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DESIGN AND THERMAL ANALYSIS OF STEAM TURBINE BLADE BY USING ANSYS

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ABSTRACT
A steam turbine is mechanical device which converts thermal energy of steam into mechanical work. The steam turbine gives the better thermodynamic efficiency by using compound 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.The aim of the project is to increase the life steam turbine blade using different materials design of steam turbine blade using catia software with and without holes and analysis by using ansys software we preferred two types of analysis structural and thermal analysis in structural analysis find out stress and total deformations and in thermal point of view find out temperature distribution and total heatflux choosing three materials they are Nimonic 80A, Chrome steel, inconel 600 taking two designs without holes and with holes finally concluded the suitable design and material of the steam turbine

1.1 INTRODUCTION
A turbine (from the Latin turbo, a vortex, related to the Greek τύρβη, tyrbē, 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.Earlyturbineexamplesare 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.

The word "turbine" was coined in 1822 by the French mining engineer Claude Burdin from the Latin turbo, or vortex, in a memo, "Des turbines hydrauliques ou machines rotatoires à grande vitesse", which he submitted to the Académie royale des sciences in Paris. Benoit Fourneyron, a former student of Claude Burdin, built the first practical water turbine

FIG 1TURBINE

1.2 STEAM TURBINE: Steam turbine is used for the generation of electricity in thermal power plants, such as plants using coal, fuel oil or nuclear fuel. They were once used to directly drive mechanical devices such as ships' propellers (for example the Turbinia, the first turbine-powered steam launch, but most such applications now use reduction gears or an intermediate electrical step, where the turbine is used to generate electricity, which then powers an electric motor connected to the mechanical load. Turbo electric ship machinery was particularly popular in the period immediately before and during World War II, primarily due to a lack of sufficient gear-cutting facilities in US and UK shipyards.

1.3 USES OF TURBINES

Almost all electrical power on Earth is generated with a turbine of some type. Very high efficiency steam turbines harness around 40% of the thermal energy, with the rest exhausted as waste heat.Most jet engines rely on turbines to supply mechanical work from their working fluid and fuel as do all nuclear ships and power plants. Turbines are often part of a larger machine. A gas turbine, for example, may refer to an internal combustion machine that contains a turbine, ducts, compressor, combustor, heat-exchanger, fan and (in the case of one designed to produce electricity) an alternator. Combustion turbines and steam turbines may be connected to machinery such as pumps and compressors, or may be used for propulsion of ships, usually through an intermediate gearbox to reduce rotary speed. Reciprocating piston engines such as aircraft engines can use a turbine powered by their exhaust to drive an intake-air compressor, a configuration known as a turbocharger (turbine supercharger) or, colloquially, a "turbo". Turbines can have very high power density (i.e. the ratio of power to weight, or power to volume). This is because of their ability to operate at very high speeds. The Space Shuttle main engines used turbo pumps (machines consisting of a pump driven by a turbine engine) to feed the propellants (liquid oxygen and liquid hydrogen) into the engine's combustion chamber. The liquid hydrogen turbo pump is slightly larger than an automobile engine (weighing approximately 700 lb) and produces nearly 70,000 hp (52.2 MW).Turbo expanders are widely used as sources of refrigeration in industrial processes.Military jet engines, as a branch of gas turbines, have recently been used as primary flight controller in post-stall flight using jet deflections that are also called thrust vectoring.[7] The U.S. Federal Aviation Administration has also conducted a study about civilizing such thrust vectoring systems to recover jetliners from catastrophes.

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1.4 STEAM TURBINE

A steam turbine is a device that extracts thermal energy from pressurized steam and uses it to do mechanical work on a rotating output shaft. Its modern manifestation was invented by Sir Charles Parsons in 1884. Because the turbine generates rotary motion, it is particularly suited to be used to drive an electrical generator – about 90% of all electricity generation in the United States in the year 1996 was by use of steam turbines.[3] The steam turbine is a form of heat engine that derives much of its improvement in thermodynamic efficiency from the use of multiple stages in the expansion of the steam, which results in a closer approach to the ideal reversible expansion process.

1.5 MANUFACTURING :

The present-day manufacturing industry for steam turbines is dominated by Chinese power equipment makers. Harbin Electric, Shanghai Electric, and Dongfang Electric, the top three power equipment makers in China, collectively hold a majority stake in the worldwide market share for steam turbines in 2009-10 according to Platts.[14] Other manufacturers with minor market share include Bharat Heavy Electricals Limited, Siemens, Alstom, General Electric, Doosan Škoda Power, Mitsubishi Heavy Industries, and Toshiba.[14] The consulting firm Frost & Sullivan projects that manufacturing of steam turbines will become more consolidated by 2020 as Chinese power manufacturers win increasing business outside of China Steam turbines are made in a variety of sizes ranging from small <0.75 kW (<1 hp) units (rare) used as mechanical drives for pumps, compressors and other shaft driven equipment, to 1.5 GW (2,000,000 hp) turbines used to generate electricity. There are several classifications for modern steam turbines.

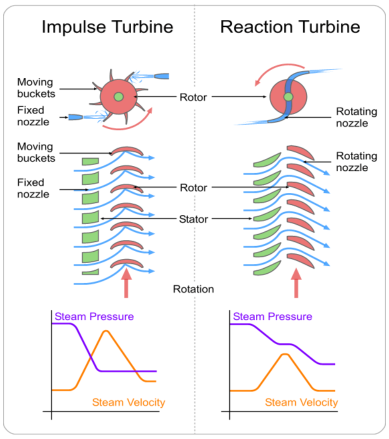

FIG 2 TYPES OF STEAM TURBINE

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 postprocessing 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.

Zachary Stuckl [3] addresses steam turbine efficiency by discussing the overall design of steam turbine blades with a specific focus on blade aerodynamics, Nimonic (Ni20 Cr20 Co0.4 Fe6 Mo2.1 Ti0.4 Al0.06 C) Nickel-base super alloy NIMONIC® alloy 80A) is a wrought, age-hardenable nickel-chromium composite, reinforced by increases of titanium, aluminium and carbon, produced for administration at temperatures up to 815°C (1500°F). It is delivered by high-recurrence materials are used in the manufacture of steam turbine blades, and the factors that cause turbine blade failure and therefore the failure of the turbine itself. This paper enumerates and describes the currently available technologies that enhance the overall efficiency of the generator and prevent turbine failure due to blade erosion and blade cracking. The stresses developed in the blade as a result of steam pressure, steam temperature, and the centrifugal forces due to rotational movement are delineated; current designs calculated to counter the fatigue caused by these stresses are existing. The aerodynamic designs of impulse and reaction turbine blades are compared and contrasted, the effect of those designs have on turbine efficiency are debated. Based on the research unfilled herein, this paper presents a complete summary of what modifications to existing steam turbine generator blades can be made to increase turbine efficiency.

CHAPTER 3 TERMINOLOGY OF STEAM TURBINE BLADE AND BASIC DEFINITIONS

3. 1 STEAM TURBINE BLADE TERMINOLOGY:

It is necessary to define the parameters used in describing blade shapes and configurations of blade. Blade profiles are usually of airfoil shape for optimum performance, although cost is more important than the ultimate in efficiency, simple geometrical shapes composed of circular areas and straight line are of ten used. Journal of Engineering and Development, Vol. 11, No. 3, December (2007) ISSN 1813-7822 85 The spacing or pitch of the blade is the distance between corresponding points of adjacent blade and is expressed either by the pitch-chord ratio or alternatively the solidity. When the blades are evenly spaced around a rotor, the pitch is the circumference at any radius divided by the number of blades.

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Blade Nomenclature

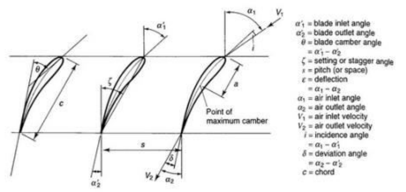

FIG 3 STEAM TURBINE BLADE NOMENCLATURE

3.2 TURBINE BLADE DESIGN OVERVIEW:

Almost all of the blading used in modern mechanical drive steam turbines is either of drawn or milled type construction. Drawn blades are machined from extruded airfoil shaped pieces of material stock. Refer to Fig. for the steps in machining a drawn blade. Milled blades are machined from a rectangular piece of bar stock. The cost of a drawn blade is much less than the cost of a milled blade, the reasons being obvious from Figs. showing the number of steps needed to produce each blade. As will be seen later, a certain percentage of steam turbine blades are neither drawn nor milled type construction. These blades are usually large, last-stage blades of steam turbines or jet gas expanders. They are either made by forging or a precision cast process.

3.3 MATERIAL PROPERTIES:

MATERIAL	NIMONIC 80A	CHROME STEEL	INCONEL 600
Density g/cc	8.19	7.31	8360
Young's modulus(Gpa)	144	200	214
Poisson's ratio	0.348	0.3	0.324
Tensile strength ultimate(Mpa)	1120	485	570
Tensile strength yield(Mpa)	980	275	340
Melting point(°c)	1380	1365	1370
Thermal conductivity (W/m/k)	33.5	14.0	13.6
Specific heat capacity(J/g°-c)	0.448	0.418	0.419

3.4 PROBLEM DEFINITION:

All modern steam power plants use impluse-reaction turbines as their blading efficiency is higher than that of impulse turbines. Last stage of steam turbine impluse-reaction blade is 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 thermal 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.

3.5 OBJECTIVE

The objective of this project is to make a Steam turbine blade different 3D models of the steam turbine blade with holes and without holes we are taking two designs and 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.

3.6 METHODOLOGY

THE METHODOLOGY FOLLOWED IN THE PROJECT IS AS FOLLOWS:

1) Create a 3d model of the different turbine blades using parametric software catia v5.
2)Convert the surface model into its and import the model into ansys to do analysis.
3)Perform static thermal analysis on the steam turbine blade. Finally it was concluded

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which material is the suitable for steam turbine blade on these materials Nimonic 80A, chrome steel, Inconel 600.

3.7 SCOPE OF THE PROJECT:

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, deformation, temperature distribution and heat flux of the component under the thermal load conditions.
3. To compare analysis between two different designs and three materials Nimonic 80a, chrome steel, Inconel of steam turbine blade.

4. Finally concluded the suitable design and material of the steam turbine blade.

3.8 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

CHAPTER 4 INTRODUCTION TO SOFTWARES

4 .1CATIA SOFTWARE:

Welcome to **CATIA (Computer Aided Three Dimensional Interactive Application)**. As a new user of this software package, you will join hands with thousands of users of this high-end CAD/CAM/CAE tool worldwide. If you are already familiar with the previous releases, you can upgrade your designing skills with the tremendous improvement in this latest release.

4.2 DIMENSIONS AND DESIGN PROCEDURE IN CATIA:

Go to the sketcher workbench create profile blade shape by using Arcs radius is R55,R60,R80 after create the fillet is R4 apply pad in part design workbench again go to the sketcher create the rectangle 120x100 apply pad is 25 mm again go to sketcher create 85x10025mm rectangle apply pad in part design workbench again go to sketcher create rectangle is 120x100 apply pad is 25mm in part design workbench finally show the steam turbine blade as shown below figure.

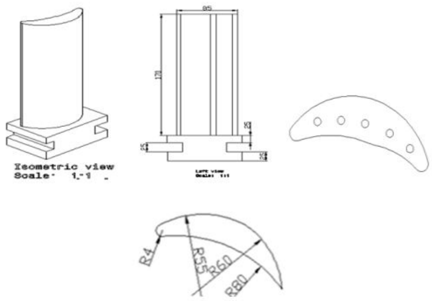

FIG 4 BLADE DIMENSIONS

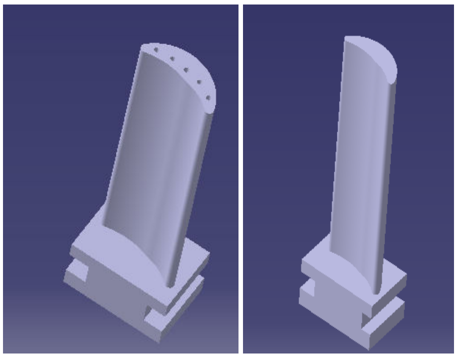

FIG 5 STEAM TURBINE BLADE WITH AND WITH OUTHOLES IN CATIA WORK BENCH

4 .3 ANSYS SOFWARE:

ANSYS is a large-scale multipurpose finite element program developed and maintained by ANSYS Inc. to analyze a wide spectrum of problems encountered in engineering mechanics.

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4.4 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

4.5 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:

4.6 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.

WITH HOLES: Nodes 17425, Elements 11132 / WITHOUT HOLES: Nodes 18555, Elements 12548

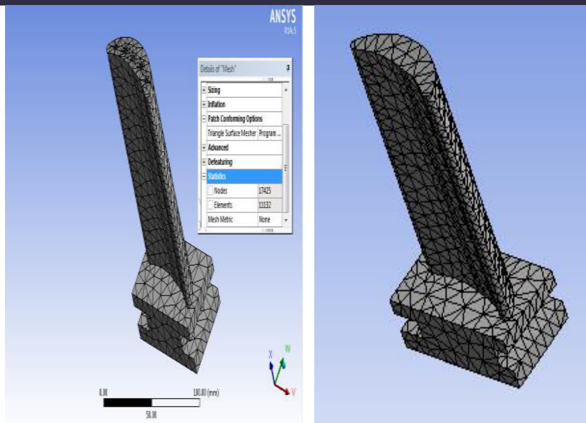

FIG 5 MESHING

4.7 BOUNDARY CONDITION

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

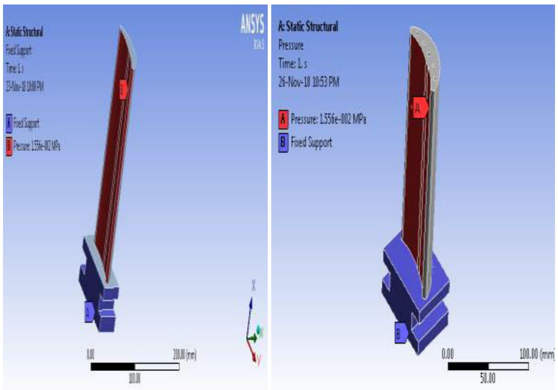

FIG 6 BOUNDARY CONDITION WITH AND WITHOUT HOLES IN STATIC ANALYSIS

Boundary condition in steady state thermal analysis: With and without holes apply temperature 229^{0}c, apply convection 22^{0}cfilm coefficient is 0.0025w/mm2^{o}c

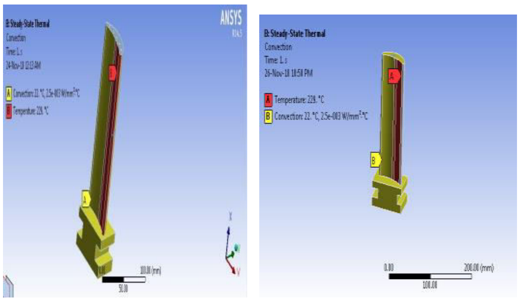

FIG 7 BOUNDARY CONDITION IN STEADY STATE THERMAL ANALYSIS

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CHAPTER 5 RESULTS AND ANALYSIS

This analysis is performed to find Structural and thermal parameters such as Stresses, Deformation, heatflux, temperature distribution with and without holes of steam turbine blade using three materials namely Nimonic 80A, Chrome steel, Inconel 600 finally observed results as shown below figures

5.1 VON-MISES STRESS GRAPH

The below graph shows that ,with Variation of stresses 2 different designs with and without holes and 5 different materials stainless steel, Nimonic 80A, Chrome steel, Inconel 600, haste alloy like has least stress is nimonic 80A materials

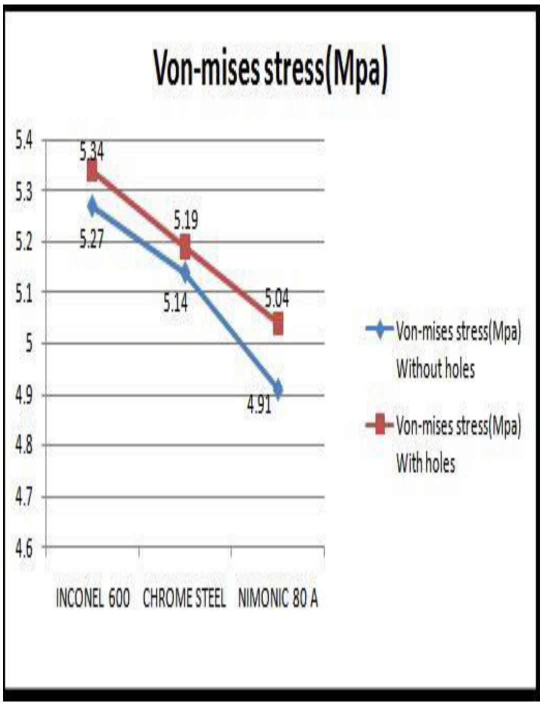

FIG 8 STRESSS GRAPH

5.2TOTAL DEFORMATION GRAPH :

The below graph shows that ,with Variation of Total deformations 2 different designs with and without holes and 3 different materials Nimonic 80A, Chrome steel, inconel 600 like has least total deformation is nimonic 80A materials.

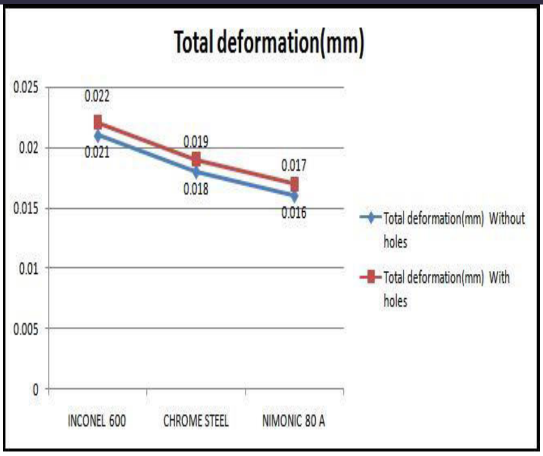

FIG 8 TOTAL DEFORMATION GRAPH

5.3 TEMPERATURE DISTRIBUTION GRAPH :

This graph shows the different temperature distribution values in 2 different designs and different materials like Nimonic 80A, Chrome steel, inconel 600 finally nimonic80A with hole material has highest temp distribution minumum value

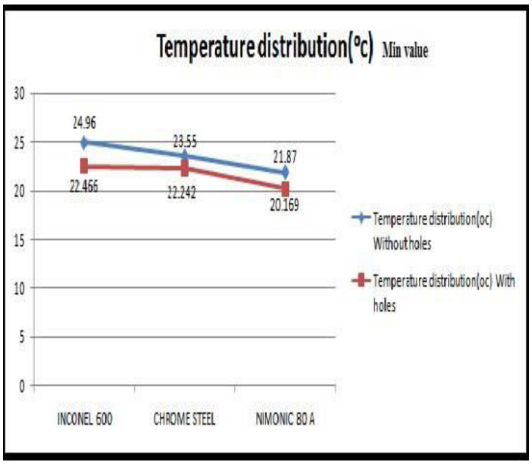

FIG 9 TEMPERATURE DISTRIBUTION GRAPH

5.4 TOTAL HEAT FLUX GRAPH:

This graph shows the different Total heat flux values in 2 different designs and different materials like Nimonic 80A, Chrome steel, inconel 600 finally nimonic80A with hole material has highest total heat flux distribution

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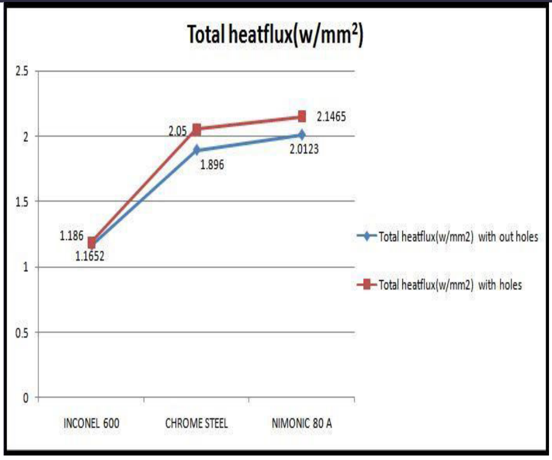

FIG 10 HEAT FLUX GRAPH

CHAPTER 6 CONCLUSION

Modeling of steam turbine blades with and without holes 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 Nimonic 80A, Chrome steel,inconel 600. From the obtained Von-misses stresses deformation, temperature distribution and heat flux for the materials, respectively Compared with all materials with holes Nimonic80A material have less stresses, deformations, and min temperature distribution and heat flux values .Finally from structural analysis and thermal analysis based on results it is concluded that with holes Nimonic80A material is suitable material for stream turbine .

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