Modelling and Structural Analysis of Pelton Wheel Turbine at Maximum Load Condition

Mr. S. Chandra Kiran*, Mr. T.D. Satyanarayana*, Mr. K. Mani Sridhar*, Mr. N. Naga Sai*, Mr. V. Sai*, Mr. A Phanibhaskar, Mrs. K Aravinda****

***UG students, **Faculty, Department of Mechanical Engineering College, Pragati Engineering College (A)**

ABSTRACT:A Pelton turbine bucket is the individual component which makes up the turbine section of a pelton turbine. The blades are responsible for extracting energy from the high pressure water produced by the nozzle jet. The pelton buckets are very often the limiting component of pelton turbines. To survive in this difficult environment, blades often use exotic materials. In this paper a pelton turbine bucket is designed and Modeled in 3D modeling software CATIA. We know that the efficiency is directly related to material performance making the material selection of primary importance. In this paper, materials considered for turbine blades are steel, cast iron and fiber glass reinforced plastic. Optimization is done by different materials by performing coupled field analysis on the turbine blade for both the designs. The objective of this work is to perform coupled field analysis of pelton wheel buckets for various materials and varying the number of buckets on the pelton wheel for finding out the efficiency, high stress handling factors.

Keywords: Pelton wheel, Load condition, Optimization, CATIA V5 software and ANSYS work bench

I. INTRODUCTION

Pelton turbines belong to the family of free jet turbines. A nozzle is placed at the end of the pressure line which converts the potential energy of the water into kinetic energy by forming a water jet. The jet is directed to the runner buckets, the hydraulically active parts of the turbine. At the entrance into the symmetrically shaped buckets the water jet is split into two parts, each developing a sheet of water on the bucket's curved surface. At the end of the working cycle, the water leaves the bucket in the opposite direction of the free jet. The rotational Mechanical energy is then transferred through the shaft to the generator which is produced by the momentum and pressure of the water jet striking the buckets. Pelton turbine basins, single or two pails together are for the most part made by mold throwing. The throwing of basins for Pelton turbines should be possible by replicating from other existing buckets. It is fitting to cast the single cans and, subsequent to machining, to settle them to the rotor plate. In this way convoluted throwing molds can be kept away from. It is not prescribed to make the pails of split channel areas or other welding developments of sheet metal segments, as a result of lacking quality and poor effectiveness. The basins can be made of diverse materials. This is likewise the case if the rotor is cast in one piece. On present day Pelton turbines the basins are basically of cast steel with 13% chrome. However, different materials and routines are additionally utilized, including cast iron, or composites, for example, bronze or aluminum, or infusion forming with fiberglass fortified plastic.

WORKING PRINCIPLE:

- The water is transferred from the high head source through a long conduit called Pen stock.
- Nozzle arrangement at the end of pen stock helps the water to accelerate and it flows out as a high speed jet with high velocity and discharge at atmospheric pressure.
- The jet will hit the splitter of the buckets which will distribute the jet into two halves of bucket and the wheel starts revolving.
- The kinetic energy of the jet is reduced when it hits the bucket and also due to spherical shape of buckets the directed jet will change its direction and take U-turn and fall into tail race.
- In general, the inlet angle of jet is in between 1^o to 3^o, after hitting the buckets the deflected jet angle is in between 165^o to 170^o.
- The water collected in the tail race should not submerge the Pelton wheel in any case.
- To generate more power, two Pelton wheels can be arranged to a single shaft or two water jets can be directed at a time to a single Pelton wheel.

INTRODUCTION TO CAD/CAM/CAE:

The Modern world of design, development, manufacturing and so on, in which we have stepped can't be imagined without interference from computers. The usage of

 DOI : 10.35291/2454-9150.2022.0262

computers is such that they have become an integral part of these fields. In the world market now the competition is not only cost factor but also quality, consistency, availability, packing, stocking, delivery etc. So are the requirements forcing industries to adopt modern techniques rather than local forcing the industries to adapt better techniques like CAD / CAM / CAE, etc. The Possible basic way for industries to have high quality products at low costs is by using the computer Aided Engineering (CAE), Computer Aided Design (CAD) And Computer Aided Manufacturing (CAM) set up. Further many tools have been introduced to simplify & serve the requirement CATIA, PRO-E, UG are some among many.

CAD: Computer Aided Designing (Technology to create, Modify, Analyze or Optimize the design using computer.

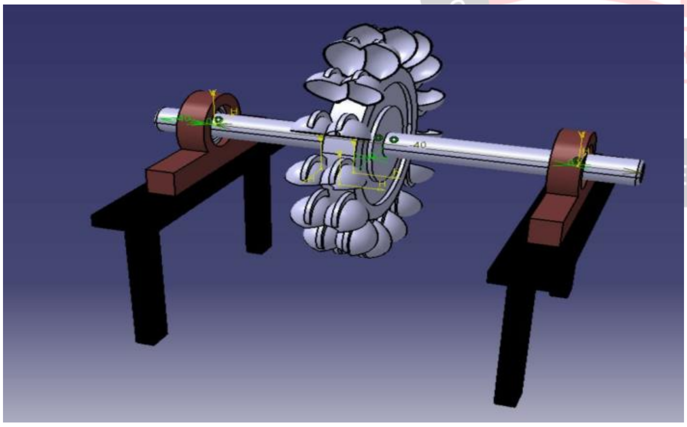
CAE: Computer Aided Engineering (Technology to analyze, Simulate or Study behavior of the cad model generated using a computer.

CAM: Computer Aided Manufacturing (Technology to Plan, manage or control the operation in manufacturing using computers.

Need for CAD, CAE & CAM :

The usage of CAD CAE & CAM have changed the overlook of the industries and developed healthy & standard competition , as could achieve target in lean time and ultimately the product reaches market in estimated time with better quality and consistency . In general, it has led to a fast approach and creative thinking.

PELTON WHEEL:



Go to start select the assembly design we will enter into the assembly work area, select the existing component and click on product open the Catia part, repeat the procedure till the for all the Catia parts. select the manipulation command and move the parts according to their destination place. After the positions are placed fix the main component and go coincidence constraint and give axis the constraint axis of both the parts clicks on update, repeat the all the parts to place their position. select the contact constraint apply the option ware it is necessary and click on update option the object will be placed. Use offset constraint option place part according to distance and click on update option the object will be placed repeat the option ware it is necessary, by using above commands the assembly part is created we are This complete Assembly part of Shock Absorber and it is done Catia v5 by using assembly option where we can assemble all the parts. Go to DMU kinematics select fix the one part and apply the simulation to the different parts and apply motion mechanism Save the file to your destination file.

SURFACING & SHAPE DESIGN:

CATIA provides a suite of surfacing, reverse engineering, and visualization solutions to create, modify, and validate complex innovative shapes. From subdivision, styling, and Class A surfaces to mechanical functional surfaces.

MECHANICAL ENGINEERING:

CATIA enables the creation of 3D parts, from 3D sketches, sheet metal, composites, and molded, forged or tooling parts up to the definition of mechanical assemblies. It provides tools to complete product definition, including functional tolerances, as well as kinematics definition.

EQUIPMENT DESIGN: CATIA facilitates the design of electronic, electrical as well as distributed systems such as fluid and HVAC systems, all the way to the production of documentation for manufacturing.

CATIA USER INTERFACE :

Below is the layout of the elements of the standard CATIA application.

A. Menu Commands
B. Specification Tree
C. Window of Active document
D. Filename and extension of current document
E. Icons to maximize/minimize and close window
F. Icon of the active workbench
G. Toolbars specific to the active workbench
H. Standard toolbar
I. Compass
J. Geometry

Different types of engineering drawings, construction of solid models, assemblies of solid parts can be done using inventor.

Different types of files used are:

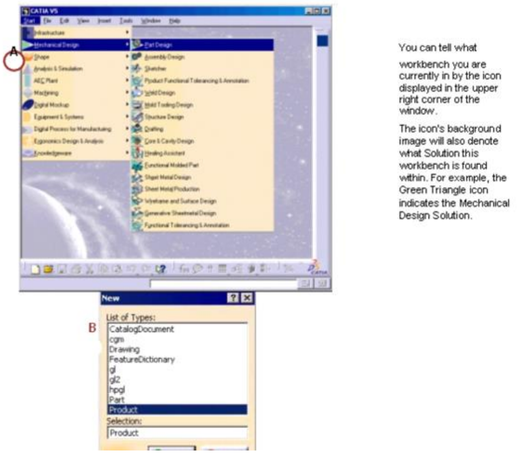
1. Part files: .CAT Part
2. Assembly files: .CAT Product

WORKBENCHES

Workbenches contain various tools that you may need to access during your part creation. You can switch between any primary workbenches using the following two ways:

 DOI : 10.35291/2454-9150.2022.0262

International Journal for Research in Engineering Application & Management (IJREAM)
ISSN : 2454-9150 Vol-08, Special Issue, MAY 2022



A. Use the Start Menu.

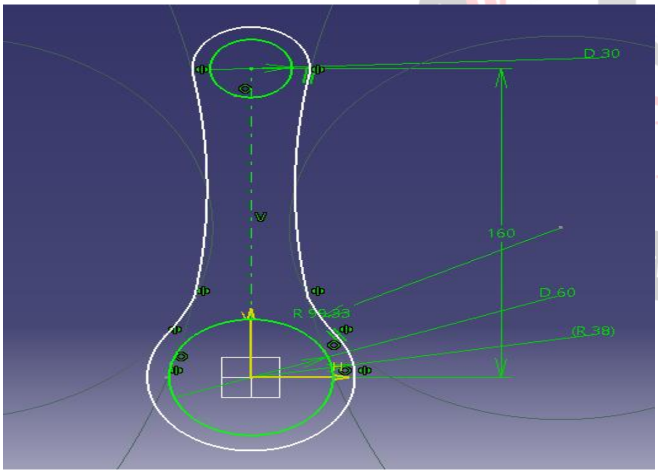
B. Click File >New to create a new document with a particular file type.

The associated workbench automatically launches.

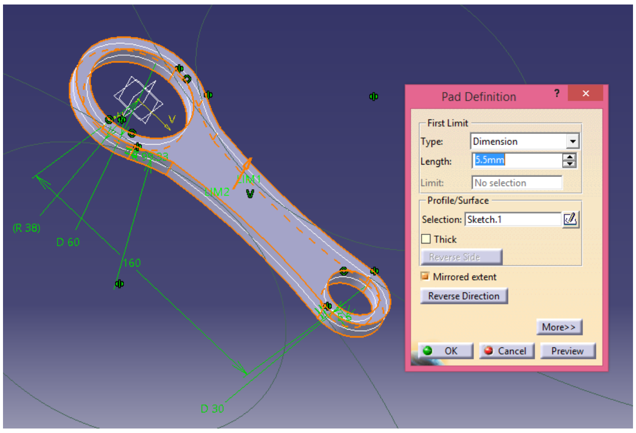
II. DESIGN PROCEDURE

After selecting the part design module screen is as shown is below figure in the screen there will be three planes XY, YZ and ZX planes. The XY plans represent top or bottom view, the YZ plane represent front or back view and ZX plane represent right side or left side view. In that three plans select ZX-plane and select sketcher your screen looks like.

Sketch drawing:

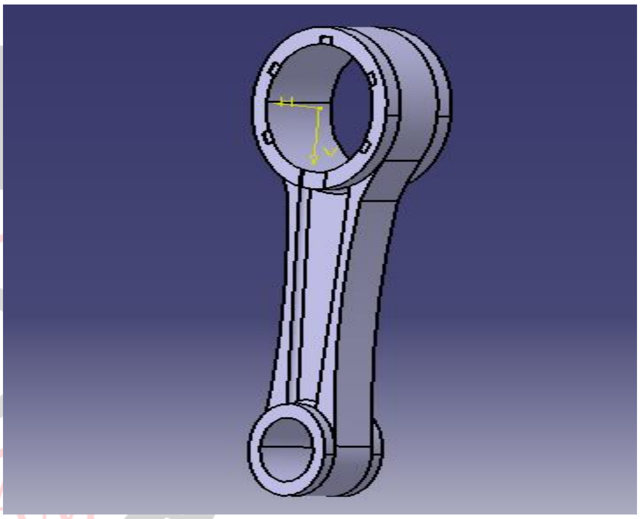


Drawing the sketch on front plane axis with using profile lines. In the part designing we have drawn the part model by using line command from the horizon. With maintaining constraints according, to the required dimensions. After the drawing we go to exit workbench for 3d modeling



In the 3d modeling we use shaft command with selecting the profile drawing with selecting object the dialogue box will open in that we select first angle select the angle and second angle and select the profile selection

After that select the axis and click on ok and object will develop according to our required dimensions



Now select the small end face and go to sketcher and draw a circle and go to exit sketch select pocket command and subtract the hole from the object

FINITE ELEMENT ANALYSIS

There are 3 main steps, namely; pre- processing, solution, post processing. In pre- processing (model definition) includes: define the geometric domain of the problem, the element type(s) to be used, the material properties of the element, the geometric properties of the element (length, area), the element connectivity (mesh the model), the physical constraints (boundary conditions) and the loadings.

In the solution phase, the governing algebraic equations in matrix form are assembled and unknown values of the primary field variable are computed. The compound results are then used by back substitution to determine additional, delivered variables, such as reaction forces, element stresses and heat flow. Actually, the features in this step such as matrix manipulation, numerical integration and equation solving are carried out automatically by

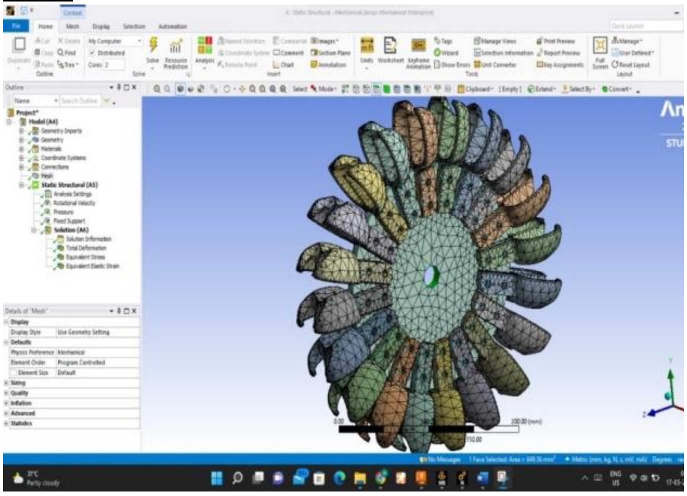
 DOI : 10.35291/2454-9150.2022.0262

commercial software. In post processing, the analysis and evaluation of the result is conducted in this step.

III. RESULT

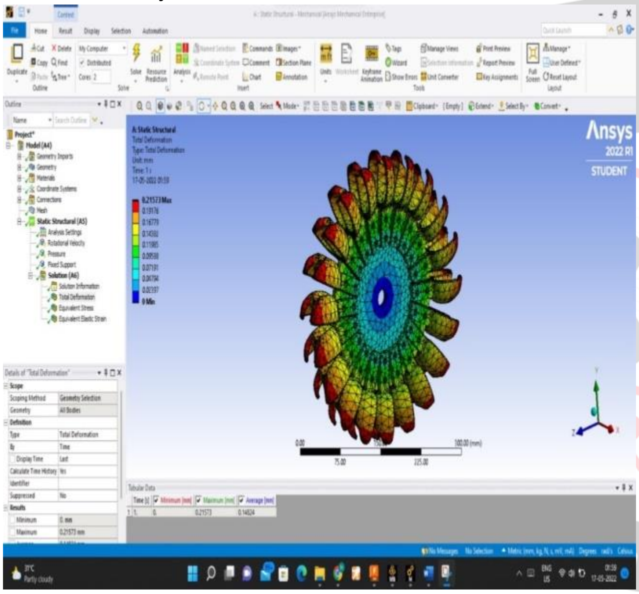
Stage 1 stainless steel:

MESH:



Total deformation:

Rotational velocity of 65 rad/sec



- **Model (A4) > Static Structural (A5) > Solution (A6) > Total Deformation**

Equivalent strain:

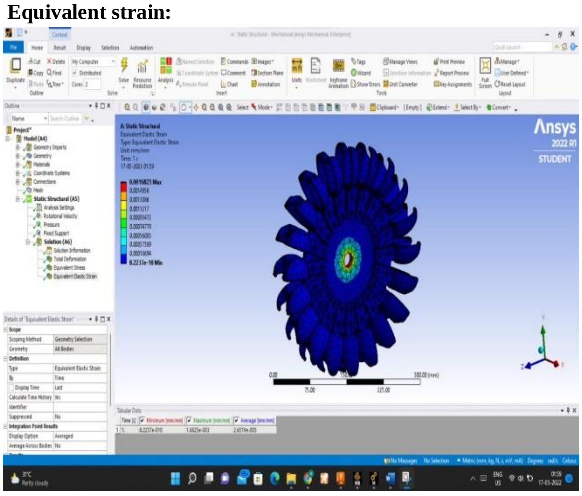
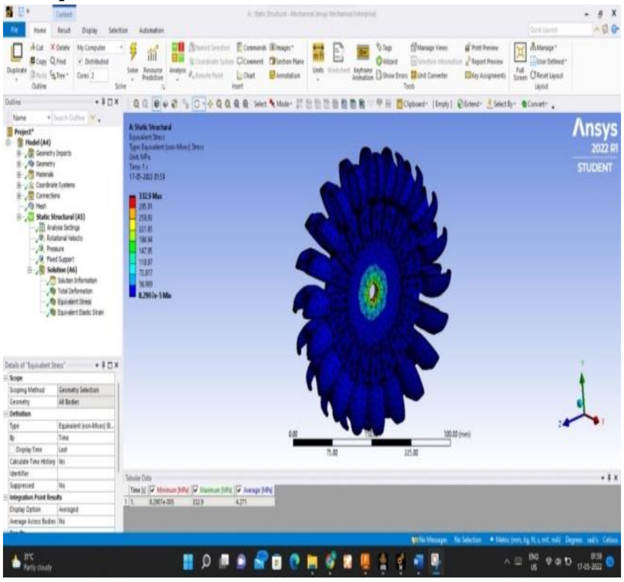


TABLE 15

Model (A4) > Static Structural (A5) > Solution (A6) > Equivalent Elastic Strain

Equivalent stress:



- **Model (A4) > Static Structural (A5) > Solution (A6) > Equivalent Stress**

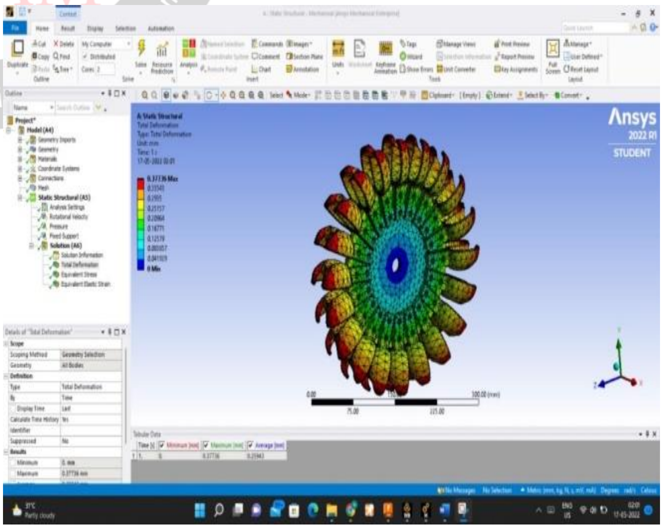
Time [s]	Minimum [MPa]	Maximum [MPa]
1.	8.2907e-5	332.9

Stage 1 at rotational velocity 65 rad/sec :

S NO	material	Solutions	max
1	Stainless steel	Total Deformation	0.2157mm
2	Stainless steel	Equivalent Elastic Strain	1.5818e-003 mm/mm
3	Stainless steel	Equivalent Stress	332.9Mpa

TOTAL DEFORMATION:

Rotational velocity of 80rad/sec

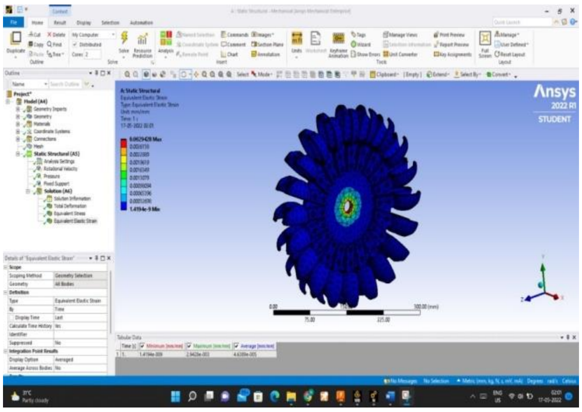


- **Model (A4) > Static Structural (A5) > Solution (A6) > Total Deformation**

Time [s]	Minimum [mm]	Maximum [mm]
1.	0	0.37736

 DOI : 10.35291/2454-9150.2022.0262

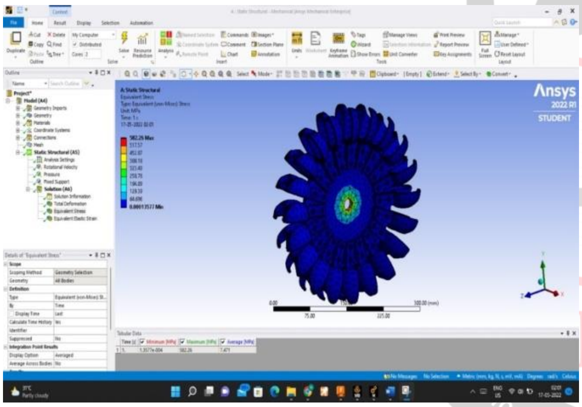
EQUIVALENT STRAIN:



- **Model (A4) > Static Structural (A5) > Solution (A6) > Equivalent Elastic Strain**

Time [s]	Minimum [mm/mm]	Maximum [mm/mm]
1.	1.4194e-9	2.9428e-003

EQUIVALENT STRESS:



Model (A4) > Static Structural (A5) > Solution (A6) > Equivalent Stress

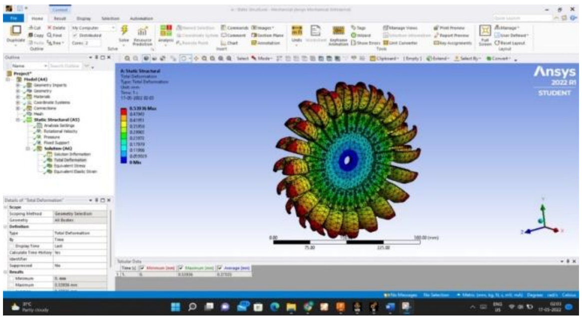
Time [s]	Minimum [MPa]	Maximum [MPa]
1.	1.3577e-4	582.26

Stage 2 rotational velocity 80 rad/sec :

S NO	material	Solutions	max
1	Stainless steel	Total Deformation	0.377mm
2	Stainless steel	Equivalent Elastic Strain	2.9673e-003 mm/mm
3	Stainless steel	Equivalent Stress	582.26Mpa

TOTAL DEFORMATION :

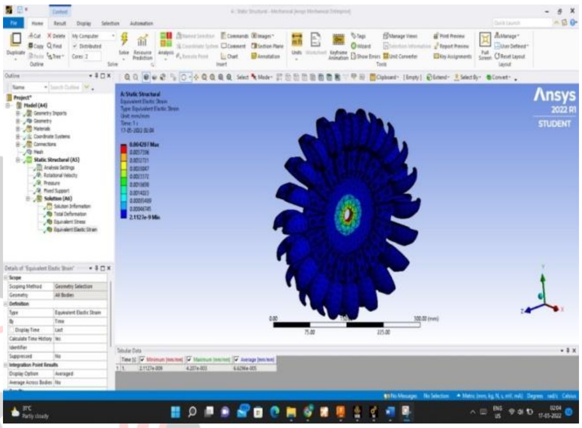
Roatational velocity of 100 rad/sec



- **Model (A4) > Static Structural (A5) > Solution (A6) > Total Deformation**

Time [s]	Minimum [mm]	Maximum [mm]
1.	0	0.53936

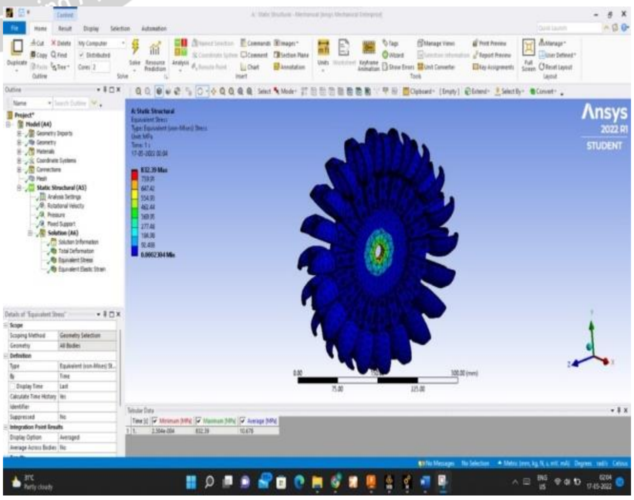
EQUIPMENT ELASTIC STRAIN:



- **Model (A4) > Static Structural (A5) > Solution (A6) > Equivalent Elastic Strain**

Time [s]	Minimum [mm/mm]	Maximum [mm/mm]
1.	2.1127e-009	4.207e-3

EQUIVALENT STRESS:



Model (A4) > Static Structural (A5) > Solution (A6) > Equivalent Stress

Time [s]	Minimum [MPa]	Maximum [MPa]
1.	2.304e-4	832.39

 DOI : 10.35291/2454-9150.2022.0262

Stage 3 rotational velocity 100 rad/sec :

S NO	material	Solutions	max
1	Stainless steel	Total Deformation	0.539mm
2	Stainless steel	Equivalent Elastic Strain	4.2438e-003 mm/mm
3	Stainless steel	Equivalent Stress	832.39Mpa

IV. CONCLUSION

We Complete model design using Catia software with standard measurements. we saved the part file in Initial Graphics Exchange (IGS) and we imported in Ansys work bench. In Ansys work bench we used Static Structural Analysis System to validate the strength of our design, we done structural analysis on the Pelton wheel. We done analysis by varying materials and different Rotational Velocities.

In Ansys we observe the various Parameters like Total deformation, Equivalent stress ,Equivalent strain ,Total deformation and Rotational velocities for stain less steel. From the Obtained output values we can select the Pelton wheel Which are having desirable properties .

Percentage % deformation reduced in case of 65 rad/sec when compared with 100 rad/sec is 59.98 %. Percentage % of stress reduced in case of 65 rad/sec when compared with 100 rad/sec is 59.96 %. Percentage % of strain reduced in case of 65 rad/sec when compared with 100 rad/sec is 61.9 %

REFERENCES

[1] R.Yadav,(1993). Steam and Gas turbine, Central Publishing House, Allahabad.

[2] Meherwanp.Boyce, (2012) Gas turbine engineering,fourth edition,Elsevier Inc, United States of America.

[3] S. Gowreesh, N.Sreenivasalu Reddy and N.V.Yogananda Murthy. "CONVECTIVE HEAT TRANSFER ANALYSIS OF AERO GAS TURBINE BLADE USING ANSYS", International journal of Mechanics of solids, vol4, No.1, March 2009(ppt55-62).

[4] Claire Soares,(2008). gas turbine a hand book of air,land and sea applications ,Elsevier Inc, united states of america.

[5] P.Kauthalkar, Mr.Devendra S.Shikarwar, and Dr.Pushapendra Kumar Sharma. "ANLYSIS O F THERMAL STRESES DISTRIBUTION PATTERN ON GAS TURBINE BLADE USING ANSYS", International journal of Engineering Education and technology, Vol.2, No.3, Nov 2010.

[6] John.V, T.Ramakrishna. "THE DESIGN AND ANALYSIS OF GAS TURBINE BLADE", International Journal of Advanced Research and Studies, Vol 2, No.1, Dec 2012.

[7] Nageswara Rao Muktinutalapati, (2011).Application in Gas Turbines, Materials Science and Engineering, Vol.88, pp11-19, ISSN 0921-5093.

[8] V.Raga Deepu, R.P.Kumar Ropichrla. "DESIGN AND COUPLED FIELD ANALYSIS OF FIRST STAGE GAS TURBINE ROTOR BLADES", International journal of Mathematics and Engineering, Vol 13, No.2, Pages: 1603-1612.

a. C. Han, S. Dutta, and S.V. Ekkad, (2000).Gas Turbine Heat Transfer and Cooling Technology, Taylor &Francis, Inc, New York, ISBN # 1-56032-841-X, 646 pages.

[9] A.John. Sedriks, (1979).Corrosion of Stainless Steels, Original from the University of California,ISBN 0471050113, 9780471050117, 282 pages.

a. Niinomi, (1998).Mechanical properties of biomedical titanium alloys, Mater. Sci. Engng,A 243 pp 231–236.

[10] K. Mahadevan and K.Balaveera reddy, (1984).Design data hand book for mechanical engineering, CBS Publ, second Edition, 434 pages.

[11] S. S. Rao, (1999).The Finite Element method in Engineering, BH Publications New Delhi, 3rd Edition.

 DOI : 10.35291/2454-9150.2022.0262