Static and Fatigue Analysis of a Steam Turbine Blade

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***Abstract*-Steam turbine is one of the most important prime movers for generating electricity. This falls under the category of power producing turbo-machines. Single unit of steam turbine can develop power ranging from 1 MW to 1000 MW. The purpose of turbine technology is to extract the maximum quantity of energy from the working fluid, to convert it into useful work with maximum efficiency, by means of a plant having maximum reliability, minimum cost, minimum supervision and minimum starting time. This present work explores the finite element analysis of a steam turbine blade using ANSYS software. Life cycle assessment of steam turbines is essential to improve their design and maintenance plans, since they should operate more than 20 years with minimum interruptions and without failures. Important element of this turbine is the blades and rotor due to their size, mass and cyclic stresses with relatively high frequencies and amplitude. To cope up with this we are using titanium alloy as a material. Different types of loads acting on steam turbine blade and consequential stresses develops in blade are studied. Fatigue stresses are developed on the steam turbine blade due to change in steam speed. The maximum steam speed range (from cut-in to cut-out steam speed) is considered for design of blade as well as predicting the fatigue life of the blade.**

***Key words - ANSYS*, Titanium alloy, Fatigue life, Finite element analysis, Steam turbine**

I. INTRODUCTION

Steam turbines are used in all of our major coal fired power stations to drive the generators or alternators, which produce electricity. The turbines themselves are driven by steam generated in 'Boilers' or 'Steam Generators' as they are sometimes called. Energy in the steam after it leaves the boiler is converted into rotational energy as it expands through the turbine. The turbine normally consists of several stages with each stage consisting of a stationary blade (or nozzle) and a rotating blade. Stationary blades convert the potential energy of the steam (temperature and pressure) into kinetic energy (velocity) and direct the flow onto the rotating blades. The rotating blades convert the kinetic energy into forces, caused by pressure drop, which results in the rotation of the turbine shaft. The turbine shaft is connected to a generator through the gear box. The high magnetic flux cut by shaft rotation which produces electricity in alternator.

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 is presented in [1]. An algorithm for calculating a turbine flow path compartment is considered using which it is possible to minimize the loss of energy in a group of stages while fulfilling strength limitations is explained in [2]. The optimized structure strength design and finite element analysis method for very high pressure (VHP) rotors of the 700°C ultra-super-critical (USC) steam turbine are presented in [3]. The basic design features and technical characteristics of the turbines installed on the foundation of the T_100 family turbines are presented In the period from the 1950s to 1970s are presented in [4]. A specific focus on aero foil 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 capable of thermal and chemical conditions in blade substrate from to prevent the corrosion when exposed to wet steam [5]. The main cause of failure of LP steam turbine blade is high cycle fatigue [6] .

III. OBJECTIVES

To conduct the static stress analysis of blade to check the static and fatigue strength. Make an unbalance response analysis of a blade in order to calculate blade deformation and quantify the forces acting on the blade supports that are caused due to blade imbalance and Assess potential risks and operating problems in general related to the blade of a given turbine blade system.

IV. DESIGN AND CALCULATION

In this present work, blade is subjected to static and fatigue analysis will be predicted a model analysis. From literature review of blade analysis information's like geometrical parameter, material properties, boundary conditions which supported with experimental results on static and fatigue analysis. Blade is in static and fatigue analysis will be done under model analysis by using FEA packages like ANSYS software.

Fig. 1 Turbine blade before applying load

The above figure shows the steam turbine blade before applying load and the geometry of the blade is as fallows. Blade cross section=A= 0.001m^2, Material density=ρ= 4620 kg/m^3, Radius= r1= 0.34m, r_2 =0.57m, Blade length= L= 0.23m, Velocity=142.961 rad/sec, F=47.73 KN/Blade, Factor of safety for given material is $n = 2.11$ Ultimate yield strength $\sigma_u = 1070$ Mpa, Working stress$\sigma_1 = 510$ Mpa

IV. RESULTS

Fig. 2 Turbine blade with meshed

Fig. 3 Turbine root of blade meshed

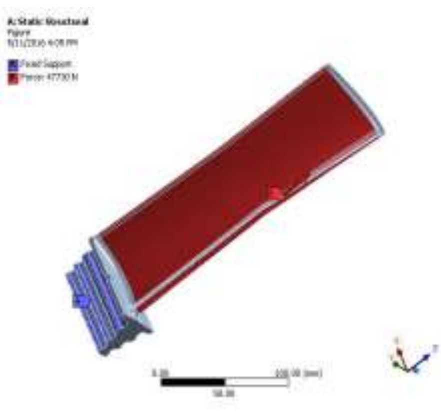

Fig . 4 Force applied on turbine blade

The above fig. shows the force applied on the turbine blade, and the force applied is 47KN.

A. Deformation Results:

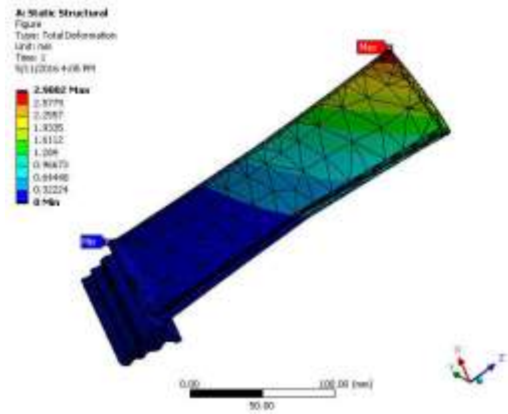

Fig . 5 Showing Deformation values

The above figure shows the deformation values of a steam turbine blade, the maximum deformation is around 2.992mm, and minimum deformation is 0.3324 mm is observed.

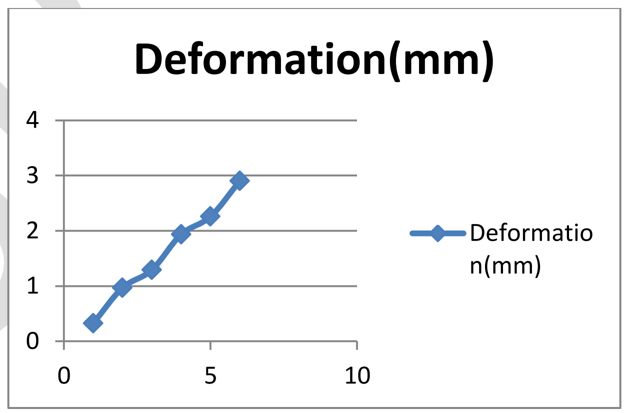

Fig. 6 Deformation Graph

The above graph clearly indicates the deformation values in mm

B. Stress Results

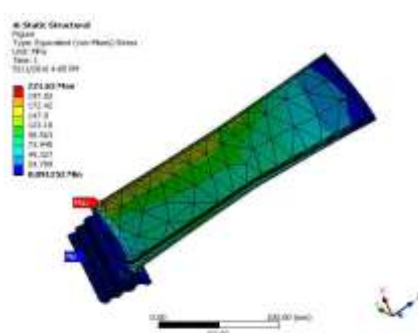

Fig . 7 Showing Stress values

The above fig. shows the stress results for the steam turbine blade and the maximum stress observed is around 221 Mpa and minimum stress is 0.09125 Mpa..

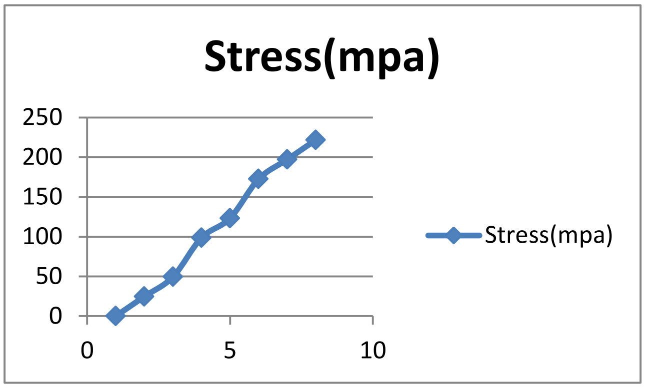

Fig.8 Stress Graph

C. Fatigue Results

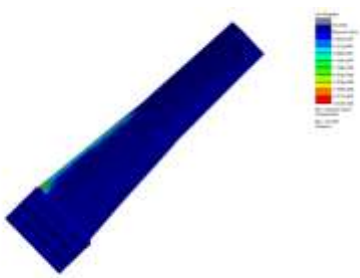

Fig. 9 Showing Fatigue values

The above figure shows the fatigue results of a turbine blade, for the minimum stress 0.09125Mpa the No.of cycles is 5.903e007 and for the maximum stress 221 Mpa it is around 5.516e005.

TABLE I FATIGUE VALUES

Sl.no	Stress(MPa)	No. of cycles
1	0.091252	5.903e007
2	24.709	3.512e007
3	49.327	2.090e007
4	73.945	1.243e007
5	98.563	7.388e006
6	123.18	4.402e006
7	147.8	2.619e006
8	172.42	1.558e006
9	197.03	9.271e005
10	221.65	5.516e005

The above tables shows the stress with respect to number of cycles

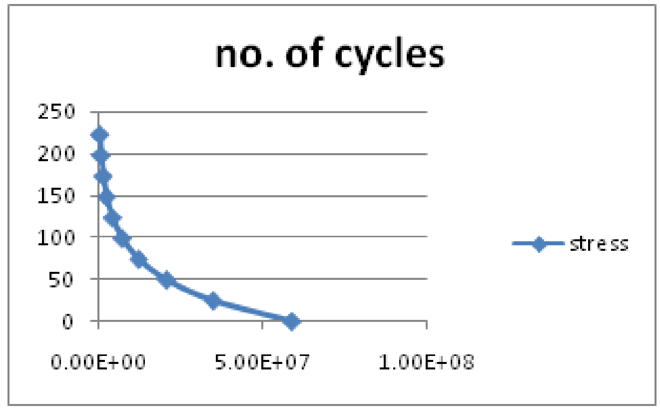

Fig. 10 Fatigue cycles Graph

The above graph shows the sterss v/s number of cycles.

V. CONCLUSION

The mechanical properties of titanium alloy are comparatively high in strength, efficiency, resistance and light in weight so that we can use this material. When the load of 47730N is applied on a turbine blade then the deformation and von mises stress will be obtained. The obtained maximum deformation is 2.9002mm and von misses stress will be 0.091252MPa (minimum) and 221.65MPa(maximum).The consideration blade will be safe at this load. For the same turbine blade of same load/force and the based a obtained stress the fatigue life cycle is be determined/predicted.Within this fatigue criteria our consideration blade is safe.

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