International Journal of Mechanical Engineering and Robotics Research

ISSN 2278 – 0149 www.ijmerr.com
Vol. 2, No. 1, January 2013

Research Paper

ESTIMATION OF STRESS CONCENTRATION FACTOR AND STRAIN CONCENTRATION FACTOR IN STEAM TURBINE BLADE BY FINITE ELEMENT METHOD

Sandip G Ghugal[1]*, R D Askhedkar[1] and S K Choudhary[1]

Corresponding Author: **Sandip G Ghugal, ✉ s_ghugal@yahoo.co.in*

Geometric discontinuities cause a large variation of stress and produce a significant increase in stress. The stress at any discontinuity is higher than the normal stress in the machine element. This high stress is known as stress concentration. There are many investigators who have studied the stress distribution around the notches, groove, and other irregularities of various machine components. The present research work analyses the effects of thermal and fatigue load on a steam turbine blade under the operating conditions. Stresses due to thermal and dynamic loads of High Pressure Steam Turbine blade of 210 MW power stations are analyzed in two stages. In first stage a three dimensional model of turbine blade was prepared in Pro-E. This model was imported in ANSYS-11 for Finite Element Analysis. A source code is developed for calculating the nominal stress at each section of HPT blade. Maximum stress is obtained using Finite Element Analysis (FEA) at the corresponding section. Thermal and Fatigue Stress Concentration Factors at each section are calculated. It is observed that the SCF due to the combined effect of thermal and dynamic loads at the temperatures beyond 540 °C is exceeding the safe limits.

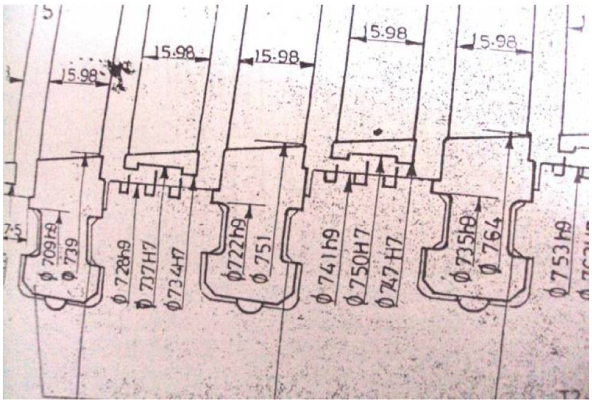
Keywords: Stress concentration factor, FEM, Steam turbine blade

INTRODUCTION

Steam turbines are major prime movers in thermal power stations (Figure 1). The main parts of simple impulse steam turbine are rotor, blades and nozzles. Blade is a major component of the turbine, which receives the impulse directly from the steam jet and converts this force into the driving force. Turbine blade is exposed to various loads such as thermal, inertia, and bending and may fail due to different factors like Stress-Corrosion Cracking, High-Cycle Fatigue, Corrosion-

[1] Department of Mechanical Engineering, KDK College of Engineering, Nagpur, RTMNU.

Figure 1: 2-D Drawing of the Turbine Rotor Grooves with Dimensions (mm)



Fatigue Cracking, Temperature Creep Rupture, Low-Cycle Fatigue, corrosion, etc.

The software offers a comprehensive range of stress analysis and other capabilities in an integrated package for such large-scale, complex problems. An integrated infrastructure, ANSYS Parametric Design Language customization capabilities and non linear simulation with contact plasticity work together to provide powerful simulation capabilities for this type of application. Key dimensions of the blade root were modified using ANSYS Parametric Design Language (APDL) capabilities, with ANSYS Mechanical software analyzing the various combinations of parameters. In this way, engineers evaluated the sensitivity of the design to the geometric modifications in reducing the Stress Concentration Factor (SCF).

Validation of FEM Method for Finding Stress Concentration Factor

Steps of validation of fem method for finding stress concentration factor.

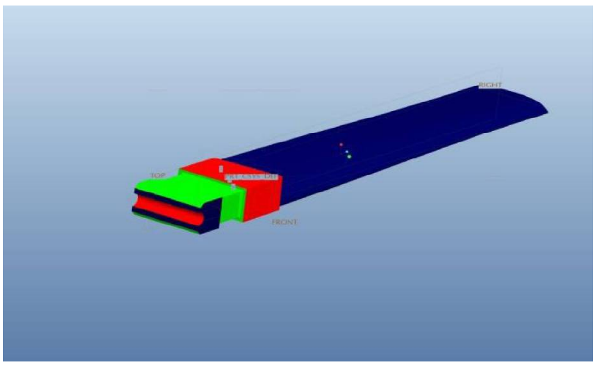
- Assume an irregularity like change of cross section, key way or grooves.
- Prepare a three dimensional model in Pro-E.
- Import the Pro-E model in ANSYS software.
- Mesh the ANSYS model.
- Apply boundary conditions and find out stress distribution in the component.
- Validate that maximum stress in component is as predicted by assuming stress concentration factor for discontinuity in the component.

RESEARCH METHODOLOGY

The following methodology is used for carrying out Finite Element Analysis of 210 MW high pressure blade of steam turbine.

- Validation of FEM method for finding stress concentration factor.
- Modeling the steam turbine blade using CAD software PRO-E (Figure 2).
- Finite Element Modeling using ANSYS 11.
- Determination of Stress Concentration factor using FEM (ANSYS 11).

Figure 2: Pro-E Model of Steam Turbine Blade



Modelling of Steam Turbine Blade

Modeling is nothing but the design of any product or element by consideration of parameters which will be previously used. As per the input drawings of High Pressure (HP) turbine blade received from CPRI, complete modeling was done using PRO-E modeling software.

- Validation of fem method of finding stress concentration factor.
- Modeling the steam turbine blade using CAD software Pro-E.

FINITE ELEMENT ANALYSYS

Finite element modelling of any solid component consists of geometry generation, applying material properties, meshing the component, defining the boundary constraints, and applying the proper load type. These steps will lead to the stresses and displacements in the component. In this work, similar analysis procedures were performed for steam turbine blade (Figures 3, 4 and 5).

- Finite element modeling using ANSYS 11.
- Mesh generation.
- Boundary condition (structural).

Figure 3: Blade Model in Ansys 11.0

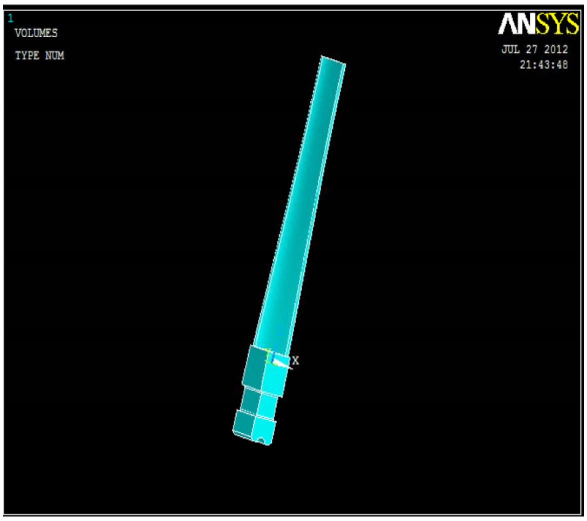


Figure 4: Meshed Model of Turbine Blade

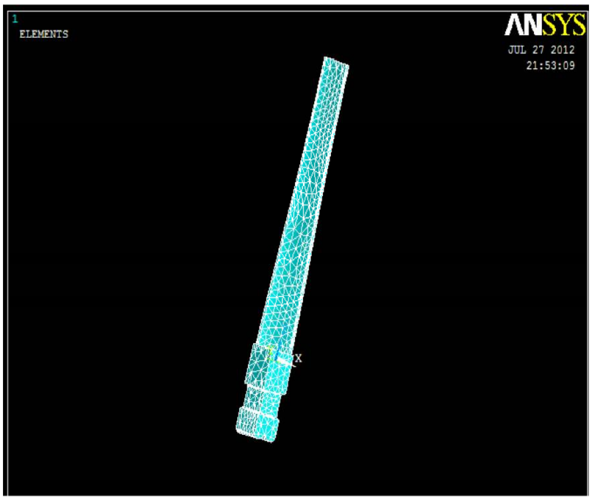
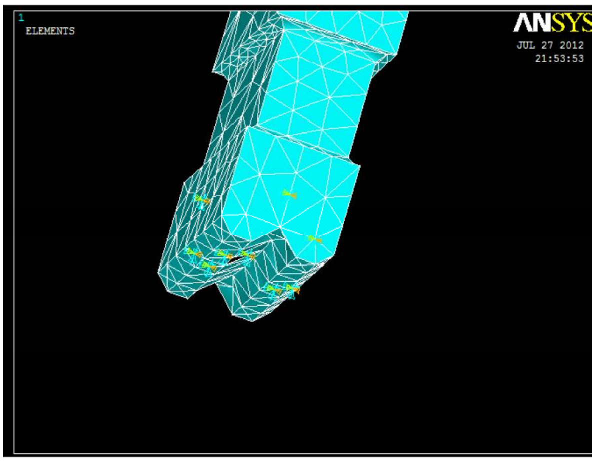


Figure 5: Boundary Condition Applied to Blade



FEM RESULT ANALYSIS

The results of FEM analysis using ANSYS software were calculated as follows:

For Mechanical Loading

Stress Concentration factors at different nodes from Centre towards the tip using Finite Element Method (Mechanical Loading) (Figures 6, 7, 8 and 9). Table 1 shows the results of the analysis calculated manually and by using Analysis software.

Figure 6: Vonmises Stress in Mechanical Loading

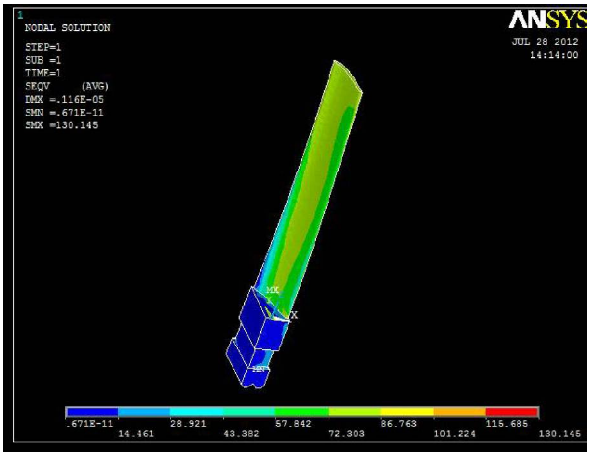


Figure 7: Von Mises Strain in Mechanical Loading

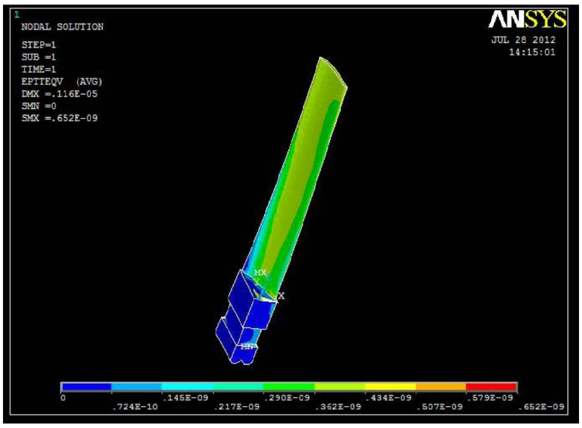


Figure 8: Stress Concentration Factor for First Node in Mechanical Loading

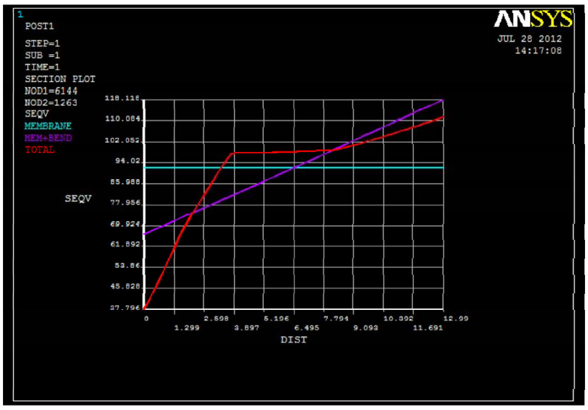


Figure 9: Graphical Representation of Kt in Mechanical Loading

Kt = 115/89 =1.29

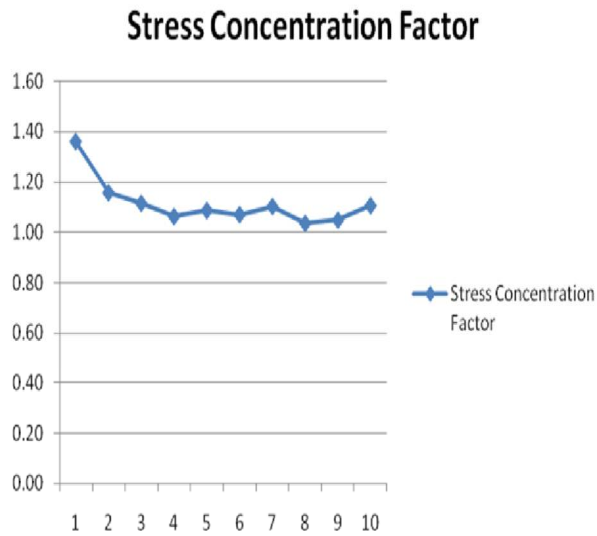


Table 1: Stress Concentration Factor in Mechanical Loading

S. No.	Maximum Von Mises Stress	Nominal Vonmises Stress	Stress Concentration Factor
1.	115	89	1.29
2.	89	77	1.16
3.	88	79	1.11
4.	104	98	1.06
5.	89	82	1.09
6.	93	87	1.07
7.	87	79	1.10
8.	91	88	1.03
9.	89	85	1.05
10.	95	86	1.10

For Thermo Mechanical Loading

Stress concentration factors at different nodes from centre towards the tip using Finite Element Method (Thermo-Mechanical Loading) (Table 2) (Figures 10, 11, 12 and 13).

Table 2: Stress Concentration Factor in Thermo Mechanical Loading

Node No.	Maximum Von Mises Stress	Nominal Vonmises Stress	Stress Concentration Factor
1	321	115	2.79
2	305	121	2.52
3	302	124	2.44
4	298	134	2.22
5	291	138	2.11
6	289	132	2.19
7	280	152	1.84
8	321	176	1.82
9	348	195	1.78
10	247	169	1.46

Figure 10: Von-Mises Stress in Thermo Mechanical Loading

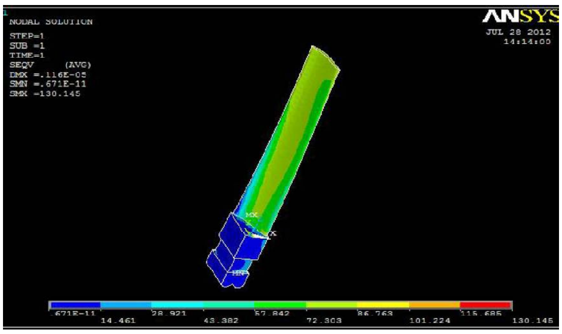


Figure 11: Von-Mises Strain in Thermomechanical Loading

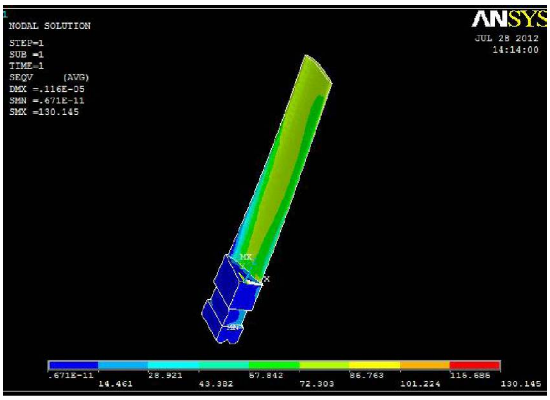


Figure 12: Stress Concentration Factor for First Node in Thermo Mechanical Loading

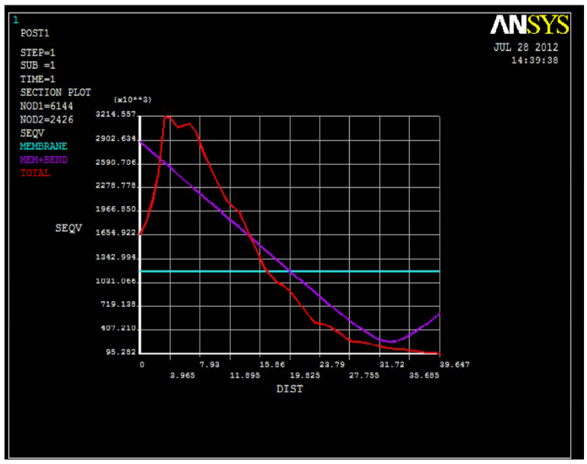
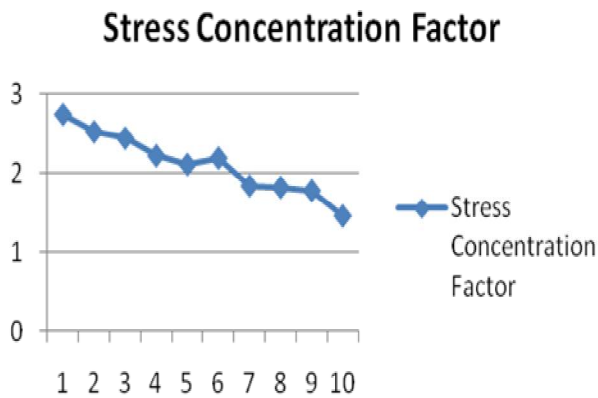


Figure 13: Graphical Representation of Kt in Thermo Mechanical Loading

Kt = 321/115 = 2.79



CONCLUSION

Based on the present analysis the following conclusions can be drawn for both mechanical loading and thermo mechanical loading:

Stress Concentration Factor for Mechanical Loading

- The maximum Stress Concentration Factor was found to be 1.29 at the first node near to the root or base of blade.
- The Average Stress Concentration Factor was found to be 1.10.

Stress Concentration Factor for Thermo-Mechanical Loading

- The maximum Stress Concentration Factor was found to be 2.79 at the first node near to the root or base of blade.
- The Average Stress Concentration Factor was found to be 2.11.

REFERENCES

1. Ana-Maria Pittner *et al.* (2010), "Stress Concentration Factors for Pin Lever of Runner Blade Mechanism from Kaplan Turbines", ISSN: 1792-4294, ISBN: 978-960-474-203-5.
2. Chunlin Zhang *et al.* (2011), "Thermal Stress Analysis for Rotor of 600 MW Supercritical Steam Turbine", School of Power and Mechanical Engineering of Wuhan University Wuhan University, Hubei Province.
3. Dawson R A T and Neill D A (1969), "Thermal Fatigue Analysis of Turbine Components", in International Conference on Thermal Stresses and Thermal Fatigue Berkeley.
4. Devendra A Patel *et al.* (2011), "Stress and Displacement Analysis of Turbine with Stainless Steel Rotor Blade Material", *I. J. E. S. S.*, Vol. I, No. 2, ISSN: 2249-9482.
5. Herbert J Sutherland *et al.* (1996), "Application of the High Cycle Fatigue Data Based to Wind Turbine Blade Lifetime Predictions", *Proceeding of Energy Week*, ASME.
6. Kumar Kenche Gowda *et al.* (2009), Avoiding Stressed-Out Steam Turbines, Ansys Advantage.
7. Nagendra Babu R *et al.* (2008), "Determination of Stress Concentration Factors of a Steam Turbine Rotor by FEA", *World Academy of Science, Engineering and Technology*, pp. 302-306.
8. Ramana K V *et al.* (2010), "Prediction of Stress Concentration Effect Under Thermal and Dynamic Loads on a High Pressure Turbine Rotor", *I. J. E. S. T.*, Vol. 2, No. 8, pp. 3456-3467.
9. Sanjay Kumar S M *et al.* (2012), "Creep Life Prediction of Steam Turbine Blade Using Finite Element Method", *I. J. A. E. R. S.*, Vol. I, No. II, pp. 95-98.
10. Tilan H M *et al.* (2006), "Effect of Notch Depth on Strain-Concentration Factor of Rectangular Bars with a Single-Edge-Notch Under Pure Bending", *International Journal of Solids and Structures*, Vol. 43, pp. 459-474.
11. Tilan H M *et al.* (2009), "Strain-Concentration Factor of Cylindrical Bars with Double Circumferential u-Notches Under Static Tension", *J. J. M. I. E.*, Vol. 3, No. 2, pp. 97-104, ISSN: 1995-6665.