ENGINEER 1C03 - Engineering Design & Graphics

Engineering 1 Cornerstone Design Project

Instructor: Dr. Doyle

Final Report

Team 50

Lab Section: L09

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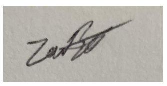
As a future member of the engineering profession, the student is responsible for performing the required work in an honest manner, without plagiarism and cheating. Submitting this work with my name and student number is a statement and understanding that this work is my own and adheres to the Academic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

Submitted by [Zain Talat, 400270358]

Signature



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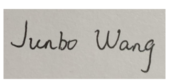
Submitted by [Junbo Wang, 400249823]

Signature



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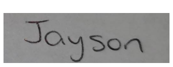
Submitted by [Jayson Narendran, 400265823]

Signature



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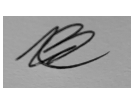
Submitted by [Jiheon Yoo, 400195372]

Signature



Introduction

Summary of the Design Problem

Team 50 has been employed by the biomedical company 'BME Devices' to cultivate a low-budget gripping mechanism as a proof-of-concept for an advanced prosthetic. The purpose of a proof-of-concept is to prove the potential of an idea or theory for real-world applications before considerable time and expense are exhausted to formulate the final design. The clasping apparatus is expected to serve as a full-right-hand prosthesis. The thumb and forefinger must open and close through a gearing mechanism and this gear train must connect to a single motor. Team 50 is responsible for designing the forefinger and thumb portion of the right-hand prosthesis.

Description of your Final Design

For our final design, we have decided to use a total of nine spur gears that have a gear ratio of 37.5. The output speed of the mechanism is 12 RPM and the input speed was calculated to be 450 RPM. In order for the gears to fit within the dimensions of the frame, a module of 1 mm/tooth was used. The diameters of the gears were decided to be; 12mm, 40mm, 12mm, 45mm, 12mm, 36mm, 28mm, 36mm, and 12mm. Since the module is 1 mm/tooth, the number of teeth is the same in magnitude as their diameter. During operation, the tips of the forefinger and thumb will meet each other someplace within a 30-mm x 30-mm functional space. Our design was also pirate-themed. For this reason, the mechanism includes a handle that looks similar to a ship's steering wheel. This handle also allows users to manually spin the gears without a motor.

To complete this “pirate ship” we included a 3D-printed flag that has Team 50 engraved in the flag.

An Overview of the Material Covered in the Technical Report

This report will include a set of calculations used to design the gear train. It will also contain a table of mechanism design parameters. Furthermore, a simple design mechanism diagram along with screenshots of the assembly can also be found. Moreover, the input and output graphs from the dynamic simulator will be present. In this report, we will talk about the prototype design and outline any challenges that were met as well as an explanation of any unique features of the design. A table of all team meetings and member attendance is included, as well as a Gantt chart.

Calculations

To solve the problem, we first determined the overall gear ratio. To find this, we need our output speed and our input speed. Our output speed was given already with a value of 0.20 RPS which can be converted to RPM, by multiplying RPS by 60. This gave us an output speed of 12 RPM. Our initial speed was determined by multiplying our group number (50) by 9.0; this gave us an input speed of 450 RPM. To calculate the gear ratio, the following was done.

$\omega o = 0.20\,RPS \times 60$

ωo= 12 RPM

$\omega i = 50 \times 9.0$

$\omega i = 450$RPM

$GR = \omega i / \omega o$

GR = 450 RPM/ 12 RPM

GR = 37.5

We then noted the dimensions of the prosthetic frame, to establish boundaries for the diameters of the gear. We also decided that all gears should have a module of 1. Next, we drew a rough design and calculated Z for all gears, using the gear ratio. Since there are two outputs, we have to calculate each separately as shown below, this was done by multiplying the denominator by an even number such 1728 that would also make the numerator even. Then Z values were determined by trial and error.

Output 1:

$GR = ZB \times ZD \times ZF / ZA \times ZC \times ZE$

37.5/1 = $ZD \times ZF / ZA \times ZC \times ZE$

$64800/1728 = 40 \times 45 \times 36 / 12 \times 12 \times 12$

Therefore, ZA= 12, ZB = 40, ZC= 12, ZD = 45, ZE=12, ZF =36

Output 2:

$GR = ZB \times ZD \times ZG \times ZH / ZA \times ZC \times ZE \times ZG$

37.5/1 =$ZB \times ZD \times ZG \times ZH / ZA \times ZC \times ZE \times ZG$

$64800/1728 = 40 \times 45 \times 28 \times 36 / 12 \times 12 \times 12 \times 28$

Therefore, ZG= 28 and ZH= 36

We then used the dimensions of the frame to ensure that each part would fit perfectly to the axis of the thumb landmark and the forefinger landmark and also ensured that the gears would not protrude from the frame. Our diameters to the axis of both landmarks were perfect using a module of 1 for all gears. When looking at the dimensions we had to ensure that ZE would reach the thumb landmark horizontally, so this meant the length from ZA to ZE was approximately 50 mm, while the distance from thumb landmark to forefinger landmark horizontally had to be ~52 mm. Whereas, the depth from the center of ZE to the axis of the thumb landmark (the center of where ZF has to be) has to be approximately 30 mm. After 3D modelling, we realized that Gear E, F & G would all mesh together which was not what we wanted. We then had to create an axially connected Gear I which would mesh with Gear F, and Gear E would mesh with Gear G. Since Gear I was axially connected to the rod containing Gear D and Gear E this had no effect on the gear ratio or any calculations.

Table 1. Gear Design Parameter Table

Gear Name	Type of Gear (e.g., spur, worm)	Connection to Preceding Gear		Pitch Diameter (mm), *D*	Module (mm/tooth), *m*	Number of Type (axial or mesh) Name Teeth, *z*
		Type (axial or mesh)	Name			
A	Spur	N/A	N/A	12	1	12
B	Spur	Mesh	A	40	1	40
C	Spur	Axial	B	12	1	12
D	Spur	Mesh	C	45	1	45
E	Spur	Axial	E	12	1	12
F	Spur	Mesh	I	36	1	36
G	Spur	Mesh	E	28	1	28
H	Spur	Mesh	G	36	1	36

I	Spur	Axial	D	12	1	12

Simplified Gearing Mechanism Diagram

Figure 1: Simplified Drawing of the gear train (Front View)

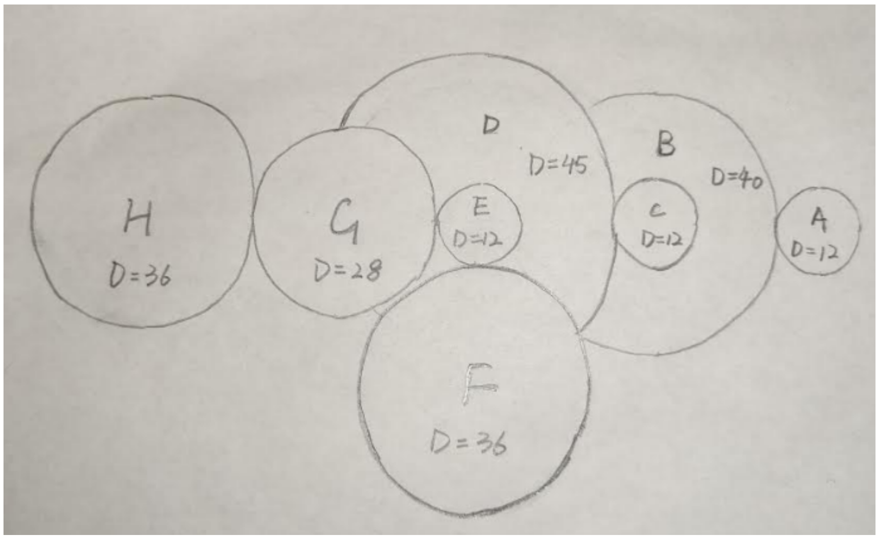
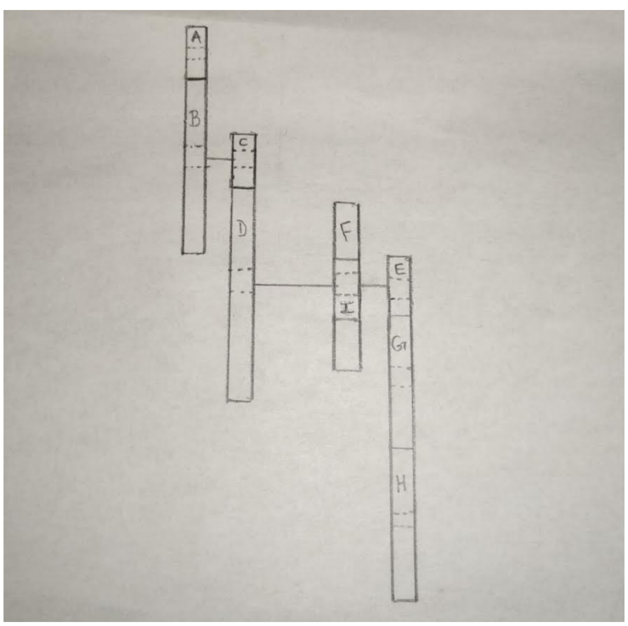


Figure 2: Simplified Drawing of the gear train (Top View)



Assembly Screenshots & Pictures

Figure 3: 3D-Printed Final Prototype

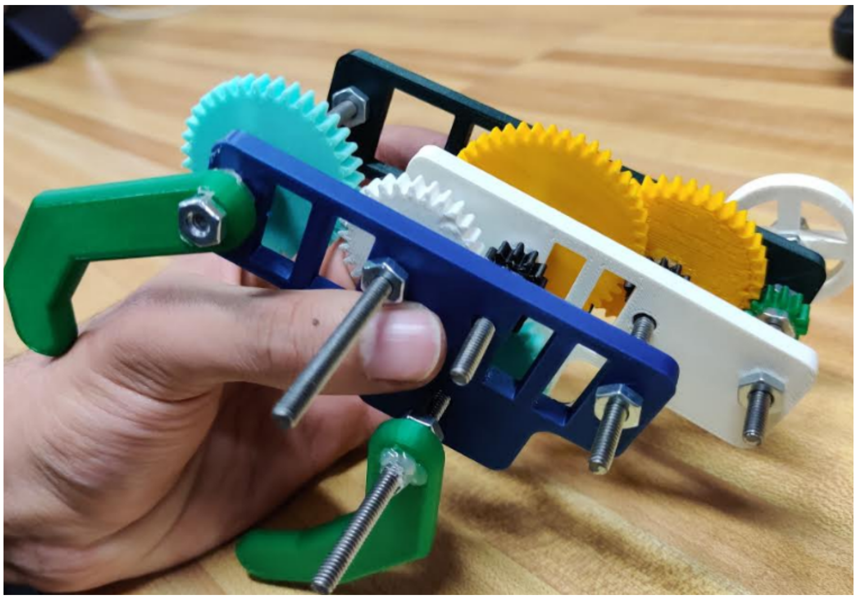


Figure 4: Gear Assembly with Prosthetic Frame

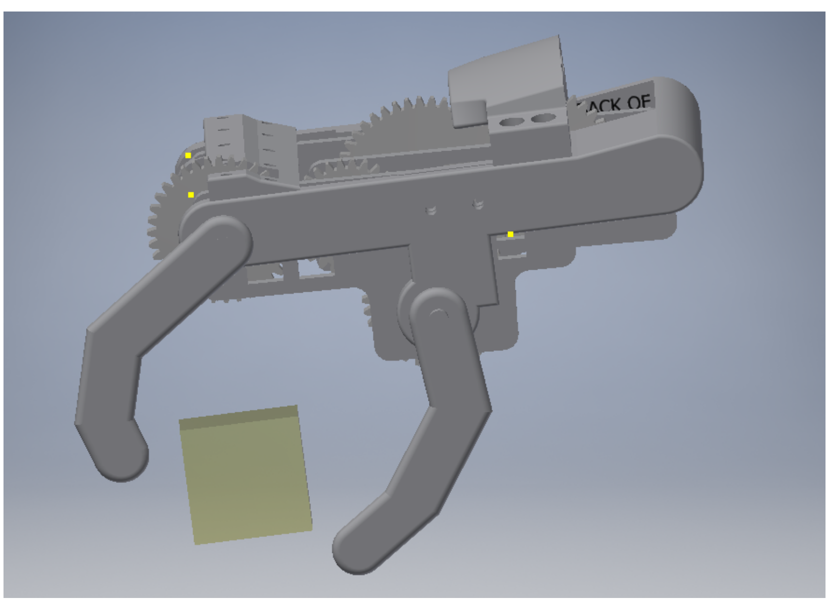
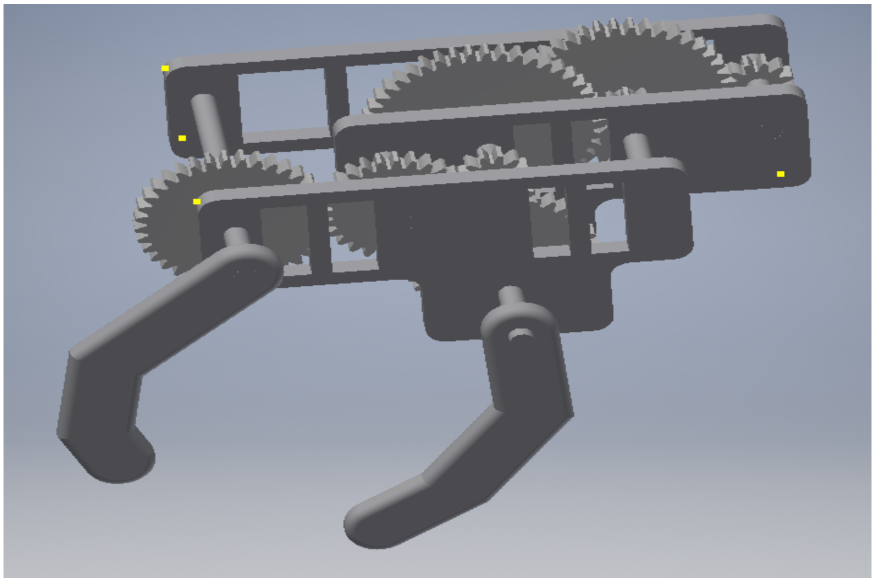


Figure 5: Gear Assembly without Prosthetic Frame



Dynamic Simulation Graphs

Figure 6: Dynamic Simulator Output Speeds

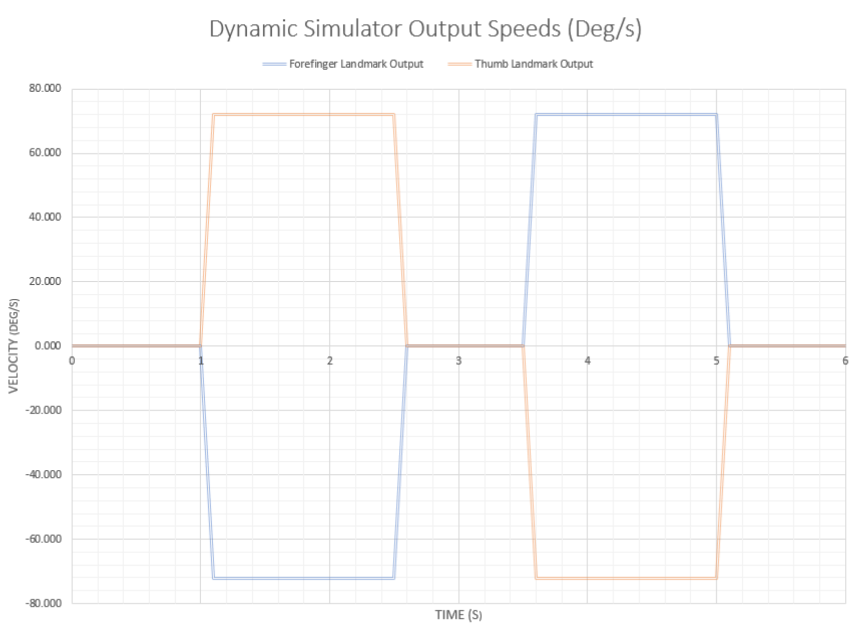
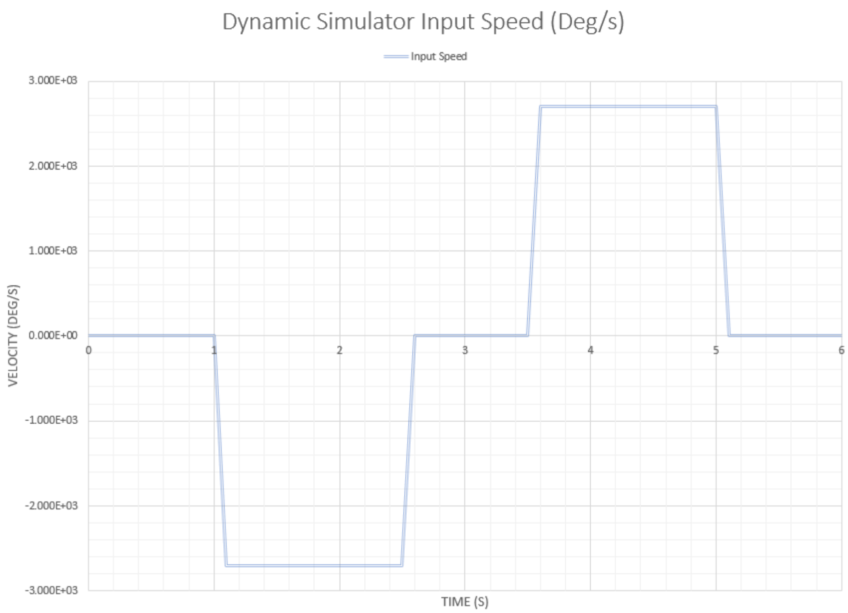


Figure 7: Dynamic Simulator Input Speed



Brief Explanation of Prototype

Our prototype consists of a gear train that is made of nine spur gears and has a gear ratio of 37.5. Five of the spur gears have a mesh connection and three gears have an axial connection to their preceding gears as shown in *Table 1*. To reference the size of the gears, the largest spur gear had a pitch diameter of 45mm, and the smallest gear had a pitch diameter of 12mm. This design only utilizes spur gear; this is to ensure the overall simplicity of the design. By doing this, it will be easier for others to understand the design, without needing knowledge of other forms of gears (i.e. Worm Gear). We decided to incorporate the theme of "Pirates" in our prototype since it is a cliche for pirates to have prosthetic hands (hooks). We used colourful gears to make it look like a pirate's parrot and we also included a handle that looks similar to a ship's steering wheel. The purpose of this handle was to allow users to manually rotate the gears without a motor. It was also shaped like a ship's steering wheel to reduce the print time in the scenario that it needs to be reprinted. It has a small cylinder that allows the user's fingers to grip and rotate the handle comfortably. We place a 3D printed flag that had the words "TEAM 50" engraved on it to fit the theme of pirates/sailors. One of the problems that we encountered was that some of the rods were too long and were interfering with the gears. As a result, we needed to move the location of the rods, which resulted in an uneven balance of the mechanism. To fix this, we had to build another wall to bring the center of mass back to the center of the mechanism this can be seen in *Figure 3, Figure 4* and *Figure 5*. Furthermore, we also incorrectly assumed the diameter of the rods to be 5mm. However, the actual diameter of the rod was less than 5mm. To solve this problem, glue was added to keep the gears/rods in place. Moreover, one of the gears was too large and began to interfere with other gears. This problem was solved by adding another spur gear to allow for enough free space to avoid unwanted interference from other gears. There were also some problems that were encountered during the printing process such as the first layer not sticking to the heat bed. As shown in *Figure 6* the input speed of the assembly was 2700 deg/s or 450 RPM. Whereas, both output landmark has a speed of 72 deg/s or 12 RPM as shown in *Figure 7*.

Table 2: A table documenting all team meetings

Meeting Number	**Date**	**Summary**	**Attendance**
1	2019-10-07	Milestone 0	Zain Talat Frank Wang Jiheon Yoo
2	2019-10-21	Discussed what each team member needed to do for milestone 1 and how the work should be broken up. Members were instructed to come up with designs and calculations	Jayson Frank Wang Zain Talat Jiheon Yoo
3	2019-10-22	Asked IAI for clarification	Zain Talat
4	2019-10-24	Worked on milestone one and finalized possible designs. Began to do calculations and write up for milestone 1	Jayson Frank Wang Zain Talat Jiheon Yoo
5	2019-10-25	Asked IAI for clarifications, and submitted milestone 1	Jayson Frank Wang Zain Talat

6	2019-11-10	Worked inventor files. Created gears to be 3D printed	Jayson Frank Wang Zain Talat Jiheon Yoo
7	2019-11-12	3D Printed First set of gears and familiarize ourselves with the printer	Jayson Frank Wang Zain Talat
8	2019-11-13	Printed second set of gears	Jayson Frank Wang Zain Talat Jiheon Yoo
9	2019-11-15	Printed third set of gears and discussed and broke down final report.	Jayson Frank Wang Zain Talat Jiheon Yoo
10	2019-11-21	3D printed brackets/mounts. Worked on final report and design	Jayson Frank Wang Zain Talat Jiheon Yoo
11	2019-11-28	3D Printed in Epic Lab	Jayson

			Frank Wang Zain Talat Jiheon Yoo

Table 3: Each team members' contributions

Project	**Task**	**Team Member**
Milestone 0	Contract	Frank Wang Zain Talat Jiheon Yoo
Milestone 1	Gear Calculations and Table of Parameters	Zain Talat
Milestone 1	Clearly Labeled Sketches	Jayson Frank Wang
Milestone 2	Gear Modeling	Zain Talat
Milestone 2	3D Printing	Everyone
Final Report/Project	Introduction	Jayson
Final Report/Project	Table of Team Meetings	Jayson Jiheon Yoo
Final Report/Project	Explanation of Prototype	Jayson
Final Report/Project	Calculations and Table of Parameters	Zain Talat
Final Report/Project	Dynamic Simulation	Zain Talat
Final Report/Project	Full Assembly and 3D Model	Zain Talat

	for all gears and walls	
Final Report/Project	Construction of prototype	Zain Talat
Final Report/Project	Simplified gearing mechanism diagram	Frank Wang Jayson Narendran Jiheon Yoo
Final Report/Project	Software Model (forefinger and thumb)	Frank Wang
Final Report/Project	Complete set of Working Drawings	Frank Wang
Final Report/Project	GANTT Chart	Jiheon Yoo

GANTT Chart

Figure 8: GANTT Chart

Milestone 0	Start Date	Due Date	Assigned To	Duration (hour(s))
Team Contract	10/07/19	10/07/19	All Members	1
Milestone 1				
Preliminary Design Sketches	10/07/19	10/12/19	Jiheon Y	1
Documentation of Gearing Mechanism	10/17/19	10/21/19	Jayson N	2
Team Meeting	10/20/19			1
Hand Calculations	10/21/19	10/23/19	Zain T	1
Table of Gear Design Parameters	10/21/19	10/24/19	Junbo W	3
Team Meeting	10/23/19			1
PDF Compiling	10/24/19	10/25/19	Jayson N	1
Milestone 2				
Solid Modelling all the gears	10/26/19	10/30/19	All Members	4
Team Meeting	10/28/19			1
3D Printing Session 1	10/31/19		All Members	1
Final Submission				
3D Printing Session 2	11/10/19		All Members	1
3D Printing Session 3	11/13/19		All Members	1
3D Printing Session 4	11/15/10		All Members	1
Complete Set of Working Drawing	11/15/19	11/29/19	Junbo W	2
Autodesk Software Files	11/15/19	11/29/19	Zain T	1
Team Meeting	11/18/19			1
Team Meeting	11/20/19			1
Printing Session 5	11/21/19		All Members	1
Technical Report	11/25/19	12/03/19	Jayson N & Jiheon Y	(Couple Days)
Printing Session 6	11/28/19		All Members	1
Assemble 3D Parts together and create Video	11/28/19	12/03/19	All Members	(Couple Days)