ENGINEER 1C03 - Engineering Design & Graphics

Engineering 1 Cornerstone Design Project

Instructor: Dr. Nease

Technical Report

Team **74**

Lab Section**: L04**

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As a future member of the engineering profession, the student is responsible for performing the required work in an honest manner, without plagiarism and cheating. Submitting this work with my name and student number is a statement and understanding that this work is my own and adheres to the Academic Integrity Policy of McMaster University and the Code of Conduct of the Professional Engineers of Ontario.

Submitted by [Wenxuan Wang – 400177283]

Peihua Jin

Signature

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Submitted by [Peihua Jin – 400175999]

Wenxuan Wang

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Submitted by [HaoJun Zhao – 400179164]

HaoJun Zhao

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Introduction

Today, different kinds of mechanical products are playing important way in human's life. Prosthesis replacement technology is very popular right now. the definition of prosthesis replacement is that using artificial material to replace the missing human body part. Our design product is a prosthetic hand that can simulate the motion of the thumb and forefinger. If the whole mechanism is linked to the motor and a power supply, it will lead the thumb and forefinger to move in different directions and snatch the small box below.

For our project, the biggest problem we faced is how to make the thumb and forefinger rotate in a specific speed and different directions. Our assigned input speed is 139 revolutions per minute and the expected output speed is 15 revolutions per minute. Another challenge we face is the spacing. The whole frame has a length limit. Our design must be smaller or equal to this length. In order to solve these problems, our team designed 16 gears with different dimensions to achieve the output speed. With the appropriate arrangement of the gear, the whole gear train can fit in the frame.

In addition to how the mechanism works, there are 16 gears in our final design. Since our input speed is 139 revolutions per minute and our output speed is 15 revolutions per minute, the gear ratio of the whole gear train is. According to our calculation, 16 gears can satisfy the requirement within the error plus and minus 0.5%. the thumb and forefinger are connected to the two terminal gears respectively. In this way, two fingers can move at the same terminal speed since they are in the same axis. To simulate the close and open motion, two fingers should move in different directions. There are two gear trains in our 16 gears. One gear train is to achieve the final speed, the other is to connect fingers and change directions. The finger connection gear train has gear ratio is 1 so it only changes directions not the speed. The result of that gear train makes the thumb change direction for three times and forefinger change direction for twice. So, the two fingers will rotate in different directions but the same output speed.

The report is covered by the table of contents, set of calculations for the gear train, table of mechanism design, simplified gearing mechanism diagram. It covers screenshots of design, output graphs for dynamic simulation, Brief explanation prototype design and answers to the group discussion questions as well. Finally, the report covers team member contribution, team meeting attendance, Gantt chart outlining and Team contract.

Set of Calculation of gear train design

According the input and output, our input speed is 139 RPM and output speed is 15 RPM (0.25RPS).

So, our Gear Ratio = $\frac{139}{15} \approx 9.266667 \pm 0.046$

We rounded our Gear Ratio to $\frac{279}{30}$ = 9.3. 9.3 is in the appropriate error range. ($\pm$ 0.5%)

So, we can divide $\frac{279}{30} = \frac{31\times3\times3}{15\times2}$

$\frac{31\times3\times3}{15\times2} = \frac{31}{15}\times\frac{20}{20}\times\frac{36}{12}\times\frac{22}{22}\times\frac{18}{12}$

The reason why we choose two set of gears which has gear ratio is 1 to fir in the frame of our project.

We choose module = 1

So, our teeth for each gear is 15mm, 31mm, 20mm, 20mm, 12mm, 36mm, 22mm, 22mm, 12mm, 18mm

The length constraint of the frame is 102 $\pm$ 6 mm.

Our radius of gears = $\frac{1}{2}(31 + 15 + 20 + 20 + 36 + 12 + 22 + 22 + 18 + 12)$ = 104 mm which is in the correct error range.

Forefinger-thumb part connection:

Since we have already calculated the final output, in this part, our goal is to keep the remaining gear train having the same input and output speed. We design a 6-gear train which has a trapezoid shape in order to make the directions opposite between forefinger and thumb, so the gear ratio should be 1 for this gear Train.

$$1 = \frac{12}{12} \times \frac{12}{12} \times \frac{12}{12} \times \frac{12}{32} \times \frac{32}{12}$$

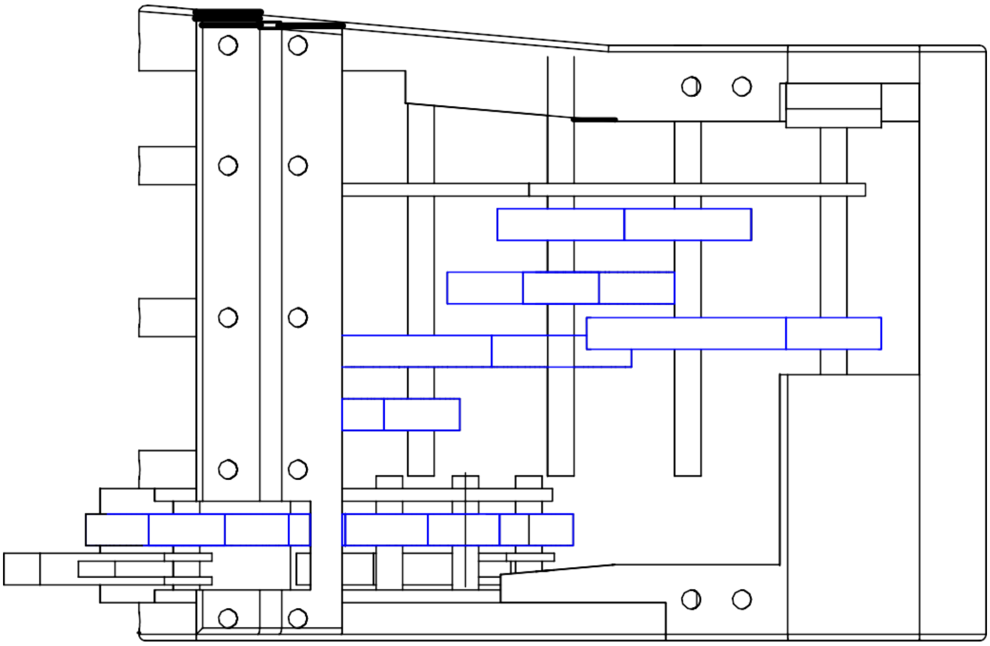
The reason why we choose 12mm spur gear is that 12mm spur gear is small enough. We can have enough space to adjust the length of the gear train.

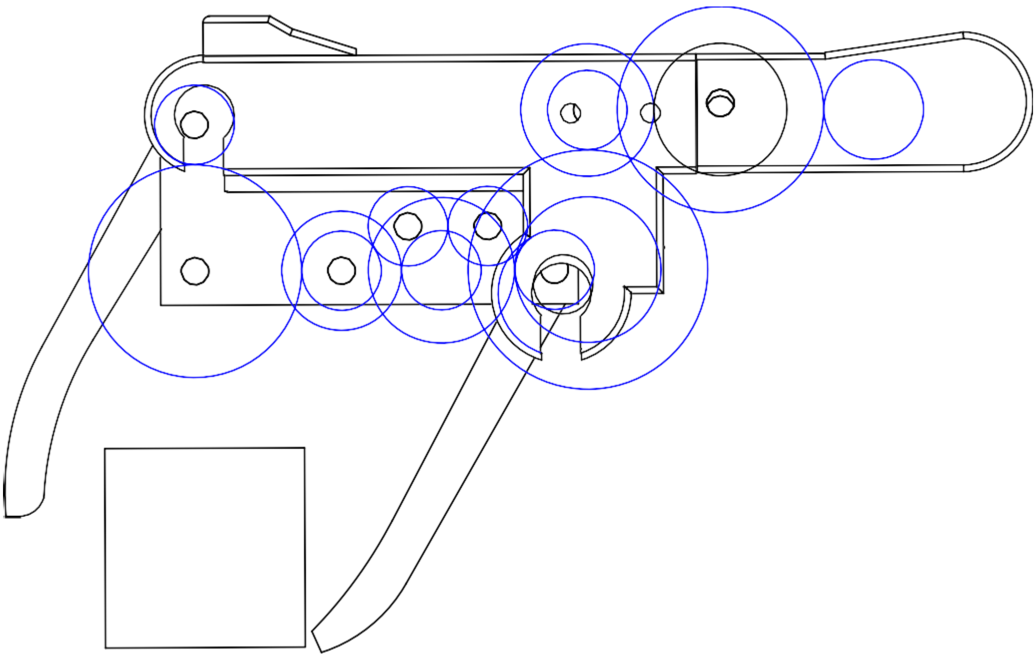
Table of mechanism design parameter

Gear Name	Type of Gear	Connecting Type	Pitch Diameter(mm)	Module (mm/tooth)	Number of Teeth, Z
A	Spur	N/A	15	1	15
B	Spur	Mesh	31	1	31
C	Spur	Axial	20	1	20
D	Spur	Mesh	20	1	20
E	Spur	Axial	12	1	12
F	Spur	Mesh	36	1	36
G	Spur	Axial	22	1	22
H	Spur	Mesh	22	1	22
I	Spur	Axial	12	1	12

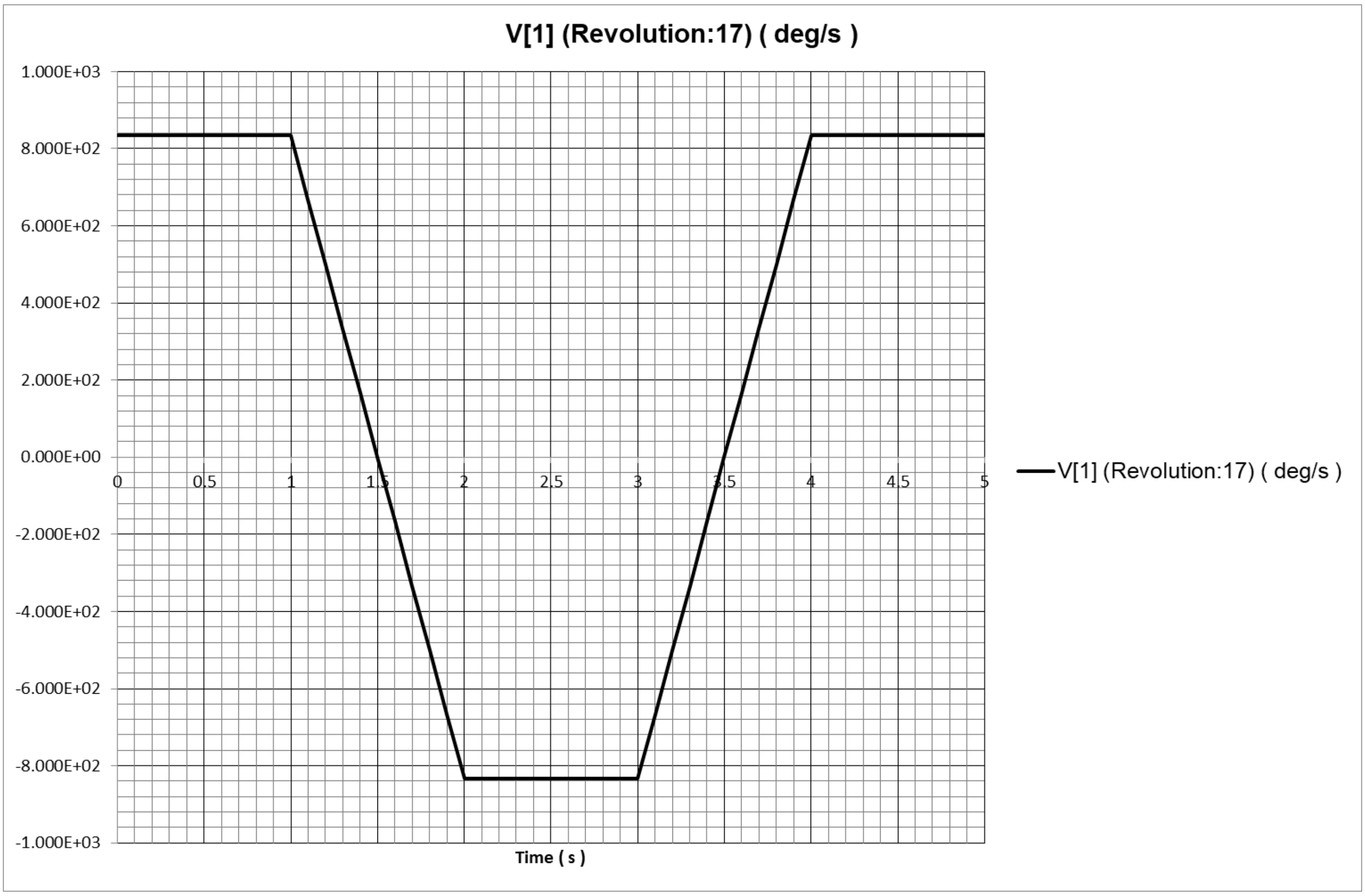
J	Spur	Mesh	18	1	18
K	Spur	Mesh	12	1	12
L	Spur	Mesh	32	1	32
M	Spur	Mesh/Axial	12	1	12
N	Spur	Mesh	12	1	12
O	Spur	Mesh	12	1	12
P	Spur	Mesh	12	1	12

Simplified gear mechanism diagram

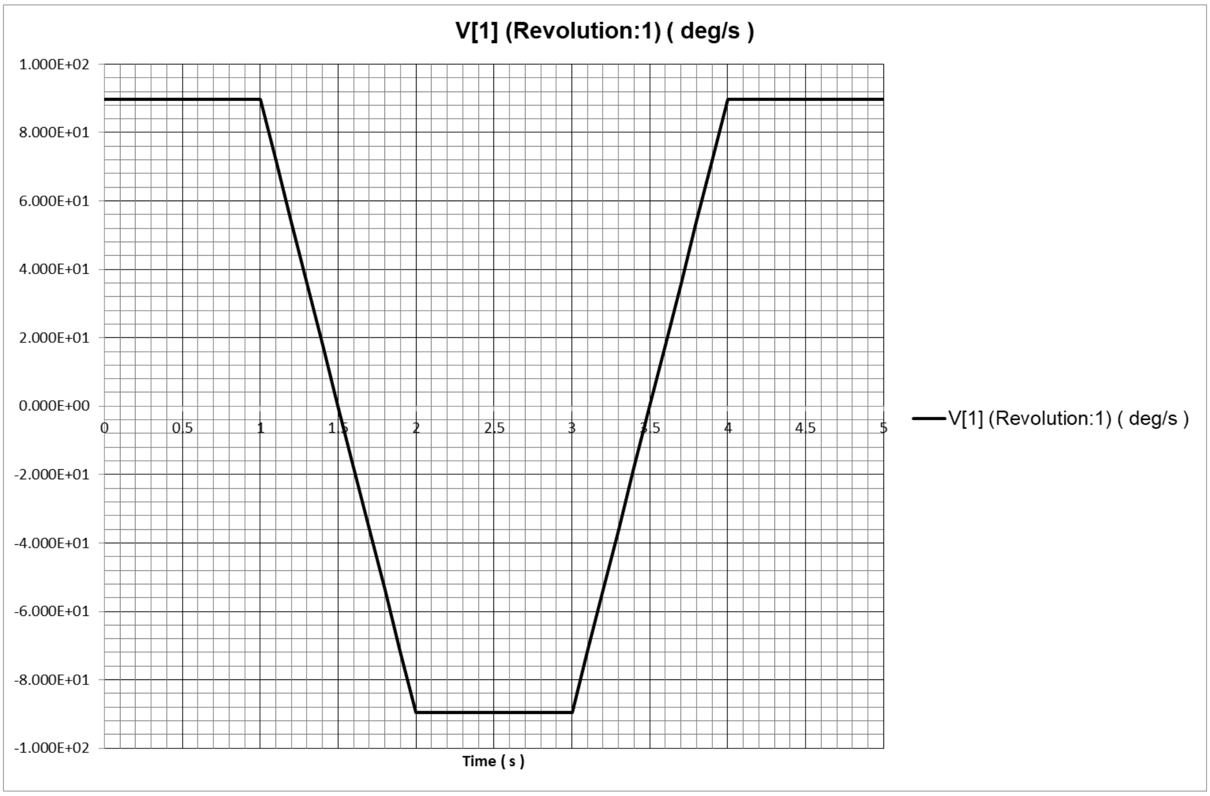




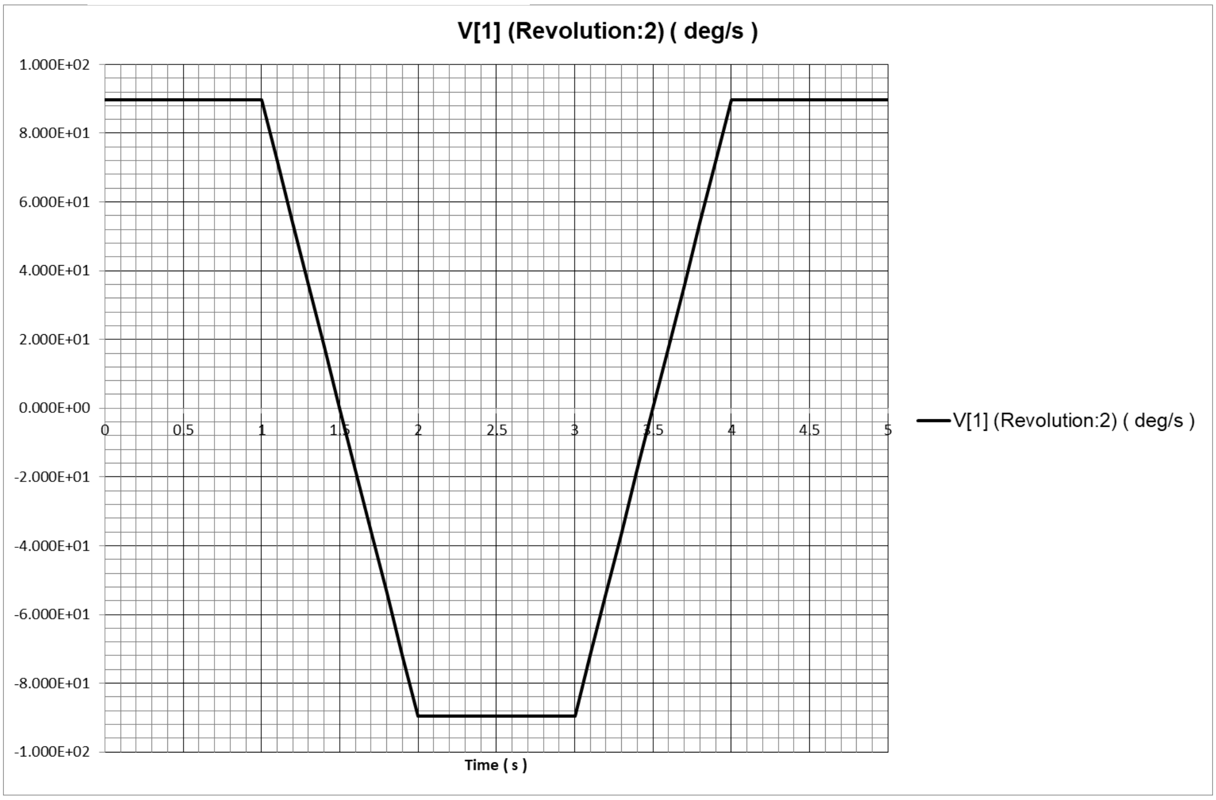
Images of the output graphs for Dynamic Simulation



(input speed graph)



(forefinger output speed)



Thumb output speed

Explanation of Prototype

The final prototype designed by Group 74 consisted of 16 spur gears. These 16 spur gears relate to 6 long rods and 6 short rods which are put on 3 mounting brackets. Basically, the design had a function of rotating the forefinger and the thumb in the opposite direction but the same speed with the given input speed. The gear group was designed to convert the input speed into the output speed.

During the design process, there are several challenges being encountered. The first problem is to arrange the gears in a proper order. To be more specific, if the wrong order is designed, one spur gear may block the rod. Consequently, the whole mechanism cannot work normally. Our group then tries different combinations of the gears and finally finds the proper order. The second main challenge we met was that the outer frame is not flat. Therefore, we are not able to simply place the rods on it. Then, our group decided to design a support bracket to house the rods. Moreover, we also apply the similar strategy to help fix the gears and rods in the finger part. Thirdly, our forefinger and thumb rotated in the same direction at first. Then we add one more gear to make these two fingers rotate at different directions to satisfy the requirement of our design product. However, we need to recalculate the relationship among our gear trains. Finally, our group built a trapezoid shape to place our gear to make sure that both two ends are at the correct position for our forefinger and thumb.

The most unique implement of our final design is the trapezoid shape designed in the finger part. If we put all gears mesh on one straight line, even though we use the smallest size we are allowed to choose, the last gear cannot correctly connect with the thumb and it will also exceed the maximum length of our mounting bracket. Therefore, we designed a trapezoid shape to shorten the length and succeed in making our last gear stay in the right position. During the process, we do plenty of calculations about length and height in order to attain the accurate position where we fix our rods and spur gears on the bracket.

Answers to Discussion Question

1. The first unique part we designed was the trapezoid shape in the second gear train. The reason was that we wanted our terminal gear to connect to the thumb correctly. We calculated the length and the angle of the trapezoid shape to make sure the gear connection was correct. Also, the support frame we designed was the mounting brackets, which are used to support the gears. On the brackets, we calculated the distance between the holes we made to make sure each gear can work correctly. Considering DFM, the brackets have very simple shapes. we cut the unnecessary part during the design process. it reduces the cost and difficulty to produce it.

2. Our design meets the design objectives. Firstly, After the dynamic simulation, we can plot the output speed. The output speed is 90 deg/s which is consistent with the expected output speed 0.25 revolution per second (the actual graph on the page). Also, the tip of the forefinger and thumb contact with each other in the workplace. The evidence is under the screenshot of the design which is on the page (). Furthermore, our team designed two different types of mounting bracket based on our gear design and frame constraints. The evidence of the mounting bracket we designed has been shown on the working draw part (on the page xxxxxxxxxx).

3. The greatest challenge we met was that different members may have different thoughts. Sometimes, it is hard to negotiate and find out the better solution. Our team communication became much harder due to the explosion of the virus. We can only revise our design and technical report through the Internet. The lack of face-to-face

communication makes it hard to receive help from our professor and IAIs. Sufficient communications were necessary during the design process, our team managed to overcome the difficulties.

4. The first difference between our design and the real prosthetic hand is that our design does not have enough flexibility. if there is a power supply, our mechanism can move in two different directions, but it can only move forward and backward. it can not realize some more complicated motions which are like the prosthetic hand technology right now. The second difference is that our project mainly focuses on the forefinger-thumb part, the versatility is not satisfying enough. This project is not able to do the actions which require all five fingers to simulate the real hand. We may reinforce our design by applying more complex mechanisms to achieve more functions such as twisting, making a fist. Furthermore, we could start to test different types of material to make it have high tensile strength and appropriate Young's modulus.

Team Member Contribution

(Notice: 1=very engaged, 2=engaged, 3=need more work)

Responsibility Chart	Wenxuan Wang	Haojun Zhao	Peihua Jin
Millstone0	1	1	1
1.0 Millstone1	1	1	1
1.1 Labelled sketches	2	1	1
1.2 Hand calculation	1	1	2
1.3 Gear design parameter	1	2	1
1.4 Test and check works	1	1	1
2.0 Millstone2	1	1	1
2.1 Solid modelling of gears	1	1	1
2.2 3D printing	1	2	1
2.3 Assembly prototype	1	1	1
3.0 Final submission	1	1	1
3.1 Report writing	2	1	1
3.2 Work drawing	1	1	1
3.3 Test and check work	1	1	2

Team meeting attendance:

Dates and time:
#1- February 12th, 2020, 2:00pm- All member presented
#2- February 27th, 2020, 6:00pm- All member presented
#3-March 6th, 2020, 6:00pm- All member presented
#4-March 12th, 2020,6:00pm- All member presented
#5-March 20th, 2020,6:00pm- All member presented (online)
#6-March 25th, 2020,6:00pm- All member presented (online)
#7-April 4th, 2020,6:00pm- All member presented (online)

Team Contract:

1.All members should attend at least one meeting per week.

2.All members should work together to complete all the assignments.

3.All members should report their progress of their tasks to the team leader per week.

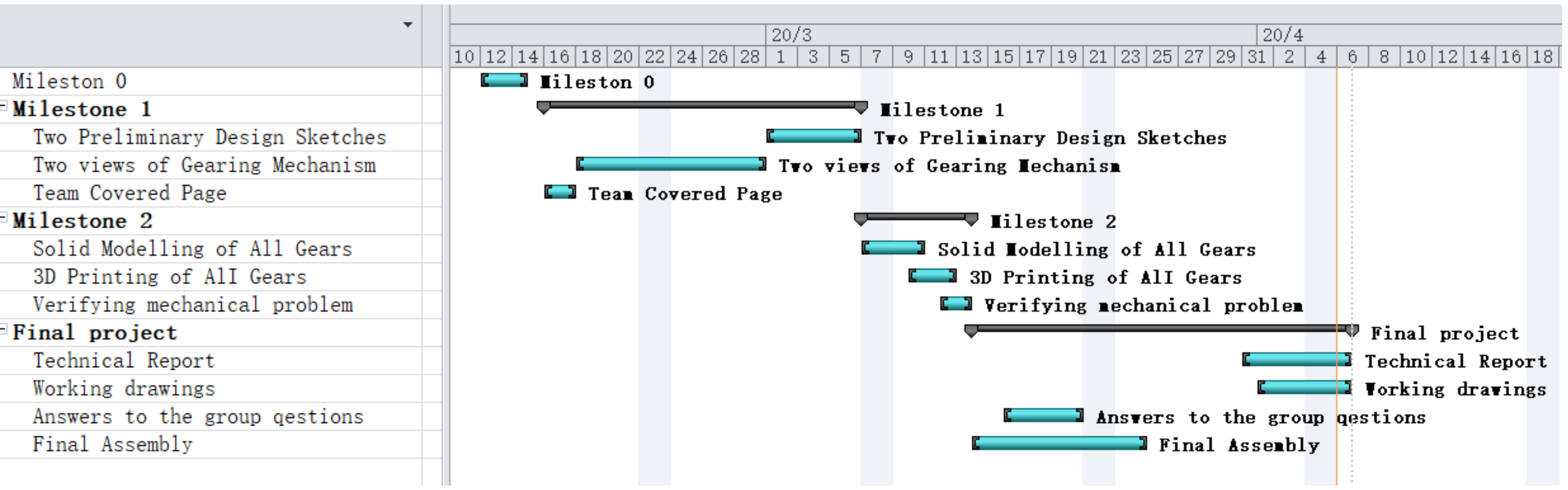
4.If members absent the team meeting with no reason, they will lose marks in peer evaluation.

5.All the decisions should be made after all the team members agree on the decisions.

6.All members should be prepared before attending the group meeting.

7.All members should try their best to complete this project.

Gantt chart outlining



Screenshot of the design