Water Bottler Final Report

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Contents

1 Abstract:

The Water Bottle project was an organized approach to amending current global issues. Currently, each day, millions of plastic bottles are used and then simply disposed without any hesitation. While this is a problem in of itself, there are other dilemmas. For instance, many companies fill their products with tap water, a natural resource which is available without the need of purchasing. The issue here is not in the bottle but rather in the transportation. Shipping filled bottles of tap water wastes resources such as gas and time due to the weight and room which accumulates with container of bottles. More bottles could be shipped in the same amount of loads if the bottles were filled on site rather than in a factory and they were collapsible.

Using a college campus as a basis for this project three main methods of obtaining water were analyzed. The first two were simple; purchasing a bottle either at a store or vending machine. The third option was filing a refillable bottle (at a water fountain) that the students brought with them to class. After analyzing the situations it was concluded that the three could be combined and solved in one. The device was to be implemented in a non-invasive way, in the sense that existing water fountains could be used. A user would interact with the device, either through a lever or button sensor, this would then activate a process in which a empty water bottles would be filled at the fountain.

The device can be broken down into a few components. A lever arm, a cup holder (and support), electronic components and storage. The lever arm was to be rotated around a central axis. This would keep the device from interfering with those who wanted to simply use the fountain and also allow for it to return to a designated for the next bottle. The cup holders would support the bottle's weight even if it was fully filled. Additionally the top component kept the water bottle upright and from tipping over. The electronics consisted of an Arduino and a stepper motor to power and rotate the device. Sensors and timers were used to start the entire process and send instructions to the motor to either initiate, wait or return to the initial position.

At the conclusion of the prototyping phase the project worked precisely as expected. Although it was attached to a simulated fountain of 8020 steel, the conditions and constraints were met. The device started when the bottle was dropped into place, it then rotated the desired angle and paused for six seconds (the time had been determined at an early point when filing the testing water bottle). Then the motor turned and waited for the bottle to be removed by the user, allowing for a few seconds to pass to prevent any collision with the user's arm or hand. The device simply returned to its starting position, resetting and being prepared to start again. However, there were minor issues such as some hard coding and having to manually feed the water bottle since there was no storage unit. These issues were accounted for at the prototyping stage and were expected to be solved at later stages.

2 User Requirements

A large amount of insight resulted after conducting a multiple of interviews on campus.To begin, the consumer market that we expected to be most impacted by this product were students, teachers, and gym users. The feedback showed that users were not excited to use a flexible water substitute for current rigid plastic bottles. Due to this feedback we decided that creating an alternative bottle is worthless but what could be better is an improved mechanism that can deliver reusable rigid bottles at a water fountain. As Toron Deluz says "I would reusable water bottles because water bottles are $1.75, but I would not use flexible ones." The group decided that our prototype should then be used to demonstrate how the mechanism would deliver the user a water from a storage place. To receive feedback for this new idea, a new interview was conducted orally and notes were taken accordingly. In these new interviews future users were being asked question about time, appearance,and responsiveness. Using the new insight it was clear that users wanted a mechanism that could deliver them a water bottle in under 10 seconds, work every time with no problems or delays, and be appealing so that it can be acceptable next to a water fountain in the hallway. With this feedback, a few of the preliminary ideas that the group had became inept and it had narrowed the possible prototype to about 2 designs.

3 Problem Statement:

Currently, billions of water bottles are being transported around the world. Water is bottled in a few factories, and then shipped domestically and even internationally. Water is necessary for life, but the market price of bottled water is much higher than tap water. In 2012, the average price of bottled water nationwide was $1.22 per gallon compared to $0.004 per gallon for tap water. The reason for the high market price is because of bottling costs and shipping costs. In addition to high prices, shipping the water such long distances poses unnecessary environmental issues.

To avoid high markups and environmental problems, we would like to make a water bottler that can fill water bottles locally. The biggest detriment of the water bottle industry is having to ship already filled bottles. If there was a method of filling the bottles on site, the price of bottled water would decrease due to the exclusion of shipping costs and the environmental damage would be lessened.

In an attempt to combat these issues, our group is designing a method to locally fill water bottles. It is our goal to make this method widespread and easy to implement. By having water bottles be filled on-site, consumers can have access to bottled water that is much close to the price of their own tap water rather than the price companies set to make a profit.

This will be done by creating a system that improves the water bottle filling stations by automating the process. However, there are many issues that this project would encounter such as being competitive with the existing market's cost. The materials needed to build such a process create a high upfront cost to whoever owns the water filling stations and don't generate any profit. The machines can often be liable to failure or vandalism which is another cost to the owners whereas they are completely detached if people just buy their own water bottles. A constraint for this assembly is filling it under 10 seconds.

4 Objectives and Metrics:

TABLE I: Objective and Metric Chart

Objective	**Metric**	**Score**
Responsiveness in sensing water bottle	10- seconds over 2 seconds to respond	10
Accuracy in trajectory of swinging arm	10- .1*degrees below or over 180	9.7
Security of the water bottle	10- # of times bottle tipped over in 10 tests	10
Cheap	Price to make below 100$	60
Understandable function	1-10 by accuracy of described function by user	9
Aesthetically pleasing	1-10 by user	9

In the above table, one can see the metrics for our objectives for this project. In evaluating the most important parts of the product for pleasing the customers by using results from the interviews and the group's own experiences, the detailed list is seen above. The most prioritized objective was responsiveness. Students interviewed had said that they would like this product only if it worked every time with no glitches or slowing down their busy day. For this we needed to decide on a metric that can keep all this in mind and therefore a score of 10 - the amount of time over the allotted time of 2 seconds. Overall there was a max possible score of 150 and our product was able to score a 107.7 with 40 of those points being cost based.

5 Functional Analysis:

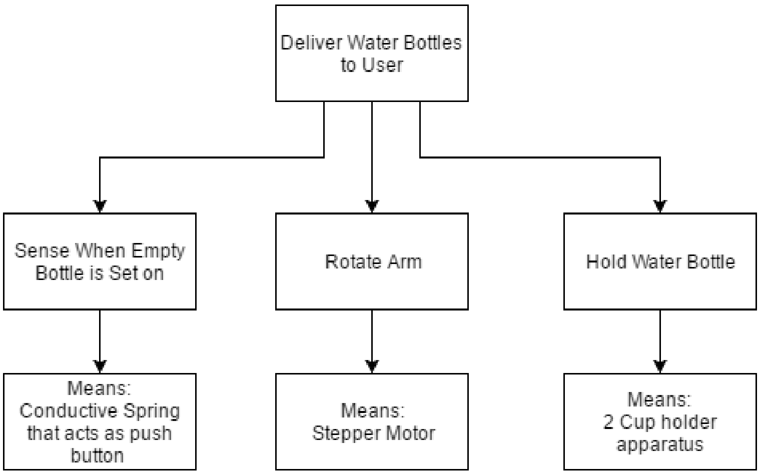

FIG. 1: Chart displaying primary and secondary functions

As seen in the functional analysis the primary functions of this prototype is to sense when the empty bottle is set on, rotate arm, and hold the water bottle. The secondary functions of these functions are for the circuit to have a provided voltage to begin the program, time the function, create 180 degrees of motion, and delay program until bottle is taken out of the cup holder. Some of the means are listed above, but most of the other means are represented by code which can control most of these function like timing the circuit, delaying the motor, and specifying the rotation of the arm.

6: Concept Generation and selection:

TABLE II: Morphological Chart

Store Bottles	Transport Bottle	Hold Bottle
Vertical Dispenser	Vex Lift	Live Spring Claw
Horizontal Dispenser	Swinging/Rotating Arm	Cup Holder
Tank	Conveyor Belt	Platform
	Counter-Weight Arm	

1. Vertical - Vex - Platform
2. Horizontal – Conveyor- Live Spring
3. Tank – Swinging Arm – Cup Holder
4. Vertical – Swinging Arm – Cup Holder
5. Horizontal – Counter Weight Arm – Cup Holder

TABLE III: Pugh Chart

Criteria (factor scale)	Design 1 (Datum)	Design 2	Design 3	Design 4	Design 5
Cost (2)	0	0.5	0	0	0.5
Density (1)	0	0	1	1	-1
Speed (1)	0	0	0	1	0
Total	0	1	1	2	0

Initially the group brainstormed ideas and solutions to the delivery system. Using a morphological chart system, the designs were broken down into three categories of storage, transportation and method of physically holding the bottle. Once the chart was completed five designs were chosen by picking one option from each column in the chart. The chosen concept was design number four. The basis for this decision was by creating a datum design to compare and contrast other designs with. The three most important criteria for this product were the cost, the speed in which the device could function and the density. In this scenario, we took the density as an umbrella term to cater to issues such as overall size and weight. For each criteria, we assigned a weighted multiplier to represent its importance in designing the product. Following the pugh chart method it was determined that a combination of a Vertical dispenser, Swinging Arm and Cup Holder would be the most successful for the project.

7 Engineering Analysis:

Using PTC Creo, an FEA analysis was done on our assembly. Three critical assumptions were made in doing this. One was that our acrylic base and rod assembly was a "continuous" piece of acrylic. Another assumption made was that the load was evenly distributed on the loading area. One last assumption made was that this product would be used exactly in the way designed.

To achieve this FEA model, top and bottom was fixed and supported on their respective faces. Then a 5 pound uniformly distributed load was applied to the loading area of the product. Although in reality, the force would only be around a 1 pound force, we wanted to maintain a larger margin for error regarding the factor of safety. A 5 pound force, therefore, was applied rather than a 1 pound force.

The first analysis run was a displacement analysis, which can be seen in this figure below.

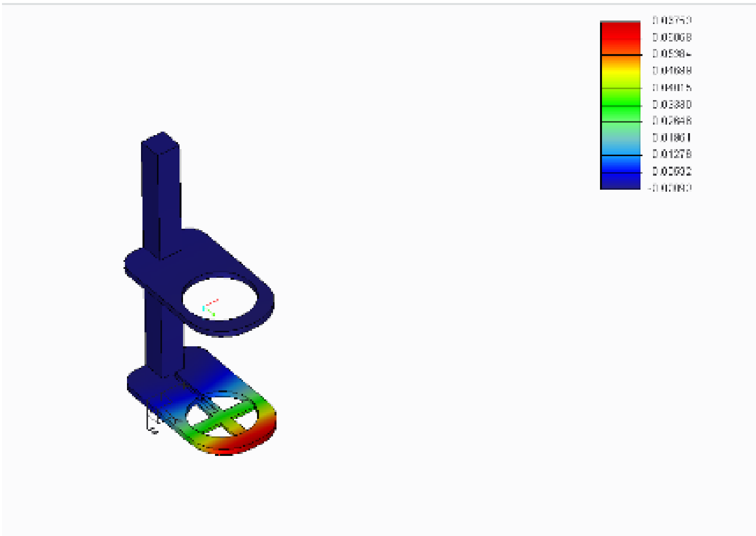

FIG. 2: Displacement of assembly with a 5 pound load

A displacement analysis was run to see if a noticeable displacement would occur upon loading the water bottle. In our model, the maximum displacement is .06753 in, not noticeable to the human eye.

The next analysis run was a stress analysis, which can be seen in the next two figures.

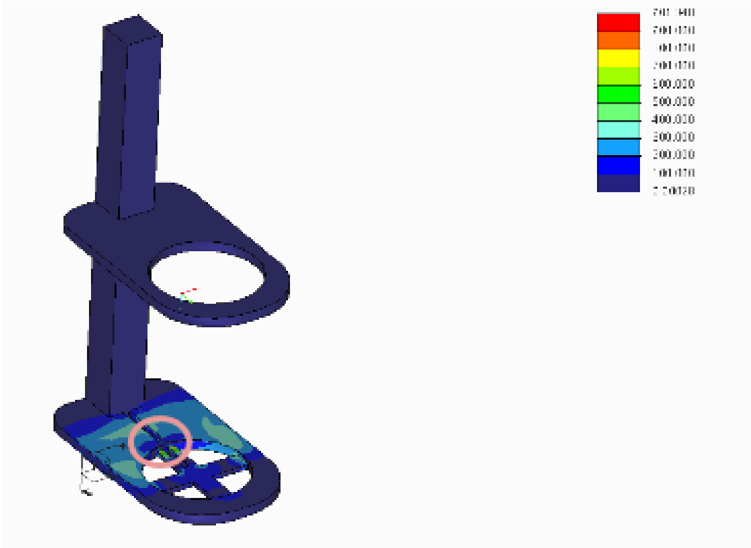

FIG. 3: Von Mises Stress on Assembly with 5 pound load - Upper View

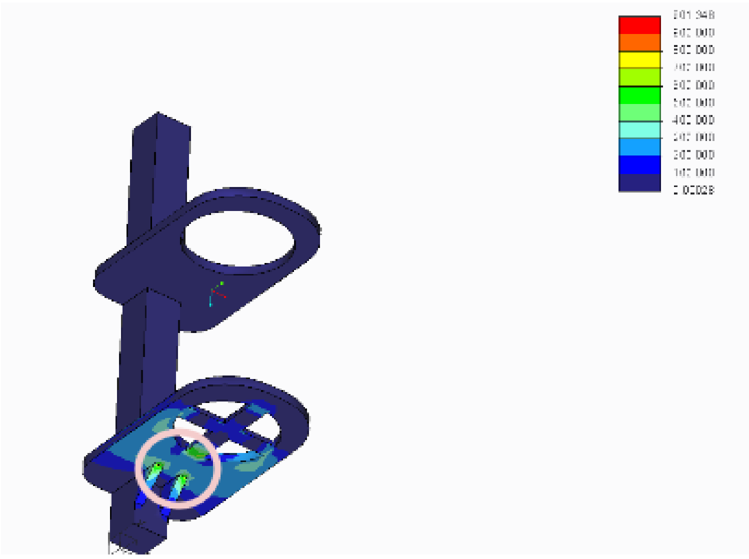

FIG. 4: Von Mises Stress on Assembly with 5 pound load - Lower View

The largest stress achieved was 901.3 psi. This largest stress happened at intersection of the thinnest portion of the base and the thicker portion, circled in the figure above. Using this largest stress, we can find a factor of safety using this formula below.

$$FactorofSafety = \frac{\tau_{ultimate}}{\tau_{workingload}} \tag{1}$$

The factor of safety with a 5 pound force was found to be 10.0. This figure would, however, be inaccurate due to the assumptions made. One assumption made was that the product would be used exactly in the way intended, and this model is for a static situation. However, the product is dynamic, taking varying amounts of forces, impacts, and impulses. Another assumption made was that the product was essentially a uniform piece of acrylic. This assumption is wrong as well, due to the manufacturing of the assembly in real life. The slot cut for the acrylic is not exactly the size of the piece of acrylic. Therefore, there is empty space between the top of the slot in the rod, and the acrylic base. Additionally, the acrylic cement is not a perfect bond. Bubbles and areas where the cement does not seep into exists, creating a weaker bond between the base and the rod. Therefore, the joint would likely be the weakest point in the model.

Finding such a generous factor of safety is comforting for our product. Due to the loading conditions (1lb), the assembly should never reach the amount of stress listed in the model.

8 Embodiment of prototype:

Using solder and a soldering iron, we connected the wires, resistor, and the spring. Then the motor shield was mounted on the Arduino, and the wires and other electrical components were added to the ports of the Arduino.

Once we had the CAD models for the base, guide, and motor mount, we translated the files into GibbsCAM. The same could not be done for the bar, due the design of extrudes and cuts on all 6 sides on the bar. For that, the NC mill was used. Cuts were made on one side, then the material was rotated to make the next cut. On the top, holes were drilled exactly perpendicular to the ground for the motor shaft. A hole for the set screw was also drilled, and then threaded. On the bottom face, a hole for the screw of a radial bearing was drilled and then threaded.

Next, we took pieces of 80/20 and cut them to length using a circular saw, for the purpose of making a model of the water fountain. We used the L-brackets and screws made for the 80/20 for the assembly. Next, we mounted the motor mounting bracket to the top of the 80/20 assembly, and screwed out motor on. Then we slid the bar and base assembly onto the motor shaft, and technically the mechanical portion of the product was finished.

To hide the wires of the motor and Arduino, the decision was made to create an acrylic box with our remaining material of the acrylic sheet. The box was mounted using the 80/20 screws, and plastic insulation was added between the screws and the Arduino.

Another decision was made to add a radial bearing was an afterthought due to the materials our group had access to at the EPIC center. Although the radial bearing predominantly handles loads perpendicular to the shaft, this radial bearing was able to handle the light load of the assembly, and allowed for free rotation.

Vibration was a problem during the manufacturing process. At some portions of using the NC mill, the bar extended past the support of the vice. When machining that portion, the end of the part shook, leaving some rough marks behind. The marks did not have an effect functionally, rather it was not as aesthetically appealing. Afterwards, our group received the tip to clamp the end of the part to a weighted support to reduce the vibration in future endeavors.

9 Iterations:

After completing an initial prototype out of cardboard there were many issues apparent. The system of delivery and solution were over complicated. The final prototype amended many of these issues but could still be improved upon. Currently the final prototype needed to use timers and weight sensors to begin the intended process. An improved design would use either thermal detectors, phototransistors to determine if the bottle was at the filling location, filled and set to be returned. These alterations would eliminate the need to depend on a timing function which could be incorrect depending on water pressure flows at other locations than those tested. The weight sensor is also a liability due to it being exposed and it being susceptible to wearing down quickly. A device which could detect if a water bottle was simply present would remove the dependence on a mechanical movement to activate the device.

While studying the intended fountains which would be used it was realized that the device would need to go more than 180 degrees. A step motor needed to be used due to its range of motion. However, the programming needed to be calculated as opposed to using a motor which could stop based on a specific location. This would allow for a more fluid motion and resolve any small discrepancies when the device traversed the path of motion.

10 Material Selection:

Due to the expected usage and other factors the material selection was based on cost, density and young's modulus. The equation which was formulated to pick a material called for a material that was cheap, somewhat rigid and had a low density. The materials would undergo stress and needed to house electronics. These factors meant that the material needed to be non-conductive and water repellant. The initial design called for acrylic for both the cup holders and lever arm. During the prototyping stage issues such as mass production were not at the forefront of design. Acrylic was chosen for its easy machinability and cost. The formula suggested the use of porous ceramics for the design. However, after further investigation into how to make molds for mass production it was decided that the initial material of acrylic was far better suited for desired properties. It as a material was very similar to the desired cost, rigidity and density of the ceramics and seemed to be an appropriate compromise.

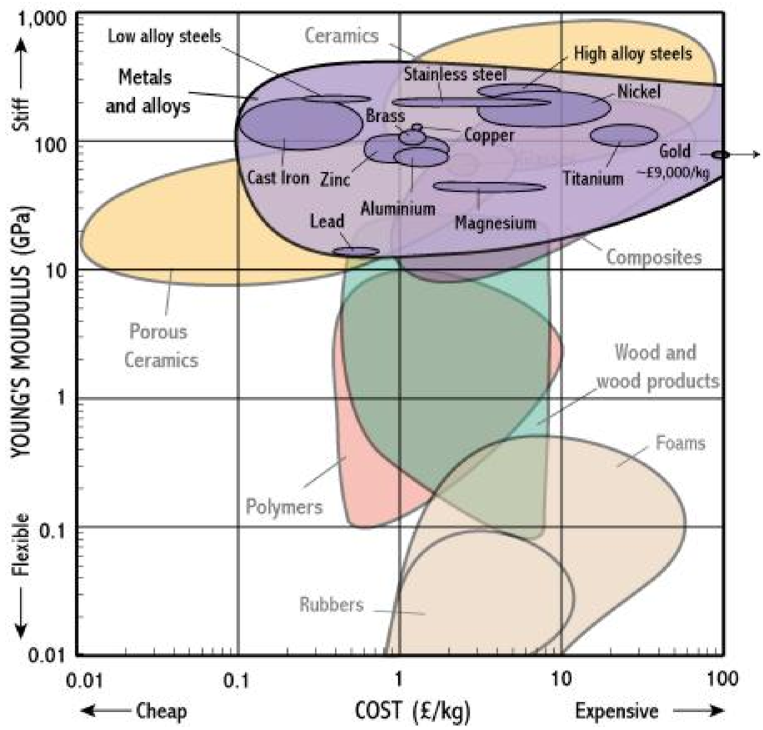

FIG. 5: Materials Selection Chart - Young's Modulus vs. Cost

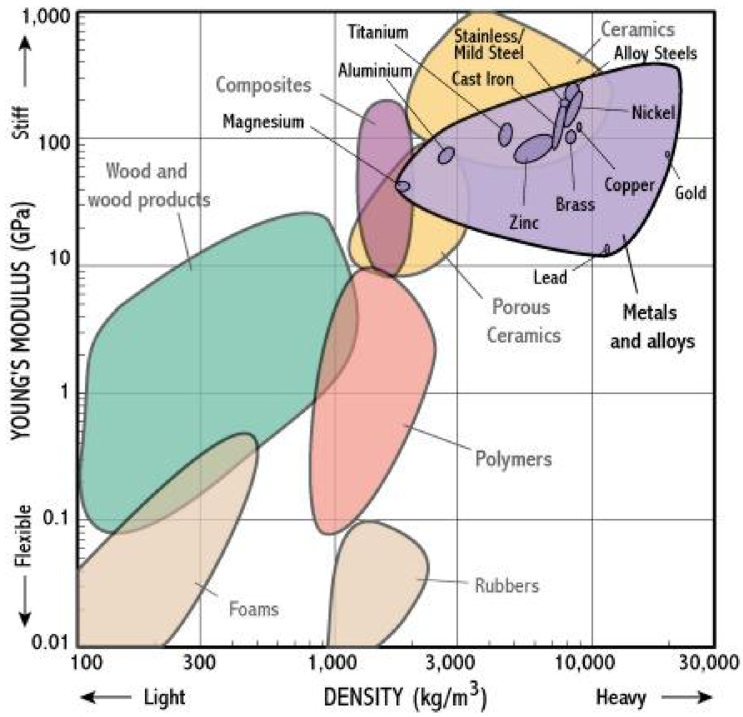

FIG. 6: Materials Selection Chart - Young's Modulus vs. Density

11 Design for Manufacture:

The shapes reflect the idea of reducing the amount of time manufacturing. The goal would be to create molds and then use a method of injection molding with acrylic. There would be three main parts, only two of which needed to be created with the molds. The third part, the lever arm, is simply a rectangular piece of acrylic and would just needed to be cut to the desired length. Additionally, the necessary cutouts for wires, the motor shaft and where the cup holder sections would be connected needed to be done manually. These cuts are simple and do not require a lot of time to complete. The cup holders are connected to the lever arm via a bonding adhesive and slid snuggly into the slots carved out for them.

Holes were added to the bottom cup holder to prevent excess water from accumulating. These were cut out quickly with a laser cutter. However, the shapes that were cut out were chosen so that they could then become the bottom supports to prevent any deflection. This reduced the waste when producing the product. The bottom cup holder also needed a track to be cut for the wiring and spring mechanism to be placed. This extrusion would not be necessary if the product was updated to the aforementioned iteration and used a non-mechanical sensor.