USB Hub Design - Lockheed Martin Project

EDSGN 100 - Section 022
Dr. Ritter 5-1-16

Team #8 - The Tinkerers

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Figure 1: The Final Model
Executive Summary

For this project sponsored by Lockheed Martin, the desire to improve the current USB bracket for better efficiency with a new and well-improved design using additive manufacturing was the primary motivation. The Tinkerers’ goal for the new design is to reduce the amount of parts in the assembly while providing greater capability through vertical installation in various areas on the platform. Based on the concept of a Lego block, the Tinkerers’ were able to innovate a lightweight, durable USB bracket by taking into consideration of all of the customer needs and requirements as well as setting standards on what an effective and efficient USB bracket should be.

Introduction and Problem Statement

The purpose of The Tinkerers is to innovate a lightweight, shock absorbent USB bracket, that is multifunctional and serves the purpose of the consumer. Currently there are many bracket designs that are ineffective and are not created utilizing additive manufacturing principles. The current model of brackets is not optimized for the lightweight and compact needs of current industries. This excess size and weight causes unnecessary inefficiencies that can be cut with additive manufacturing techniques. The Tinkerers seek to redesign the USB bracket using additive manufacturing techniques.

Background

To clarify on how the USB hub bracket is manufactured and as example to support the goal, there is a LCD device that supports a housing that consists of USB connectors, which are mounted on top of each other and connected to a USB hub controller to install a USB hub capability into the device. The capability is provided in order to increase the functionality of the device and it may be increase the cost of the device which is why manufacturers would build both a device that has a USB hub capability and another device that doesn't. To satisfy every consumer's needs, the USB hub module can be purchased as an optional component so that the consumers can choose whether they need it or not.

Customer Needs

Table 1: AHP Matrix
<table>
<thead>
<tr>
<th></th>
<th>Durable</th>
<th>Lightweight</th>
<th>Shock Absorbent</th>
<th>Affordable</th>
<th>Stackable</th>
<th>Compact</th>
<th>Easily Constructed</th>
<th>Total</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Durable</td>
<td>1.00</td>
<td>1.5</td>
<td>0.75</td>
<td>3.00</td>
<td>1.00</td>
<td>9.75</td>
<td>3.5</td>
<td>11.5</td>
<td>0.18</td>
</tr>
<tr>
<td>Lightweight</td>
<td>0.67</td>
<td>1.00</td>
<td>0.5</td>
<td>2.00</td>
<td>1.5</td>
<td>0.75</td>
<td>1.5</td>
<td>7.92</td>
<td>0.12</td>
</tr>
<tr>
<td>Shock Absorbent</td>
<td>1.33</td>
<td>2.00</td>
<td>1.00</td>
<td>3.00</td>
<td>2.00</td>
<td>1.00</td>
<td>2.5</td>
<td>12.83</td>
<td>0.20</td>
</tr>
<tr>
<td>Affordable</td>
<td>0.33</td>
<td>0.5</td>
<td>0.33</td>
<td>1.00</td>
<td>0.33</td>
<td>0.5</td>
<td>0.33</td>
<td>3.32</td>
<td>0.05</td>
</tr>
<tr>
<td>Stackable</td>
<td>1.00</td>
<td>0.67</td>
<td>0.5</td>
<td>3.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.5</td>
<td>8.67</td>
<td>0.135</td>
</tr>
<tr>
<td>Compact</td>
<td>1.33</td>
<td>1.33</td>
<td>1.00</td>
<td>2.00</td>
<td>1.00</td>
<td>1.00</td>
<td>2.00</td>
<td>9.66</td>
<td>0.15</td>
</tr>
<tr>
<td>Easily Constructed</td>
<td>0.29</td>
<td>0.67</td>
<td>0.4</td>
<td>3.00</td>
<td>0.67</td>
<td>0.5</td>
<td>1.00</td>
<td>10.13</td>
<td>0.16</td>
</tr>
</tbody>
</table>

By taking the customer needs into consideration, an AHP matrix can be constructed to fully weigh and compare each aspect. This allows the producer to design their prototype strategically, as some features have a greater importance than others. In this case, the most important characteristic turned out to be shock absorbance, with a weight of 0.20. Since the USB bracket for the hub will be mounted in an aerodynamic setting, it is essential for it to sustain multiple large forces and still be fully functional. On the other hand, Table 1 shows how affordability is the least important aspect, with a weight of 0.05. In the customer’s perspective, the material should be able to do its job, and the price isn’t highly prioritized. It can be concluded that shock absorbance is four times important than affordability.
Concept Generation

Discuss your methodology. What were all of your initial ideas? Which top ideas did you move forward with and why? Include your classification tree.

(Alan)

Creating a classification tree was the initial step to narrow down all of the information. As shown below in Figure 4, the three main components on the first sublevel of the tree are process, design, and materials. The process category consists of additive manufacturing techniques that the team could research and then apply to the prototype. After going through each technique thoroughly, the team concluded that material extrusion was the best additive manufacturing technique to provide a prototype with reduced materials, thus making it lighter and retaining its durability. The other two technique involves metal material that the team did not have access to. Based on a previous image of a USB Hub Bracket design given to the team by Lockheed Martin, it was decided that the focus would be on a rectangular lattice infill because rectangles are easy to modify and can be defined to be compact and stackable. The team intended to incorporate both horizontal and vertical installation into the design, a bonus feature assigned by Lockheed Martin. Since the team focused more on reducing the number of parts needed for the assembly, the material used to make the prototype was very important. Some materials that the team thought of were metal, plastic, polymer, and rubber.

Rubber was quickly ruled out because it would be more impractical than helpful. The metal, plastic, and polymer categories were narrowed down to aluminum metal, PLA plastic, and a nylon and carbon fiber polymer. Aluminum was both lightweight and fairly inexpensive, PLA was very inexpensive but fairly weak, and the polymer was a middle ground between the two in terms of strength, but it was the most expensive of the three. Because of this the polymer was eliminated. After receiving the physical print of the model made out of PLA, the team decided on aluminum. The material extrusion technique with PLA plastic proved to be too weak and imprecise for the bracket, but powder bed fusion with aluminum would eliminate both of those problems.
Concept Development and Selection

Describe the processes (both informal and formal) used to select the final concepts. Discuss how you used your initial 3D printed sample part to inform your process. Include an image of the submitted sample part (i.e., 50 x 50 mm square with parts). Show the team concept scoring matrix and briefly discuss the choices available for the final design. What were the pros and cons of the different ideas? Provide a complete evaluation of the different ideas.

(Justin)

Lockheed Martin (LM) Project: Design Selection Matrix

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Weight</th>
<th>Rectangular Tower</th>
<th>Cylinder Tower</th>
<th>Rectangle</th>
<th>Skeletal Frames</th>
<th>Prism</th>
<th>Lego</th>
<th>Weighted Score</th>
<th>Rating</th>
<th>Weighted Score</th>
<th>Rating</th>
<th>Weighted Score</th>
<th>Rating</th>
<th>Weighted Score</th>
<th>Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Affordable</td>
<td>5%</td>
<td>3</td>
<td>0.15</td>
<td>3</td>
<td>0.15</td>
<td>4</td>
<td>0.2</td>
<td>4</td>
<td>0.2</td>
<td>3</td>
<td>0.15</td>
<td>3</td>
<td>0.15</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shock Absorbent</td>
<td>25%</td>
<td>3</td>
<td>0.75</td>
<td>3</td>
<td>0.75</td>
<td>4</td>
<td>1</td>
<td>3</td>
<td>0.75</td>
<td>2</td>
<td>0.5</td>
<td>3</td>
<td>0.75</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Compact</td>
<td>25%</td>
<td>2</td>
<td>0.5</td>
<td>2</td>
<td>0.5</td>
<td>3</td>
<td>0.75</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>0.25</td>
<td>4</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stackable</td>
<td>20%</td>
<td>5</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>0.6</td>
<td>4</td>
<td>0.8</td>
<td>1</td>
<td>0.2</td>
<td>5</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Durable</td>
<td>15%</td>
<td>3</td>
<td>0.45</td>
<td>3</td>
<td>0.45</td>
<td>3</td>
<td>0.45</td>
<td>2</td>
<td>0.3</td>
<td>3</td>
<td>0.45</td>
<td>4</td>
<td>0.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lightweight</td>
<td>10%</td>
<td>2</td>
<td>0.2</td>
<td>2</td>
<td>0.2</td>
<td>4</td>
<td>0.4</td>
<td>4</td>
<td>0.4</td>
<td>3</td>
<td>0.3</td>
<td>3</td>
<td>0.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>100%</td>
<td>3.05</td>
<td>3.05</td>
<td>3.4</td>
<td>3.45</td>
<td>1.85</td>
<td>3.7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

After establishing the customer needs, the producer comes up with as many ideas as possible for the prototype. With the criteria and their weights in mind, each design is
rated from one to five, with one being the worst and five being the best. This allows the producer to compare each model and decide on which one has the highest weighted score. In this case, the Lego design prevailed over the other five design, so its concept was selected for the first prototype.

![Lego Design](image)

Although the Lego design ended up being the selected prototype, other designs had pros and cons associated with them. For example, the Rectangular and Cylinder Tower designs had a rating of 5 in the “stackable” category, but their other criteria such as “lightweight” and “compact” weren’t as efficient as the other models. The Rectangle and Skeletal Frames concepts had the highest rating for “affordability”, considering they used the least amount of material. Unfortunately, the Prism design was a fluke, resulting in the lowest rating out of all the models.

**Description of Prototype (3D Model + 3D Printed Prototype)**

![Sample Part](image)
The initial prototype was a combination of many aspects of the initial set of ideas. For instance, the focus on having as little material as possible was taken from the Skeleton design, and the ability to hold multiple hubs in a single bracket was taken from the Tower design. Additionally, Alan came up with the idea of having Lego-like structures on the top and bottom to allow for multiple brackets to be snapped together, thus allowing for additional stackability. As shown in Figures # and # above, the prototype features the Lego top, with identical indents on the bottom. Furthermore, much of the excess material has been removed, leaving only structure that helps maintain strength. The prototype was also able to hold three USB hubs within one bracket, which was a stretch goal provided by Lockheed Martin.

**Design Review**

Briefly describe the findings of your design review. How did this affect your final design?

(Alan)

*Figure #: Initial Prototype*

**Description of Final Design (3D Model)**
Figure #: The final model of the USB Bracket.

Figure #: A rendered image of the final model.
As shown in Figures # and # above, is the final model. It is very similar to the prototype, but with a few alterations. There are two primary differences, with some minor ones as well. The first improvement from the prototype is the back of the bracket. The back was simply a solid chunk attached to the rest of the body. But this new back is its own separate entity. It utilizes the Lego attachment feature that the rest of the bracket uses for stacking multiple units. Furthermore, as shown in Figure #, the left side eliminates unnecessary material. The right side is for the backside ports of the USB hub, in which size holes would be optimized when given more specific measurements. The second major difference is the removal of the third row. This allows for a smaller bracket, which then uses less material and is finished faster. This change was made in consideration for Lockheed Martin's versatility of the bracket. The smaller bracket can be more widely used, and when additional USB hubs are desired, multiple brackets can be snapped together using the Lego feature. Many of the smaller changes were done to help disperse any forces the bracket would experience, and to further reduce material.

In assessing the strength of the prototype and final model, two simulation tests were done. One being a displacement test and the other a stress test.

The displacement test shows that the final model experienced 140% less movement when under the same conditions as the prototype, as shown in Figures # and #. In these figures, the prototype is on the left and the final is on the right.
The stress test further shows the improvements of the final model. As shown above in Figures # and #, the prototype experiences six times more stress than the final model, while under identical conditions. The major improvements of the final in both tests shows how great the changes from the prototype made an affect. For instance, in the prototype one can see that the left and right sides were one large cross support, but in the final, the support was broken down into two separate patterns, with a central column perpendicular to both. Additionally, all the non-USB corners were filleted, to help disperse loads.

The current model used by Lockheed Martin uses at least 27 parts, with 6 unique parts. The Tinkerers’ design largely reduces that number. With only 14 total parts, and 5 unique parts, the Tinkerers’ design is highly improved. This allows for quicker creation as well as quicker assembly. A list of parts is as follows:

- Bracket Body: 1
- Bracket Back: 1
- Screw: 4
- Washer: 4
- Lock Washer: 4

Lockheed Martin had five main requirements that it sought fulfilled, with two being bonuses. The first was to create a USB bracket that could hold two USB hubs as well as maintain a low part count. The Tinkerers’ design completely fulfilled this objective. The second was to maintain the four-point screw mounting system, which was completed. The third was to reduce any additional screw/mounting holes, which was also fulfilled by the new design. The first bonus was to allow for vertical hub mounting. The simple yet multifunctional design allows for this to be met. The second bonus, and last request, was to allow for three USB hubs to be stacked together. This was not met directly, but because of the Lego functionality, this can easily be met by attaching another bracket.

The Tinkerers’ would recommend that Lockheed Martin use the powder bed fusion technique and aluminum as the material for creation of the bracket. Aluminum is
a metal that is lightweight but also maintains a good strength. The powder bed fusion would be the best way to utilize aluminum.

The prototype that was printed by the Tinkerers’ was created using PLA plastic on a material extrusion printer. As such, the bracket was weaker and more fragile. The smaller Lego outcrops on the back were easily broken off. But using Aluminum on powder bed fusion these problems would be missed. Aluminum would be much stronger, and powder bed fusion can produce a much more precise print.

Conclusions
Summarize your product’s pros and cons. Where might the design go from here? What were the main lessons your team learned from this project?

The Tinkerers’ USB bracket covers all areas requested by Lockheed Martin, and (then some).? The current design uses fewer parts, is easily adaptable for both vertical and horizontal mounting, and possesses excellent strength and weight distribution. If more time and testing would have been possible, then further reduction in weight and an increase in strength would have been possible.

The current “final” design is very good, but there is always room for further improvement. For instance, to help further secure the bracket when stacking, the Lego outcrops can be textured to increase surface area, which would then make it more secure. The struts on the top could be further developed to more effectively disperse any weight that the bracket may receive.

References
Cite any references used in this report. The references must be cited within the text when used. The team can consider numbering the references and including the numbers as superscripts or within brackets in the text.