The Green-Tube

GOGO Engineering

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Mission Statement

Our main goal is to develop a product that can be used on the greenhouses in Mozambique. The product’s main purpose will be to protect the glazing on the greenhouse from being damaged by the joints. The glazing is a plastic material that is placed over the greenhouse frame after construction. The glazing is effective in preventing water loss and regulating the temperature within the greenhouse, thus making it a very effective and helpful to farmers in the country. Over time, however, the glazing can tear from moving due to the wind and lose its effectiveness. This is where our product comes in. Our product will be of low cost, using materials that are cheap, can be shipped at low prices, and/or can be made in developing countries such as Mozambique. Our product will also meet the need of being easy to assemble. We will be using materials that we assume our primary customers, the people of Mozambique, will know how to use and assemble on the joints. Due to the communication and education barriers we will encounter with our primary customers, we will have to make sure everything is simple, yet still being explained completely and thoroughly. Our secondary customers will include other developing countries using a similar greenhouse to grow crops. If other countries experience the same problem with their greenhouses, our product will provide its assistance and keep the greenhouses effective.
Who is HESE?

The department of Humanitarian Engineering and Social Entrepreneurship, better known as HESE at Penn State, aids in the development of technological solutions to address the most pressing issues in the developing world and marginalized communities. Of the 2.2 billion children on earth nearly half of them are living in poverty and most are in a developing country.[1] Developing countries’ citizens have no purchasing power, therefore they struggle to get out of poverty without some help from others.[2] However, this is a major issue due to the high failure rate of donation schemes. There are a multitude of reasons why handouts don’t work in developing countries and often create more problems than they solve. This is obvious when looking at piles of expensive disposed medical devices that often lay outside of hospitals in developing countries. Often times there are no trained staff to use the equipment, they do not have the proper resources to use the item, they cannot afford to use it, or it simply is something the people don’t want to use. Such cases of neglected donations are more common than expected in developing countries and are why organizations such as HESE exist. HESE isn’t a donation model; it is the bridge that aids the citizens to travel from sustenance farming to sustainability.

The sector of HESE that our group has worked with is developing the Affordable Greenhouse Venture. HESE greenhouses provide a durable, sustainable, and expandable solution that allows farmers to protect their crops from harsh weather conditions and grow year-round, increasing their yields. The greenhouses can be adapted to meet the needs of regions and individuals throughout the developing world benefiting farmers, distributors, producers, and nations as a whole, increasing their food security.[3] East Africa, faces a food
crisis unlike any they have faced before.[4] There are a variety of causes that contribute to the food insecurity from population growth to desertification. Several programs such as the United Nations’ World Food Program, and Kenya’s Vision 2030 Program are dedicated to addressing the food security crisis by improving accessibility, availability and usability of resources. But often, these programs address the symptoms of the problem, rather than the root causes.[5] In East Africa 60% of the food is insecure and approximately 200 million people are malnourished.[6] The greenhouses create a viable solution to combat the array of problems being faced in East Africa right now. In our area of interest, Mozambique, there are very rough climate seasons for crop production making it nearly impossible to sustain crops without the greenhouses. But, the summation of wind, heat, excessive rainfall, and arid conditions that are typical in Mozambique put a tremendous amount of wear on any product left outside for a long period of time. Unfortunately, these harsh conditions have caused wear along the joints to exceed initial expectations damaging the expensive glazing. Our team was given the task of designing a solution to the premature wear of the glazing rubbing on the joints. As a team we created 3 separate prototypes and tested the wear of the glazing on wooden joints buffered by our prototypes. We also had to create tests that measured the heat resistance capacity of the prototypes, along with resistance to puncture, and ease of assembly.
DEM Mozambique Research

Mozambique is located on the east coast of Africa. The average temperature in Mozambique is 28 degrees celsius. The terrain is mostly coastal lowlands, high plateaus and mountains. The climate is typically warm, humid and it often rains. However, the winter is moderately cool and dry [7]. It was important for us to consider the climate and average temperature when researching what material to use for our project. If we didn’t pick a material that could withstand extreme heat and humidity our design would become damaged by the weather.

The official language of the nation is Portuguese but the most commonly spoken language is Emakhuwa [8]. We will need to consider language barriers when communicating our design idea. It is possible that not all of the terms we use in our instructions will translate, in which case, we would need to find new terminology, such as pictures.

From 1891 to 1975 Mozambique was a Portuguese territory but in June 1975 Mozambique declared its independence and became its own nation. Following their independence Mozambique suffered through a 16 year civil war which left their infrastructure disheveled and their citizens impoverished [9]. Farming is their main source of food and income but their agricultural productivity is low due to a lack of appropriate agricultural technologies. With the help of HESE’s greenhouse project, the people of Mozambique could all have enough
food to move past subsistence farming and start selling their crops, which would give them more purchasing power.

Mozambique is 117th in the world in purchasing power and has an average annual income of 250 US dollars per person, which is in the lowest 10% of the world [9]. The lack of purchasing power means that our product will have to be very cost efficient.

Mozambique’s electrical output is ranked number 83 in the world. They produce about 14.83 billion kWh yearly. To give you some perspective the United States produces 4.09 trillion a year [10]. Electrical output won’t play a huge role in the implementation of our product but it should be taken into consideration when planning on how they will produce the polyethylene tubing.

They have access to many natural resources including coal, titanium, natural gas, hydropower, tantalum and graphite. They also produce aluminum, petroleum products, chemicals (fertilizer, soap, paints), textiles, cement, glass, asbestos, tobacco, food and beverages [8]. Because they are able to produce petroleum products they will have the ability to make the polyethylene tubing and zip ties that are required to assemble our product.

Currently there are no real solutions found for the tearing of the plastic covering, but our proposed solution seems to be well in reach. Our product uses heat resistant polyethylene tubing to surround the cross joints to prevent tearing. We used zip ties as a quick and easy way of fastening the tubing to the wooden cross beams. The zip ties also hold the tubing in place and prevent it from moving along the wood. The polyethylene tubing is inexpensive, simple to assemble and fairly durable.
Design Selection Process

After gaining an understanding of the problem we were trying to solve and the location we would be implementing our product, we needed to decide which design would best suit the customer’s needs. To do this we compared each of our possible design ideas by using a table to rank them in reference to the most important customer needs [chart 1]. Our criteria were price, ease of assembly, durability, portability and effectiveness at protecting the glazing. We used either a “+” to show it fulfilled this need or a “—“ to show if it didn’t.

[Chart 1] Design Selection Chart

<table>
<thead>
<tr>
<th>Selection Criteria</th>
<th>Polyethylene Tubing</th>
<th>PVC Pipe</th>
<th>Rubber Coating</th>
<th>Trampoline Tubing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Price</td>
<td>+</td>
<td>+</td>
<td>—</td>
<td>+</td>
</tr>
<tr>
<td>Ease of Assembly</td>
<td>+</td>
<td>—</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Durable</td>
<td>—</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Portability</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>—</td>
</tr>
<tr>
<td>Effectiveness</td>
<td>+</td>
<td>—</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Sum +’s</td>
<td>4</td>
<td>3</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Sum —’s</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Net Score</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>3</td>
</tr>
</tbody>
</table>

After doing our first design selection chart we discovered that our design idea using PVC piping as our main joint protection satisfied the least customer needs. This meant we could
eliminate it from the prototyping phase. We then took the our remaining design ideas and into a selection chart using the same criteria. However, this time we weighted each of the criteria depending on how important we thought it would be to the final product. We used a scale of 1, being it didn't fulfill the need at all, to 5, it fulfilled the need perfectly. [chart 2.].

[Chart 2] *Weighted Design Selection Chart*

<table>
<thead>
<tr>
<th>Selection Criteria</th>
<th>Weight (%)</th>
<th>Rating</th>
<th>Weighted Score</th>
<th>Rating</th>
<th>Weighted Score</th>
<th>Rating</th>
<th>Weighted Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Price</td>
<td>30%</td>
<td>2</td>
<td>0.6</td>
<td>1</td>
<td>0.3</td>
<td>2</td>
<td>0.6</td>
</tr>
<tr>
<td>Ease of Assembly</td>
<td>10%</td>
<td>4</td>
<td>0.4</td>
<td>5</td>
<td>0.5</td>
<td>3</td>
<td>0.4</td>
</tr>
<tr>
<td>Durability</td>
<td>20%</td>
<td>3</td>
<td>0.6</td>
<td>5</td>
<td>1</td>
<td>2</td>
<td>0.8</td>
</tr>
<tr>
<td>Portability</td>
<td>5%</td>
<td>3</td>
<td>0.15</td>
<td>1</td>
<td>0.05</td>
<td>3</td>
<td>0.15</td>
</tr>
<tr>
<td>Effectiveness</td>
<td>35%</td>
<td>5</td>
<td>1.75</td>
<td>4</td>
<td>1.4</td>
<td>5</td>
<td>1.75</td>
</tr>
<tr>
<td>Total Score</td>
<td></td>
<td>17</td>
<td>3.5</td>
<td>16</td>
<td>3.25</td>
<td>18</td>
<td>3.75</td>
</tr>
</tbody>
</table>
Prototype Planning, Fabrication, and Testing

Prototype 1

Prior to making the “first cut” on our project we needed to do research on our customer and understand their needs and how we were going to help them. We had to do research on the lifestyle of the citizens of Mozambique and understand the climate we would be facing and any other obstacles we would have to overcome. We were given two options on how to improve the greenhouse, creating a better setup, and creating a way to protect the glazing from tearing on the joints. Once we did research and choose which option we had to decide how we would attack the problem. We chose to find a way to protect the glazing from the joints. We decided that a polyethylene foam covering, much like a pool noodle, would be an option for protecting the joint and glazing. We would bore holes in the foam tubing and secure it using mason twine which is weather and heat resistant. After deciding on this approach we were going to take we drew a multi-view sketch of our product. After our sketching was done we put in an order of the materials we would need to make our prototype. As you can see a large portion of this project was done even before we started constructing our prototypes.

Multi-view sketch of our original prototype
## Prototype 1 Testing Plan and Results

<table>
<thead>
<tr>
<th>User Need/Feature/Requirement</th>
<th>Describe Test</th>
<th>What is a “pass”?</th>
<th>Materials/Tools Needed to Run Tests</th>
<th>Did it Pass?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protect Glazing/Friction Resistance</td>
<td>Wrap glazing over joint, apply weight, and pull it repeatedly over the joint</td>
<td>No glazing comes off and does not tear</td>
<td>Weight (10 lbs) String Glazing</td>
<td>No, the tubing would shift when tension was applied to the glazing and expose the joint which could cause tearing in the glazing.</td>
</tr>
<tr>
<td>Easy to Assemble</td>
<td>Another student or group could assemble it</td>
<td>If the student can build it using only the instructions given</td>
<td>Other Students</td>
<td>Yes, other students were able to construct our product.</td>
</tr>
<tr>
<td>Sustainability</td>
<td>Using a heat lamp to heat up the material to see if it can withstand the high temperatures of Mozambique</td>
<td>The material does not change</td>
<td>Lamp</td>
<td>No, however the test we used was unrealistic. By placing it under a very hot lamp with all of the heat focused on the material, it caused the material to melt. This is unrealistic because the heat under the lamp was much higher than the temperature of Mozambique because it was completely concentrated.</td>
</tr>
<tr>
<td>Cheap</td>
<td>Can this be made with materials that cost under $2?</td>
<td>If the total price for the materials was under $2.</td>
<td>Any Materials needed for the prototype</td>
<td>Yes, Our materials per joint cost under $2.</td>
</tr>
<tr>
<td>Availability of Materials</td>
<td>Research products that can be manufactured in Mozambique to prevent having to import them</td>
<td>If the materials can be made and manufactured in Mozambique</td>
<td>Research materials like a computer to discover if there are manufacturing plants for the materials being used.</td>
<td>Yes, there is a plant in Mozambique that manufacture polyethylene tubing</td>
</tr>
</tbody>
</table>
**Observations Summary**

3 of our 5 tests passed which was not too bad for the first prototype. So far the majority of the tests were successful. We saw that our biggest problem was still that the glazing was not being protected when the covering was secured using string. As the tension tests were performed the covering would shift and expose the joint to the glazing causing it to rip. Another thing we realized is that our test for heat was not successful because of the materials we had to test it. We created a heat shield but this concentrated the heat too much and caused the polyethylene to melt, it also warped the lamp.

We learned that we needed to make adjustments to our prototype to ensure that it would be more secure. We again had to brainstorm ways as to how we could keep our prototype cheap but also improve the prototype to protect the glazing. Our two biggest surprises from this prototype were that the string was not as secure as we thought and that the heat lamp we used was hot enough to melt our material.
Prototype 2

Our failures in prototype 1 fueled the changes we made to construct prototype 2. We saw that one of the biggest failures of the first prototype was that the glazing was not being protected. However we saw that the polyethylene tubing was protecting the glazing as long as it did not shift if the glazing shifted. So we had to decide on a better way to secure it to the wooden joints. We decided that a cheap alternative would be zip-ties. By using zip ties they could be securely fastened to the joint and would prevent the tubing from moving and would protect the glazing from being torn on the wooden joint.
# Prototype 2 Testing Plan and Results

<table>
<thead>
<tr>
<th>User Need/Feature/Requirement</th>
<th>Describe Test</th>
<th>What is a “pass”?</th>
<th>Materials/Tools Needed to Run Tests</th>
<th>Did it Pass?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protect Glazing/Friction Resistance</td>
<td>Wrap glazing over joint, apply weight, and pull it repeatedly over the joint</td>
<td>No glazing comes off and does not tear</td>
<td>Weight (10 lbs) String Glazing</td>
<td>Yes, the tubing was much more secure using zip ties and protected the glazing when a tension test was performed.</td>
</tr>
<tr>
<td>Easy to Assemble</td>
<td>Another student or group could assemble it</td>
<td>If the student can build it using only the instructions given</td>
<td>Other Students</td>
<td>Yes, other students were able to construct our product.</td>
</tr>
<tr>
<td>Sustainability</td>
<td>Using a heat lamp to heat up the material to see if it can withstand the high temperatures of Mozambique</td>
<td>The material does not change</td>
<td>Lamp</td>
<td>Yes, We used a less direct source to apply heat and the polyethylene foam was able to survive the heat.</td>
</tr>
<tr>
<td>Cheap</td>
<td>Can this be made with materials that cost under $2?</td>
<td>If the total price for the materials was under $2.</td>
<td>Any Materials needed for the prototype</td>
<td>Yes, Our materials per joint cost under $2.</td>
</tr>
<tr>
<td>Availability of Materials</td>
<td>Research products that can be manufactured in Mozambique to prevent having to import them</td>
<td>If the materials can be made and manufactured in Mozambique</td>
<td>Research materials like a computer to discover if there are manufacturing plants for the materials being used.</td>
<td>Yes, there is a plant in Mozambique that manufacture polyethylene tubing.</td>
</tr>
</tbody>
</table>
Observations of Prototype 2

We found prototype 2 to be a much bigger success than prototype 1. We were able to keep the glazing protected because the foam tubing did not shift as a tension test was applied. This prototype was also more aesthetically pleasing and would be easier to market due to its more appealing appearance. The only negative we saw with prototype 2 was that a larger amount of materials were used. Because we used 8 inch zip ties they needed to be combined so that they could fit completely around the wooden joint. So we needed to use a lot of them to ensure that the foam would not move. We would improve this by using longer zip ties so they would not need to be combined and we would not need as many. We would also bore less holes in an attempt to use less zip ties to secure the covering securely.
Lessons Learned

As a group if we were to make a prototype 3 we would stay with the same concept of a foam covering secured by zip ties. However, we would focus on the ease of our assembly. One of the biggest problems without prototype 2 was that it took a long time to assemble. We had to make sure our prototype would stay secure but would not break. We reinforced the holes for the zip ties with glue then bored holes in the glue to thread the zip ties in. Another problem we found with our prototype was the amount of materials we used. Because our zip ties were only 8 inches each we needed to connect them together often times to secure the joint covering all the way around the wooden joint. So if we used longer zip ties we could reduce the amount of product we used. We also would focus on creating less holes to minimize the amount of securing that would be required. A test that we would perfect would be our heat test. We used a lamp to heat up a piece of our material to show that it would withstand the high temperatures of Mozambique. However, because we focused the heat so much using a heat shield made of tinfoil we melted the material. This was definitely not a good test for the heat. Although the material melted we feel that it would survive in the heat of Mozambique because the heat will not be as direct as sitting under a heat lamp.

As a group we worked very well together. Although we all have different personality types we used the techniques we learned in class to maximize our production and teamwork by taking each other’s personalities into account before working. We all brought different skills to this project. Some of us brought creative ideas to the group of how to attack our problem, some brought drawing skills, and others were skilled in the machine shop. We split up the duties in the machine shop, so while one person was constructing the joint, others
were preparing the joint covering, and others were preparing tests to perform on the joint, such as the resistance-tension test and the heat test. We worked well as a team and focused all of our efforts to creating a prototype and keep making improvements to it.

Most things in this project went well. However, like in every project, everything does not go exactly as planned. For example our first prototype failed our tension test because it failed to keep the greenhouse glazing from ripping over the joint. Our heat test also did not go as planned, which was mentioned above. We also were faced with the problem of using the materials we had at our disposal. Our original plan consisted of tubing that is used to cover trampoline poles. The advantages with this would be that it is weather resistant and the material would not be as soft as the pipe insulation tubing that we used. The trampoline tube would also have a larger inner radius so we would not need to use as much material to cover it. However because this is merely a prototype we were able to work with our available materials, to create a joint that successfully protected the glazing from being ripped by the joint.

Some ways our group feels the DEM project as a whole could improve would be having more time to prototype than 2 hours a week. Also a little more direction as to what is expected with each group could help out. There were times when we felt that we did not know what part of the project was due when and if the various worksheets needed to be completed and included in our final report or not.
References:


[7] our-afric.org


[9] ruralpovertyportal.org

[10] historyworld.net