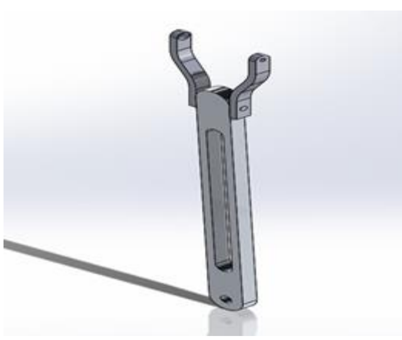


Figure 10.11: Outlet Arm

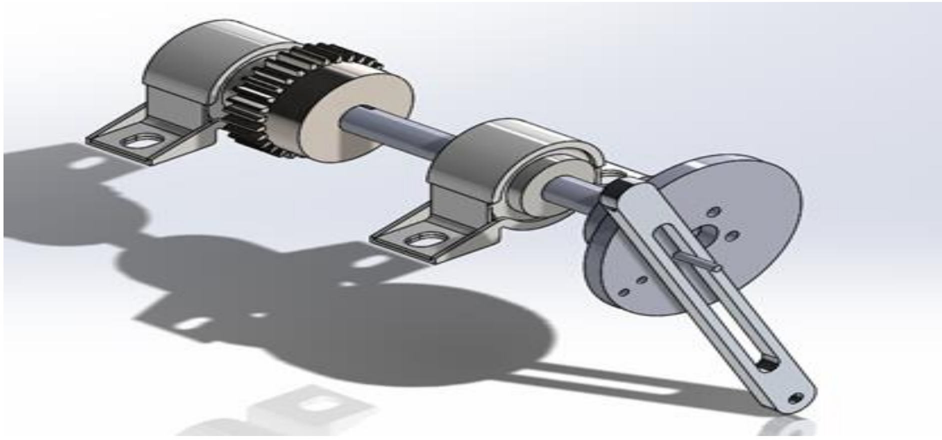


Figure 10.12: The 3rd Shaft

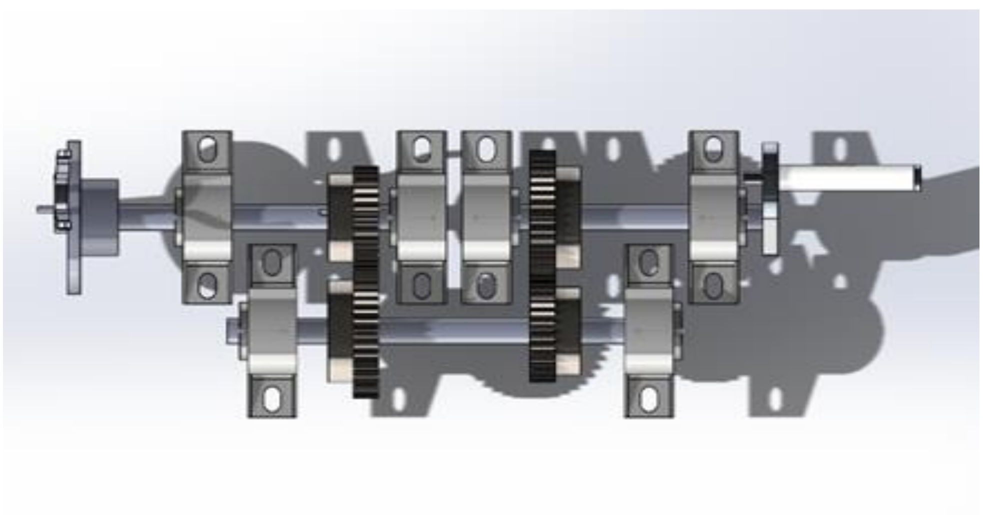


Figure 10.13: Top view of shafts

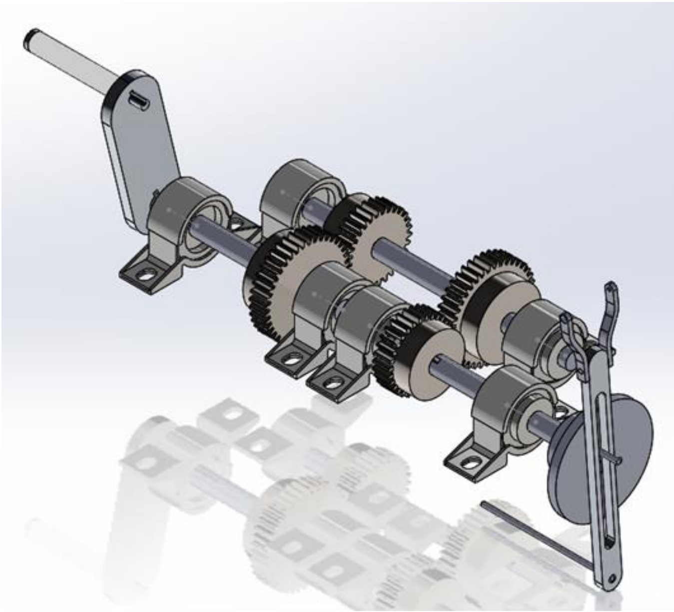


Figure 10.14: ISO-View of shafts

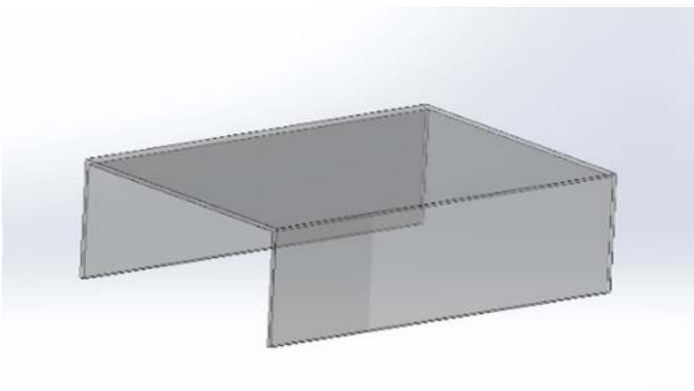


Figure 10.15: Cover Case

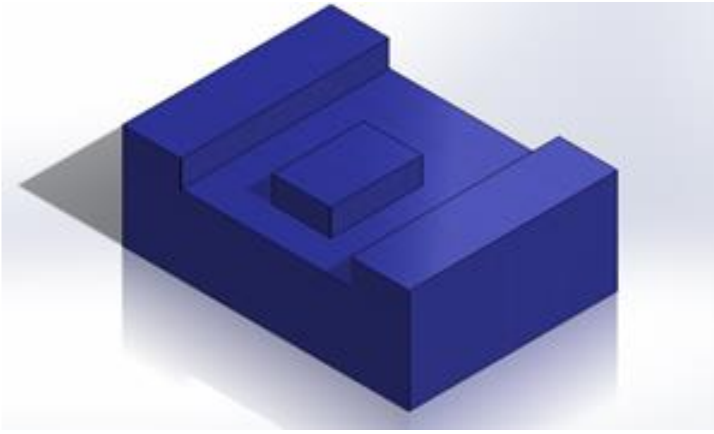


Figure 10.16: Wooden Base

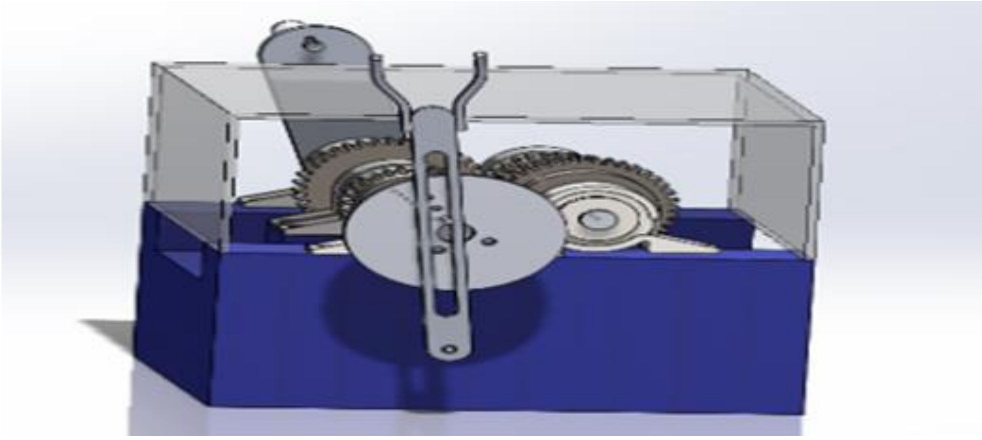


Figure 10.17: Final Design left-side view

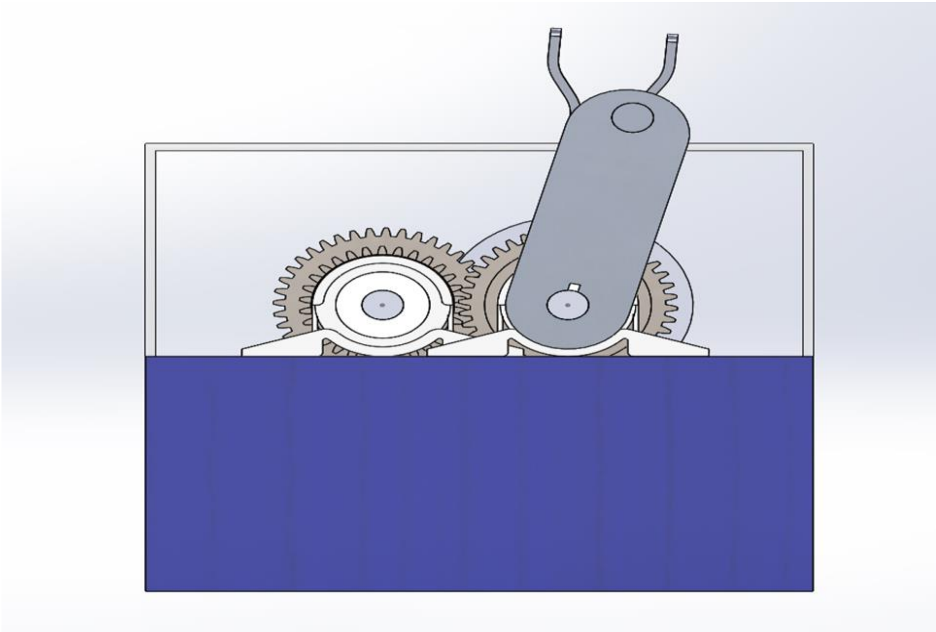


Figure 10.18: Final Design Right-side view

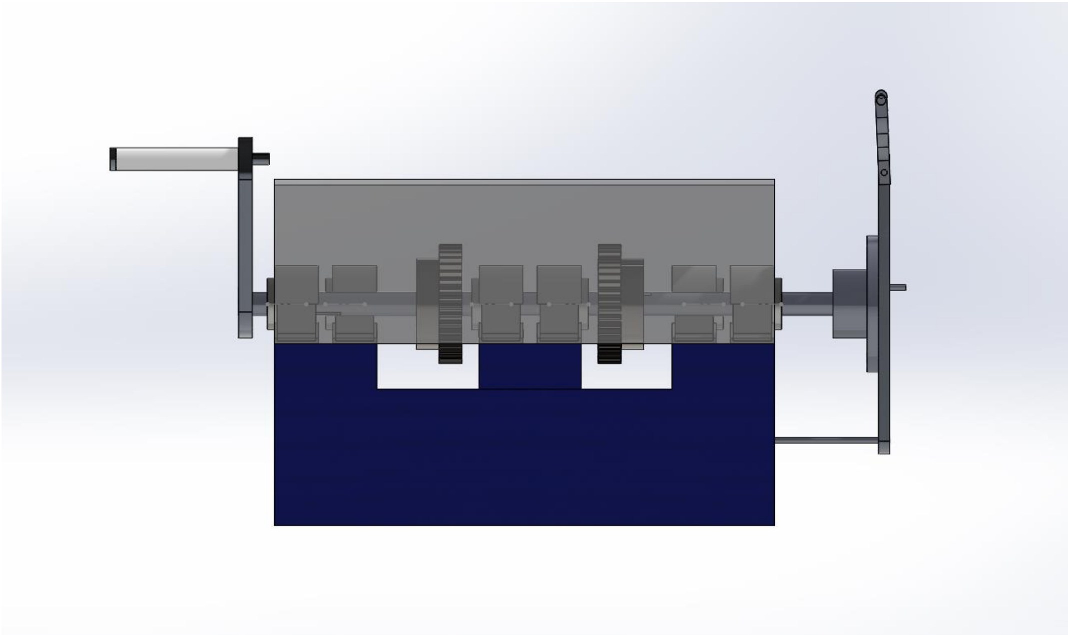


Figure 10.19: Final Design Front side view

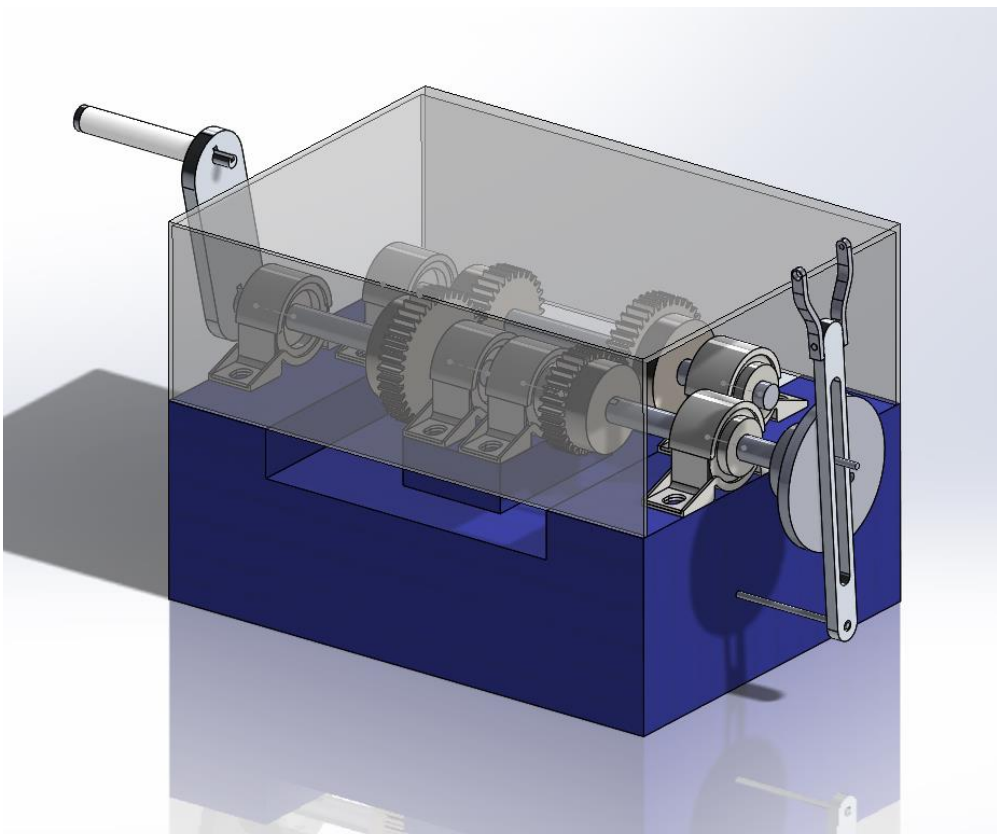


Figure 10.20: Final Design ISO-View

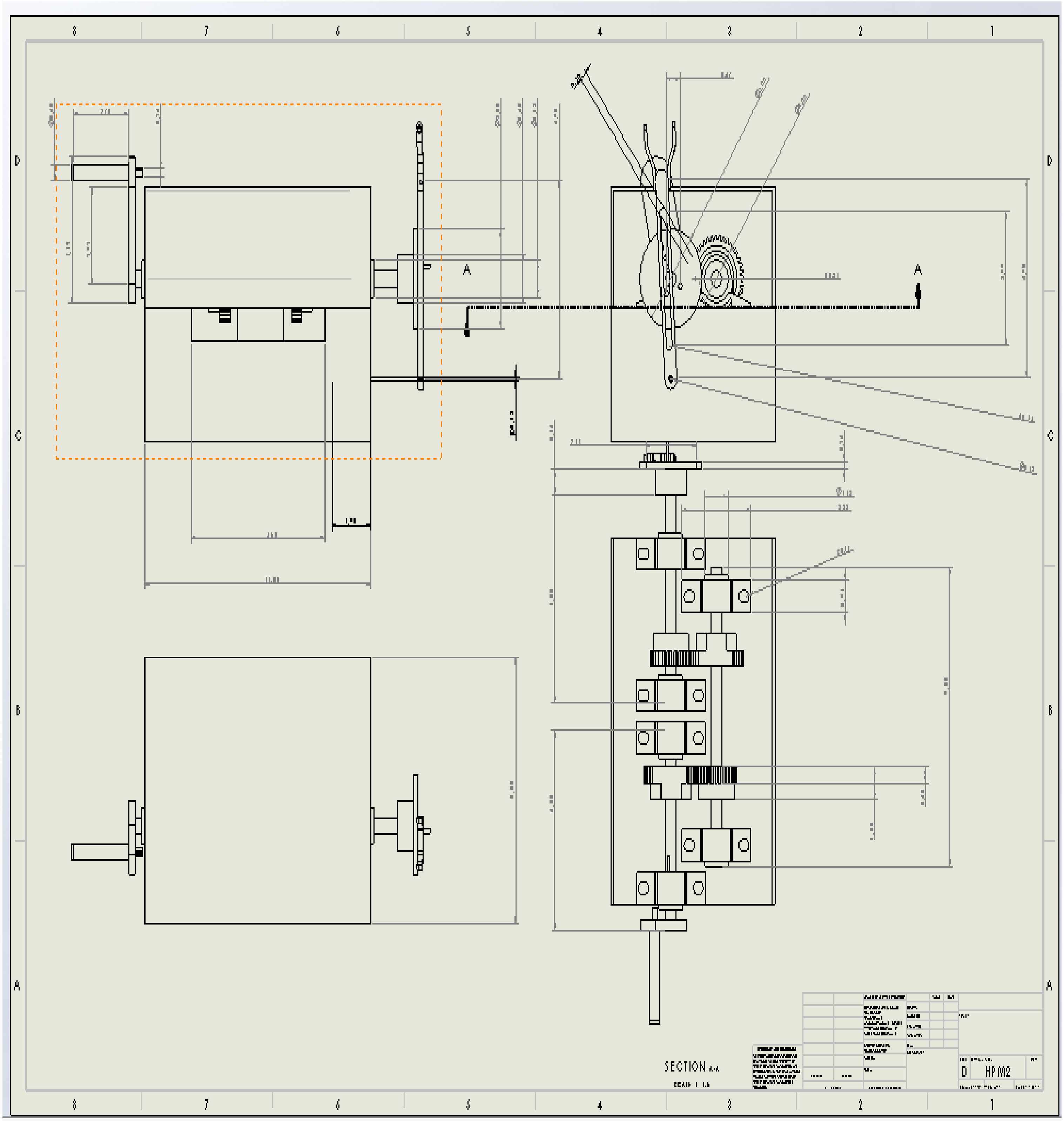


Figure 10.21: Final Design Drawing

Figure 10.22: Actual Device

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