Contact Pressure Analysis of Steam Turbine Casing

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Abstract - *Steam turbine is a device used to covert thermal energy (Steam) into mechanical energy, then after converted to Electrical energy. In turbine, casing is the main component as it hoses blades, rotor, nozzles and diaphragms. Steam turbine casings operate at very high pressure and temperature which results in large stress strain distribution. If the contact pressure is not attained then it leads to leakage of steam which further can cause explosion.*
In this paper, a contact pressure analysis of steam turbine casing under static loading condition is done.

Key Words: Steam turbine casing, low cycle fatigue, contact pressure, bolts loads, thermal stress concentration factor (TSCF).

1. INTRODUCTION

Steam turbine is most flexible mechanical machines and it can be used to drive even generators. Steam turbine can work at high temperatures. Turbine casing is essentially a pressure vessel which endures the high pressure of steam and supports all the internal components. Important components of steam turbine casings are shells, head, flange, bolts and inlet section. To endure high pressure, thick cylinder walls are essential but, to minimize thermal stress, there should not be rapid change in thickness nor asymmetrical Sections. The casing are either cast, fabricated depending upon operating conditions. The casing material can be iron, carbon steel, carbon moly steel, or chrome moly steel [1]. Since the stream turbine casing is subjected to very high temperature and pressure, casing will undergo fatigue damage. Fatigue is the phenomenon which affects mostly to moving or rotating parts especially in automobiles, reactors etc.

2. LITERATURE REVIEW

J. Ramesh et al [1]
Had created the three dimensional model of steam turbine casing. As the model is complex, so they made some assumptions to simplify the model.
Theoretical calculation for the steam turbine casing is made and compare with FEM result. The analysis concludes that the turbine casing develops the higher stress level in startup condition.

Laxminarayan.k et al [2]
In this work, the contact pressure analysis of steam turbine is validating by using the comparison of hand calculation and Finite element analysis results. The aim of this paper was to estimate the contact pressure so that there should not be any leak. Pretension in bolts is considered to attain a strong contact between the casings. Boundary conditions are applied in the supports and bolting locations. From the Analysis, they conclude that the stress generated in the casing is well within the maximum allowable stress and validated the comparison of hand calculation of contact pressure with FEM results.
Into Jacob et al [3]
In this this paper, they explained the brief concept about the low cycle fatigue in the steam turbine casing due to cyclic loading. Since the turbine casings are huge and complex it is very important to understand the concept of low cycle fatigue and the life estimation. Their Analysis includes the calculation of lifetime for the casing and compares the results with FEM. From the analysis made, they found that the life time (number of cycles), generated by FEM was more compared with technically calculated one. From this one can say that turbine casings and bolts are safe for number of cycles calculated.

Woosung Choi et al [4]
In this paper, thermal stress concentration factors (TSCFs) are defined for the inner surfaces of casings and valves through three dimensional finite element analysis(FEA) Considering the deviations in geometry. Elastic-plastic strain ranges are also derived in order to assess Low cycle fatigue life according to the life assessment processes in Korea. An approximate relationship among thermal strains (stresses), casing size, and material properties is used to obtain nominal thermal strains (stresses) at the casing surface. After determining the nominal thermal strain, it is necessary to estimate the concentrated strain produced in regions of strain concentration, such as notches. The model can be used to achieve maximum thermal stresses and strains related to creep and fatigue damage. Using this model, precise data on life consumption can be achieved by using steam turbine inner casings as an input for the Korean simple life assessment procedure without much complication and time-consuming calculations.

L. Cui et al [5]
In this paper, both a constitutive and a phenomenological crack initiation lifetime assessment model for steam turbine components are considered. The efficiency of each method is shown by recalculation of uniaxial as well as multiaxial service type creep–fatigue experiments on high-chromium 10%Cr stainless steel. Finally, the two models are compared with respect to different aspects, such as the type and number of necessary investigation to find model parameters like, the qualification for the use and the disadvantage of each model.

3. METHODOLOGY

The casing consists of the upper half and the lower half the lower half casing houses both the inlet and exhaust connections. It is very challenging 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.

3.1 Modeling and Geometry

Because of the intricate shape of the turbine casing, the exact calculation of the wall thickness becomes very difficult.

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.

Table -1: Material Properties.

Description	Casing	Bolt
Material	Chromium Steel	Chromium Steel
Young's Modulus(GPa)	2e5	2e5
Poisson's ratio	0.3	0.3
Density (Tonnes/mm^3)	7.8e-9	7.8e-9

Casing thickness, tc= PR/ (SE-0.6P) +1.5

Where, P = Inner Pressure = 5 MPa
R = Radius of Casing=250 mm
S = Allowable Stress = 77.5 Mpa
E = Joint Efficiency = 1

tc= 5 (500/2)/((77.5 1)-(0.6 5)) +15
= 31.78 mm
=32 mm

15 mm is taken into consideration for casting allowance. Flange thickness is usually 3-5 times the casing thickness [3]. Three dimensional model of simple pressure vessel like structure which resembles the steam turbine casing is modeled using ABAQUS as shown if the figure 1. Since the Model is symmetric about a z-axis, so half of the model is being created.

Table -2: Dimensions and units.

Internal pressure	5	MPa
Casing diameter	500	mm
Allowable stress	77.5	MPa
Bolt diameter	40	mm
Cap nut diameter	60	mm
Casing thickness	32	mm
Flange thickness	95	Mm
Bolt preload	103	Kips
Bolt load	458166.6	N

Bolt load is taken from standard as ASTM A325 Grade and ASME B16 part D for material properties.

Calculations are given below
Bolt Torque, T = F k D
Where, F= Bolt preload in N
k= nut factor. 0.2 For non-lubricated bolts and 0.1 for lubricated bolts
D=Bolt Diameter in mm.
In this case we can directly find the pre load. Sometime we will know only bolt torque, and then we use above equation to calculate the bolt preload.

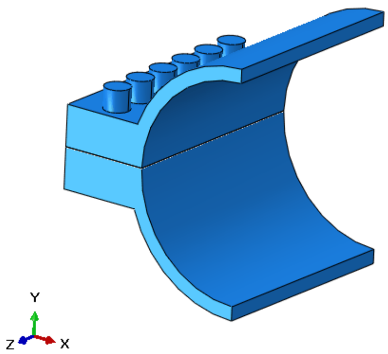

Fig -1: Model of Simple Steam turbine casing.

3.2 Meshing

Discretization (Meshing) of model is done using ABAQUS.

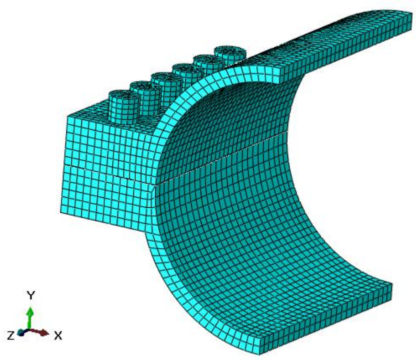

Fig -2: Meshed model of casing.

Table 3: Meshing Details.

Component	Element Type	Number of elements	Number of nodes
Upper Casing	C3D8R	4990	7044
Lower Casing	C3D8R	4634	6334
Bolts	C3D8R	4680	6348

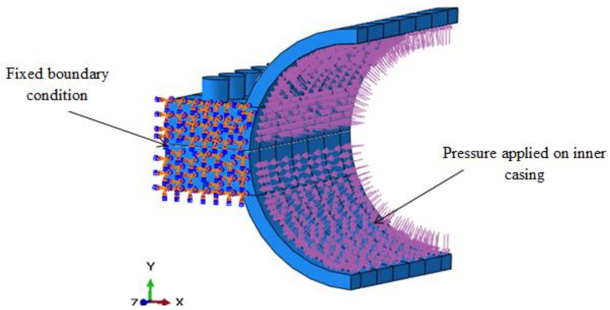

Fig -3: Loading and Boundary condition.

3.3 Analysis

Analysis of the model is done using ABAQUS. After giving the initial clamping force (Pretension) in the bolt, Boundary conditions are applied at both ends.

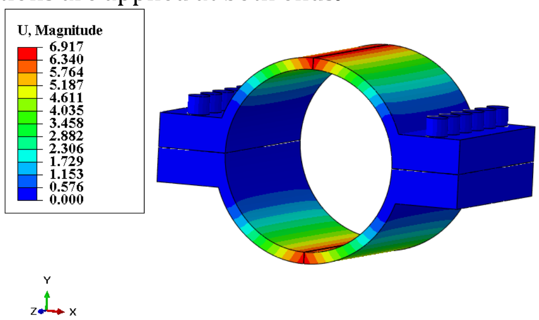

Fig -4: Displacement plot for the model under pressure of 5 Mpa.

Maximum displacement in the whole model is 6.913 mm.

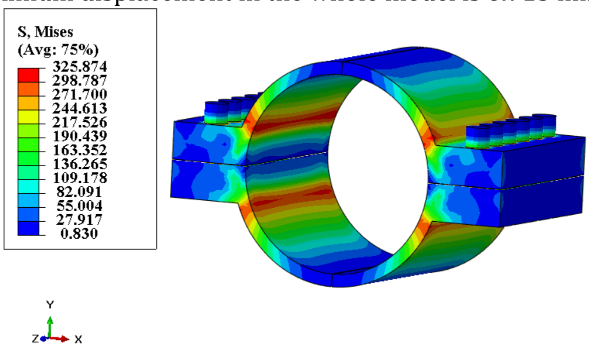

Fig -5: Stress distribution for the model under pressure of 5 Mpa.

Since the maximum von-Mises Stress developed in the casing is 325.87 Mpa which is less than a yield stress of 410 Mpa for chromium steel. Hence the casing is safe in static analysis.

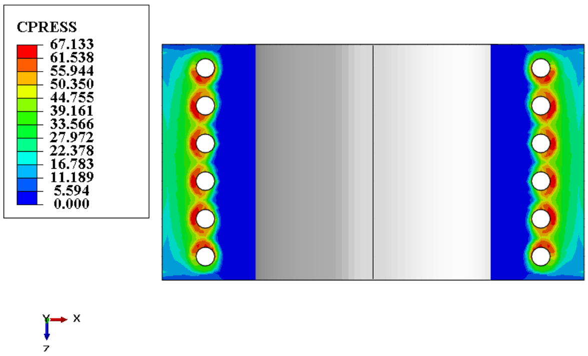

Fig -6: Contact pressure under pressure of 5 Mpa.

3.3.1 For safe condition

Contact Pressure = 3* Inner Pressure
Inner Pressure applied= 5 MPa
Therefore Contact Pressure = 15 MPa
From the above calculation it is clear that pressure in analysis must be greater than 15 MPa or else the design is considered to be unsafe.
In the Analysis the contact pressure is 67.133 MPa is greater than the 15 MPa. Hence design is Safe.

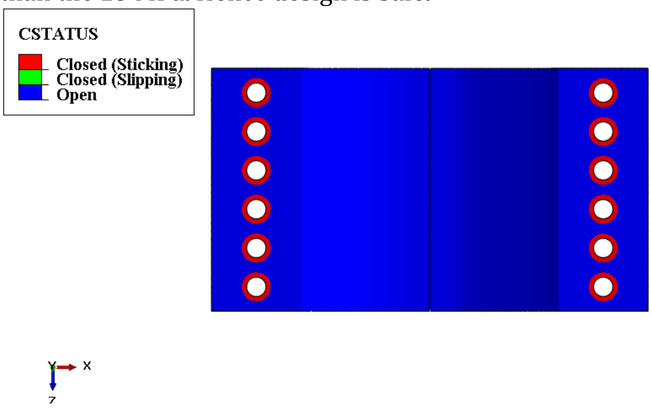

Fig -7: Contact status at bolt head and upper casing interface.

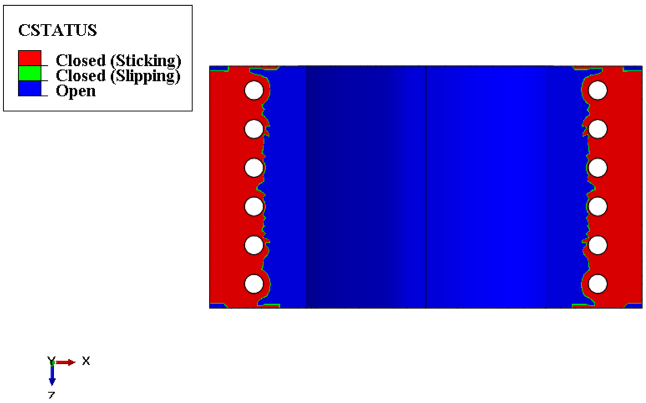

Fig -8: Contact status at upper casing and lower casing interface.

Fig -7 and 8 shows the contact status at the upper casing and the bolt head interface and upper casing and lower casing interface respectively. Contact pressure ensures the complete and leak proof condition.

4. CONCLUSIONS

From the analysis we found that the contact pressure obtained by analytically 67.133 MPa is greater than 15 MPa. Hence Design Criteria is satisfied. Also the von-Misses stress in the model 325.87 MPa is also well within the yield limit of 410 MPa. Hence the design is Safe. Contact status of the model is also shown in the paper.

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BIOGRAPHIES

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Kiran Kumar P is having 18 years of experience in industry and academics. He has published many journal papers and also presented paper in various national and international conferences. His area of interest includes radiation curing of materials, polymer composites and design of experiments. Presently he is working as a professor at Department of Mechanical Engineering, SJBIT, Bangalore.