THE UNIVERSITY OF TEXAS AT DALLAS

Jaw Force Sensor For Medical Applications

MECH 6V49.005 Soft Robotics

Group Project Presentation

Spring 2023

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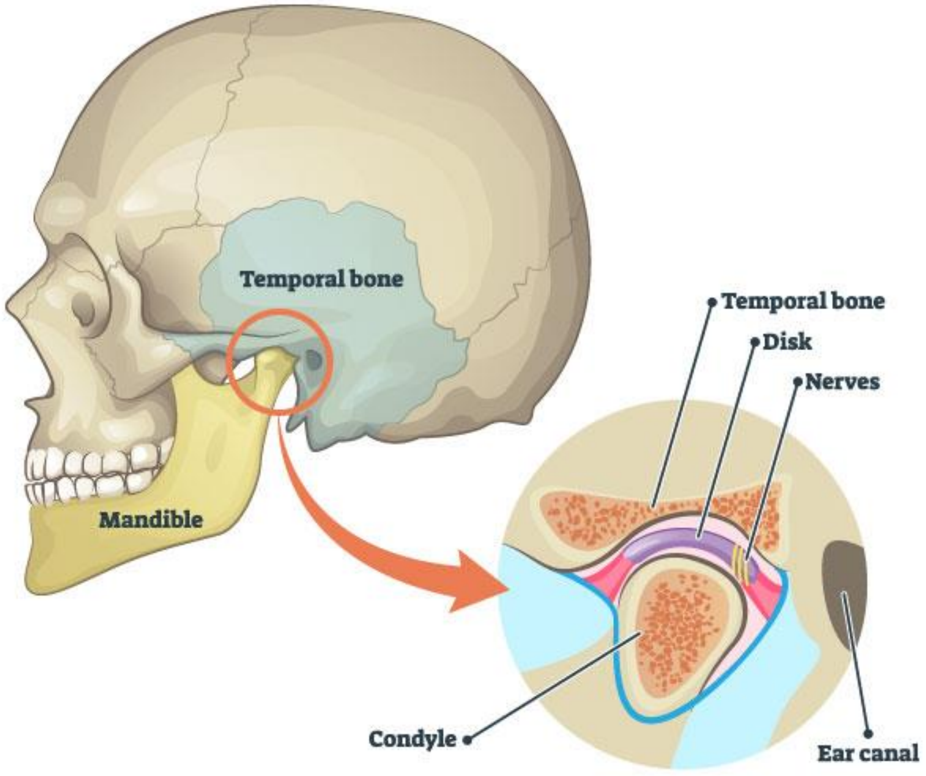
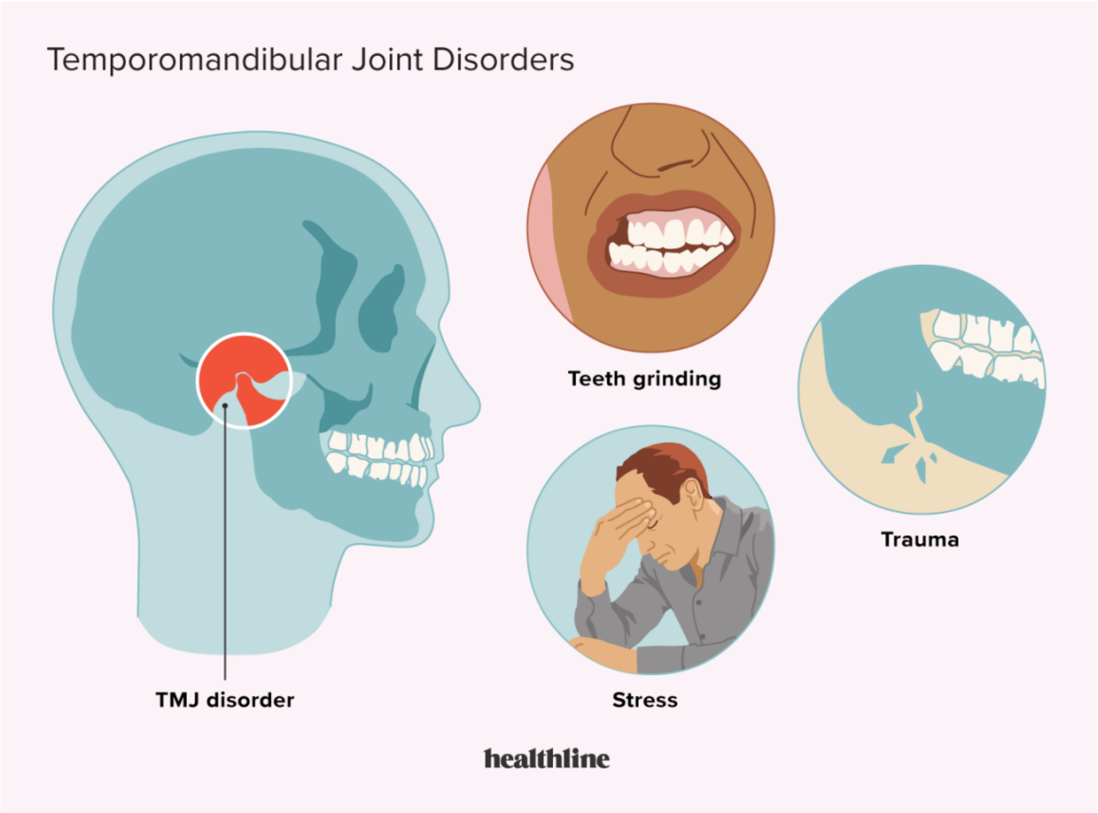
(05/04/2023)

Significance and Background



Temporomandibular Joint

Image Reference: https://www.google.com/url?sa=i&url=https%3A%2F%2Fwww.tmjsleepmacon.com%2Ftmj-disorders.html&psig=AOvVaw2ftLiaeGQKu64DxfVMweO6&ust=1683258605577000&source=images&cd=vfe&ved=0CBIQjhxqFwoTCKj7-Yvh2v4CFQAAAAAdAAAAABAw

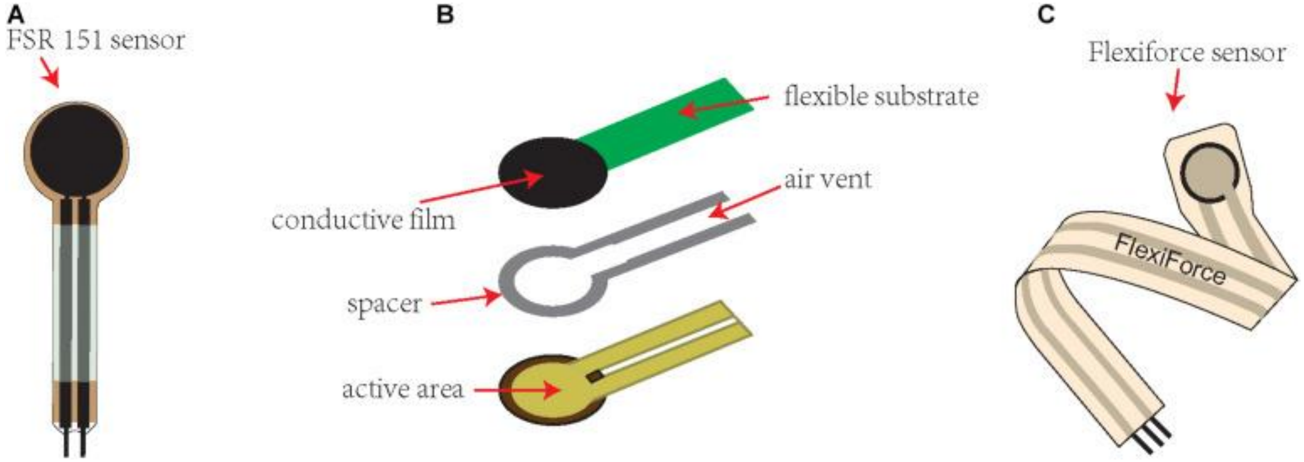


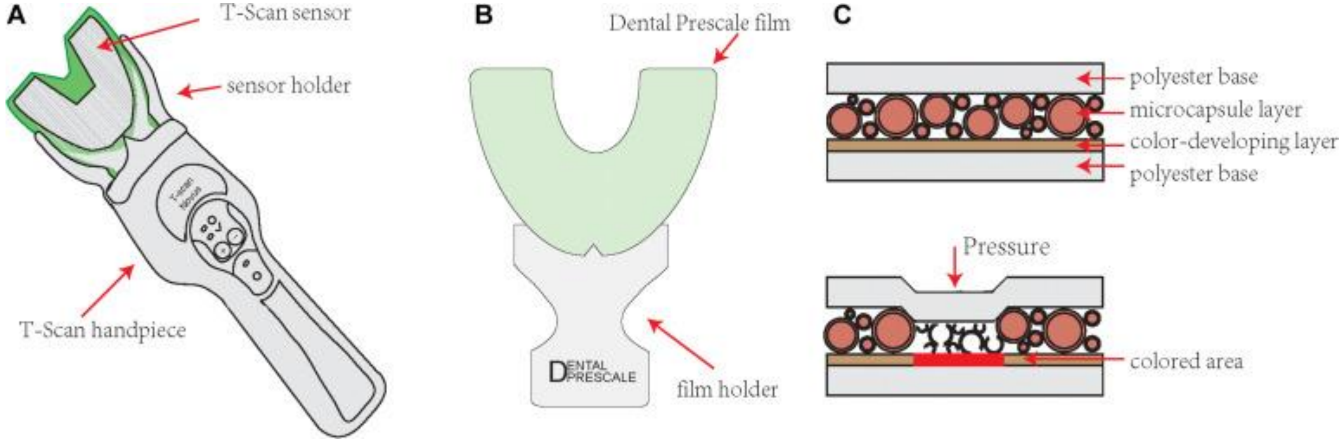
Causes for Temporomandibular Joint Disorder (TMJD)

Image Reference: https://www.google.com/url?sa=i&url=https%3A%2F%2Fwww.healthline.com%2Fhealth%2Ftmj-disorders&psig=AOvVaw3Iu6RPYd-PhzLgRENmGd0C&ust=1683259107222000&source=images&cd=vfe&ved=0CBIQjhxqFwoTCKjvnwi2v4CFQAAAAAdAAAAABAE

The most common way to identify the early onset of TMJD is to notice the reduction in bite force.

Existing Technologies for Bite Force Measurement





Piezoresistive Sensors

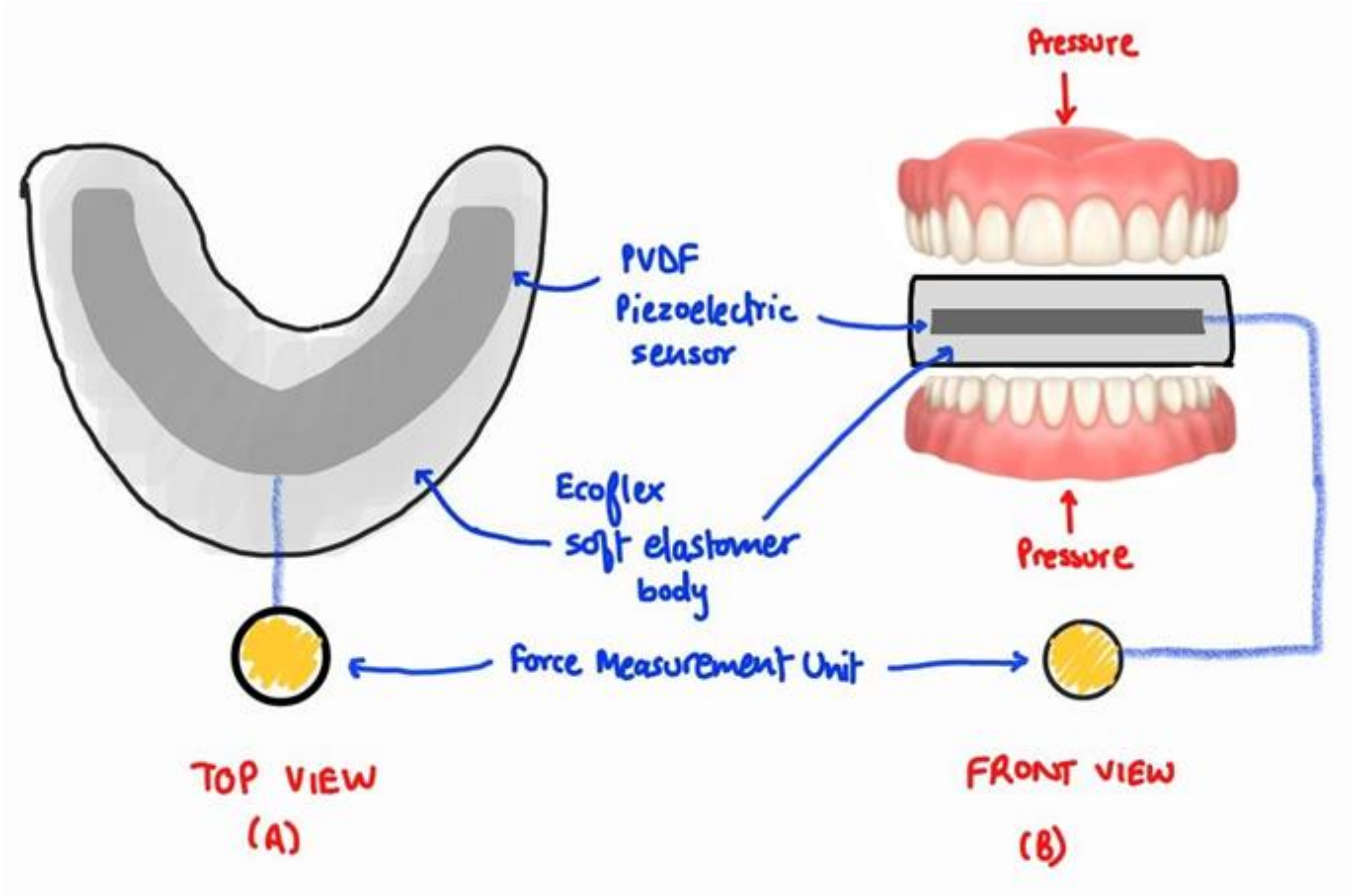
Pros: High sensitivity, thin, light, cheap
Cons: Less accuracy, low durability

Piezoelectric Foil Sensors

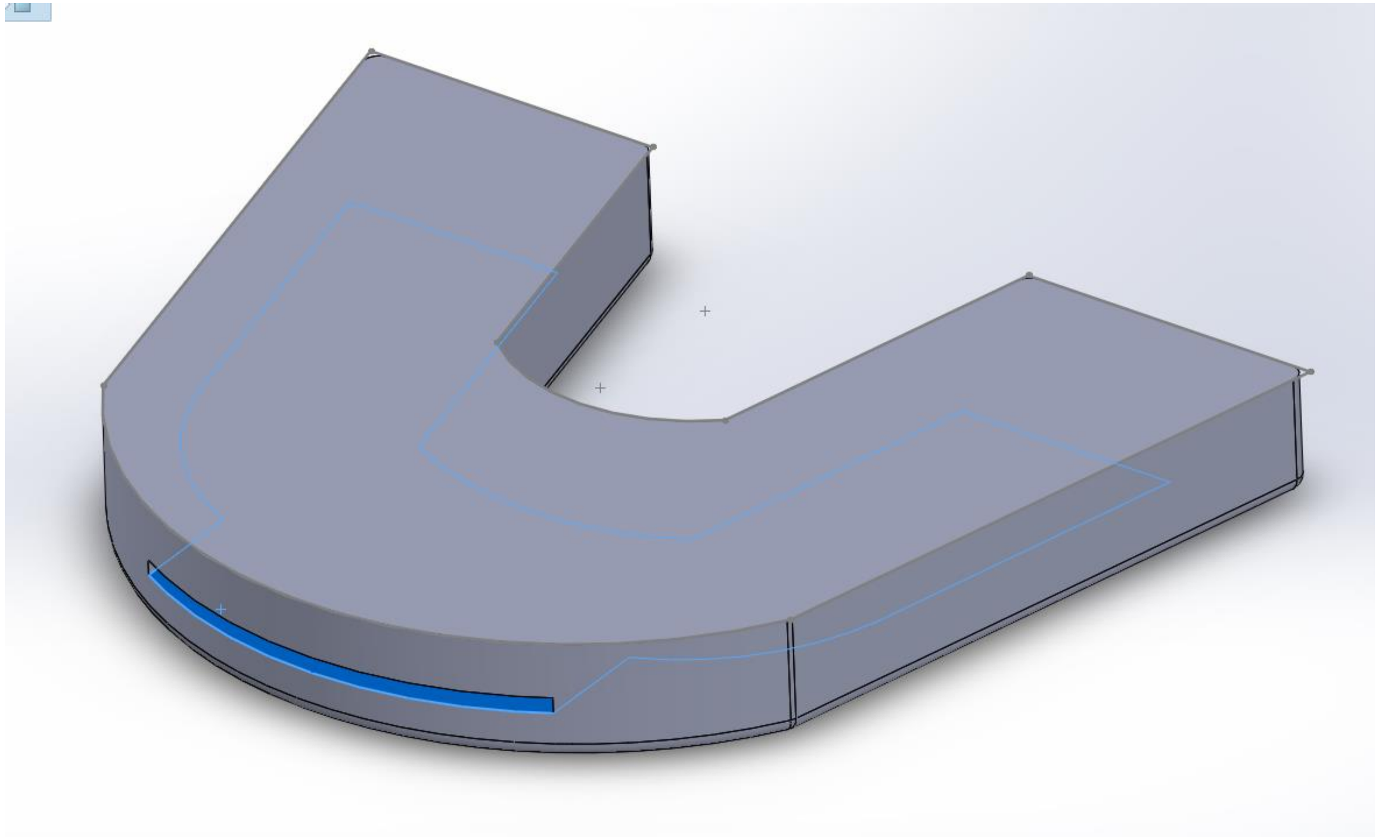
Pros: Super-thin, high accuracy
Cons: Low sensitivity and flexibility

Images Reference: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8062967/#

Our Device Idea



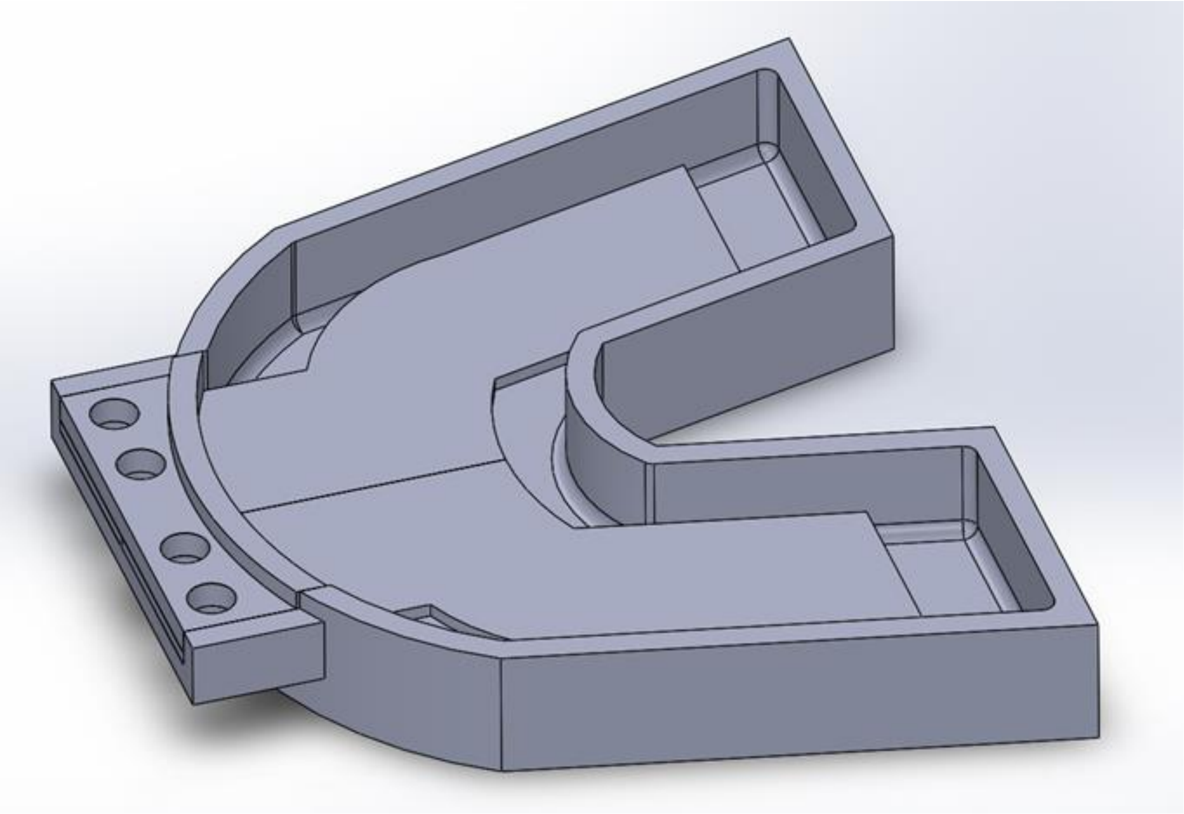
CAD Model of Our Device



CAD model of our device using Solidworks

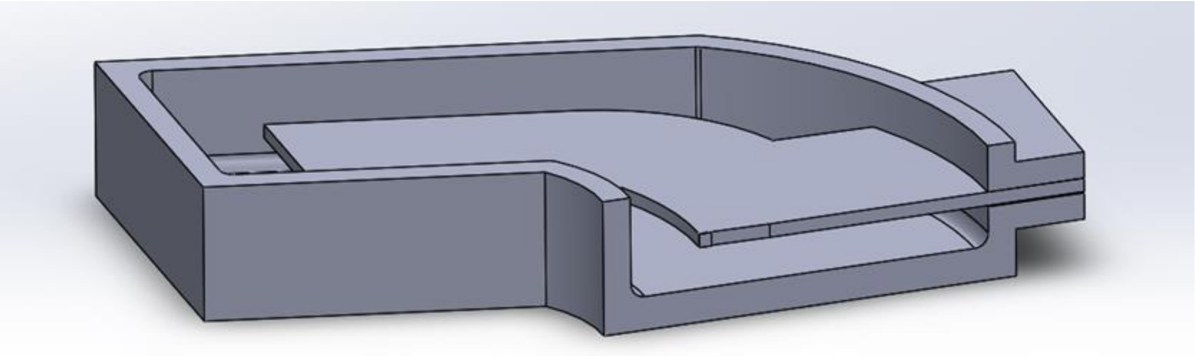
Cavity for sensor

CAD Model Assembly of the Mold for Casting



CAD model of the mold using Solidworks

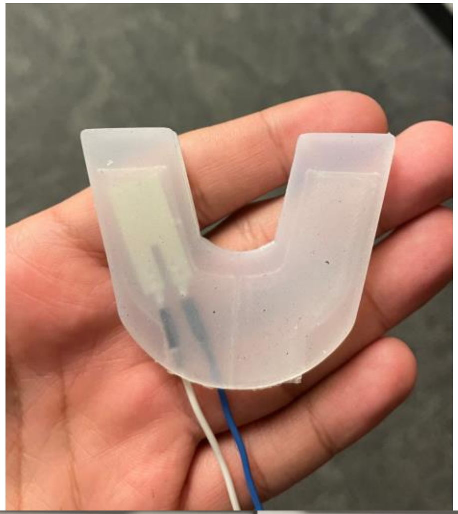
Additively manufactured (FDM) using PLA

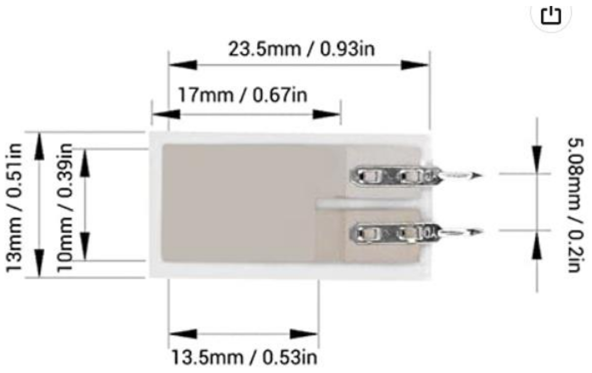


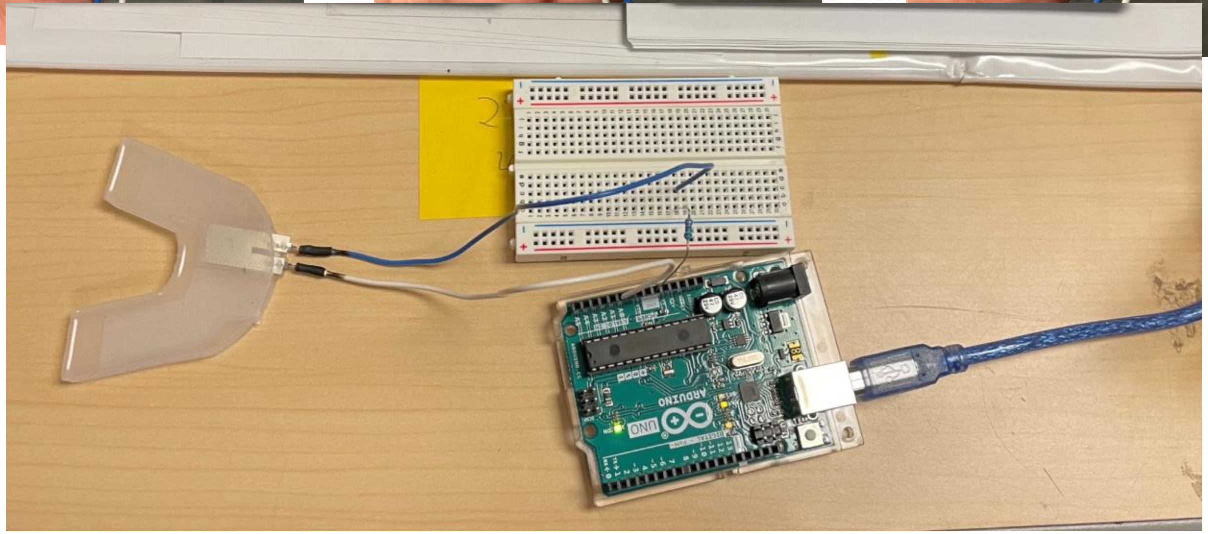
Sectional view of CAD model of our device

Casting of EcoFlex 00-10

Final Prototype Assembly and Setup



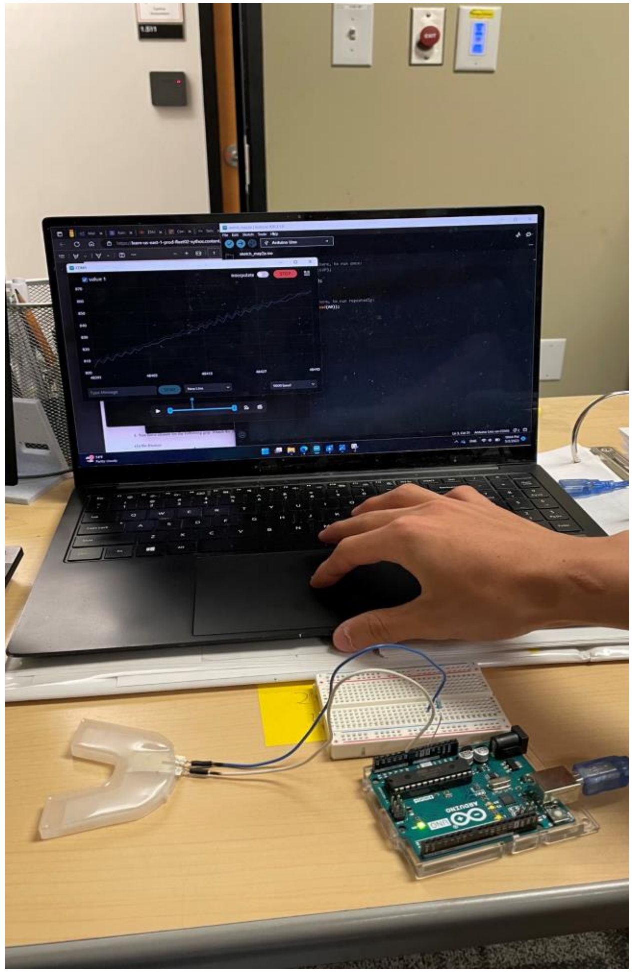




Setup and Testing

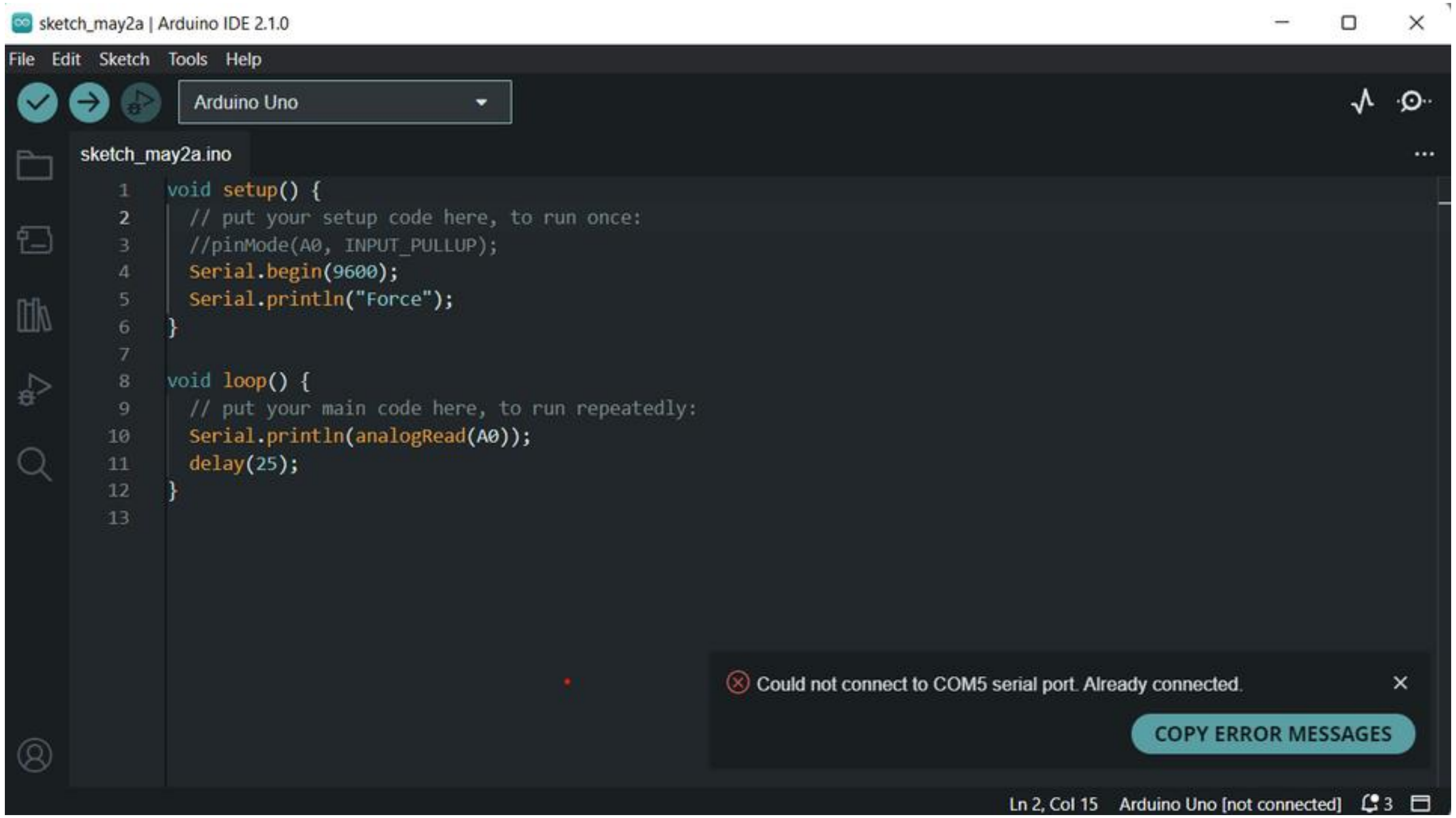
Setup:

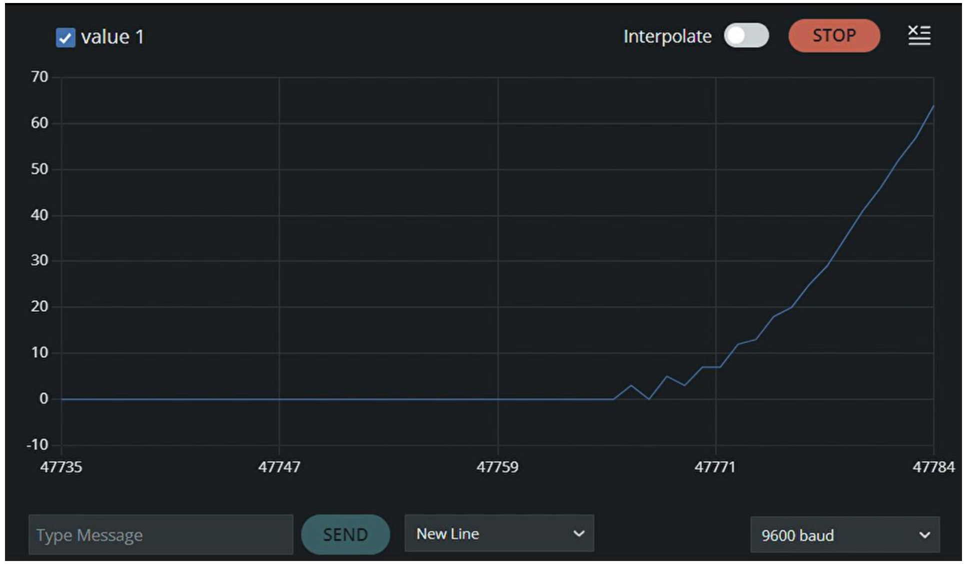
- Piezoelectric Pressure sensor
- Wires for soldering
- Arduino UNO
- 220Ω Resistor
- EcoFlex 00-10 cast
- Board
- Laptop
- Cable



https://youtube.com/shorts/N3CgNRUDO80?feature=share

Arduino IDE Code for Generating Signal Graph





FEA Simulation (using ANSYS Workbench)

Material Properties:

Outline of Schematic B2: Engineering Data

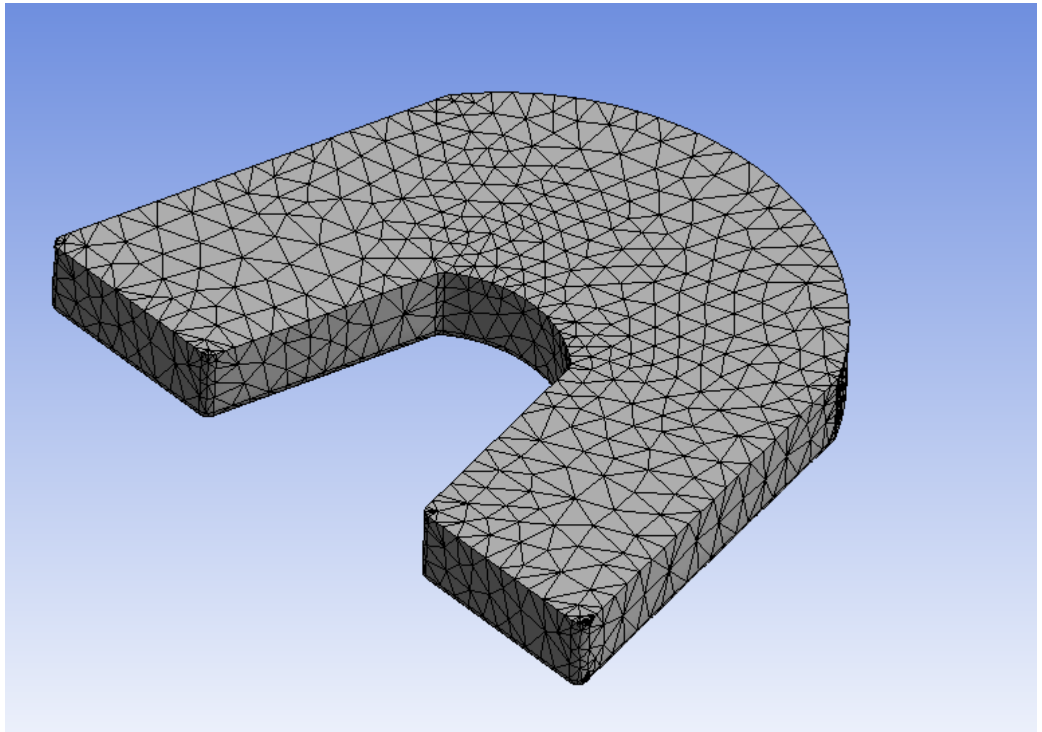
	A	B	C	D	E
1	Contents of Engineering Data			Source	Description
2	Material				
3	Rubber1			Exp	Coefficients fitted to experimental data from Treloar, L.R.G., Stress strain data for vulcanized rubber under various types of deformation, Transactions of the Faraday Society, vol. 40, pp.59-70 (1944)
*	Click here to add a new material				

Properties of Outline Row 3: Rubber1

	A	B	C	D	E
1	Property	Value	Unit		
2	Material Field Variables	Table			
3	Density	0.04	g cm^-3		
4	Neo-Hookean				
5	Initial Shear Modulus Mu	0.18	MPa		
6	Incompressibility Parameter D1	0	Pa^-1		

FEA Simulation (Meshing)

Meshing Parameters:



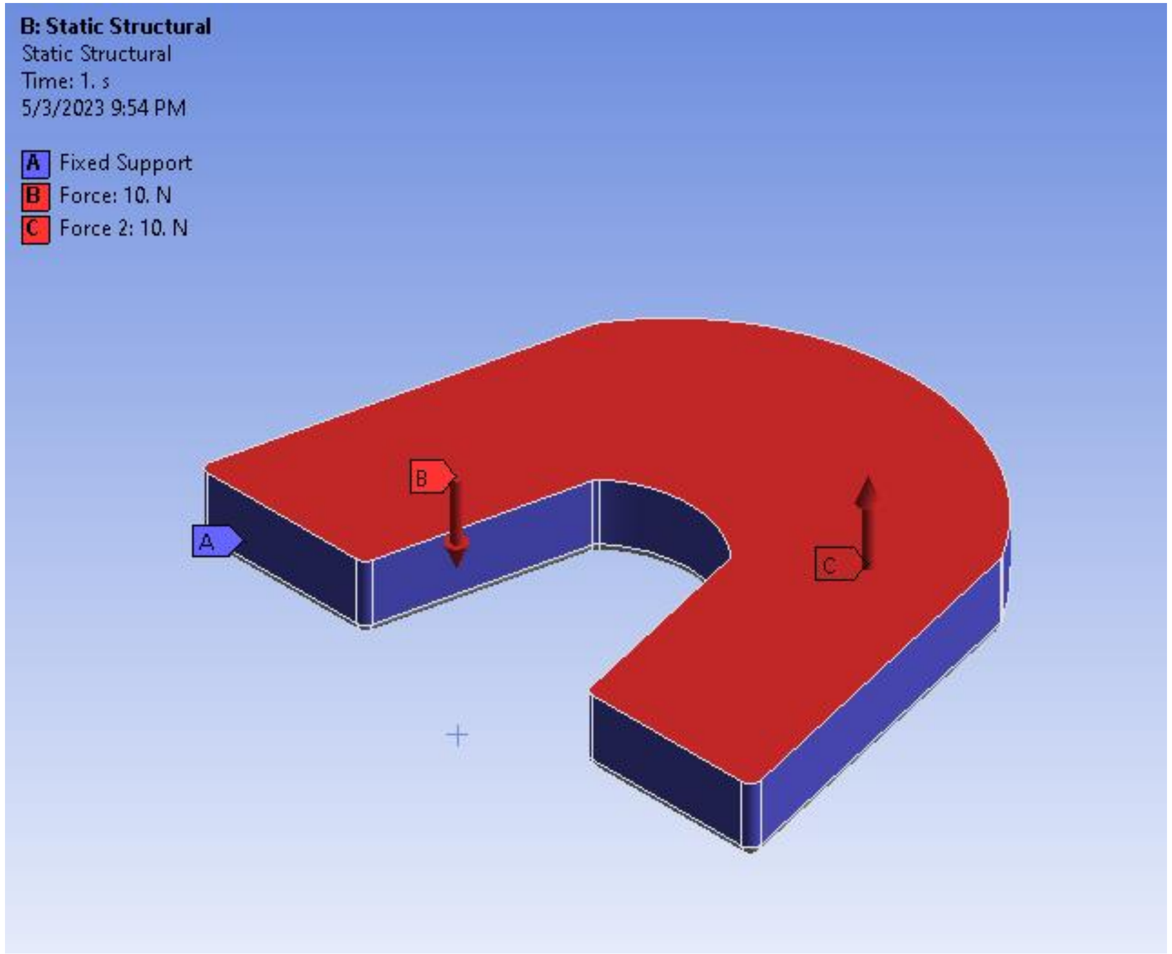
Details of "Mesh"

Display	
Display Style	Use Geometry Setting
Defaults	
Physics Preference	Mechanical
Element Order	Program Controlled
Element Size	Default
Sizing	
Use Adaptive Sizi...	Yes
Resolution	5
Mesh Defeaturing	Yes
Defeature Size	Default
Transition	Fast
Span Angle Center	Coarse
Initial Size Seed	Assembly
Bounding Box Di...	9.9379e-002 m
Average Surface ...	1.7489e-004 m²
Minimum Edge L...	2.2471e-004 m
Quality	
Check Mesh Qua...	Yes, Errors
Error Limits	Aggressive Mechanical
Target Elemen...	Default (5.e-002)
Smoothing	Medium
Mesh Metric	None
Inflation	
Advanced	
Statistics	

Details of "Mesh"

Initial Size Seed	Assembly
Bounding Box Diagonal	9.9379e-002 m
Average Surface Area	1.7489e-004 m²
Minimum Edge Length	2.2471e-004 m
Quality	
Check Mesh Quality	Yes, Errors
Error Limits	Aggressive Mechani...
Target Element Quality	Default (5.e-002)
Smoothing	Medium
Mesh Metric	None
Inflation	
Use Automatic Inflation	None
Inflation Option	Smooth Transition
Transition Ratio	0.272
Maximum Layers	5
Growth Rate	1.2
Inflation Algorithm	Pre
View Advanced Options	No
Advanced	
Number of CPUs for Para...	Program Controlled
Straight Sided Elements	No
Rigid Body Behavior	Dimensionally Redu...
Triangle Surface Mesher	Program Controlled
Topology Checking	Yes
Pinch Tolerance	Please Define
Generate Pinch on Refre...	No
Statistics	
Nodes	16123
Elements	9112

FEA Simulation (Boundary Conditions)



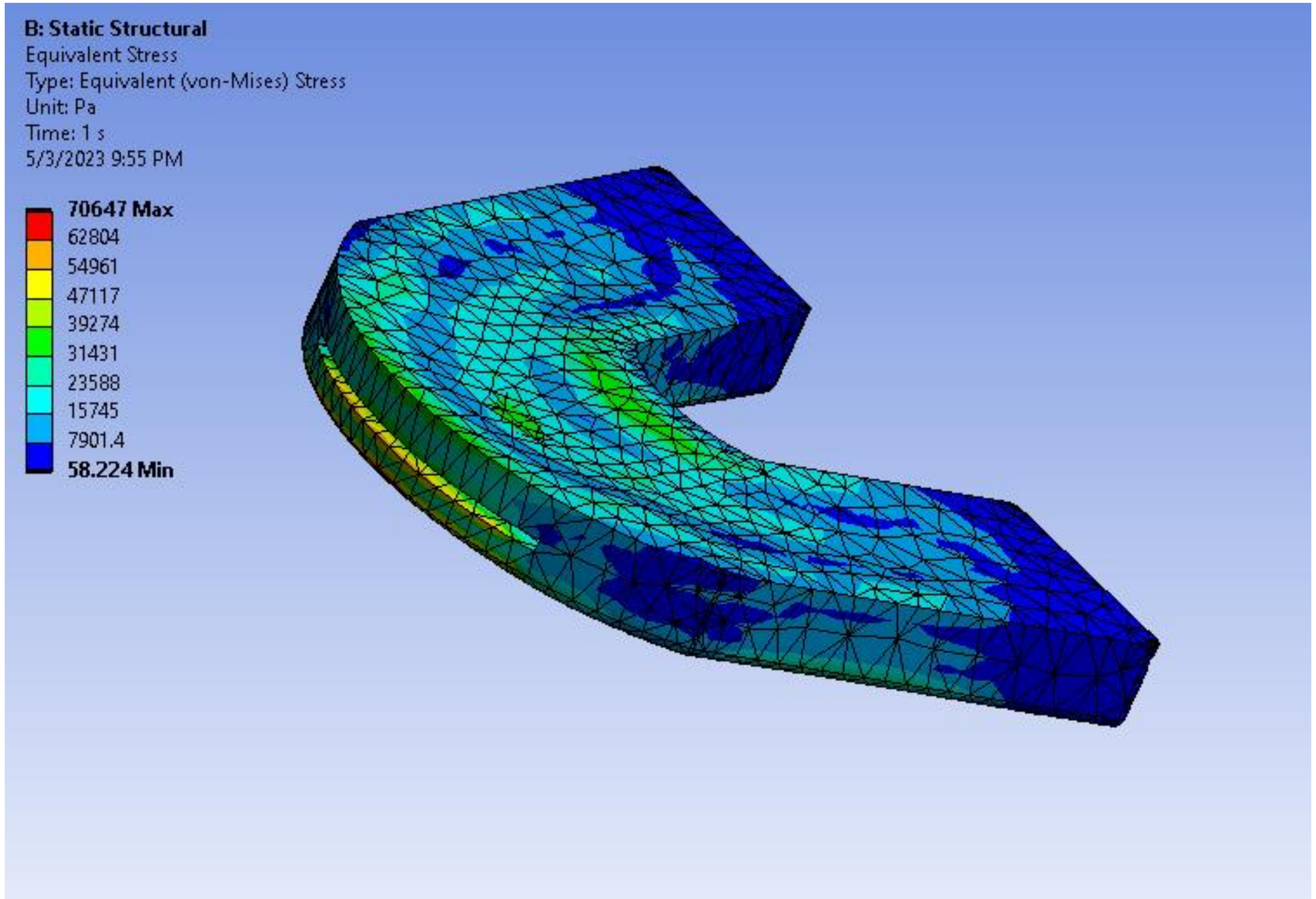
FEA Simulation (Analysis Settings)

Details of "Analysis Settings"

Step Controls	
Number Of Steps	1.
Current Step Number	1.
Step End Time	1. s
Auto Time Stepping	On
Define By	Substeps
Initial Substeps	10.
Minimum Substeps	10.
Maximum Substeps	100.
Solver Controls	
Solver Type	Program Controlled
Weak Springs	Off
Solver Pivot Checking	Program Controlled
Large Deflection	On
Inertia Relief	Off
Quasi-Static Solution	Off
Rotordynamics Controls	
Restart Controls	
Nonlinear Controls	
Advanced	
Output Controls	
Analysis Data Management	
Visibility	

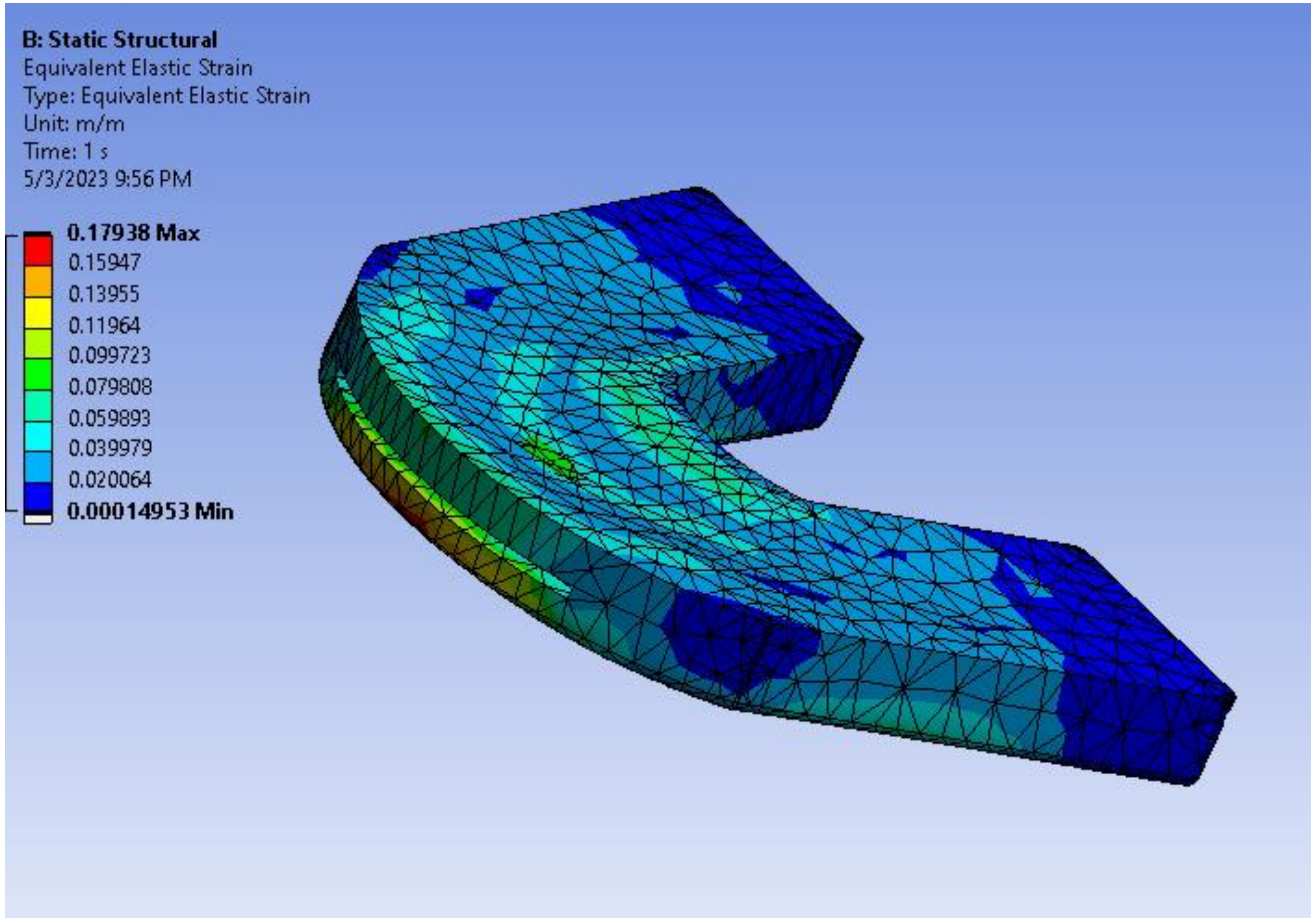
FEA Simulation (Results)

Stress:



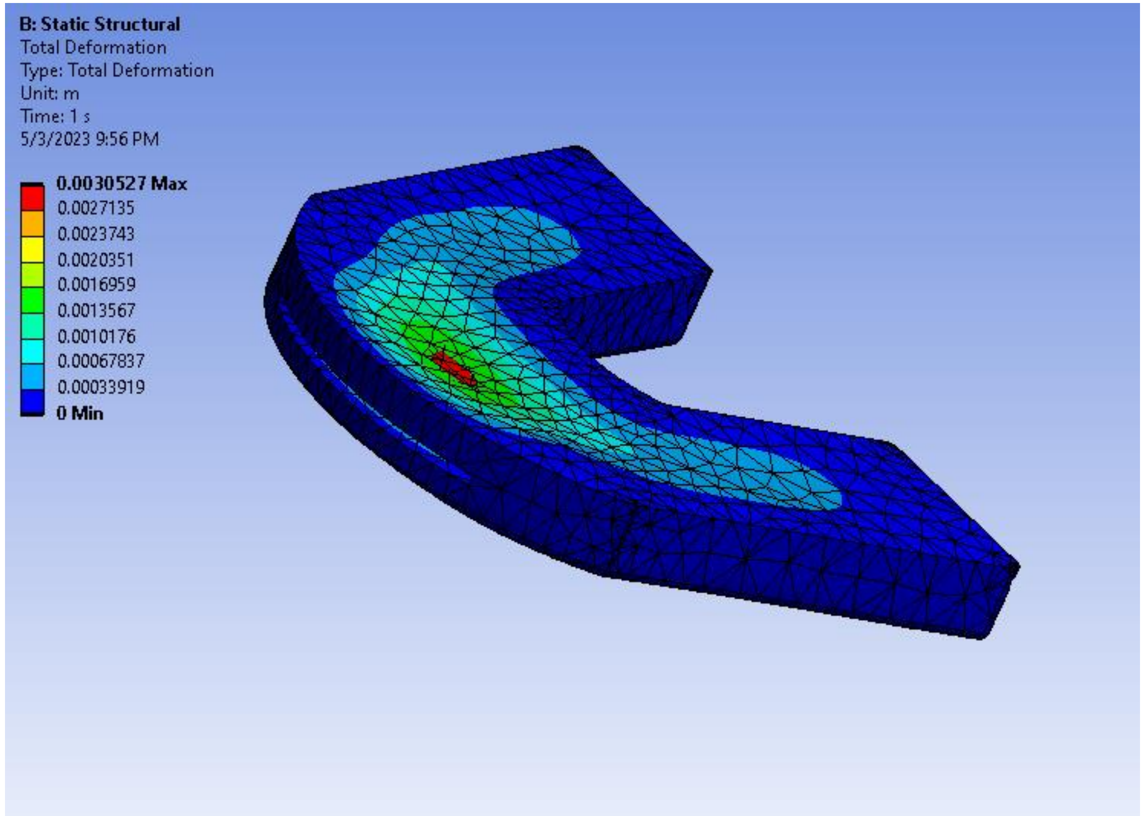
FEA Simulation (Results)

Strain:



FEA Simulation (Results)

Deformation:



https://youtu.be/MeNV149ahEk

Our Learnings and Future Scope

New things we learnt during this project:

- The maximum bite force of the natural teeth of healthy adults in the molar area can be anywhere between 300 and 600 Newtons.
- If you increase resistance in the circuit, the sensitivity of the piezo sensor increases.

Future Scope:

- Thin film flexible piezoelectric pressure sensors can be custom made to desired shape that can be used to ensure complete coverage of teeth surface area.
- A tougher grade of EcoFlex (probably 00-50) or a more rigid yet hyperelastic material would withstand higher values of force.
- This device could be used by dentists to note changes in the patient’s bite force, during every visit, over a period of time to detect early onset of TMJD.
- This device could also be used to design and develop better night-time dental guards for bruxism patients.

Thank You

Any Questions?

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