GNG 2101 – Intro. to Product Development and Management for Engineers

Deliverable D- Detailed Design, Prototype 1, BOM, Peer Feedback and Team Dynamics

Team 11

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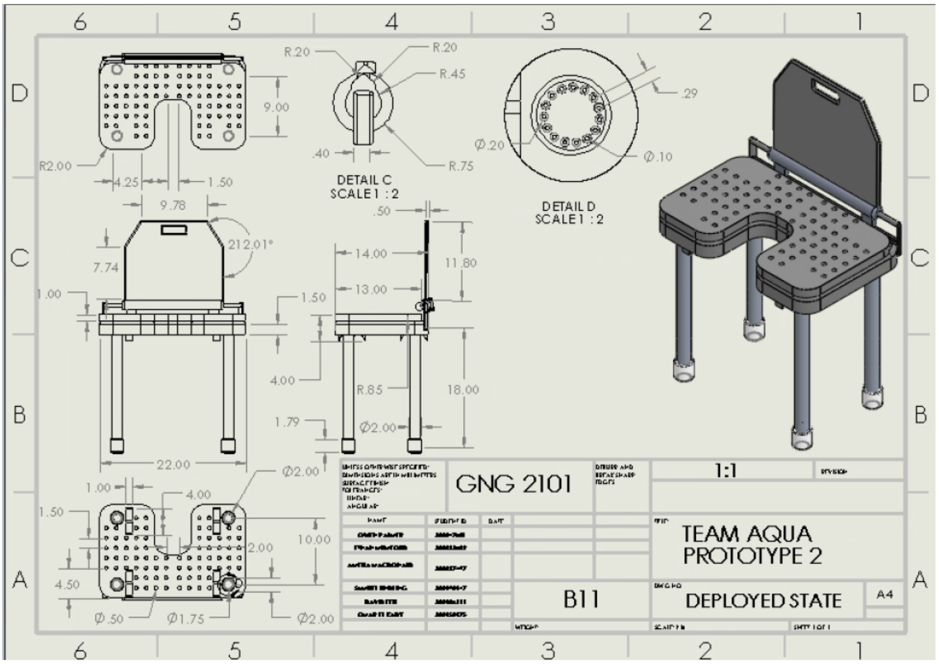
1.0 Client Feedback

Before our second client meeting, our team wanted to know Darcy’s general perception and thoughts regarding our preliminary prototype. We wished to address the 5lb weight limit, removable back rest, maximum volume, and personalized designs on the portable shower seat. Firstly, Darcy clearly stated that the shower seat must be approximately 5lb and the volume should take up less than 50% of the carry-on luggage. He implied that the removable backrest and personalized designs are not mandatory but are nevertheless preferable. When asked if he would like flames along the side of the shower seat, Darcy agreed that they would be nice. In addition, Darcy explained that he would like a rougher seat more than a smooth seat, since the shower water heavily reduces friction. Darcy seemed content with our general design concepts; particularly, the removable legs, along with their plastic clips. Our client, however, expressed two main concerns; he believes the preliminary seat design may be too large for the carry-on suitcase and the drain holes are too large. Darcy stressed that large holes in the shower seat may result in pressure sores. Overall, our client meeting went well; our team gained valuable feedback and insights about our preliminary design and believe we are on track to produce a fully functional portable shower seat.

2.0 Updated Prototype

Figure 1 Illustrating the Detailed Drawing of the Modified Prototype



All the measurements cited in the figure above are in inches and at a 1:1 scale, in other words, they are real life measurements. The detailed drawing above illustrates the following components: Backrest, backrest attaching mechanism, seat cushion, seat skeleton, legs, and legs incasing.

2.0 Prototype

Figure 2.1 Illustrating the Top View of the Prototype in Compact State

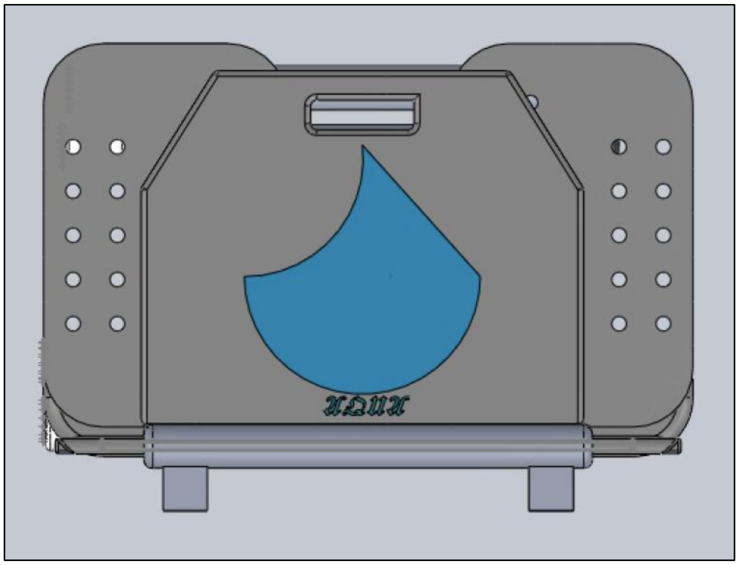


Figure 2.2 Illustrating the Isometric View of the Prototype in Compact State

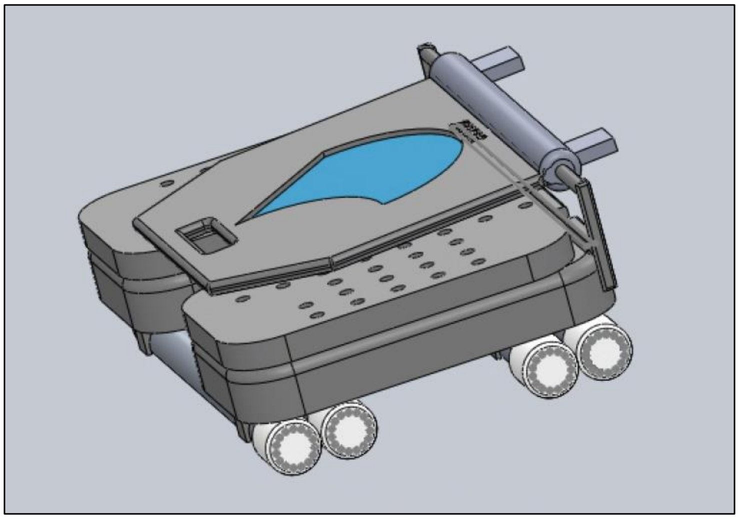


Figure 2.3 Illustrating the Bottom View of the Prototype Showing the Leg Storage

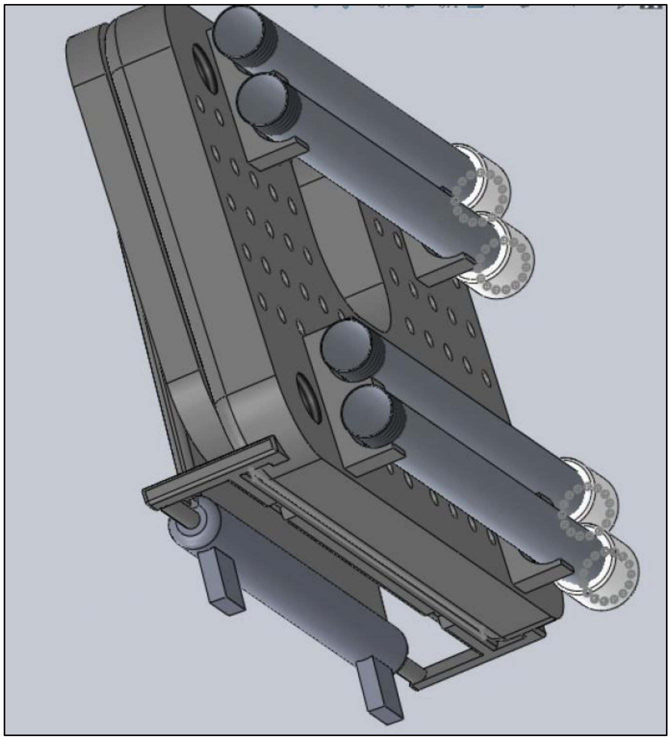


Figure 2.4 Illustrating the Isometric View of the Prototype in the Deployed State

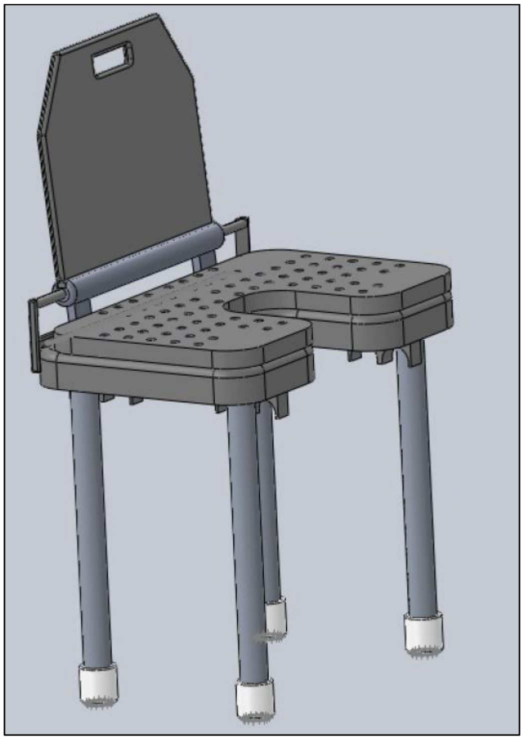


Figure 2.5 Illustrating the Detachable Back Mechanism

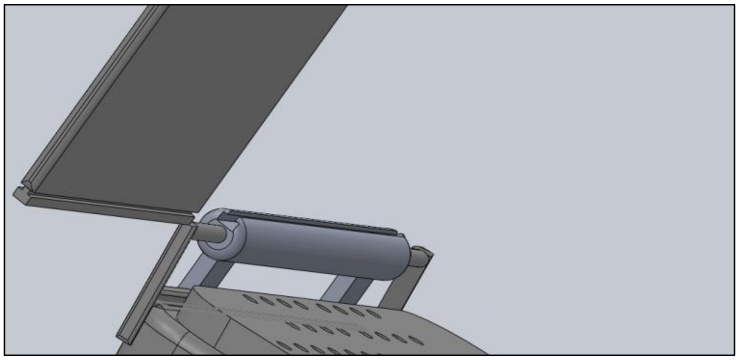
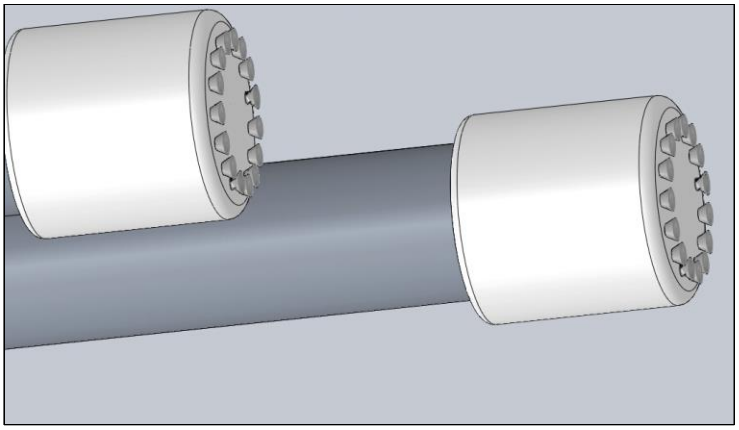


Figure 2.6 Illustrating the Anti-Resisting Components



2.1 Conceptual Prototype Parts Description & their Relation to the Functional Decomposition

The Conceptual Prototype illustrated in the figures above was designed based on the functional decomposition created in the past deliverable, as well as the client's feedback on our preliminary prototype.

Weight Withstanding Function: Figure 2.4 illustrates the legs used in the conceptual prototype, whereas both the measurements and the material of the legs were specifically chosen to satisfy this function and are discussed in detail in section 5 of this report.

Slip Resistance & Tub Adaptation Functions: Figure 2.6 illustrates the slip resistant incasing used for the legs of the chair; as it also illustrates the suction cups used for maintaining better resistance over wet surfaces.

Free Water Flow Function: Figure 2.4 illustrates the seat of the chair which was designed to satisfy the said function by drilling a series of symmetrical holes on the surface of the chair. The size and number of holes were initially different in the preliminary design; however, based on the client's feedback, the design was modified to the current version.

Cleaning Channel Function: Figure 2.4 illustrates the manufactured cleaning channel located at the center of the chair seat.

Cushioning Function: Figure 2.4 illustrates the cushion adhered to the top of the seat. The cushion can be observed to be slightly less in length than the seat to accommodate the detachable back mechanism.

Deployment / Retraction Functions: This prototype, as illustrated in all the figures above, consists of 3 main components. Namely, the bottom component, the middle component, and the back component. Moreover, the bottom component includes the legs and their encasings; the legs are partially threaded to enable them to be fastened to the bottom of the seat when deployed, and to be unfastened and stored in the storing compartment under the chair when retracted. Furthermore, the middle component of the chair includes the seat and the fixed back mechanism attachment; this component is the stationary component of this prototype, in other words, all other components are to be attached to this parent component. The seat also has threaded holes at the bottom of it to allow the legs of the chair to be fastened to it when deployed. Finally, the back component of the chair simply includes the back rest that can simply slide in the designated slot at the back of the seat when needed, see figure 2.5.

3.0 Bill of Materials (BOM)

Table 3.1 displays the materials required for our first prototype and final product. More specifically, this includes: each item's description, quantity, and associated costs. Additionally, Table 3.1 states the total costs to be purchased before and after tax. Table 3.2 provides a link to the main source of each item which describes the product in more detail.

Table 3.1 Bill of Materials

Item Number	Item Name	Description	Units of measure	Quantity	Unit Cost (CAD)	Extended Cost (CAD)
1	Rubber Stoppers	Rubber stopers for the feet of the shower chair	Package (4 units per package)	1	4.69	4.69
2	Suction Cups	Suction cups for the feet of the shower chair	Package (2 units per package)	2	5.49	11.98
3	Aluminum pipe	Aluminum pipe for legs of shower chair	8-foot length	1	21.99	21.99
4	Polyethylene (low density)	Polyethylene pad for seat cushioning (10”x8”x0.4” x 2 sheets)	Package (2 sheets per package)	1	13.99	13.99
5	Polyethylene (high density)	Polyethylene sheet for seat base (5/8”x12”x24”)	Sheet	1	36.44	36.44
Total Product Cost (Excluding Taxes and Shipping) (CAD)						89
Total Product Cost (Including Taxes and Shipping) (CAD)						100.57

Commented [SF1]: are we using pipes or rods?

Table 3.2 Links to Suppliers

Item Number	Link
1	https://www.homehardware.ca/en/4-pack-78-off-white-rubber-furniture-leg-tips/p/2349738?rrec=true
2	https://www.homehardware.ca/en/2-pack-large-clear-suction-hooks/p/2353610?page=search-results%20page
3	https://www.princessauto.com/en/3-4-x-1-16-in-aluminum-round-tubing/product/PA0008829491
4	https://www.amazon.ca/Polyethylene-Customizable-Convoluted-Polyethlene-Costumes/dp/B0B41RK4DP/ref=sr_1_3?keywords=polyethylene+foam&qid=1664908391&qu=eyJxc2MiOiI0LjM4IiwicXNhIjoiNC4xMyIsInFzcCI6IjMuNDAifQ%3D%3D&sprefix=polyet%2Caps%2C115&sr=8-3
5	https://www.amazon.ca/BuyPlastic-Natural-Plastic-Density-Polyethylene/dp/B08NK8Z28J/ref=sr_1_27?keywords=hdpe&qid=1664909842&qu=eyJxc2MiOiI1LjEzIiwicXNhIjoiNC43NSIsInFzcCI6IjMuOTMifQ%3D%3D&refinements=p_36%3A2500-6000&rnid=12035759011&s=industrial&sr=1-27&th=1

4.0 Assumptions

The current design for the shower chair is based on two main assumptions, 1) the availability of high-density polyethylene (HDPE) and 2) the 5-pound maximum weight for our shower seat. The biggest issue is the availability of high-density polyethylene (HDPE). This material was selected because of its load bearing ability and water-resistant properties; however, HDPE is very difficult to obtain for small-scaled projects. HDPE is typically ordered in large, commercial quantities and buying it as a market consumer would be challenging and expensive. We have selected a 5/8” x 12” x 14” HDPE board from a plastic supplier on Amazon. The second assumption, that the weight of the prototype is less than 5 lbs, is highly dependent on our first assumption. Since there is a high degree of uncertainty in attaining the required HDPE material, our product may require a heavier plastic material. This would increase our product’s weight and therefore, might not satisfy our customers’ lightweight requirements. While HDPE is the most appropriate material for the project at hand, its inaccessibility and high price point must be considered before being implemented into our high-fidelity prototype.

5.0 Prototype

Our team unanimously decided to use Solidworks CAD software for the design and testing components of our low-fidelity prototypes. We will continually update our designs based on the client feedback, while using mathematical modelling software to test our portable shower seat. This provides much more experimental freedom and data than a low-fidelity prototype made from cardboard. The Solidworks software allows users to modify designs with ease, apply material conditions and use advanced testing methods which would otherwise be inaccessible. Moreover, our team will be able to invest more time and resources in the final prototype, rather than the low-fidelity ones. We will use Solidworks' mathematical models to analyze parts under maximum tensile stress and buckling instabilities. Our prototype has been provided in *Section 2.0*.

6.0 Prototype Details

The function of this new prototype is to analyze the required tensile strength and buckling conditions of the plastic seat and legs. The strength of aluminum, carbon fiber and fiber glass will be compared, and the HPDE material will be tested to ensure it can withstand the user's weight. This will allow our team to establish the importance of each material and analyze their material properties in relation to their cost. We hope to determine whether aluminum, carbon fiber or fiber glass would be the most optimal material for the seat legs. Please see S*ection 2.0* to view CAD illustrations of our prototype. Below are several more figures for the same prototype.

Figure 6.1: Top View

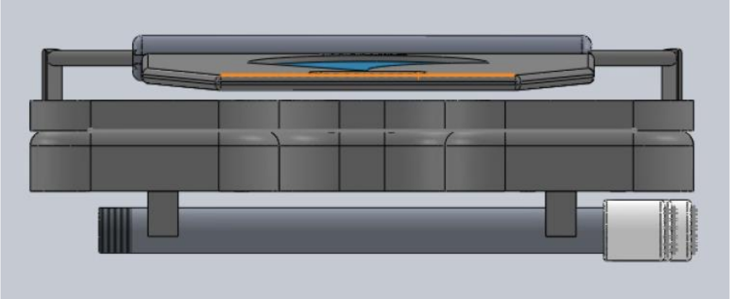


Figure 6.2: Bottom View

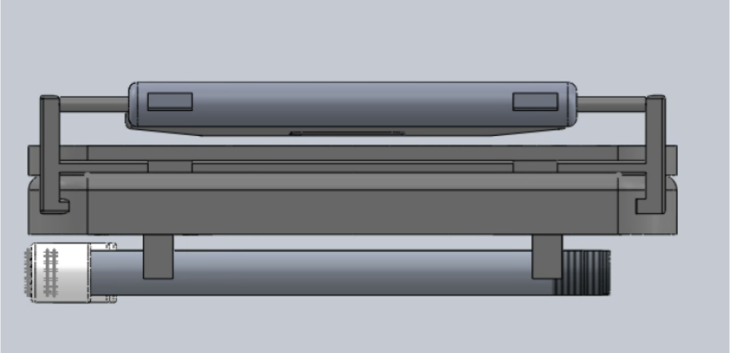


Figure 6.3: Front View

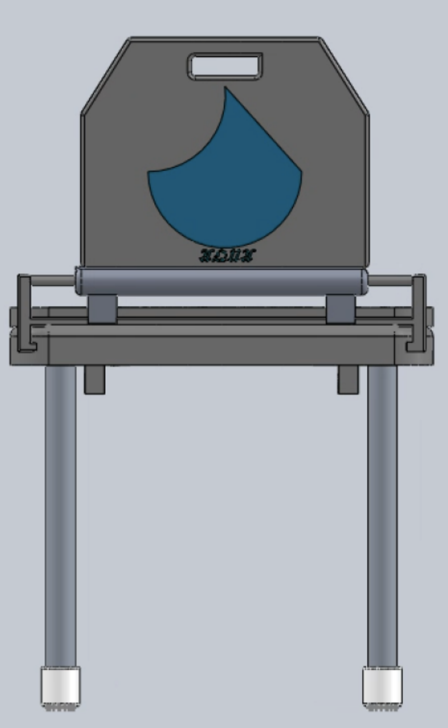


Figure 6.4: Left Side View in Folded State

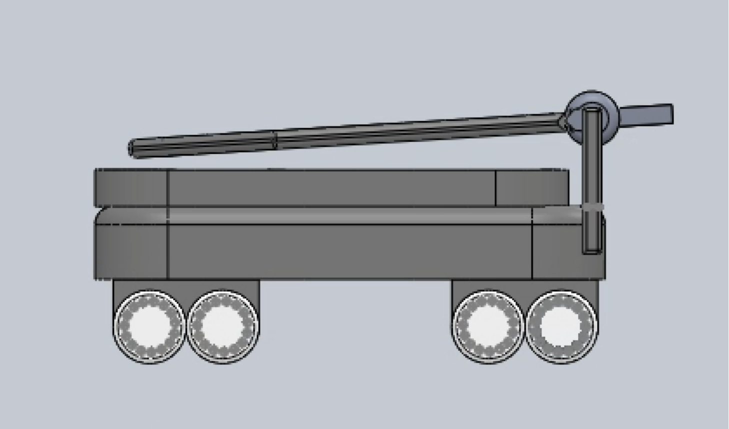


Figure 6.5: View of Updated Drainage System

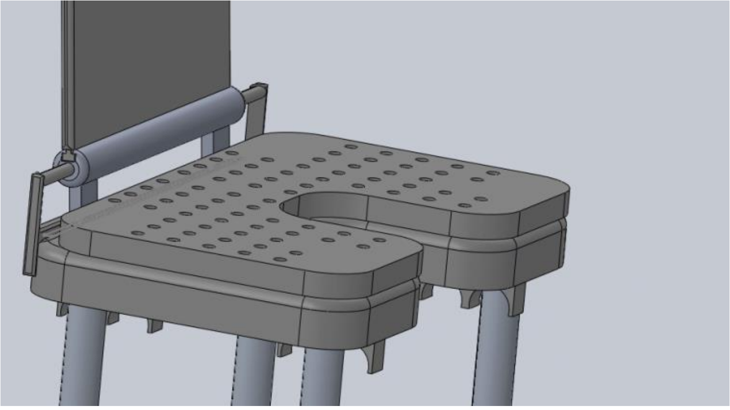
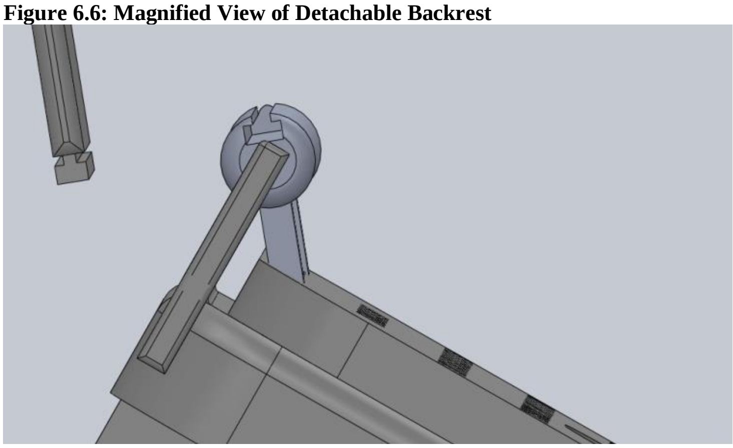


Figure 6.6: Magnified View of Detachable Backrest



7.0 Testing

In this section of our report, we analyze the required chair legs dimensions by establishing critical assumptions before applying Euler's buckling equation.

7.1 Assumptions

There are multiple assumptions which must be considered before implementing Euler's buckling equation. These include:

Assumption #1: Although the weight will usually be distributed between the 4 legs, the force distribution can vary especially when the user is entering or exiting the chair. To ensure that the chair will not break during such occasions, one must assume that each leg must withstand the user's entire weight.

Assumption #2: The shower seat legs must have a safety factor of at least 1.3.

Assumption #3: The legs are fixed-free columns.

Assumption #4: The legs are 21 inches long.

Assumption #5: The legs will be made from a solid rod and a single material.

Assumption#6: The strength of carbon fibers is dependent on the direction of the applied load. It will be assumed that the applied load is parallel to the fibers, resulting in a modulus of elasticity of approximately 520 GPa.

7.2 Equations:

$P_{cr} = \frac{\pi^2 EI}{4L^2}$

$$I = \frac{\pi D^4}{64}$$

$$L = 21in \approx 54cm = 0.54m$$

$$P_{cr} = \frac{\pi^2 E \left(\frac{\pi D^4}{64}\right)}{4L^2} = \frac{\pi^3 E D^4}{256 L^2}$$

$$D = \sqrt[4]{\frac{256 P_{cr} L^2}{\pi^3 E}}$$

7.3 Calculations

Aluminum[1] *:*

$$E_{Al} = 68.0GPa = 68.0 \times 10^9 Pa$$

$$D = \sqrt[4]{\frac{256 P_{cr} L^2}{\pi^3 E}}$$

$$D = \sqrt[4]{\frac{256(1500)(0.54)^2}{\pi^3 (68 \times 10^9)}}$$

$$D = 0.015180639m = 15.180639mm \approx 0.6inch$$

Carbon Fibers[2]*:*

$$E_{CF} = 2.62 - 520Gpa \rightarrow E_{CF} = 500\ GPa = 500 \times 10^9 Pa$$

$$D = \sqrt[4]{\frac{256 P_{cr} L^2}{\pi^3 E}}$$

$$D = \sqrt[4]{\frac{256(1500)(0.54)^2}{\pi^3 (69 \times 10^9)}}$$

$$D = 0.00921880822m = 9.21880822mm \approx 0.363in$$

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[1] https://www.matweb.com/search/DataSheet.aspx?MatGUID=0cd1edf33ac145ee93a0aa6fc666c0e0

[2] https://www.matweb.com/search/datasheet.aspx?matguid=39e40851fc164b6c9bda29d798bf3726

Fiber Glass[3]*:*

$E_{FRP} = 69GPa = 69 \times 10^9 Pa$

$$D = \sqrt[4]{\frac{256 P_{cr} L^2}{\pi^3 E}}$$

$$D = \sqrt[4]{\frac{256(1500)(0.54)^2}{\pi^3 (69 \times 10^9)}}$$

$$D = 0.015125335m = 15.125335mm \approx 0.6in$$

7.4 Results:

Based off the calculations done above, he minimum diameter for the chair legs is 0.6 in for aluminum, 0.6 in for fiberglass and 0.363 in for carbon fiber. It is important to note that greater diameters for each material are acceptable since it will increase both the safety factor and stability of the shower seat.

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[3] https://www.matweb.com/search/DataSheet.aspx?MatGUID=3dbc779c2f034329b2836b02b9483629&ckck=1

8.0 Reflection

Our team intends to present the changes we have made in this prototype since presenting our conceptual design. We have implemented Darcy's feedback by decreasing the size of the drainage holes and by adding a removable backrest which includes a handle for carrying. During our next meeting, we plan to present our prototype and discuss our analysis and testing calculations. We will discuss our current concerns related to HPDE suppliers and lightweight complications to ensure that Darcy is aware of any challenges we may face in future reiterations. Overall, our team is confident in our new prototype, and we are prepared to show Darcy our new and improved design implementations.

9.0 References:

1. Beatriz, Martin-Preze. “Task 3 - Design of truss members” Mechanics of Materials I, University of Ottawa, 2022.

2. “Aluminum, Al”. Matweb. https://www.matweb.com/search/DataSheet.aspx?MatGUID=0cd1edf33ac145ee93a0aa6fc666c0e0

3. “Fiberglass Grade B”. Matweb. https://www.matweb.com/search/DataSheet.aspx?MatGUID=3dbc779c2f034329b2836b02b9483629&ckck=1

4. “Overview of materials for Epoxy/Carbon Fiber Composite”. Matweb. https://www.matweb.com/search/datasheet.aspxmatguid=39e40851fc164b6c9bda29d798bf3726