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Design and Analysis of Steam turbine blade using different materials

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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 for steam turbine blade.

KEY WORDS:Steam Turbine, Thermal Energy, Impulse Turbine, Reaction Turbine, StaticAnalysis, Thermal Analysis

1. INTRODUCTION

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 jetengines. 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 SirCharles 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. BenoitFourneyron, a former student of Claude Burdin, built the first practical water turbine

FIG 1TURBINE

1.2 TYPES OF TURBINES

- Steam turbine
- Gas turbine
- Transonic turbine
- Contra-rotating turbine
- Statorless turbine
- Ceramic turbine
- Shroudless turbine
- Bladeless turbine
- Water turbines
- Wind turbines
- Velocity compound
- Pressure compound multi stage impulse
- Mercury vapour turbine

1.3 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 SirCharles 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.

1.3.1 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, GeneralElectric, Doosan Škoda Power, Mitsubishi Heavy Industries, and Toshiba.

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.

1.3.2 Blade and stage design

Turbine blades are of two basic types, blades and nozzles. Blades move entirely due to the impact of steam on them and their profiles do not converge. This results in a steam velocity drop and essentially no pressure drop as steam moves through the blades. A turbine composed of blades alternating with fixed nozzles is called an impulse turbine, Curtis turbine, Rateau turbine, or Brown-Curtis turbine. Nozzles appear similar to blades, but their profiles converge near the exit. This results in a steam pressure drop and velocity increase as steam moves through the nozzles. Nozzles move due to both the impact of steam on them and the reaction due to the high-velocity steam at the exit. A turbine composed of moving nozzles alternating with fixed nozzles is called a reaction turbine or Parsons turbine.

Except for low-power applications, turbine blades are arranged in multiple stages in series, called compounding, which greatly improves efficiency at low speeds.A reaction stage is a row of fixed nozzles followed by a row of moving nozzles. Multiple reaction stages divide the pressure drop between the steam inlet and exhaust into numerous small drops, resulting in a pressure-compounded turbine. Impulse stages may be either pressure-compounded, velocity-compounded, or pressure-velocity compounded. A pressure-compounded impulse stage is a row of fixed nozzles followed by a row of moving blades, with multiple stages for compounding. This is also known as a Rateau turbine, after its inventor. A velocity-compounded impulse stage (invented by Curtis and also called a "Curtis wheel") is a row of fixed nozzles followed by two or more rows of moving blades alternating with rows of fixed blades. This divides the velocity drop across the stage into several smaller drops.A series of velocity-compounded impulse stages is called a pressure-velocity compounded turbine.

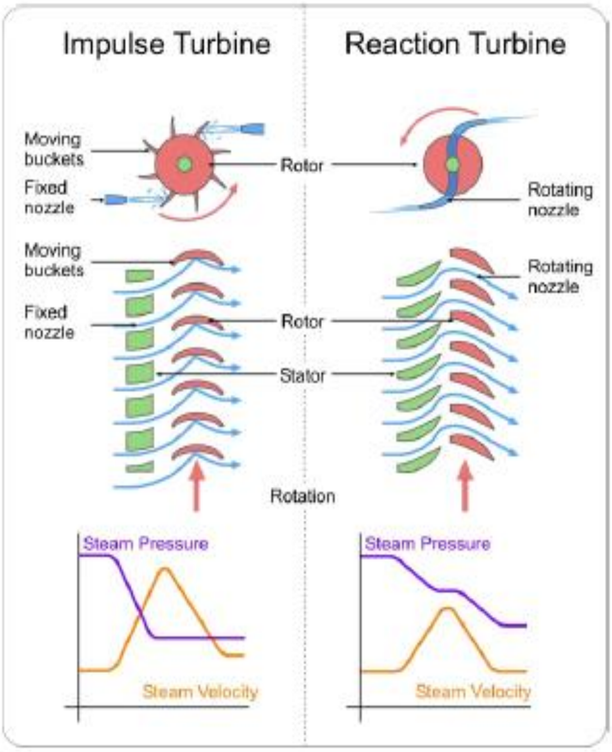

FIG 2 TYPES OF STEAM TURBINE

By 1905, when steam turbines were coming into use on fast ships (such as HMS Dreadnought) and in land-based power applications, it had been determined that it was desirable to use one or more Curtis wheels at the beginning of a multi-stage turbine (where the steam pressure is highest), followed by reaction stages. This was more efficient with high-pressure steam due to reduced leakage between the turbine rotor and the casing.[18]This is illustrated in the drawing of the German 1905 AEG marine steam turbine. The steam from the boilers enters from the right at high pressure through a throttle, controlled manually by an operator (in this case a sailor known as the throttleman). It passes through five Curtis wheels and numerous reaction stages (the small blades at the edges of the two large rotors in the middle) before exiting at low pressure, almost certainly to a condenser.

The condenser provides a vacuum that maximizes the energy extracted from the steam, and condenses the steam into feedwater to be returned to the boilers. On the left are several additional reaction stages (on two large rotors) that rotate the turbine in reverse for astern operation, with steam admitted by a separate throttle. Since ships are rarely operated in reverse, efficiency is not a priority in astern turbines, so only a few stages are used to save cost.

1.3.3 Blade design challenges

A major challenge facing turbine design was reducing the creep experienced by the blades. Because of the high temperatures and high stresses of operation, steam turbine materials become damaged through these mechanisms. As temperatures are increased in an effort to improve turbine efficiency, creep becomes significant. To limit creep, thermal coatings and superalloys with solid-solution strengthening and grain boundary strengthening are used in blade designs.

1.3.4 Steam supply and exhaust conditions

These types include condensing, non-condensing, reheat, extraction and induction.

Condensing turbines are most commonly found in electrical power plants. These turbines receive steam from a boiler and exhaust it to a condenser. The exhausted steam is at a pressure well below atmospheric, and is in a partially condensed state, typically of a quality near 90%.

Non-condensing or back pressure turbines are most widely used for process steam applications. The exhaust pressure is controlled by a regulating valve to suit the needs of the process steam pressure. These are commonly found at refineries, district heating units, pulp and paper plants, and desalination facilities where large amounts of low pressure process steam are needed. Reheat turbines are also used almost exclusively in electrical power plants. In a reheat turbine, steam flow exits from a high-pressure section of the turbine and is returned to the boiler where additional superheat is added. The steam then goes back into an intermediate pressure section of the turbine and continues its expansion. Using reheat in a cycle increases the work output from the turbine and also the expansion reaches conclusion before the steam condenses, thereby minimizing the erosion of the blades in last rows. In most of the cases, maximum number of reheats employed in a cycle is 2 as the cost of super-heating the steam negates the increase in the work output from turbine.

Extracting type turbines are common in all applications. In an extracting type turbine, steam is released from various stages of the turbine, and used for industrial process needs or sent to boiler feedwater heaters to improve overall cycle efficiency. Extraction flows may be controlled with a valve, or left uncontrolled.

Induction turbines introduce low pressure steam at an intermediate stage to produce additional power.

2. PROBLEM DEFINITION:

All mordern 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 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 bldde and check FEA data of std. blade with various matirial.

3. 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.

3.1 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 thermal analysis on the steam turbine blade.
- Finally it was concluded which material is the suitable for steam turbine blade on these two materials(Nimonic 80A,Chrome steel)

3.2 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, deformation, of the component under the static- thermal load conditions
3. To compare analysis between two different designs and materials of steam turbine blade

3.3 LOAD CALCULATION :

= ×

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=23319.1mm2

Pressure =F/A

P=0.01556N/mm2

3.4 MATERIAL PROPERTIES

TAB 1CHROME STEEL PROPERTIES

Material	Chrome steel
Density	7.70 g/cc
Young’s modulus	200Gpa
Poisson’s ratio	0.32
Tensile strength ultimate	325000psi
Tensile strength yield	295000psi
Melting point	1400^0c
Thermal conductivity	33.5W/m/K
Specific heat capacity	0.448J/g-^{0}C

TAB 2 NIMONIC80A PROPERTIES

Material	Nimonic80a
Density	8.19 g/cc
Young’s modulus	222Kn/mm^2
Poisson’s ratio	0.35
Tensile strength ultimate	1250Mpa
Tensile strength yield	800MPa
Melting point	1365^0c
Thermal conductivity	11.2W/m/K
Specific heat capacity	0.448J/g-^{0}C

4.DIMENSIONS AND DESIGN PROCEDURE IN CATIA:

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

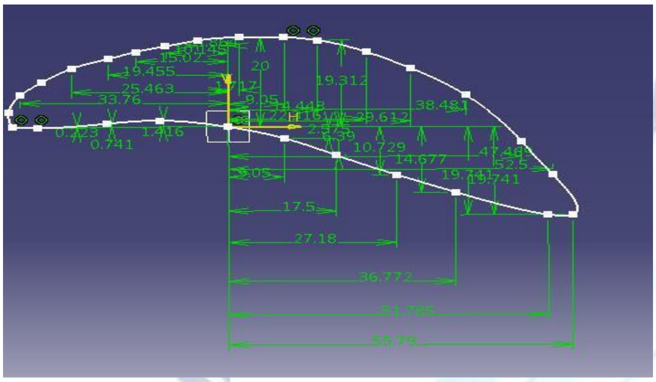

FIG 9BLADE DIMENSIONS

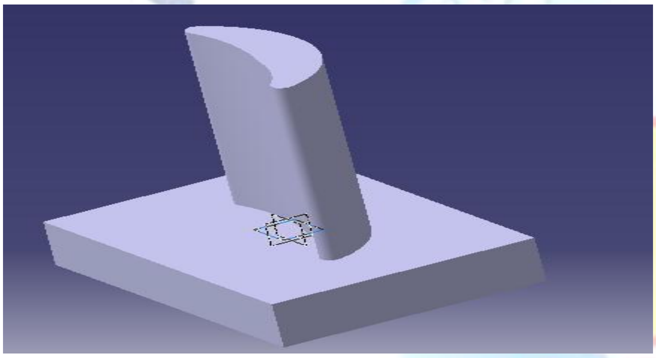

FIG 10 STEAM TURBINE BLADE IN CATIA WORK BENCH

5.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

5.1STATIC 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:

5.2 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.

Nodes 7911,elements 4848

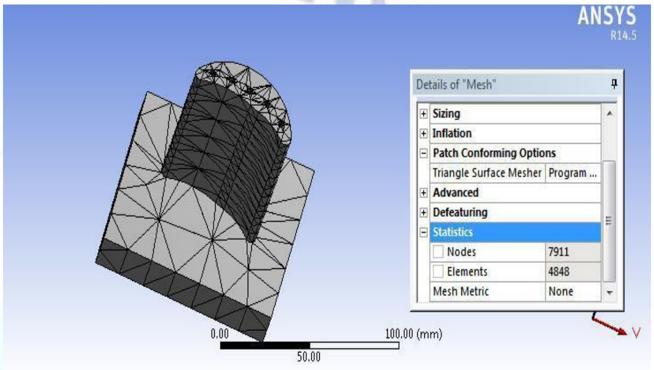

FIG 11MESHING

5.3 BOUNDARY CONDITION

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

FIG

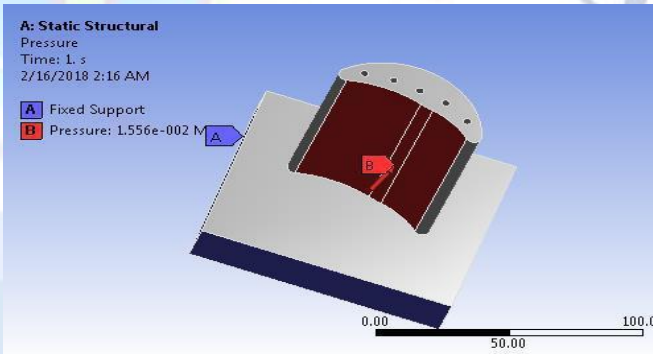

FIG 12 BOUNDARY CONDITION IN STATIC ANALYSIS

Boundary condition in steady state thermal analysis: apply temperature 2290c, apply convection 220cfilm coefficient is 0.0025w/mm2oc

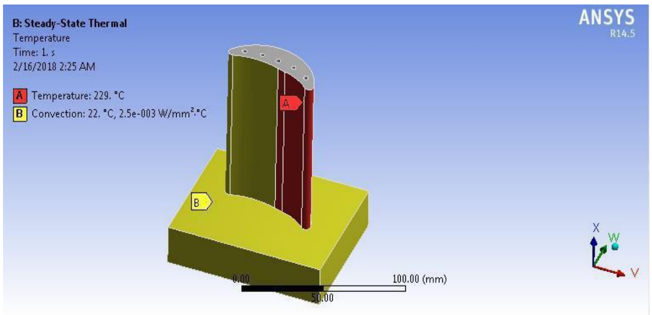

FIG 13 BOUNDARY CONDITION IN STEADY STATE THERMAL ANALYSIS

6 RESULTS AND DISCUSSION

6.1 STATIC ANALYSIS:

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

6.1.2 Chrome steel

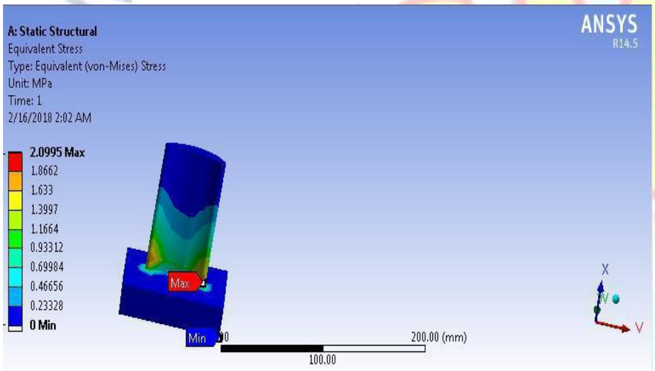

FIG 14 STRESS ON CHROME STEEL

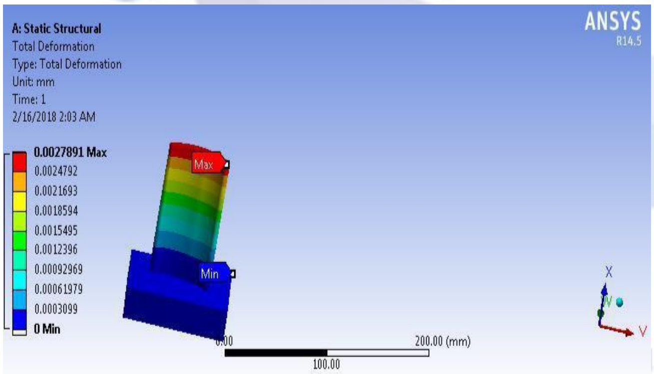

FIG 15 DEFORMATION ON CHROME STEEL

6.1.2 Nimonic 80a material

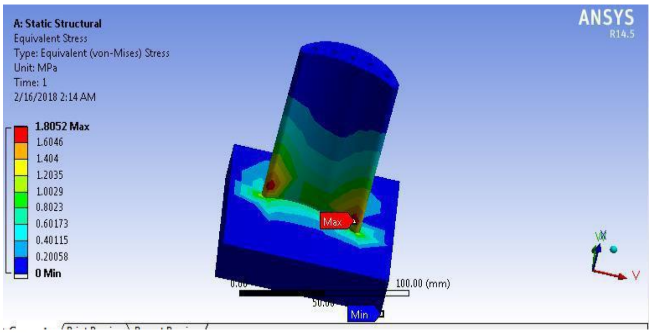

FIG 16 STRESS ON NIMONIC 80A

6.2 THERMAL ANALYSIS:

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

6.2.1 Chrome steel

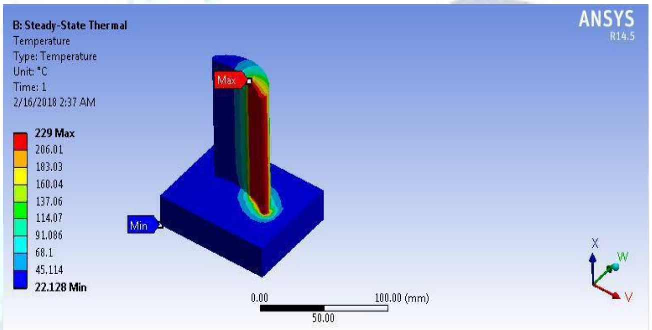

FIG 18 TEMPERATURE DISTRIBUTION CHROME STEEL

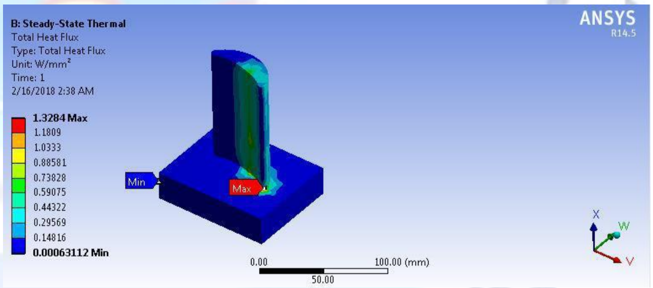

FIG 19 HEAT FLUX CHROME STEEL

6.2.2 Nimonic80a

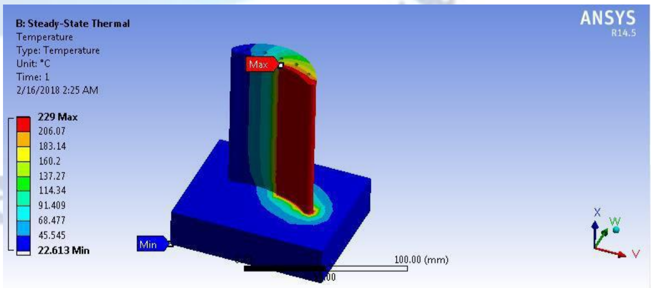

FIG 20TEMPERATURE DISTRIBUTION NIMONIC80A

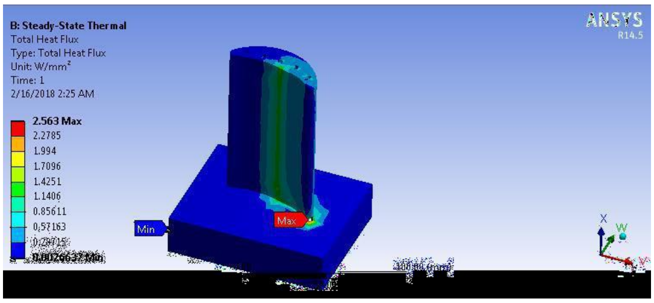

FIG 21 HEAT FLUX NIMONIC80A

6.3 GRAPH

6.3.1 Stress graph

This graph shows the different maximum stress values in different materials,nimonic80A material has least shear stress value of 1.8052Mpa compared to another materials as shown in the graph 1

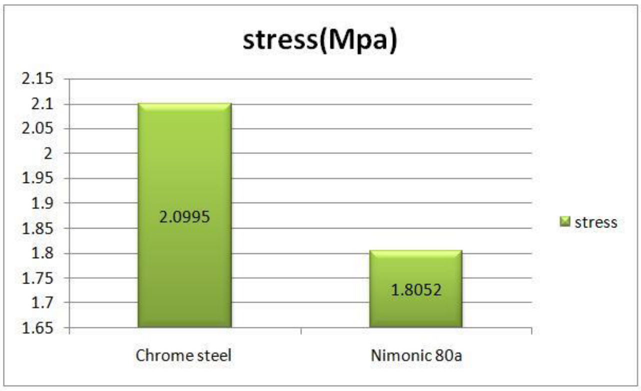

FIG 22 STRESSS GRAPH

6.3.2 Total deformation graph

This graph shows the different total deformation values in different materials, nimonic80A material has total deformation value of 0.0025894mm compared to another materials as shown in the graph 1

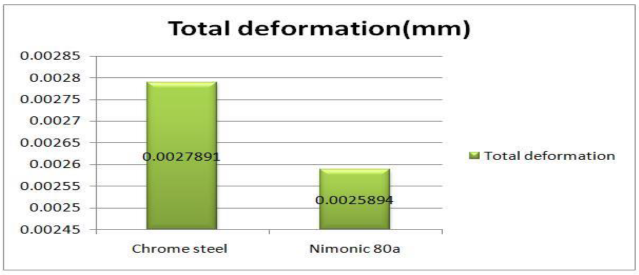

FIG 23 TOTAL DEFORMATION GRAPH

6.3.3 Temperature distribution graph

This graph shows the different temperature distribution values in different materials, nimonic80A material has highest temp distribution value of 22.613 (0c) compared to another materials as shown in the graph 1

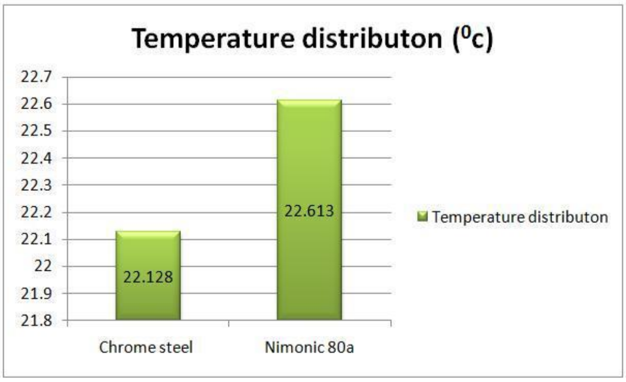

FIG 24 TEMPERATURE DISTRIBUTION GRAPH

7.3.4 Heat flux graph

This graph shows the different heat flux values in different materials, nimonic80A material has highest heat flux value of 2.563w/mm2 compared to another materials as shown in the graph 1

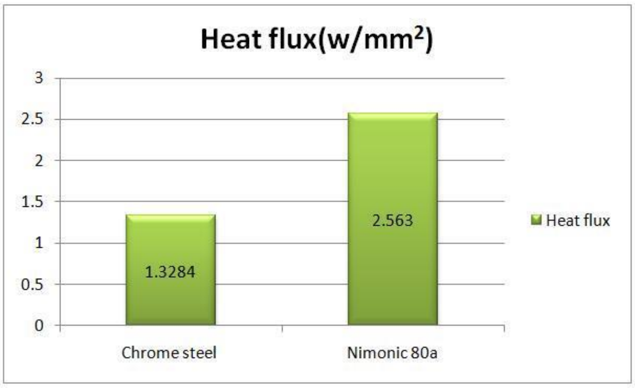

FIG 25 HEAT FLUX GRAPH

7. 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, Nimonic80A, and chrome steel. From the obtained Von-misses stresses, , deformation, temperature distribution and heat flux for the materials, respectively Compared with all materials Nimonic80A 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 Nimonic80A material is suitable material for stream turbine .

Conflict of interest statement

Authors declare that they do not have any conflict of interest.

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