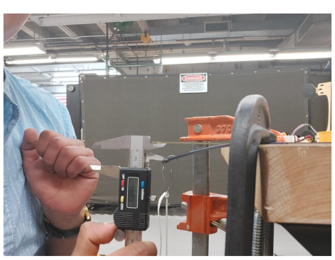
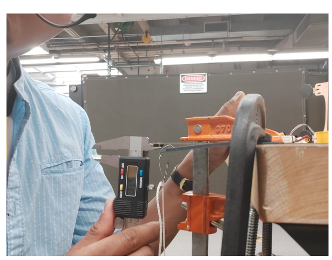
Design Optimization

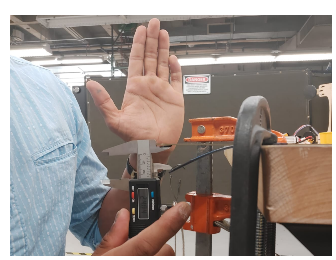
The end effector of the five bar mechanism used to power the was swapped out and tested for different thickness while maintaining the geometry.

Experimental Design

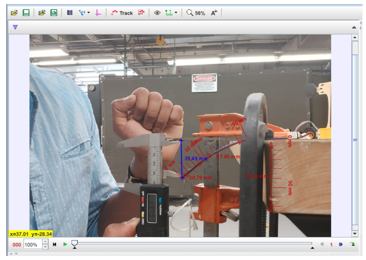
The end effectors were tested under a uniform loading condition to understand the effect of relative stiffness of each of the different iterations.For this test the different end effectors were clamped to a table in a cantilever position. A uniform load of 320 gms was applied to them while keeping a length of 75mm overhanging. The deflection from the normal was measured via a vernier caliper (as shown in image)







Later, the change in length caused due to bending was calculated using the tracker app.



We were not able to make the pynamics simulation work as the team faced issues in simulating the ground reaction forces.
Thereby I choose to go to the basics and estimate the Young's modulus by the basic formula

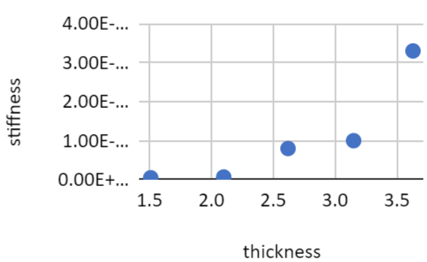
$$Y = \frac{Stress}{Strain} = \frac{Force}{Area} \times \frac{1}{Change\ in\ Volume}$$

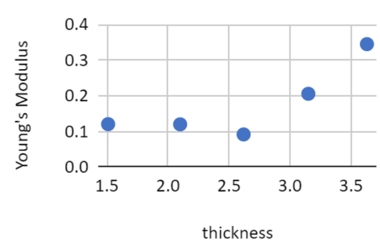
$$= \frac{mg}{w \times t} \times \frac{1}{\Delta l \times (w \times t)}$$ *where w= width; t=thickness; l=length*

$$Y \, \alpha \, \frac{1}{\Delta l \times t^2}$$

Data Collection

Weight (g)	Overhang (mm)	Thickness (mm)	Deflection (mm)	k(stiffness) [Euler Bernoulli]	Length after loading (mm)	dl (mm)	(t^2 x dl)^(-1) [Relative Young's Modulus]
320	75	1.51	39.49	5.03E-03	78.64	3.64	0.12048825
320	75	2.1	24.04	7.00E-03	76.89	1.89	0.11997744
320	75	2.62	16.85	8.00E-02	76.59	1.59	0.0916221
320	75	3.15	8.56	1.00E-01	75.49	0.49	0.20567561
320	75	3.63	5.71	3.30E-01	75.22	0.22	0.34495629

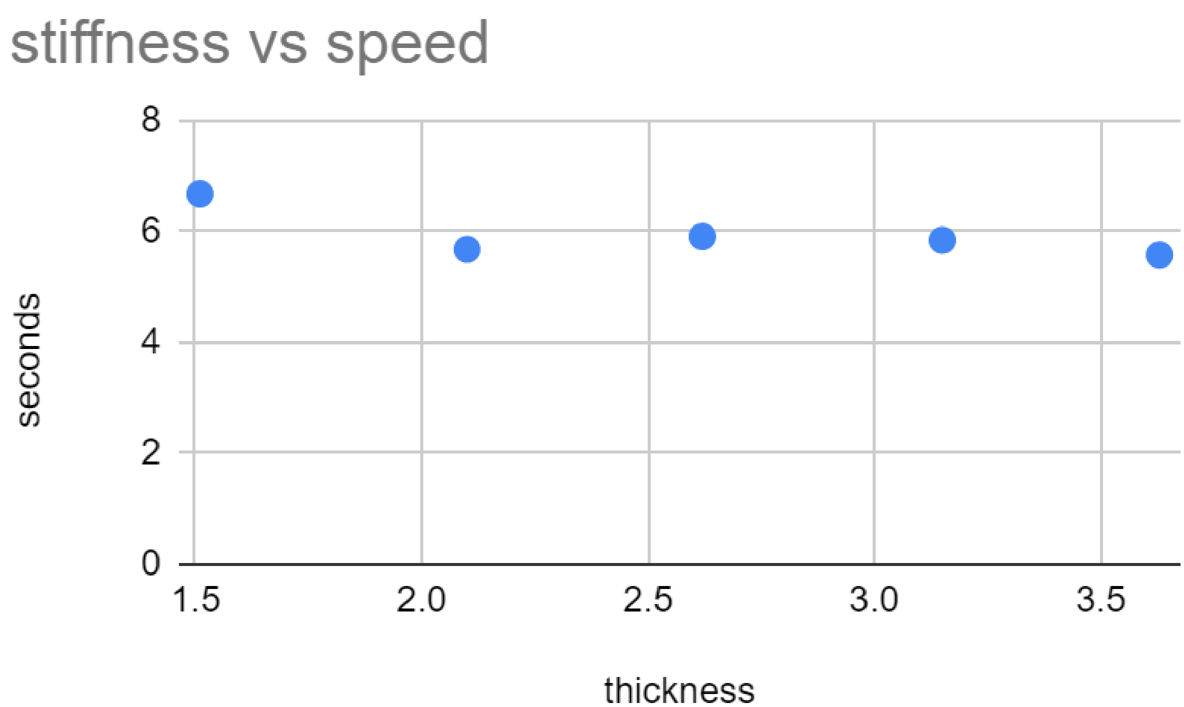




In the above graphs we can see that the simulated values for the stiffness (Eluer Bernoulli approximation) and the measured stiffness (Relative Young's modulus) follow the trend. The region where they diverge is at the lower thickness where deflections are too big to approximate with the 1/3rd principle.
As it is quite obvious from the above data, increasing thickness increases the stiffness of the part.

Data Visualization
For the test as mentioned in the plan, the bot was operated for a fixed distance of 1m while varying the end effector stiffness (and as we have established above, thickness) w

thickness	frames	seconds
1.51	200	6.666666667
2.1	170	5.666666667
2.62	177	5.9
3.15	175	5.833333333
3.63	167	5.566666667



Above is the graph for the observed readings for the speed vs stiffness experiment.

Conclusion
Ideally I would be comparing the experimental results with the simulated results and thereby make a comment on the level of accuracy of the simulation and what are the possible methods of improving the said simulation. But in the absence of simulated data I am relying on educated guesses.
The forward velocity is mainly dependeant on the gait (size and frequency). Since those factors are constant in this experiment, the way the end effector interacts with the ground is crucial. To obtain maximum speed we would want all the motion of the motor to be transferred to the end effector without any “wastage”/”lag” at the end effector caused due to bending and/or flexing of

the same. Overall we can clearly see a downward trend in the lap time vs stiffness graph; as with increasing stiffness more and more energy is transferred to the ground. Although there seems to be an upper limit to this as maximizing the thickness beyond a point would just add to the weight without having any impact on the stiffness. Anyways, for the purpose of this experiment that point of saturation didn't seem to have been encountered.

An exception to this rule would be the test result at 2.1mm thickness. The entire system seems to have fallen in tune at that thickness as the springiness and bounce. Therefore the higher speed.