Human Power Dental Mixer

Preliminary Proposal

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1 BACKGROUND

Most of the dental triturators use a central power source in order to work. Due to this, there is a need to have a dental mixer that doesn't use electricity from a socket. Because the dental hygiene department her at NAU will be sending student to some poor countries such as morocco and other countries in Africa. Moreover, these countries have many villages that don't have access to electricity. Our Mechanical engineering team will be creating dental mixer that does not use electricity from the socket but rather from a set of batteries held within the device.

1.1 *Introduction*

A dental triturator is a device that is used to mix amalgam for many dental proposes. Each year the NAU dental department sent student to poor countries in Africa and Asia so that the senior student practice what they have learned and help people that don't have access to dental clinic. Most of the triturators on the market use high electric power from the wall to work. However, many of these poor countries do not have access to electricity. For that reason, the Dental Hygiene department requested from the senior student from Mechanical Engineering to design a triturator is that does not use electricity from the wall however it can use a manual, solar system or battery power in order to help them fix this problem.

1.2 *Project Description*

The following is the original project description provided by the 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 triturators are not compatible with international outlets.
Collaboration between NAU's Dental Hygiene (DH) Department and NAU Mechanical Engineering Department (CHHS and CEFNS) have created this spring 2017 capstone project for 3-6 mechanical engineering students to create a human powered mixer that can shake a capsule for 10 seconds."

1.3 *Original System*

Our project is considered as a re-engineering project. The original system is an electronic device that needs a specific amount of voltages in order to shake the capsule for 10 seconds. Mixing speed is between 3000 rpm to 4500 rpm. With the existing electronic triturator, the challenge is that it is not compatible with the existing outlets of certain countries and sometimes, lack of power in some places makes it difficult to use. In order to achieve the expected results, requirements from the sponsor constraints will be followed by taking a number of tradeoffs such as weight, life expectancy and size of the triturator.

1.3.1 Original System Structure

The original system was built of metal gears, heavy plastic, rubber, plastic handle and a metal capsule holder. The heavy plastic is used to protect the metal gears and the plastic handle is to crank the gears. The gears were made of metal with gear oil on it. The shaking part was made of rubber to protect the capsule from damage and also to keep the capsule from falling out.

Figure 1: Human Powered Mixer Prototype

1.3.2 Original System Operation

The existing device uses no electric power to operate. The operator turns the handle at a constant speed for ten seconds. This shakes the capsule back and forth until a homogenous mixture is achieved.

1.3.3 Original System Performance

The original devices uses different gear sizes to increase the shaking speed with the lowest handle cycle possible. The mixer was designed to meet the existing electronic design which shakes the capsule at 4000 rpm and has a self-timing device that stops the shaking at the precise time needed.

1.3.4 Original System Deficiencies

The original device worked in the sense that it was able to shake the amalgam capsule until the proper mixture was achieved. However, the device was very large and very heavy due to the materials used in its construction. Also, there was no guarantee that the user would be able to crank the handle at the required speed and could change from user to user providing inaccurate results.

2 REQUIREMENTS

The Manual Dental mixer is a device that uses human energy to achieve the same result provided by commercial triturators in areas where such devices will not work so that dental care can be provided to poorer parts of the world. To accomplish this, the team took inspiration from existing and working designs and adapted these existing technologies into a new design that reduced both the size and weight without requiring a power source.

2.1 *Customer Requirements (CRs)*

Customer requirements are the first step in the design process. Before brainstorming can begin, the limitations placed by the customer must be established so that all designs from that point forward can be based around these needs. While these needs must be met, some are not as important as others and as such the customer needs must be weighted in accordance with their importance. The project sponsor and chair of the NAU dental department, Dr. Tracye Moore, was contacted in order to create an accurate list of requirements.

One of the most important requirements given to the team is that the device must be as small as possible and weigh no more than 10 pounds to allow for easy operation and transportation. Equally as important as the size of the device is its ability to operate without the use of an external power source due to the fact that the device will be used in areas where there either is no power, or the power available would cause the device to fail. The customer also placed a very high importance on the durability and lifespan of the device. It should be able to be used for at least two years before it needs to be replaced. This goal can be achieved by either having a device with the required lifespan or by making the device capable of being repaired easily and inexpensively which prolongs its lifespan indefinitely. The device must be able to shake the amalgam capsule at the same frequency as the commercial devices, or approximately 4,000 rpm. Another major customer requirement is user safety and usability. This requirement means that the device must be a completely enclosed system that does not expose the user to anything that could cause them harm while making sure that it does not require extensive instruction before it can be used. The customer requirements and their respective weights can be found below.

Customer Requirement	Weight
1. Light Weight	5
2. Human Powered	4
3. Keep Budget as low as possible	4
4. Shake at specified frequency	5
5. Shake for specified time	5
6. Same size as electric model	3
7. Decent life span	2
8. Replaceable Parts	4
9. Easy to use	3
10. Completely enclosed system	5

Table 1: Customer Requirements

2.2 *Engineering Requirements (ERs)*

While customer requirements help guide the design process, these requirements and needs must be quantified so that the customer needs can be measured and evaluated as they are met. These engineering requirements are each tied to an individual customer need and is quantified in a way that can be tested. Each engineering requirement as well as its target and tolerance can be found below.

Engineering Requirement	Weighs 10 lbs	Operating Speed 4,500 rpm	Operating time, ten seconds	8"x6"X8"	10,000 use lifespan	# of tools required	Instruction time	No openings in device	Hold standard capsule	No external energy source
	10 lb	4,500 rpm	10	8"x6"x8"	10,000	0 tools needed	20 minutes training	0 openings	1 Capsule	0v
	+- 2 l	4500	-0.1	1+-	1000+-	< 2 tools	< 30 minutes	< 3 openings	1	0v

Table 2: Engineering Requirements

The first engineering requirement is that the device must weigh 10 pounds at the most. This requirement has a tolerance of two pounds in either direction. This tolerance takes the weight over the customer requirement that was given to us but we determined that an extra two pounds will not negatively impact the portability of the device as long as the size limitation is not passed as well.

The next engineering requirement is that the operating speed must be 4,500 rpm or that the system must enact an equivalent mixing force on the capsule. This requirement does not have a given tolerance as it must be met exactly as we were told by our project sponsor. The amalgam in the capsule requires a very specific set of variables to mix properly, and the mixing speed is one of those.

The next engineering requirement is one of the most important out of the entire list and that is the size. The size limit that we gave our device was based on the electronic model that we were shown by Dr. Moore. We want our device to be able to fit within an 8”x6”x8” box while and it was shown by the example device that full functionality is a possibility with that size limit. The main reason for this size limit however, is that the device must be able to be stored in a bag and taken onto a plane as a carry-on item or placed within a suitcase with the rest of someone’s luggage without too much trouble.

After the size and operating requirements, the next engineering requirement is a long lifespan. The customer need related to this requirement is a life span of 2+ years so we quantified this by have a goal of 10,000 uses of the device before it requires replacement. This requirement is crucial to its implementation as it will often be used in an environment where a replacement may not be readily available. This relates to the next customer requirement that it must be repairable and must not require more than two different tools to repair any component on the device which allows it to be repaired without extensive technical expertise.

Our final design must be easy to use which leads to our engineering requirement of how much time is required for instruction. The team decided that only 20 minutes of training or instruction should be required for this device to be used effectively. This would allow new dental students to be able to quickly learn how to use the device and would also allow locals to easily learn how to use it themselves.

Safety is a very important part of our design process and is crucial to making the device user friendly. The engineering requirement that we gave to this need is that the device will have zero openings to the internal workings of the device so that a user can not access any components that could cause them harm without intentionally opening it to make repairs or adjustments.

Our device, as with the commercial triturators, must be able to hold a standard amalgam capsule. The engineering requirement present with this need is that our device must be able to hold a single, standard sized, amalgam capsule safely and without risk of the capsule coming loose during operation.

Our last engineering requirement is that the device must require zero volts from an external power source to operate. This requirement is one that must be closely adhered to as the entire point of this project is to create a device that can mix an amalgam capsule without external power.

2.3 *Testing Procedures (TPs)*

The purpose of this section of the report is to give a detailed description of how each engineering requirement will be tested to determine whether or not it has been met.

1. Weighs maximum of ten pounds: The weight of the device will be tested using a standard bathroom scale. The weight will be tested by having a member of the team stand on the scale and the displayed weight will be recorded. The same team member will then pick up the device and the new weight will be recorded. The difference between these two weights will equal the weight of the device.
2. Operating Speed 4,500 rpm: The electric motors that the team is planning on using are rated by the manufacturer as having an operating speed of 4,600 rpm. Testing for a frequency of this

level cannot be done without the use of specialized recording equipment so we will test this engineering requirement by using amalgam capsules provided by the dental department. We know from the commercial models that they operate at 4,500 rpm for exactly ten seconds in order to achieve the proper mixture. We will test this requirement by running our device with an amalgam capsule attached for the same amount of time as the commercial model. If the same mixture is achieved after this time, we know that the operating frequency was high enough.

3. Operating time ten seconds: In order to test whether or not our device can run for the required time of ten seconds, a team member with a stopwatch will start the timer at the same time that another team member presses the on switch of the device. The device will remain switched on until the team member with the stopwatch notes that ten seconds have passed at which point the device will be switched off.
4. Maximum size: 8”x6”x8”: In order to determine whether or not the device fits these size constraints, a box made of cardboard will be put together that measures exactly the maximum allowable size. The device will then be placed within the box. If it fits, the size constraint is achieved.
5. 10,000 use lifespan: To test the lifespan of the device it will be made subject to a torture test that will determine how long the components present in the device will last. To accomplish this, the device will be switched on and then left on until the batteries lose all of their power. Once the device turns off, the time will be recorded and the process will be repeated until a component fails. Once failure occurs, the total run time will be divided into ten second increments which will give an idea of what the lifespan will be.
6. Number of tools required: Reparability is a major concern for us which is why there should be a maximum of two different tools required in order to perform any maintenance on the device. To test this, the team will attempt to replace each part of the device individually and will record every time that they were forced to stop due to the lack of a certain tool.
7. Instruction time: The team’s goal is that this device requires no more than twenty minutes of instruction for the user to become fully capable of using our device. To test this, a random person with no previous knowledge of either the project or dental triturators will be brought in and instructed on the use of the device while the time is being recorded. Once they have no more questions and they can successfully operate our device, the time will be stopped.
8. No openings in device: To account for the need for safety, the device will have no openings in its housing that would allow the user to access the inner workings of the device. In order to test for this, the device housing will be fully assembled and a small LED flashlight that the team already owns will be placed within the housing and switched on. The device will then be closed and the team will check for any escaping light which would indicate an opening.
9. Hold standard capsule: The device must hold a standard amalgam capsule. All capsules on the market have been standardized so that they can fit any triturator on the market. To test for this, an amalgam capsule will be placed in the clip on our device. Once it fits, the device will be switched on. If the capsule remains secure in the clip, the test was successful and the requirement was met.
10. No external energy source: The device must be able to operate without the use of an external power source. To test for this, the device will be placed on an insulated surface and switched on. If the device continues to function as before, then the requirement has been fully met and it does not use outside power.

2.4 *Design Links (DLs)*

The purpose of this section of the report is to provide the design links that meet our engineering requirements. Each engineering requirement will have a description of how that requirement is met by our device.

1. A major customer need that was presented to the team was the need for a design that was light and easily portable. The maximum weight that was made allowable by the client is tend pounds. Our design uses a combination of composite and polymer materials in conjunction with almost no moving parts to achieve this goal by giving us an anticipated weight of between five and six pounds.

2. Dental triturators require a very high operating speed in order to generate the necessary forces that allow for the proper mixing of amalgam. To accomplish this, the device will use a pair of 9V electric motors that are rated with an operating speed of 4,600 rpm. By using motors with a slightly higher speed than what is necessary, it allows for some degradation in the operating speed without sacrificing operational capability.

3. Along with operating speed, the operating time is very important for a triturator. Because of this, the user must be very aware of how long the device is running for so that the mixing process stops at the required time. In order to accomplish this awareness, a digital stopwatch will be integrated into the device so that, when switch on, the timer will automatically start and give an indication to the user of how much time has passed.

4. Our design currently meets the size requirement as it is slightly larger than a mobile phone. The dimensions as of now are 7”x4”x1” which meets the requirement and allows us room to expand the device if it is required.

5. To achieve a 10,000 use lifespan, our team is using a set of DC electric motors. Electric motors have very long lifespans due to the fact that, excluding manufacturing defects, there are no moving parts that can get worn down. Also, electric motors are designed to be able to run for a long period of time before needing replacement.

6. To limit the required number of tools, our device has been designed so that every component clips together using mounting points in the housing rather than using screwdrivers or other such mounting techniques. This is one of the great advantage of 3D printing because it allows us to easily change the design and make it easier to repair if any problems arise during testing.

7. To increases the usability of our device, which lowers instruction time, our design focuses on having the lowest number of steps possible that are needed to use the device. Our device requires only that the user place the amalgam capsule in the clip and then flip the switch to activate the device and then need only switch the device off after the allotted time.

8. To limit the number of openings in our device, the housing will only consist of two pieces that fit together seamlessly and leave only the capsule arm exposed. The enhance this, rubber seals will be used along the edges of the housing to further seal the device.

9. To ensure that the device can hold a standard amalgam capsule, our device will use the same clip that is used in commercial amalgamators. By using a proven design, we know that our device will be able to function at the same standards as the commercial models.

10. In order to neglect the need for external power sources in our device, it will be powered by using a series of either 9V or AA batteries. This will provide a cheap and accessible power source for the device that will allow a high number of uses while providing the same results as the commercial models.

2.5 *House of Quality (HoQ)*

Using the customer needs and engineering requirements, a house of quality was created to compare and weight each requirement and show their importance to one another as well as how they interact with each other. This allows the team to get an unbiased and mathematically-derived view of which needs should be focused one and which are not as important. The house of quality is shown below.

Customer Requirement	Weight	Engineering Requirement	Weighs 10 lbs	Operating Speed 4,500 rpm	Operating time, ten seconds	8"x6"X8"	10,000 use lifespan	# of tools required	Instruction time	No openings in device	Hold standard capsule	No external energy source
1. Light Weight	5		5	1	1	3	2	2	1	1	1	1
2. Human Powered	4		1	5	5	3	3	1	3	3	1	5
3. Keep Budget as low as possible	4		2	1	1	3	2	3	2	3	1	3
4. Shake at specified frequency	5		2	5	4	2	2	1	1	1	2	3
5. Shake for specified time	5		2	5	4	1	1	2	2	3	2	3
6. Same size as electric model	3		4	1	1	5	2	2	1	2	2	2
7. Decent life span	2		3	1	1	2	5	4	1	1	1	1
8. Replaceable Parts	4		3	1	1	2	3	5	3	2	2	3
9. Easy to use	3		1	1	1	1	2	3	5	3	3	2
10. Completely enclosed system	5		2	1	1	3	2	4	2	5	1	1
[add or remove CR rows, as necessary]												
Absolute Technical Importance (ATI)			100	96	86	99	89	104	95	89	63	98
Relative Technical Importance (RTI)			3	6	10	4	8	2	7	9	11	5
Target(s), with Tolerance(s)			10 lb	4,500 rpm	10	8"x6"x8"	10,000	0 tools need	20 minutes trainin	0 openings	1 Capsule	0v
[add or remove T/T rows, as necessary]			+- 2 lbs	4500	-0.1	1+-	1000+-	< 2 tools	< 30 minutes	<3 openings	1	0v
Testing Procedure (TP#)			1	2	3	4	5	6	7	8	9	10
Design Link (DL#)			1,2,4	2	3,7	1,4	2,3,7	1,7	3,8	4,8	9	2,10

Figure 3: HoQ

3 EXISTING DESIGNS

The purpose of this section of the report is to showcase designs that currently exist that accomplish the task that the team has been given. Each of these existing designs is currently available on the commercial market and the vary in both price and how they operate.

3.1 *Design Research*

Dental triturators are a perfect example of how a single task can be performed slightly differently using many different methods. This is easily seen from doing an internet search for triturators, or amalgamators, and clicking on any of the links that appear. While one particular link, medicalexpo.com, has over twelve different models displayed, they all perform the task of trituration in the same way. Each triturator shakes the amalgam capsule back and forth in the same manner but they come in all shapes, sizes, and prices while also being very different designs. From viewing these designs, as well as our conversation with Dr. Moore (our client), we know that we must follow the commonly used method of shaking the capsule back and forth.

The main benchmark that we are using to design our device is the triturator that was shown to us by Dr. Moore is very similar to the Rinn Wig-L-Bug mixer. Compared to most of the other triturators on the market, this model is quite small and compact but is also heavy. Using this design, it is our goal to design a new device that is, at most, the same size as the Wig-L-Bug but much lighter. Another major trait of dental triturators is their ease of use. From the demonstration we were given, we saw that the entire process of trituration involved only loading the capsule into the device and then pressing a button. With devices that are this easy to use, it is crucial to our design that it retains that ease of use.

One of the biggest things that we have learned from benchmarking is that triturators are already very advanced and that we should learn from existing designs. Because our project is to make a manual triturator, we do not have to focus on improving the process of trituration but rather recreate the same technology in a human-powered device.

3.2 *System Level*

A number of different mixers are in the market currently. Despite that they have the same objective of mixing the capsules, they have different advantages and disadvantages. This is due to the trade offs taken during the designing process. Such tradeoffs include, time, frequency of operation, weight, size of the mixer. Therefore, in order to achieve the expected results, certain properties get compromised, and that is why one machine cannot have all the properties at the same time. For example, in this case, three different types of capsule mixers will be considered in the designing of the manual mixing Triturator.

3.2.1 Existing Design #1: GC Capsule Mixer CM-II

This is a digitally controlled high speed Triturator which has both a manual and a pre-programmed timing modes. The system is easy to operate. In addition to that it has the following advantages [1]:

1. It provides an easy insertion point due to its flexible arms
2. It has a preset timing modes

3. It has both manual and auto programs
4. It is easy to design.

Figure 4 : GC Capsule Mixer CM-II

3.2.2 Existing Design #2: Capsule Mixer

The Henry Schein mixer has 10 programmable mixing time which can be used in for regular dental capsules mixing. This is because of its high frequency of 4.200 rpm, 180 watts usage and small in size of 22 x 23 x 18cm/weight. Therefore, this type of capsule mixer is important to my project more so in terms of frequency, weight and size of the proposed manual dental Triturator [2].

Figure 5 : Capsule Mixer

3.2.3 Existing Design #3: ProMix

This is a type of a universal capsule mixers that has a precise mixing time with a homogenous mixing times. This type of mixer is helpful in the project has this will enable us to design the specific times for high precision designed mixer in our project [3].

Figure 6 : ProMix

3.3 *Subsystem Level*

The device is made up of three main subsystems, method of providing power to the device, how the power is increased or converted, and finally the method of using that power to shake the capsule.

3.3.1 Subsystem #1: Power Input Method

There are several methods of providing power to the device. The first method is to attach a hand crank to a drive shaft. This drive shaft turns and moves the inner mechanisms of the device. This type of design would be very durable and simple to design. The drawbacks to this option is that it would require that the operator has sufficient strength to turn the handle and that is also increases the size of the device quite a bit.

The second method of providing power to the device would be a pull cord such as those used to start lawnmowers. This design would work well as it would be able to provide a very large amount of power to the device per cycle while remaining very compact and easy to use. The drawbacks to this design are that, due to the forces involved, it puts a lot of stress on the internal mechanisms, which requires that they be made of sturdier, and also heavier, materials.
The third method would use solar panels as the main power source. Solar panels would be very useful because solar technology has advanced to the point that they are both effective and also affordable while remaining portable. However, solar panels would require that the device is used somewhere near sunlight, meaning that extension cords would probably be required. Also, this would require electric motors which tend to be very heavy.

3.3.2 Existing Design #1: Power Use and Transfer

After the power has been transferred into the device, it must either used, or converted into a usable form before it can actually move the capsule. This can be done in many different ways by using gears, springs, and electric motors.

The first, and simplest method, is the same that was used in the initial prototype. It uses a multiplier gearbox to increase the speed of the input shaft before exiting the device and shaking the capsule at the other end. This design is a proven method that is known to work reliably. The downsides to this design is that gears, when made of metal, are very heavy. If lighter materials are used, the torque inherent in this design can easily be too much for the gears to handle and will lead to a failure in one of the parts. The second method would use a system similar to those used in clocks and wind-up toys which uses a coiled spring that can be wound up and then released when ready. This method would allow the user to wind the device using a key and then press a button to release the tension and shake the capsule. This could potentially allow multiple uses per winding which would allow for more efficient use and less effort from the operator. The problem with this design is that leaving anything like a spring under tension can be dangerous if a part fails and releases the stored energy. Also, springs can suffer from fatigue after prolonged use if not made from high quality materials. If a spring degrades to the point where it can no longer sufficiently shake the capsule, it could lead to a very costly repair for a very specialized part. The third method would use a system up electric motors powered by either a power source or a hand crank. Electrics motors are a very good choice for this sort of device because they will operate in the exact same manner as long as power is supplied to them, which would allow easily repeatable results for every patient. Electric motors can also create a very large amount of power which is necessary to this device's effectiveness. The problem with motors however is that they are very heavy and can be difficult and expensive to replace if in a remote environment.

3.3.3 Existing Design #2: Method for Shaking Capsule

The most important part of this device is its ability to shake the amalgam capsule at a precise speed for a precise length of time. This can be done using two different methods; a piston with the capsule attached to the end, an arm with the capsule attached that waves back and forth.

The first method would attach piston to a crankshaft similar to what is used in a combustion engine. The capsule would be attached to the end of the piston and would move back and forth linearly. This method would work well because a high rpm is easily sustainable without putting a lot of stress on the device. The second method using an arm would work in a similar manner by using a crankshaft or piston but, because the capsule is attached to the end of an arm, there is a much greater range of motion that can be achieved which will more efficiently mix the amalgam.

3.3.4 Black Box Model

The black box created shows the important functions required to fulfill our design's functionality. It shows three important functions. The first function involves giving ingredients as input and getting homogenous amalgam as output. To get required output it is also need to give human and energy as input which are in remaining two functions shown in the black box Model. This functional decomposition is the crucial part in designing to get solution for a problem. With this it becomes very easy to get complete solution to the problem. By dividing the functions, we can easily be able to know which function to be modified to get a particular change in the process or output.

Figure 7: Black Box Model

3.3.5 Black Box Model

The functional model is a graphical representation of the actions that occurs throughout the device when functioning. The functional model helps the engineers to understand what processes the device is going through. This model shows the inputs and the outputs that this device uses. The first input is hand that is used to hold the handle and the second input is human energy that is used to crank the gears. The first output is homogenous mixture, where the capsule is shaken for 10 seconds at a rate of 4000rpm and the second output is human energy and that is when the capsule is removed.

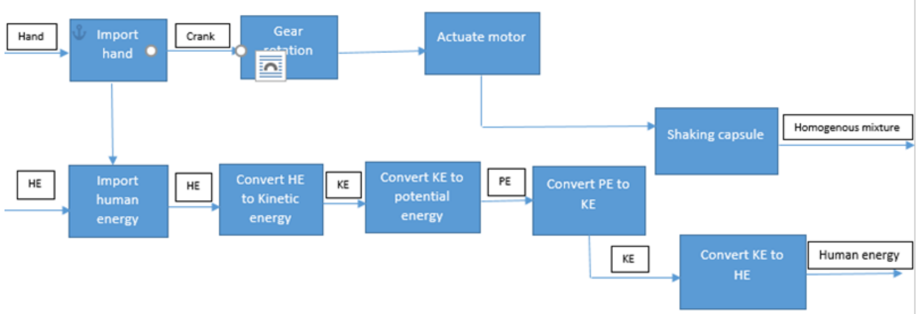

Figure 8: Functional Model

4 DESIGNS CONSIDERED

The purpose of this section of the report is to describe in detail a number of different designs that were created by the team. Each of these designs has different advantages and disadvantages that will also be listed. The final designs proposed by the team will either come from these original designs or contain major components of each design.

4.1 *Design #1: Gear Box*

The first design considered by the team is a multiplier gearbox powered by a hand crank. The crank, when turned, increases the RPM of the drive shaft up to the desired speed and is then transferred into the capsule. The design is what was used by the previous capstone group but would be improved upon to incorporate better materials to make it both smaller and lighter. The advantages of this design are that it is proven to work and that it can accomplish the task while being a robust and simple design. Unfortunately, this design will be much larger and heavier than many of the other designs considered even if different materials and gear ratios are used, which goes against one of the most important customer requirements that is portability. Despite its drawbacks, this design is quite viable to its proven design and can serve as a good backup if the final designs become unfeasible.

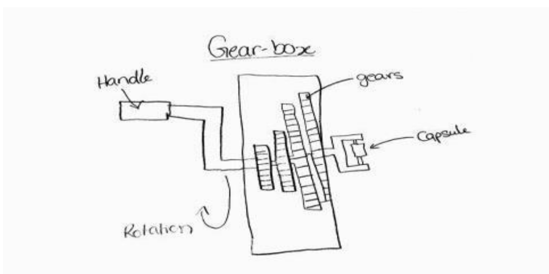

Figure 9: Gear Box

4.2 *Design #2: Wind Up Spring*

This design is based around the design that has been used in mechanical clocks for centuries that uses a wound spring and the energy stored within to drive the vibration of capsule. This design would require the user to wind the spring using a key or similar device. The spring would then be released and would either directly drive the capsule vibration or connect to a gearbox that would increase the RPM to the desired level. The main advantage to this design is that it would require very little effort from the user in winding the spring while keeping the design very compact. The disadvantages however are that it is a more complicated design that would require specialized parts that may not be available in the field if repairs were to become necessary, which goes against a major customer requirement that the design be easy to fix while having a long lifespan. Another problem with this design is that a spring that has enough power to shake the capsule sufficiently would be quite difficult to be wound by the user.

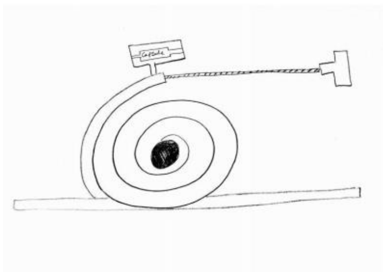

Figure 10: Wind Up Spring

4.3 *Design #3: Pull-Cord and Flywheel*

This design is a variation of the gearbox design but uses a different method of delivering power from the user to the device. This design uses a pull-chord, similar to those used to start lawnmowers, attached to a flywheel and then to a multiplier gearbox. The user pulls on the chord several times in quick succession which spins the flywheel and drives the gearbox and proceeds to shake the capsule. The main advantage of this design is that it could deliver a tremendous amount of power while remaining very small and requiring little effort from the user, satisfying two major customer needs of portability and ease of use. The disadvantages in this design are that it could have a decreased lifespan due to the high stress present in a pull-chord and flywheel and that any failure of the mechanism could cause harm to the user.

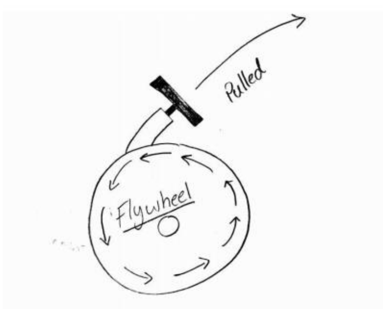

Figure 11: Pull Cord and Flywheel

4.4 *Design #4 Double handled Gear box*

This sketch shows a dental triturator that works without electricity. This device is designed of a handle, gears, band, motor and a cover box. This device works by cranking the handle clockwise and that will force the gears to rotate and to stretch the band to a limit that connects the gears with the motor. The motor will rotate, once there is no force on the handle and that will shake the capsule. The way that this device will shake the capsule for 10 seconds which is one of the requirements, is by testing the device and knowing how many times is needed to crank the handle before letting go of it. The advantage of this device is that it has 2 handles which both left and right handed people can use and the disadvantage is that it has 2 handles and that would take much space.

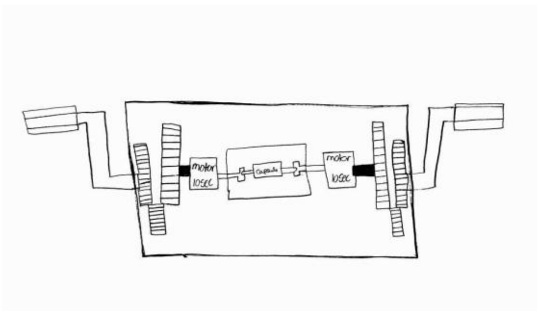

Figure 12: Double Handed Gear Box

4.5 *Design #5 Battery powered triturator*

This sketch shows a dental triturator that works with double A batteries which can be found all around the world. The batteries is connected to the motor and the LED screen. The LED screen is connected to a hardware that is programmed to shake for any period. The motor is connected is a piston that moves vertically at a rate of 4000 rpm. The advantage about this device it that it does not require human power and the disadvantage is that it is hard to assemble.

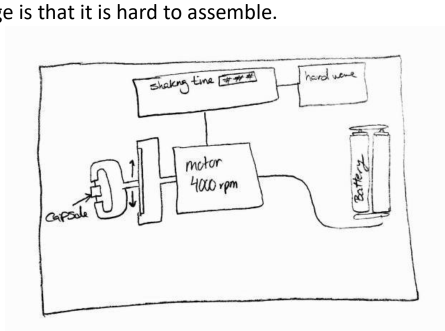

Figure 13: Battery powered Triturator

4.6 *Design #6 Bicycle Driven*

This idea is one of the ideas that will be strongly considered in our project. The way this idea works is there is big gear and small gear; each one is ached to its own tire. In addition, there is a meatal or rubber chain will rotate both gears. A handle will be placed in the big tire. A piston will be attached to the small tire with a cylinder around it. There will be a hole in the piston where the capsule will be placed. From the rotation of the small tire, the piston will be moving forward and backward. Additional gears will be applied to the system to help in achieving (4000 rpm). The gear will look similar to the gear that can be found in a bicycle. This design have positive features more than its negative. to be more specific, the light weight and the less part the design have makes it perfect for a flexible movement since the team will be using it in different countries . Some of the negative of this project that it may require a person with athletic body to let t work.

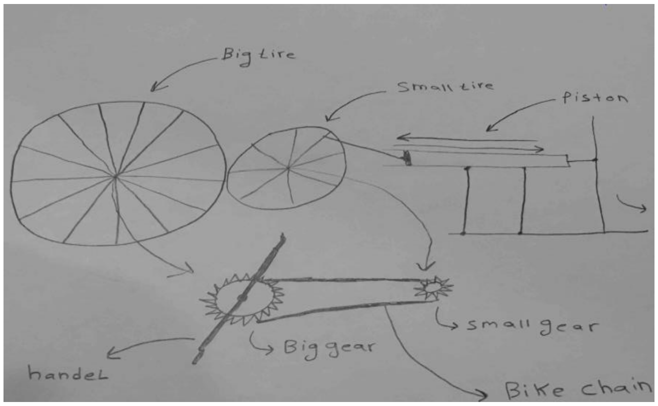

Figure 14: Bicycle Driven

4.7 *Design # 7 Solar Power System*

This design is that is more modern and it uses a nowadays technology. This design will use a solar panel to collect sunlight and turn it into electricity. this electricity will be stored in a battery and then will be sent to the electric motor which will be really small and not more than (12 V). The motor will be attached to gears to increase the speed to achieve (4000 rpm). A Small piston will be attached to the small gear to shake the capsule. The design positive feature that it can be placed in small package and it is easy to move around also it do not require any effort to let it work. The negative effect that it can be expensive build and fix.

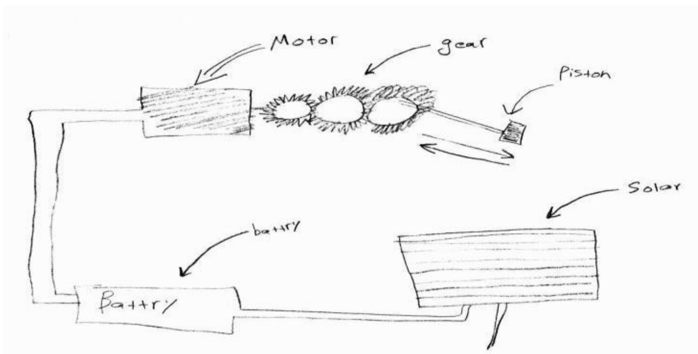

Figure 15: Solar Power System

4.8 *Design #8 Rumble Motors*

In this design, we will use a rumble motor in order to vibrate the capsule. We will use small batteries in order to generate the rumble motor. The electric power will be taken from the batteries moving to the rumble motor to transfer it to a mechanical energy. We have two issues using the batteries to generate the rumble motor. The first issue is the short life expectancy of the batteries. The users must replace the batteries daily depending on how many times they will use the device. The second issue is that we need to use more than 4 batteries in order to get the power needed which is 4000 rpm and this might increase the size of the device.

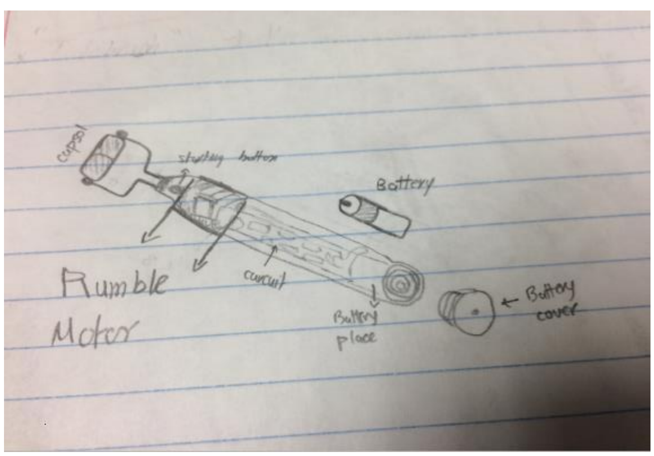

Figure 16: Rumble Motor

4.9 *Design #9 Rechargeable Batteries*

This design contains an electric motor and a rechargeable battery to source the electric motor. It has a manual hand crank that we need to rotate it for a certain time in order to recharge the battery. There will be a motor inside the device which is responsible of the rotational part. The rechargeable battery is used to store electricity that can be used for multiple times before having to be recharged.

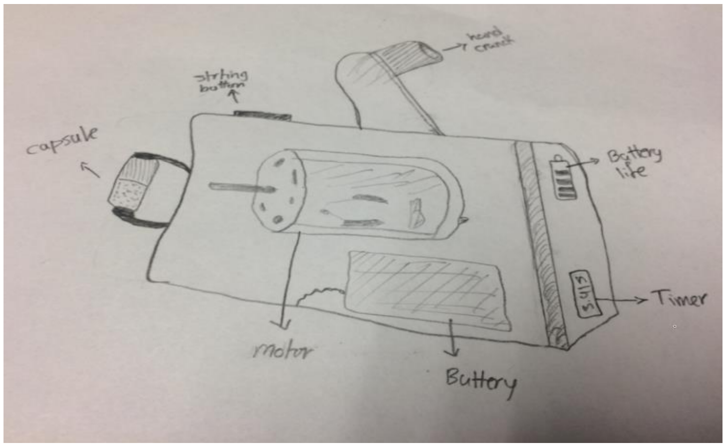

Figure 17: Rechargeable Batteries

4.10 *Design#10 pressurized air tube*

In this device, will use pipe, gas cylinder, rubber. The idea is to Shake the capsule by using Air. The pipe will be covered by two pieces of rubber in each side. The pipe will have a hole in the bottom of it and an air will be following through it. So, the capsule will be moving forward and backward until it reaches 4000 rpm. The advantage of this device is that no electrical power need it for the device. On other hand the disadvantage of this device that is gas cylinder heavy and expensive.

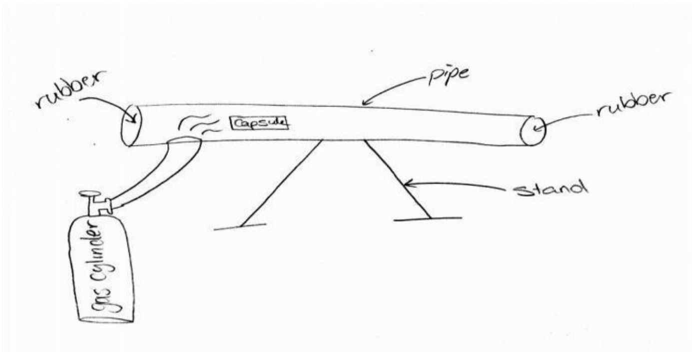

Figure 18: Pressurized Air tube

5 DESIGN SELECTED

This section of the report will describe in detail the final designs chosen by the team for further analysis and refinement. The designs chosen to be take further are the Pull-Chord and Flywheel design as well as the electric motor designs. These designs were chosen based on a number of factors, being their adherence to the customer requirements as well as their versatility and adaptability. The reason versatility is seen as important in this case is that each design can be seen as a chassis with a number of different variations that would then be added to it after further analysis and prototyping determines which is the most effective in accomplishing the goal.

5.1 *Rationale for Design Selection*

From the Pugh chart, we were able to determine the best design from the proposed list. In this case, three outcomes were possible, -1, S and 1. These outcomes represented the interaction between the customer requirement and the proposed design. For example, if the customer requirements affects the proposed design, then the interaction outcome is -1, if the customer requirement-design interaction does not have any change, then the outcome is S and if the interaction is positive, the outcome is 1. Based on these interaction outcomes, it was observed that vibration motors is the best designs to be selected.

Customer Requirements	Gear Box	Wind Up Spring	Pull-Cord and Flywheel	Double handled Gear box	Battery powered triturator	Bicycle Driven	Solor Power Sytem	Pressurized Air Type	Vibration Motors	Rechargeable Batteries
Light weight (less than 10 Lbs)	-1	1	S	-1	1	1	Datum	1	-1	-1
Human Powered	1	-1	-1	-1	-1	-1		-1	1	S
Budget (Less than 750$)	-1	-1	1	1	1	1		1	1	1
Shakes at 4.000 RPM	-1	-1	1	1	S	1		S	S	S
Time (Shake for 10 sec.)	-1	-1	-1	1	S	-1		1	S	1
Same size as electric model	S	1	-1	S	-1	1		-1	1	1
.+2 years life expectancy	S	S	-1	1	1	1		S	1	S
Replaceable parts	-1	1	S	-1	1	-1		S	-1	-1
Easy to use	1	S	1	1	S	-1		-1	1	1
Complete enclosed system	1	-1	-1	1	1	S		-1	1	1
Positives	3	3	3	5	5	5		3	7	5
Negatives	5	5	5	3	2	4		4	3	2
Same	2	2	2	1	3	1		3	2	3
Total	-2	-2	-2	2	3	1	0	-1	4	3

Figure 19: Pugh Chart

5.2 *Design Description*

The final design selected is shown in “figure 20” below. The team decided to do that specific shape because it looks like the portable phones that most of the people around the world are used to hold it and use it. The device cover will be made of plastic. The first piece will be responsible of covering the inner components. The second piece will be small and responsible of covering the batteries place. The reason of making the second piece is to allow the dentist to change the batteries easily. The dimension of the cover will be 7.4" length and 4" width. Also, there will be a small on & off button that will be responsible of operating the device. On the top of the device the will be four different pieces that will be responsible of the mixing part. Those pieces are shaft, drive wheel, arm, and the capsule holder.

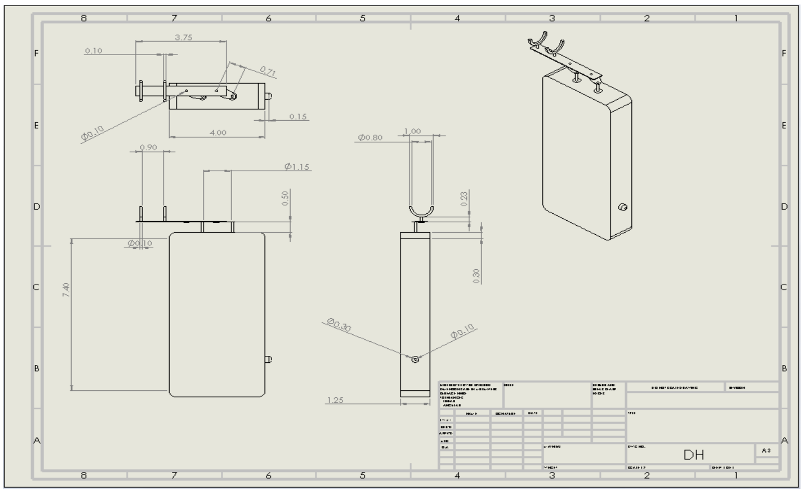

Figure 20: Design Dimensions

The Diameter of the electric motor shafts is 0.10" and the height is 0.5". This part will be responsible of rotating the drive wheels. The electric motors will be powered by 9V batteries. The team decided to use 9V batteries because they are affordable and cheap. The sizes of the batteries are 1.7" length and 1" width as it is showing in "figure 21". The drive wheels shown in "figure 20" will be attached from the bottom in the shafts and from the top to the arm. Those drive wheels will change the rotating motion to a linear motion by using the arm. The drive wheel length is 0.7" and the width is 0.5". The arm will be responsible of the linear motion and will hold the capsule holders. The arm dimensions are 3.75" length and 0.5" width. The last piece of the outer part will be the capsule holders. Those holders will be responsible of holding the capsule. The dimensions of those holders are 0.8" for the holding area part and 0.6" for the height.

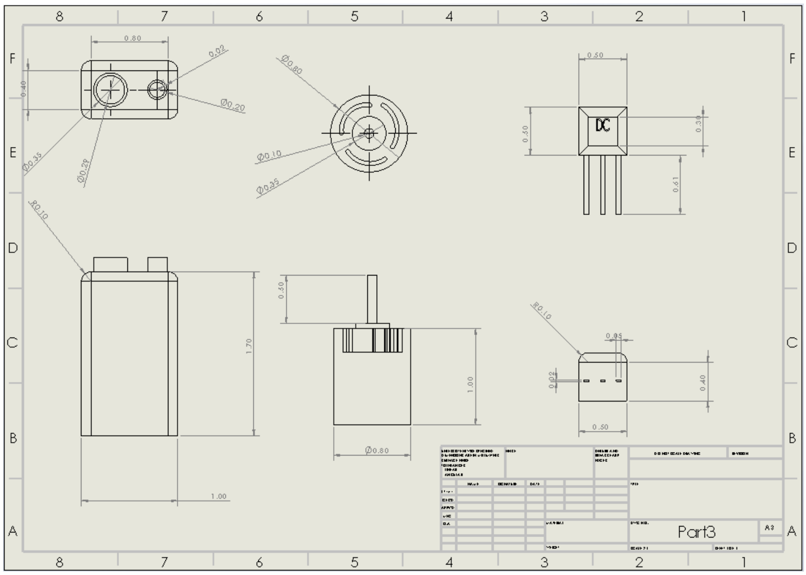

Figure 21: Inner design Components

As it is showing in “figure 21” there will be three main parts inside the device which are batteries, DC-DC converter, and electric motor. The electric motor which is responsible of rotating the drive wheels. The electric motor dimensions are 0.8” width and 1” height as it is showing in “Figure 21” above. This motor can go up to 6000 rpm which is perfect for our power requirements. There will be a DC-DC converter that will be attached to the motor. This converter is responsible of keeping the electric motors in a constant power which is 4000 rpm. Also, it will allow the team to arrange the power needed. For example, if we need to have more than 4000 rpm, this converter will help the team changing the power. The DC-DC converter dimension are 0.5” length, 0.4” thickness, and 0.95” height.

5.2.1 Solar Panel

Solar panel can define as free force of energy, since the main fuel source is the sun. It’s easy to use, easy to carry and they are durable as they can last for long period of time. The dental triturate that our team working on is mint to be light, last for two year, easy to use and heavy duty. Our current design will be having a solar panel to generate electricity, wires, voltage converter, battery and finally two symmetrical motor that can reach a 4000 rpm.

The solar panel is from Rangy Company and it can give 270 watts and 24 volts. This solar panel is designed to work with different environments such as high wind up to 2400pa and a snow load up to 5400pa. Its build using aluminum frame that makes it hard to break in case of accident. Also, its provided with bypass diodes that will ensure to have the maximum power in case of shade or leak of light. This feature will ensure to have a power delivered on cloudy days. Moreover, it has an adjustable holder to direct it to the right position where the sun is.

Figure 22: 270 watt Solar Panel [7]

The choose of this specific solar panel was based on the cost, number of unit needed, power output it produces and the time it take to charge a 12 volt battery. The following is the analyses that were made to choose this specific one:

- Time estimated to charge 12-volt battery would be **12V * 200Ah** = **2400WHr** [5] .Assuming the battery within 20 % charge. Which means **2400WHr * 80 %**. Which means that we need **1920KWHr** solar panel assuming the solar panel will be visible to the sun for 7 hours per day. So, the solar panel is needed to charge in 7 hours will be calculated as the following:

(3200KWHr **/ 7 = 274 watt solar panel**.) [5] Cost analysis: **(249.99 * 1)= 249.99 $** (solar panel)

Since the power output of the two solar panels will equal 24 volts, a voltage converter is needed to reduce the voltage output to 12 volte, which is our battery capacity. The following power converter from power Output Company will be used:

Figure 23: Voltage Converter [6]

This specific power converter able to take input of 20 to 28 voltage and convert up to 12 – 15.5 voltage which is the needed range. The price for this unit $165.50. Which makes the total cost for both the solar panel and voltage converter **415.49 $.**

5.2.2 Batteries

The batteries will be used to achieve different degrees of vibration for the amalgamator. The torque of a DC motor is attained when a current-carrying conductor cuts through a magnetic field. The difference of the current determines the magnitude of the rotation of the motor. Thus, the torque achieved is directly proportional to the current through the windings, number of turns of the windings, and the magnitude of the magnetic material. Equation 1 below is the final torque equation of DC motor.

$$T = kI\ equation.\ 1$$

Where;

$$T = torque$$

$k = constant = \frac{P.Z}{2\pi.A}$

The coils or the metal windings cause resistive and inductive losses, which are represented by R and L respectively. The inductive losses occur during the motor start. The voltage used to create the inductance is evaluated by equation 2 below as;

$$V = L\frac{dI}{dt}\ equation\ 2$$

The voltage, majorly regarded as the back EMF (electromotive force) causes a certain shove, which can be experienced by the operator of the amalgamator that is being designed here. The rotation of the motor is measured in terms of angular velocity, . The EMF, of the motor is evaluated by the product of k (the constant) and the angular velocity of the motor [9], [10]. EMF is the amount of work against the input voltage, therefore, it corresponds to the voltage applied across the terminals as shown in equation 3.

$$(V - k\omega) = IR \text{ equation 3}$$

But, rearranging equation 1 above, equation 4 is generated as shown below

$$I = \frac{T}{R} \text{ equation 4}$$

By using equation 4 in equation 3 above, the EMF produced reduces to equation 5 below

$$(V - k\omega) = (\frac{T}{k})R \text{ equation 5}$$

At the maximum torque, also regarded as the stall torque, the angular velocity is 0 and reduces to equation 6 below as

$$T=kV/R \qquad \text{equation 6}$$

Also, it should be noted that the starting current is the ratio between the applied or input voltage to the resistance across the windings. Therefore, with no load speed is determined from equation 5 in which the right-hand side becomes zero. By rearranging the equation, the no load speed is found as shown in equation 7 below.

$$\omega=V/k \qquad \text{equation 7}$$

This is assumed to be the maximum possible speed that can be achieved by a DC motor. From equation 5, figure 1 below is a graph of angular speed against torque. From the graph, it is observed that, with increase in torque, there is a corresponding decrease in angular speed.

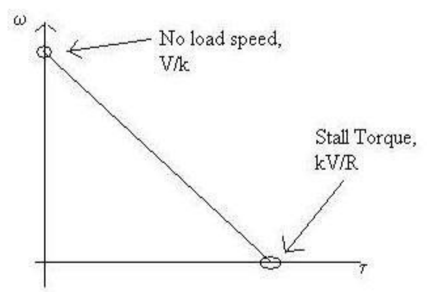

Figure 24: Velocity Versus Torque

The mechanical power obtained is the product of torque and the angular velocity (Nm/s), which corresponds to the mechanical power (VI).
The above principle can be used to develop amalgamators of different power capacities. The most efficient amalgamator operates at 75% efficiency, which can be operated with a DC voltage of 6-12V, which our team is planning on [8]. The study proposes rechargeable batteries because they are cost-effective.

Types of Batteries to Use

The following 3 types of batteries are proposed to be used in this design.

1- NiMh batteries
2- LiPo
3- Single Cell batteries

The following characteristics in table 1below are the battery requirement for amalgamator to be made:

Table 1: Required Battery Characteristics

Parameter	Value	Unit
Nominal voltage	1.2	V
Least Energy at 50mA drain	2.42	Wh
Minimum Battery Capacity	600	mAh
Rechargeable	Yes	N/A

The amalgamator that is being designed here can either use multiple or single cell batteries. The double A batteries are light, and size- efficient for our device. Choosing double A batteries for our device is the best choice, since it fits our designing goals as shown in table 1 above.

5.2.3 Safety Mechanism

In this project, the body of dental Triturator is designed with the basis of the factor of safety, applications and advantages. Selection of materials is based on the factor of safety, strength, reliability and terms of use, availability and Cost. Human Powered Dental Triturator is made to with lighter and stronger components that are made to achieve the target. Components such as Fiber glass or Plexi-glass are for the body, DC motors for the internal mechanism. This Dental Triturator is designed to work in both manual mode and electric mode. With this, this component is rechargeable and can be used up to 1 hour. The electrical components are insulated and incorporated in a plastic insulation tube such that there is no leak of current or electricity in the system.

Calculations, Equations and Symbols

- Based on Factor of Safety

  In order to achieve the design criteria, it is important to know the working factors of the component. This device will be used in the situations which contain high and low temperatures, situations where there is no electricity to be charged, situation where there will be manual power needed to run the gears. There should be minimum wires needed for the electricity transport. The device should overcome greater strength, durability, high tensile strength. Also, the corners of the device should be rounded / smoothed in order to remove the chipping from the corners. This device should incorporate the safety features such as durability, can be used in any environmental factors, easier to use and should not contain any risk factor for the patients. There should be insulation in the device, no electricity or current leak from the device [11].

$$Factor\ of\ Safety = \frac{Load\ that\ breaks\ the\ product\ (ultimate\ stress)}{Normal\ Load\ on\ the\ product(actual\ stess)}$$ ----------------- 11

= 1200/150= 8

The impact test results for the Plexi-glass are also good when compared to different materials such as Aluminum and Steel. Let’s assume the mass of 200g is getting impacted on the Plexi-glass at a velocity of 12 m/s

$F = 1/2\ m\ (v)2$

$$=\frac{1}{2}(200g)12^2$$
=144000N = 14KN.

- Cost and Availability

Cost and Availability are the main aspect in designing Dental Triturator. From the Lean Manufacturing process, it is necessary to keep the cost as minimum as possible in order to have better market. Medical and Dental products are often expensive due to research cost and production cost. Dental Triturator is available in the market with the average price of $200 piece. In order to beat this price, it is necessary to have a best material in a good price with the least manufacturing cost. Plexi glass is available in the market with a tag line of $50 a sheet [12]. This is a 4ft X 8ft sheet which comes in a thickness of ½". In order to have a best yield from this sheet, it is essential to design the dimensions in such a way that a maximum yield is obtained from the sheet. From the lean manufacturing process, getting 6 dental Triturator boxes would reduce down cost to

$500 a sheet of 4ft x 8ft

500/6= $83.33 a box. This cost is almost ¼ of the original price for steel and aluminum. One 4 feet by 8 feet of sheet generally costs around $750.

Plexi glass is available in stock. In United States it is available under 3 vendor business organizations named Orange Aluminum, Steel & Aluminum Industries and Pride Industrial Organization [12].

- **Modelling**

From the cost and factor of safety point of view, Plexi glass is chosen to be used. Plexi-glass contains all the factor of safety and it is safe to use from -46°F to 175°F. Also, Plexi-glass is insulator of heat and electricity. It is light compared to Aluminum and Steel. With this, Plexi-glass is chose to use for the body for the dental Triturator.
Plexi glass has a transparent property. With this, this can be used as a glass in order to look at the process going inside the dental Triturator.

- **Results**

With the factor of safety, cost and availability point of view, it can be stated that Plexi-glass is the best material for the outer covering of the body. Also, for the charging system, batteries of 12V will be used in such a way that there is no extra charge that is there in the system that can pose threat to the system. The insulators around the covering of the wires and the covering of the generator will resist for any voltage leak across the system. There are several ways for this Triturator can be used. With human powered, solar powered and rechargeable batteries can be used in such a way that Triturator can be used under the natural conditions.
Plexi glass thickness is chosen based on the dental Triturator desired weight. From the properties of Plexiglass [11], a glass of ½" thickness would have a weight of 15 pounds. If the Thickness of 1" is used, then the weight would be 25 Pounds. ½" thickness is desirable for the construction of Plexi glass.

5.2.4 Motor Viability

Dental Amalgamators gives excess noise and sound when vibrating for the capsules. This consumes a lot of energy and time for the amalgamator and thus loses its overall efficiency. Dental Amalgamators are actually used for the processing of the capsules that keeps the less vibration effect as well as completes the process fast. With this, the idea of using Rumble motors came into place. Rumble motors are basically electric motors that are found in videogame consoles. These rumble motors basically vibrate to a much greater frequency. The frequencies of Rumble motors are observed to be about 240Hz. This frequency provides ample oscillation that is under low voltage.

Rumble motors rotate in 1 degree of freedom calling as Driven Harmonic Vibration. This Driven Harmonic Vibration actually drives the motor from an external energy and making the system to create force that causes much vibration in the system. The motion of vibration comes from the basic sine equation of oscillation.

Rumble motors provide an excellent technique and can be placed anywhere under the dental Triturator. The motors can also be place insulated such that there is no leak of currents from the system. This makes sure that the product is safe to use. Using Rumble motors for the dental application provides a good idea for the Dental Amalgamators.

Calculations & Equations

In order to apply rumble motors for the Dental Amalgamators, it is necessary to know the working process of the Rumble motors. Rumble motors run on the Direct Current System. This system provides a constant voltage. The Sinusoidal wave explains the overall frequency of the system. A wave that generates, due to the rotating motion function from $Asinwt$. This excitation input gives the frequency of the sine wave.

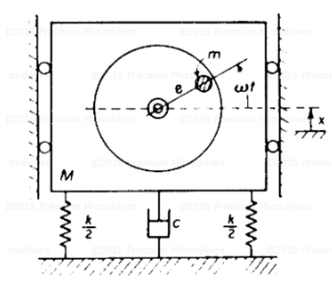

Figure 25:

The above diagram shows about the displacement axis x. The stiffness of the spring is represented by$\frac{k}{2}$. K is called as the Stiffness constant. From the Hooke's Law, the equation turns to be $F = kx$.

When this equation is derivate to F, $F = c\frac{dx}{dt}$

When the Mass of the equation is included from Newton's Second Law of Motion, the equation turns out to be $F = (M - m)\frac{d2x}{dt2}$

The Sum of the three forces equal to $F = F0\ sin(wt)$

The total motion of the system comes to $(M - m)d2xdt2 + cdxdt + kx = F0sin(\omega t)$

Modelling
In order to model a basic motor, it is necessary to understand the oscillation of the basic frequency of the sinusoidal wave. The figure below represents the basic sine function with the Asinwt function. As observed, the function represents a basic wave function.

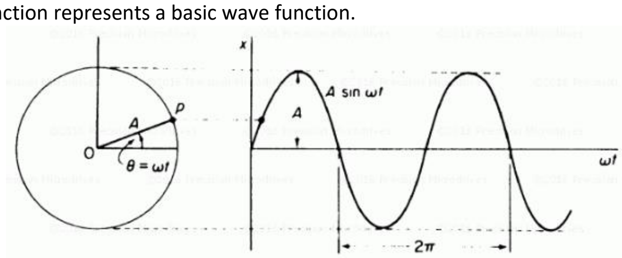

Figure 26:

From the modelling parameters of the Motor, it is essential to know the Electromotive force (EMF). The Electromotive force is the voltage of the force that is observed at both the terminals of the voltage.
EMF = KeW
From the linear relationship, it can be observed that
*V=RI+*EMF= *RI+KeW.*
From this design parameter, it is necessary to understand that the magnet of the DC Motor and the relationship between the speed and voltage is essential for the motor. With the 12V battery, this motor could able to boost its speed upto 254Hz.

Results
Rumble Motor tend to provide a frequency and oscillation that can be adjusted and could be varied to the speed required by the dental amalgamator. Also, these motors are the most advanced and safe in terms of medical history. Replacing traditional motors with the Rumble motors would be vital and efficient. When traditional motors are replaced by the rumble motors and could boost up the efficiency of the motors by 125% in dental amalgamators. Rumble motors can be operated at stable room temperatures and the temperatures could also increase up to 80°F.

5.2.5 Motor Analysis

The purpose of this section is to provide an analysis on the requirements present in the use of electric motors in our design. Our final design will incorporate two vibrating motors that will be used to shake the amalgam capsule in a linear motion. This analysis will determine how much power needs to be produced by the batteries in order to drive the motors. Once the motors are moving, it must be determined whether they have the power to move the weight of the capsule at the required frequency. Once the motor requirements have been established, its lifespan and durability will be established to determine the number of uses that can be performed before the motor fails. This lifespan can then be used to establish a cost to use ratio.

Motor Information

Vibration motors, also known as rumble motors, are easy to find as they are used in a wide variety of commercial applications such as children's toys and video game controllers. This widespread availability means that they come in a wide variety of voltages and speeds. A quick google search provided a motor that would suit our needs perfectly as it requires 12 volts to operate and spins at exactly 4,600 rpm. This is available from newegg.com for $5.77 which means that it will not take up much of our budget and that shipping will be quick and dependable. This is just one example of an available motor, but there are many more on the market that do not suit our needs as precisely.

Powering A Motor With A Battery

Powering an electric motor with a battery is very simple to set up when using a DC motor as the current does not change direction during use. The battery needs only to be connected to the motor using a single circuit(Figure 27) in order to drive the motor with the option of a switch(Figure 28) to make actuation easier for the user.

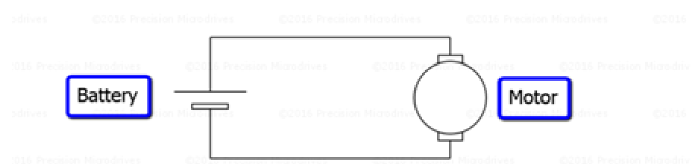

Figure 27: Simple Circuit

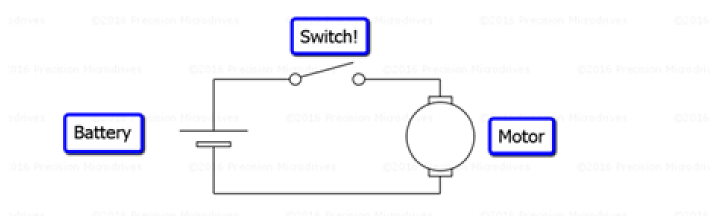

Figure 28: Circuit with switch

The only requirements present with a battery-driven motor are that the voltage of the battery does not exceed the voltage requirements of the motor, but the motor can still safely operate at reduced efficiency if the voltage provided is less than the operating voltage of the motor [14]. If the voltage provided by the battery is greater than the voltage rating of the motor, the motor can overheat which can eventually lead to catastrophic failure. The amount of time that a motor can run when connected to a particular battery can be determined using the following equation.

$$Running\ Time(h) = \frac{Battery\ Capacity(mAh)}{Operating\ Current\ (mA)}$$

A battery's capacity is measure in milliamp-hours which states how many hours a battery can provide a single amperage of current, or how many amps it can produce for one hour. This operating time can be increased by adding multiple batteries in parallel and in series in order to increase capacitance without losing power [15]. In an ideal situation, the device could be run ten times at a minimum before the batteries need to be recharged which, at ten seconds per run time, gives a total run time of 100 seconds for the battery. Once the operating amperage of the motor is determined (the example provided above does not list this), it can be easily determined what the total battery capacity must be in order to meet this need.

Motor Lifespan

Vibration motors, as with any mechanical component, can only operate for a certain amount of time before they fail. As lifespan is very important to our client, the lifespan of the motors used must be determined in order to determine the total lifespan of the device. There are two main reasons that cause an electric motor to fail which are overheating and mechanical wear, with the latter being more common. The mechanical wear usually occurs in the brushes that deliver power to the motor as dust and other debris begins to collect and the metal corrodes [15]. The first equation used to determine life span uses a value called the Mean Time To Failure, or MTTF. This equation requires the number of motors tested, the number of motors that failed, and the amount of time the failed motors lasted as well as the total time involved with the test divided by the number of failed motors. This is shown by the series of equations below in which 1,000 motors were tested for 1,000 hours during which 10 motors failed at the 900 hour mark.

$$MTTF = \frac{Total\ Time}{Number\ of\ Failures}$$

$$MTTF = \frac{[(9{,}990 * 1{,}000) + (900 * 10)]}{10}$$

This example gives a mean time to failure of close to 1,000,000 hours which is impossible for any real electric motor which shows the main downfall of this method b

$$FIT = \frac{1{,}000{,}000{,}000}{MTTF}$$

As this equation still used the MTTF, it is subject to the same inaccuracy but helps to give a better frame of reference. The next analysis that relates to more failure involves what is called the Weibull Analysis that states that there is no exact way to measure the lifespan of a motor but it can be assumed that the results will follow what is called a bathtub curve as shown in Figure 29.

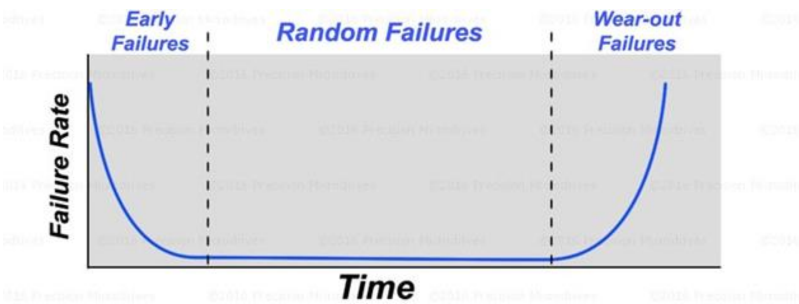

Figure 29: Weibull Analysis

The bathtub curve states that the majority of failures will occur during the early life of the motor, which is mostly due to defects, or towards the end of its life as it starts to wear out. If the current run time is between these areas, the probability of a failure occurring is very low [ ]. While these methods of analysis provide a general idea as to the lifespan of a motor, there is now way to accurately find the lifespan of a motor without doing an experiment with several of the same motor and using the gathered data in the above equations. Once these values have been experimentally determined, the total lifespan can be determined and due to the low price of the motor, and high cost-use ratio can most likely be achieved.

5.2.6 Gear Materials

Gears Type

Gears can be classified according to various categories; these include their shape, their use, the modeling of the gear teeth. Some of the common gears are spur gears, helical gears, internal gears, miter gears, bevel gears, screw gears, worm gears, cp racks and pinions. Spur gears, which are the most common type of gears, offer a good transmission of force between two parallel shafts and are the most precise gears available. This project looks to use gears to create a machine for mixing contents. Since the machine will rely on human effort to work, it is essential to make it efficient. The second criteria to meet with the design is lightness. To achieve this, it is critical to utilize light gears. Cost is the other improvement that the new design is aiming to make.

Materials for gear manufacture

The analysis of the various parameters that affect the operation of gears at different conditions while putting into consideration the material used for the design of the gears is critical. The analysis done include; stress-strain analysis, prediction of gear dynamic loads, noise levels, optimization to achieve desired speeds and torque, transmission errors.
In the past, most gears were made from metal. With current scientific advancement in mechanical engineering, polymers have been utilized to make gears where the torque involved is not much. Polymer has been used in the recent past to manufacture gears low torque gears especially in the health sector. The polymers used for this application can withstand high enough torque produced by motors

with a rating in the range of 1kW. As long as the critical torque and speed is not exceeded for polymer gears, the wear out rate is minimal due to optimal operating temperature. The critical torque can be calculated from the required surface temperature when designing gears using polymer.

Since the predecessor was considered too heavy and large by many users, it was necessary to scale down on both weight and size. To reduce the weight, polymer gears were considered.

The factors that made polymer gears an obvious choice are.

1. The machine did not require large torques to operate.
2. Polymer gears have a relatively less weight and can with stand torque due to forces applied by human.
3. Polymer gears are relatively in expensive compared to metal gears.
4. It is easier to produce small gears using polymer as opposed to metals.
5. Polymer gears require less lubrication and may be limited to initial installation.
6. The resilience of plastic gears provides better damping to shock.
7. Better durability in low stress environments compared to metals.
8. Polymer gears offer produce low noise levels.

The decrease in weight of the gears not only makes the mixer lighter to move with around but also reduces the force used during the mixing process, which depends on human effort. As a result, this would increase productivity due to the minimum effort required.

The Gear Ratio is a relationship of the speed of the input gear to the output gear speed.

The relationship is defined by the formula; $W_{in} : W_{out}$ ……………… (1)

The following equations define any gear pair:

$t_{in}\, w_{in} = t_{out}\, w_{out}$ this equation defines the power quality of the transmission… (2)

$w_{out} / w_{in} = r_{in} / r_{out}$ this equation relates the speed to the radiuses of the gears…… (3)

$w_{out} / w_{in} = n_{in} / n_{out}$ this equation relates the speed to the number of teeth in each gear… (4)

For torque relations;

$t_{out} / t_{in} = r_{out} / r_{in}$ this equation relates the torque to the radiuses of the gears………………. (5)

$t_{out} / t_{in} = n_{in} / n_{out}$ this equation relates torque to the number of teeth in the gears………….. (6)

Where;

W is the work.

t is the torque

r is the radius of the gears

n is the number of teeth

Considering a 20 degree gear, the following equations are used to determine the various parameters.

To determine the **diameter of the gear (D_B)** to make, the following equations maybe be used

$D_B = D \cos\beta$………………………………………………………… (7)

The equation for **circular pitch (p)**

$p = \frac{\pi D}{N}$……………………………………………………………… (8)

Diametrical pitch (P) can be seen as

$P = N/D$……………………………………………………………… (9)

Where N is the number of teeth and D is the diameter

To determine the size of the **addendum (a)**

$a = 1/P$…………………………………………………………….. (10)

To determine the size of the **dedendum (b)**

$b = 1.25/P$………………………………………………………… (11)

This factor is of great consideration for gears carrying heavy loads.
The **working depth** (h_k) for the a given value of P is given by
$h_k = 2/P$…………………………………………………………… (12)
The **whole depth** (h_t) can be taken to be
$h_t = 2.25/P$………………………………………………………….. (13)
The **clearance** (c) is
$c = 0.25/P$ …………………………………………………………… (14)

Loading on gear teeth
The tangential load on each tooth of the gear is described by,
$W_t = h_p / u$ -this equation is used to determine the tangential loading on the gear teeth… (15)
Where, $u = \pi d N_a / 60$
The normal load is given by
$W = W_t / \cos\beta$ - this equation determines the normal load on the gear teeth…. (16)
In this case $\beta = 20^o$
The radial load
$W_r = W_t$ tan - this equation determines the radial loading…………………….. (17)
Fatigue in polymer gears
$S_b = 2T/fYMD_p$………………………………………………………………… (18)
Where S_b = stress due to bending
T = torque on the gear
f = gear face width
Y = Lewis form factor for polymer gears loaded close to the pitch point
M = (pitch/number of teeth)
D_p = pitch diameter

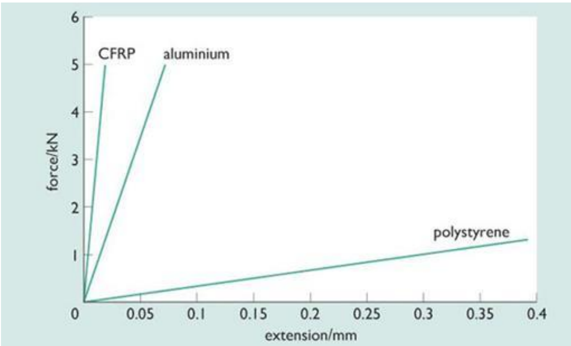

Figure 30: force against extension used for gears manufacture

6 PROPOSED DESIGN

In regards to implementation, our team's schedule will be very compressed compared to other capstone teams as we will be completing our prototyping, testing, and final implementation over the course of ten weeks during the summer rather than the standard term length and we will not have access to the school machine shop. These restrictions mean that the rest of our product development must be based around concepts that allow us to fit within this compacted schedule. This means that our device will rely heavily on 3D-printed materials as well as our design's modularity so that any problems can be adjusted to quickly.

6.1 *Experimental Setup*

The experimental setup for our device is based around achieving the same end result as the commercially available triturators. In our situation, the effectiveness of our device is not measured based on a set of parameters but is defined very clearly by whether or not it effectively mixes the amalgam within the capsule. Amalgam must be mixed under a very specific set of conditions, so our testing procedures will involve using our device to shake capsules supplied by the dental department and whether or not the mixture is achieved will be checked by applying the amalgam to the practice cavities that are also supplied by the dental department.

6.2 *Manufacturing*

One of the key aspects of our design is ease of manufacturing which is necessary due to the lack of manufacturing ability present during the summer. The device is encompassed by a plastic housing that will ideally be printed out of ABS into two separate pieces onto which all of the other parts will be mounted. This will provide a durable, cheap, and easy to produce platform around which everything else will be based. Other than the housing, all of the other parts in our design can be purchased from online and local sources. This means that our team does not have to take the time to engineer every component as we can be assured that those we purchase have already been tested and work as advertised. This extra time allows the team to engineer instead how all of these components will interact and also to ensure that they work in terms of our design. Once the final design has been made official, the manufacturing of our design will only require a basic assembly of the different parts to be ready for use.

8 Conclusions

In conclusion, the team is very happy with how our final design has turned out. We were able to meet all of our customer needs and engineering requirements with a design. Our design is slightly unorthodox when it comes to other triturators on the market, but one of our main goals was to try and make something new that has yet to be done. It may turn out during testing that our design has flaws that cannot be overcome, but we have backup plans in place to account for any eventuality.

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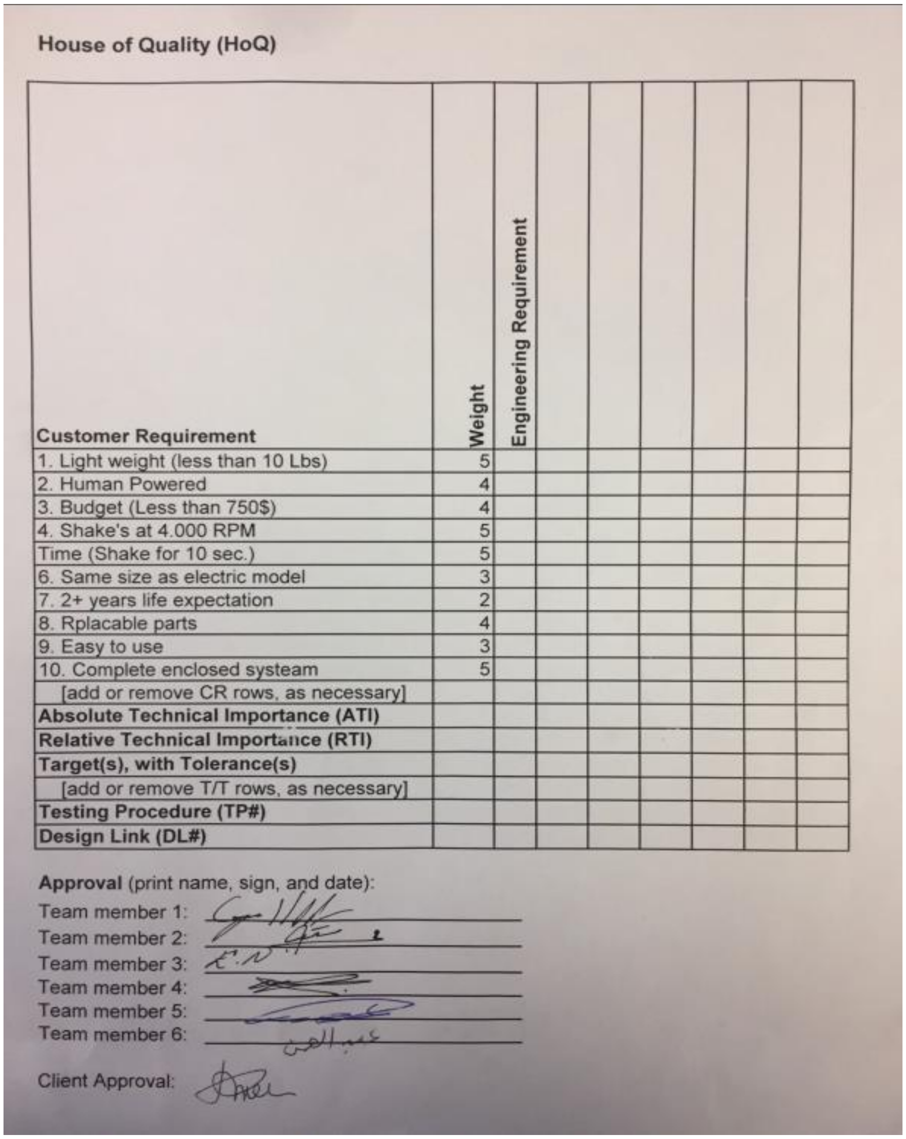
10 APPENDICES

10.1Appendix A (Client Approval)



House of Quality (HoQ)

Customer Requirement	Weight	Engineering Requirement						
1. Light weight (less than 10 Lbs)	5							
2. Human Powered	4							
3. Budget (Less than 750$)	4							
4. Shake's at 4.000 RPM	5							
Time (Shake for 10 sec.)	5							
6. Same size as electric model	3							
7. 2+ years life expectation	2							
8. Rplacable parts	4							
9. Easy to use	3							
10. Complete enclosed systeam	5							
[add or remove CR rows, as necessary]								
Absolute Technical Importance (ATI)								
Relative Technical Importance (RTI)								
Target(s), with Tolerance(s)								
[add or remove T/T rows, as necessary]								
Testing Procedure (TP#)								
Design Link (DL#)								

Approval (print name, sign, and date):

Team member 1:

Team member 2:

Team member 3:

Team member 4:

Team member 5:

Team member 6:

Client Approval:

Figure A1: Client Approval of Customer Needs

10.2 Appendix B (HoQ)

Customer Requirement	Weight	Engineering Requirement	Weighs 10 lbs	Operating Speed 4,500 rpm	Operating time, ten seconds	8"x6"X8"	10,000 use lifespan	# of tools required	Instruction time	No openings in device	Hold standard capsule	No external energy source
1. Light Weight	5		5	1	1	3	2	2	1	1	1	1
2. Human Powered	4		1	5	5	3	3	1	3	3	1	5
3. Keep Budget as low as possible	4		2	1	1	3	2	3	2	3	1	3
4. Shake at specified frequency	5		2	5	4	2	2	1	1	1	2	3
5. Shake for specified time	5		2	5	4	1	1	2	2	3	2	3
6. Same size as electric model	3		4	1	1	5	2	2	1	2	2	2
7. Decent life span	2		3	1	1	2	5	4	1	1	1	1
8. Replaceable Parts	4		3	1	1	2	3	5	3	2	2	3
9. Easy to use	3		1	1	1	1	2	3	5	3	3	2
10. Completely enclosed system	5		2	1	1	3	2	4	2	5	1	1
[add or remove CR rows, as necessary]												
Absolute Technical Importance (ATI)			100	96	86	99	89	104	95	89	63	98
Relative Technical Importance (RTI)			3	6	10	4	8	2	7	9	11	5
Target(s), with Tolerance(s)			10 lb	4,500 rpm	10	8"x6"x8"	10,000	0 tools need	20 minutes trainin	0 openings	1 Capsule	0v
[add or remove T/T rows, as necessary]			+- 2 lbs	4500	-0.1	1+-	1000+-	< 2 tools	< 30 minutes	<3 openings	1	0v
Testing Procedure (TP#)			1	2	3	4	5	6	7	8	9	10
Design Link (DL#)			1,2,4	2	3,7	1,4	2,3,7	1,7	3,8	4,8	9	2,10

Figure B1: House of Quality

10.3 Appendix C (3D Drawings)

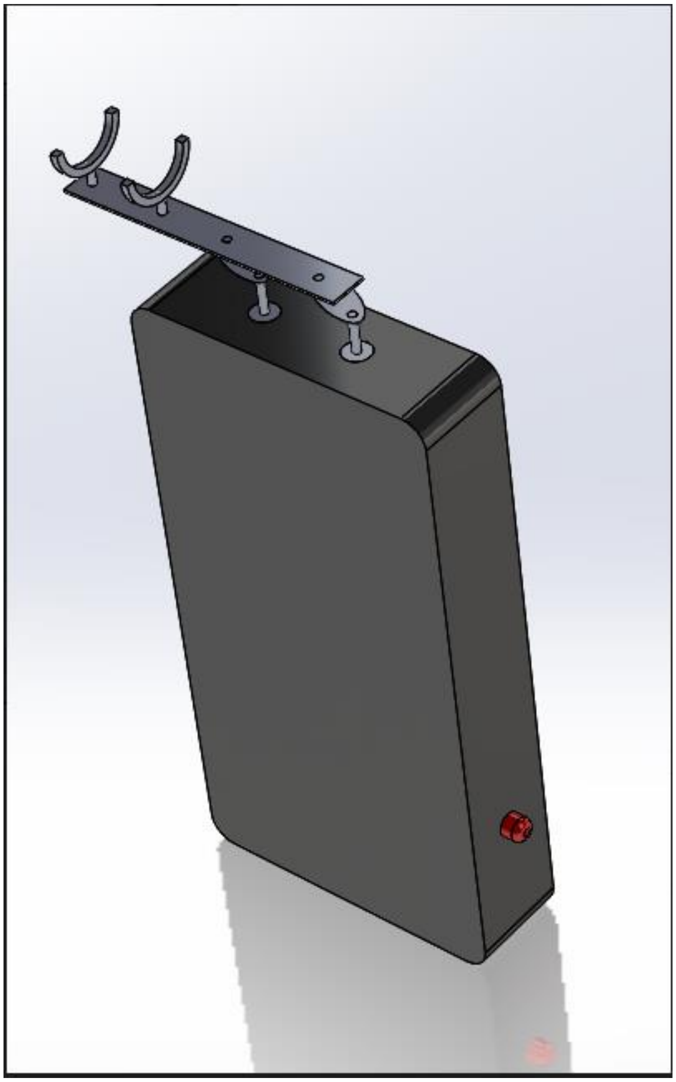


Figure C1: Rendering of Prototype

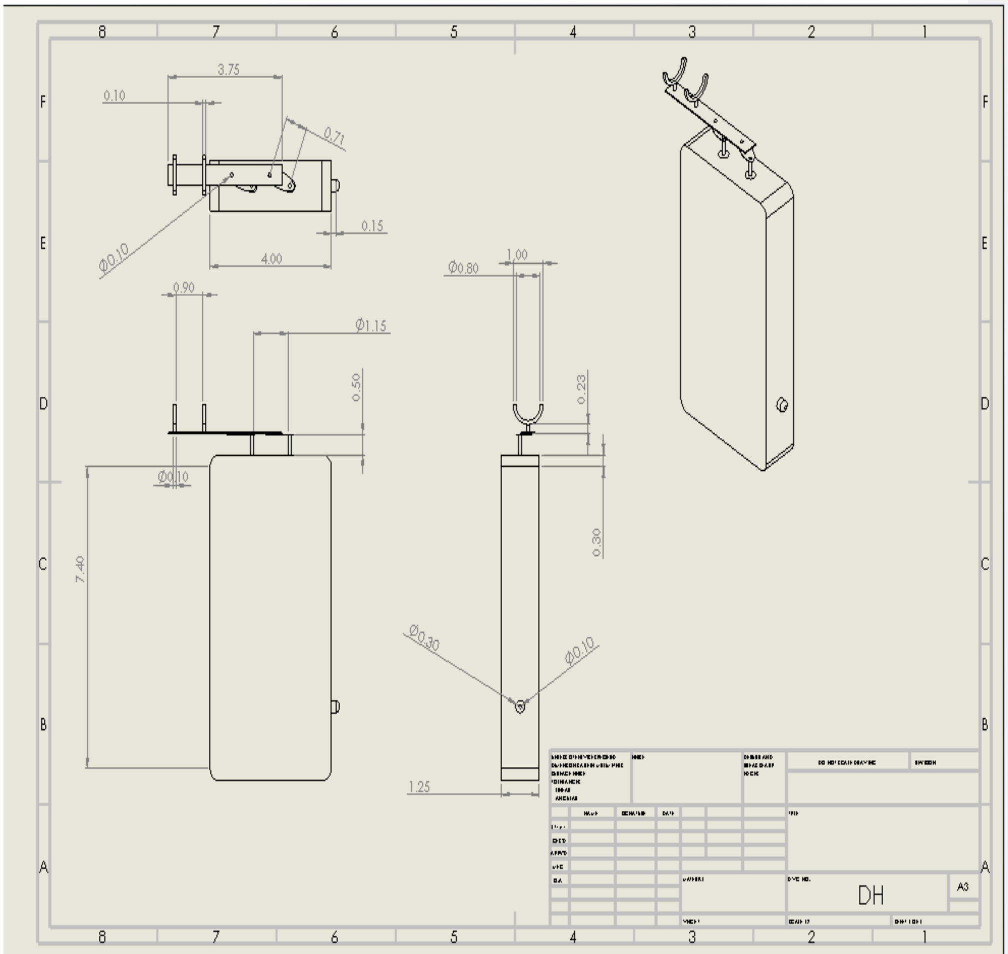


Figure C2: 3D Drawing of Prototype

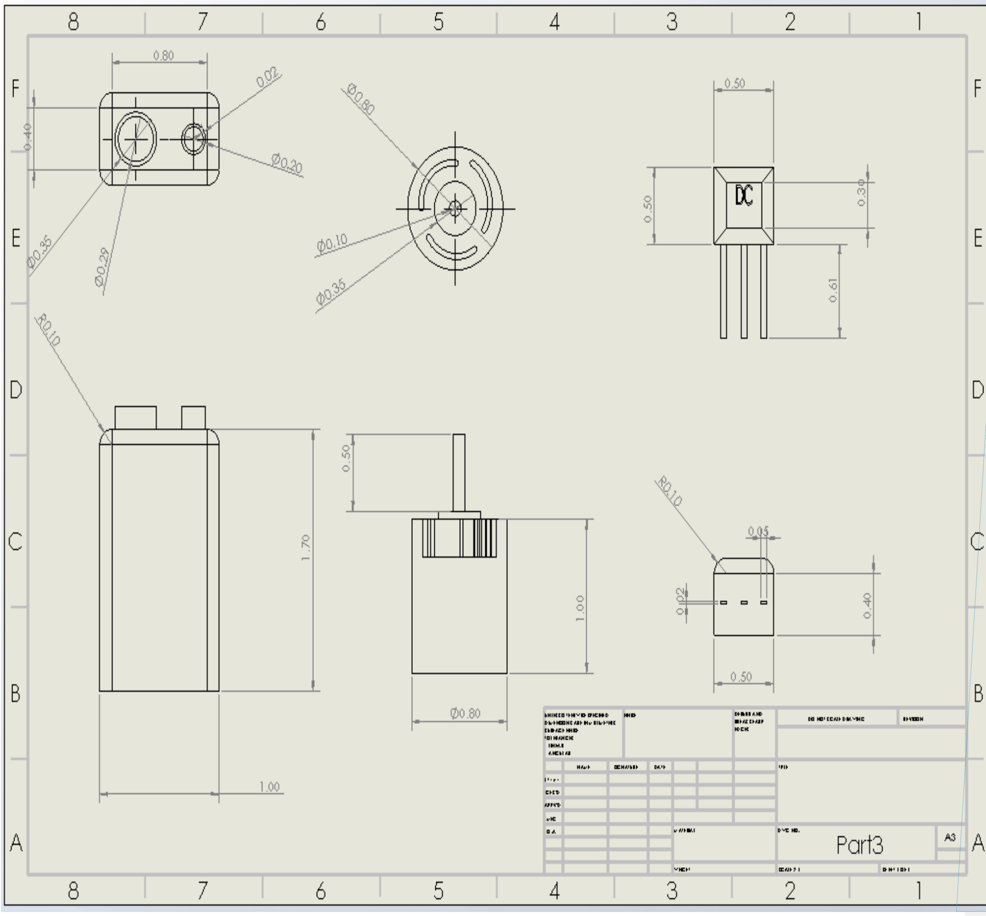


Figure C3: Drawings of Internal Components

Commented [1]: Figures in the appendices need to have captions, like figures in the body of the report.