Carnegie Mellon University
Mechanical Engineering

Engineering Design I: Skills and Methods
24-370 Project 2

Final Report

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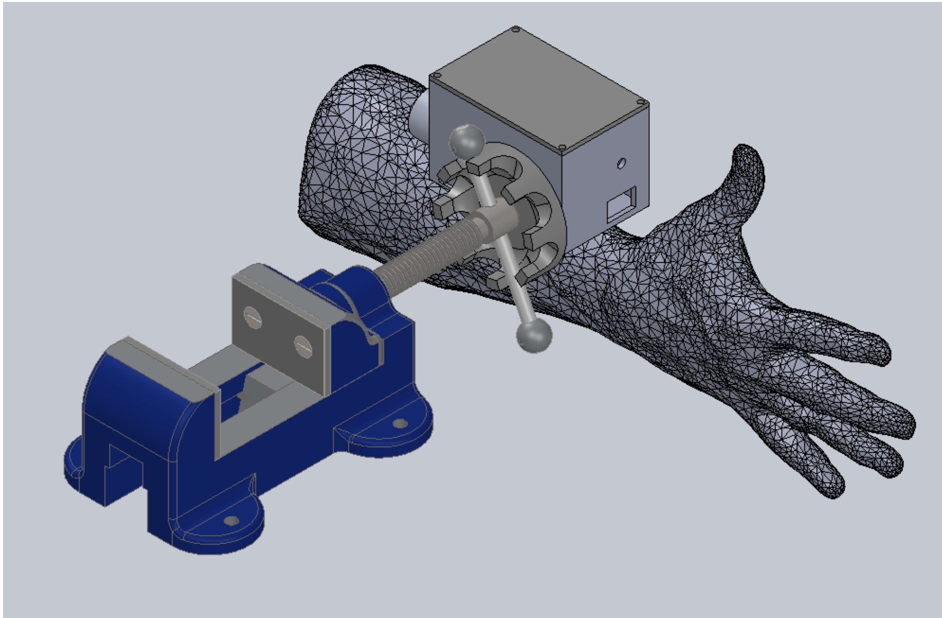
Table of Contents

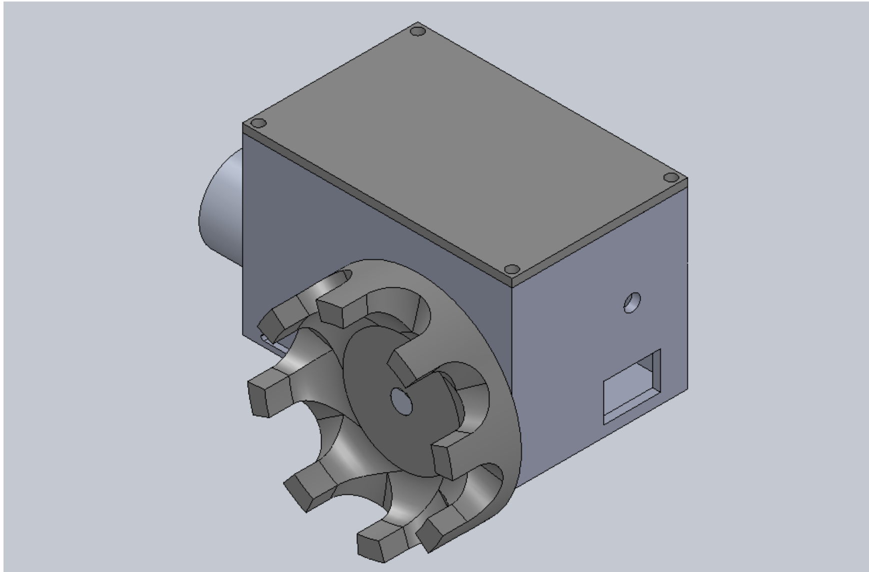
Authors	Editors
Summary: Shawn Early Ideation Shawn Developed Ideation Author: Junhan Stress Analysis Author: Junhan Prototype in CAD: Jackson Testing with FEA: Jackson Manufacturing and Drawing: Jackson Continuous Improvement: Junhan Budget: Junhan	Summary: Shawn Early Ideation Shawn Developed Ideation Author: Junhan Stress Analysis Author: Junhan Prototype in CAD: Jackson Testing with FEA: Jackson Manufacturing and Drawing: Jackson Continuous Improvement: Junhan Budget: Junhan

Summary



Our product is an arm attachment to aid in reducing the stress required to turn a vise grip. After conducting a AAPD preliminary survey on patients that suffered from wrist tendonitis as well as mild-cerebral palsy we were able to gain insight on mechanical devices that could be used to aid them in their work. The survey showed us that patients found a lot of difficulty using equipment that places large forces and torques on their wrist and would prefer for the stresses to be placed elsewhere. We conducted further research and found that the patients would be comfortable with those stresses being placed on their forearm from their wrist. meets the demands of our customers and will be a helpful addition to their daily work.

Our target population specified that the most important aspect of the design would be to reduce pain on the wrist as well as completing the task in a reasonable amount of time. Our final design dramatically reduces the force output on the wrist and in addition is faster than the human-time spent tightening a vice. The gear box is also an integral part of our design as it is what allows us to meet the required torque output for the task of tightening the vice-grip. Finally, the light weight of the device ensures that the product is comfortable to use and does not add extra unnecessary stress on the user.

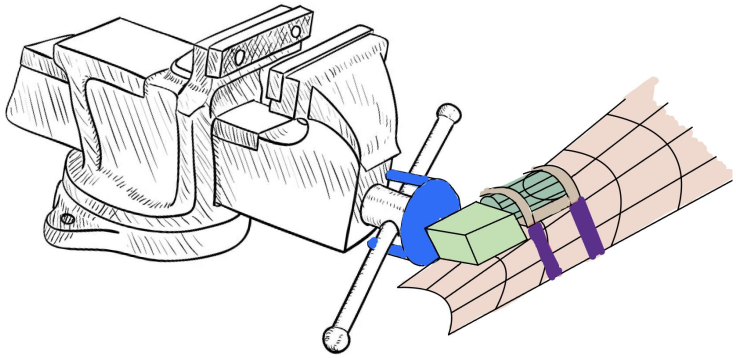
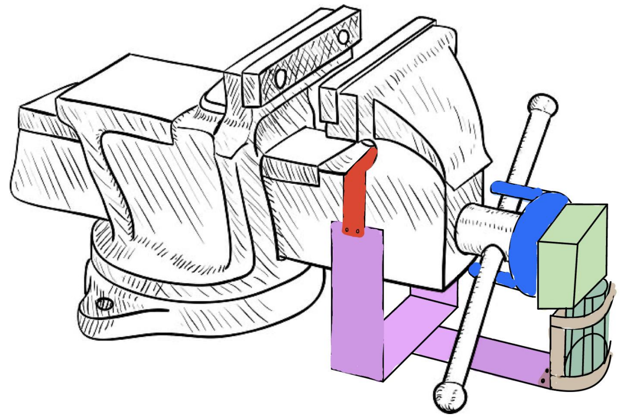


Our product is engineered to reduce the stress on your wrist when completing the task of tightening a vise grip. By integrating a high-torque motor to a wearable brace we are able to reduce both the pain, and time it takes for tendonitis and cerebral palsy users to tighten a vise.

The Arm Attachable Vise Assistant uses a gearbox to maximize the torque output of a motor that helps turn a vise by spinning a specially designed handle that users can wear and activate with ease. Our device also has a high factor of safety and is very unlikely to fail in any mode of failure.

The USD Price of our product would be $300

Early Ideation

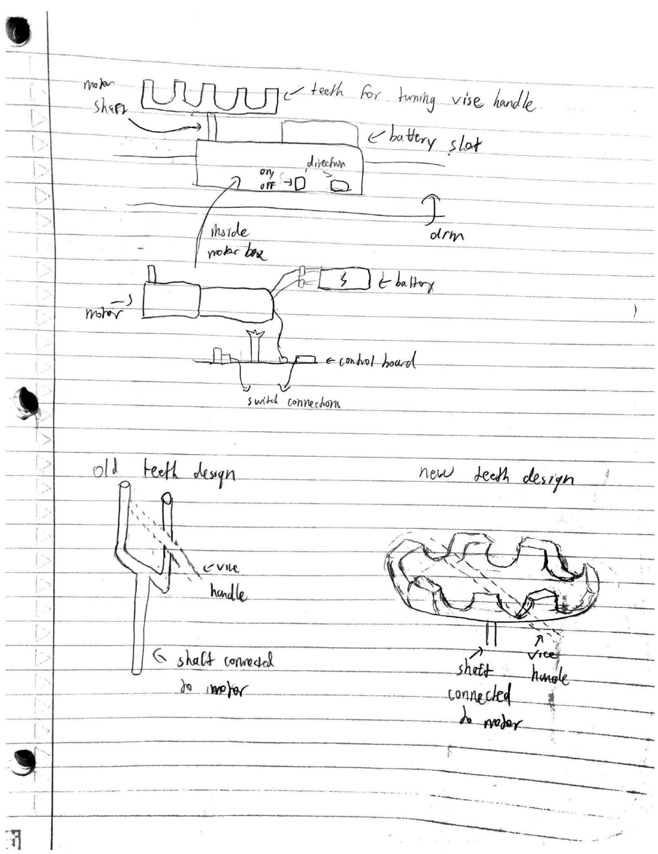
 

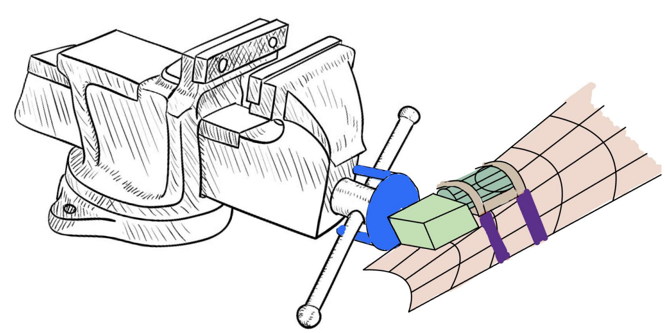
Our two earliest ideas consisted of different ways to mount the motor onto a body part that would be unlikely to be affected by tendonitis, and especially away from the wrist. The idea of connecting the motor horizontally to the forearm, as well as the two-prong clip were the most impactful changes included in our product because they drastically improved functionality. We also plan to include a harness, and 3D-Printed brace to house the motor and electronic components which will also make useability improve for the user. In terms of our mathematical requirements we used the thought-experiment of requiring the motor to output a torque of 40 lbs at a distance of 6 inches away which would result in a required output torque of at least 30 N-m while having a minimum speed of 6 rpm. Ensuring that our product would be relatively light, comfortable to use, and efficient would be the 3 most important aspects of our design.

Developed Ideation

a. In our early ideation stage, we debated between whether or not we wanted the turning device attached to the arm. An attachable arm device ensures ease of portability and allows for better interfacing with the user. However, someone with tendonitis may not be able to support the weight of it if it becomes too heavy. After extensive research into different motors, batteries, and control boards, we concluded that we can create a well-functioning device that's under 2 pounds. Thus, we settled on an arm attachment for our vise turning device. We also performed some testing on vises in order to determine just how much torque we needed from our motor. We made initial assumptions that we would need 30 N-m in order to fully tighten the vise. This became a topic of concern due to a lot of the motors we found either not satisfying this torque requirement or not being cost and weight viable. However, while performing a few tests with a 40 lb weight, we found that a vise can be tightened reasonably well with a torque of just 40 lb-in which is only about 4.5 N-m. Our chosen motor has a max torque output of approximately 46 lb-in at 27 RPM. We theoretically could choose a higher torque motor with a lower RPM, but quality of use is also important to use, and we wouldn't want someone using our product to have to wait a long time for a vise to turn and unturn.

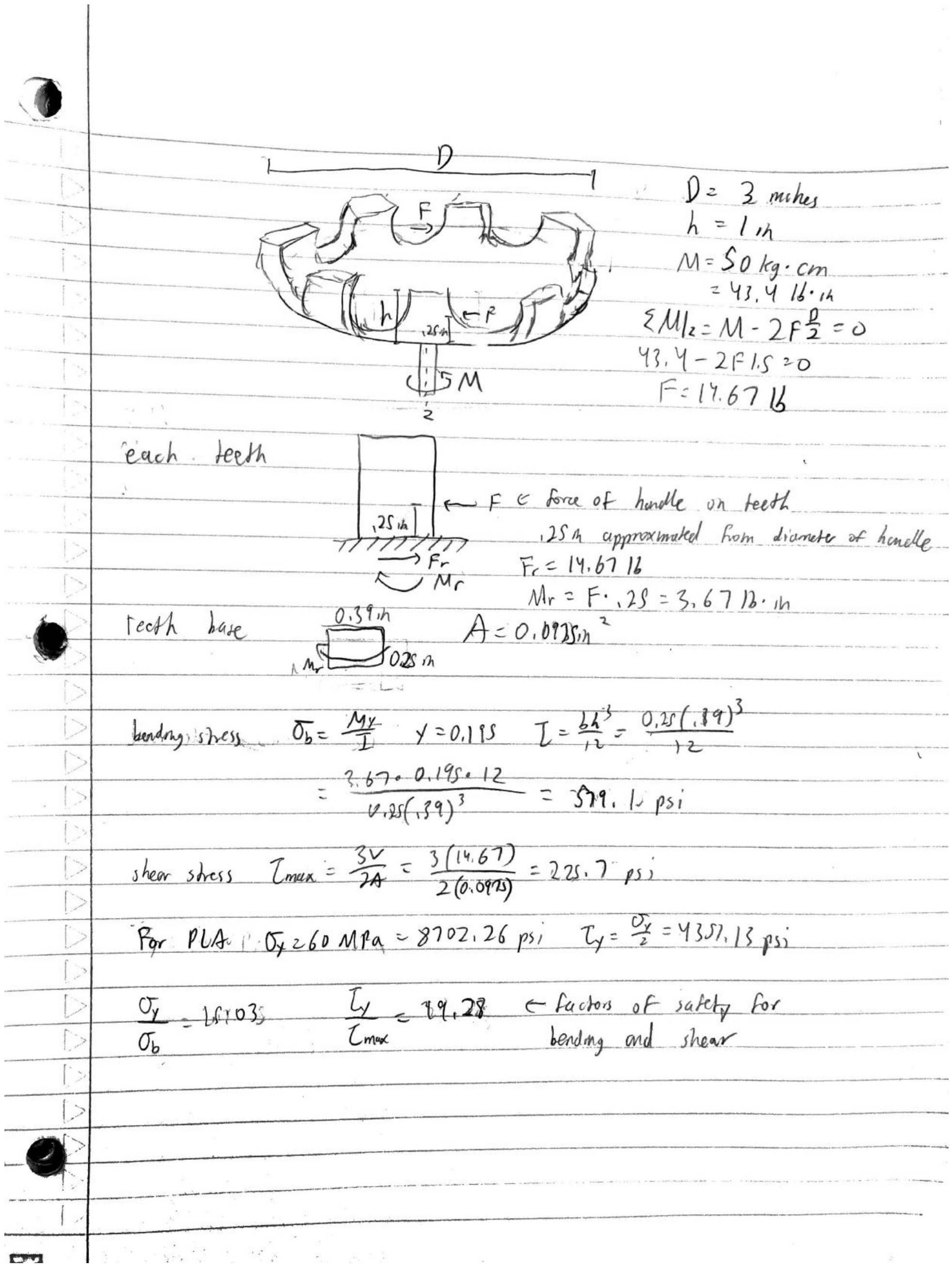
b.



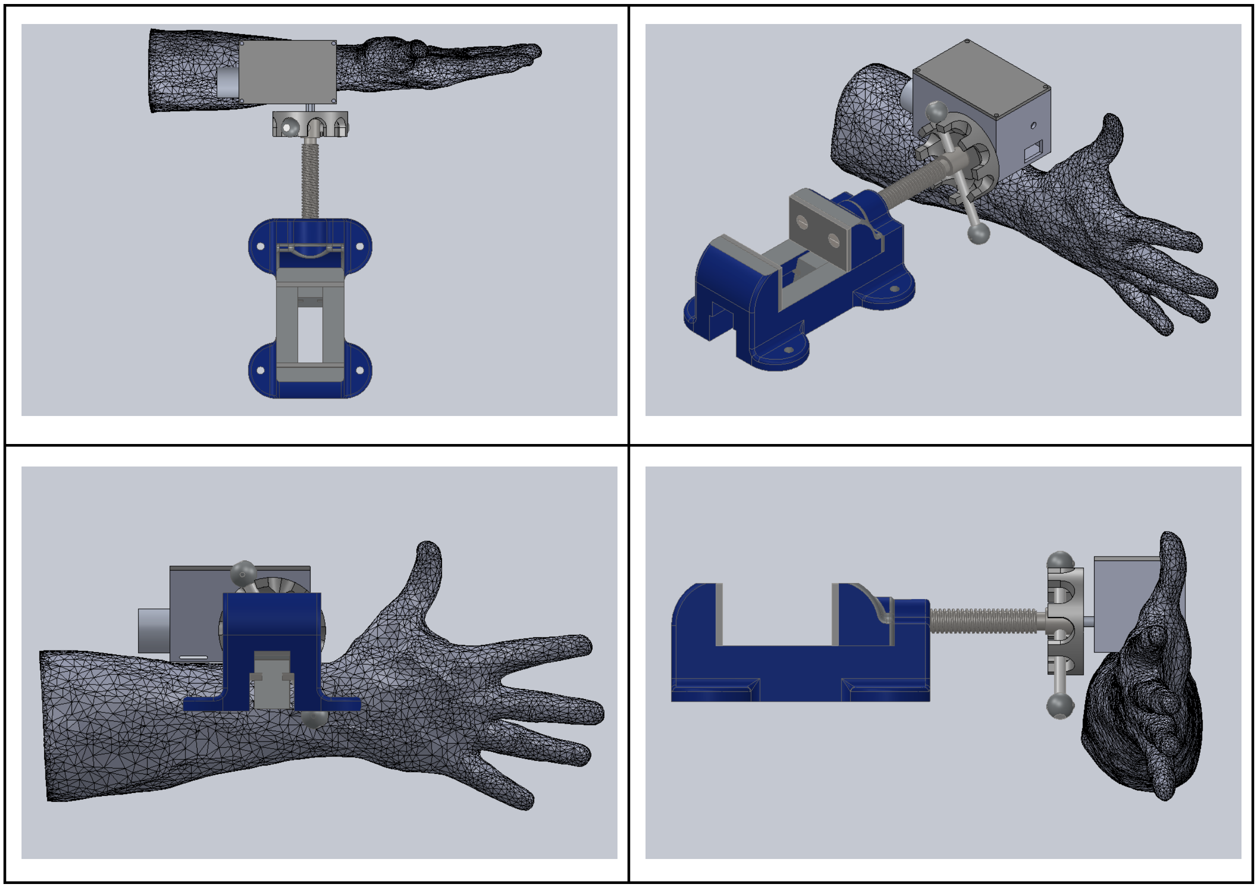


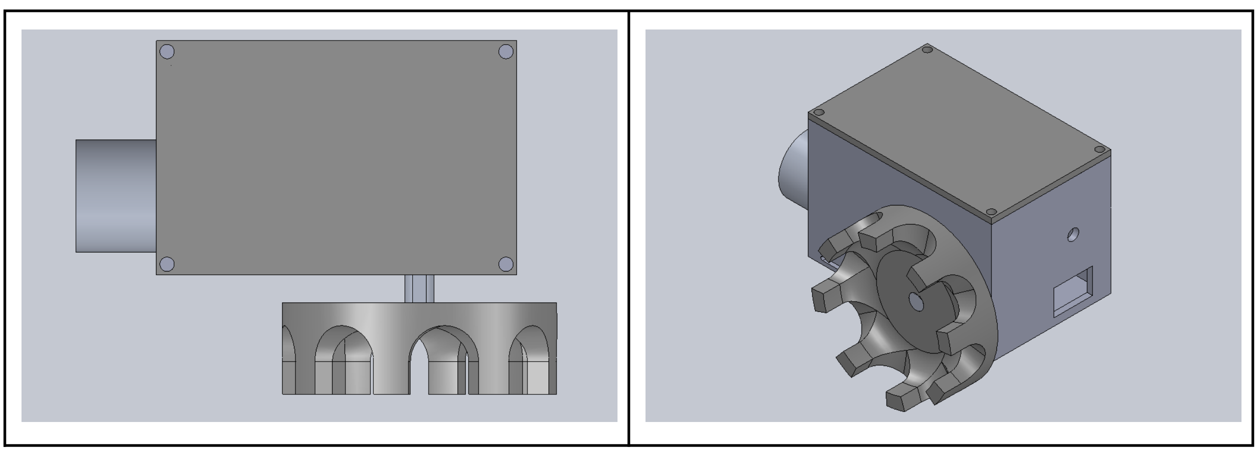
Stress Analysis

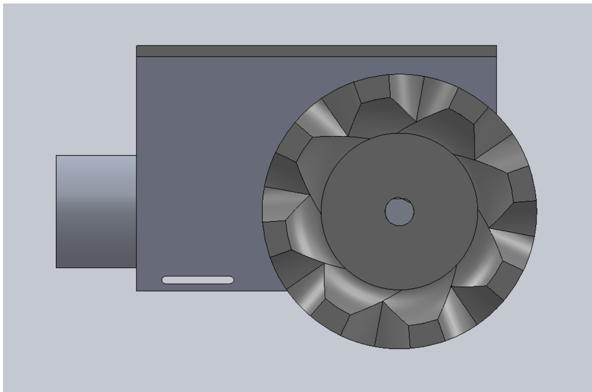
We are most concerned with the teeth on the disk snapping off when pushing against the handle. Thus, we calculated the factor of safety for shear and bending. We assumed that the force acts on a single point that is about half the diameter of the handle and that the teeth are rectangular rods fixed at one end.

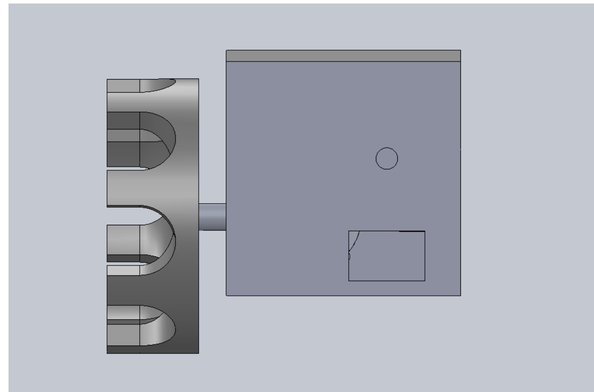


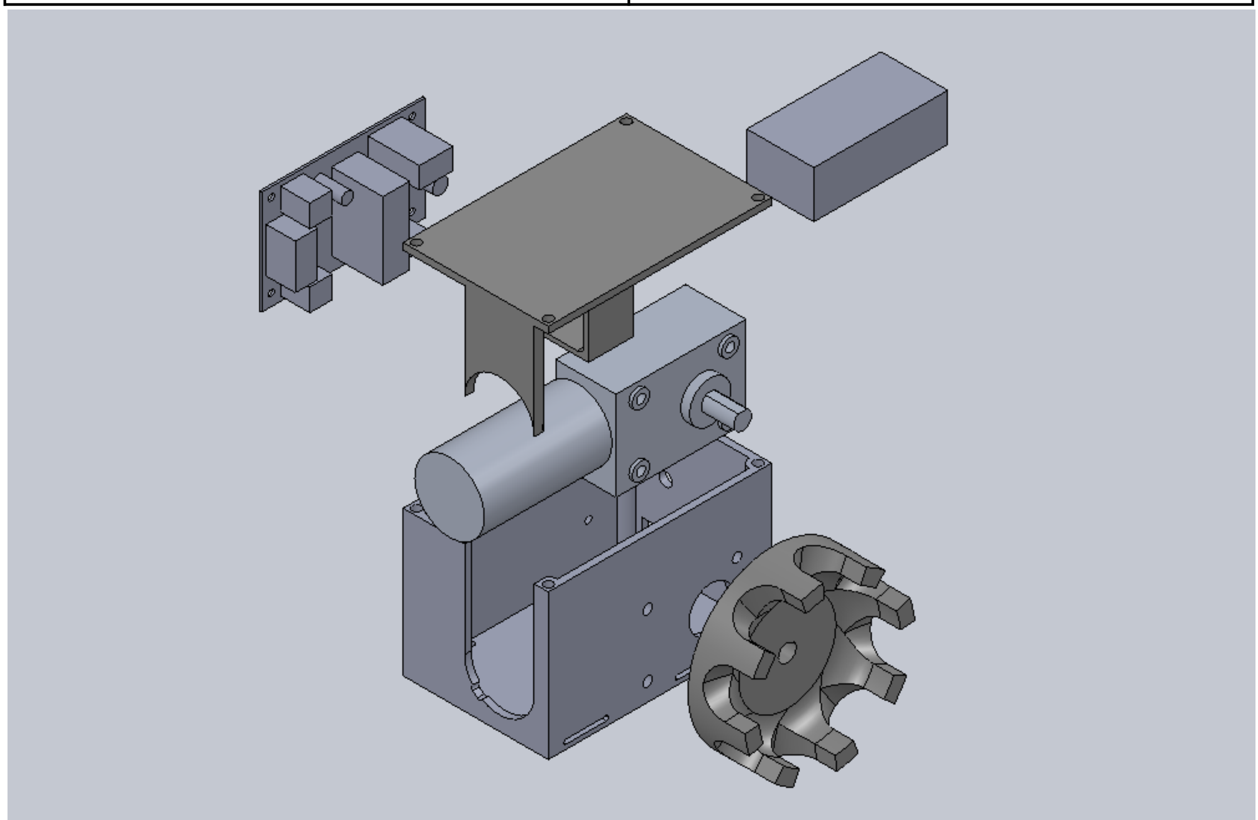
Protype in CAD







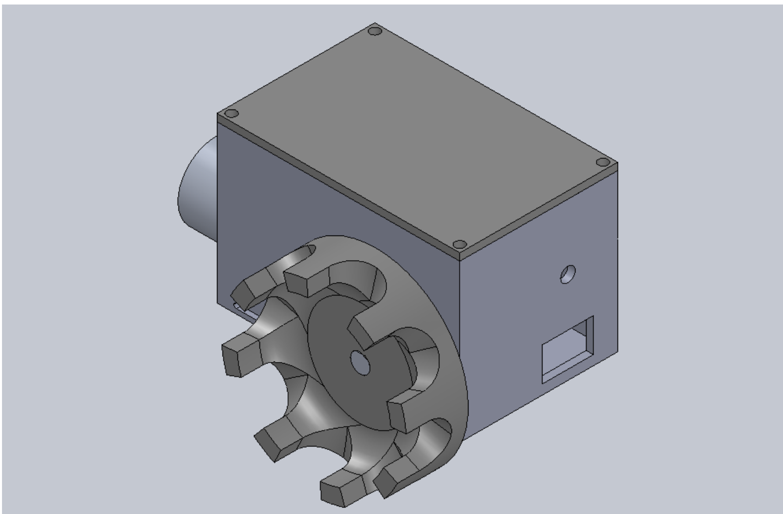




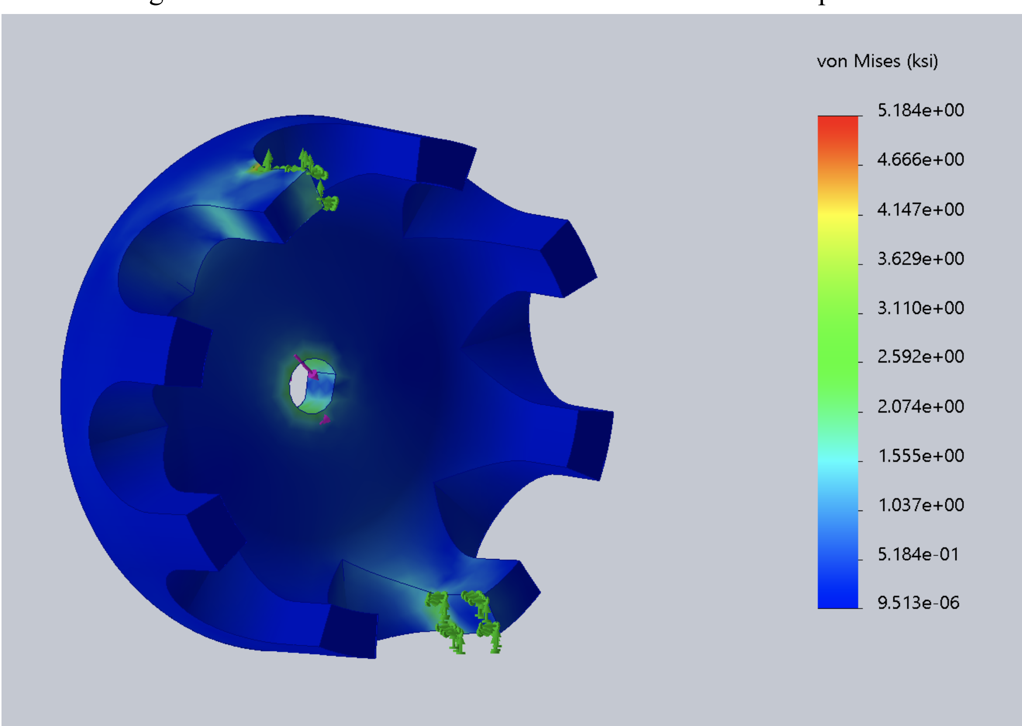
Power starts from our lipo battery mounted to the lid of the box. The battery plugs into a connector on our speed controller board. The speed controller board also has a potentiometer and switch for controlling speed and direction of the motor. The speed controller outputs power to the motor causing the claw to turn. The fingers of the claw push against the handle of the vice causing the vice to close. The whole assembly is strapped to the user's arm through slits in the box. The straps resist the moment from the turning motor and keep the whole assembly stationary.

Testing with FEA

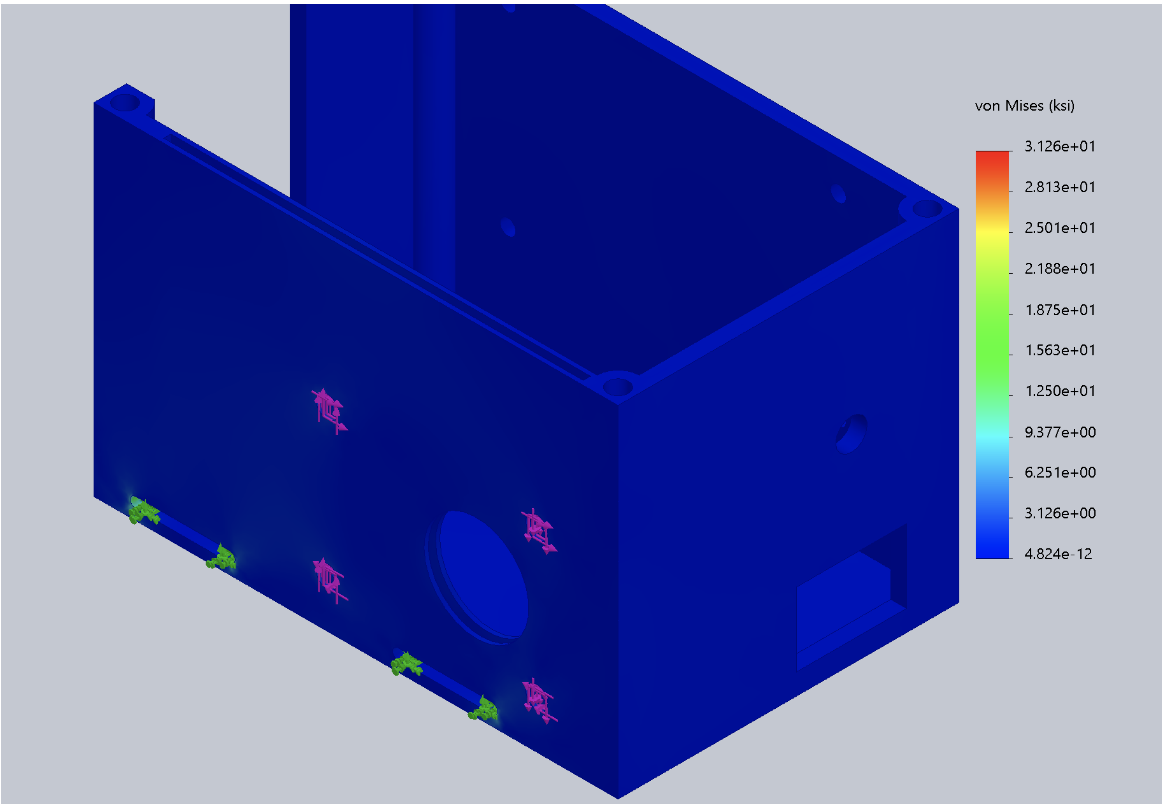
Our design involves the transfer of torque from our motor to the vice handle. Because the motor and vice will be collinear and our claw is symmetric around the central axis. we are equally susceptible to failure in all orientations.



For our FEA we chose a position where the vice handle is nearly vertical and applied our max stall torque to the center of the claw while keeping two of the claw fingers fixed. This produced a max stress of 5.184 KSI which is FOS of about 14.4. This value is very similar to FOS =15.03 which we found from hand calculations. Both FEA and hand calculations show that bending stress will be the greatest failure point for the part. In addition, FEA shows the stress concentrations around the motor axel that we could not observe from the hand calculations. Overall we trust the FEA to give us a better overall understanding of the stress concentrations and failure locations of the part.



We also chose to inspect the stress at the mounting points for the motor. Using simple hand calculations we found the forces at each bolt hole. We then fixed the slots where the arm straps will be fed through and ran the FEA. We found a max stress of 3.126 which is a FOS of 2.5. This simulation was conducted under the worst conditions including weak 3d print quality and max motor torque.



Manufacturing and Drawing

a. The 3 components of our subsystem to be considered are the motor, the motor box, and the turning appendage (disk with teeth).

   Since we are buying the motor, we don't have to consider the material that we make it out of. For the motor box and turning appendage, we want to have it fabricated out of ABS plastic. It is cost-effective, lightweight, and meets our strength requirements as determined by our FEA and hand calculations.

   Again as stated before, the motor is bought and doesn't need to be manufactured. As for the remaining 2 components, we want them to be manufactured through injection molding. We chose this process due to its compatibility with plastic and low cost per part. From the calculations done below along with the table found online, each motor box comes out to \$3.87 and each claw is \$3.65. If we were to sell 10000 units in one year, the total manufacturing cost comes out to \$75200. However, it is worth noting that with higher volume productions, the price per part will be cheaper.

	LOW-VOLUME PRODUCTION
Production volume	100
Method	In house mold production and in house molding
Mold	3D printed polymer
Lead time to final parts	1-3 days
Equipment required	3D printer, desktop injection molding machine*
Mold cost	\$100
Material cost	\$0.5 / part
Labor costs or outsourcing cost	\$2.5 / part
Total production cost	\$400
Cost per part	\$4

Figure 1

price per pound for ABS \$1.30 / lb

volume of box = $92834.21\ mm^3$

$= 92.834\ cm^3$

$1.2\ \frac{g}{cm^3} \cdot 92.834\ cm^3 = 111.4\ g$

$114.4\ g \cdot \frac{1\ lb}{453.6\ g} = 0.25\ lb$

price = \$0.33

\$0.33 · 100 = 33

\$100 + \$250 + \$33 = \$387
mold, labor

\$3.87 per part

density of ABS : $1.2\ g/cm^3$

volume of claw : $42494.74\ mm^3$

$= 42.494\ cm^3$

$1.2\ \frac{g}{cm^3} \cdot 42.494\ cm^3 = 50.99\ g$

$\frac{50.99}{453.6} = 0.112$

price = \$0.15

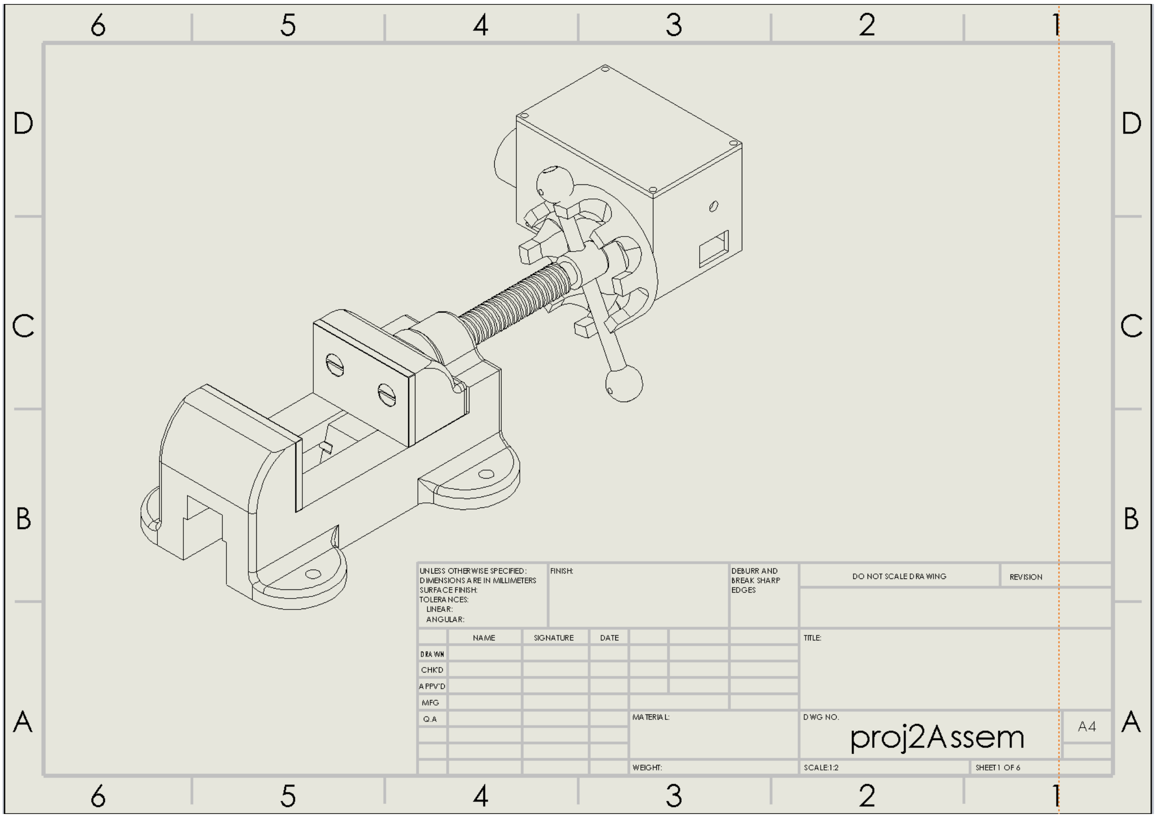
\$0.15 · 100 = 15

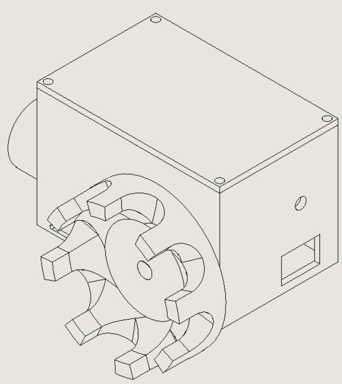
\$100 + 250 + 15 = \$365

\$3.65 per part

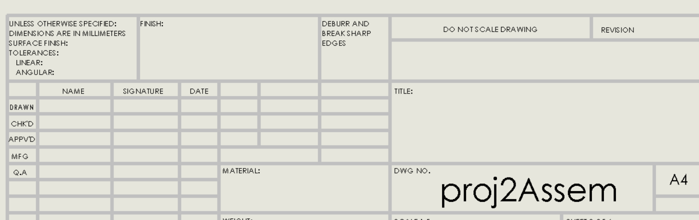
Figure 2

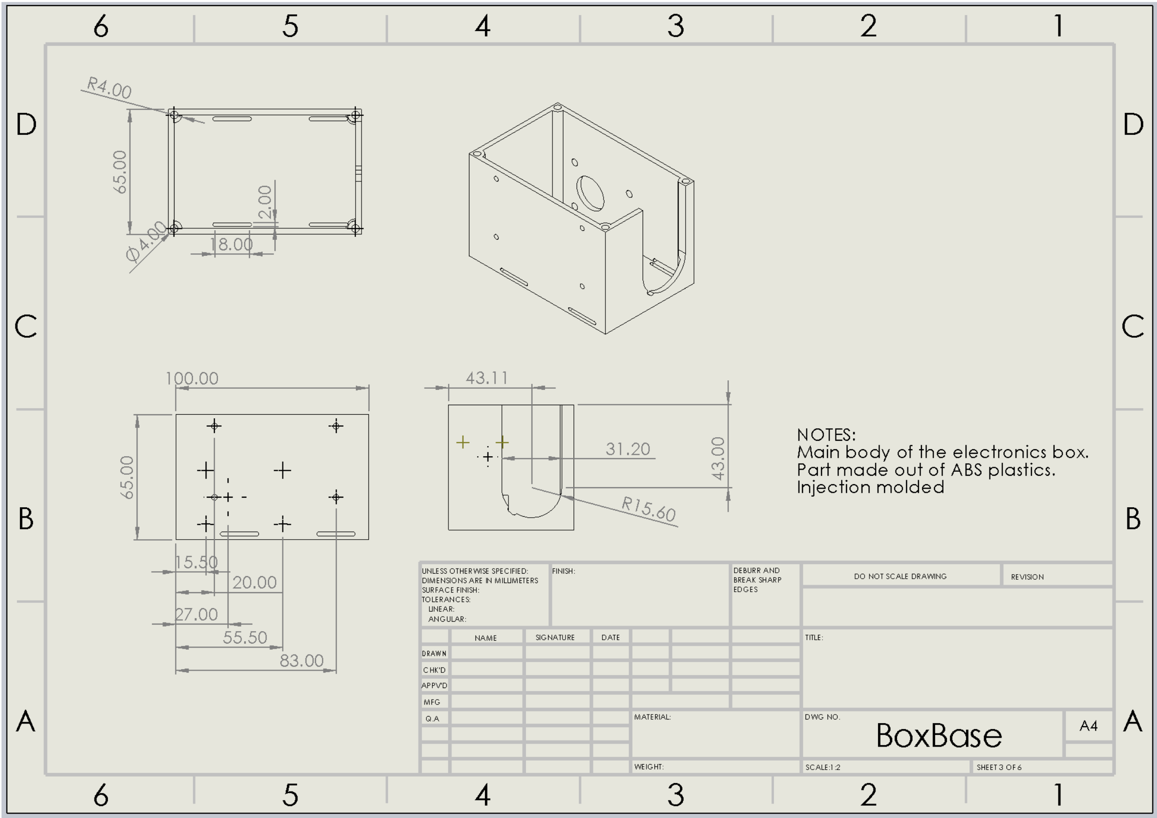
Component	Material	Manufacturing Method	Units per assembly	Cost per assembly	Units per year	Cost per year
Motor	N/A	N/A	1	$78	10000	780000
Motor Box	ABS plastic	Injection Molding	1	$3.87	10000	38700
Turning Appendage	ABS plastic	Injection Molding	1	$3.65	10000	36500

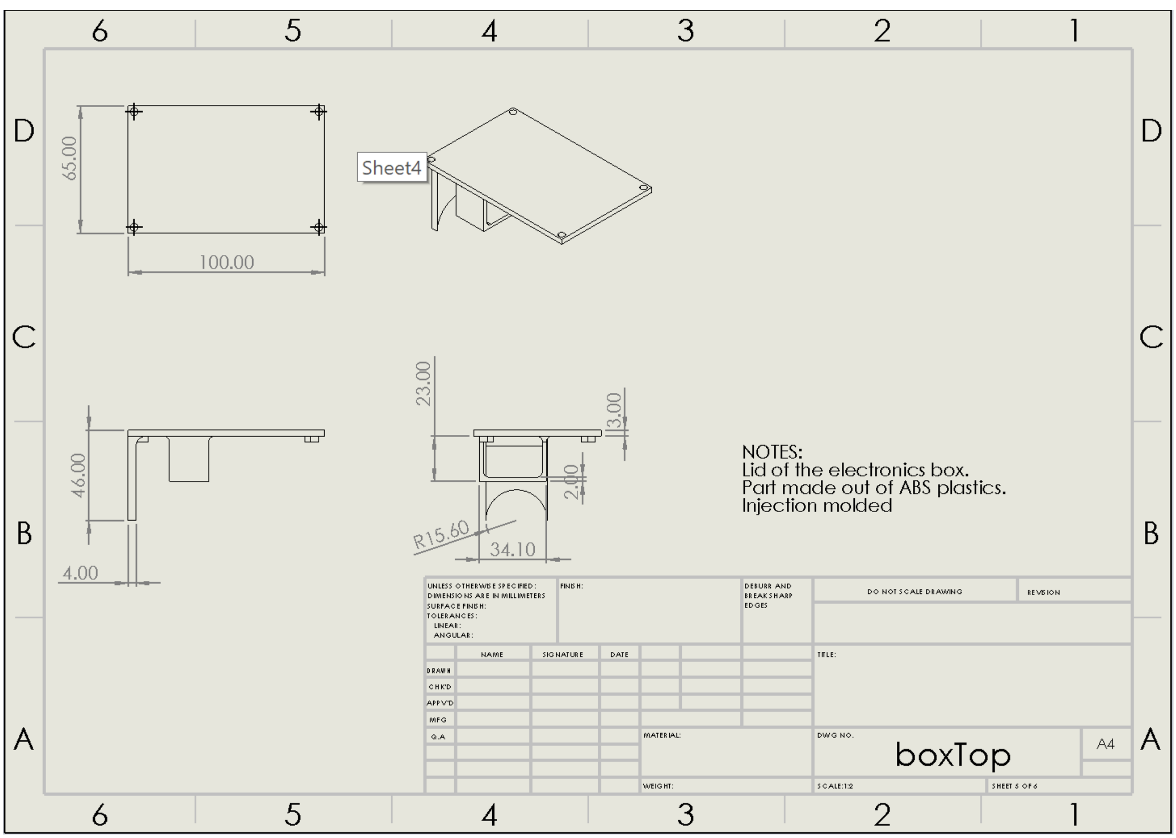


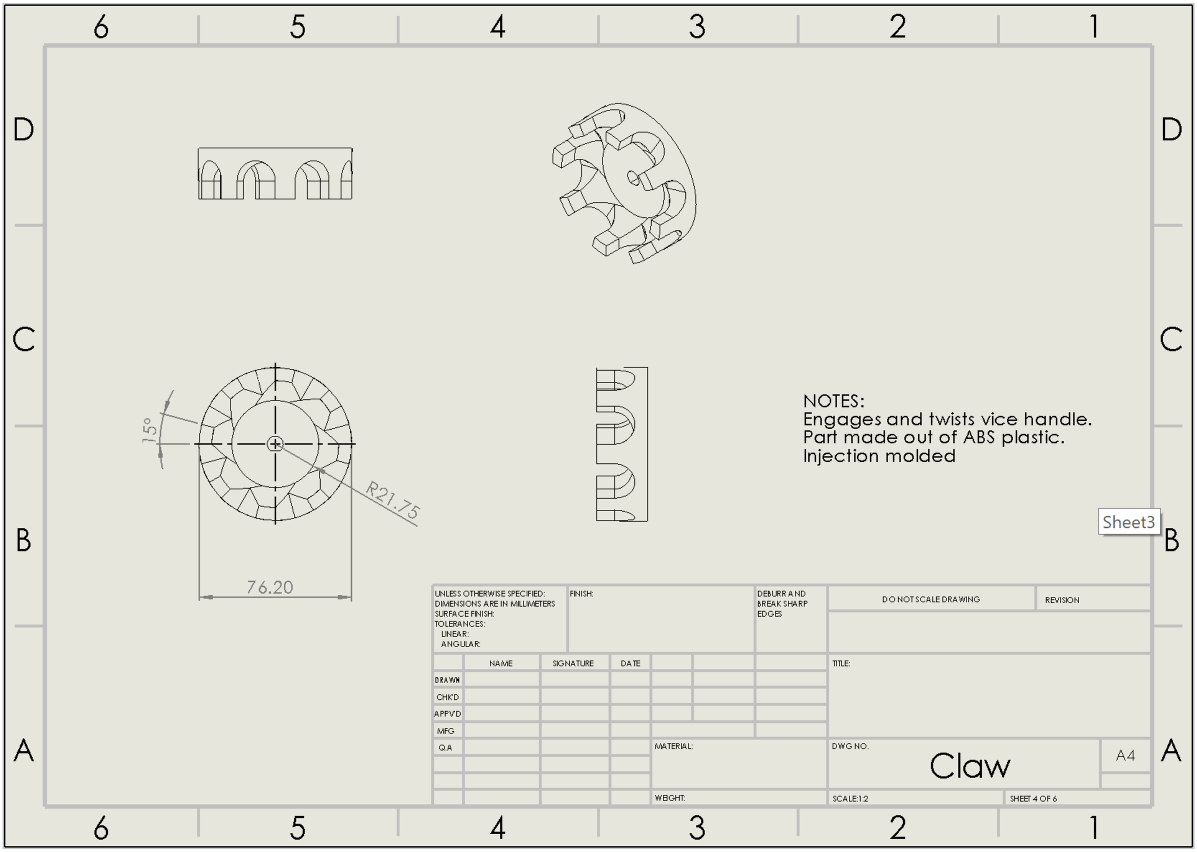


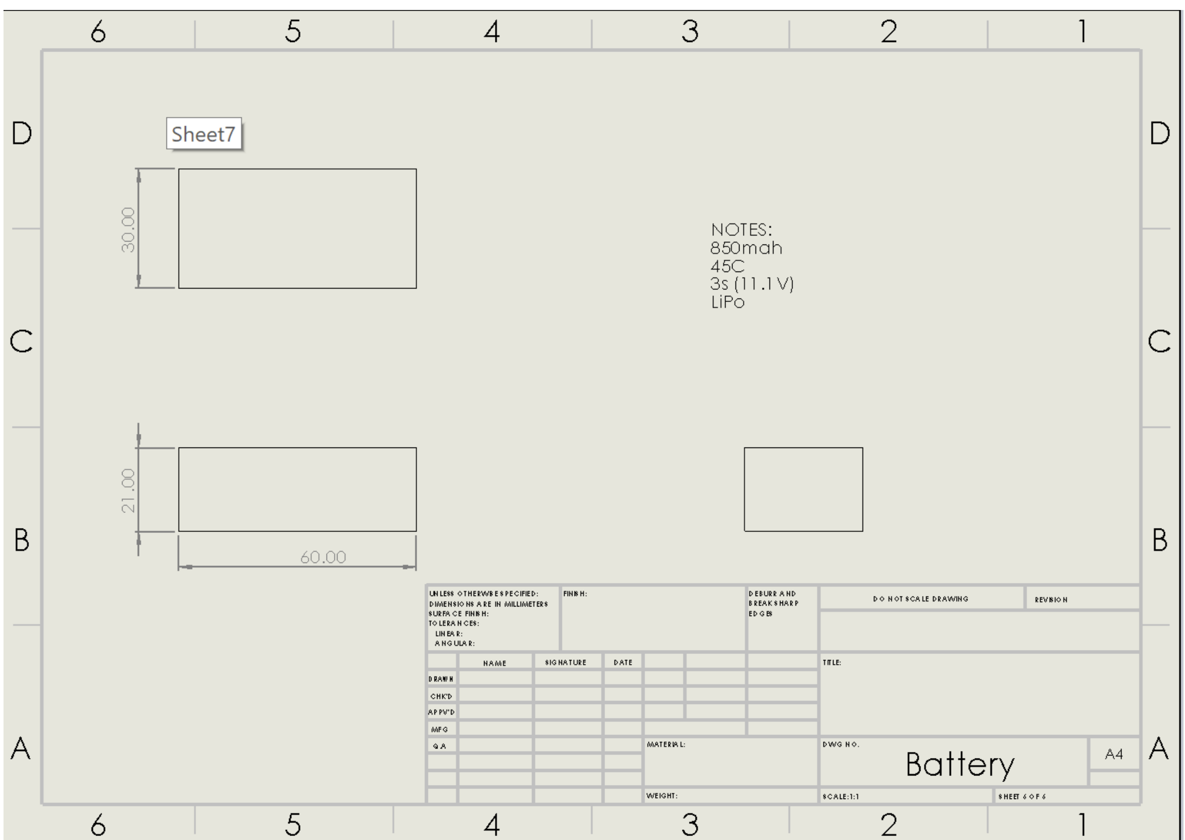
ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	board	Motor Speed Control	1
2	motor	12v 27rpm, Cast aluminum gearbox case	1
3	claw	Turns vice handle, ABS plastic, Injection Molded	1
4	boxBase	Electronics box main body, ABS plastic, Injection Molded	1
5	battery	850mah 3s LiPo	1
6	boxTop	Electronics Box Lid, ABS plastic, Injection Molded	1




R4.00
65.00
2.00
Ø4.00
18.00
100.00
65.00
15.50
20.00
27.00
55.50
83.00
43.11
31.20
43.00
R15.60
NOTES:
Main body of the electronics box.
Part made out of ABS plastics.
Injection molded
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
SURFACE FINISH:
TOLERANCES:
LINEAR:
ANGULAR:
FINISH:
DEBURR AND BREAK SHARP EDGES
DO NOT SCALE DRAWING
REVISION
NAME
SIGNATURE
DATE
DRAWN
CHK'D
APPV'D
MFG
Q.A
TITLE:
MATERIAL:
DWG NO.
BoxBase
A4
WEIGHT:
SCALE:1:2
SHEET 3 OF 6


65.00
100.00
Sheet4
46.00
4.00
23.00
13.00
2.00
R15.60
34.10
NOTES:
Lid of the electronics box.
Part made out of ABS plastics.
Injection molded
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
SURFACE FINISH:
TOLERANCES:
LINEAR:
ANGULAR:
FINISH:
DEBURR AND BREAK SHARP EDGES
DO NOT SCALE DRAWING
REVISION
NAME
SIGNATURE
DATE
DRAWN
CHK'D
APPV'D
MFG
Q.A
TITLE:
MATERIAL:
DWG NO.
boxTop
A4
WEIGHT:
SCALE:1:2
SHEET 5 OF 6


15°
R21.75
76.20
NOTES:
Engages and twists vice handle.
Part made out of ABS plastic.
Injection molded
Sheet3
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
SURFACE FINISH:
TOLERANCES:
LINEAR:
ANGULAR:
FINISH:
DEBURR AND BREAK SHARP EDGES
DO NOT SCALE DRAWING
REVISION
NAME
SIGNATURE
DATE
DRAWN
CHK'D
APPV'D
MFG
Q.A
TITLE:
MATERIAL:
DWG NO.
Claw
A4
WEIGHT:
SCALE:1:2
SHEET 4 OF 6


Sheet7
30.00
21.00
60.00
NOTES:
850mah
45C
3s (11.1V)
LiPo
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
SURFACE FINISH:
TOLERANCES:
LINEAR:
ANGULAR:
FINISH:
DEBURR AND BREAK SHARP EDGES
DO NOT SCALE DRAWING
REVISION
NAME
SIGNATURE
DATE
DRAWN
CHK'D
APPV'D
MFG
Q.A
TITLE:
MATERIAL:
DWG NO.
Battery
A4
WEIGHT:
SCALE:1:1
SHEET 6 OF 6

e. We estimate the overall sales price to be about $294. The calculations done are below.

All in USD
Motor: 78
motor controll board: 13.39
Motor bracket: 8.99
battery: 15.71
Total = $293.58
battery charger: 11.99
battery plug: 12.99
torque sensor: 135
Straps: 10
Manufacturing costs: 7.52

Continuous Improvement

Overall, our group really enjoyed this project. We believe that it was an improvement over project 1 as each deliverable and their due dates were made clear. There was also a good balance between how open-ended our product could be and what was expected in terms of quality and complexity. Allowing us to work in class was very helpful as it provided us opportunities to get early feedback and advice on getting started. Having check-in and the 0th report deliverables also helped us stay on track and ensured we were meeting expectations. Overall, we believe most of this project can be kept in its current form.

The only minor adjustment we would suggest is to extend the amount of time spent on this project. We felt a larger portion of the course was dedicated to project 1 yet project 2 is more reflective of what the goals of this course is as a whole.

Budget

Vendor	Description	Link	quantity	Unit price	Shipping	Subtotal
Amazon	BringSmart 12V 27 rpm motor	motor	1	29.99	0	29.99
Amazon	BringSmart Motor Control Board	board	1	13.39	0	13.39
Amazon	Tatu 850 mAh Battery	Battery	1	15.71	0	15.71
Amazon	Lipo Battery Charger	Charger	1	11.99	0	11.99
CMU	BoxBase 3d Print		1	86.8	0	86.8
CMU	BoxTop 3d Print		1	37.2	0	37.2
CMU	Claw 3d Print		1	29.72	0	29.72

Total = $224.8

- 3d Printed parts original cost specified based on Xometery at about 40% the cost of CMU 3d printers.

References:

Figure 1:

- https://formlabs.com/blog/injection-molding-cost/

Figure 2:

- https://rexplastics.com/plastic-injection-molding/the-cost-of-injection-molding-materials
- https://omnexus.specialchem.com/polymer-properties/properties/density
- https://www.istockphoto.com/vector/vise-hand-tool-gm503752648-82740465