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Design and Analysis of Linear Wave Energy Converter Model

Omkar Shinde[1], Sushant Chavan[2], Yash Talegaonkar[3], Neha Jadhav[4]

[1-4]Department of Mechanical Engineering, Smt. Kashibai Navale College of Engineering, Savitribai Phule Pune University

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Abstract - *The aim of the paper is to design and analyses a point absorber device to obtain the power absorbed by it. Point absorbers use the energy of Ocean to generate the electricity, because of the difficulty in actual ocean wave testing of the prototype it is important to test the prototype in a tank with favorable conditions. This paper focuses on Design of tank and calculation of power absorbed by the prototype device.*

Keywords—Point absorber wave energy converter, Scotch yoke mechanism, Wave energy, Linear generator, Flap wave maker

1. INTRODUCTION

Electric power plays an important role in today's world. You need electricity for Industry, Agriculture, transport, Communication etc. The population, geographic size, industrial diversity and abundant energy resources makes India a major producer and a major consumer of electricity. Day by day along with population, Electric Power demand is increasing with consumption rate in all the sectors. Electric energy is important in the entire process of development and growth of human beings, which plays a major role in the social and economic development of a country.

India is geographically well-placed to generate ocean thermal energy, with around 2000 kms of coast length along the South Indian coast, where a temperature difference of above 20oC is available throughout the year. That means, about 1.5x106 square kilometres of tropical water in the Exclusive Economic Zone around India with a power density of 0.2 MW/km2. The total OTEC potential around India is estimated as 180,000 MW, considering 40% of gross power for parasitic losses. However, the cost estimates of ocean energy as against conventional energy is still being worked out, as the country is still in a nascent stage of development of the technology and start generation.

2. DESIGN OF SCOTCH YOKE

A. Components :

- Motor
- Disc or Crank
- Slot
- Connecting Link

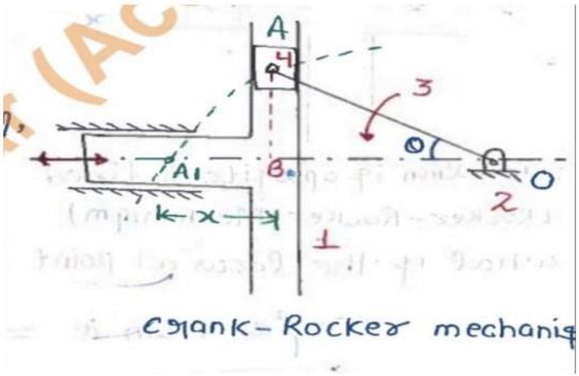
B. Motor :

From initial calculation the selected motor has specifications as follow:

RPM = 1330

Power = 0.37 KW

C. Radius Of Crank:



From the initial calculations, Stroke Length of Flap is 6cm.

Displacement of Slotted Bar

X = BA1

= OA1 – OB

=OA1 – OAcosθ

X = OA (1 - cosθ)

Where,

X = Displacement of Flap (6 cm)

OA = Radius Of Crank

Θ = Angle travelled by slot

Therefore,

6 = R (1 – cos (180))

R = 3 cm

So Radius Of Crank is 3cm,

D. Velocity Calculation

Crank rpm 1330

Radius r =3cm

$v=r\omega(\sin\theta)$

$v\_max=r\omega$

v_max=4.176 m/s

E. Force Calculation

Power of motor is given by $P = 2*\pi*N*T$ 60

Therefore $T = 0.37 * 60$ $2 * 3.14 * 1330$

Hence, T= 2.65 Nm

Torque = F * R

Therefore, F = 88.33 N

This force is cyclic in nature (SHM).

F. Final Design:

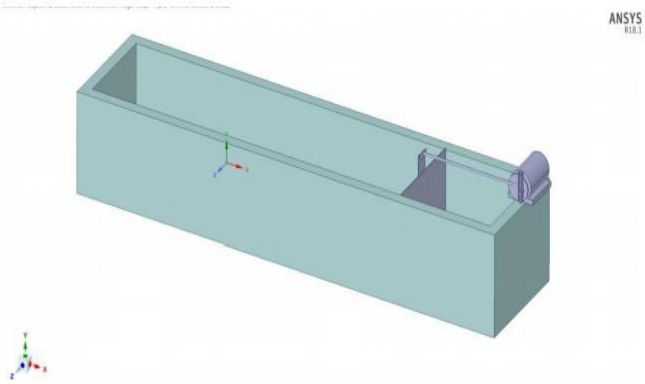


Figure 1 Final Design

3. FORCES ACTING ON FLAP

A .Theoretical Calculation

1. Static Pressure Force: The Force on the flap when the fluid is at rest is called Static Pressure Force

   Total Hydrostatic =Volume of Pressure Diagram
   Force = 0.5* ρ*g*h*h*(width of flap)
   = 0.5* ρ*9.81*0.45*0.45*0.5
   = 496.63 N

2. Dynamic Pressure Force: The Force on the flap when fluid is moving is called Dynamic Pressure Force.

$F_{(dynamic)}$= 0.5*ρ*A*V*V
= 0.5*1000*0.5*0.45*4.176*4.176
= **2300 N**

B. Virtual Analysis on Ansys Workbench Version R18.1 (Fluent)

1. Computational Fluid Dynamic (CFD) of FLAP: Input parameters are given in the below Figure

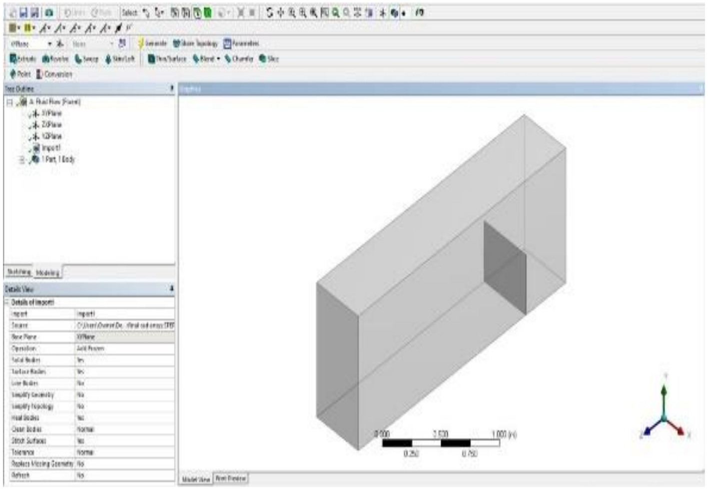


Figure 3 Geometry

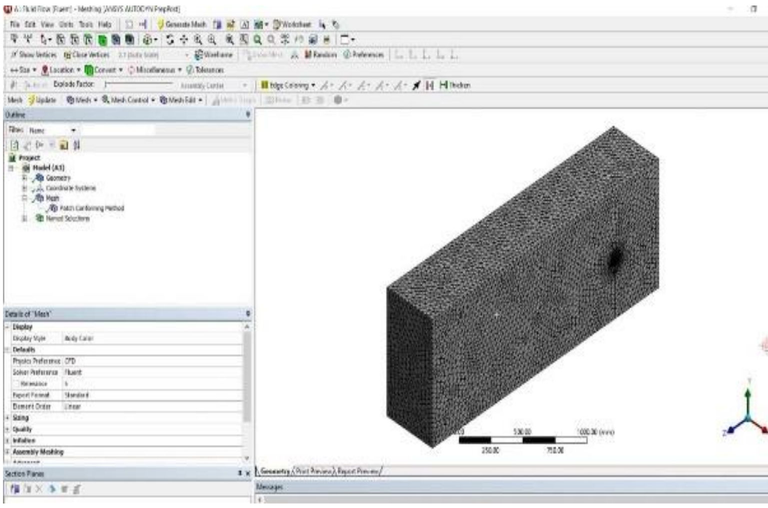


Figure 2 Meshing

Result

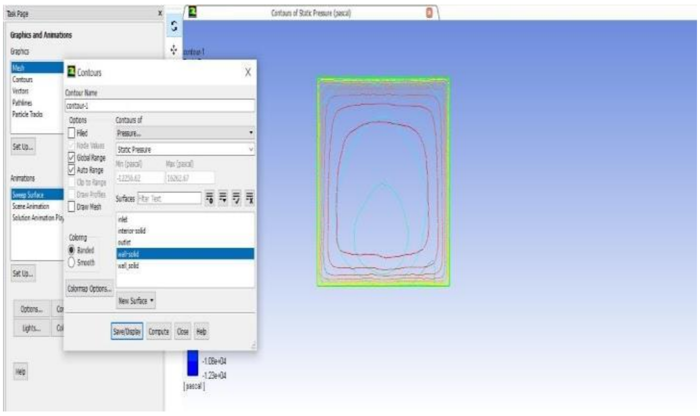


Figure 3 Static Pressure on Flap

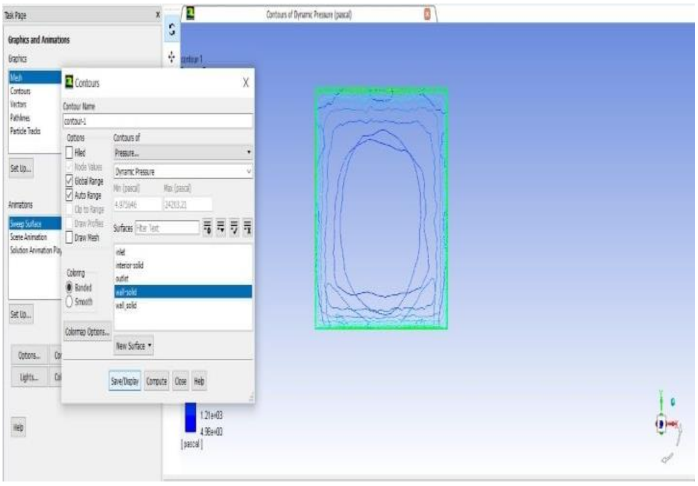


Figure 4 Dynamic Pressure on Flap

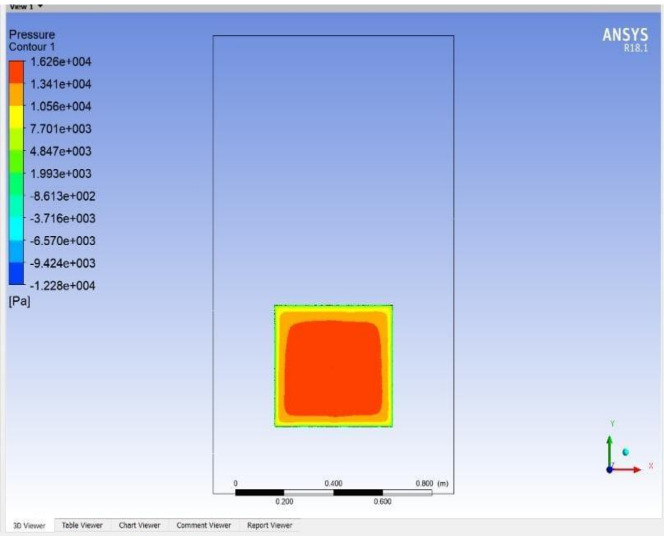


Figure 5 Pressure Distribution on Flap

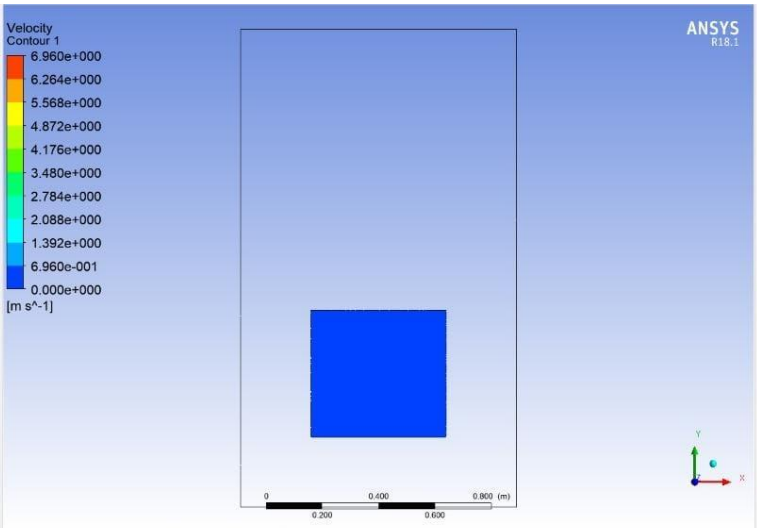


Figure 6 Velocity distribution on Flap

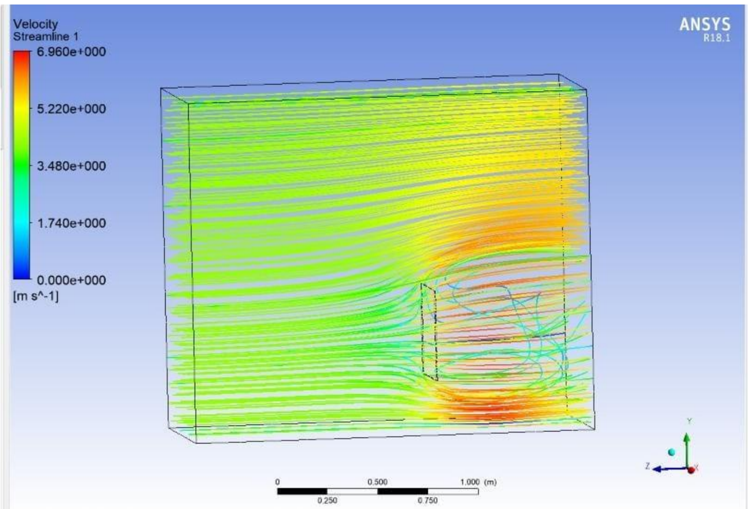


Figure 7 Streamlines around Flap

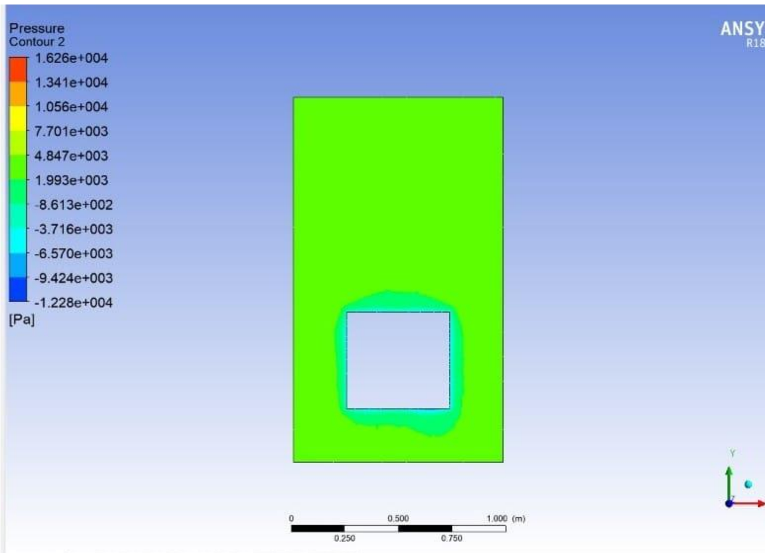


Figure 8 Pressure distribution around Flap

2. Conclusion: We have calculated the static and dynamic pressure on the flap using ANSYS CFD fluent software.
   Static Force= 500N
   Dynamic Force= 2500
   From the above obtained values it is clear that, the results obtained from Ansys CFD and Hand calculations are approximately equal.

4. STRESS ANALYSIS

The results obtaind from Computational Fluid Dynamics of the flap are used to compute the stresses on the scotch yoke mechanism.

A. Stress on connecting link

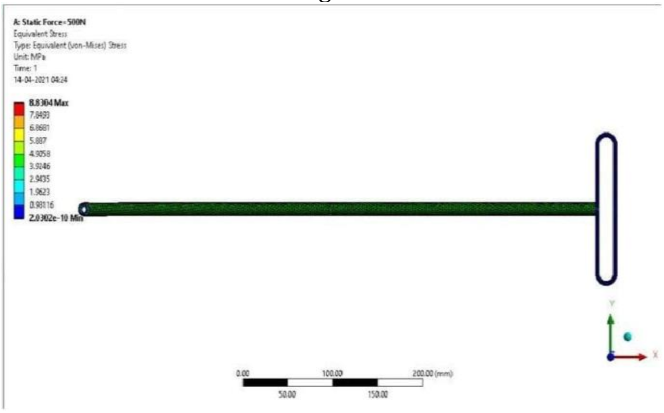


Figure 9 Equivalent Stress (Static force=500N)

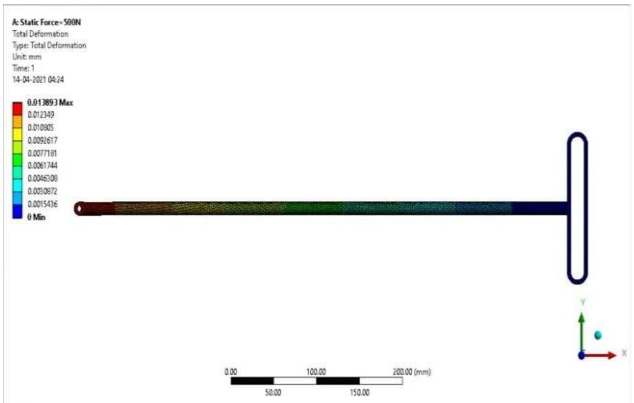


Figure 10 Total Deformation (Static force=500N)

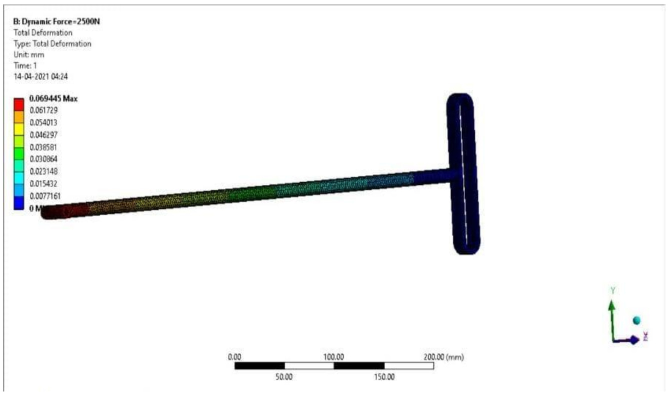


Figure 11 Total Deformation (Dynamic force=2500N)

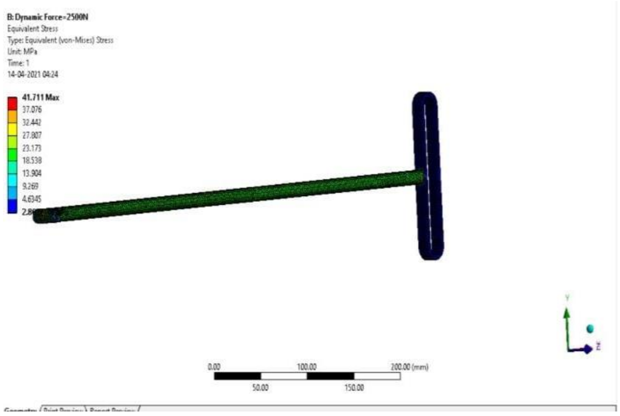


Figure 12 Equivalent Stress (Dynamic force=2500N)

B. Stress on Flap

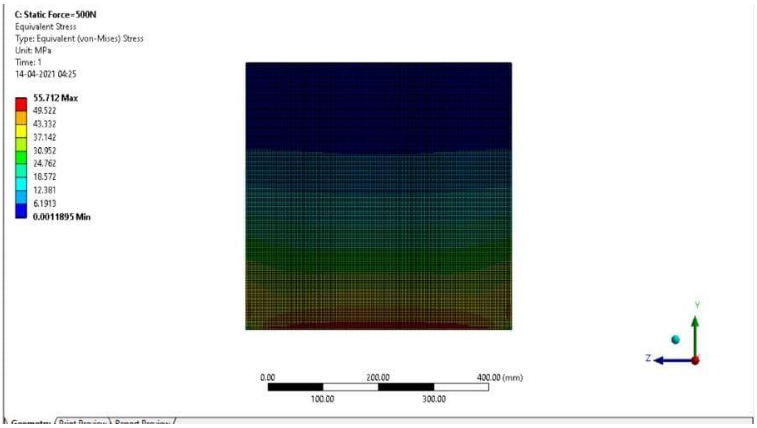


Figure 13 Equivalent stress (Static force=500N)

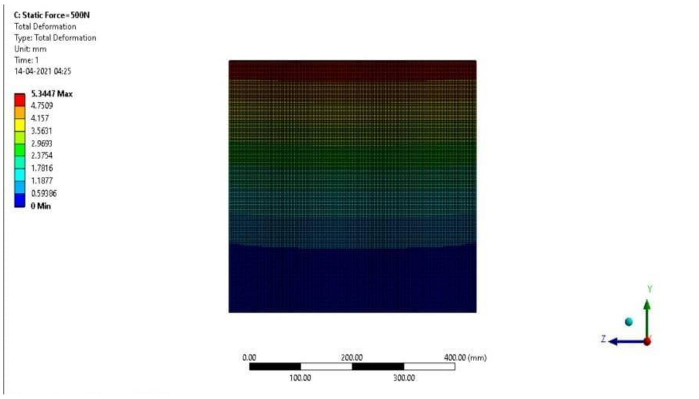


Figure 14 Total Deformation (Static force=500N)

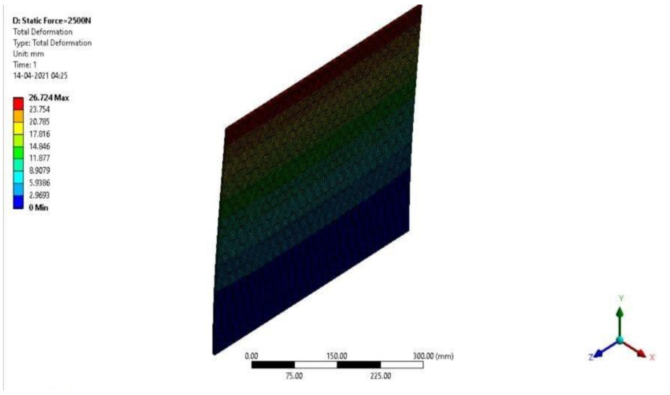


Figure 15 Total deformation (Static Force=2500N)

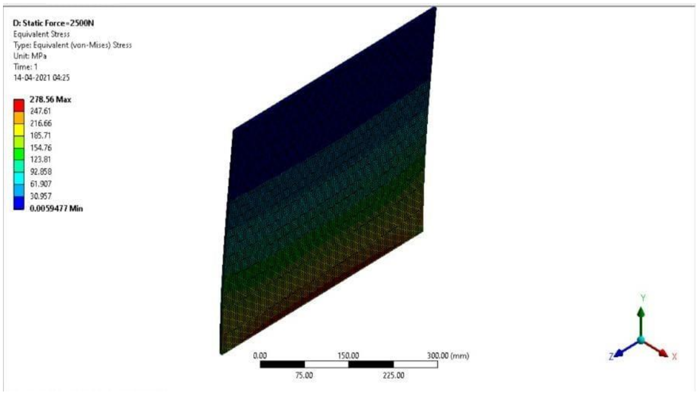


Figure 16 Equivalent stress (Static force=2500N)

C. Fatigue Analysis of Connecting link

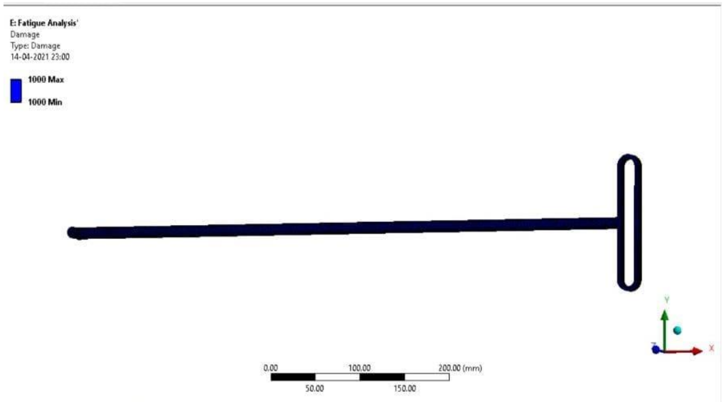


Figure 17 Fatigue Damage

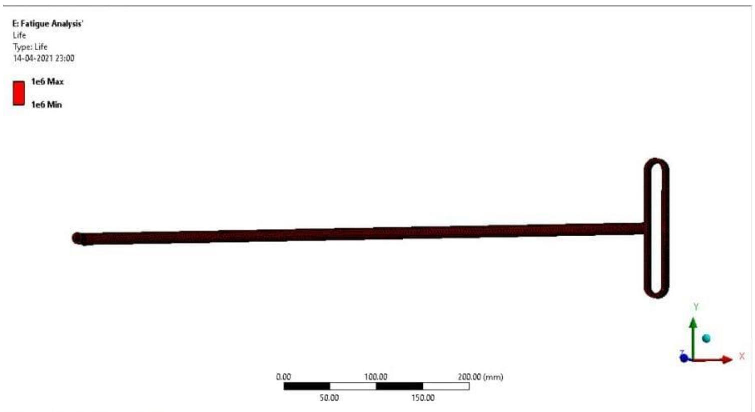


Figure 18 Fatigue life

D. CONCLUSION

The stress that we have calculated is less than the failure stress of the material. Hence, the design is safe.

In case of Fatigue Analysis, the fatigue life of the connecting link obtained is 10^6 cycles hence it will be safe for infinite number of cycles

5. MATHEMATICAL MODEL OF FLAP USING SCILAB XCOS

A. Introduction

We have mathematically modeled the wave generator that is flap using Scilab xcos. We have converted the entire model into spring mass damper system. This system is an example of forced vibration.

B. Equation of motion

This system is an example of single degree of freedom, forced, harmonic vibration.

SYSTEM = FLAP + DAMPER + SPRING.

DISPLACEMENT VARIABLE = Θ

Using D' Alembert's principle,

$$Ip \times \Theta + Fd \times (x) + Fs \times (y) = F(t) \times (y)$$

We have converted the above equation of motion into a graphical model to find the behavior of the system. We can get any one of the following behavior's

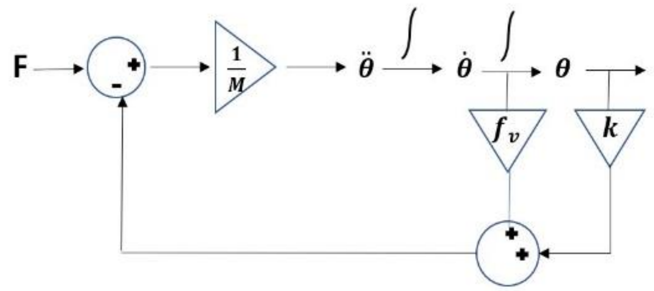


Figure 19 Mathematical model

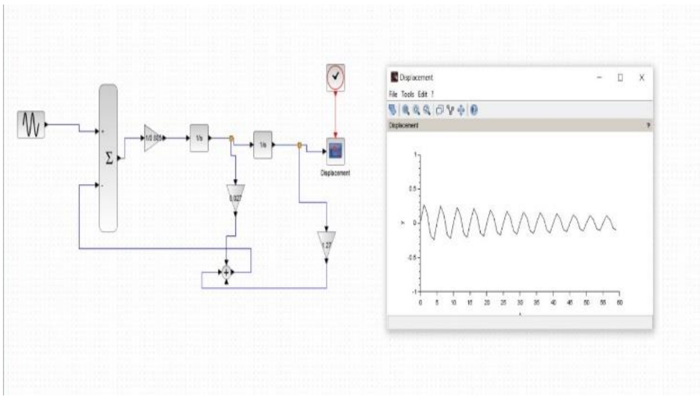


Figure 8 Result Graph

C. CONCLUSION

From the above graph we can conclude that, the system is under damped system

6. BUOY DESIGN

A. Components

- Oval Buoy
- Connecting Line
- Mechanical PTO
- Moorings

B. Working

Oval Buoy is chosen as a point absorber device because it can absorb the maximum power from the ocean waves.

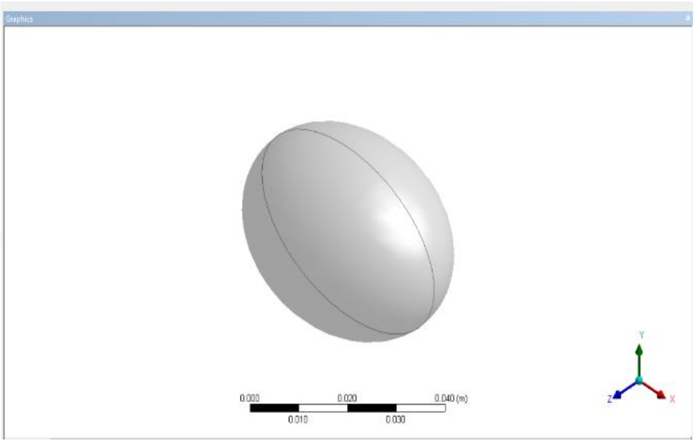
The buoy will be acted upon by the incident waves of the ocean which will result in heave type motion of the buoy. This heave type motion will be transferred with the help of connecting line to the Linear PTO.

Mechanical PTO: - It consists of magnets and a coil where magnet assembly is attached to the heaving float and the coil is located inside the spar. As the float moves up and down, the magnet assembly creates a change in magnetic field surrounding the spar that contains the coil, therefore current is induced in the coil and electricity is generated.

7. Mechanical PTO Simulink model

The entire PTO can be modelled in Simulink using WEC sim matlab as shown\ WEC-Sim (Wave Energy Converter Simulator) is an open-source wave energy converter simulation tool. The code is developed in MATLAB/SIMULINK using the multi-body dynamics solver Sims cape Multibody.

WEC-Sim has the ability to model devices that are comprised of rigid bodies, power-take-off systems, and mooring systems. Simulations are performed in the time-domain by solving the governing WEC equations of motion in 6 degrees-of-freedom



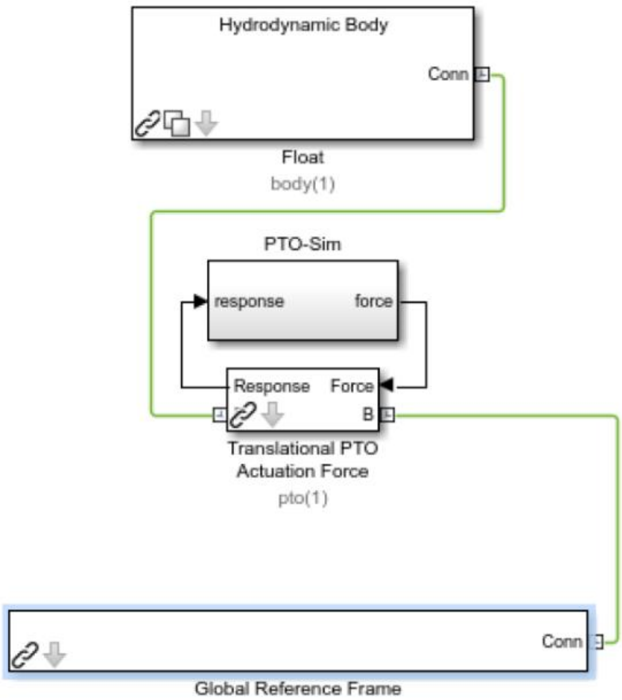
There are some main input files are needed to start a simulation in WEC-SIM which are:

1. Input File (.m)

2. Simulink Model (.slx)

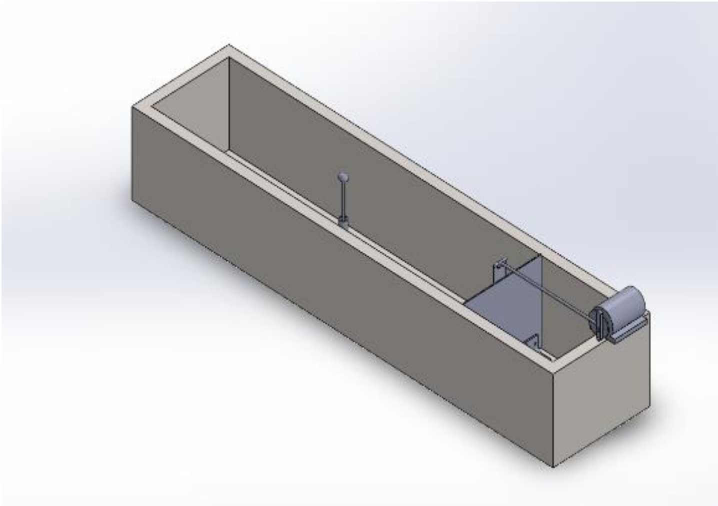
3. Hydrodynamic Data (.h5)

4. Geometry Files (.stl)



The PTO consists of a hydrodynamic body which was designed earlier. It is connected to the PTO which is connected to a Global Reference Frame.

8. Final Design



9. CONCLUSION

1) Entire ocean wave was modeled into a tank generating waves

2) Designed a buoy and the power absorber obtained was about 0.60 KW of generated electric power

10. FUTURE SCOPE

1) The tank developed a can be used for experimental verification and validation.

2) On tank testing the model can be tested in the actual Ocean condition

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