Group Number: 23

MECHENG 4B03

Final Report - ModFrames

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What is ModFrames?

Nowadays, with the modernization of technology including products such as mobile phones and computers, wearing glasses has become significantly more common than in the past. It is a fact that among every 10 people, there are more than 6 who wear glasses [1]. For children, it is very common to change between multiple glasses in a short period of time. For example, a student may need to replace his glasses at least three times from elementary school to university due to deepening myopia. The price of glasses are also relatively expensive and as a result, buying multiple glasses can increase the financial burden for many families. In addition, children are highly active and thus tend to break their glasses quite often whether it be the result of playing basketball outdoors or even lollygagging with friends. Because of these issues in the current market, we have designed a pair of glasses called ModFrames that are modular, inexpensive, can withstand large impact forces, aesthetically pleasing and are highly customizable which is targeted directly for young children and teenagers.

Inspiration for ModFrames

We believe that the reason why children change glasses frequently is because their eyesight becomes weaker over time. In this case, ModFrames can resolve this issue as the child can simply replace the lens and keep the frame which can ultimately save parents a lot of money. Additionally, the size of their face will grow as they age, so introducing a modular frame will allow for these children to simply replace specific components that need to be updated so that they have a pair of glasses that is perfectly suited for their facial structure. Next, children also tend to break their glasses frequently and in this scenario, ModFrames will allow children to once again replace the damaged components to reduce expenses.

In order for the design to meet the physical and aesthetic needs of children, the choice of material must be taken into account. In this regard, we chose PLA as the material for 3D printing so that the frames can be both light and rigid, at the same time. The yield strength of PLA is 8840psi (61Mpa) [2] which means that the ModFrames will be an extremely reliable accessory that children will not have to worry about when participating in physical activity. Furthermore, the price of PLA is 25 dollars per kilogram [3], which makes it very affordable and one of the most effective 3D printing materials.

How ModFrames Work & Testing

Our product is divided into four major parts:

1. Two temples
2. Two frames
3. A bridge to connect the frame
4. A nose pad under the bracket

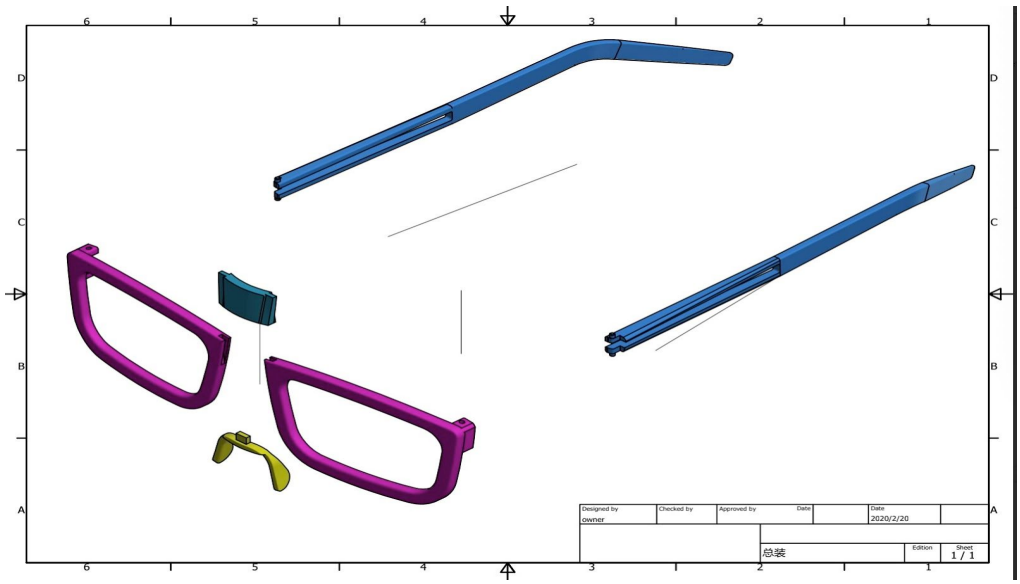


Figure 1: ModFrames

Two separate PLA frames allow the new lenses to be snapped in with ease to fit the frames. The middle bridge size will depend on the width of one's nose and will be responsible for connecting both the left and right side of the frame together. As teenagers grow older, even if the shape of their nose changes, they only need to replace the middle connecting bridge instead of buying an entirely new pair of glasses. Lastly, the length of the temples will also depend on the child's facial dimensions and can also be replaced easily as all temples will have the same hinge mechanism that connects seamlessly to the frames. In summary, Figure 1 highlights the first model of our ModFrames but all proceeding models will work in the same fashion but will be aesthetically different.

Note: *Detailed figures of the ModFrames can be found in Appendix A.*

Design Process

Firstly, once we had decided that our product choice would be the ModFrames, we attempted to go about the design process by developing a CAD model of our group member's glasses. We wanted to ensure that the frame we were developing would be aesthetically pleasing and would be a viable product that even someone in our own group could use. Once we developed this initial model, we realized that some of the parts including the hinges of the temples, bridge and nosepad were too small which could lead to manufacturing issues due to the fact that most methods of manufacturing (e.g. 3D printing, injection molding) would not be able to produce accurate small parts. As a result, we decided to magnify the temples, bridge and nosepad slightly so that the manufacturing errors could be significantly reduced and the rigidity of the frames would increase. Finally, we had developed a template of a frame that is tailored to a specific individual according to the dimensions of their face (shown in Appendix A).

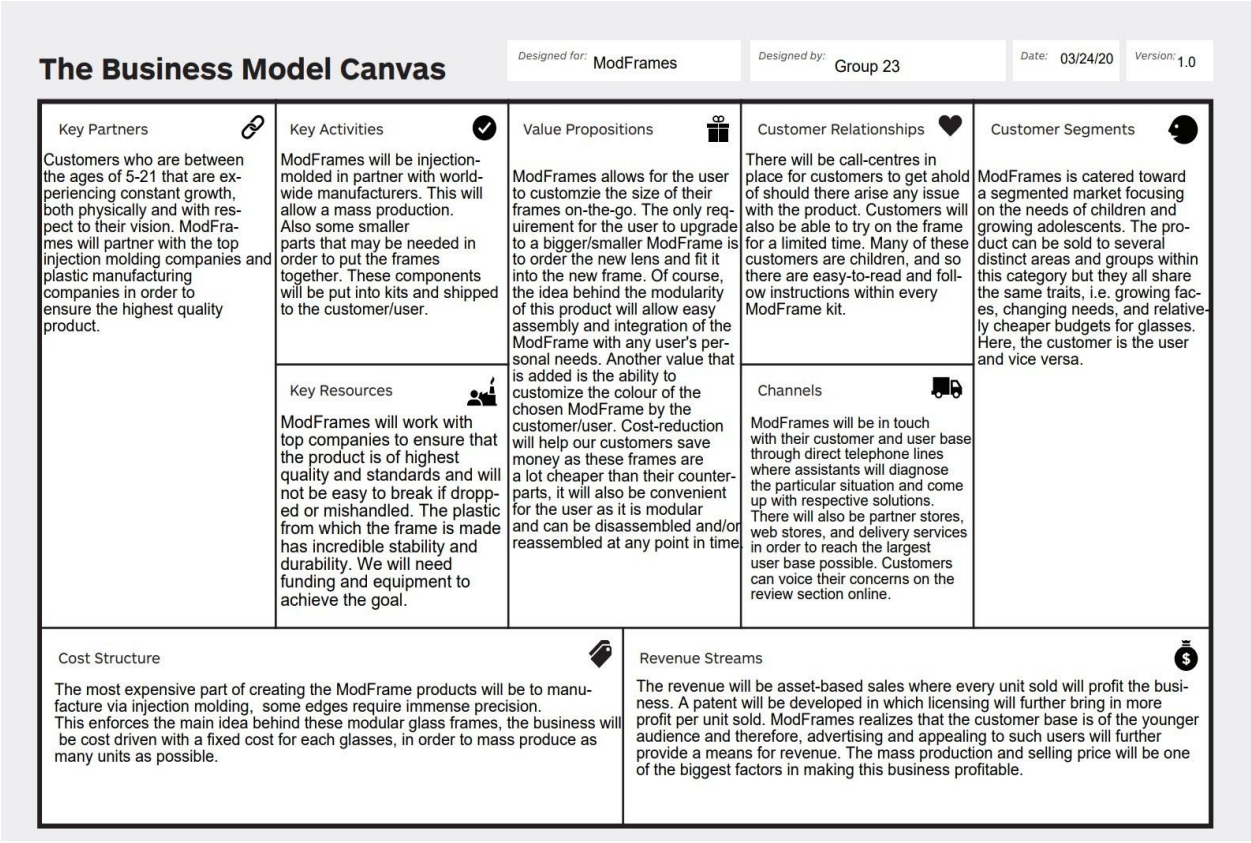
What Makes ModFrames Different?

The ModFrames are undoubtedly extremely different compared to other eyewear in the market today. ModFrames are specifically designed for young children and teenagers who often go through many glasses in a short period of time. This is normally due to the fact that this is the age group where eyesight can change very drastically. Furthermore, children are highly active and can break multiple pairs of glasses. When parents look into the current market, their options are buying designer glasses, sports goggles, memory metal glasses or contact lenses. These options are either highly expensive or are very aesthetically unpleasing. Thus, introducing the ModFrames into the market allows for parents to buy their children inexpensive frames that can be replaced if they were to break, even though the ModFrames are highly rigid and will be able to withstand a large impact. Additionally, if their child's eyesight becomes worse over time, these parents can simply buy the correct lens and install it into the frames with ease. Last but not least, ModFrames are very customizable and can be tailored to the child with the dimensions of their face and colours of their choice.

Future Plans

In the future, we plan on developing templates of many different types of frames so that children can choose from various styles and can decide on a frame that they find the most appealing. These styles will include (but are not limited to) the low bridge, heavy bridge, light temple, curved frame, close set bridge, wide set bridge and deep frame. We also plan on developing these frames in a multitude of colours so that children can use these frames as accessories and can express themselves as they grow up in the world and experience many things. Children will mature, figure out their likes and dislikes over time and can choose the frame that describes their character at that moment in time. We feel that children will, in the future, really own the ModFrames which can lead to a limitless number of possibilities for which we can grow our product idea.

Business Model



Financial Analysis

Cost for the Actual Prototype

- The actual prototype's cost is calculated by using the DFMA Worksheet. Plus, the price is from Prusa Research.
- All parts are using Prusa 3D Printer. The materials are PLA. The price for PLA is found from Prusa Research. The link has been shown in reference.
- Exploded View of the ModFrame has been shown in Appendix A, Figure 5.
- The DFMA Worksheet has been shown in Figure 2 below.

DFMA Worksheet - ModFrame

Based on Boothroyd, 1994

Notes:
- Don't forget, you may have to change the cell references to update the overall cost, data is just dummy data
- You do not need to include the arduino, batteries, motors or switches
- Part cost can be wholesale price if purchased in quantity, does not need to be YOUR actual cost
- See slides for definition of theoretical part count, assembly index
- Estimate assembly time as best you can, you may assume your assembler is skilled
- You may assume a labour rate of: $110.00 CAD/hour
- For 3D printed parts you may assume a material cost of: $15.00 CAD/cubic inch

and a **manufacturing** labour cost of: 15.00 minutes/build plate

- For wood laser cut parts you may assume a material cost of
  - 3mm thick $6.00 CAD/sheet
  - 6mm thick $9.00 CAD/sheet
- For acrylic laser cut parts you may assume a cost of
  - 3mm thick $9.00 CAD/sheet
  - 6mm thick $18.00 CAD/sheet
- For any laser cut part you may assume a **manufacturing** labour cost of: 15.00 minutes/sheet

Overall budget per device		**Assembly Index**	* calculated per lecture slides * also called design efficiency
Purchased Parts	$0.00	**0.0%**	
Material	$10.10		Assembly Index = (Total Theoretical Part Count)*3/(Total Assm Time)
Labour	$172.03	Total Theoretical Part Count	0
Total	**$182.13**	Total Assm Time	230

Purchased Parts

Part Name	*Part Cost (CAD/per)*	*Number*	*Total Part Cost*	*Theoretical Part Count*	*Assembly Time per part (s)*	*Total Assembly Time (s)*	*Assembly Labour Cost*
Subtotal			$0.00	0	0	0	$0.00

Manufactured Parts

Part Name	*Material Cost (CAD/per)*	*Number*	*Total part material cost*	*Manufacturing Time (s)*	*Theoretical Part Count*	*Assembly Time per part (s)*	*Total Assembly Time (s)*	*Total Labour Cost*
Left Frame Rim	$1.84	1	$1.84	900	0	20	20	$28.11
Right Frame Rim	$1.84	1	$1.84	900	0	20	20	$28.11
Left Template	$2.87	1	$2.87	900	0	20	20	$28.11
Right Template	$2.87	1	$2.87	900	0	20	20	$28.11
Bridge	$0.37	1	$0.37	900	0	30	30	$28.42
Nosepad	$0.32	1	$0.32	900	0	120	120	$31.17
Subtotal			$10.10	5,400	0	230	230	$172.03

Left Frame Rim Calculations - 3d printed part			
Part volume	2008.68	mm^3	
Part volume	0.1225771743	cubic inches	* from Inventor or Slicer
Material Cost	$1.84	CAD/part	
Print Time	2820	sec/part	
Right Frame Rim Calculations - 3d printed part			
Part volume	2008.68	mm^3	
Part volume	0.1225771743	cubic inches	* from Inventor or Slicer
Material Cost	$1.84	CAD/part	
Print Time	2820	sec/part	
Left Template Calculations - 3d printed part			
Part volume	3130.34	mm^3	
Part volume	0.1910250671	cubic inches	* from Inventor or Slicer
Material Cost	$2.87	CAD/part	
Print Time	2580	sec/part	
Right Template Calculations - 3d printed part			
Part volume	3130.34	mm^3	
Part volume	0.1910250671	cubic inches	* from Inventor or Slicer
Material Cost	$2.87	CAD/part	
Print Time	2580	sec/part	
Bridge Calculations - 3d printed part			
Part volume	406.09	mm^3	
Part volume	0.02478113224	cubic inches	* from Inventor or Slicer
Material Cost	$0.37	CAD/part	
Print Time	420	sec/part	
Nosepad Calculations - 3d printed part			
Part volume	353.45	mm^3	
Part volume	0.02156884235	cubic inches	* from Inventor or Slicer
Material Cost	$0.32	CAD/part	
Print Time	462	sec/part	

Figure 2 : DFMA

The cost has been recorded in the table below.

Table 1: Cost for Actual Prototype

Part Name	Quantity	Material Cost ($)	Labour Cost ($)	Purchase Part Cost ($)	Total Cost ($)
Left Frame Rim	1	1.84	28.11	0	29.95
Right Frame Rim	1	1.84	28.11	0	29.95
Left Template	1	2.87	28.11	0	30.98
Right Template	1	2.87	28.11	0	30.98
Bridge	1	0.37	28.42	0	28.79
Nosepad	1	0.32	31.17	0	31.49
Total Cost ($)		10.10	172.45	0	182.13

Thus, in order to create the prototype, we will need a total of $182.13.

Cost for Mass Production

- As you can see, the material cost is only $10.10. The major cost is the labour cost which is $172.45. Mass production can solve this problem.
- According to the research online (Link has been shown in the reference), the cheapest manufacturing is still in China like Foxconn. If manufacturing can be moved to China, the labour cost will be much lower. Even though there are some delivery costs, the delivery cost will not be high via marine transportation. According to the online research (Link in the reference), the average shipping price for 200 kg products is $692 from Shenzhen to Toronto. The transportation time might be long but the price is very cheap.
- In addition, the injection mold will be used to increase the surface roughness in order to improve the comfortability of ModFrame. The material for ModFrame has been changed from PLA to ABS in order to increase strength and durability.
- Alibaba is a good marketplace to source a lot of products. The price in the marketplace is relatively low. Also, the more products we ordered, the lower the price we got. Therefore, this e-commerce platform will be used for the components of the product for mass production, i.e. 1000 pieces.

- The revised DFMA Worksheet for injection mold with ABS materials has been shown in Figure 3 below.

Overall budget per device			**Assembly Index**	* calculated per lecture slides				
				* also called design efficiency				
Purchased Parts	$0.00		**0.0%**					
Material	$0.23			Assembly Index = (Total Theoretical Part Count)*3/(Total Assm Time)				
Labour	$34.06		Total Theoretical Part Count		0			
Total	**$34.29**		Total Assm Time		230			
Purchased Parts								
Part Name	*Part Cost (CAD/per)*	*Number*	*Total Part Cost*	*Theoretical Part Count*	*Assembly Time per part (s)*	*Total Assembly Time (s)*	*Assembly Labour Cost*	
Subtotal			$0.00	0	0	0	$0.00	
Manufactured Parts								
Part Name	*Material Cost (CAD/per)*	*Number*	*Total part material cost ($)*	*Manufacturing Cost ($)*	*Theoretical Part Count*	*Assembly Time per part (s)*	*Total Assembly Time (s)*	*Total Labour Cost*
Left Frame Rim	$550.00	1	0.046580	3.9705340	0	20	20	$0.73
Right Frame Rim	$550.00	1	0.046580	3.9705340	0	20	20	$0.73
Left Template	$437.00	1	0.063020	4.7338980	0	20	20	$0.76
Right Template	$437.00	1	0.063020	4.7338980	0	20	20	$0.76
Bridge	$161.00	1	0.004247	3.0733210	0	30	30	$1.01
Nosepad	$143.10	1	0.003288	5.7508490	0	120	120	$3.84
Subtotal			0.226735	26.2330340	0	230	230	$7.83

Left Frame Rim Calculations - From Injection Mold Cost Esitmator for 1000 parts

	1000 Parts	1 Part	CAD
Material:	34	0.034	0.04658
Production	$550.00	0.55	0.7535
Tooling	2348.2	2.3482	3.217034

Right Frame Rim Calculations - From Injection Mold Cost Esitmator for 1000 parts

	1000 Parts	1 Part	CAD
Material:	34	0.034	0.04658
Production	$550.00	0.55	0.7535
Tooling	2348.2	2.3482	3.217034

Left Template Calculations - From Injection Mold Cost Esitmator for 1000 parts

	1000 Parts	1 Part	CAD
Material:	46	0.046	0.06302
Production	$437.00	0.437	0.59869
Tooling	3018.4	3.0184	4.135208

Right Template Calculations - From Injection Mold Cost Esitmator for 1000 parts

	1000 Parts	1 Part	CAD
Material:	46	0.046	0.06302
Production	$437.00	0.437	0.59869
Tooling	3018.4	3.0184	4.135208

Bridge Calculations - From Injection Mold Cost Esitmator for 1000 parts

	1000 Parts	1 Part	CAD
Material:	3.1	0.0031	0.004247
Production	$161.00	0.161	0.22057
Tooling	2802.3	2.0823	2.852751

Nosepad Calculations - From Injection Mold Cost Esitmator for 1000 parts

	1000 Parts	1 Part	CAD
Material:	2.4	0.0024	0.003288
Production	$143.10	0.1431	0.196047
Tooling	4054.6	4.0546	5.554802

Figure 3: Revised DFMA Worksheet for injection mold with ABS materials

The cost has been shown in Table 2 Below.

Table 2: Cost for Mass Production

Part Name	Quantity	Material Cost ($)	Labour Cost ($)	Manufacturing Cost ($)	Total Cost ($)
Left Frame Rim	1	0.034	0.73	3.970534	4.749547
Right Frame Rim	1	0.034	0.73	3.970534	4.749547
Left Template	1	0.046	0.76	4.7338980	5.552676
Right Template	1	0.046	0.76	4.7338980	5.552676
Bridge	1	0.0031	1.01	3.0733210	4.088142
Nosepad	1	0.0024	3.84	50750849	9.596524
Total Cost ($)		0.226735	7.83	26.233034	34.289112

Thus, the total cost for one pair of ModFrame is $34.289112 if the mass production is made.

Selling Price

According to the cost of the mass production which is $34.289112, one pair of ModFrame can be sold for $39.99 in order to make a profit. Compared with the current low price glasses frames from the internet which the lowest price is around $30, the selling price of ModFrame is not competitive. However, the quality of ModFrame is absolutely good. All injection molds use high precision and polish. In addition, ModFrame can change the broken parts or relatively small parts. It means the user does not need to change the whole glasses frame. They just need to change their broken or relatively small parts like templates or nose pads. In the long term, it is beneficial for the customers.

Net Present Value (NPV) and Profits

- The NPV is analyzed through the worksheet given. The result has been shown in Figure 4.
- The annual discount rate will be 0.07. Then, the quarterly discount rate will be 0.0175. In the first year, it is in the developing period. The product development for each quarter will be $12500 because this is a small, cheap and simple product. The development fee should be too much. The production ramp-up fee for the last quarter in the first year and first quarter in the second year will be $5000. In order to open the market and make the profit, the market and support fee is relatively high, which is $20000 for the last quarter in the first year and the first quarter in the second year. For the second and third in the second year, the market and support fee will be reduced to $10000 for saving money. For the fourth quarter in the second year, the market and support fee will be reduced further to $5000 because, at this time, the market should be famous for the current product. More fees should be moved to develop new products. In the second year, the products start to sell. The sales price is $39.99 for one pair of ModFrame. The sales volume in the first, second, and third quarters of the second year will be 10000. Then, in the fourth quarter of the second year, the sales volume will be increased to $12000 in order to increase the profit.
- According to the NPV analysis, the products can earn $87701 after two years. If the sale volume can be increased again like 15000 or even 100000, the profit can be increased too because the number of people who wear glasses is extremely large. If 1% of these people want to use the ModFrame, the production must be over 1 million.

MECHENG 4B03 - NPV Calculator - Net Present Value

Annual Discount Rate	0.07	* this represents opportunity cost,interest
Quarterly Discount Rate	0.0175	interest/4

	Year 1				Year 2			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
n=	1	2	3	4	5	6	7	8
Inflows								
ModFrame					$399,900	$399,900	$399,900	$479,880
Total Revenue					**$399,900**	**$399,900**	**$399,900**	**$479,880**
Outflows								
Product Development	$12,500	$12,500	$12,500	$12,500				
Equipment and Tooling			$5,000	$5,000				
Production Ramp Up				$5,000	$5,000			
Marketing and Support				$20,000	$20,000	$10,000	$10,000	$5,000
Production Machines					$342,891	$342,891	$342,891	$411,469
Total Costs	**$12,500**	**$12,500**	**$17,500**	**$42,500**	**$367,891**	**$352,891**	**$352,891**	**$416,469**
Quarterly Cash Flow	-$12,500	-$12,500	-$17,500	-$42,500	$32,009	$47,009	$47,009	$63,411
Quarterly NPV	-$12,500	-$12,074	-$16,612	-$39,651	$29,349	$42,362	$41,633	$55,193
Total NPV	$87,701							
Supporting Calculations								
ModFrame								
Sales Volume (units)					10000	10000	10000	12000
Sales price per unit					39.99	39.99	39.99	39.99

Figure 4: NPV for ModFrame

References

[1] Statistics Netherlands. “More than 6 in 10 People Wear Glasses or Contact Lenses.” *Statistics Netherlands*, Centraal Bureau Voor De Statistiek, 20 Sept. 2013, www.cbs.nl/en-gb/news/2013/38/more-than-6-in-10-people-wear-glasses-or-contact-lenses.

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Appendix A: Exploded Drawing and Multiview Drawings

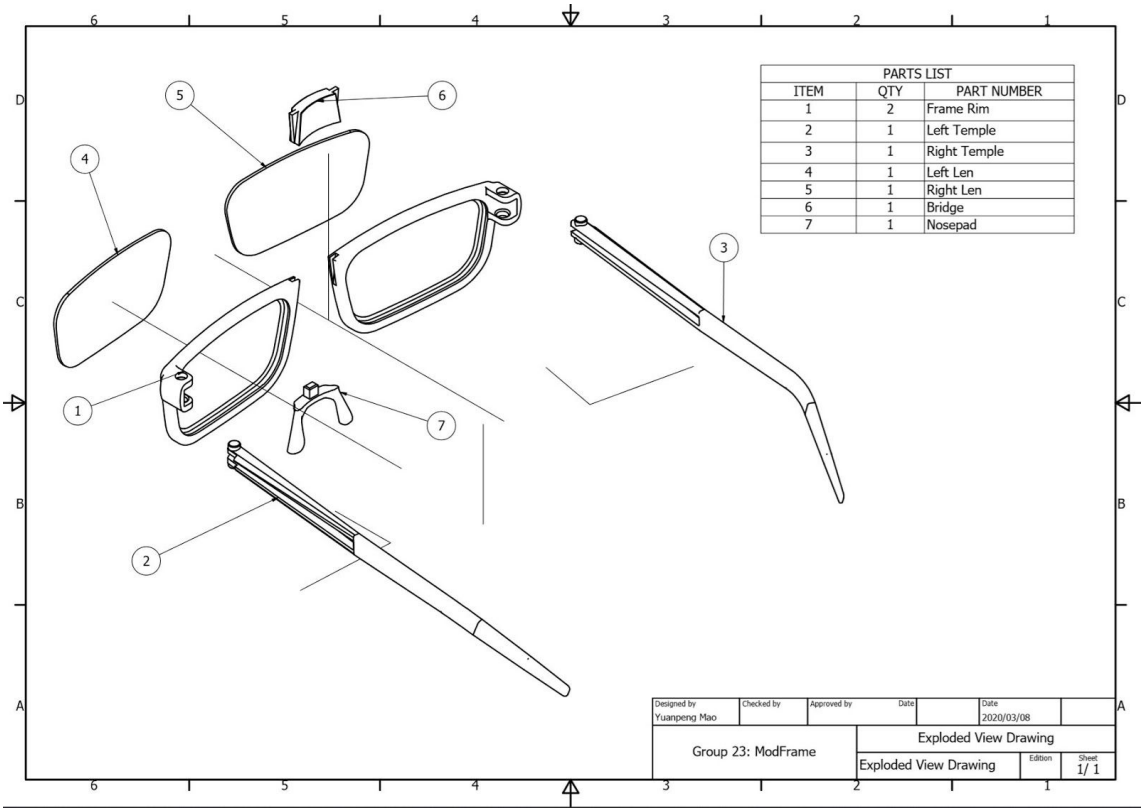

Figure 5: Exploded View Drawing

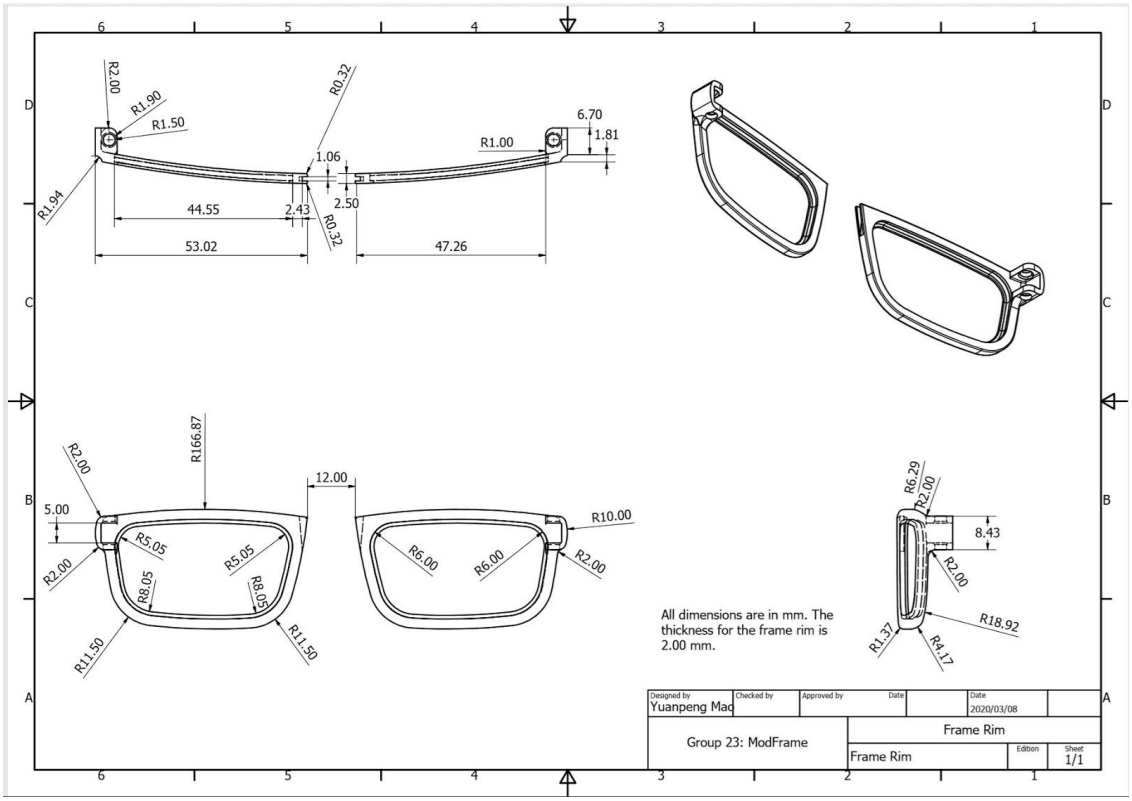

Figure 6: Frame Rim

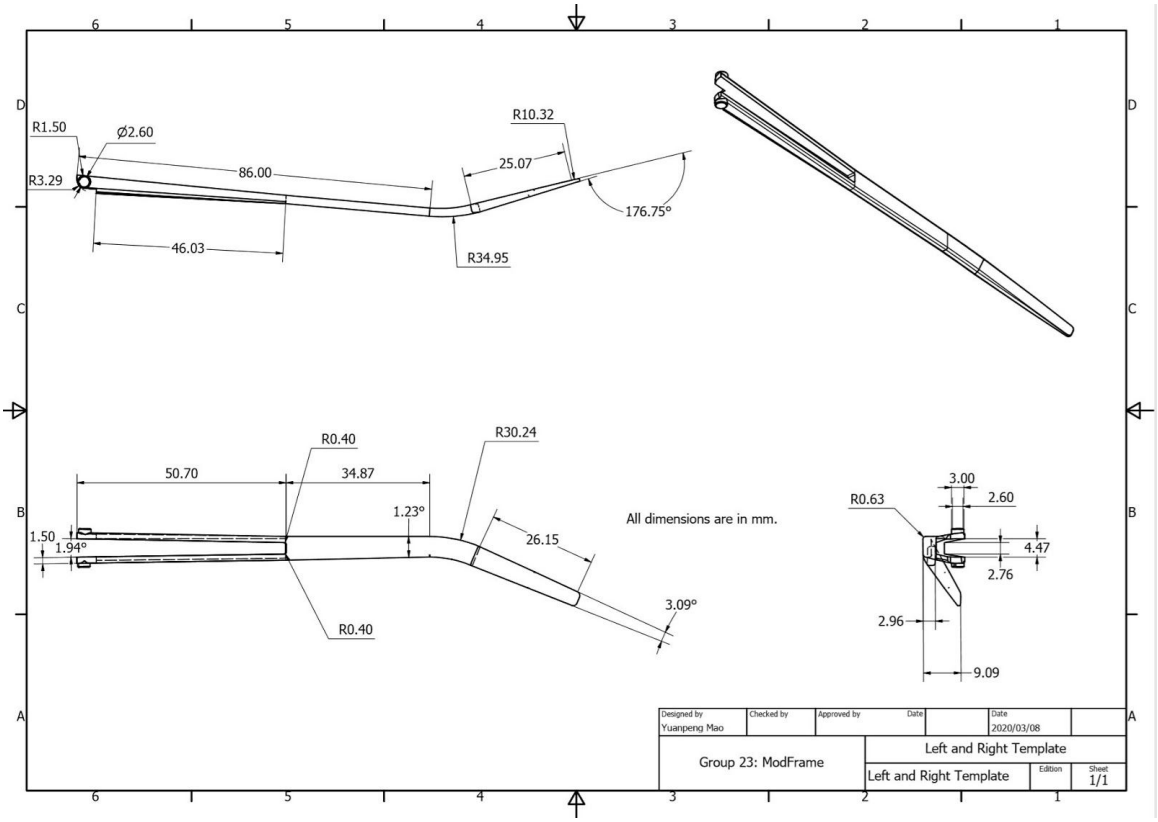

Figure 7: Left and Right Template

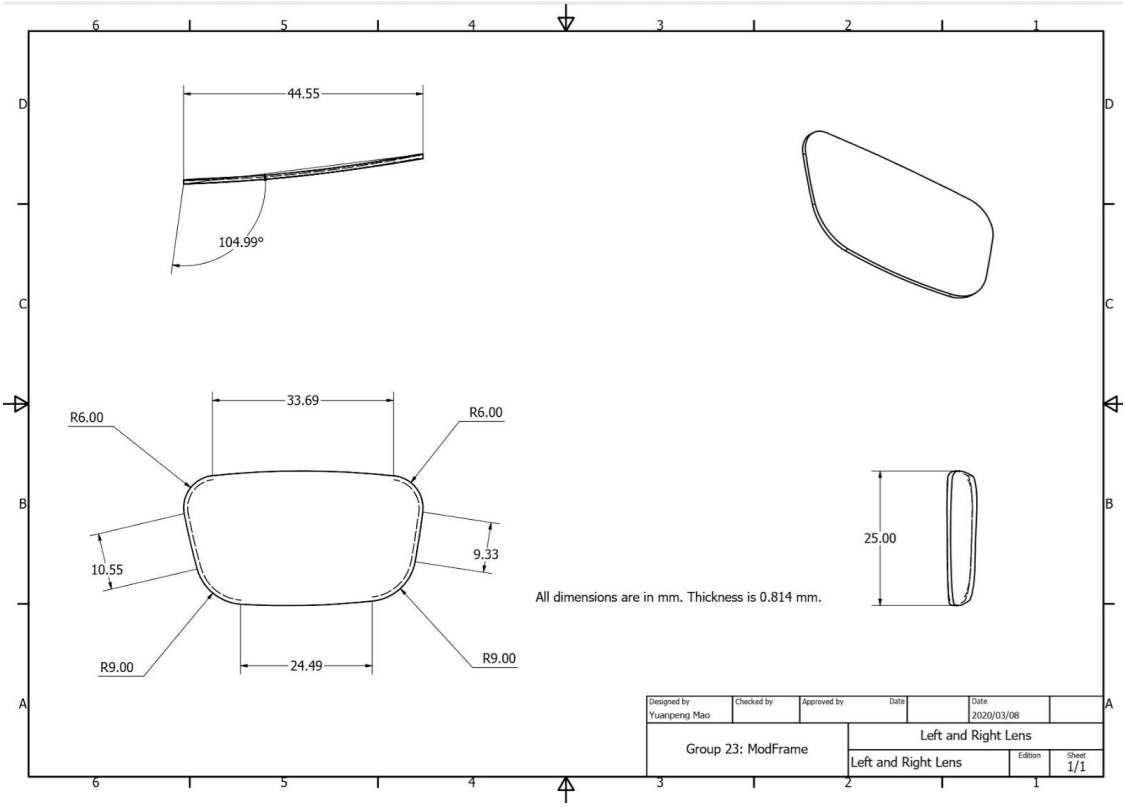

Figure 8: Left and Right Rim

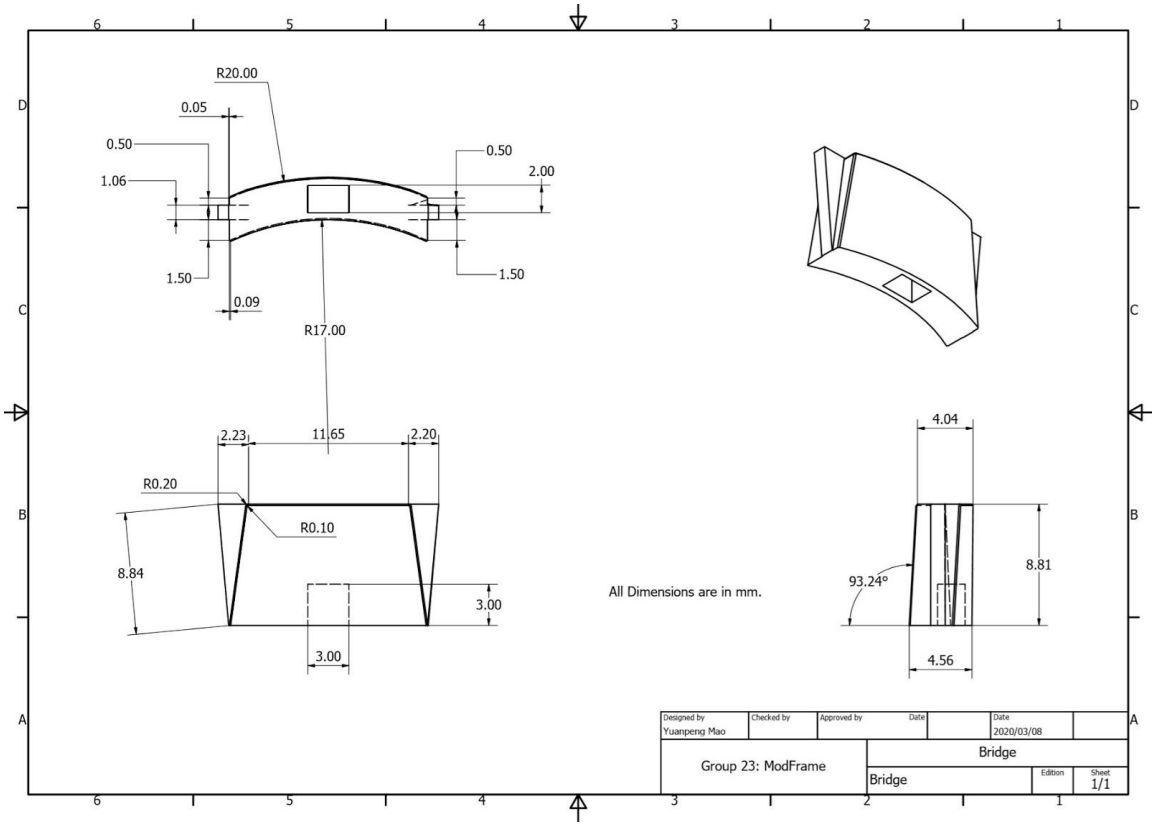

Figure 9: Bridge

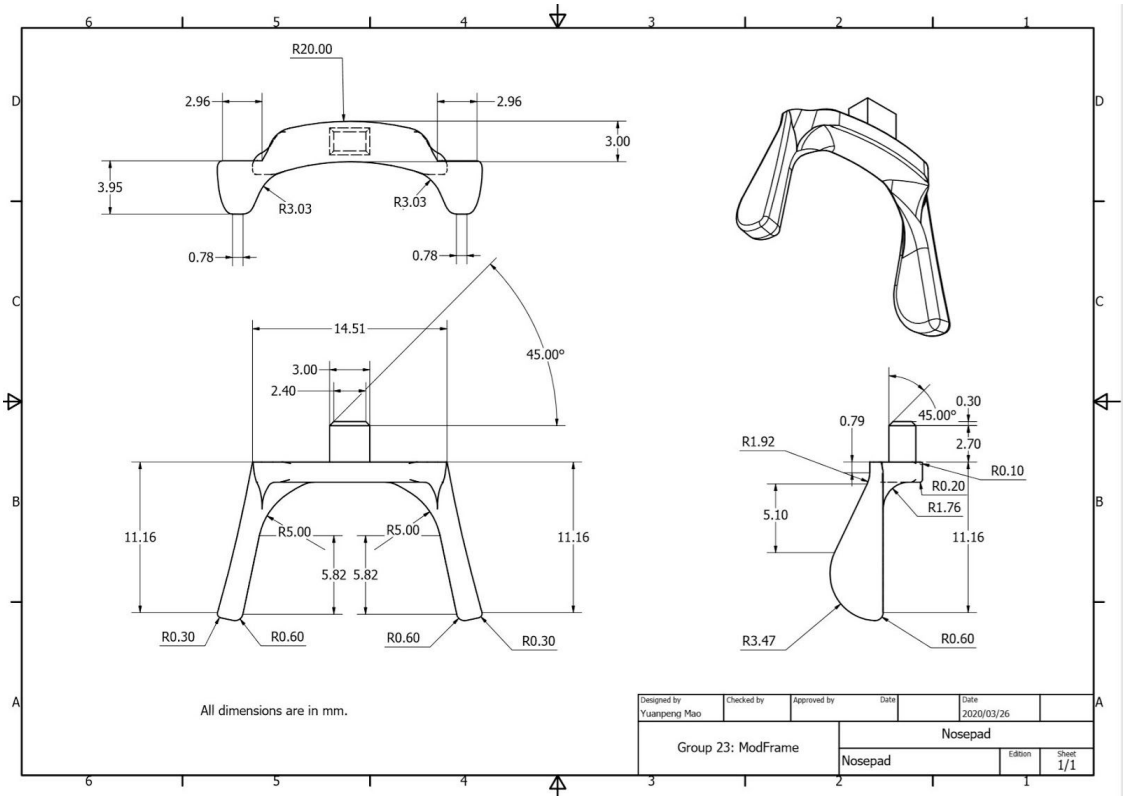

Figure 10: Nosepad