DESIGN AND THERMAL ANALYSIS OF HIGH PRESSURE CASING OF A STEAM TURBINE

CHALLURI ANUSHA
M. Tech Student, Dept of Mechanical-THERMAL, Brilliant grammar school educational institutions group of institutions integrated campus, T.S, India

G. SORNA LATHA
Assistant Professor, Dept of Mechanical-THERMAL, Brilliant grammar school educational institutions group of institutions integrated campus, T.S, India

ABSTRACT

Contact pressure and pretension in bolts-analysis has been made easier in recent years due to the availability of high computational capabilities and flexibility in the computational methods using finite element analysis. In the present work, one such analysis is carried out blending the hand calculations and steady-state finite element analysis to evaluate the contact pressure in a high pressure steam turbine casing. The work involves design considerations, design checks, validation and sensitivity analysis to achieve the design criteria to full fill the structural requirements for mechanical integrity. During the last several years the primary changes to the design of steam turbines have focused on improving their efficiency, reliability and reducing operating costs. Siemens Power Generation, for example, has improved the overall efficiency and availability of its steam turbines by decreasing the steam flow energy losses in each of the steam turbines components. The steam turbine unit largely influences the efficiency and reliability of power stations. Any improvement in the design of steam turbine enables more efficient use of fuel and results in reduced cost. The high pressure steam at 565 °C and 156 bar pressure passes through the high pressure turbine. The exhaust steam from this section is returned to the boiler for reheating before being used. On leaving the boiler reheated, steam enters the intermediate pressure turbine at 565 °C and 40.2 bar pressure. From the intermediate pressure turbine, the steam continues its expansion in the three Low pressure turbines. The steam entering the turbine is at 306 °C and 6.32 bar. To get the most work out of the steam, the exhaust pressure is kept very low. The casing thus witnesses, energy of the steam turned into work in HP and IP stages. So, the design of the casing is a very important aspect.

Keywords: *Fem Analysis, Overall Efficiency, high pressure steam turbine casing*

1.0 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 axial 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 Max watt use multiple piece casings consisting of two or more pieces that are split at the horizontal centre line 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:

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

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.

TEMPERATURE AND PRESSUREREQUIREMENTS

The main stream flow, the second major design parameters are the main stream conditions. Main stream temperatures are continuously increasing to optimize the overall performance of SPPs, and as in gas turbine development, also for CCPPs. At the same time high temperatures require expensive material to withstand the associated optimum pressure levels. In order to keep price increase moderate for such advanced steam cycles, one focus of the modular concept is to reduce the amount of required high-temperature material to a minimum. The basic design elements of the concept are:

- To apply identical designs for the main components at different temperature levels (e.g. 565°C and 600°C) and thereby only to change material.
- To weld main components in order to minimize the amount of high-temperature material to shield

components against the hot steam to cool affected areas.

2.0 Literature Review:

[1] Laxminarayan.k1, Dr.M.Venkatarama Reddy (2012) Steam Turbines are devices used to convert thermal energy of steam into mechanical energy, which may be used to produce Electrical Energy. Steam turbine generator units are being used extensively all over the world for generation of electric power and for co-generation of steam and power. Contact pressure and pretension in bolts-analysis has been made easier in recent years due to the availability of high computational capabilities and flexibility in the computational methods using finite element analysis. Theoretical, Analytical and experimental procedure show that this design procedure has been successful in generating an optimum design solution and thus can be easily implemented.

[2] J. Ramesh, C.Vijaya Bhaskar Reddy, Dr. B. Jayachandraiah (2012) 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.

[3] GayatriChoudhary, NishitaKispotta, DhaneshwariSidar(2014)The work involves design consideration, design checks and sensitivity analysis to achieve the design criteria to fulfill the structural requirement for mechanical integrity. During the last several year the primary changes to the design of steam turbine have focused on improving their efficiency, reliability and reducing operating cost. Siemens Power Generation, for example, has improved the overall efficiency and availability of its steam turbine by decreasing the steam flow energy losses in each of the steam turbine components.

3.0 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 behaviour 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 modelling we always ignore the things that are of less importance and have little impact on the analysis.

- The elastic modulus of casing: 210 GPa;
- The poisson's ratio of casing: 0.3
- The elastic modulus of cement ring: 7 GPa
- The Poisson's ratio of cement ring: 0.18

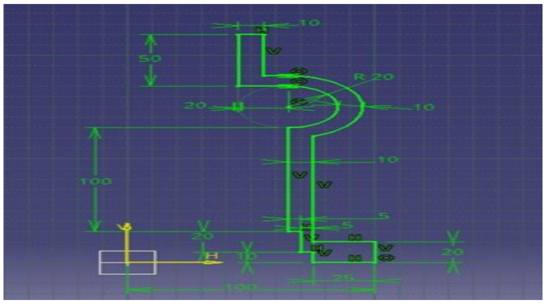
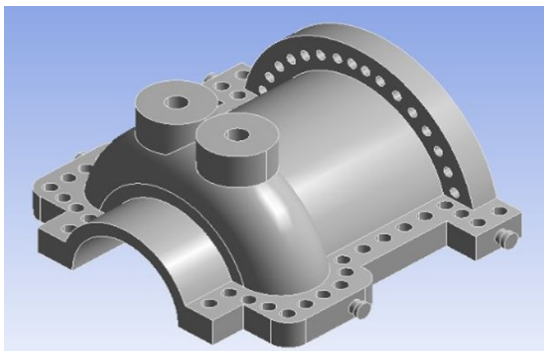


Figure 2D cad layout



CAD model of the casing turbine

- 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.

Transient Thermal Analysis

The ANSYS Multi physics, 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

Meshing:

The meshed model of steam turbine casing is shown in Figure Initially UG part file is imported to ALTAIR HYPERMESH, then meshing is carried out. In the present work we have used higher order tetra mesh for the accuracy of the results. The total mesh consists of 83999 nodes and 346571 elements. Chromium steel material is used since this material is anti-corrosive and has good resistance to high temperature and pressure. Given Below are the material properties defined for the analysis.

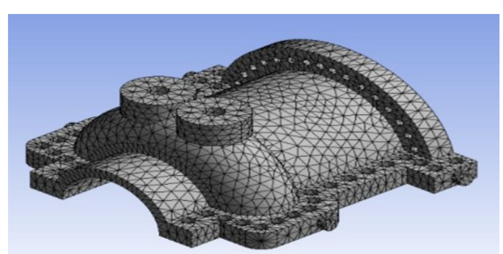


Fig casing turbine meshed model

Table Detail Information about Steam Casing Meshing

statics	
nodes	34297
elements	18672
Mesh metric	None
Length of units	mm

Chromium properties:

Chromium atomic number	24
Melting point	1 900 °C / 2 173 K
Boiling point	2 672 °C / 2 945 K
Density at 20 °C (293 K)	7.15 [g/cm^3]

RESULTS:

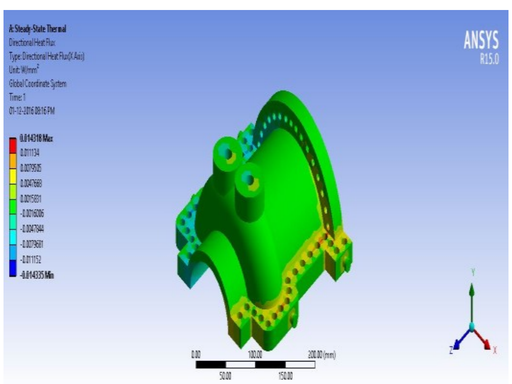


Fig Directional heat flux x-axis

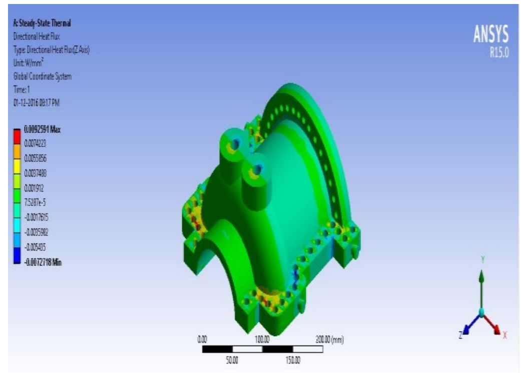


Fig Directional heat flux z-axis

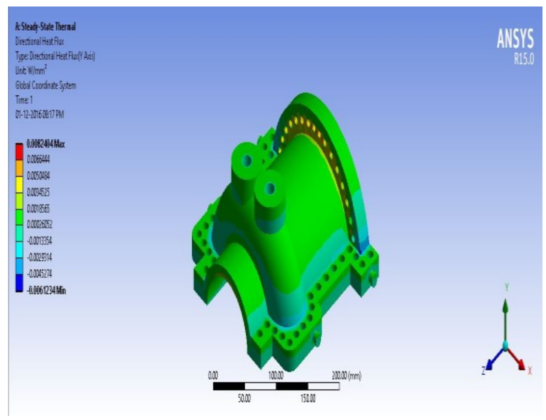
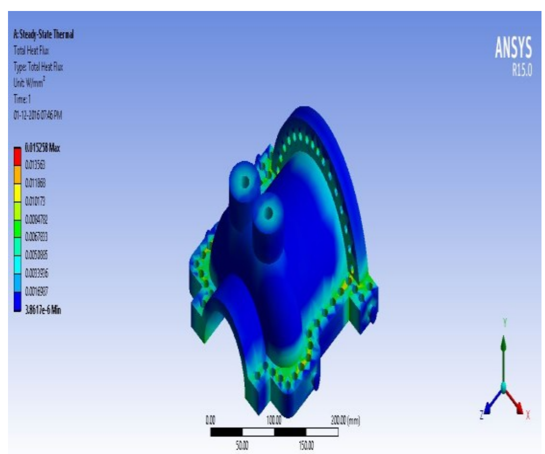
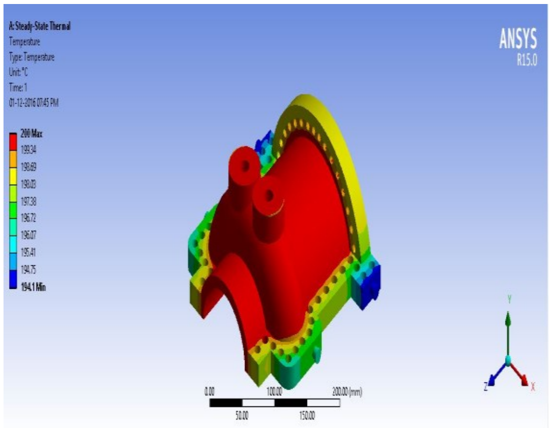


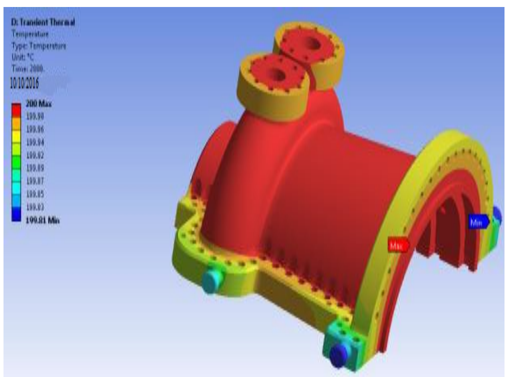
Fig Directional heat flux y-axis



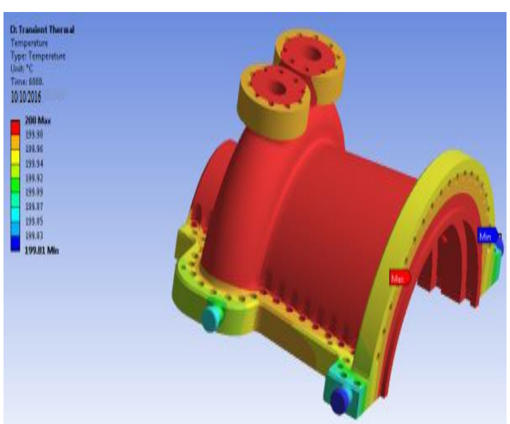
Total heat flux



Temperature distrubution along casing



Temperature Distribution in inner casing in unsteady (Transient) state condition after 2000s



Temperature Distribution in inner casing in unsteady (Transient) state condition after 6000s

parameters	Maximum (w/mm2)	Minimum (w/mm2)
Directional heat flux x-axis	**0.014318**	**0.0143.35**
Directional heat flux y-axis	**0.0082404**	**0.0061234**
Directional heat flux z-axis	**0.0092591**	**0.0072718**
Total heat flux	**0.015258**	**3.8617e-6**
Temperature distrubution	**200**	**194.1**

Theoretical Calculation:

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.

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

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°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

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 start-up condition.

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