Deliverable F - Design Constraints and Prototype II

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Introduction

In this deliverable we will identify, explain, and analyse different design constraints for our prototypes. We will use these constraints to adjust and improve on our design. We will then take what we've learned from prototype I, along with the materials we've acquired to develop our second prototype. Once we have completed our second prototype we will perform testing on it to analyse new aspects of our design.

F.1 Design Constraints

F.1.1.1 Constraint I: Weight of Steel vs aluminium

Originally we had planned to use steel in our design as it is cheap, sturdy, and easy to weld compared to aluminium tubing. However, once we learned the theoretical specifications of our product we realised that designing it with steel rather than aluminium would add a lot of weight to the product once built.

F.1.1.2 Constraint II: Structural integrity of the product

Before changing our primary material to aluminium, we had planned to weld our tubing together. This would have been the most cost-efficient, and reliable method to mount our individual pieces to each other. Now that we are building with aluminium tubing, we must take into account that aluminium can be difficult to weld.

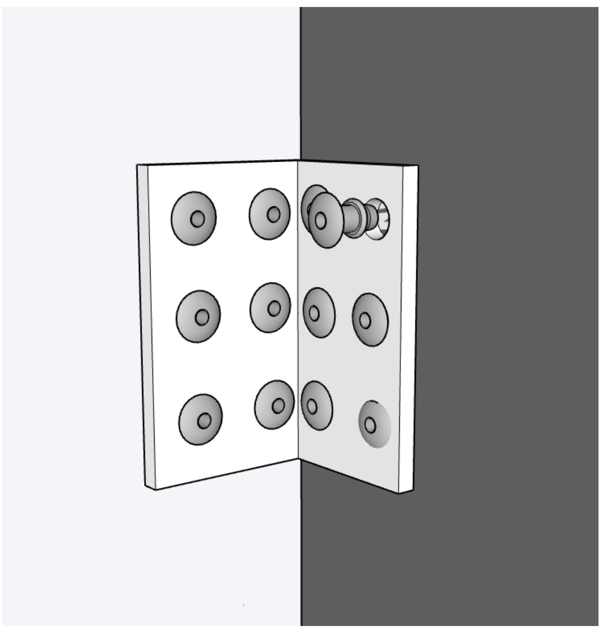
We plan to weld the pieces together as we believe some of them will be weldable. However, if we are unable to weld certain pieces, we must have alternatives. These can include mounting using brackets/screws, and tubing connectors. Through research, we have found that these alternatives can also be effective if we are unable to weld the pieces together. We now plan to use brackets to attach the pieces of aluminium tubing since they offer a simple and effective solution for our prototypes.

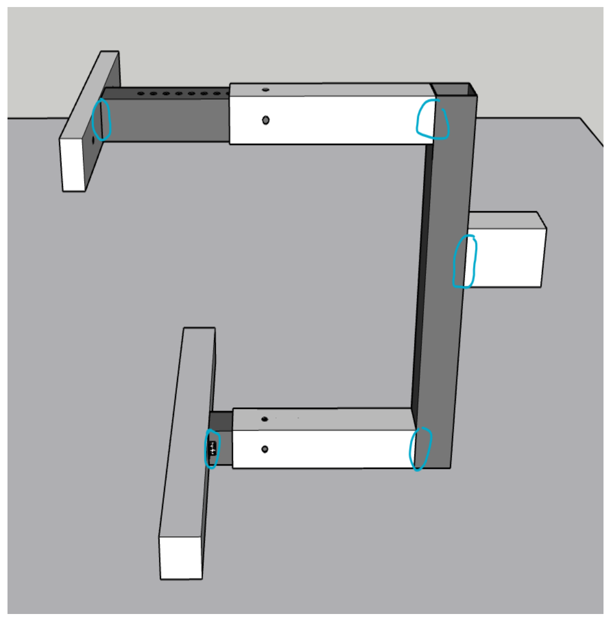
F.1.2 Effectiveness Analysis

We performed an analysis of the weight of our design using modelling software to determine how much metal would be needed. After this value was found, we used it and the average weight of steel and aluminium to determine the theoretical weight of the product if it was built with steel vs if it was built with aluminium. We determined that, if built with steel, our product would weigh roughly 25kg. However, if the product is built with aluminium it would weigh just 8kg. This provides a massive difference in the manoeuvrability of the product overall as one of our key goals is the portability/ease of use of the product. For these reasons, we have decided to build our product out of aluminium despite the larger costs and difficulty of welding.

The constraint of structural integrity is solved by adding an alternative connection technique to every area that was initially going to be welded together. The main alternative used will be riveting and mounting with brackets at the necessary locations. Since riveting is typically not as effective as welding, we will be doubling the amount of rivets used in each section to compensate for the structural integrity of welding.

F.1.3 Updated Design Concept





The updated concept has not changed significantly besides showing the use of latches to attach components together.

F.2 Prototype II

F.2.1 Summary of New Client Feedback and Testing Results

While we haven't had any new client feedback since our first prototype we have done testing on the dimensions as well as some further analysis of our design. We have verified some of our dimensions while adjusting others, like the height of the product and the length of our telescopic tubing. We also decided to use a pre-made handle holder from the Concept2 rower website rather than create our own, making it significantly easier to mount and cheaper. These changes can be seen in our updated design concept.

F.2.2 Critical Assumptions Not Yet Tested

One critical assumption we haven't tested yet is the clearance between the two parts of our telescopic tubing, we must test whether these pieces will fit snugly and be moveable once put together. We also must test our brackets and mount for the different pieces of aluminium throughout the product. Furthermore, it is important that we test our clip which attaches our design to the Concept2 rowing machine. These are all assumptions we've made that we will be testing in prototype 2 and going forward.

F.2.3 Analysis of Prototype II and Our Critical Assumptions

The objective of this prototype was to iterate on our first prototype and make the subsystems of higher fidelity, so as to be able to do testing with them to ensure we are still abiding by our target specifications. The main objectives were making a working latch system and working telescoping tubes. These are the most crucial subsystems of our product.

This prototype is made out of aluminium and a pre-made latch from Concept2. With the development of the second prototype, we were able to create a high-fidelity model to examine the design with precise measurements and compensate for any oversights or incorrect assumptions in the theoretical design. By making the prototype out of aluminium, we were also able to gauge the feasibility of working with the material, test the basic strength of aluminium, and get a sense of the product's weight. This prototype includes all of the subsystems of Prototype I along with the latching mechanism.

We were able to create the telescoping tubing pieces and work with the brackets to ensure precise and smooth interaction between the pieces of aluminium given the thickness of the metal. The latching system was completed using specially ordered hardware from the Concept2 website to ensure a secure attachment to the existing rowing machine clip, however, the latch was slightly too tall to fit into its holding beam and had to be shortened.

The telescoping tubes were made by cutting long aluminium tubes to our desired length using a band saw. The holes were milled afterward to precise locations within our tolerances of 0.002 of an inch. The diameter of the holes is half an inch, which gives us plenty of sizes of pins available to use. We wanted the pin to be big enough to resist shearing when the telescoping tube was fully extended. With 10 holes for adjustability, the maximum extendability of the tube is 10", right in the middle between 8 and 12 inches, like some of our previous designs. Other pieces have also been ordered such as the knee rests and vertical support tube but these have not been worked on for the prototype.

Like the tubes, the aluminium piece for the latching system was also milled. We temporarily put the latching pieces onto the tubes and measured where the fastener holes were. We then precisely milled out the holes and fastened the pieces on the tube. Everything will be put together using rivets and brackets.

F.2.4 Prototype testing

Target Specification	Expected Value	Actual Value
Adjustability (Height of Cable holder)	Between 20-30 inches	24 inches (height of knee stopper)
Supported Weight	≥ 20 kg	N/a
Attachment Set Up/Removal Time	≤ 5 minutes	N/a
Product Weight	< 30 kg	11 kg
Cost	$\leq$ \$100	400$
Latching system	Yes	Yes

Dimensions of product	≤ 3x3x3 ft^3	2' tall, 2.2' width (wheel stopper)

Testing for the height of the cable holder was done by measuring the height of the knee stopper. This came to 24 inches, which is higher than previous measurements since we once again measured the average height of someone's knees when they have sat in the chair.

At the time of client meeting 3, the product wasn't assembled so we weren't able to test the supported weight. The main concern is that the top telescoping tube is going to be too heavy for the brackets that support it and break the rivets. That is why we have multiple rivets per bracket to make it as secure as possible.

No setup time can be measured since our product is not assembled, but attaching the latch itself with nothing attached takes less than 10 seconds.

Even if the product isn't assembled, we can weigh it by weighing everything and adding it together. This includes the rivets and brackets. The weight of the pieces for this prototype is 11kg or 24.25 lbs. This is good because it is well below our ideal weight of less than 30kg. It also leaves us room to make changes in the future in case we need to add pieces.

Unfortunately, the cost of this prototype is more than the target of 100$. The aluminium tubes were the most expensive part. The cost of everything for this prototype was 400$.

Testing the latching mechanism was done by going to the Minto Sports Complex Fitness Centre on campus and trying to attach our latch to one of their rowing machines. Unfortunately, the height of the latch was too big and we had to mill 0.025 inches off of the top and bottom face of the tube. After this, we went back to the fitness centre and the latch worked. This meant that one of our main objectives was completed.

The size of the prototype was simply measured with a measuring tape. The height of the product, which goes from the floor to the top of the knee stopper tube, was 24 inches, which is more than our target specifications. The maximum width, which is the width of the wheel stopper, is 26 inches, to account for the width of many different wheelchairs. The length of the product with no extended tubes is 26” which goes from the telescoping tube to

F.2.5 Preparations for Client Meet III

Our intent for the next client meeting is to make sure the client is satisfied with each subsystem before we finally assemble everything together. Since the subsystems aren’t attached, it is still possible to make some last-second changes to the dimensions of the product. Information we are looking to get from this meeting is certain dimensions of the rower we were unable to get in the previous meetings. With the confirmation of the client, our team will be able to assemble all subsystems to make our third prototype.

Conclusion

In this deliverable, we made adjustments to our global design based on our prototype 1 testing. After making these changes we developed and tested our second prototype where we learned about different critical assumptions we’ve made to develop the best possible final prototype. In the coming weeks, we will continue to analyze and make adjustments as necessary while working on deliverables G, H, and our final prototype for design day.

Updated Wrike Gantt Chart:
https://www.wrike.com/frontend/ganttchart/index.html?snapshotId=eqsHR9GDt21NoqhMpRBbNfdcyuHOtTtG%7CIE2DSNZVHA2DELSTGIYA