Smart Materials and Structures (MECH 6334)

# Underwater propulsion system using Piezoelectric actuator

Project by
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# O U T L I N E

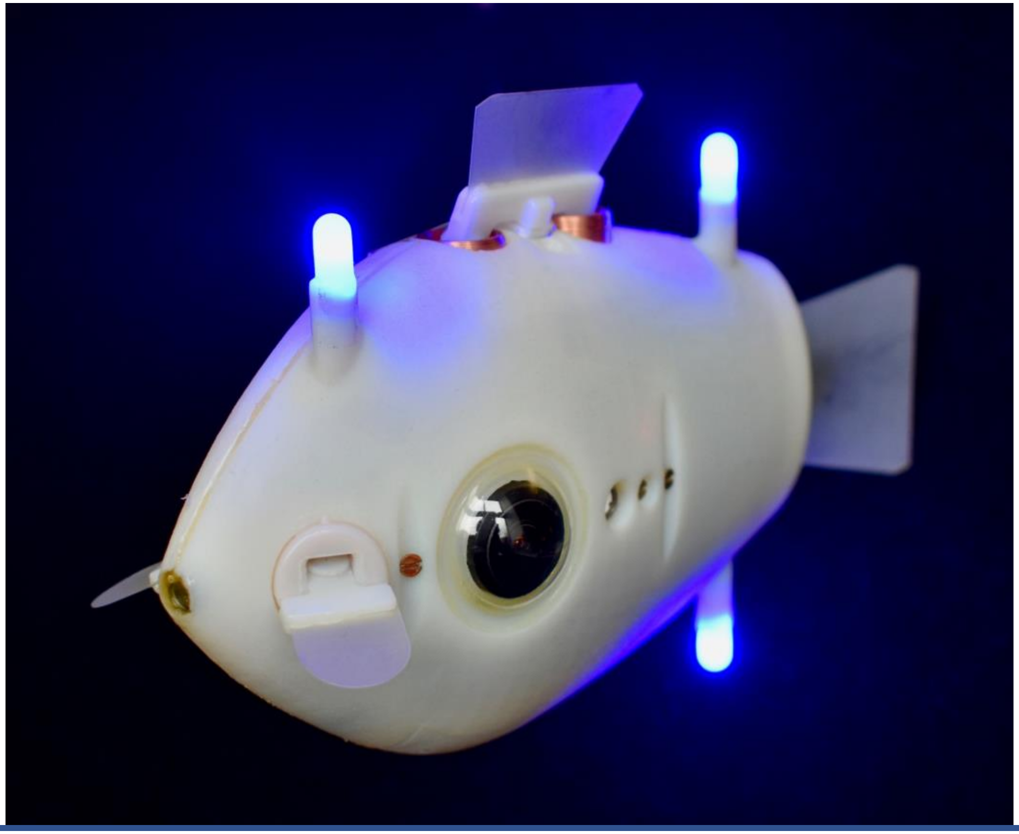
- ➢ Design Concept
- ➢ Operation Methodology
- ➢ Fabrication
- ➢ Results & Discussions
- ➢ Learning

# INPSIRATION

## SO-FI BY MIT

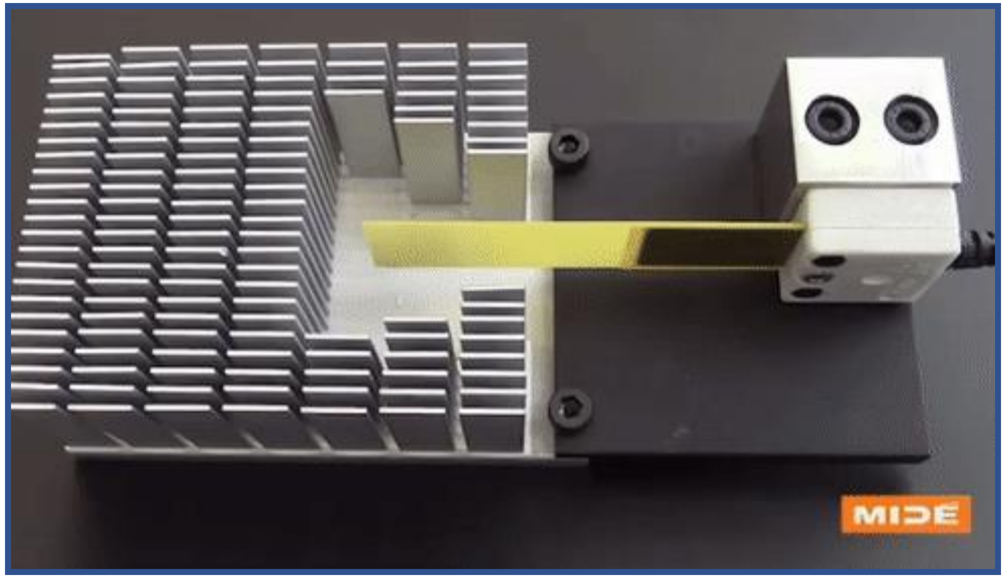

Katzschmann, R.K., DelPreto, J., MacCurdy, R. and Rus, D., 2018. Exploration of underwater life with an acoustically controlled soft robotic fish. *Science Robotics*, *3*(16), p.eaar3449.

## SWARM FISH BY HARVARD



Berlinger, F., Gauci, M. and Nagpal, R., 2021. Implicit coordination for 3D underwater collective behaviors in a fish-inspired robot swarm. *Science Robotics*, *6*(50), p.eabd8668.

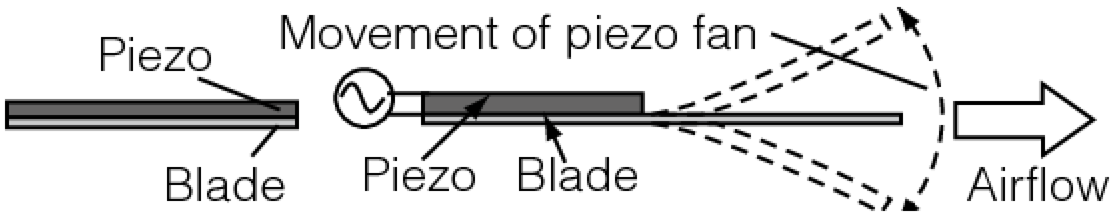
# PEIZO-ELECTRIC FAN

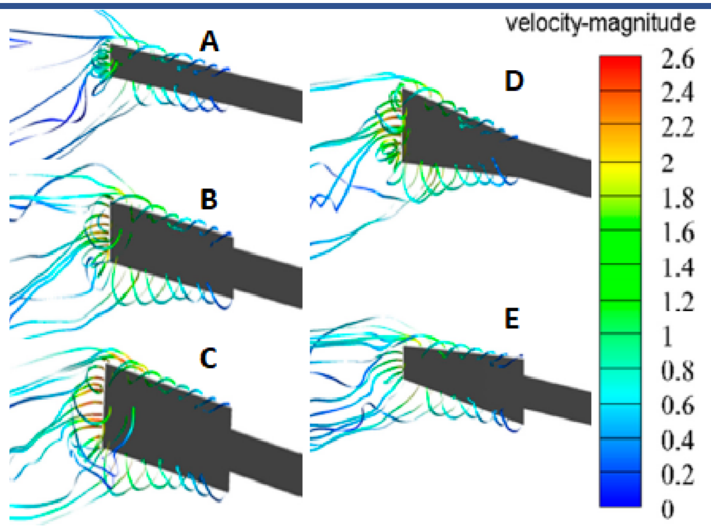


MIDE PZT Fan

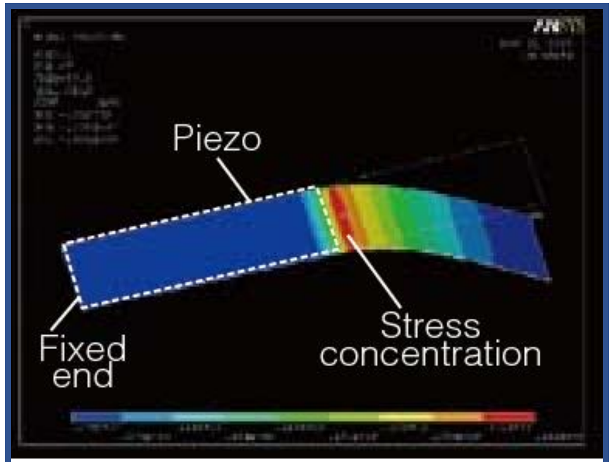
- Solid State device
- No moving parts
- Better efficiency
- Higher life span

WORKING OF A PZT FAN

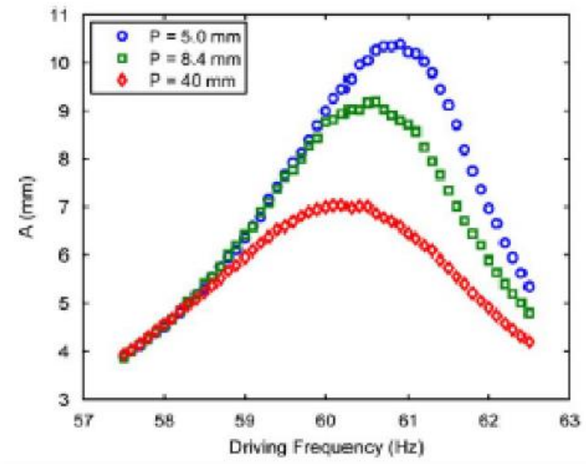



AIRFLOW OVER BLADE



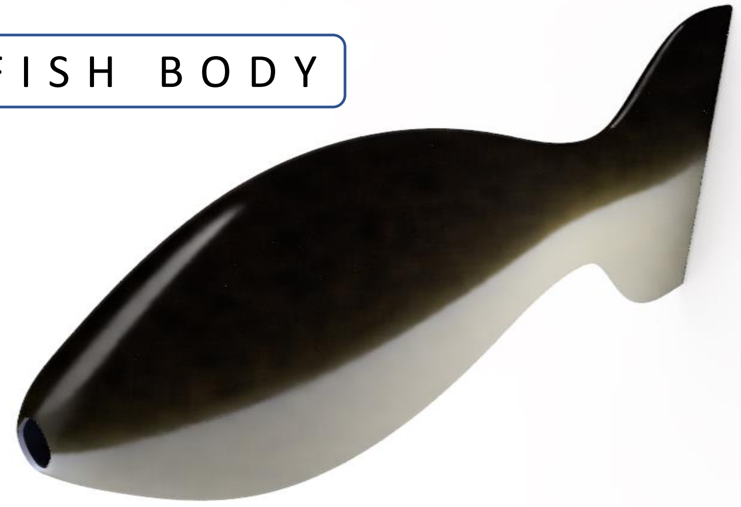

STRESS ANALYSIS



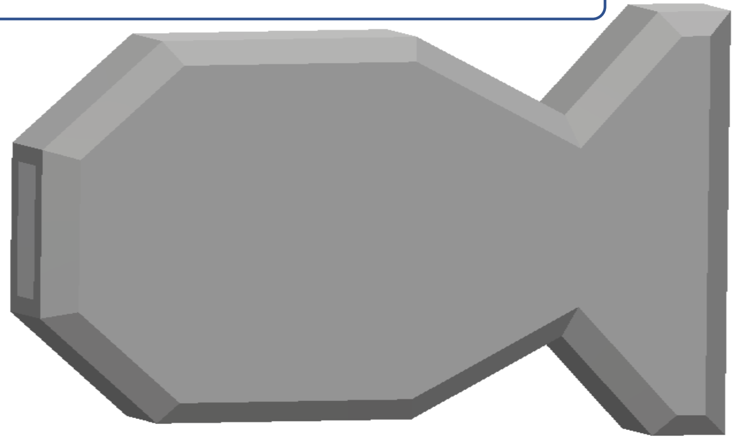

AMP VS FREQUENCY

# DESIGN CONCEPT

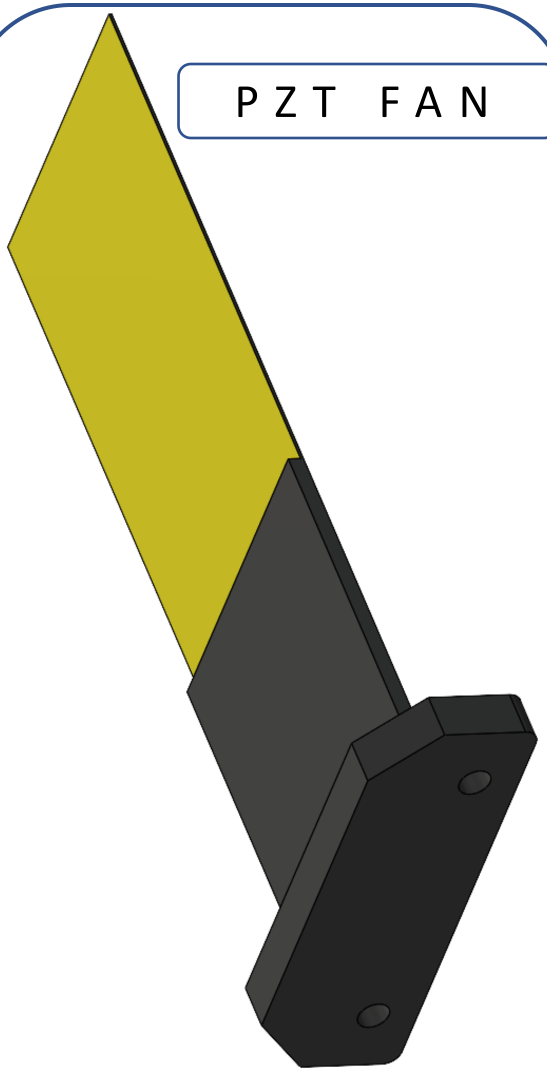
FISH BODY

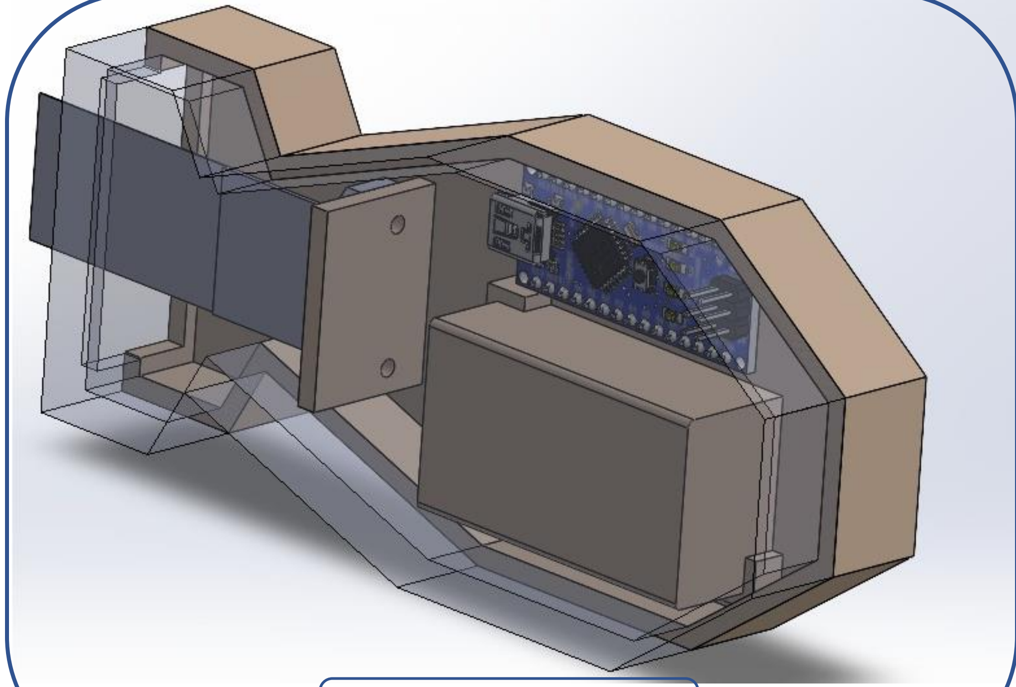


SIMPLIFIED DESIGN



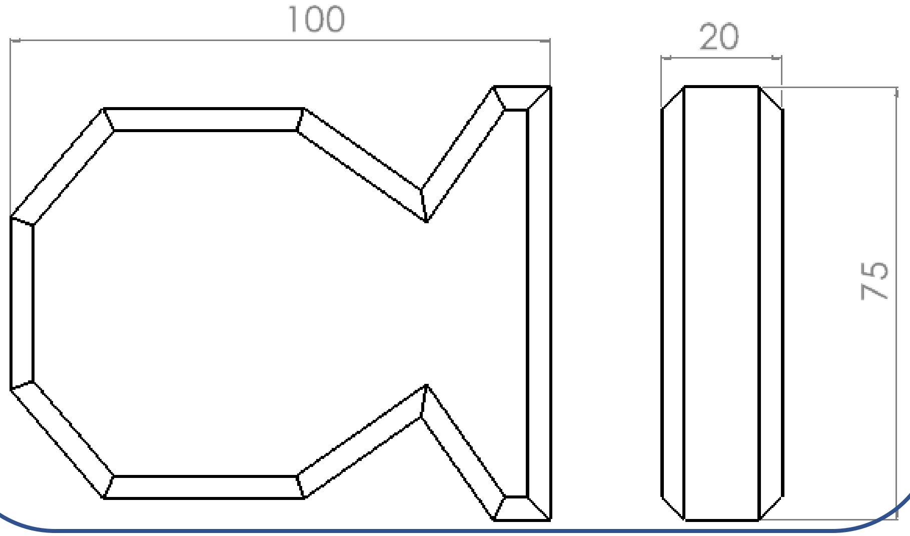
PZT FAN

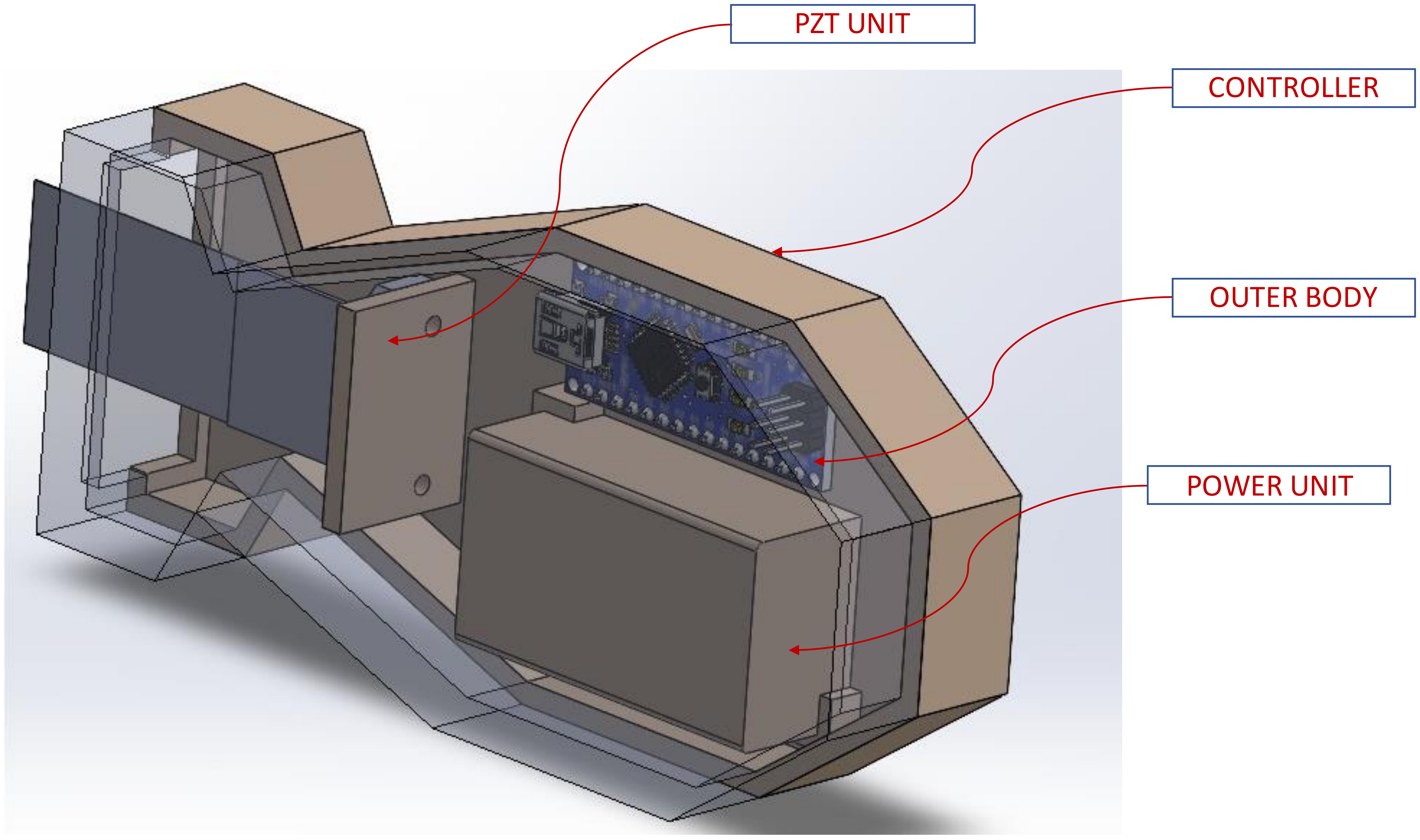




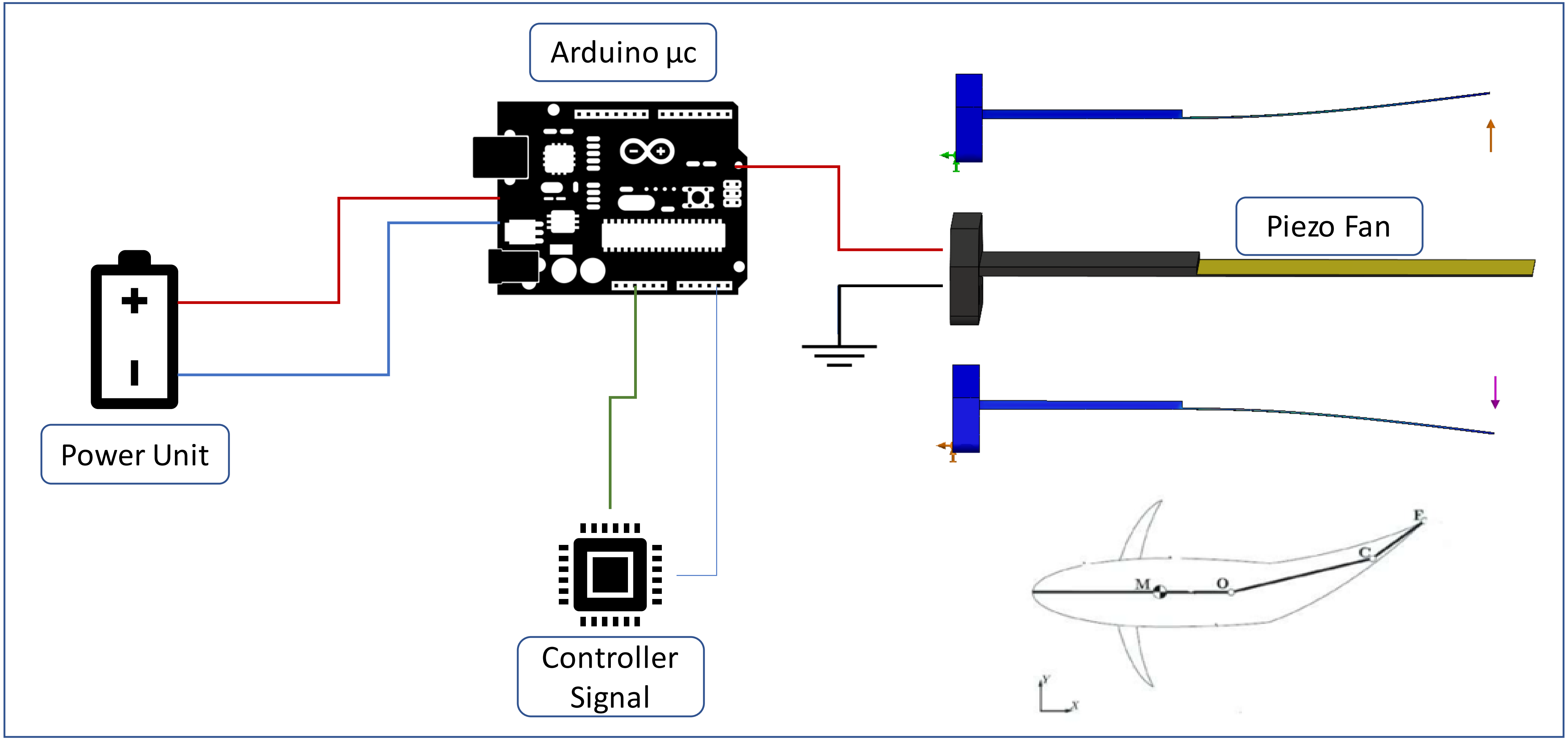
ASSEMBLY

DRAWING

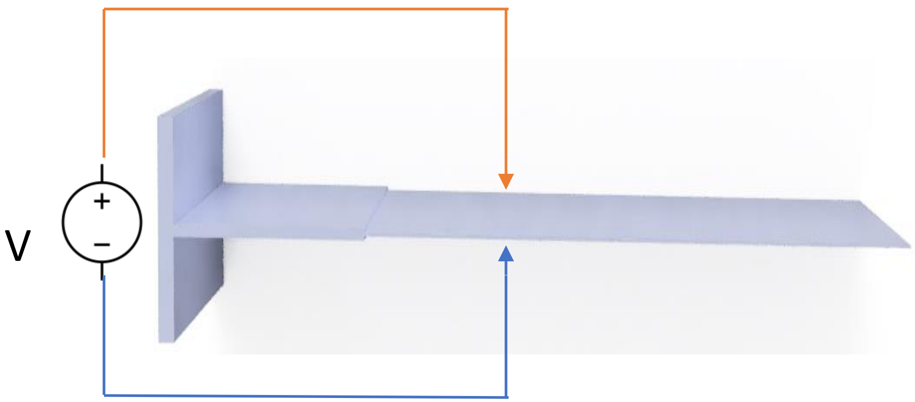



PZT UNIT
CONTROLLER
OUTER BODY
POWER UNIT

# O P E R A T I O N

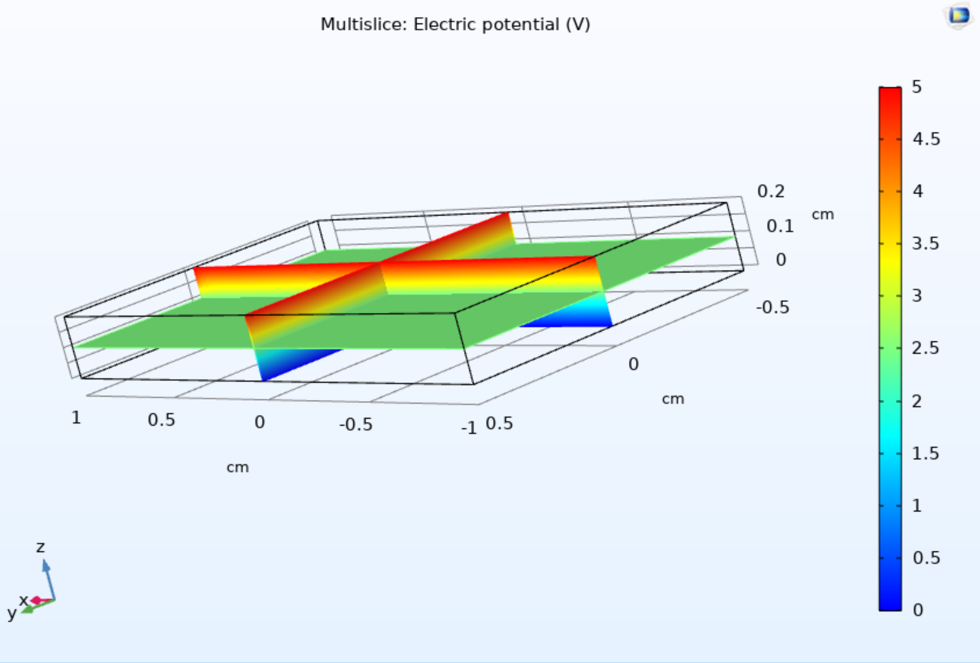


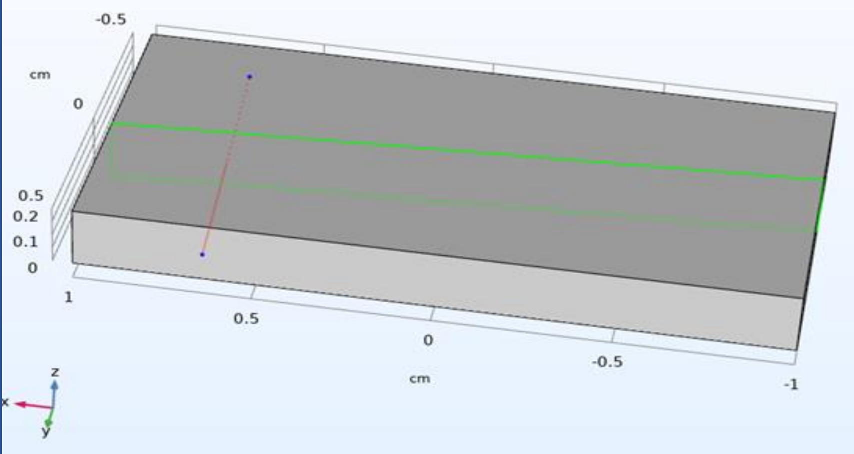
# S I M U L A T I O N S

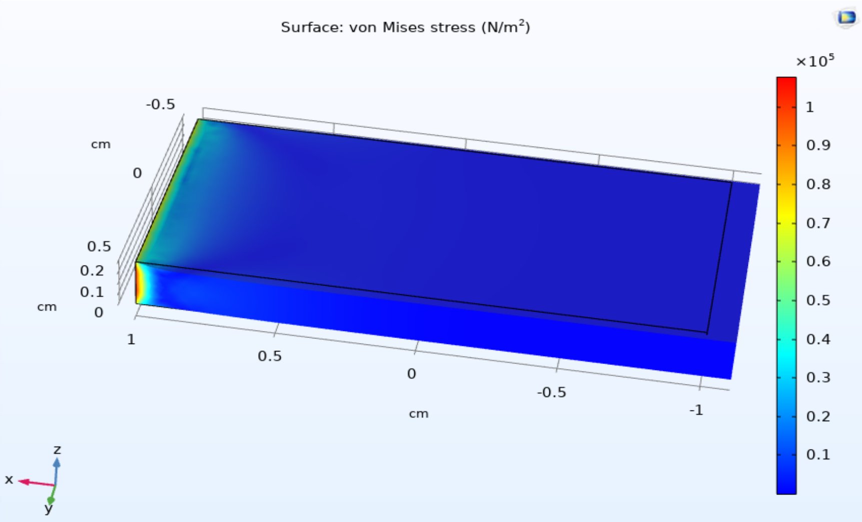


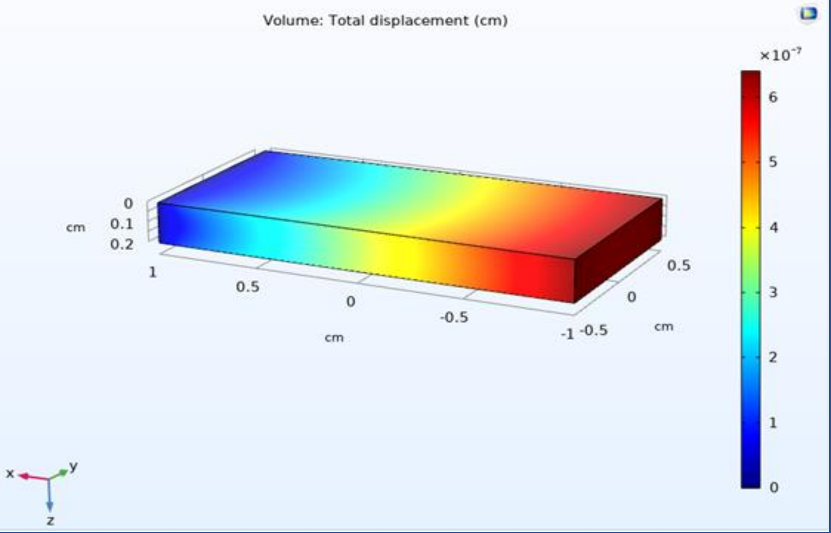

## COMSOL MULTIPHYSICS

- Stationary Simulation of Piezo-electric effect.
- One side fixed
- Electric potential in transverse direction



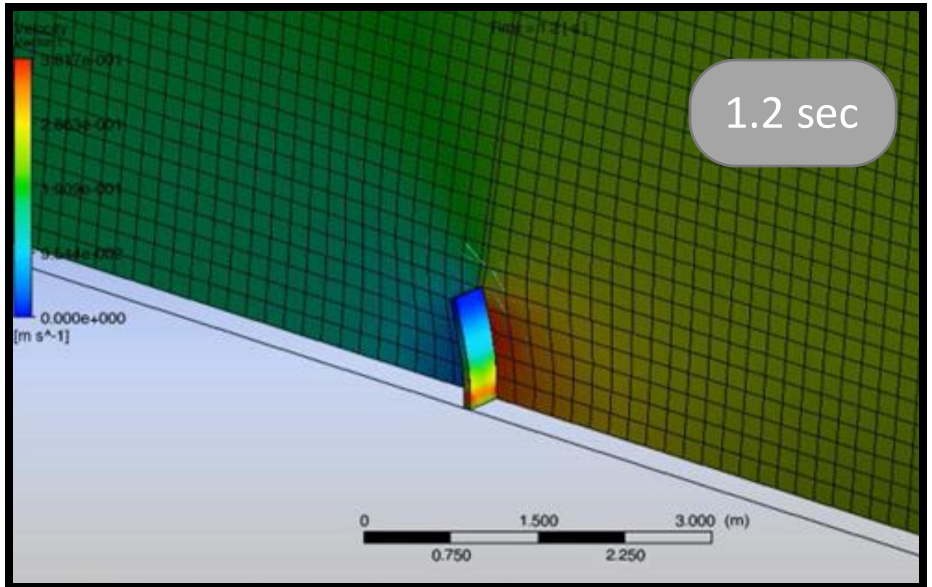



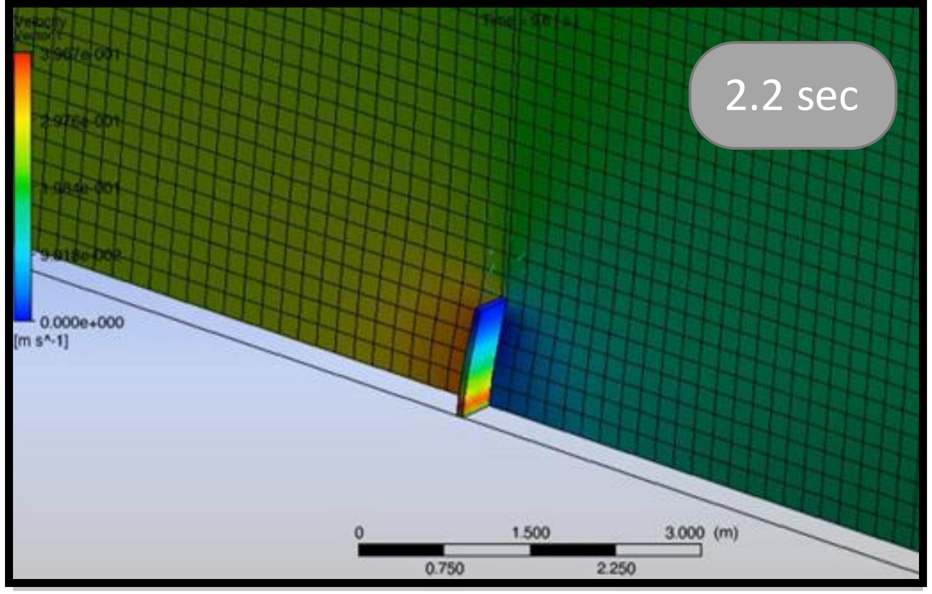



# SIMULATIONS

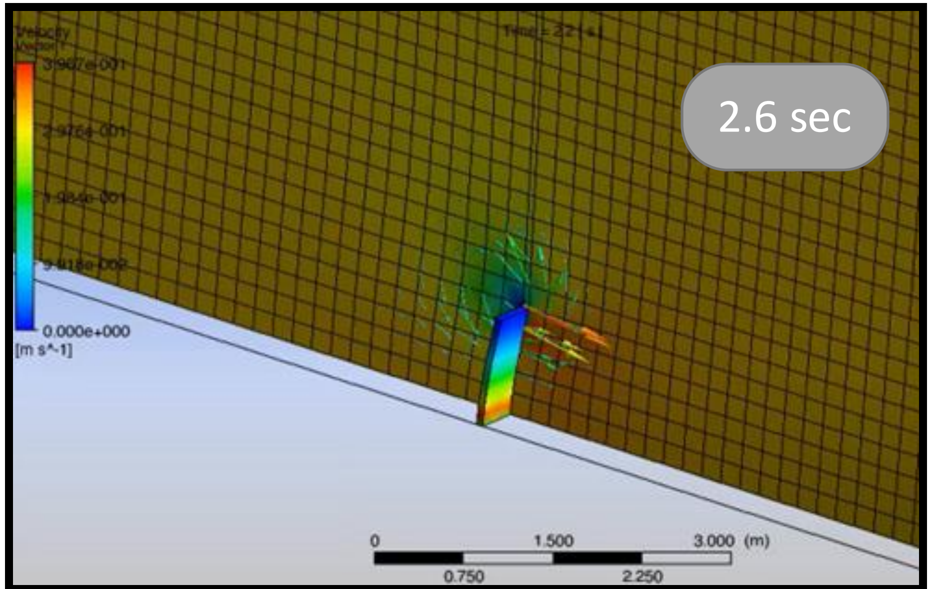
## ANSYS WORKBENCH

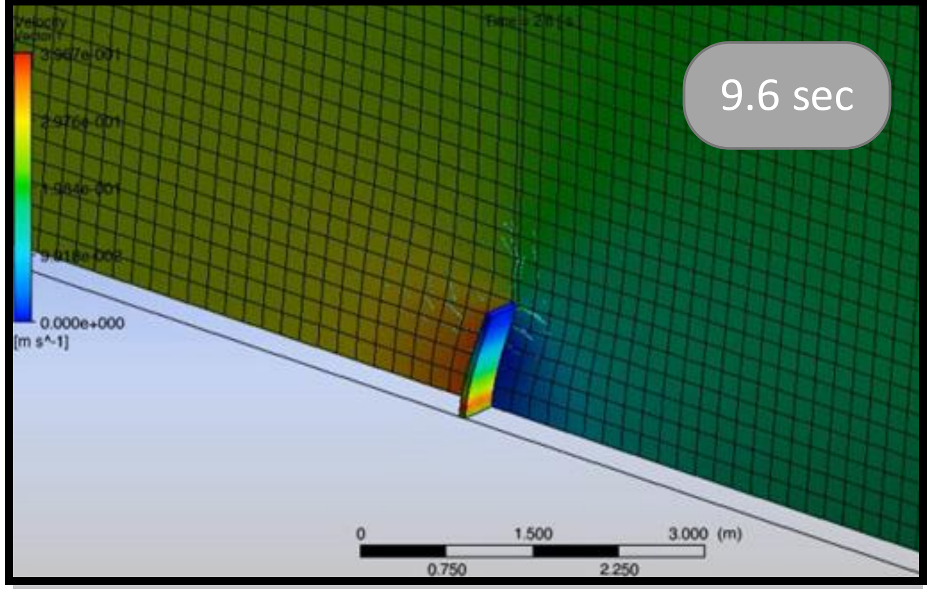
## VELOCITY DISTRIBUTION



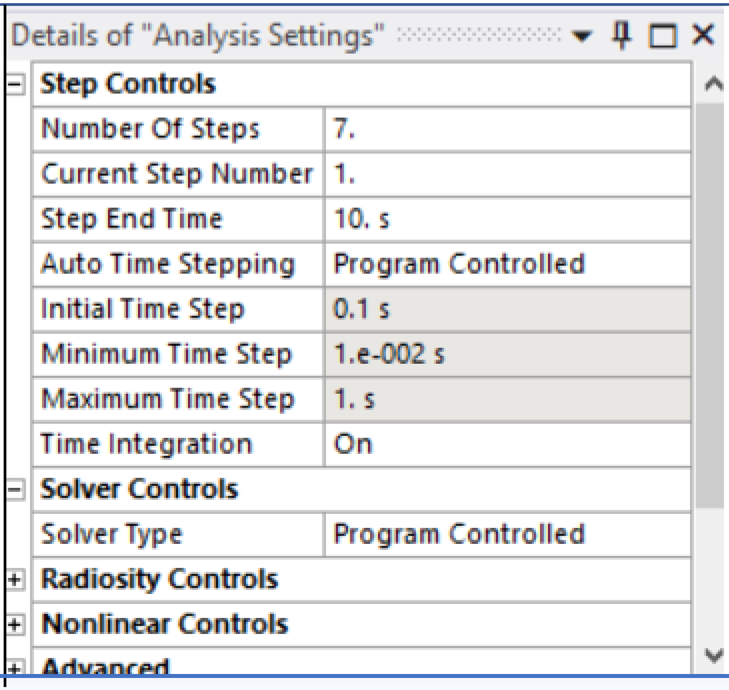

Velocity change at different time intervals for piezo-electric fin in water medium



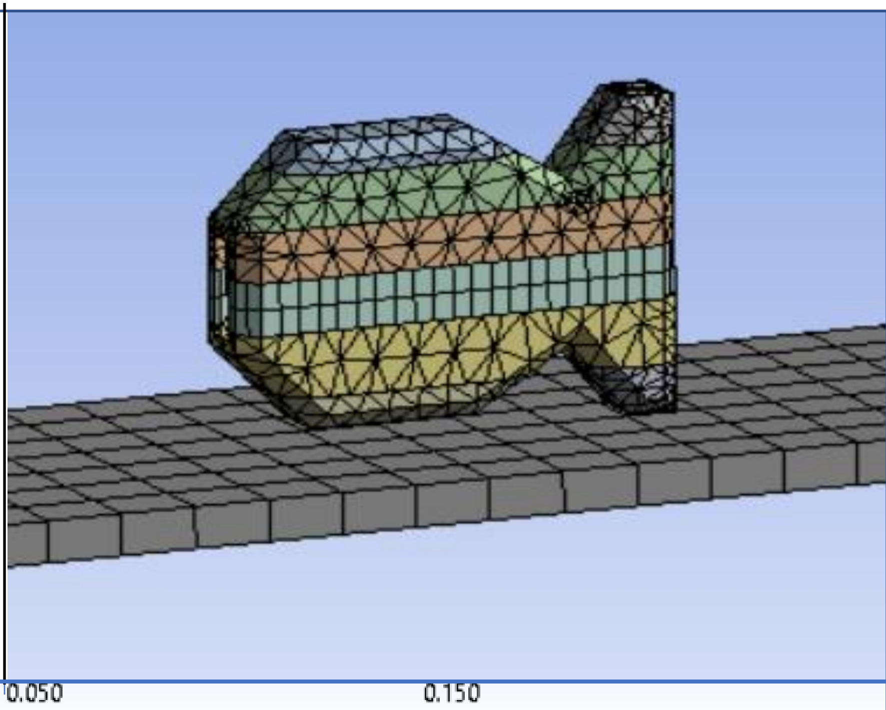



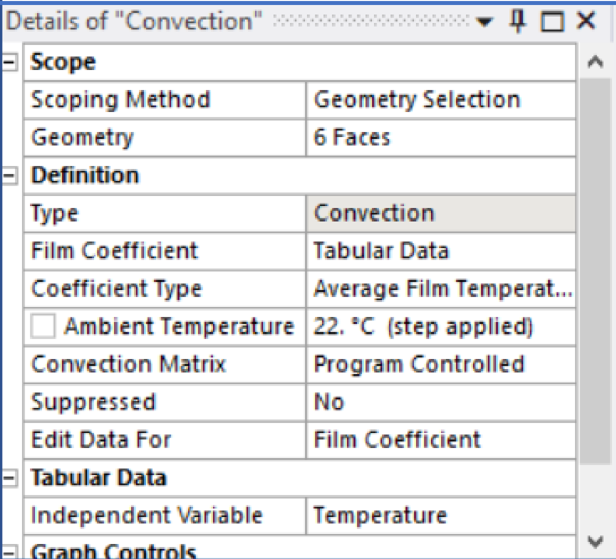
# F A B R I C A T I O N

- 3D PRINTING OF FISH BODY
- FDM PROCESS
- SIMULATED IN ANSYS WORKBENCH
- USING SIMPLIFIED DESIGN FOR ANALYSIS PURPOSE

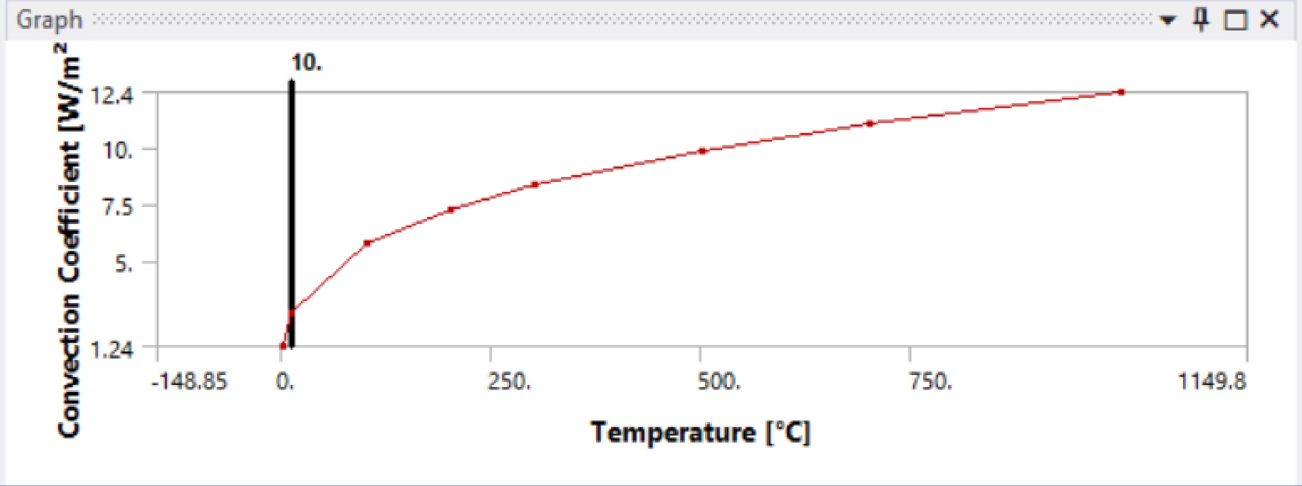

Details of "Analysis Settings"

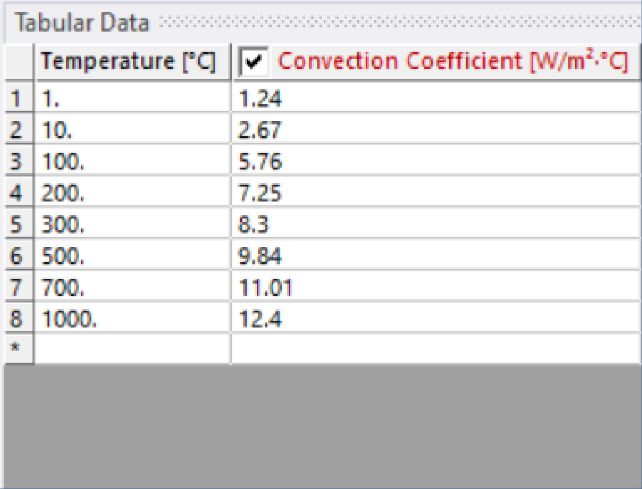
| | |
|---|---|
| **Step Controls** | |
| Number Of Steps | 7. |
| Current Step Number | 1. |
| Step End Time | 10. s |
| Auto Time Stepping | Program Controlled |
| Initial Time Step | 0.1 s |
| Minimum Time Step | 1.e-002 s |
| Maximum Time Step | 1. s |
| Time Integration | On |
| **Solver Controls** | |
| Solver Type | Program Controlled |
| **Radiosity Controls** | |
| **Nonlinear Controls** | |
| **Advanced** | |



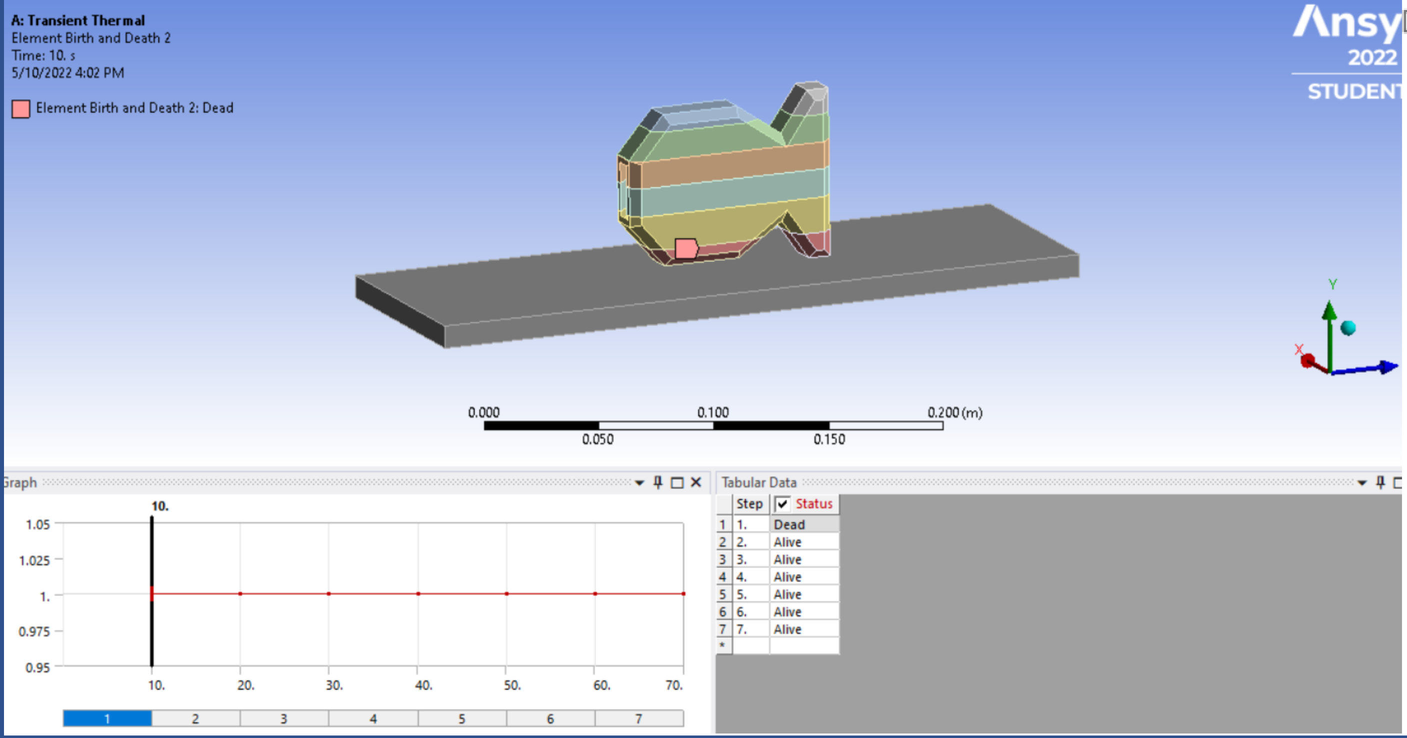


Details of "Convection"

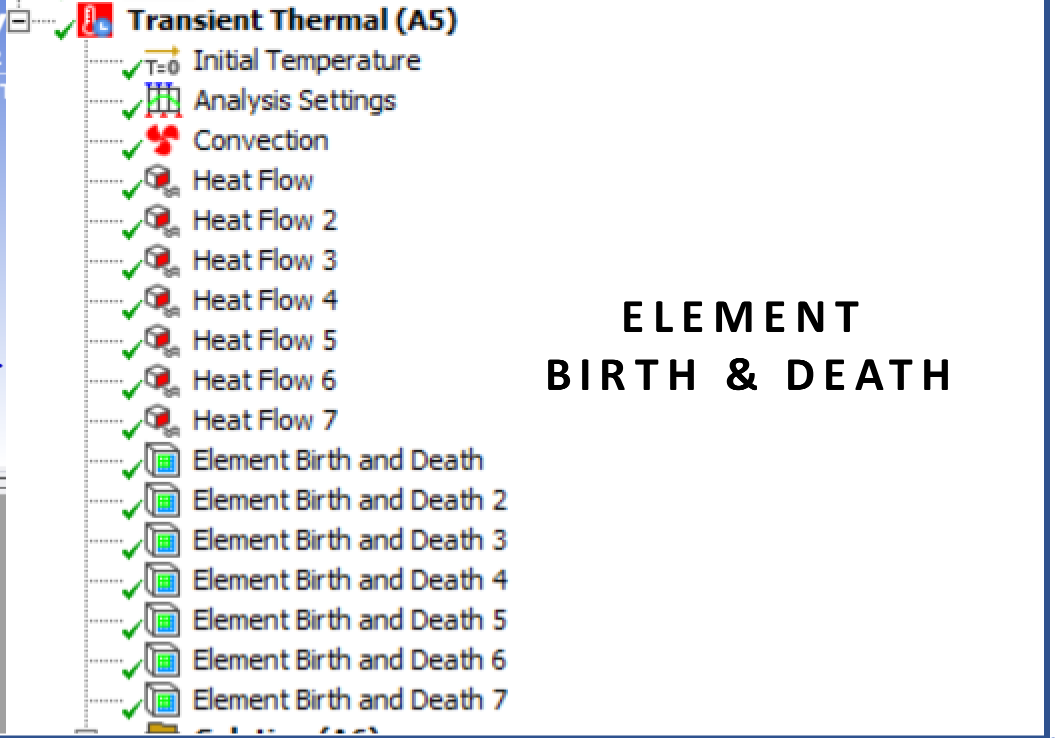
| | |
|---|---|
| **Scope** | |
| Scoping Method | Geometry Selection |
| Geometry | 6 Faces |
| **Definition** | |
| Type | Convection |
| Film Coefficient | Tabular Data |
| Coefficient Type | Average Film Temperat... |
| Ambient Temperature | 22. °C (step applied) |
| Convection Matrix | Program Controlled |
| Suppressed | No |
| Edit Data For | Film Coefficient |
| **Tabular Data** | |
| Independent Variable | Temperature |
| **Graph Controls** | |





Tabular Data

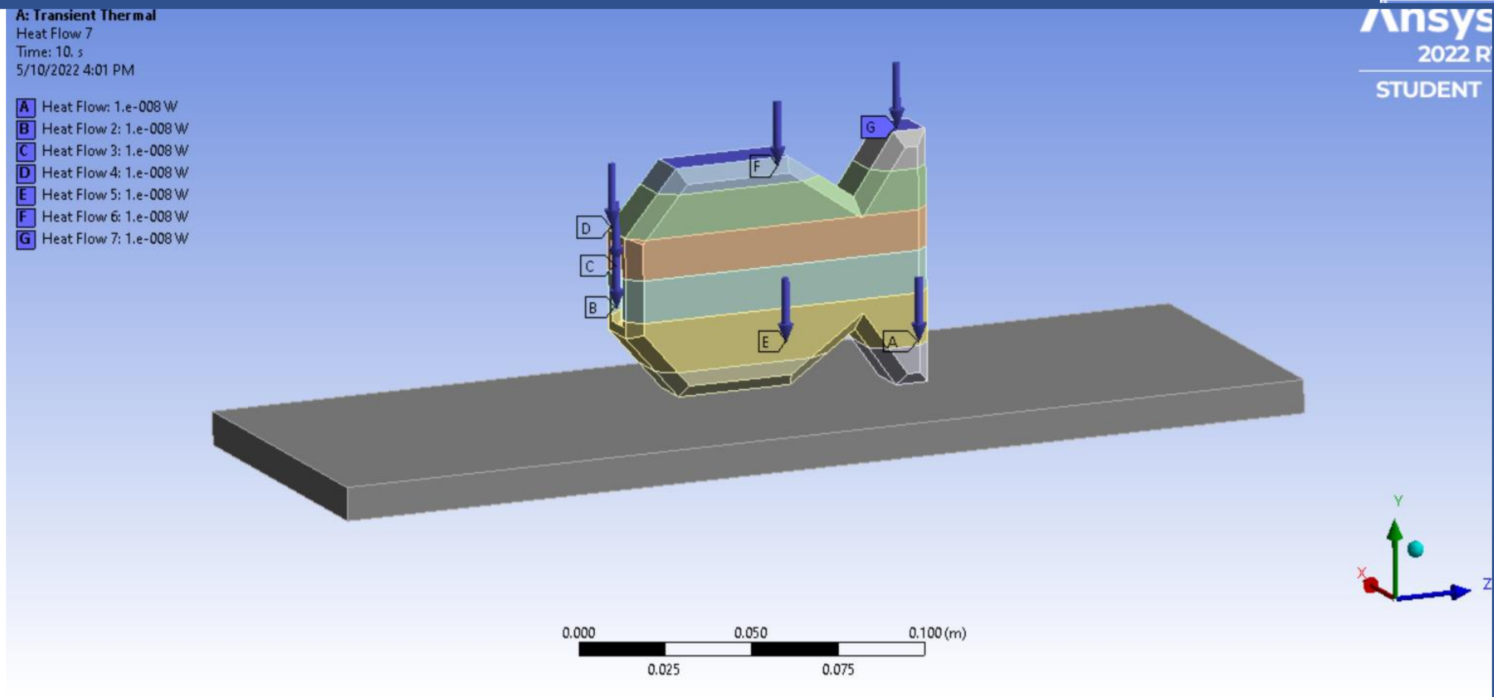
| | Temperature [°C] | Convection Coefficient [W/m²·°C] |
|---|---|---|
| 1 | 1. | 1.24 |
| 2 | 10. | 2.67 |
| 3 | 100. | 5.76 |
| 4 | 200. | 7.25 |
| 5 | 300. | 8.3 |
| 6 | 500. | 9.84 |
| 7 | 700. | 11.01 |
| 8 | 1000. | 12.4 |
| * | | |

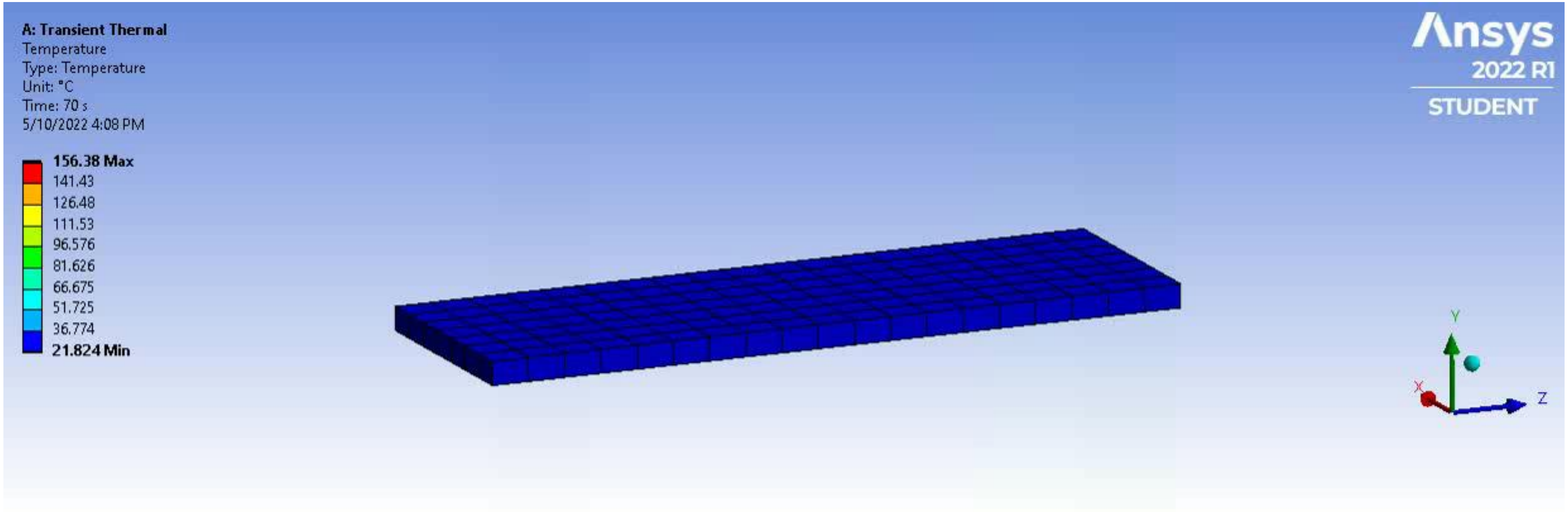



**ELEMENT BIRTH & DEATH**

**HEAT FLUX INPUT**



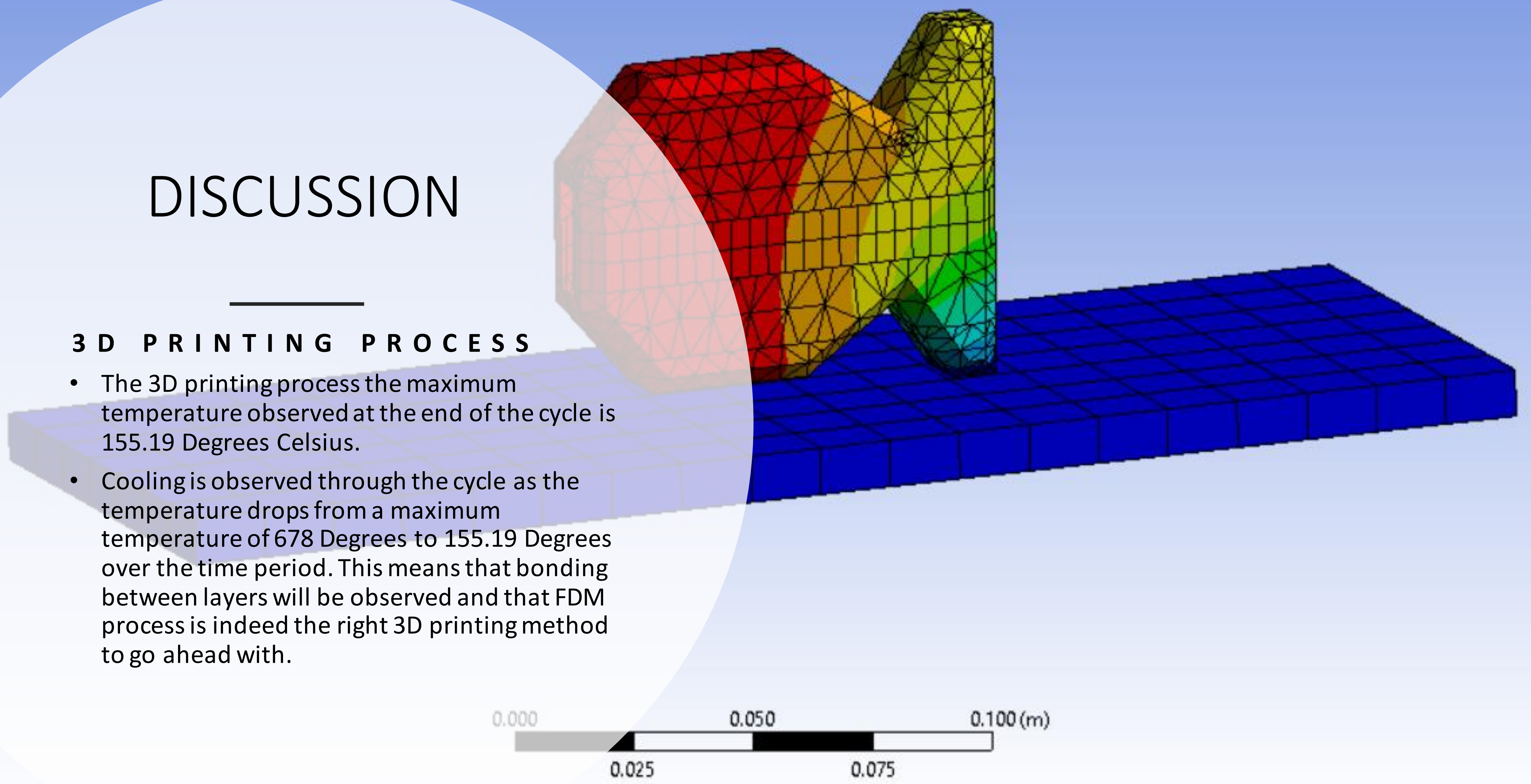

A: Transient Thermal
Temperature
Type: Temperature
Unit: °C
Time: 70 s
5/10/2022 4:08 PM
156.38 Max
141.43
126.48
111.53
96.576
81.626
66.675
51.725
36.774
21.824 Min
Ansys
2022 R1
STUDENT
Y
X
Z

# SIMULATION

# DISCUSSION

### 3D PRINTING PROCESS

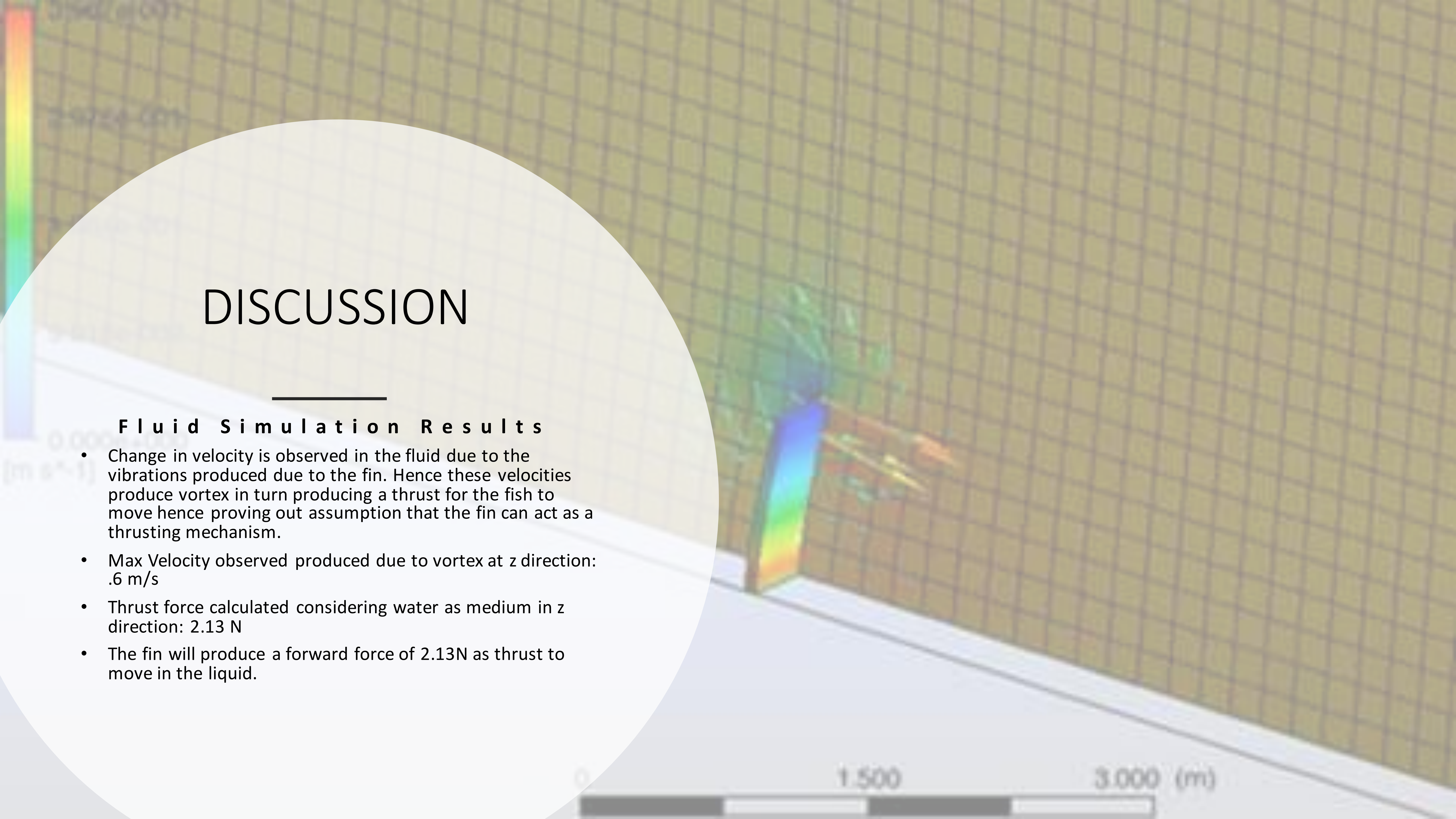
- The 3D printing process the maximum temperature observed at the end of the cycle is 155.19 Degrees Celsius.
- Cooling is observed through the cycle as the temperature drops from a maximum temperature of 678 Degrees to 155.19 Degrees over the time period. This means that bonding between layers will be observed and that FDM process is indeed the right 3D printing method to go ahead with.



# DISCUSSION

**Fluid Simulation Results**

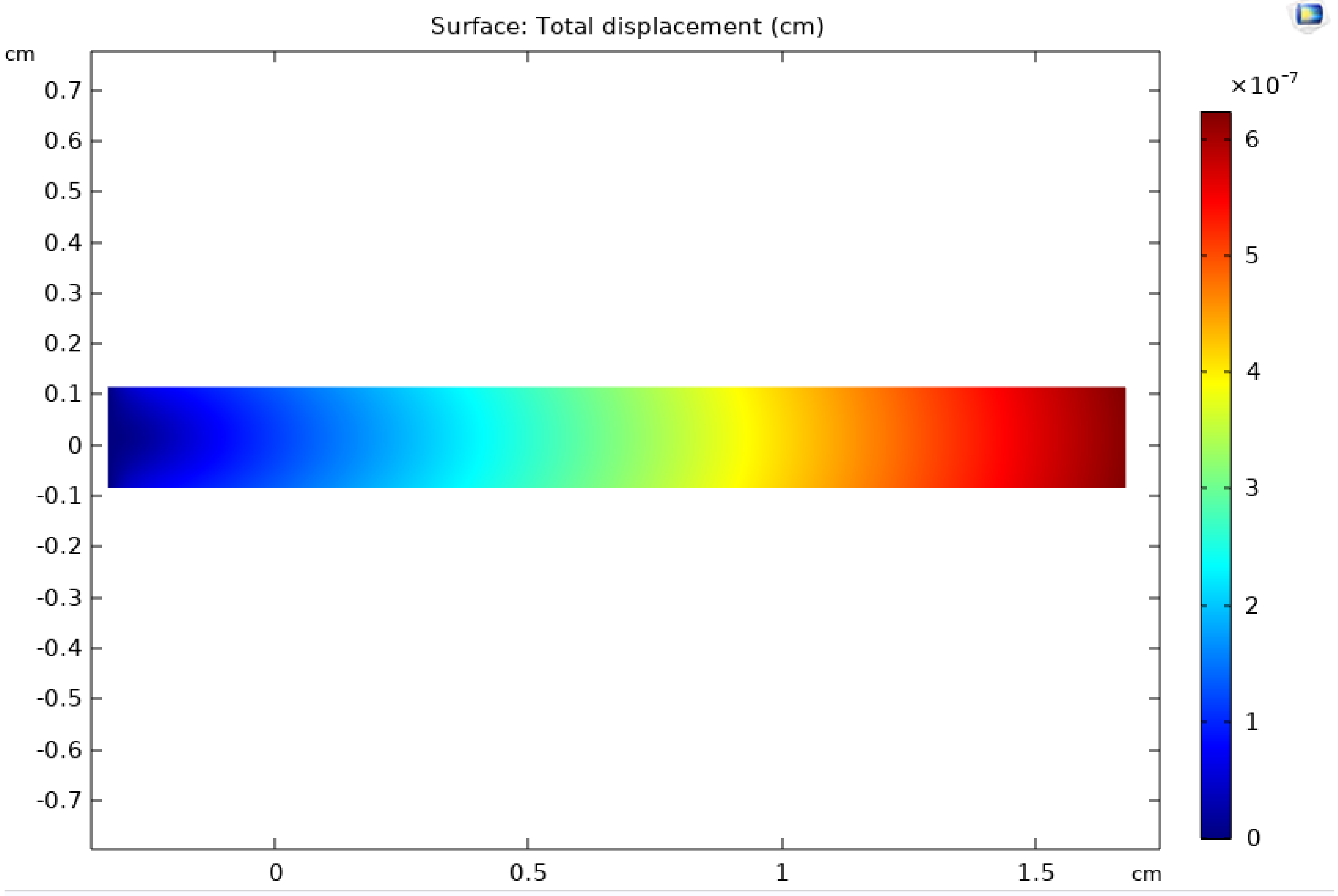
- Change in velocity is observed in the fluid due to the vibrations produced due to the fin. Hence these velocities produce vortex in turn producing a thrust for the fish to move hence proving out assumption that the fin can act as a thrusting mechanism.
- Max Velocity observed produced due to vortex at z direction: .6 m/s
- Thrust force calculated considering water as medium in z direction: 2.13 N
- The fin will produce a forward force of 2.13N as thrust to move in the liquid.



# DISCUSSION

### COMSOL RESULTS

- The comsol Multiphysics simulations were carried out with ideal conditions.
- The results clearly show the displacement at free end when voltage potential is provided.
- The deflection can be amplified by using amplification linkage mechanism, which is a necessity since displacement is very small.



# L E A R N I N G

- PEIZO-ELECTRIC EFFECT
- THERMO-ELECTRIC SIMULATIONS
- CFD SIMULATIONS
- FDM (3D PRINTING) ANALYSIS
- FUTURE WORK