MIT | Academy of Engineering

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DESIGN OF HYDRAULIC TURBINE

PELTON TURBINE

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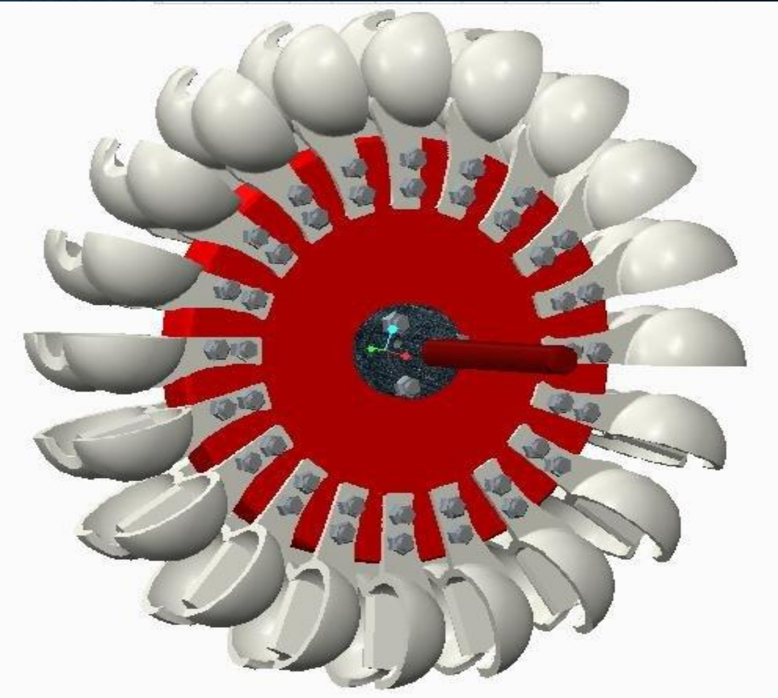
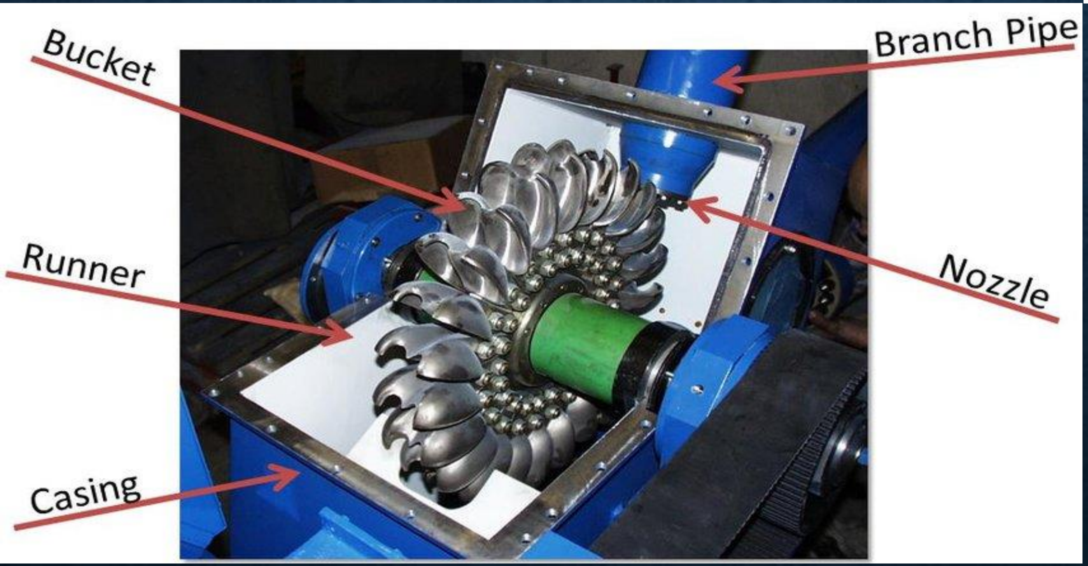
INTRODUCTION PELTON TURBINE



- The Pelton wheel or Pelton Turbine is an impulse-type Hydro turbine frequently used in hydroelectric plants.
- It is invented by American inventor Lester Allan Pelton in the 1870s.
- Is tangential flow impulse turbine in which the pressure energy of water is converted into kinetic energy.
- It is used for high Head.
- Parts of Pelton Turbine :-
    1. Nozzle
    2. Runner and Buckets
    3. Casing
    4. Braking Jet



LITERATURE SURVEY

Journal Name	Author	Year	Title of paper	Scope of work	Conclusion
INTERNATIONAL JOURNAL OF ADVANCE SCIENTIFIC RESEARCH AND ENGINEERING TRENDS	Mr. Uvaraj V Mane , Mr. Satchidanand S Choure	2020	DESIGN AND STRUCTURAL ANALYSIS OF PELTON WHEEL TURBINE BLADE	1) The design parameters such as turbine strength, turbine torque, runner diameter, runner length, runner velocity, and bucket dimensions, bucket number, nozzle dimension, and specific velocity of the turbine. 2) Designing a Pelton turbine bucket and testing its suitability for Pelton turbine.	1) Considering high head and a low water flow rate, the Pelton turbine is ideal for building small hydroelectric power plants. 2) The Maximum turbine efficiency is found to be 97% constant. 3) The maximum stress produced by the water jet is about 45 N/mm2
International Journal of Computational Engineering Research (IJCER)	Kailash Singh Chouhan , G. R. Kisheorey Manish Shah MIEEE, MIE, MISLE	2017	Modelling, Fabrication & Analysis of Pelton Turbine for Different Head and Materials	1) Studying the Material by which the turbine is constructed to achieve the speed and efficiency. 2)To design the Pelton wheel turbine for high altitude area especially in north and north east part of the country. 3) Determining the parameters on which the speed of turbine depends and modifying it.	1)Different runner such as wooden, solid cast iron, hollow cast iron and bakelite were used. 2) Velocity, relative velocity, power input, power output and efficiency of different runner materials are compared . 3) . It was observed in first experiment that at 2.32 m/s and 0.00125m3/s for the solid cast iron runner the RPM was 117.8 while 122.5, 137.5 and 142.5 for hollow cast iron, wooden and Bakelite respectively. 4) Among all the material of runner, Bakelite runner gives the maximum RPM and solid cast iron gives the minimum RPM. 5) As this was done for low head, Bakelite is benifical for low head.
International Journal of Engineering Research and Technology.	P. B. Sob	2020	Improving the mechanical efficiency of a Pelton Wheel impulse turbine at Low head during operation	1) To improve the efficiency and performance of a Pelton wheel turbine at very low head.	1) By optimising the head , weight of the runner and vanes the efficiency was able to improve without material failure during the vane operation. 2)By reducing the weight of the vanes the therotical simulation improve energy and power generation at very low head also. 3) There is also uniform distribution of stress and strain in shown very low head. 4) It was revealed that at very high energy head the vane will have high stress and strain deformation at the tip of the vane and the materials can easily suffer from material failure due to very high stress concentration at the tip of the vane.

International Journal of Engineering Research & Technology (IJERT)	**A. J. Ujam , S. O. Egbuna and N. E.Nwocha.**	**2014**	**Simulation of the Influence of Head on the power Output of a Pelton Turbine**	**1) Investigate the influence of head on the power output of a Pelton turbine.**	**1) As the head was increasing in elevation from 100m – 1000m, the flow through the nozzle was reducing with increased pressure. 2) As the head was increasing the power delivered to the generator was also increasing and hence the output from the generator was affected positively. 3) High head and low flow with increased pressure is suitable for commercial use or for large MHPP over 1000 megawatt output.**
	P.K. Sinha , Souma Ghosh , B. Halder , B. Majumder	2021	Performance Characteristics for a Pelton Wheel – A Case Study		1) Maximum efficiency of the present Pelton turbine at various wicket gate openings lies between 72% - 89% of full load. 2) No appreciable change in unit discharge for Nu . 3) Maximum unit power the machine can develop at Nu = 138. For all the wicket gate openings. 4) Maximum efficiency of the machine is around 67% at 92% opening of wicket gate.

STEPS OF DESIGN

- **Problem Statement:-**

To Design Hydraulic turbine for Koyna Dam which can be operated at 103 m design head.

1) Selection of hydraulic turbine:-

We have,

Electric power = 83.86 KW

Net Head = 103 m

Nozzle Diameter = 48.5 mm

From Calculation,

Speed of turbine N = 637.3 rpm

Specific Speed N_s = 17.78

$$N_s = \frac{N\sqrt{P}}{H^{5/4}}$$

$$N_s = \frac{637.3 * \sqrt{83.86}}{103^{5/4}}$$

$$N_s = 17.78$$

1) Calculation of the net head (H_n):

$$H_n = H_g - H_{t1}$$

For Hydro Power Plant , let us assume H_g = 103 m and $H_{t1} = 0$

$$H_n = 103 \text{ m}$$

2) Velocity of the Jet at inlet (V) :

$$V = C_v * \sqrt{2gH}$$

But C_v = Coefficient of friction = 1

H = Net head

$$V = 1 * \sqrt{2 * 9.81 * 103}$$

$$V = 44.95 \text{ m/s}$$

Therefore , Velocity of the jet is 44.95 m/s.

3) Speed ratio (ψ) :

$$\Psi = \frac{u}{v}$$

Where , u = mean speed of bucket.

$$0.45 = u / 44.95$$

$$u = 20.23 \text{ m/s}$$

As, speed ratio varies from 0.43 to 0.48 , therefore the average value is considered.

4) Calculation of Discharge through the nozzle (Q) :

$$Q = A * V$$

Where,

A = Area of the nozzle with diameter 48.5 mm.

V = velocity of the jet at inlet

$$\therefore \quad Q = \frac{\pi}{4} d^2 * V$$

$$Q = \frac{\pi}{4} (48.5 * 10^{-3})^2 * 44.95$$

$$Q = 0.083 \text{ m}^3/\text{sec}$$

Therefore, the discharge through the nozzle is 0.083 m^3/sec.

5) Jet Ratio (m) :

$$m = \frac{D}{d}$$

where,

m = jet ratio value varies from 12 to 14 , so the average value is taken

D = mean pitch diameter of the wheel

d = diameter of the jet

$$\therefore \quad 12.5 = \frac{D}{48.5}$$

$$\therefore \quad D = 606.25 \text{ mm}$$

6) Speed of Turbine (N) :

$$u = \frac{\pi D N}{60}$$

$$20.23 = \frac{\pi * 0.60625 * N}{60}$$

$$N = 637.3 \text{ rpm}$$

Therefore, Speed of the bucket is 637.3 rpm.

7) Calculation of Turbine Input Power (P) :

$$P = \rho * g * Q * H_n$$

Where , ρ = specific gravity of water

g = gravitational constant

$$P = 10^3 * 9.81 * 0.083 * 103$$

$$P = 83865.69 \text{ watt}$$

$$P = 83.86 \text{ KW}$$

Therefore , Input Power is 83.86 KW.

8) Specific Speed (N_s) :

$$N_s = \frac{N\sqrt{P}}{H^{5/4}}$$

$$N_s = \frac{637.3 * \sqrt{83.86}}{103^{5/4}}$$

$$N_s = 17.78$$

Therefore , the Specific speed of the Turbine is 17.78.

9) Width of Bucket :

Width of the bucket varies from 4d to 5d. Therefore, the average value is taken for the calculation i.e. 4.5d

$$4.5d = 4.5 * 48.5 \text{ mm}$$

$$= 218.25 \text{ mm}$$

Therefore, Width of Bucket is 218.25 mm.

10) Depth of the Bucket :

Depth of the bucket varies from 0.81d to 1.05d. Therefore, the average value is taken for the calculation i.e. 0.93d

$$0.93d = 0.93 * 48.5 \text{ mm}$$

$$= 45.1 \text{ mm}$$

Therefore , Depth of the Bucket is 45.1 mm.

11) Length of Bucket :

Length of the bucket varies from 2.4d to 3.2d. Therefore, the average value is taken for the calculation i.e. 2.8d

$$2.8d = 2.8 *48.5 \text{ mm}$$

$$= 135.8 \text{ mm}$$

Therefore , Length of Bucket is 135.8 mm.

12) Number of Bucket (Z) :

$$Z = 15 + \frac{D}{2d}$$

$$Z = 15 + \frac{606.25}{2*48.5}$$

$$Z = 15 + 6.25$$

$$Z = 21.25$$

Therefore, the Number of Bucket is 21.

13) Velocity Triangle related calculation :

From Inlet Velocity Triangle

$V_1 = V_{w1} = 44.95$ m/s

$V_{r1} = V_1 - U_1$

$= 44.95 - 20.23$

$V_{r1} = 24.72$ m/s

$V_{r1} = V_{r2} = 24.72$ m/s

In Outlet velocity triangle ,

$\sin\emptyset = V_{f2} / V_{r2}$

$\sin(15) = V_{f2} / 24.72$

$V_{f2} = 6.39$ m/s

Now, $\tan\emptyset = V_{f2} / (u_2 + V_{w2})$

$\tan(15) = 6.39 / (20.23 + V_{w2})$

$V_{w2} = 3.62$ m/s

Now ,

$\tan\beta = V_{f2} / V_{w2}$

$= 6.39 / 3.62$

$\tan\beta = 1.7654$

$\beta = 60.46°$

Hydraulic Efficiency , $\acute{\eta}_H = \frac{2(V_{w1} + V_{w2})_U}{V1^2}$

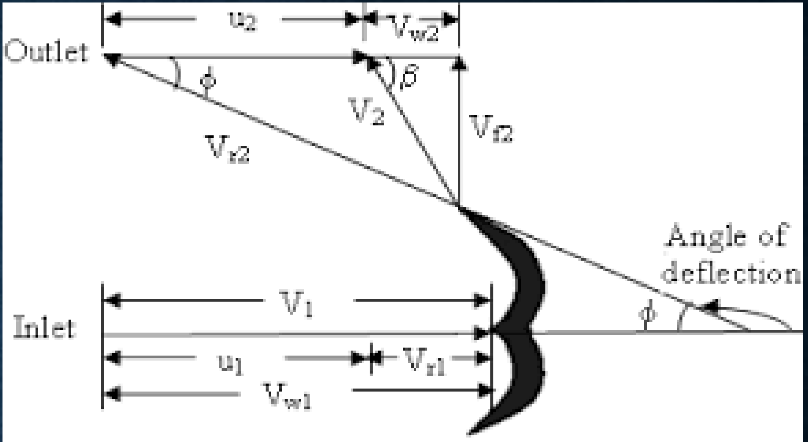
$\acute{\eta}_H = 0.97$

Hydraulic Efficiency of the turbine is 97%.

$(\acute{\eta}_H)_{max} = \frac{1 + \cos\emptyset}{2}$

$= 0.98$

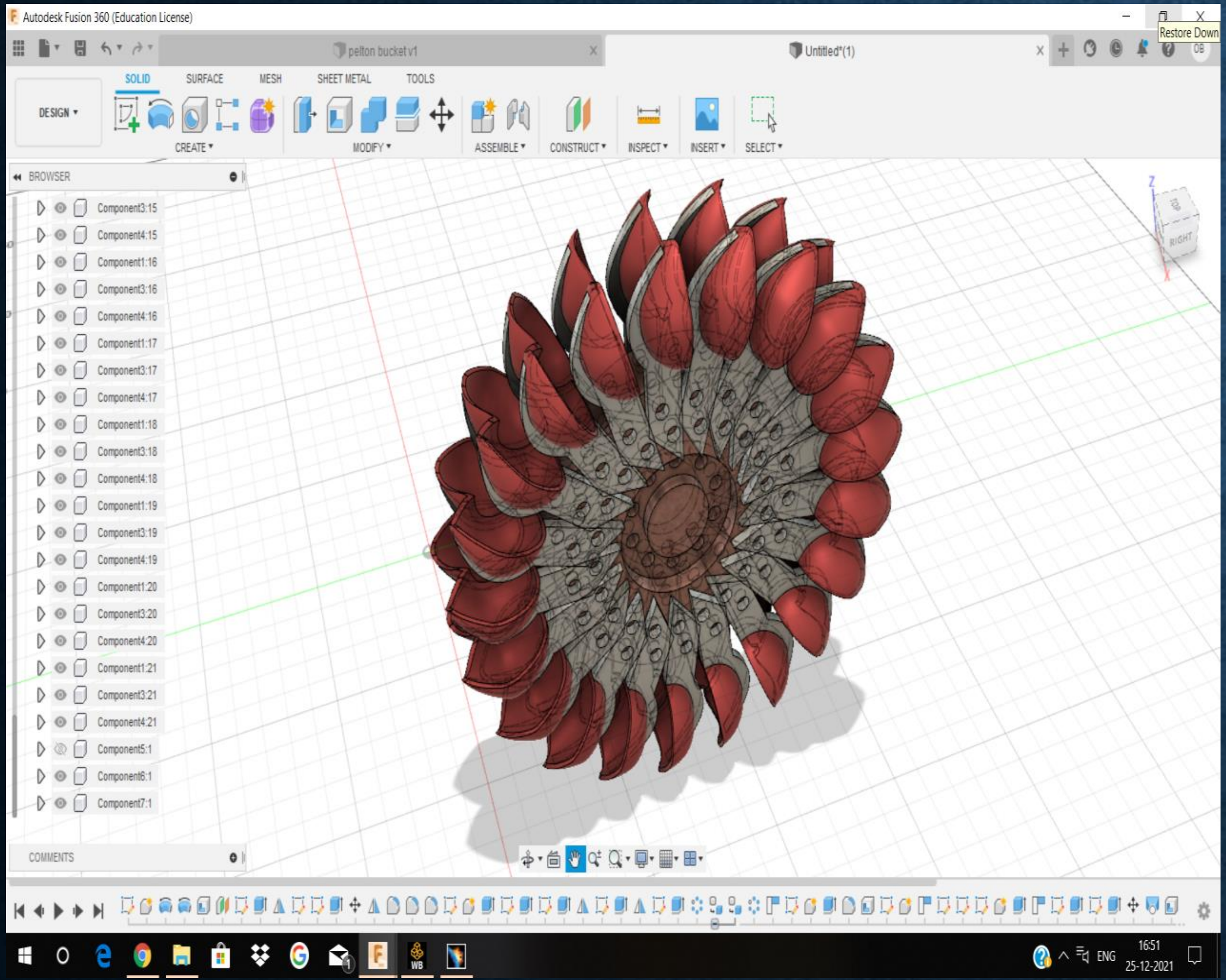
Maximum Hydraulic Efficiency is 98%.



RESULT

RESULT DATA			
Descriptions	**Symbols**	**Values**	**Units**
Width of Bucket	B	218.25	mm
Depth of Bucket	T	45.1	mm
Length of Bucket	L	135.8	mm
Number of Bucket	Z	21	
Absolute Velocity at Inlet	$V_1 = V_{w1}$	44.95	m/s
Flow Velocity at Outlet,	V_{f_2}	6.39	m/s
Inlet Tangential Velocity	u_1	20.23	m/s
Outlet Tangential Velocity	u_2	20.23	m/s
Guide Blade Angle at Inlet	α	0	Degree
Guide Blade Angle at outlet	β	60.46	Degree
Vane Angle at Inlet	θ	0	Degree
Vane Angle at Outlet	φ	15	Degree

CAD MODEL


Autodesk Fusion 360 (Education License)
pelton bucket v1
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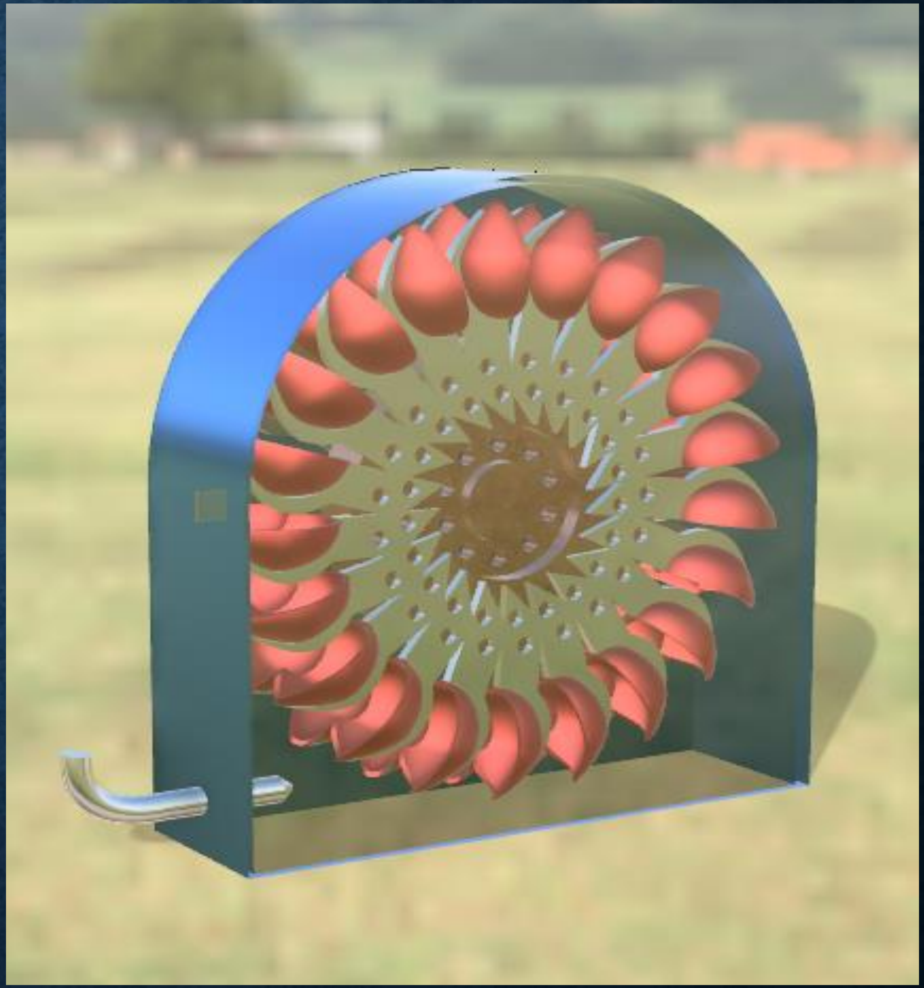


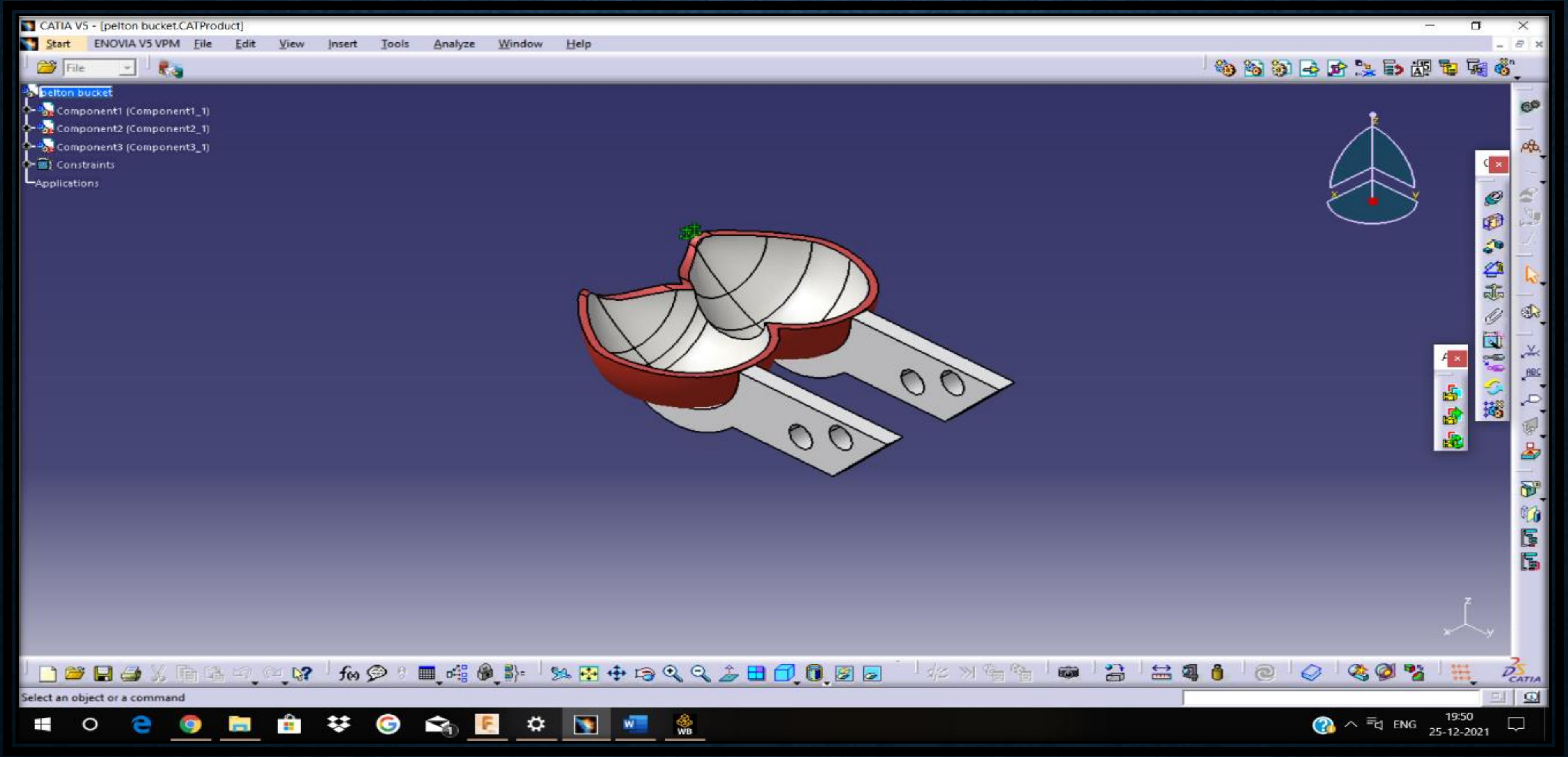
ANALYSIS OF THE BUCKET OF PELTON TURBINE

LITERATURE REVIEW :

Journal Name	Author	Year	Title	Scope of work	Conclusion
International Journal of Scientific and Research Publications, Volume 4,	Amod Panthee* , Hari Prasad Neopane ** , Bhola Thapa**	2014	CFD Analysis of Pelton Runner	1. This paper presents Computational Fluid Dynamics (CFD) analysis of Pelton turbine of Khimti Hydropower in Nepal. 2. To determine torque and pressure distribution in bucket .	1. . The time and cost in CFD analysis of Pelton turbine is also reduced by selecting 3 buckets to predict the behavior of complete turbine 2. The pressure peak is at bucket tip 3. The torque results obtained from CFD showed that the model Pelton turbine has efficiency of 82.5%.
Journal of the Institute of Engineering, Department of Mechanical and Aerospace Engineering, Pulchowk Campus.	Neeraj Adhikari, Anup Pandey a , Anushka	2021	Design of Pelton Turbine and Bucket Surface using Non-Uniform Rational Basis Spline and its Analysis with Computational Fluid Dynamics Subedi, Nitesh Subedi	1. Focusing on the design of Pelton bucket and runner considering flow rate, head and speed as design parameters. 2. Study of mechanical stress generated on bucket surface.	1. the force on the bucket increases with the increase of depth up to a certain limit and then the force decreases. 2. also shows that with the increase in depth of the bucket after the limit, the vortices become more dominant.

Basic Engineering / Hydraulic Laboratory, Hitachi Mitsubishi Hydro Corporation	**Takashi KUMASHIRO, Haruki FUKUHARA and Kiyohito TANI**	**2016**	**Unsteady CFD simulation for bucket design optimization of Pelton turbine runner**	**1. To investigate flow patterns on the bucket of Pelton turbine runners. 2. In this paper, a numerical study on two different design buckets and simplified analysis domain with consideration for reduction of computational load is introduced.**	**1. To understand what causes the difference of efficiency, some investigations for time evolution of flow patterns on bucket were performed based on the numerical analysis. 2. From the comparison of flow patterns between bucket A and B, some types of loss were evaluated and its generation mechanisms were also discussed.**
Procedia Manufacturing	Felix A. Isholaa, Joseph Azetaa , George Agbia , Obafemi O. Olatunjib , Festus Oyawale	2019	Simulation for Material Selection for a Pico Pelton Turbine's Wheel and Buckets	1. The objective of this study is to design a pico hydropower plant for supplementary power storage using the velocity of water. 2. Complete design calculations of the turbine have been performed as well as analysis of the model Pico energy device.	1. The power produced by the Pico hydropower system is to be used as supplementary to reduce total dependence on the national grid. Recommendation for future research can be to investigate the possibility of developing a composite material that will be most suitable for a Pico Hydropower Turbine.
IAHR Symposium on Hydraulic Machinery and Systems	Mohannad Farhat, Francois Avallan, Claude Bissel, etienne Parkinson	2004	Numerical Flow Analysis in Pelton Turbine Bucket	This study shows that an analysis of the bucket pressure and torque fields is paramount to quantitatively assess the effective energy transfer in the bucket.	A pressure field analysis highlights the evolution of the flow distribution in the bucket. The radius of application of the location, where the momentum change occurs, does not seem to play a significant role in the resulting bucket torque. The most critical point is the jet energy, the surface orientation, and the trajectories of the water particles.

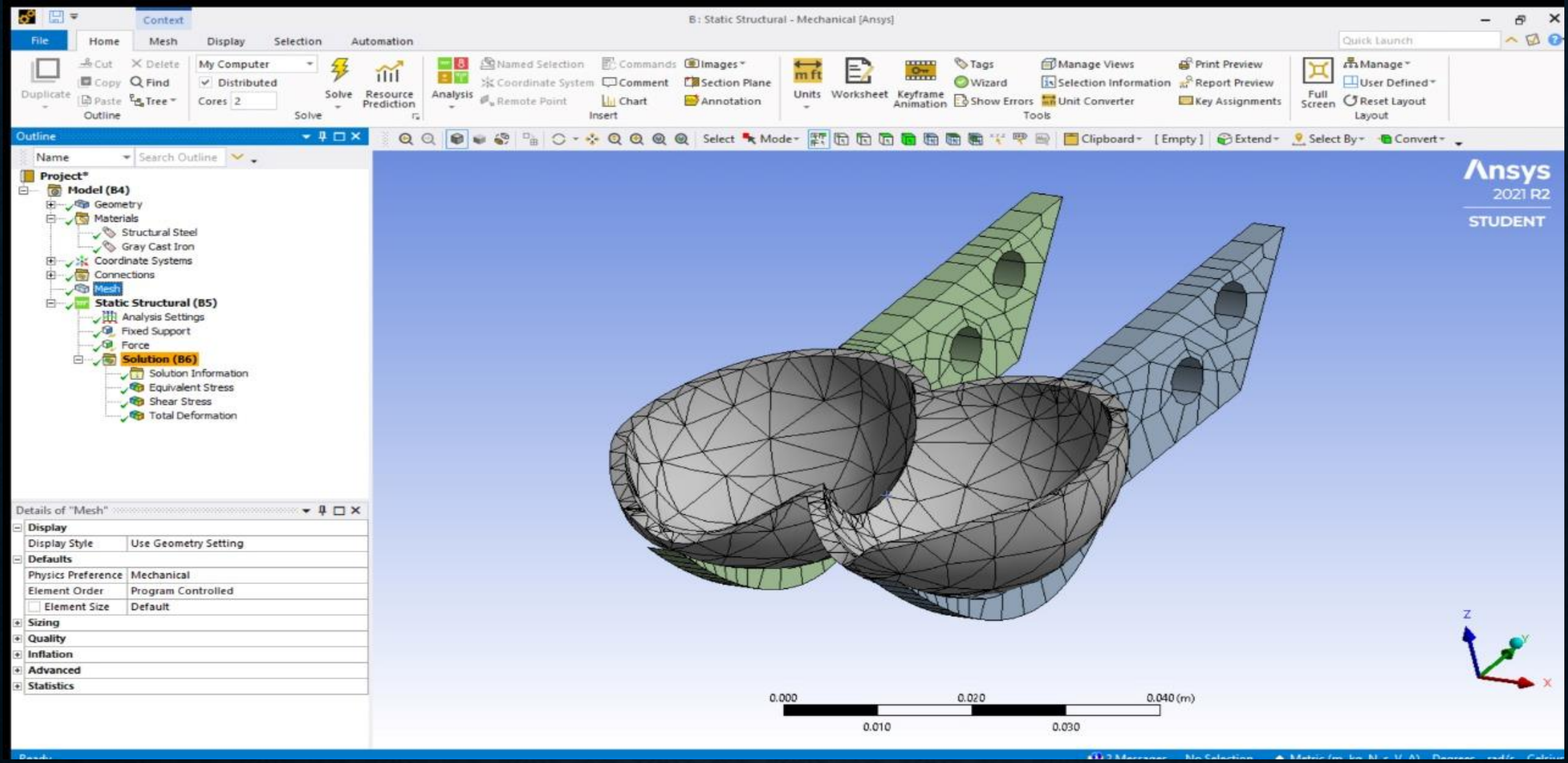
CAD MODEL OF BUCKET



NUMERICAL ANALYSIS

The Analysis part has been done the software name ANSYS and the version used is 2021 R2 student version.
While doing these Numerical Analysis the fixed force is applied at the holes on the rod of the bucket. The fixed support has been applied on 8 faces i.e 4 from the front side and 4 from the back side of the rod.
The force of 4033.39 N has been applied on the splitter section of the bucket. The splitter section is that section where the flow of the water get distributed in two different parts. The other calculation part has been directly assumed by the software.

MESHING :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Resource Prediction
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Remote Point
Commands
Comment
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Section Plane
Annotation
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Units
Worksheet
Keyframe Animation
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Manage Views
Selection Information
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Report Preview
Key Assignments
Full Screen
Manage
User Defined
Reset Layout
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Geometry
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Structural Steel
Gray Cast Iron
Coordinate Systems
Connections
Mesh
Static Structural (B5)
Analysis Settings
Fixed Support
Force
Solution (B6)
Solution Information
Equivalent Stress
Shear Stress
Total Deformation
Details of "Mesh"
Display
Display Style
Use Geometry Setting
Defaults
Physics Preference
Mechanical
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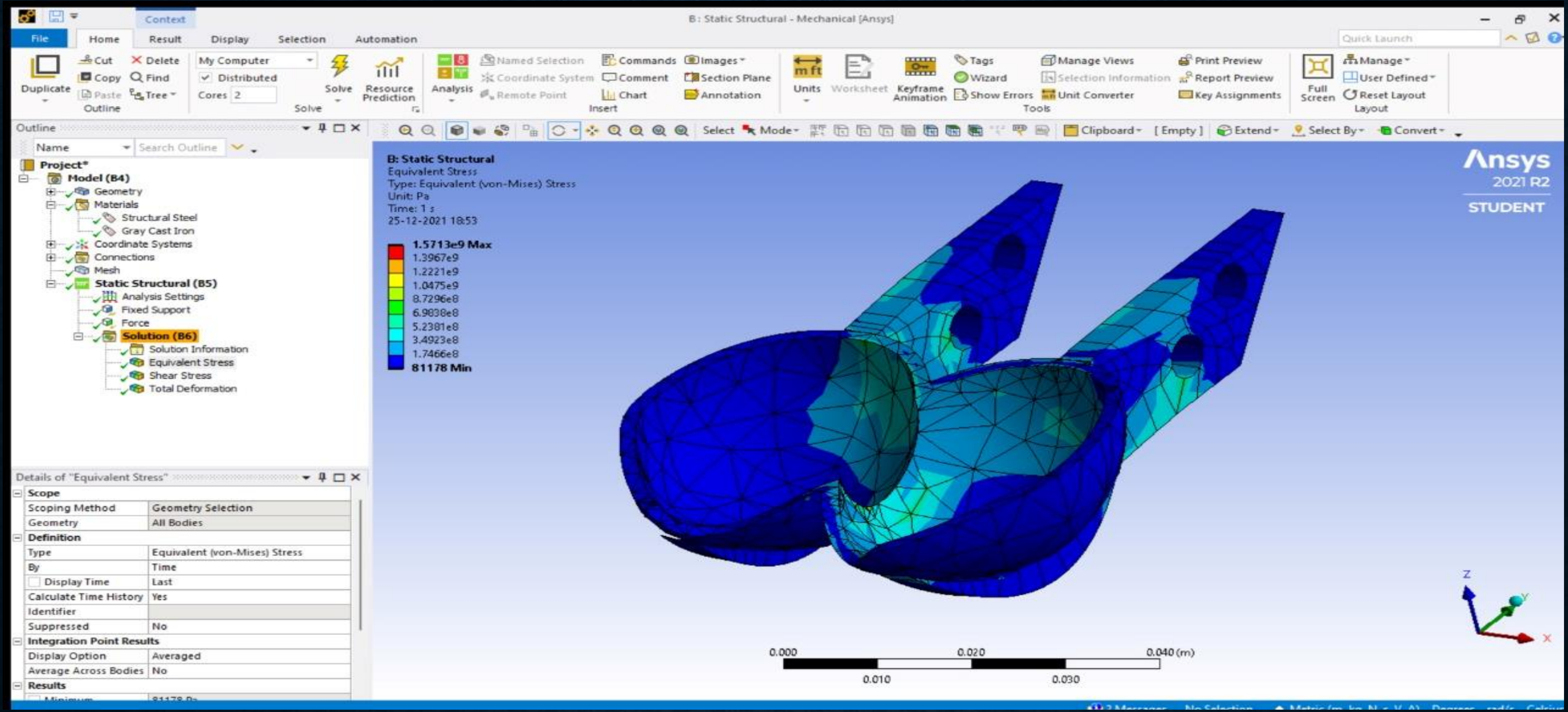
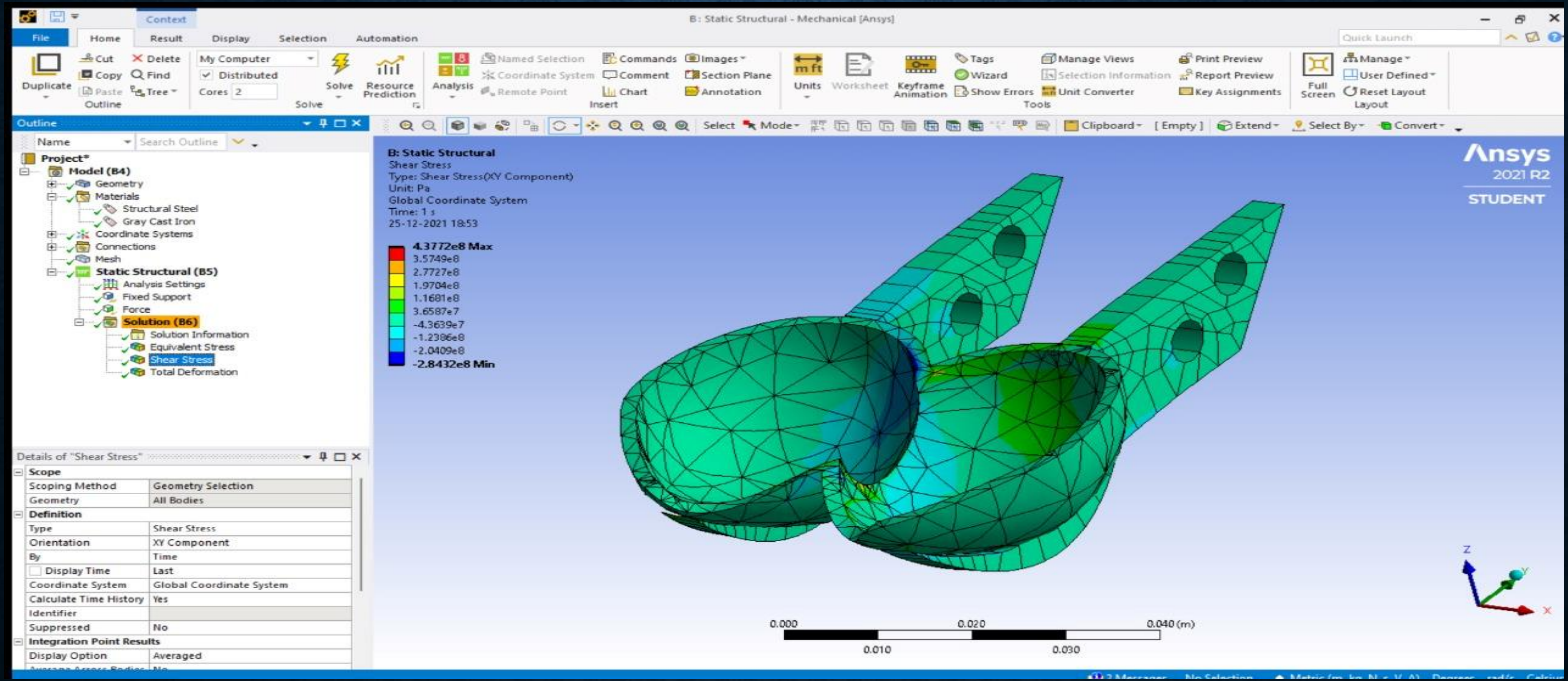
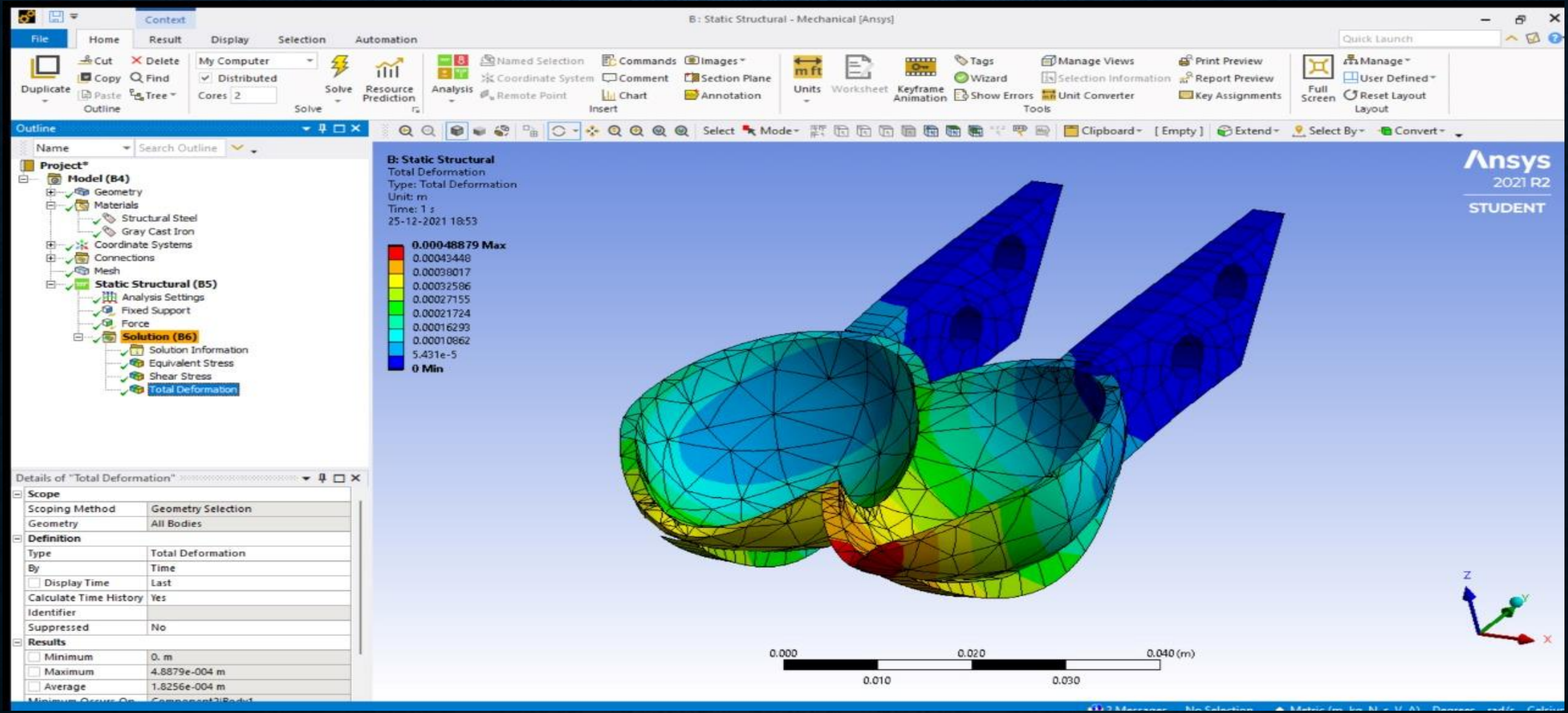
EQUIVALENT STRESS :



SHEAR STRESS :



TOTAL DEFORMATION :



Thank You !!!