Osprey Design Experience Weekly Memo

**TEAM NAME**: Green Ellipsis - Upcycling of Single Use Plastic Softdrink Bottles

**DATE**: 09/09/2022

**ATTACHMENTS:**

1. Problem Statement
2. Concept Selection with Decision Matrix

**MEMO AUTHOR:** Marc Caina

**WORK COMPLETED THIS WEEK**:

* Wrote Problem Statement due 9/09/2022
* Wrote Concept Selection due 9/09/2022
* Devised Individual Weekly Planning Schedule due 9/09/2022
* Created Decision Matrix

**WORK TO BE COMPLETED NEXT WEEK**:

* Report Introduction due 9/16/2022

**TEAM HOURS**:

|  |  |
| --- | --- |
| Name | Hours |
| Antonio Mendoza | 10 |
| Christian Ventouras | 11 |
| Marc Caina | 9.5 |
| Nicholas Wedyck | 10 |
| Tyler Johns | 10 |
| Total | 50.5 |

# **(1)**

**Team Green Ellipsis Problem Statement**

Single-use polyethylene terephthalate (PET) bottles continue to pack landfills around the country. Because of this, the need for recycling and upcycling of PET grows greater every day. 3D printers can uniquely contribute by upcycling PET bottles into PET filament. Green Ellipsis has a solution to this issue that converts plastic bottles into 3D printer filament (Figure 1). This method of upcycling PET bottles cuts a two-liter bottle into one long strip. The strip is then pulled through a heated chamber which deforms the plastic into usable filament. Currently, this process is intensely laborious and is not competitive compared to non-recycled filaments. To solve this problem automation is required. There are seven main components to the solution:

* Bottle cleaning
* Bottle cutting
* Strip pultrusion
* Filament winding
* Filament splicing
* Filament packaging
* By-product processing

Automating these components would reduce the labor costs of PET filament, providing consumers a cost effective, environmentally sustainable alternative to traditional filament. Additionally, it would provide a cost-conscious option for hobbyists to recycle already existing single-use PET bottles into reclaimed filament. The design must automate at least one of the components, while generating no additional waste.

Graphical user interface

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(a) (b) (c)

*Figure 1: (a) This image shows the overall system. (b) This image shows the hot end and pultrusion device. (c) This image shows the PET bottle cutter*.

The following are the design requirements and constraints for this project. Each requirement and constraint was established based on the project description, as well as the meeting with Green Ellipsis.

**Design Requirements**

* Automation of at least one step in the process
* Reduce duration of reclamation process
* Minimize PET bottle waste
* Minimize the number of tools needed to complete the process
* Process must accept unwashed two-liter bottles
* Must prioritize health and safety of the operator at all steps

**Design Constraints**

* Approximately $1,000 budget
* Additional money is available if justified
* Machine needs to fit on a 4’ by 8’ table
* Must run off standard wall power (120Vac/60hz)
* Must not produce excess hazardous fumes
* Must use environmentally friendly chemicals (I.e. not petroleum based)

**(2)**

**Team Green Ellipsis Concept Selection**

Three different concepts were considered during this process. Each concept focuses on a different process in the overall design. This is because there is a requirement to automate at least one process in the design. Furthermore, it is necessary to focus on the most important and feasible process to automate, given the deadline for this design. The three concepts considered for automation include:

* Bottle cutting
* Bottle cleaning
* Strip pultrusion

Each of the selected concepts was discussed extensively during team meetings. Rough, hand-drawn sketches were generated based on these discussions to get an idea of potential automation solutions. A down selection process was then utilized to narrow the concepts down to one final concept.

**Bottle Cutting**

The bottle cutting stage concept will cut the bottom of the bottle in an automated process. Additionally, this concept includes the beginning pointed strip cut that is needed for the pultrusion process. A couple of factors explain the importance of automating this concept. First, the tool usage would benefit from this concept automation. The current process has the bottom cut and strip cut completed separately using two different tools. Moreover, the user must first use a modified blade to cut the bottom of the bottle off, then a pair of scissors to start the strip cut. Another importance to automating this process is the accuracy between strip cuts. As mentioned, the current strip cut is done with scissors. In addition, this pointed strip cut must be a certain thickness and length in order to properly enter the heated chamber during the pultrusion process. As observed, the current process has a variation in strip cut between bottles. An automated solution would allow for a thickness and length that could be accurately replicated each time.

Figure 1 shows a potential automated solution to the bottle cutting concept. The bottle is set into a device with a blade as shown in Figure 1. The bottle or device then rotates automatically, which cuts off the unusable bottom portion of the bottle. Then the y-axis angle of the blade adjusts. Finally, the device or bottle is rotated slightly to cut a pointed strip into the bottle. The accuracy of the pointed strip is crucial to the next step in the process.

Diagram

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*Figure 1: Sketch showing the bottle cutting concept*

**Bottle Cleaning**

The bottle cleaning stage concept includes label removal, adhesive removal, and bottle washing. All these processes will occur within the same stage. There are a couple of reasons why this concept is important to the automation of this design. First, it is necessary to remove all external components from the bottle itself. This is because the bottle cannot enter the heating chamber without the label and adhesive being removed. Likewise, the inside of the bottle needs to be rinsed to ensure there are no contaminants that transfer to the PET filament. Contaminants would cause issues when trying to 3D print using the filament. Another reason of importance is that this process is labor intensive. Currently, the user must cut the bottle label with scissors and peel it off carefully. Then the user must use a rag and D-Limonene solution to remove the adhesive from the bottle. Finally, the inside of the bottle must be rinsed with water. An automated solution would reduce the time spent on this laborious process.

A potential automated solution for the bottle cleaning concept is shown in Figure 2. In this concept, one or more bottles are lowered into a heated solution of D-Limonene. The bottles are then rotated in the heated solution while rubbing against a light abrasive material such as a sponge. This removes both the label and adhesive from the bottle. In addition, the heated solution would also swish around the inside of the bottle during this process, cleaning it. The bottles are then removed from the solution and transferred to the next stage of the process.

Diagram, engineering drawing

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*Figure 2: Sketch showing the bottle cleaning concept*

**Strip Pultrusion**

The Strip pultrusion automation process would remove the need to pull the initial filament from the first cut of the PET bottle through the hot end as well as guide it to the winding spool. Afterwards, the winding of the spool would drive the pultrusion process instead of the initial rollers. Automating this process would reduce the number of tools and human interactions needed by eliminating the need for pliers to start the pultrusion process.  This keeps the hands of the operator away from the heating element, ensuring a safer design. Additionally, this will reduce the cycle time for the entire process as it needs to be manually started for each bottle being upcycled.

Figure 3 shows the first iteration of the automated strip pultrusion process. As the cut strip is set into the pultrusion guides, the rollers would grab the strip and push it throughout the process until it passes the heating element and is wound on the spinning spool. The rollers would also have guides that ensure the filament stays on track because it tends to curve.

Diagram

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*Figure 3: Sketch showing the strip pultrusion concept*

**Down Selection Process**

A weighted, down selection matrix was used to determine the most suitable concept for our project. The Analytical Hierarchy Process (AHP), from *Engineering Design*[1], was employed to generate normalized weights for each criterion. The “AHP’s Ratings for Pairwise Comparison of Selection Criteria” from *Engineering Design*[1, Tab. 7.8] was used to generate the normalized criteria weights. The ratings are listed in Table 1 below. Table 2 shows the Normalized Criteria Comparison Matrix. This matrix was used to determine criterion weight by comparing their impact on design success. Table 3 below depicts the down selection matrix. The matrix uses the qualitative ranking system listed in Table 4 to obtain the most suitable concept. The table includes a value, correlated with a description, that represents how effectively the concept meets the design criterion.

*Table 1: Engineering Design AHP Ratings*

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*Engineering Design[1, Tab. 7.8]*

*Table 2: Normalized Criteria Comparison Matrix*

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*Table 3: Design Concept Down Selection Matrix*

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*Table 4: Evaluation Scheme for Down Selection Matrix*

Table

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The “Impact on Duration of Process” criteria ranks how much a concept affects the overall duration of up-cycling the two-liter bottles into 3D printer filament. As the production time of the 3D printer filament decreases, its production cost also decreases. Since the major goal of this design is to automate this process to make the filament more economical, this criterion ranked highest alongside the “Human Interaction Needed” criterion. This is because the more a person needs to interact with a process, the less the process can run on its own. Therefore, increasing the labor costs of 3D printer filament production. Since our design is provided a budget of $1000, the “Cost” criterion is ranked second highest. For the scale of this project, $1000 is a sufficient budget, however, to maximize the effectiveness of our design, the cost of each concept is weighted heavier than other criteria.

The “Waste Minimization” criterion was given a moderate ranking as the main design goal of the original process was to minimize waste and pollution in the world. The “Manufacturability” criterion is ranked the same since this characteristic of the design affects the overall cost of the design. Both “Feasibility while Writing Report” and “Complexity” are ranked with the same moderate value. Since the project entails designing, manufacturing, and testing a design while writing an extensive design report over a nine-month period, the complexity and feasibility of the concept are important criterion. The more complex a concept is, the more time is needed to create a successful design, and the time needed to write the extensive design report is a factor that must be taken into consideration when determining the design concept. The “Automation Risk Avoidance” was also given the same ranking. The ability of the design to reduce the risk of injury for a user can reduce the liability taken on by Green Ellipses.

The “Power Requirement” criterion was given a lower ranking. The design is constrained to run on standard wall power(120Vac/60hz). This is so hobbyists who are interested in creating their own 3D printer filament can run this machine in their own homes. Since the power requirements of the original design are well below what is supplied from standard wall power, the power requirement of the automation design concept is not a major element in the decision-making process. The “Size” and “Testing Time” criteria were ranked lowest. The size requirement given by the sponsor is that the design must fit in a 75cm by 240cm area. The current design takes up roughly 60cm by 45cm, therefore, there is abundant room for the automation component. The “Testing Time” criteria represents the amount of time needed to test the concept once it is manufactured. The amount of time needed to prove a design’s effectiveness contributes to the suitability of the concept but isn’t a defining factor.

**Final Concept Selection**

The down selection process yielded the bottle cleaning concept as the final concept. Once all the criteria were normalized and ranked, the down selection matrix was used to determine the final concept. Bottle cleaning ranked first with a net score of 3.873, bottle cutting second with a net score of 3.423, and the pultrusion process third with a net score of 2.934.

There are several key areas that attributed to the bottle cleaning concept scoring highest. First, bottle cleaning ranked highest on “Impact on Duration of Process,” which was tied as the highest weight out of the twelve criteria. This is important because it means that bottle cleaning automation will save the most process time compared to the other two concepts. Next, bottle cleaning ranked high again for “Human Interaction Needed,” which was also the highest weighted criterion. Moreover, it shows that the bottle cleaning design will benefit greatly from automation, making that process less labor intensive. Finally, bottle cleaning ranked moderately in the “Cost” criteria with a value of three. Even though it was only moderate here, it was still important because “Cost” had the second highest weight associated with it. The moderately projected cost of the bottle cleaning concept is imperative because it means there is a low risk of exceeding the proposed budget. All of this leads to the fact that the bottle cleaning concept is the design that will be focused on moving forward.