Project Number: 16420

LIP BALM AND HAND SALVE PRODUCTION PROCESS IMPROVEMENT

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ABSTRACT

Rochester Institute of Technology (RIT) Multidisciplinary Senior Design (MSD) Team P16420 has assumed responsibility in picking up where P15420, the previous year’s team, left off with a non-functioning system. The initial customer interview and system demo indicated that the biggest problem that led P15420 to failure was system clogging. The main thing that P16420 will need to address is that beeswax, due to its physical properties, will only stay in liquid form in elevated temperatures (> 180°F). P15420 had designed a system that transports beeswax in liquid form from a soup pot to the lip balm tubes and hand salve tins via a thin hose. This turned out to be a poor choice as the wax began to solidify as it traveled down the hose, making the system unfit for any type of repeated use.

P16420 addressed this issue by shortening the path traveled by the molten product as much as possible. In fact, tubing has been eliminated completely and molten product falls directly from the water boiler nozzle into the lip balm tubes and hand salve tin trays. Moreover, to increase the production speed, pouring trays have been designed for both types of packaging and the customer can safely expect to see at least 80% decrease in cycle time per tube or per tin tray. To improve the safety of the system, a linear actuator is used along with a 3-stage rocker switch to dispense the product from the water boiler into the trays. The final system designed meets all minimal customer requirements in that it is safe for kids to use and it dispenses the product rapidly and evenly.

BACKGROUND

Rochester Roots is a non-profit organization with a focus on helping students learn about sustainability and entrepreneurship. One of their projects is working with students to manufacture lip balm and hand salve products with different medicinal plants that the students grow themselves. A previous RIT MSD team was tasked with designing a complete process from harvesting to packaged final products. While they were successful in many aspects, their solution for dispensing the product was not sufficient for Rochester Roots. It did not maintain heat properly which caused clogging and unreliable dispensing. The goal of our project was to develop an improved design that emphasizes safety, dispensing reliability, and has a decreased production time per tube of lip balm or tin of hand salve. The system should be sustainable with reusable parts, produce little to no waste, and should require little maintenance. It should also be able to be used easily and safely by students 8 years old and up.

The design challenge of this project was to develop a cost-efficient solution to quickly dispense hot wax into lip balm and hand salve tins for small batches. While machines that complete this function do exist, they are for large commercial batch uses. Subsystems for commercially available large scale wax dispensing machines were benchmarked however. Systems that use assorted pumps, mixing arms, and dispensing nozzles were thoroughly analyzed to identify key viable components.
PROCESS
Rochester Roots had a few key requirements for their final system. The system had to be usable and safe for students as young as 8 years old. Ideally, their lip balm and hand salve product should be dispensed with little to no handling by the operator – i.e. children. The previous MSD team had originally tried to avoid contact with the material by dispensing through a long tube. The customer found that this method didn’t work as the product cooled before reaching the end of the tube, becoming solid and clogging. Therefore, the team brainstormed several other ideas to dispense the product without needing student contact while minimizing the distance from the heating vessel to the product containers. The remaining customer requirements are detailed in Appendix A.

From the Customer Requirements, the team created Engineering Requirements that would be used to design the solution. These requirements were then used to evaluate the concepts that were generated. Additionally, each requirement was used to create a test plan to ensure there was a metric to measure against. The full list of Engineering Requirements can be viewed in Appendix B.

HEATING VESSEL
To create the product, the system must melt oil, beeswax, and fragrances together at a constant heat. The previous team decided to utilize a hotplate and simple kitchen pot as the heating vessel. While this solution works, it was determined that having kids create their material with a hot pot was not safe, so benchmarking and research was conducted to find an alternative heating solution. Additionally, to minimize the risk of the system clogging, the team reasoned that the heating vessel should utilize a spigot to dispense the product. This will ensure that the distance the hot product must travel to the container is minimized. This in turn reduces the risk of having the melted product cooling and solidifying thus leading to the system clogging.

The most viable alternative that was discovered was a water boiler. The characteristics of a water boiler that make it suitable for this project were its self-contained heating element, dispensing spigot, and adjustable temperature setting. After a few Pugh analysis iterations, the water boiler was found to be the best heating solution, and was purchased near the end of MSD I, shown in Figure 1.

Unexpectedly, the water boiler needed to be modified to melt the wax. The boiler was manufactured with a safety cutoff near the heating element to prevent the system from over heating. After consulting with a subject matter expert and diagnosing how the safety cutoff was operating, the team inferred that the water boiler was utilizing a bi-metallic switch that would trip once a certain temperature was reached. Due to the properties of the oil, the bi-metallic switch would trip very quickly after being turned on thus shutting off the heating element. The team determined that the root cause of this problem was the fact that oil heats up much faster than water. As such, the temperatures that the switch was exposed to were much higher than with water. Once the problem and cause were understood, the team modified the safety switch by moving it to the bottom of the heating unit, thus greatly increasing the distance between the heating element and the switch. After a few iterations and many tests, the modification was found to solve the problem and allowed for the oil and beeswax to be melted.

POURING TRAYS
During MSD I, the team had to make a critical decision between a rack-and-pinion rail system and a pouring tray system. In other words, dispensing the product precisely into individual containers, or into multiple containers at once using an overflow type pouring tray. Research from benchmarking found that the production processes were usually used in combination in manufacturing environments. However, the team decided to pursue only the pouring tray. The rationale for this decision is summarized in Table 1.

Figure 1: Water Boiler
<table>
<thead>
<tr>
<th>Number</th>
<th>Reason</th>
<th>Rationale</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Reduce Footprint of system</td>
<td>Allows system to be constructed vertically, thus meeting the customer's requirement of the system fitting on school lab bench.</td>
</tr>
<tr>
<td>2</td>
<td>Simplicity</td>
<td>While electronics do add STEM learning opportunities for students, the risk of electrical failures and more complex maintenance outweigh the possible benefits.</td>
</tr>
<tr>
<td>3</td>
<td>Feasibility with Lip Balm Tubes</td>
<td>The meniscus must cool down evenly with the top surface of the lip balm, which could be disturbed before it is completely cooled. Otherwise the meniscus would break, spill, and disrupt the surface finish along with the lip balm tube and thus yielding the packaged product</td>
</tr>
</tbody>
</table>

Table 1: Rationale for using pouring trays

Lip Balm Tube Pouring Trays

It has been agreed upon by the team that the system should be kept as simple as possible with the smallest number of parts as possible for maximum life expectancy. One thing that had to be factored into the design of the tube trays is that the lip balm tubes needed to form a meniscus of product on top that will later cool down evenly with the top surface of the lip balm. The meniscus properties meant that while the product was cooling in a tube, it could not be moved, thus eliminating individually dispensing into the tubes.

Lip-balm pouring trays (tube tray) were commercially available for purchase; in fact, the team had access to one previously purchased by the customer. After conducting experiments using the commercially available tube tray (commercial tube tray), the team found out that: 1) the commercial tube tray’s walls were not high enough to be easily handled. This caused spillage that had be followed with a lengthy cleaning process; 2) significant bending was observed within the commercial tube tray and attempts to locate the root cause were unsuccessful as the retailer was unable to provide the team with details about the materials used. This was a significant problem as a warped tray would not provide the necessary finish needed on the lip-balm tubes; 3) there are few restrictions in the scraper design or material used to scrape off the excess lip balm material - a credit card worked perfectly well during testing. It was apparent that the low quality of the commercial tube tray would drag the performance of the entire apparatus down and thus the quality of the overall system would depend on the quality of the trays. To create a reliable working system, the team decided to allocate the budget needed to manufacture custom trays in-house - the biggest design part of team P16420. The design for the tube tray can be seen in Figure 2.

The Material selected for the lip-balm tube tray was Ultra-High-Molecular-Weight Polyethylene (UHMW-PE). The criteria used for this decision are summarized in Table 2. This was purchased at the end of MSD I to begin prototype testing.
Table 2: Rationale for selecting UMHWPE material for pouring trays

<table>
<thead>
<tr>
<th>Number</th>
<th>Reason</th>
<th>Rationale</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Repeatable Use</td>
<td>Material should not be much harder than that of the lip-balm tube - otherwise it could damage the lip balm tube - while being hard enough for maximum life expectancy</td>
</tr>
<tr>
<td>2</td>
<td>Sanitary</td>
<td>Material should be easily cleanable and able to be disinfected</td>
</tr>
<tr>
<td>3</td>
<td>Easy to Manufacture</td>
<td>Resources to machine material readily available</td>
</tr>
<tr>
<td>4</td>
<td>Budget</td>
<td>Can be purchased at a reasonable cost</td>
</tr>
<tr>
<td>5</td>
<td>Mechanical Properties</td>
<td>Material must be strong and stiff enough to resist against impacts. Other materials considered were aluminum, stainless steel, and wood. Wood was excluded since it could not be disinfected; stainless steel was excluded since it was too costly for our budget; and both metals were too hard and were could damage the lip-balm tubes.</td>
</tr>
</tbody>
</table>

Tube tray design was benchmarked from commercial tube trays available for purchase online. The initial 2x2 prototype had a thickness equal to the height of the top portion of the main body of the tube and each hole was sized to be the smaller diameter of the tube (section of the tube where the cap attaches). In other words, the section of the tubes where the cap attached, inserted into the prototyped pouring tray completely. The small thickness was not a problem with the prototype, but turned out to be one in the 10x10 tray. The tray began to experience warping as it was exposed to elevated temperatures. Benchmarking from the tin tray, which did not experience warping due to its larger thickness and therefore higher thermal mass, the team decided to increase the thickness of the tube tray as well. The finalized tube tray now produces 8x8 tubes per cycle.

Upon machining the of the tube trays, a tolerance issue was discovered. The team had originally thought to make the diameter of the holes for the tube trays slightly smaller than the actual tubes so that there would not be any leaking between the tube/tray interface over time. After successfully testing this on a smaller 2x2 prototype, the team did not expect any problems to arise when the larger 8x8 tray was manufactured. However, during the systems test it was discovered that after the tubes had been filled and cooled, the caps would not stay on. The tray had deformed the tubes in such a way that the slip interface for the cap was damaged causing the caps to no longer click on. For that test, almost half of the batch failed keeping the cap on. The team re-measured the tubes and tray and noted a slight discrepancy. Having discovered the error, it was corrected by reaming the holes in the tray so the hole was a few thousands larger.

**Hand Salve Tin Pouring Trays**

The hand-salve tin tray (tin tray) design was a challenge of its own. Unlike the tube tray, which can be filled up all the way to the top without worrying about how much material to put in, the tin tray needed to have the functionality of curbing the amount of product that goes into the tins. Since the tin trays are not filled all the way to the top, the tin tray design had to be different from the tube tray design. The team decided to pursue an inverse tin tray design; that is, the tray would fit around the inside the case it fills. This way, we will still be able to pour in excess amount of oil and not worry about dispensing the exact amount within the tins (design shown in Figure 3). The problem with this inverse tray method is that the surface finish will not be ideal as it encounters the tray instead of being cleanly scooped out via the scraper. The next step for the team was to identify a process to refinish the surface of the product. The customer suggested researching a hairdryer to re-melt...
the surface finish. After testing, it became apparent that the hair drier had too much airflow and not enough heat. Heat flow from the hairdryer was not able to penetrate through the tin tray and it ended up making the surface smooth, but bumpy.

However, this suggestion led the team to further investigate other portable heating elements. It was found that a heat gun quickly and effectively re-melted the tins. This solution was discarded because of the small heating area of the heat gun- each tin would have to be melted individually thus eliminating the cycle time gains from using the pouring trays. This solution was also eliminated due to safety concerns over children operating a heat gun. When these results were discussed with the customer, a heat lamp approach was mentioned. Unexpectedly, this simple solution worked very well. By using a standard heat lamp and radiating cone, the 9 tins (one batch) could be re-melted in under 10 minutes. The results for each refinishing test are shown in Figure 4.

![Figure 4: From left to right: Hair dryer, Heat gun, and Heat Lamp methods used to re-treat the surface finish of the tin trays](image)

**BOILER BASE**

Since P16420 decided on the bulk manufacturing method using pouring tray, the heating vessel could be positioned above the pouring tray, effectively decreasing the footprint of the system. The main reason for this was because it was found through testing that by dispensing the product in the middle of the pouring tray results in a faster filling of all the containers. If no base was used, the spigot could only reach one side of the tray. The material for the base was chosen as wood (poplar) because it would not meet the product, so there were no sanitary requirements. Additionally, resources for manufacturing wood were readily available, the material was inexpensive, durable, and lightweight. The final design for the base was octagonal for manufacturability. A hard foam filler piece is slotted in behind the water boiler once on the base to ensure little wiggle room.

**ELECTRONICS**

Initially, most the design for this project was centered around a fully automated system. The goal of this design was to make the system completely foolproof by removing any chance for the children who are operating this system to interact with dangerous components like the heating element. However, as time progressed it became evident that such a system would be very difficult to fully design, construct, and test in the time allotted for this project. Additionally, the benefits from the automation were minimal, providing no more functionality than the manual alternatives. While keeping safety in mind, many aspects of the original design- such as a microcontroller and light-up buttons- were cut to make the system as fast and lean as possible. While testing, it became apparent that a stirring mechanism was not needed because the water boiler was observed to generate its own convection currents which effectively mix the material naturally. The final design incorporates a primarily mechanical design with some electronic controls used to control dispensing.

The electronics present in the final design include a linear actuator, a three-stage rocker switch, and a power supply. These three components are mounted on a wooden mount that can be moved away from the water boiler in the event of an emergency (i.e., overflow, or system power loss). When wired together and provided sufficient power, the rocker switch controls the actuator in much the same way as an electronic car window. Pressing the switch to the down position extends the actuator downwards while pressing the switch upwards retracts the actuator upwards. Moreover, not pressing the switch holds the actuator at its current position. The method for wiring the switch to the actuator can is shown in Figure 5.

The actuator is strategically placed directly atop the dispensing nozzle of the water boiler unit. When the actuator is extended, the nozzle is pressed and the product is dispensed into the waiting tray. The actuator also has a
built in cutoff switch which prevents it from over extending. When the tray has been filled sufficiently, the actuator is retracted and the nozzle closes. The system is deceptively simple yet also quite effective. With the heat shield in place around the tray, the system remains safe as well, with no chance of hot product splashing on the user.

![Diagram](image)

**Figure 5: Linear Actuator Schematic, Reprinted from WindyNation.com, Retrieved 12/7/16**

**Actuator Mount**

To position the actuator in a location that will depress the nozzle, a mount was fabricated out of Red Oak. There were concerns on how the actuator would interface with the nozzle because it needs to be able to depress the nozzle while being able to disconnect quickly in the event of an emergency to stop the hot product from dispensing. This safety consideration was deemed to be very serious because in the event of a loss of power, the actuator would remain in the extended position, thus meaning the hot product would continue dispensing. The design that was derived allows for the user to simply move the actuator mount forward, by removing pins, thus disconnecting the actuator from the nozzle. Another risk that was faced by the team was how the nozzle can rotate, which could cause the nozzle and actuator to not interface correctly. This risk was mitigated by installing wood fins that protrude outward from the actuator mount that are spaced so that the nozzle cannot rotate. Red Oak was chosen as the type of wood to use for its aesthetics and hardwood properties, thus increasing the durability and manufacturability. The actuator mount is shown in Figure 6.

**Capping Method**

The team utilized the pre-existing capping solution to complete the packaging for the lip balm tubes. The customer provided a piece of PVC tube that has a diameter slightly larger than a lip balm tube. To cap, the user simply places a cap in the PVC tube with a lip balm container. Due to the small size of the PVC tube, the cap is not allowed to rotate, meaning the cap always falls onto the lip balm tube in the correct orientation. To finish, the user inserts in a wooden dowel rod in the PVC tube and presses the cap onto the lip balm tube. This solution is simple but very effective. The team measured that a tube could be capped in 3 seconds.

**User Manual**

The team concluded that for this project there were to be two user manuals. This was due to the nature of working with both teachers and students. The first user manual is very technical and made for adults who can handle the larger amount of information. The second user manual was made for children. In this manual, steps were spaced by page, fonts were changed, and pictures were added to help maintain the attention of the students. Both user manuals flow like a recipe; this is largely due to the very nature of this system in that the user is essentially cooking.
RESULTS

The team conducted testing to validate that the subsystems would work independently then completed integration testing to ensure the system functioned properly. The heating and dispensing system was tested using prototyped trays and were found to meet the customer’s desired function. The modified water boiler proved to heat the oil and wax efficiently and effectively while mixing the two via convection currents. Additionally, when the oil and wax were heated the nozzle did not clog. However, it was found that if the boiler turned off with material inside, the nozzle could clog on the next dispensing cycle. Intuitively, this is because the product cooled and solidified in the nozzle while the heating element was turned off. This problem was found to be easily fixed by simply reheating the product in the water boiler and having the instructor move the nozzle up and down. This movement of the nozzle breaks up the cooled product, and then by using the hot liquid material in the boiler, melts the remaining solid product in the nozzle to completely unplug the spigot. Furthermore, the customer has informed us that this will never be a use case because they always clean out the boiler of all product after every cycle.

While testing the full system, the team discovered the time to cool the pouring trays was longer than initially expected. This is believed to be a result of the amount of material that is being poured on top of the tray. This discovery was not viewed as a problem because the customer has requested three trays of each, so parallel processing is possible. In other words, the customer can be simultaneously dispensing into trays while others are cooling. The team also found methods to speed up the cooling time by placing the warm trays in a cold environment.

CONCLUSIONS

The team was successful at providing the customer a working solution to melt and dispense product into lip balm and hand salve containers. By utilizing many simple and inexpensive materials and subsystems, the solution should also be low cost to maintain and use. Moreover, this system will provide the customer with teaching opportunities for students. Such topics that can be demonstrated by this system are line balancing, machining operations, heat transfer, and circuits. The project also helps teach students the merits of designing a custom solution for your customers.

RECOMMENDATIONS

Future work could be completed on implementing a fully automated dispensing solution. The customer showed interest in this type of solution because it would expose the children to more STEM opportunities. Areas that could be automated include using a microcontroller to tell the system when to stop flow by triggering the actuator to close the nozzle. Moreover, sensors could be used to allow for the system to automatically stop dispensing when the pouring trays are filled. A rack and pinion system could be implemented to automate the movement of the pouring trays in and out of the system also.

The other aspects of the project that could be expanded upon are the water boiler. Modification was required to prevent the emergency cut-off from triggering when oil was heated. Other heating vessels could be used to remove this possible issue in the future. A final improvement could be switching out the plastic nozzle with a
metal one, as a metal nozzle would hold the heat in the material better. It is anticipated that a metal nozzle would not clog as much as the plastic one.

REFERENCES

ACKNOWLEDGMENTS
Joseph Chun – 3rd year Furniture Design Major Student - Helped in manufacturing the wooden base
John Kaemmerlen – Faculty Advisor
Jan McDonald – Customer
RIT Machine Shop Staff

APPENDIX A – CUSTOMER REQUIREMENTS

<table>
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<th>CR#</th>
<th>Category</th>
<th>Requirements</th>
<th>Priority</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1</td>
<td>Physical Constraints</td>
<td>Fits in allotted classroom space (where it will be used), preferably a lab desk/counter</td>
<td>1</td>
</tr>
<tr>
<td>1.2</td>
<td>Physical Constraints</td>
<td>Portable, able to transport to events</td>
<td>3</td>
</tr>
<tr>
<td>1.3</td>
<td>Physical Constraints</td>
<td>Dispensing process does not clog</td>
<td>9</td>
</tr>
<tr>
<td>2.1</td>
<td>Ease of Use</td>
<td>Easy to clean</td>
<td>3</td>
</tr>
<tr>
<td>2.2</td>
<td>Ease of Use</td>
<td>Easy to setup and tear down for storage.</td>
<td>3</td>
</tr>
<tr>
<td>3.1</td>
<td>Cost</td>
<td>Within Budget (under $500), extra can be raised if needed</td>
<td>9</td>
</tr>
<tr>
<td>4.1</td>
<td>Safety</td>
<td>Kids have no access to heated elements</td>
<td>9</td>
</tr>
<tr>
<td>4.2</td>
<td>Safety</td>
<td>No exposed sharp edges</td>
<td>9</td>
</tr>
<tr>
<td>5.1</td>
<td>Quality</td>
<td>Sanitary, Product must remain sterile during entire process</td>
<td>9</td>
</tr>
<tr>
<td>5.2</td>
<td>Quality</td>
<td>Product weight is accurate</td>
<td>3</td>
</tr>
<tr>
<td>5.3</td>
<td>Quality</td>
<td>Finish on product in tins is smooth and relatively blemish free</td>
<td>9</td>
</tr>
<tr>
<td>6.1</td>
<td>Diversity</td>
<td>Easily teachable to user</td>
<td>3</td>
</tr>
<tr>
<td>7.1</td>
<td>Feasibility</td>
<td>Efficient dispensing process</td>
<td>9</td>
</tr>
<tr>
<td>8.1</td>
<td>Teaching</td>
<td>Provide feedback for students (tempo, stir speed, etc), and keeps students involved, STEM learning</td>
<td>3</td>
</tr>
<tr>
<td>9.1</td>
<td>Durable</td>
<td>Low maintenance (possibly combined), Financially self-sustaining, long product life cycle</td>
<td>3</td>
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</tbody>
</table>

APPENDIX B – ENGINEERING REQUIREMENTS