Study on Ti-8Al-1Mo-1VAlloy (Near Alpha Alloy) Steam Turbine Rotor Blade using FEA

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Abstract: **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. There are two types of steam turbine Impulse steam turbine and Reaction steam turbine. At present, the reaction turbines are widely used, because blades which are used in impulse turbine are symmetrical in shape and in reaction turbine blades they are in aerofoil shape. So reaction turbines are more efficient than impulse turbine. In this present study, blade is made up of titanium alloy (Ti 8Al-1Mo-1V). For this Von mises stress and deformation are carried out. And also modal analysis is carried for blade material and natural frequencies are determined.**

Key words: **Von mises stress, Aerofoil, modal analysis, Ti811, Natural Frequency**

I. INTRODUCTION

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[1]. Steam turbine can classify into two major classes which depend on power output required, one is domestic or utility steam turbine and another one is industrial steam turbine. Domestic or utility steam turbines are mostly used to produce more than 100MW power production power plants like nuclear power sectors and steam power plant etc. These steam turbines will run at speed of 8000-10000 rpm with working temperature and pressure ranging between 540^0-600^0 C and 180-240 bar respectively.

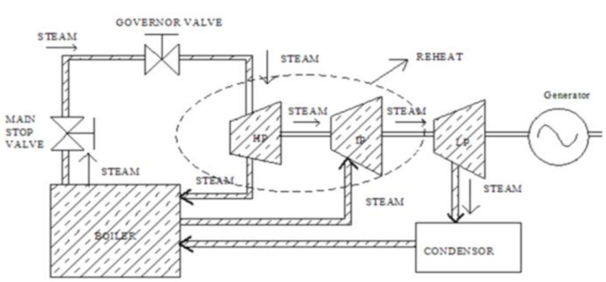

Figure 1: A schematic view of steam turbine

II. LITERATURE SURVEY

The manufacturing of the large capacity steam turbine at low pressure stage is difficult, because so many problems arises i.e. erosion, corrosion effects, corrosion cracking, abrasive & droplet impingement during the operation. But solution is there to replace the material with coating and also some materials will not absorb the wet steam hence so many precautions need to take when wet steam is coming at the operation. Titanium alloys, because of their excellent specific strength/density ratio. In addition to this titanium alloys are excellent in corrosion resistance, high fracture toughness and creep strength up to 600°C. Though a number of alloys are in use, Ti-8AL 1Mo- 1V alloy, due to its advantageous characteristics has been selected for HP compressor blades for different applications. Optimization of chemical composition, forging technology and heat treatment were the main objectives to obtain best combination of properties for the end use. The alloy has been successfully evaluated in accordance with mandatory airworthiness requirements.

III. OBJECTIVES

To carry out the static stress analysis of Ti-8Al-1Mo-1V FEM to calculate Von mises stress and deformation of the rotor blade in maximum force and also to carry the modal analysis, to predict the natural frequencies.

IV. DESIGN OF TURBINE BLADE

The efficiency and reliability depends on proper design of blades, therefore it's necessary for design engineers who involved in steam turbine engineering to have an overview of importance and basics design aspects of steam turbine blades. Hence it involves thermodynamic, material science, aerodynamic, and mechanical disciplines [2]. The below figure 2 shows the geometry of steam turbine blade with varying cross sectional area [3].

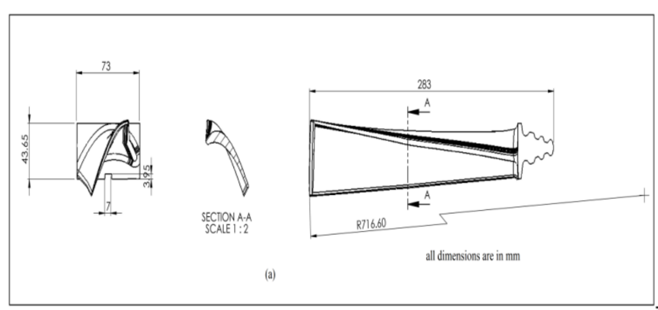

Figure 2: Geometry of Steam Turbine blade

A. *Meshed Turbine Blade*

Below Figure 3(a) describes the meshed view of Ti 811 blade, here we can observe 50800 nodes, 28936 elements and it is

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been meshed using “ANSYS” with solid 192 elements. Figure 3(b) shows force on turbine blade around 9600N.

Figure 3: Meshed view of steam turbine blade

V. RESULTS & DISCUSSION

A. *Analysis of Ti-8Al-1Mo-1V alloy (Near Alpha alloy) Rotor blade*

Ti811 is a near-alpha alloy and suitable for application at elevated temperature. It contains a relatively large amount of the alpha stabilizer, aluminum (Al). The presence of small amount of the beta-stabilizer (Mo and V) improve workability since these elements broaden the alpha + beta temperature range sufficiently for alpha + beta working and stabilizes only small amount of the beta phase. Although the tensile strength of this alloy is about equal to Ti-6AL-4V alloy, the elevated temperature strength and creep resistance are superior to other commonly available alpha or alpha + beta alloys. It has the highest tensile modulus and lowest density (4.37 g/cc) among the titanium alloys. Chemical composition, physical and mechanical properties are mentioned in following tables [4].

Table I: Chemical composition of Ti 811 in wt%

A1	Mo	V	Fe	C	Ti
7.35	0.75	0.75	0.30	0.08	Bal

Table II: Mechanical and other properties of Ti 811 alloy

Volume	1.723e+005 mm³
Mass	7.5293e-004 t
Density	4.37e-009 tonne mm^-3
Young's Modulus	1.17e+005 MPa
Poisson's Ratio	0.32
Bulk Modulus	1.0833e+005 MPa
Shear Modulus	44318 MPa

B. *Von mises stress and Deformation results of Ti 811 using Ansys*

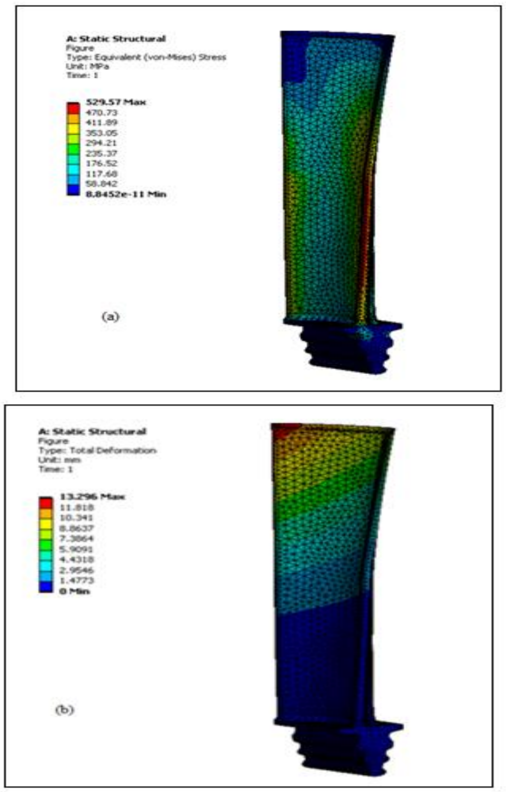

Fig 4: Results of Von mises stress and deformation

On apply of 9600 N force, fig 4(a) shows analysis of Von mises stress results of rotor blade and clearly we can observe a minimum stress induced is 8.815e-11 MPa and maximum stress induced is 529.57MPa. Fig 4(b) shows analysis of deformation results of rotor blade and clearly we can observe a minimum deformation induced is 0 and maximum deformation induced is 13.296mm.

C. *Modal Analysis of Ti 811 using Ansys*

Rotating flexible structures like turbine blades are often idealized as rotating cantilever beams. The procedure followed in ANSYS to perform modal analysis for rotating cantilever beam, respectively are discussed in the below sections. Solid 3D model of the turbine blade was developed and analyzed using ANSYS. Using SOLID 192 element, hexahedral mesh was generated The FE model was used to obtain the mode shapes and natural frequencies for the turbine blade in a stationary reference frame. The natural frequencies obtained are listed below.

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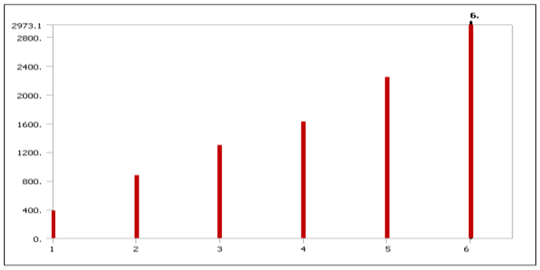

Figure 5: Mode shape v/s Frequency

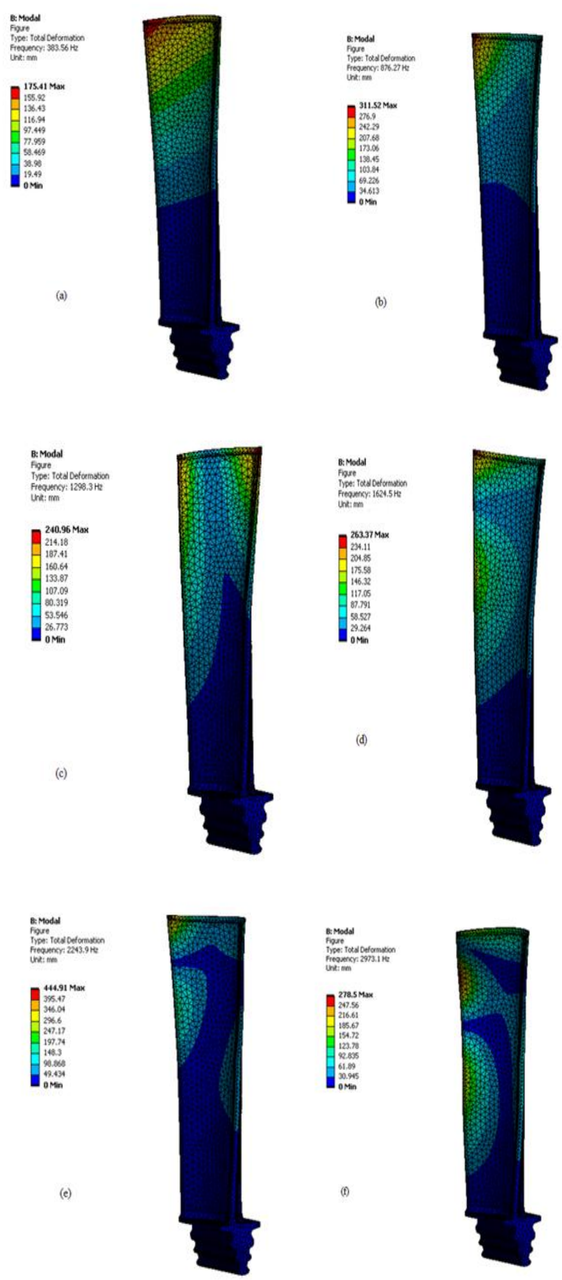

Fig 6: Six different mode shapes of respective frequencies.

The above figure represents different mode shapes obtained from different frequencies. Fig 6(a) shows mode shape 1 of frequency 383 Hz and its minimum deformation is zero and maximum deformation is 175.41mm. Fig 6(b) shows mode shape 2 of frequency 876.27 Hz and its minimum deformation is zero and maximum deformation is 311.52mm. Fig 6(c) shows mode shape 3 of frequency 1298.3Hz and its minimum deformation is zero and maximum deformation is 240.96mm. Fig 6(d) shows mode shape 4 of frequency 1624.5Hz and its minimum deformation is zero and maximum deformation is 263.37mm. Fig 6(e) shows mode shape 5 of frequency 2243.4 Hz and its minimum deformation is zero and maximum deformation is 444.91mm. Fig 6(f) shows mode shape 6 of frequency 2973.1 Hz and its minimum deformation is zero and maximum deformation is 278.5mm.

VI. Conclusion

Since, blades suffer from different types of loading from centrifugal force and steam flow, which intern leads to different stresses like tensile and bending. To overcome this, in our present work we have varied blades cross sectional area and Ti811 alloy is used as a blade material. We observed 529.57Mpa maximum stress induced by Vonmises stress analysis and 13.296mm deformation can be observed by applying 9600N force. Also we carried out modal analysis to predict natural frequencies and six different mode shapes.

References

[1]. Aurel Stodola (1927) Steam and Gas Turbines. McGraw-Hill.
[2]. "ISSN 0040-6015 at 2011, Erosion Wear of the Blades of Wet Steam Turbine Stages: Present State of the Problem and Methods for Solving It Published by V. A. Ryzhenkov, A. I. Lebedeva, and A. F. Mednikov.
[3]. ISSN 0040-6015, 2012, Optimizing the Geometrical Parameters in a Group of High and Intermediate Pressure Stages Used in Large Steam Turbines Published by V. G. Gribin, V. V. Nitusov, and E. V. Mednikova.
[4]. B SAHA, B JANA, J S YADAV, CH RAMA KRISHNA, Y V H RAO and B GUPTA, Regional Centre for Military Airworthiness (Materials), Defense Research and Development Organization (DRDO). Hyderabad, paper entitled "Development and certification of Ti-8AI-1Mo-IV alloy for HP compressor blades for Adour engine applications" published at Bull. Mater. Sci., Vol. 19, No. 4, August 1996, pp. 661 669.

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