DESIGN AND THERMAL ANALYSIS OF STEAM TURBINE BLADE USING FEM METHOD

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ABSTRACT

A steam turbine is mechanical device which converts thermal energy in steam into mechanical work. The steam turbine gives the better thermodynamic efficiency by using multiple stages in the expansion of steam. The stages are characterized by the way of energy extraction from them is considered as impulse or reaction turbines. In this thesis the parameters of steam turbine blade varied and analysis is done for strength, life and heat transfer rates. The varied parameters are the ratio of X-axis distance of blade profile by chord length and ratio of maximum height of blade profile in Y-direction to the chord length. The 3D modelling is done by using catia software. The ANSYS software is used for static, thermal analysis, finally concluded the suitable design and material (Haste alloy, Chrome steel, Inconel 600) for steam turbine blade.

KEY WORDS: *Steam Turbine, Thermal Energy, Impulse Turbine, Reaction Turbine, Static Analysis, Thermal Analysis.*

CHAPTER 1
TURBINE INTRODUCTION

1.1 INTRODUCTION

A turbine (from the Latin turbo, a vortex, related to the Greek, meaning "turbulence") is a rotary mechanical device that extracts energy from a fluid flow and converts it into useful work. The work produced by a turbine can be used for generating electrical power when combined with a generator or producing thrust, as in the case of jet engines. A turbine is a turbo machine with at least one moving part called a rotor assembly, which is a shaft or drum with blades attached. Moving fluid acts on the blades so that they move and impart rotational energy to the rotor. Early turbine examples are windmills and waterwheels.

Gas, steam, and water turbines have a casing around the blades that contains and controls the working fluid. Credit for invention of the steam turbine is given both to British engineer Sir Charles Parsons (1854–1931) for invention of the reaction turbine, and to Swedish engineer Gustaf de Laval (1845–1913) for invention of the impulse turbine. Modern steam turbines frequently employ both reaction and impulse in the same unit, typically varying the degree of reaction and impulse from the blade root to its periphery.

FIG 1TURBINE

1.2 PRINCIPLE OF STEAM TURBINE:

The steam energy is converted mechanical work. Expansion takes place through a□by expansion through the turbine. series of fixed . In each row fixed blades (nozzles) and moving blades Blade and moving blade are called stage

1. 2.1 Impulse steam turbine

The steam turbine is a device for obtaining mechanical work from the energy stored in steam. There are two main types of turbine, the 'impulse' and the 'reaction'. The names refer to the type of force which acts on the blades to turn the turbine wheel. The impulse arrangement is made up of a ring of nozzles followed by a ring of blades. The high-pressure, high-energy steam is expanded in the nozzle to a lower-pressure, high-velocity jet of steam. This jet of steam is directed into the impulse blades and leaves in a different direction . The changing direction and therefore velocity produces an impulsive force which mainly acts in the direction of rotation of the turbine blades. There is only a very small end thrust on the turbine shaft.

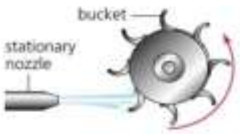


FIG 2 IMPULSE STEAM TURBINE

The turbine consists of a single rotor he single stage impulse turbine to which impulse blades are attached .The steam is fed through one or several convergent nozzles. If high velocity of steam is allowed to flow through one row of moving bladesIt produces a rotor speed of. about 30000 rpm which is too high for practical use

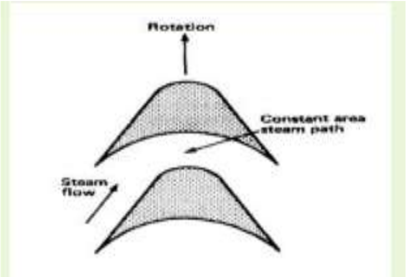


FIG 3 IMPLUSE BLADING

1.2.2 Reaction steam turbine

The reaction arrangement is made up of a ring of fixed blades attached to the casing, and a row of similar blades mounted on the rotor, i.e. moving blades . The blades are mounted and shaped to produce a narrowing passage which, like a nozzle, increases the steam velocity. There is also a change in velocity of the steam as a result of a change in direction and an impulsive force is also produced with this type of blading. The more correct term for this blade arrangement is 'impulse-reaction'. A reaction turbine utilizes a jet of Reaction steam turbine: steam that flows from a nozzle on the rotor

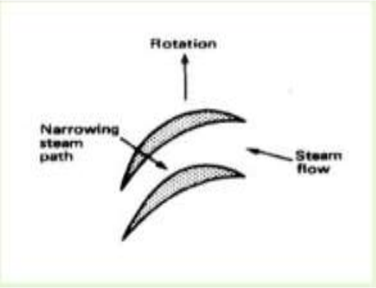


FIG 4 REATION TURBINE BLADE

CHAPTER 2
LITERATURE REVIEW

Many investigators have suggested various methods to explain the effect of stress and loading on turbine blade, roter and analysis the various parameters: John. V, T. Ramakrishna was investigated on design and analysis of Gas turbine blade, CATIA is used for design of solid model and ANSYS software for analysis for F.E. model generated, by applying boundary condition, this paper also includes specific post processing and life assessment of blade. How the program makes effective use of the ANSYS pre-processor to mesh complex geometries of turbine blade and apply boundary conditions. The principal aim of this paper is to get the natural frequencies and mode shape of the turbine blade. In this paper we have analyzed previous designs and generals of turbine blade to do further optimization, Finite element results for free standing blades give a complete picture of structural characteristics, which can utilized for the improvement in the design and optimization of the operating conditions.

Subramanyam Pavuluri, Dr. A. Siva Kumar was investigated on design of high pressure steam turbine blade addresses the issue of steam turbine efficiency. A specific focus on airfoil profile for high-pressure turbine blade, and it evaluates the effectiveness of certain Chromium and Nickel in resisting creep and fracture in turbine blades. The efficiency of the steam turbine is a key factor in both the environmental and economic impact of any coal-fired power station. Based on the research presented modifications to high-pressure steam turbine blades can made to increase turbine efficiency of the turbine. The results and conclusions are presented for a concerning the durability problems experienced with steam turbine blades. The maximum operational Von Mises Stresses are within the yield strength of the material but the deformation is comparatively better for material CA-6 NM (Chromium Nickel). Modified solutions for Steam turbine blade values to machines to maximize their reduce life cycle costs, efficiency, and improve reliability Sanjay Kumar was investgated on creep life of turbine blade. Inertia load is the constant load that will cause creep failure. Creep is a rate dependent material nonlinearity in which material continues to deform in nonlinear fashion even under constant load. This phenomenon is predominant in components, which exposed to high temperatures. By studying the creep phenomenon and predicting the creep life of the component, we can estimate its design life. The main objective is to predict the creep life of the simple impulse steam turbine blade, and to give the FEM approach for creep analysis. The analysis of turbine blade for different loads, which shows that the maximum stresses, induced in each case. These stresses are within yield limit of the material and will not undergo plastic deformation during operationresult is found that, creep life decreases as the stress value increases. Hence, by decreasing the stress value in the component we can increase its creep life. This was be achieved by modifying the blade design. Avinash V. Sarlashkar, MARK L. Redding investigated on the architecture and capabilities of Blade Pro. An ANSYS based turbine blade analysis system with extensive automation for solid model and F.E. model generation, boundary condition application, file handling and job submission tasks for a variety of complex analyses; the program also includes turbo machinery specific post processing and life assessment modules. Blade Pro is a cutting-edge example for vertical applications built on the core ANSYS engine using ANSYS APDL. Examples of how the program makes effective use of the ANSYS preprocessor to mesh complex geometries of turbine blade and apply boundary conditions are presented using specific examples. A real world application is used to demonstrate the pre-processing capabilities, static and dynamic stress analyses results, generation of Campbell and Interference diagrams and life assessment. The principal advantage of Blade Pro is its ability to generate accurate results in a short amount of time, thus reducing the design cycle time. The good correlation achieved is a testament to the accuracy of the ANSYS solvers and validity of the modeling techniques adopted in Blade Pro. DR.SHANTHARAJA.M, DR. Kumar. K., was work on the large variety of turbo-machinery blade root geometries used in industry prompted the question if an optimum geometry could be found. An optimum blade root was defined, as a root with practical geometry which, when loaded returns the minimum fillet stress concentration factor. The present paper outlines the design modification for fillet stresses and a special attention made on SCF of the blade root (T-root) which fails and to guarantee for safe and reliable operation under all possible service conditions. Finite Element Analysis is used to determine the fillet stresses and Peterson's Stress Concentration Factor chart is effectively utilized to modify the blade root. The root modified due to the difficulty in manufacturing the butting surface of the tang that grips the blade to the disk crowns A Review on Analysis of Low Pressure Stage of Steam Turbine Blade with FEA (ANSYS Software) (IJSRD/Vol. 1/Issue 10/2013/0003) All rights reserved by www.ijsrd.com 2060 having small contact area. Verify the same using Finite Element Analysis for two cases with and without the tang in the blade. Firstly, to study the fillet stresses with tang and then Petersons chart is used to reduce the peak stresses with the modification to the butting area and reducing the fillet radius. To conduct the sensitivity analysis for the fillet stresses in blade and disk using FEA.

CHAPTER 3
PROJECT OVER VIEW

3. 1 STEAM TURBINE NOMENCLATURE:

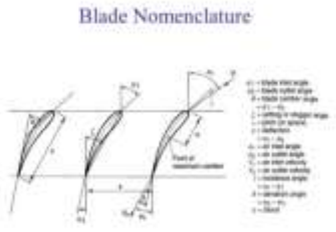


FIG 5 STEAM TURBINE BLADE NOMENCLATURE

3.2 PROBLEM DEFINITION:

All modern steam power plants use impulse-reaction turbines as their blading efficiency is higher than that of impulse turbines. Last stage of steam turbine impulse-reaction blade are very much directly affect efficiency of plant with the information that an understanding of the forces and stresses acting on the turbine blades is vital importance, in this work we will compute such a force acting on a last stage Low Pressure (LP) blade of a large steam turbine rotating at 3000 rpm in order to estimate the material stresses at the blade root. One such LP steam turbine blade is show in Figure 1. We studied structural and themal analysis of blade using FEA for this work and by use of the operational data have performed by using FEA (ANSYS) and This study work involved the analyze blade and check FEA data of std. blade with various material.

3.3 OBJECTIVE

The objective of this project is to make a Steam turbine blade different 3D model of the steam turbine blade, To study the static - thermal behaviour of the steam turbine blade with different materials by performing the finite element analysis.3D modelling software (catia v5) was used for designing and analysis software (ANSYS) was used for analysis.

3.4 METHODOLOGY

THE METHODOLOGY FOLLOWED IN THE PROJECT IS AS FOLLOWS:

- Create a 3D model of the different Steam turbine blades using parametric software catia v5.
- Convert the surface model into IGS and import the model into ANSYS to do analysis.
- Perform static and thermal analysis on the steam turbine blade.
- Finally it was concluded which material is the suitable for steam turbine blade on these three materials.

3.5 SCOPE OF THE PROJECT :

The scopes of this proposed project are:

1. To generate 3-dimensional geometry model in catia workbench of the steam turbine blade

2. To perform structural analysis on the model to determine the stress, shear stress, deformation, of the component under the static- thermal load conditions

3. To compare analysis between three different materials of steam turbine blade

3.6 LOAD CALCULATION:

$$F = M \times Vm$$

M=Mass of stream flowing through turbine

Vm=velocity of steam in m/s

M=1000kg/hr

Vm=1310m/s

F=362.87N

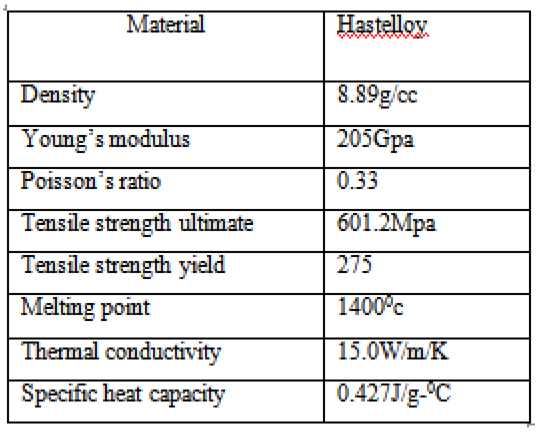
Blade area=23319.1mm^2

Pressure =F/A

P=0.01556N/mm^2

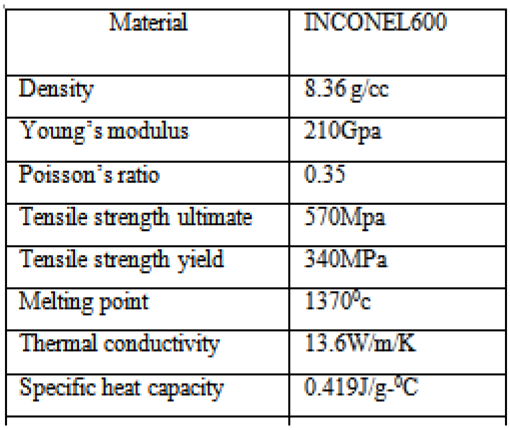
3.7 MATERIAL PROPERTIES

TAB 1HASTELLOY PROPERTIES



Material	Hastelloy
Density	8.89g/cc
Young's modulus	205Gpa
Poisson's ratio	0.33
Tensile strength ultimate	601.2Mpa
Tensile strength yield	275
Melting point	1400^{0}c
Thermal conductivity	15.0W/m/K
Specific heat capacity	0.427J/g-^{0}C

TAB 2 INCONEL600 PROPERTIES



Material	INCONEL600
Density	8.36 g/cc
Young's modulus	210Gpa
Poisson's ratio	0.35
Tensile strength ultimate	570Mpa
Tensile strength yield	340MPa
Melting point	1370^{0}c
Thermal conductivity	13.6W/m/K
Specific heat capacity	0.419J/g-^{0}C

TAB 3 CHROME STEEL PROPERTIES

Material	CHROME STEEL
Density	7.31 g/cc
Young's modulus	200Gpa
Poisson's ratio	0.3
Tensile strength ultimate	485Mpa
Tensile strength yield	275Mpa
Melting point	1365^{0}c
Thermal conductivity	14.0W/m/K
Specific heat capacity	0.418J/g-^{0}C

CHAPTER 4

4.1 DIMENSIONS AND DESIGN PROCEDURE IN CATIA:

Go to the sketcher workbench create profile blade shape by using spine and arcs as below dimensions after go to the part design workbench apply pad as shown below figure

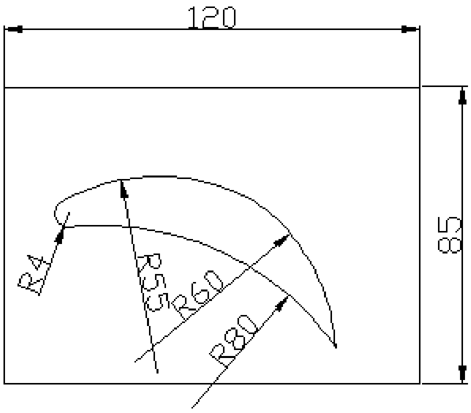


FIG 2BLADE DIMENSIONS

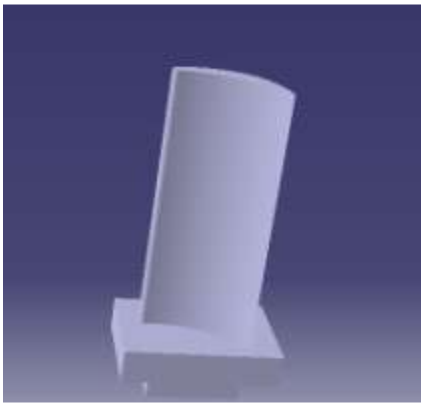


FIG 3 STEAM TURBINE BLADE IN CATIA WORK BENCH

NTRODUCTION TO

CHAPTER 5

5.1 ANALYSIS PROCEDURE IN ANSYS:

Designed component in Catia workbench after imported into Ansys workbench now select the steady state thermal analysis.

1. ENGINEEERING MATERIALS (MATERIAL PROPERTIES).

2. CREATE OR IMPORT GEOMENTRY.

3. MODEL (APPLY MESHING).

4. SET UP(BOUNDARY CONDITIONS)

5. SOLUTION

6. **RESULTS**

5.2 STATIC STRUCTURAL ANALYSIS

The static structural analysis calculates the stresses, displacements, strains, and forces in structures caused by a load that does not induce significant inertia and damping effects. Steady loading and response conditions are assumed; that the loads and the structure's response are assumed to change slowly with respect to time. A static structural load can be performed using the ANSYS WORKBENCH solver. The types of loading that can be applied in a static analysis include:

5.3 STEADY STATE THERMAL ANALYSIS:

A steady state thermal analysis calculates the effect of steady thermal load on a system or component, analyst were also doing the steady state analysis before performing the transient analysis. A steady state analysis can be the last step of transient thermal analysis. We can use steady state thermal analysis to determine temperature, thermal gradient, heat flow rates and heat flux in an object that do not vary with time

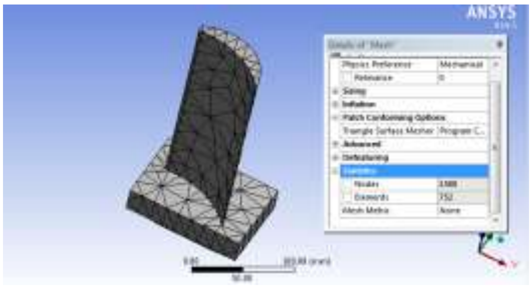


Fig 4Meshing Nodes 1580,elements 752

5.4 BOUNDARY CONDITION

In static analysis fixed the bottom side after apply pressure on blade face

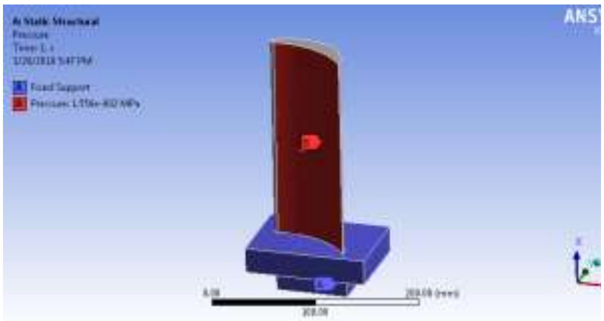


FIG 5 BOUNDARY CONDITION IN STATIC ANALYSIS

Boundary condition in steady state thermal analysis: apply temperature 229^0c, apply convection 22^0cfilm coefficient is 0.0025w/mm2^{o}c

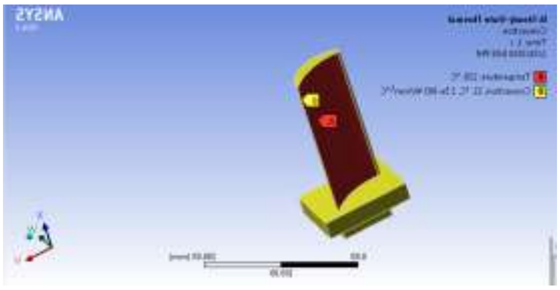


FIG 6 BOUNDARY CONDITION IN STEADY STATE THERMAL ANALYSIS

CHAPTER 6
RESULTS AND DISCUSSION

6.1 STATIC ANALYSIS:

This analysis is performed to find Structural parameters such as Stresses,shearstress, Deformation, Here we observed results on three materials namely chrome steel, hastelloy, and Inconel as shown below figures

6.1.2 Chrome steel

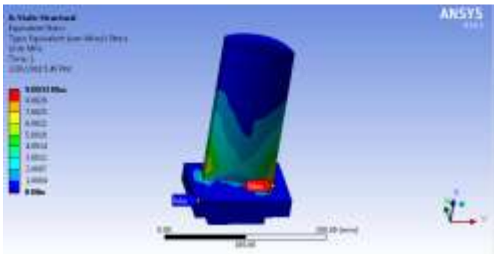


FIG 7 STRESS ON CHROME STEEL

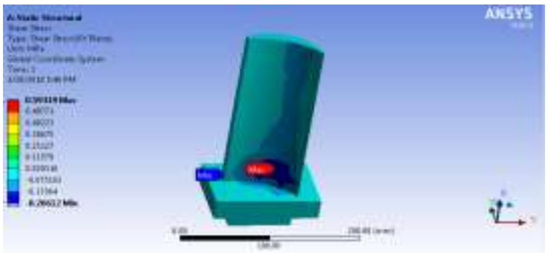


FIG 15 SHEAR STRESS ON CHROME STEEL

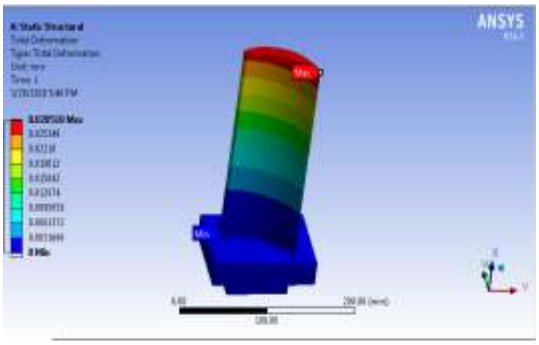


FIG 16 DEFORMATION ON CHROME STEEL

6.1.3 Inconel material

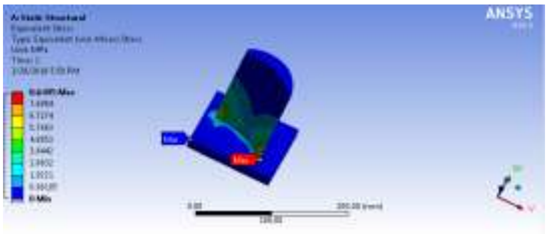


FIG 17 STRESSES ON INCONEL

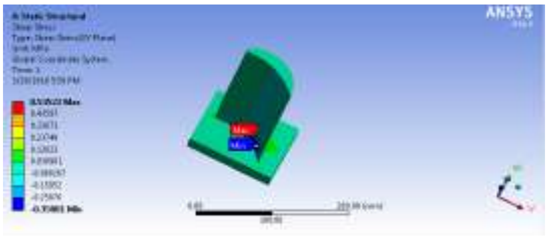


FIG 18 SHEAR STRESS ON INCONEL

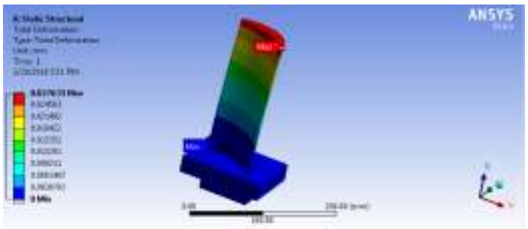


FIG 19 DEFORMATION NIMONIC 80A

6.1.4 HASTELLOY:

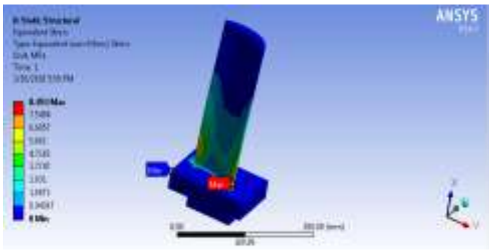


FIG 20 STRESSES ON HASTELLOY

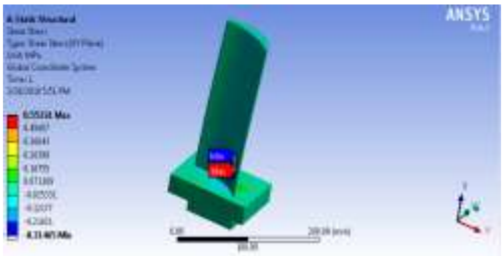


FIG 21 SHEAR STRESS ON HASTELLOY

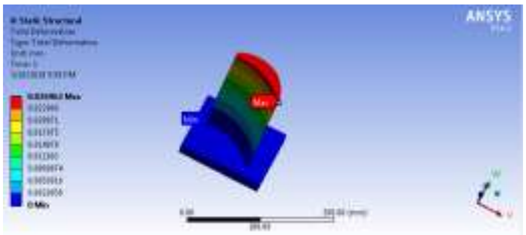


FIG 22 DEFORMATIONS ON HASTEALLOY

CHAPTER 7. THERMAL ANALYSIS:

This analysis is performed to find thermal parameters such as Here we observed results on four materials chrome steel, hastelloy, and Inconel as shown below figures

7.1 CHROME STEEL

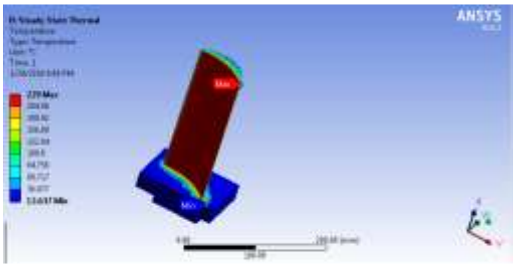


FIG 23 TEMPERATURE DISTRIBUTION CHROME STEEL

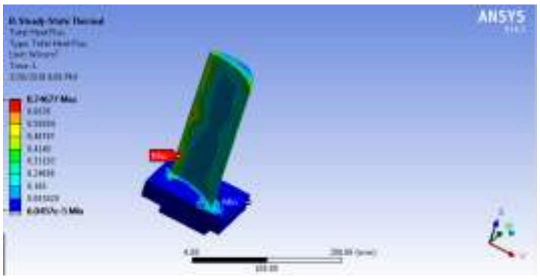


FIG 24 HEAT FLUX CHROME STEEL

7.2 HASTELLOY:

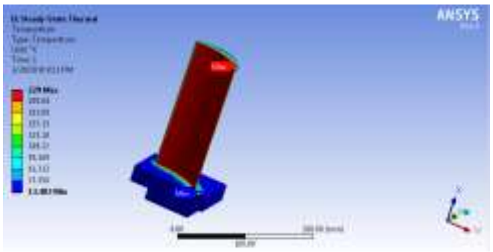


FIG 25 TEMPERATURE DISTRIBUTIONS ON HASTELLOY

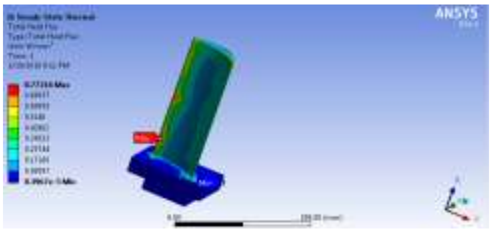


FIG 26 HEAT FLUX ON HASTELLOY

INCONEL 600:

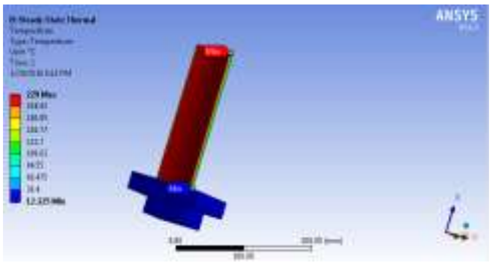


FIG 27 TEMPERATURE DISTRIBUTION ON INCONEL 600

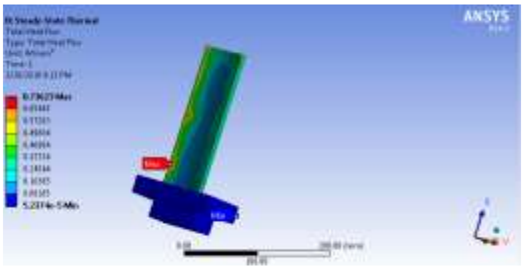


FIG 28 HEAT FLUX ON INCONEL 600

7.3 GRAPH

7.3.1 Stress graph

This graph shows the different maximum stress values in different materials, chrome steel, hastelloy, and Inconel materials, hastelloy has least shear stress value of 8.49Mpa compared to another materials as shown in the graph 1

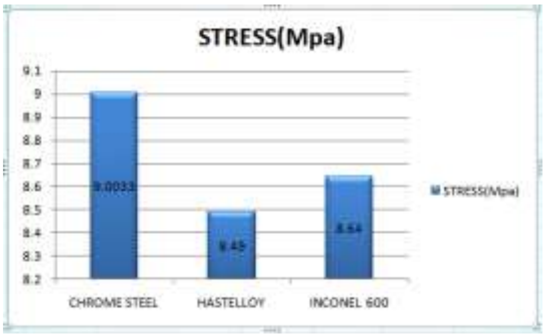


FIG 29 STRESS GRAPH

7.3.2 Total deformation graph

This graph shows the different total deformation values in different materials, chrome steel, hastelloy, and Inconel, hastelloy material has least total deformation value of 0.0026mm compared to another materials as shown in the graph 1

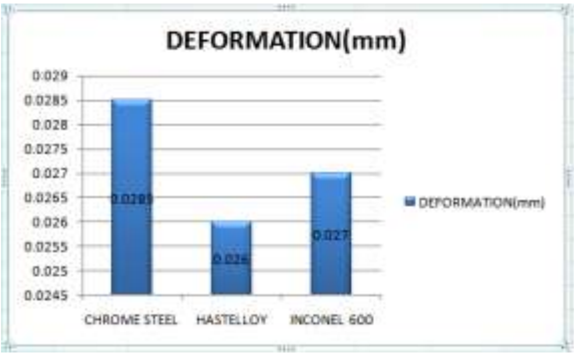


FIG 30 TOTAL DEFORMATION GRAPH

7.3.3 Shear stress graph

This graph shows the different total deformation values in different materials, chrome steel, hastelloy, and Inconel , inconel material has least shear stress compared to another materials 0.53mpa as shown in the graph 1

FIG 31 SHEAR STRESS GRAPH

7.3.4 Temperature distribution graph

This graph shows the different temperature distribution values in different materials, chrome steel, hastelloy, and Inconel , hastelloy has highest temp distribution value of 13.403 (^{0}c)(min) compared to another materials as shown in the graph 2

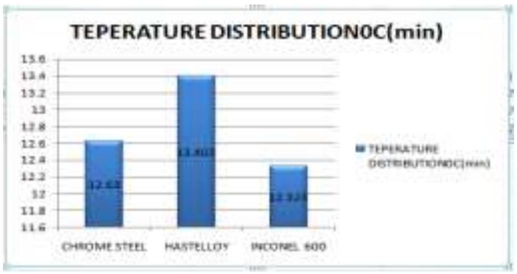


FIG 32 TEMPERATURE DISTRIBUTION GRAPH

7.3.5 Heat flux graph

This graph shows the different heat flux values in different materials, chrome steel, hastelloy, and Inconel, hastelloy has highest heat flux value of 0.772w/mm^2 compared to another materials as shown in the graph 1

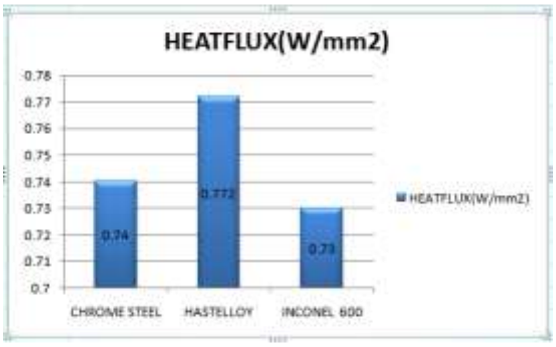


FIG 33 HEAT FLUX GRAPH

CHAPTER 8
CONCLUSION

Modeling of steam turbine blade is done by using CATIAV5 Software and then the model is imported into ANSYS Software for Structural analysis on the steam turbine blade to check the quality of materials such as, chrome steel, hastelloy, and Inconel. From the obtained Von-misses stresses, shear stress , deformation, temperature distribution and heat flux for the materials, respectively Compared with all materials hastelloy material have less stresses, deformations, and High temperature distribution and heat flux values .Finally from structural analysis and thermal analysis based on results it is concluded that haste alloy material is suitable material for stream turbine .

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