Micro D Connector Backshells

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Executive summary

In this project the design of a Micro-D MIL-DTL-83513 connector backshell, and how it could be improved through the use of additive manufacturing was researched. The initial design caused the wires to fray due to the sharp edges on the outside of the backshell. Also contributing to the fraying was the lack of internal organization of the backshell. By first brainstorming ideas, five initial concepts were generated and tested by using an AHP matrix. The AHP matrix ranks the relative weight of each of the customer needs. The design selection matrix then ranked the five designs, with the winner being the lane concept.

Prototype one was made in SolidWorks modeled to the connector specifications. The lane prototype yielded mediocre results with the lanes being insufficient in width, but having an appropriate interior with smooth curves and edges. The final prototype improved upon the first by creating a larger area inside of the backshell and with filleted edges inside. The lane prototype also had a redesigned backshell shape that was more rounded and closer in image to the original backshell. The final prototype would use the material extrusion type of additive manufacturing. The extrusion would be stopped twice, once to enter the lower wires into their lanes, and then once for the upper wires to be placed into their lanes.

Introduction and Problem Statement

In order to create a lightweight backshell that protects the integrity of the wires while maintaining a small volume and an organized interior, additive manufacturing had to be utilized in the design project. This backshell will support a Micro-D MIL-DTL-83513 connector. The goal was to reduce the amount of materials used to manufacture the backshell without sacrificing anything like strength or resistance...

In the current backshell design, wires are easily damaged and frayed due to the sharp edges. This requires constant maintenance and replacement of the wires. There is insufficient space for the wires to be properly organized so the wires are packed into the end of the backshell. Thus causing them to be in constant contact with the sharp edges and contours of the inside of the backshell.

In this project the standard components of the design process like product dissection and critical thinking will be used to help create complete and appropriate designs. Additive
manufacturing will enable the designs created after dissection to be much more efficient by using less materials and complex internal structures to reorganize the wires inside the backshell. The new materials being used in additive manufacturing will allow designs to be made out of metal and plastic filaments through processes like material extrusion or laser metal deposition (LDM).

Background

Connector backshells were first factory manufactured in the early 1930’s. Cannon was the first to mass produce these circular connectors before the start of World War II. Initially they were primarily used in almost every military aircraft. Connector backshells soon evolved after the war changing in shape and size to look like a “D”; “The D-sub designation defines the physical structure of the connector, not the purpose of each line”, which is where the name originates from. The D-sub connector is a standard connector and comes in many different sizes. Its uses evolved as well, currently ranging from communication ports to video gaming ports. The Micro- D MIL-DTL-83513 is the specific connector we chose to do a complete redesign. The only components of the design that remained unchanged were the shape and size of the D-sub connector itself.

Traditionally D-Sub connectors are manufactured in two parts. The backshell and the connector. The backshell is the part that needed redesigned. The backshell is typically manufactured in two halves which are then connected after the wires are placed inside the backshell. The backshell is hollow on parts of the inside but is filled near the outside edges. The backshells are either made by molds or by hollowing out the inside portion. The backshell is held together by two screws, one on each side of the backshell at the top connector region. Later after issues arose with the D-sub disconnecting from the port, two pins that screwed into the port were added to insure connectivity.

Additive manufacturing can be used to make this process completed in one part, while adding an organized internal structure. Specifically, material extrusion will be used to 3D print the backshells. The material used to print the backshell could either be nylon or a polycarbonate filament. Both of these filaments are much stronger and more heat resistant than ABS and PLA which are used for standard printing which will be necessary for the backshell. However, nylon
is a very absorbent material and needs drying measures taken before printing. Both nylon and polycarbonate filaments are very good options for Lockheed Martin to choose between.

**Customer Needs**

Before the brainstorming process began, the customer needs had to be clearly identified first. Organization, Protectiveness, Resistance, Ease of Manufacturing, Durability, Lightweight, and Cost were deemed the most important needs to consider. During our initial research, it was found important that the backshell’s durability and resistance to shock were not sacrificed. When the connector is removed from a device, the pulling force can’t be strong enough to ruin the internal components of the connector. The backshell should be strong and not easy to break or ruin. One criteria unique to our group is organization. We brainstormed on how to fix the fraying problem. A proposed solution was to design some form of internal organization.

It was found that the micro D-sub backshell can be used on airplanes and military defense weapons. So in order for Lockheed to maximize payload, it was critical that a light backshell was created. Since Lockheed Martin, is a global company it was necessary for the backshell to be easily produced anywhere, which is where additive manufacturing and 3D printing came into play. In order to determine the relative weight of each customer need, an AHP matrix, which can be seen below in Table 1 was used.

**Table 1: The Analytic Hierarchy Process Matrix.**

<table>
<thead>
<tr>
<th></th>
<th>Cost</th>
<th>Durability</th>
<th>Ease of Manufacturing</th>
<th>Lightweight</th>
<th>Organization</th>
<th>Resistance</th>
<th>Protective</th>
<th>Total</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost</td>
<td>1</td>
<td>0.33</td>
<td>0.20</td>
<td>0.33</td>
<td>0.20</td>
<td>0.20</td>
<td>0.33</td>
<td>4.39</td>
<td>0.659</td>
</tr>
<tr>
<td>Durability</td>
<td>3</td>
<td>1</td>
<td>0.25</td>
<td>1</td>
<td>0.33</td>
<td>1</td>
<td>0.50</td>
<td>7.08</td>
<td>0.695</td>
</tr>
<tr>
<td>Ease of Manufacturing</td>
<td>5</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>0.50</td>
<td>0.20</td>
<td>0.25</td>
<td>11.95</td>
<td>0.160</td>
</tr>
<tr>
<td>Lightweight</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0.25</td>
<td>0.25</td>
<td>0.50</td>
<td>7</td>
<td>0.093</td>
</tr>
<tr>
<td>Organization</td>
<td>5</td>
<td>3</td>
<td>2</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>17</td>
<td>7.08</td>
<td>0.227</td>
</tr>
<tr>
<td>Resistance</td>
<td>0.5</td>
<td>1</td>
<td>5</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>13.5</td>
<td>0.180</td>
<td>1.00</td>
</tr>
<tr>
<td>Protective</td>
<td>3</td>
<td>2</td>
<td>4</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>14</td>
<td>1.00</td>
<td>1.00</td>
</tr>
</tbody>
</table>

Grand TOTAL: 74.52 1
By evaluating each need against each other, the weights were determined for the Design Selection Matrix. The rankings of the customer needs are as follows:

1. Organization (23%)
2. Protectiveness (18.8%)
3. Resistance to Shock (18%)
4. Ease of Manufacturing (16%)
5. Durability (9.5%)
6. Lightweight (9.3%)
7. Cost (5.9%)

It was found that organization, protectiveness, and resistance to shock had very similar weights. Since we believe each of these three criteria are critical to a good back shell design, it makes sense they resulted with the highest weights. Also, it was concluded that the cost is going to be relatively the same for each design since they are about the same size and amount of materials. The cost will more so depend on the materials selected later rather than the design process. This is why cost is has a lesser weight.

**Concept Generation**

The brainstorming process started with a classification tree as shown below in Figure 1. The tree addressed the primary problem of the current design; protecting the wires from being damaged. We then moved on to the interior organization of the backshell. There are two ways to organize the wires; in groups or individually. Although bouncing ideas around as a team gave us a general direction for designs, individual brainstorming was equally important. This ensured the freedom to imagine whatever possible without negative influences from others. Thus resulting in new ideas and new ways to organize the wires. The most promising ideas consisted of using lanes or pegs to guide the wires through the backshell.
It was then realized that if each wire had its own lane or pegs leading up to the connector piece, unnecessary material would be used. Someone in the group came up with the triangle design (Design 1) in Figure 2 below. After introducing it to the group, a new way was developed to group the wires while maintaining the intricate geometry of the triangles as shown in Design 2 (Figure 2). It would take a long time to create these triangles within the backshell using traditional manufacturing processes, so the pros of additive manufacturing were employed. After making an STL file, MakerBot predicted that the print time would only be seventy-five minutes. Design 2 also eliminates the sharp edges causing the damage, while meeting the other customer needs the best.
Concept Development and Selection

Figure 2: The triangle designs we decided to move forward with

In order to select the best design to model and prototype, the team debated the pros and cons of each design. It was agreed upon that the designs would have the same outer shell and that we would assess the different internal organizations in the 7 criteria that were chosen when discussing our customer needs. 5 designs were evaluated: the triangle design in Figure 2, a checkerboard design, pegs, lanes, and grouping the wires by top and bottom. The checkerboard design wasted materials as shown below in Figure 3. We were able to determine this by comparing the idea to the sample part printed earlier in the project, which is shown in Figure 3 below. It was clear that the sample part wasn’t using the pros of additive manufacturing to its benefit by having unnecessary material used. Therefore the checkerboard design wouldn’t utilize the pros either. We liked how the lanes design guided the wires to the connector piece and eliminated some of the chaos in old designs. However, it created sharp angles and contours. As
shown in Table 2, the designs were assessed and it was decided that the triangle design had the most potential because of its ability to keep the wires organized with using a minimal amount of material.

Figure 3: 3D printed sample part

Table 2: Our concept selection table.

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Weight</th>
<th>Triangles Rating</th>
<th>Triangles Weighted Score</th>
<th>Checkerboard Rating</th>
<th>Checkerboard Weighted Score</th>
<th>Pegs Rating</th>
<th>Pegs Weighted Score</th>
<th>Lanes Rating</th>
<th>Lanes Weighted Score</th>
<th>Grouped Rating</th>
<th>Grouped Weighted Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Organization</td>
<td>17.00</td>
<td>5</td>
<td>0.85</td>
<td>5</td>
<td>0.85</td>
<td>4</td>
<td>0.68</td>
<td>5</td>
<td>0.85</td>
<td>3</td>
<td>0.51</td>
</tr>
<tr>
<td>Protective</td>
<td>14.50</td>
<td>5</td>
<td>0.70</td>
<td>5</td>
<td>0.70</td>
<td>4</td>
<td>0.56</td>
<td>4</td>
<td>0.56</td>
<td>3</td>
<td>0.42</td>
</tr>
<tr>
<td>Resistant</td>
<td>13.50</td>
<td>4</td>
<td>0.54</td>
<td>4</td>
<td>0.54</td>
<td>4</td>
<td>0.54</td>
<td>4</td>
<td>0.54</td>
<td>4</td>
<td>0.54</td>
</tr>
<tr>
<td>Ease of Manufacturing</td>
<td>11.95</td>
<td>4</td>
<td>0.48</td>
<td>3</td>
<td>0.36</td>
<td>5</td>
<td>0.60</td>
<td>5</td>
<td>0.60</td>
<td>5</td>
<td>0.60</td>
</tr>
<tr>
<td>Durability</td>
<td>7.00</td>
<td>5</td>
<td>0.35</td>
<td>3</td>
<td>0.21</td>
<td>5</td>
<td>0.35</td>
<td>5</td>
<td>0.35</td>
<td>3</td>
<td>0.21</td>
</tr>
<tr>
<td>Lightweight</td>
<td>7.00</td>
<td>4</td>
<td>0.28</td>
<td>3</td>
<td>0.21</td>
<td>5</td>
<td>0.35</td>
<td>4</td>
<td>0.28</td>
<td>5</td>
<td>0.35</td>
</tr>
<tr>
<td>Cost</td>
<td>4.39</td>
<td>3</td>
<td>0.13</td>
<td>2</td>
<td>0.09</td>
<td>3</td>
<td>0.13</td>
<td>3</td>
<td>0.13</td>
<td>3</td>
<td>0.13</td>
</tr>
<tr>
<td>Total</td>
<td>100%</td>
<td>3.53</td>
<td></td>
<td>2.96</td>
<td></td>
<td>3.21</td>
<td></td>
<td>3.51</td>
<td></td>
<td>2.76</td>
<td></td>
</tr>
</tbody>
</table>
Description of Prototype (3D Model + 3D printed Prototype)

some obstacles we had to overcome when creating our first prototype on SolidWorks was the internal organization part. The thickness of the lines, see Figure 4, was not much bigger than the diameter of the 3D printer's nozzle, .04mm. We had to be careful about how much larger we could make that distance because it could not alter the distance between each of the pegs in the connector piece. If we did that, the backshell would no longer support a micro D-sub connector.

Figure 4: The thickness of our organization part was small and hard to print.
The first prototype largely focused on the interior organization of the wires. In the original model, the wires were jammed into the backshell leaving no organization and a lot of tangled wires. Because of this, it took a large precedents in the first round of designs. The other area that was focused on, was getting rid of sharp edges and any unnecessary material. This is where additive manufacturing was incorporated in order to make the design more efficient in material usage. Using material extrusion, the back of the backshell that was used to place the screws in order to connect the two halves of the backshell together, were cut out since it was all printed in one single piece. Doing this reduced the weight and material used to create the whole backshell, which also helped meet a few of the other requirements that were stated in Lockheed Martin’s project statement. After deliberating, five designs were created according to the Concept Design Tree in Figure 1. The designs were somewhat similar based on the fact that they all dealt with the organization of the wires in some manner. One of the designs that was created, incorporated pegs that guided each specific wire to its designated port. It was determined that there was not enough space to have a lane for each wire however, and the increase in weight and cost would outweigh its functionality. After looking at this design, it was decided that the

**Figure 5**: Final render (left) and 3D print (right) of Prototype one.
materials used to make this design work, would be cut by a large margin if the wires were grouped together in small portions. In the end, the design with the triangle shaped-lanes was chosen over the others because it not only had the highest rating in the design selection matrix. The chosen design, in Figure 5, was also selected because it was the most cost and material efficient. A few problems seen with this design are the amount of space in the back for the wires to lead into the cord. Figure 6 also shows that there was no space left at the front of the backshell for the D-sub connector piece. These problems were kept in mind for the redesign process when creating the second prototype.

![Figure 6: The Section view of Prototype 1](image)

**Design Review**

To get an outside perspective on our design, the team met with another group that could give feedback and ideas for improvement. We were told that our design met criteria and solved the initial problem. They agreed we rounded the edges to prevent damage but, suggest we curve the inside of the backshell even more. It was hard to feed wires through our prototype one, so
they suggested we cut the backshell in half and screw them together like the original design. This helped generate new ideas that were used in the final design like adding screw holes and changing the shape to a more rounded backshell.

**Description of Final Design (3D Model)**

![Figure 7: Final render (left) and 3D print (right) of Prototype two.](image)

The final design came out to be a lot different than the first prototype, but it still incorporated the triangle channels for the wires on the interior to keep the organization that is seen in the first prototype. As shown in Figure 7, it was determined for the final product that the overall shape and size of the original product did not necessarily have to be changed. Of course, it has to be lightweight, protective, and durable as stated in Lockheed Martin’s requirements, but there is a high chance that if something that is functional is changed or fixed, another component that is functional can break or fail in the unseen future. Using this concept, the final design really focused on the problem that was presented initially, which was the wires fraying due to the sharp edges and bends on the interior of the original backshell. Therefore, compared to the original backshell, the final design provides for a better option. With the triangle channels guiding small groups of wires and preventing them from running into the walls at sharp angles, the integrity of the wires should not be affected even in long term usage. On top of that feature, filleted edges on the ends of the channels and rounded corners on the interior walls were also incorporated to
ensure that the wires that do end up bumping into the wall will not be harmed or affected in any form. Nylon or polycarbonate ion is the material that will be used to print these subshells through material extrusion. They are very tough and durable materials and will provide the wires with enough protection over a long period of time. However, the different environments that the subshells are exposed to have not been researched all too in depth. Therefore, different materials would have to be used in different environments. For example, in high temperature environments, a more heat resistant material such as any form of metal, would have to be used instead of something like nylon that will wear away very quickly in heat. For more humid conditions, nylon may be a better choice than a metal due to the oxidation rate. Finally, to further improve the design to make it suitable for big companies such as Lockheed Martin, the size and thickness of the walls of the backshell could be reduced in order to improve on the cost and weight of the product. When the prototype was 3D printed, it was much more bulky than was hoped for and is probably more protective that is required. Due to this, through future testing we could determine the minimum level of protection the wires need and match that to the thickness and weight of the final backshell to ensure material efficiency and cost.

Also in the future, the backshell could possibly be even further changed to incorporate a lattice structure design on the top and bottom. This is very likely to occur, because of the complex geometries that can be printed through additive manufacturing. The backshell could have a dual layer outer shell, by having a minimum layer thickness as stated above, and then have a lattice structure incorporated above to reduce the amount of materials used without diminishing the integrity of the backshell.

Conclusion

The new design has improved organization and has gotten rid of unnecessary weight. This reduces the material used through the use of additive manufacturing. Looking forward, we could continue to look to reduce the product’s weight in order to reduce the payload if the connectors were used on space ships or other machines where weight was a concern. Some cons are that we are not sure what the most efficient way is to insert the wires. In the future, we believe it would be smart to cut the design in half and have it clip together. This way it will be easy to access the internal organization. We want to explore new materials to print the product
with to appeal to a broader market. Backshells can be printed in metal, rubber, or plastic. This project has taught our group the advantages of using additive manufacturing over traditional subtractive manufacturing methods. In this project, we were given an old design that did not work and had to learn how to identify what in the design needed fixed and what should remain the same. It also taught us how to work with a company and understand their needs. Our knowledge of the design process broadened and we are even more prepared for a potential career in engineering.
References


