Design and Analysis of HP steam turbine casing for Transient state condition

[1]J.Ramesh,[2]C.Vijaya Bhaskar Reddy, [3] Dr. B. Jayachandraiah

P.G Student[1]
Assistant Professor[2] (Sr)
Head & Vice-principal[3]
Department Of Mechanical Engineering,
Sri Kalahasteeswara Institute Of Technology, Srikalahasti.

Abstract

Transient regimes arising during start-ups, shut-downs and load changes give rise to unsteady temperature distribution with time in steam turbine casing high pressure (HP) which results in non-uniform strain and stress distribution. So that problems such as stress corrosion, cracking and fatigue of steam turbine casing, In this work the thermo mechanical analysis of steam turbine casing will be established by finite element method. In this work the temperature and stress distributions for turbine inner casing were calculated by finite element analysis. The three dimensional model of the Steam Turbine Casing was created using the CATIA software. The model was meshed using software HYPERMESH. Boundary conditions were given on the finite element model through ANSYS.

In this paper, the transient temperatures and stresses distributions within a turbine inner casing were achieved from actual operation data during cold start-up. The paper analyses the creap, centrifugal stress sub stained at high temperature in thermal stresses setup during the startup and shutdown the stream turbine and most serious thread of the rotor blades near the bore, creep cracks to initiates go to size which could results brittle fracture of the rotor blades. Due to crackness life of the steam turbine decreases.

Keywords: Transient condition, 3-D model, Hypermesh, FE model, Thermal expansion

1.Introduction

Generally turbine casings used are split horizontally and vertically. The casing houses the blades rotor, nozzles, and diaphragms. It also holds glands for steam sealing at each end for preventing leakage of steam from where the shaft passes through. The steam casing of turbine is generally arranged with centre line support i.e the support points are on the same horizontal plane as the centre line of the turbine. The steam end pedestal sits upon a flexible panting plate which provides rigidity in the vertical and lateral planes, but allows flexibility in the axial plane for casing thermal expansion.

The combined thrust and journal bearing of the turbine rotor is housed in the steam end pedestal. The rotor, therefore, is moved axially towards the steam end with the axil movement of the casing. The casing is that portion of the turbine that either supports or supported by the bearing housings. The steam ring is attached to or is a part of the casing. All casing joints have metal to metal sealing surfaces no strings or gaskets are used. All turbines manufactured by Maxwatt use multiple piece casings consisting of two or more pieces that are split at the horizontal centerline to facilitate inspection or removal of the turbine rotor. The casings are either cast, fabricated, or a combination of both depending on operating conditions. The casing can be of iron, carbon steel, carbon moly steel, or chrome moly steel.

Types Of Casings

1.1 Single Stage Turbine Casing

Single stage turbine casings are two piece casings. The casing consists of the upper half and the lower half the lower half casing houses both the inlet and exhaust connections. The bearing housings are either cast integrally with or bolted to the lower half casing. All single stage frames except the type GA and SA turbine have the steam ring cast integrally with the casing this means that the material required for the steam ring is also required for the casing. In those cases where the steam ring is not cast as the part of the casing, different materials for the steam ring and casing can be utilized. The two components are bolted together.

1.2 Multistage Turbine Casing:
Multistage turbine casing are considered to be horizontally split casing even through a vertical split may also be used. The point of juncture of the vertical and horizontal splits is called a four way joint and is the most difficult area in the whole turbine assembly to seal against steam pressure because of this Maxwatt employs a construction called barrel construction in normal construction the steam ring forms the high pressure section of the casing and is bolted directly to the intermediate and exhaust portions of the casing. This puts the four way split at the first stage which is where the highest case pressure is encountered in the multistage turbine.

2. Literature Review

[1] Has developed modern CAE tools like Hyper mesh, ANSYS and Pro-E etc. have been utilized to model and analyze existing LP casing and for redesigning it to suit the new efficient modern design of rotor. This paper presents the numerical stress analysis of the turbine casing of an aero-engine. High thermal stress gradients were found at the region of casing where fatigue cracks were detected during engine operation [2]. [3] Has analyzing the failure of a weld repaired turbine casing after 30 years of total service including 5 years after weld repair. The casing was weld repaired by a high Cr–Ni weld metal (24Cr–32Ni–4Mn–Fe). The base metal low alloy ferritic steel (1Cr–0.5 Mo steel) with ferrite–pearlite structure did not show any abnormality to indicate significant degradation. [4] Has studied about designing of complex steam turbine low pressure casing the ever growing competition in capital intensive power sector is pressing turbine manufacturer's world over to develop new efficient steam turbine designs and to update/retrofit the old steam turbine which are in service. BHEL is also putting up major design development efforts to meet the present market challenges. This paper depicts how the modern CAE tools like Hypermesh, ANSYS and Pro-E etc. have been utilized to model and analyse existing LP casing and for redesigning it to suit the new efficient modern design of rotor.

3. Modeling And Analysis

3.1 Steam Turbine Casing Model

It is very difficult to exactly model the Steam Turbine casing, in which there are still researches are going on to find out transient thermo mechanical behavior of casing during operating under higher temperature and pressure. There is always a need of some assumptions to model any complex geometry. These assumptions are made, keeping in mind the difficulties involved in the theoretical calculation and the importance of the parameters that are taken and those which are ignored. In modeling we always ignore the things that are of less importance and have little impact on the analysis. The assumptions are always made depending upon the details and accuracy required in modeling.
The assumptions which are made while modeling the process are given below

- The casing material is considered as homogeneous and isotropic.
- Inertia and body force effects are negligible during the analysis.
- The casing is stress free before the start up.
- The analysis is based on pure thermal loading and vibration and
- Thus only stress level due to the above said is done. The analysis does not determine the life of the casing.
- The thermal conductivity of the material used for the analysis is uniform throughout.

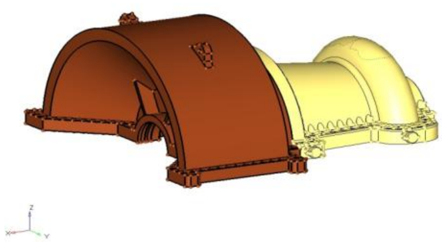

Fig 3.1 CAD model of the casing

3.2 Steps Involved in Finite Element Analysis

- Discretization of the continuum
- Selection of the displacement model
- Derivation of element stiffness matrix
- Assemblage of the algebraic equations for the overall discretized Continuum.
- Solution of the unknown displacements.

3.3 Heat Transfer Analysis

Heat transfer of a casing surface is affected by convection and temperature distribution of inner part is calculated by conduction. The boundary conditions between surface and inner area for the thermal analysis were derived from calculated heat transfer coefficient according to time Heat transfer analysis was conducted from pre-warming to steady state condition using heat transfer coefficients and a steam temperature of each location acquired from operating data. For HP casing are made from castings and the life assessment portions are corner radius, pipe inner surfaces and welds. For turbine casing, especially, the major damage occurs at the nozzle fit and disk corner of casing.

3.4 Thermal Analysis

A thermal analysis calculates the temperature distribution and related thermal quantities in steam turbine casing. Typical thermal quantities are

- The temperature distribution
- The amount of heat lost or gained
- Thermal fluxes
- Thermal gradient

Thermal simulations play an important role in the design of many engineering applications, including internal combustion engines, turbines, heat exchangers, piping systems, and electronic components. In many cases, engineers follow a thermal analysis with a stress analysis to calculate thermal stresses (that is, stresses caused by thermal expansions or contractions). The basis for thermal analysis in ANSYS is a heat balance equation obtained from the principle of conservation of energy. The finite element solution perform via ANSYS calculates nodal temperatures, and then uses the nodal temperatures to obtain other thermal quantities.

3.5 Transient Thermal Analysis

The ANSYS Multiphysics, ANSYS Mechanical, ANSYS Professional, and ANSYS FLOTRAN products support transient thermal analysis. Transient thermal analysis determines temperatures and other thermal quantities that vary over time. Engineers commonly use temperatures that a transient thermal analysis calculates as input to structural analyses for thermal stress evaluations. Many heat transfer application heat treatment problems, nozzles, engine blocks, piping systems, pressure vessels, etc. - involve transient thermal analyses. A transient thermal analysis follows basically the same procedures as a steady-state thermal analysis. The main difference is that most applied loads in a transient analysis are functions of time. To specify time-dependent loads, and then apply the function as a boundary condition, or you can divide the load-versus-time curve into load steps

3.5 Meshing

The goal of meshing in HYPERMESH Workbench is to provide robust, easy to use meshing tools that will simplify the mesh generation process. These tools have the benefit of being highly automated along with having a moderate to high degree of user control. In order to carry out a finite element analysis, the model using must be divided into a number of small pieces known as finite elements. Since the model is divided into a number of discrete parts, FEA can be described as a discretization technique. In simple terms, a mathematical net or mesh is required to carry out a finite element analysis. If the system under investigation is 1D in nature, use line elements to represent our geometry and to carry out our analysis. If the problem can be described in 2 dimensions, then a 2D mesh is required. Correspondingly, if the problem is complex and a 3D representation of the continuum is required, then we use a 3D mesh.

Fig 3.2: Steam Casing (HP) Meshed Model

The meshed assembly of a steam turbine casing is as shown in the Figure 3.1.Initially IGES file of a CATIA product has been imported to the HYPERMESH workbench then the meshing is carried out. In the present case we did tetra type of element has been used and detail information on meshed assembly as shown in Table 3.1

Object Name	**Steam Casing**
Length Unit	Millimeters
Bodies	13
Nodes	332917
Elements	1828152

Table 3.1 Detail Information about Steam Casing Meshing

Pre-Processing

The goals of the pre-processing are to develop an appropriate finite element mesh, assign suitable material properties and apply boundary condition in the form restraints and loads. The finite element mesh subdivides the geometry into elements, upon which are found nodes. The nodes which are just point location in the space are generally located at the element corner and near each mid side node there may be two-dimensional or three-dimensional elements 2D-elements can be plane stress axis-symmetric and plane strain condition s for a 3D solid analysis only one temperature or many temperature degrees of freedom exists at each node. Developing a mesh, most time consuming work in FEA. The geometry is meshed with mapping algorithm or free algorithm. The first maps a rectangular grid on to a geometric region, which must have the correct number of sides. Free meshing automatically sub-divides meshing regions into elements easy messing, disadvantage is of distorted elements.

Post- Processing

Post processing begins with a thorough check for problems that may have occurred during solution. Once the solution is verified to be free of numerical problems; the quantitative of interest may be examined.. Dynamic viewing and animation capabilities aid greatly in obtaining an understanding of the deformation pattern. Stresses being sensor qualifies, currently lack a single visualization technique, and thus derived stress quantifies are extracted and displayed. Principle stress vectors may be displayed as color-coded arrows, indicating both direction and magnitudes. Von-Misses stress may be displayed on the model as color bands. Displacements magnitudes may also be displayed by color bands, but this can lead to misinterpretation as stress plot.

4. RESULTS:

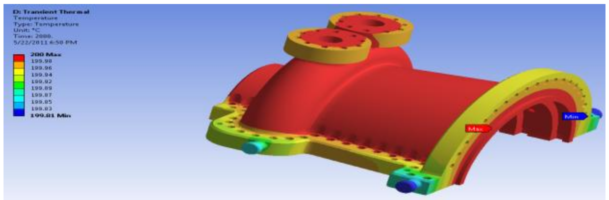

Fig4.1: Temperature Distribution in inner casing in unsteady (Transient) state condition after 2000s

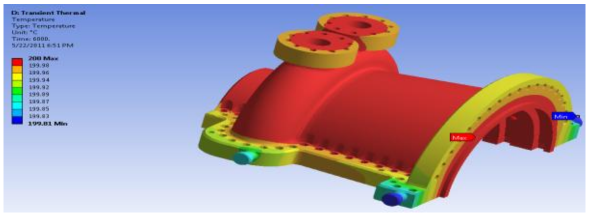

Fig4.2: Temperature Distribution in inner casing in unsteady (Transient) state condition after 6000s

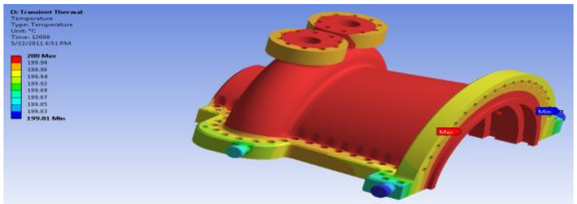

Fig43: Temperature Distribution in inner casing in unsteady (Transient) state condition after 12000s

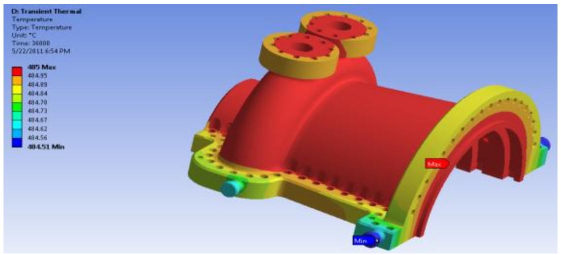

Fig4.5: Temperature Distribution in inner casing in unsteady (Transient) state condition after 36000s

5. Theoretical Calculation:

1. Thickness of Casing (t) = $\frac{P \times d}{2 \times (SE + PY)} + 1.25$

Where P is the Inlet pressure in bar, d is the diameter of casing in mm S is the Maximum allowable stress in material in (PSI) 500 Psi, E is the Joint efficiency factor 0.75 and , Y is Temperature coefficient 0.4.

2. Thermal Expansion = $\delta_t = \alpha \times \Delta t \times l$

3. Thermal Stresses ($\sigma_{Thermal}$) = $E \times \alpha \times \Delta t$

Here δ_t= Thermal expansion of casing in inch and α is Coefficient of thermal growth is 8.3×10^{-6} in/in^{0}F, Δt is the Temperature difference in ^{0}F and L be the length of casing in inch.

The Theoretical calculation for the whole HP casing is calculated as shown above and the calculations for each stage are tabulated in table

6. Comparison of Results:

	Analytical	Mm FEA-ANSYS
Total deformation mm	0.07	0.1
Stress (first stage) Pa	0.235E9	0.38 E9

Stages	**Temperature**		**Pressure(bar)**	**Diameter (mm)**	**Length (mm)**	**Thermal Expansion (mm)**	**Thermal Stresses 10^9 N/m^2**
	^{0}C	**^{0}F**					
1	260	500	8	688	68	0.042	0.1254
2	230	446	6	706.5	68	0.030	0.0941
3	185	365	4	725.5	74	0.049	0.1411
4	150	302	3.5	793	104	0.109	0.1098
5	105	221	3	851	163	0.029	0.1411

7. Conclusion:

To maintain a high level of availability and reliability in a fossil power plant, substantial consideration of failure by repeated thermal loading should be carried out.

- In this study, the transient temperatures and stresses distributions within a turbine inner casing were achieved from actual operation data during cold start-up.
- The maximum deformations are calculate in transient state condition within inner casing.
- Equivalent (von-Misses) Stress distribution in Transient condition.
- Total deformation and stress values are compared with analytical results calculated for 2D geometry.

If the thermal gradient is great enough, the stress at the bottom of the threads may be high enough to cause the carking. The result shows the casing develops higher stress levels in startup condition.

8. Scope for the Future Study:

Turbine facilities that operated repeatedly under transient start-up condition are affected by various damage mechanisms such as creep, fatigue, and oxidation and so on. In general, it is known that low cycle fatigue is one of main damage mechanisms to determine life time of turbine rotor or casing components.

This study can be extended further to calculate the fatigue damage by the stress analysis based procedure. This approach is based on Neuber's rule. Neuber's rule expresses the relationship between local stress and local inelastic total strain-range. Using this study, life consumption of steam turbine inner-casing can be obtained and a guideline for effective maintenance also can be proposed. The analysis can be extended further considering Elasto-Plastic analysis using non linear material properties as well as temperature dependent material properties.

References:

[1] W. S. Choi, E. Fleury, G. W. Song and J.-S. Hyun, A life assessment for steam turbine rotor subjected to thermo-mechanical loading using inelastic analysis, Key Eng. Mat. 326–328, 601–604 (2006).

[2] Lucjan Witek, Daniel Musili Ngii, thermal fatigue problems of turbine casing Vol. 1 (2009) 205-211

[3] Maneesh Batrani, BHEL Haridwar, Hypermesh an effective 3-D CAE Tool in Designing of complex steam turbine low pressure casing in 2006.

[4] T.Stubbs, the role of NDE in the life management of steam turbine rotors, Swindon, England

[5] K. Fujiyama, Development of risk based maintenance planning program for Power Plant steam turbine, Final report on the Joint Project, pp. 69–82 (2007).

[6] Kiyoshi SAITO, Akira SAKUMA and Masataka FUKUDA, "Recent Life Assessment Technology for Existing Steam Turbines", JSME International Journal Series B, Vol. 49, No. 2 (2006), pp.192-197.

[7] Development of Life Prediction System for Thermal Power Plant Based on Viscoplastic Analysis, Final report, KERPI (2007).