Human Powered Dental Mixer (Team I)

Department of Mechanical Engineering

Final Proposal

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1 BACKGROUND

1.1 Introduction

A dental Triturator forms the basis for this project. This project is all about the schematics that go with the Triturator and the efforts that the team has applied to make changes to this device. The changes the team have instituted are informed by a need to have a more user friendly Triturator especially for the student users who are finding it hard to cope with the existing dental triturator. The team set out with the chief objective of making a hand driven Dental Triturator. 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 other subsequent minor objectives that were informed by the customer needs. However, the above three 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 student travel abroad 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 project description from our sponsor "A dental triturator 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 triturations are not compatible with international outlets. Collaboration between NAU's Dental Hygiene (DH) Dept.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 one is that the model that the team had to make was 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 mixer uses ten seconds to mix the dental formulation. [1] This purpose therefore informs the desire to keep the time that is used 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 oversee assignment and work as such.

1.3 Original System

What is being undertaken in this project is not something entirely new. This is because there already exist a 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 triturator. There are various types of dental triturators that are there. 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 triturators. This is also the most basic factor that the redesigned model will alter in the triturator.

1.3.1 Original System Structure

The original system comes in different particulars but there are some structures that are generally the same for these devices. One of the common features is the size. Most of the devices have the dimension of 7 Inch by 10 inches by 9 inches.

There may be some variance to these measures but they are never all that far from the dimensions that have been mentioned above. 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 is the one that mixes the capsule.

1.3.2 Original System Operation

The operation process begins with the plug in of the power cable into a socket. Current flows into the mixer to the lower compartment where the motor setup is located at. 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 common place 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 weight only 20 grams. There is therefore 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. There are other uses that the dental triturator is put to other than mixing of the capsule. The time scale that the device has is testimony to this. The performance of the original system is characterized by a motion that has a periodic time of 4000 revolutions per minute. 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

The device is as good as the best when it is working in an environment where there are the ideal conditions. However, in places where the conditions are less than ideal, the device slowly becomes useless. 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 carton as it is so rugged.

2 REQUIREMENTS

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 itself. 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 design requirement sets for the first set of the criterion of the customer needs that needs to be met by the redesigned model. 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 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 could be reduced for the device, there are many customers who would be glad. Students like travelling with bag packs and if it could fit in a bag pack, it would do a lot of good to the students.

Table 1: Relative weight of the customer requirements

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

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.

2.3 Testing Procedures (TPs)

Testing procedure that will be carried out will be to ensure that the device does meet the demands of the customers that they have. The testing procedures will be carried independently. This means that one will be carried out and then the subsequent ones will be done afterwards in the order that they follow each other. The first one which rather critical is the speed that needs to be attained. We stated that we need a speed of 4000 revolutions per second. This can be done by the use of a stroboscope. This device measures the frequency of oscillating objects. There hooks that are used to hold the capsule are in oscillating motion. The second testing procedure entails testing the safety of the device. The safety compromise comes in if there are some parts that are loose. A capsule can be placed in the space that it is supposed to be place in and the device operated. If the capsule comes loose or any other part, then the device is not secure. After the operation, the device should also be checked to see if any of the parts have adjusted or if they are at the places where they are usually at. The other testing procedure is the performance of the task. The task to be performed is mixing of the dental capsule. A capsule should be shaken with the mixer and then the content checked to see if there had been a thorough mixing of the content of the capsule. The time aspect also needs to be tested. A stop watch can be used to make this timing. After the timing has been done, the capsule should be removed and a test done to find out if there is a total mixing of the content of the dental capsule.

2.4 Design Links (DLs)

The human hand is the one that provides the torque for attaining the needed speed and power. To attain a speed of 4000 revolutions per minute, there is a need to mechanically multiply the human power by a factor that is appropriate to reach this needed power. The various systems that are targeted can be able to reach this speed. One of them is the gear system multiplications that can be able to reach this needed speed. This is the most viable option though it is subject to verification through other analysis tools. In an event that there is an alternative method that is used that entails the spring; they will have to produce a resonance that can make the 400rpm possible.

To ensure there is safety in the device, we have voted to use plexus glass. This material is characteristically famous for being tough and therefore it can be regarded as being safe. There are no materials that can break through this glass and it is therefore ideal for our purpose. Use of light materials for the design will aid in two areas. One, it will help to make maximum power to be available for shaking the capsule. With a maximum power, there will be more power within the ten seconds; the capsule will be completely mixed. The second thing that it will help in making the overall weighs of the device to be little. We need to meet this requirement that was outline earlier on.

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.

Table 2: House of Quality

House of Quality (HoQ)

Customer Requirement	Weight	Engineering Requirement	Takes 10 seconds to shake *	Speed 4500 rpm *	Mixing Energy *	Lighter internal materials have a 2-3 yr life expectancy *	Heavier internal materials have a 5-10 yr life expectancy *	Cost—Y
1.Use of human power to power the device	5		9	9	6	3	1	3
2.Light weight	4		3	3		9	9	6
3.Smaller size	3			3		6	6	3
4.Durablility	2		3	6	6	3	3	
5.Easy to use	3		3	3	6	1		
6.Transparent compartment	1		3		3			1
7. Safe	3		1		6			6
8.Stability	2		6	3	1			6
9.Quality of part	3		6	9	6	6	6	9
Absolute Technical Importance (ATI)			108	111	101	96	83	106
Relative Technical Importance (RTI)			1	2	3	5	6	4
Target(s), with Tolerance(s)								
[add or remove T/T rows, as necessary]								
Testing Procedure (TP#)								
Design Link (DL#)								

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 triturator. '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 triturators are in the world. Many of the sites had repeated information that was in other sites as well. There are about five types of triturators that the team were 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 were keen to check was if the system did use any power or 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 Triturator

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.

3.2.2 Existing Design #2: Jains Triturator

This design is made of a gears cogs and sprigged system. The gears multiply the power and the spring's offers the return force for the transfer of the force from the triturator 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.

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.

3.3.1 Subsystem #1: The sprigged rod

In the subsystem, there is the rod that is at attached to a spring. The spring receives the depression and then gets released. When the spring is released, it bounces back and oscillates at a certain speed. As it oscillates the capsule bounces up and down with the rod that is holding it.

3.3.2 Subsystem #2 sprigged box

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 sprigged 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 self. 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 Deceptions

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 triturator. The team seek to make the hand powered dental triturator 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.
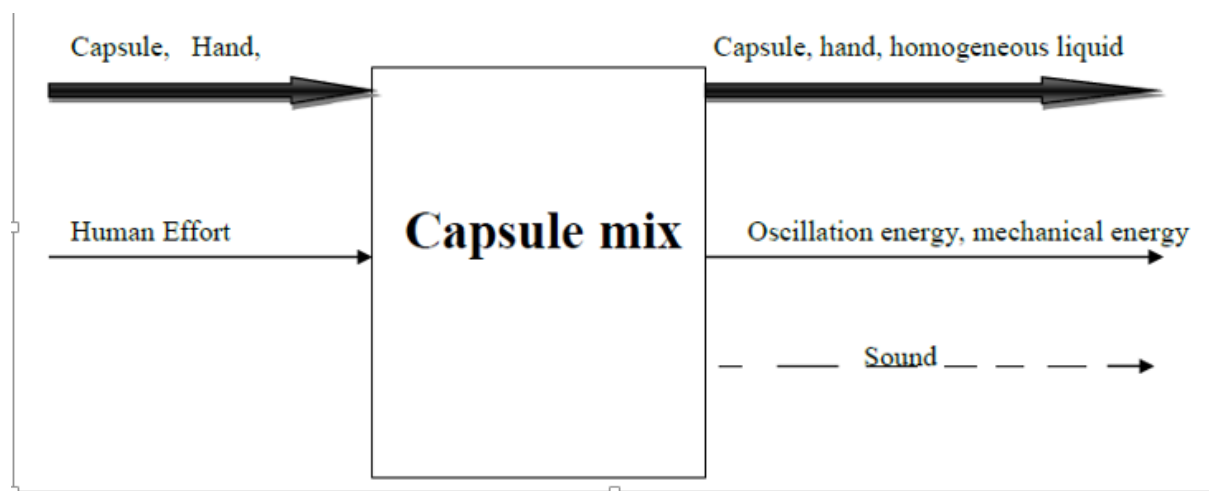
3.4.1 Black Box Model

Figure 1: Black Box Model
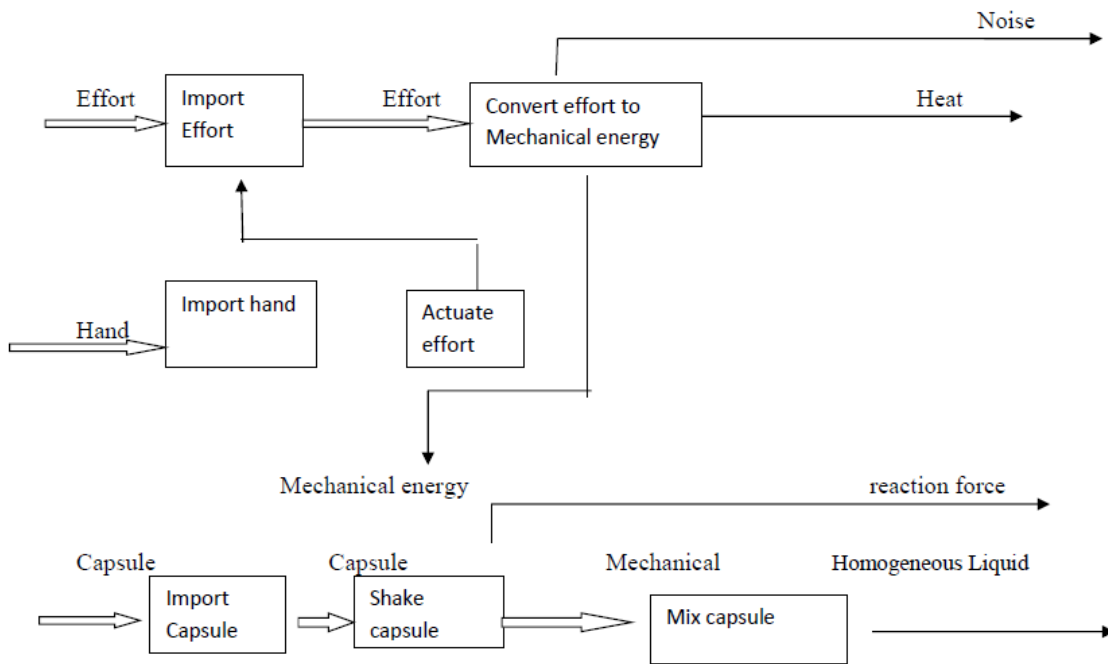
7

3.4.2 Functional Model

Figure 2: Functional 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 go the designs that are considered for this the hand powered dental triturator.

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 well mixed.
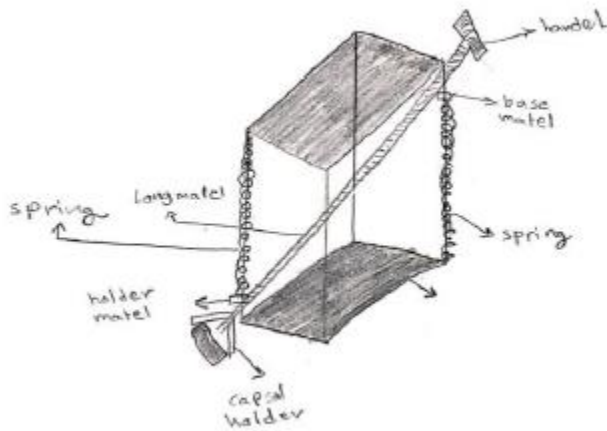

Figure 3:Resonate Box

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.

Figure 4:Vibrating Spring

4.3 Design #3: Gear Triturator

The gear triturator 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.
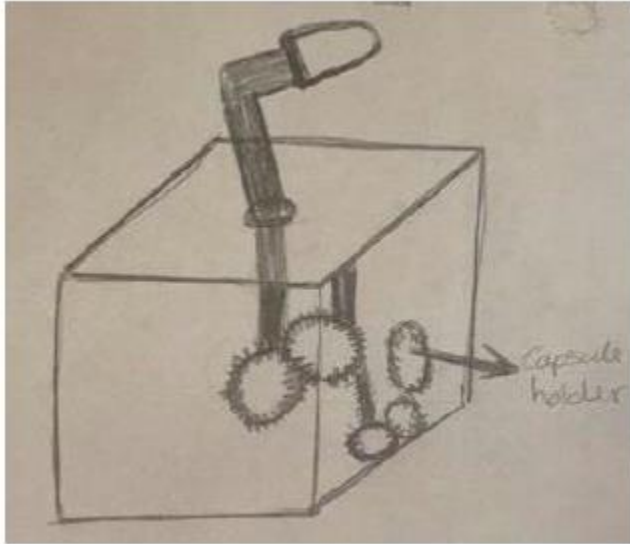

Figure 5:Gear Triturator

4.4 Design #4: Sprigged Pipe

In this design, a pipe contains a spring. On one end, there is a faucet that 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.
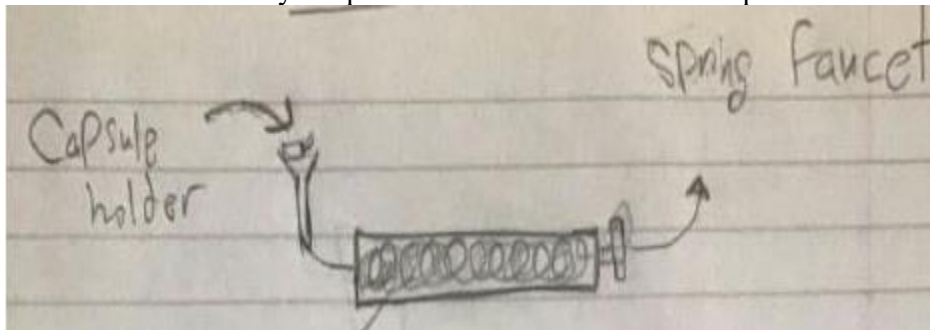

Figure 6: Sprigged Pipe

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.
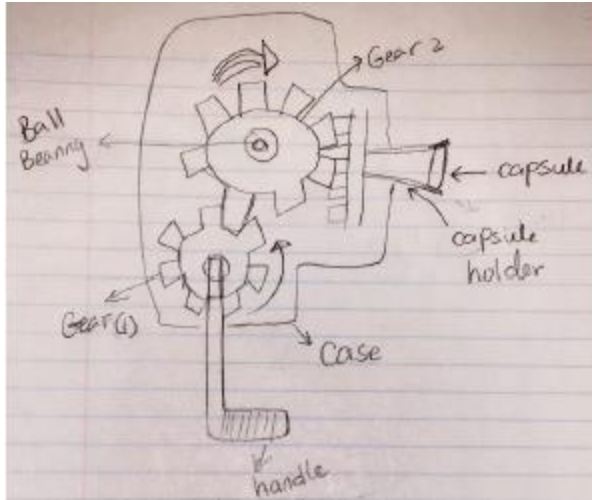
Figure 7: Bearing

4.6 Design #6: Solar Powered Model

The solar power can be a great source of energy to drive our triturator. The solar panel replaces the cable system that supplied power to the original model. The solar panel is connected to a storage unit for power that is used to drive the motor
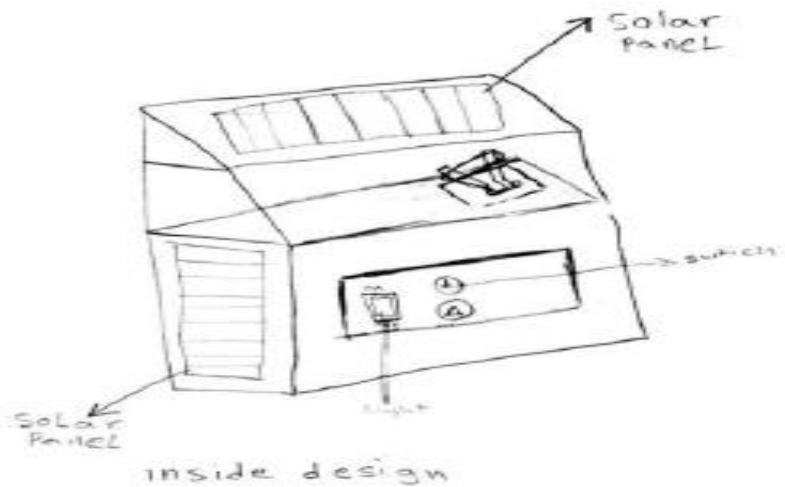

Figure 8:Solar Powered Model

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.
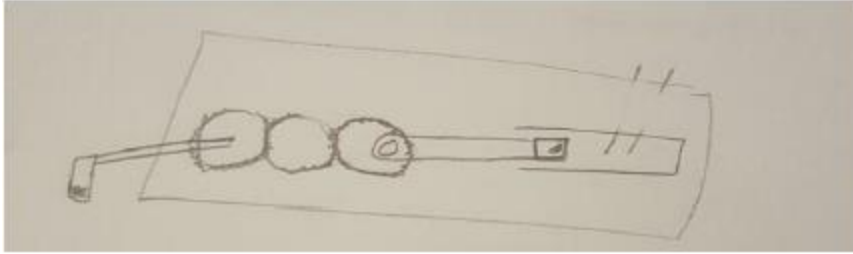
Figure 9: Series Gears

4.8 Design #8: Single Pulley

This model has is made of a single gear that is attached to a triturator. 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.
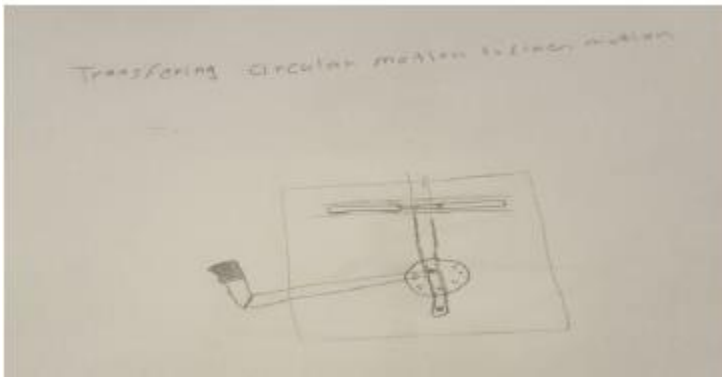

Figure 10: Series Gears

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.

Table 3: 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.

5.2.1 Gear Ratio Analysis.

To achieve the best gear ratio, a gear train will be used to determine the amount of output kinetic energy. 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 a handle to initiate the rotation that 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 gearbox 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.

The gears are connected to the holder of the capsule. The device obtains its initial drive from the spring that converts the circular motion provided by the human hand to a vertical power, which is fed to the gear system. The following equations will be used to determine a gear ratio of the gear train.

If the number of teeth in the driving gear is $N1$

The number of teeth in the driven gear is $N2$

Therefore, the ratio between the first two gear will be.

$$Gear\ ratio = \frac{N2}{N1} \quad \text{........ Eq. 1}$$

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 the driver while the last gear in the box will remain the driven. 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 ratio is the relationship between the input speed to the output speed, and it is typically written as

$$Gear\ ratio = Win : Wout \quad \text{........ Eq. 2}$$

Therefore,

The system is made up of four gears, namely 1,2,3 and 4.

If the number of teeth in gear 1, is $N1$.

The number of teeth in gear 2 is $N2$.

The number of teeth in gear 3 is $N3$.

The number of teeth gear 4 is $N4$.

The driven becomes the driver in the next pair of gears.

And hence,

$$Gear\ Train = \frac{N2}{N1} \, x \frac{N4}{N3} \quad \text{........ Eq. 3}$$

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.

$$T\ in\ W\ in = T\ out\ Wout \quad \text{...... Eq. 4}$$

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

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

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

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

$$\frac{Speed\ in}{ratio} \ \text{..............} \ Eq.\ 8$$

$$Torque\ out\ = Torque\ in\ x\ Gear\ Train \ \text{......} \ Eq.\ 9$$

Results

   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 1 is 31 teeth, gear 2 is 15 teeth, gear 3 is 31 teeth, and gear 4 is 15 teeth. Therefore, the gear train is determined as shown below by using equation 2.

$$Gear\ Train\ = \ \frac{15}{31}\ x\ \frac{15}{31}$$

Therefore,

$$Gear\ train\ =\ 0.2341$$

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. The same can be confirmed by using equation 8, which relates the speed of a shaft to the gear train.

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

The torque of the initial shaft was 0.25 FtLbs

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

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

Table 4: summary of the analysis and parameters of the design of the Human Powered Dental mixer

Gear	1	2	3	4
Number of teeth	31	15	31	15
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

5.2.2 Material Weight Analysis.

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 7.10 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.

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 5

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 (ºC)
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.

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 was the next best alternative, 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.

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.

Table 6: Manufacturing Parts

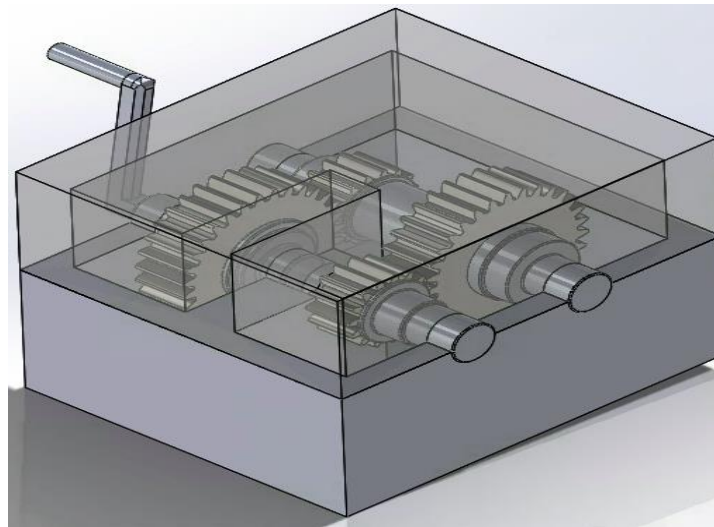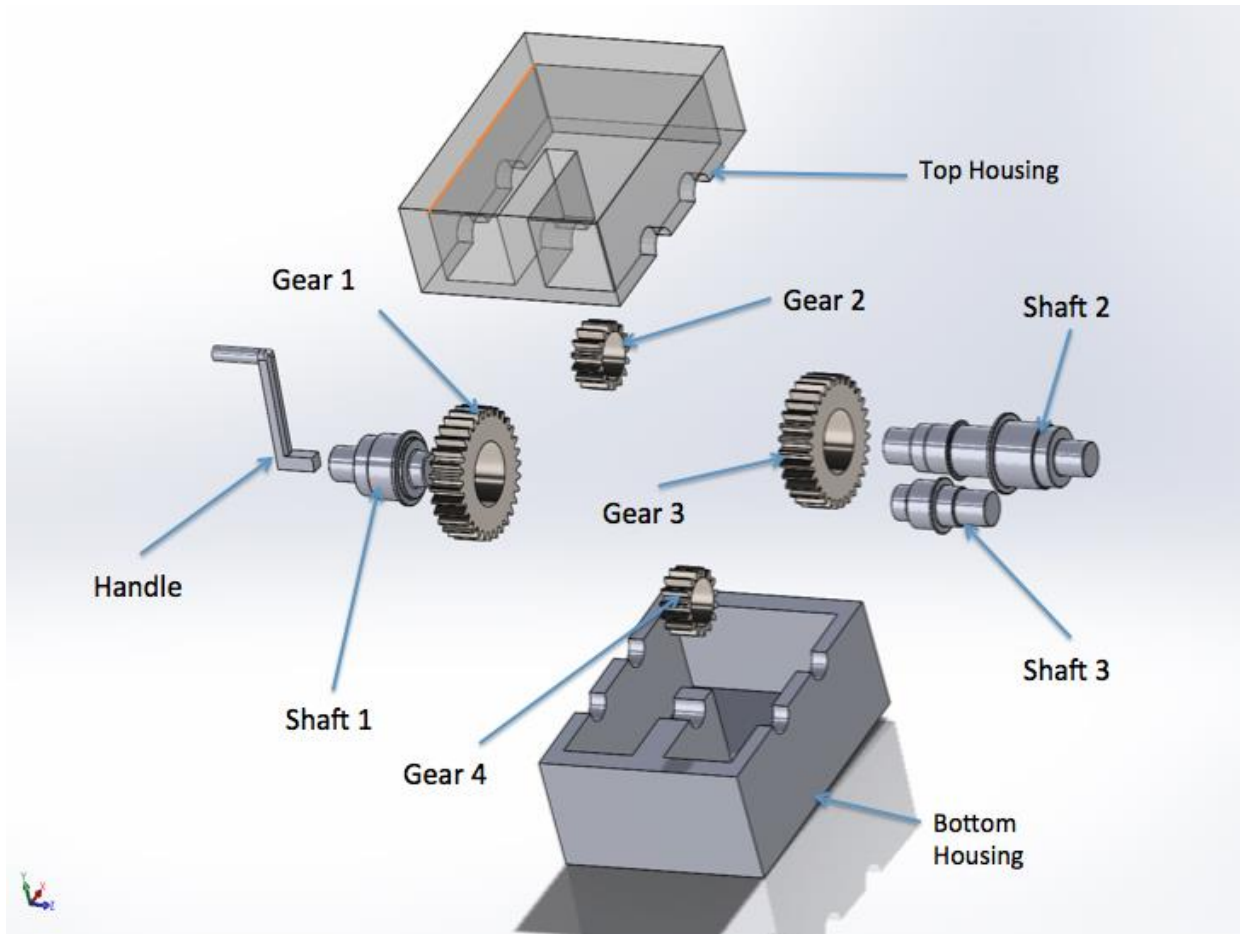| Part	Quantity	Estimated Cost
31 Teeth Gear	2	2x$50
15 Teeth Gear	2	2x$30
Shafts	3	$500
Housing	1	$120
Handle	1	$20

Figure 12: CAD Design

Figure 13: Exploded View CAD Design

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