STRUCTURAL DESIGN AND ANALYSIS OF A BLEEDER IN MULTISTAGE STEAM TURBINE CASING

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Abstract: In the steam turbine power plant working on theoretical rankine cycle, the steam produced in the boiler is feed into the turbine, where pressure energy of the steam is converted to theoretical work, which in drives the generator. The steam coming out of the turbine is condensed and recirculate in the cycle, a bleed is a device used to extract steam coming out of the turbine before entering the condenser. This steam can be used for other process industries like paper industries, sugar industries and steel making industries. In this work, a bleed used at the lower stage of the turbine for carrying steam and ejecting the steam from the steam pocket is analysed for the static and thermal loads.
The design and steady state static structural analysis of the strength of the bleed for carrying the steam is done by using NX-CAD 11 software for modelling and ANSYS WORKBENCH 18.2 is used for FEM analysis used satisfaction result are found.

I. INTRODUCTION

A steam turbineis a rotary type of steam engine, having a rotating wheel to which is secured a series of buckets, blades or vanes, uniformly spaced on its periphery. Steam from nozzles or guide passages are directed continuously against these buckets, blades or vanes, thus causing their rotation. Expansionof steam in the nozzles or buckets converts its heatenergy into energy of motion and gives it a high velocity which is expended on the moving wheel or buckets. The difference in the various types of steam turbines is due to different methods of using the steam. For industrial applications, steam turbines are often designed to extract steam at definite pressures from one or more points along the expansion cycle. This is done on either the impulse or the reaction machine, with the turbine acting as a reducing valve and at the same time driving a machine.

Where steam is taken off from the turbine for process work, non-return valves are required at the turbine, just in case that there may be a live steam connection somewhere in the plant, to prevent a backup of steam into the turbine, which would allow it to over speed, and being beyond the main steam inlet, the governor would have no control over the speed and a runaway would result.

Bleed pocket flange connected to the steam turbine casing flange, customarily in steam turbine after processing steam send to thecondenser to condense, by connecting the bleed pockets in steam turbine casing flange steam will be extract from the steam turbine and steam utilize for the processing industry like paper industry, sugar industry, steel industry.

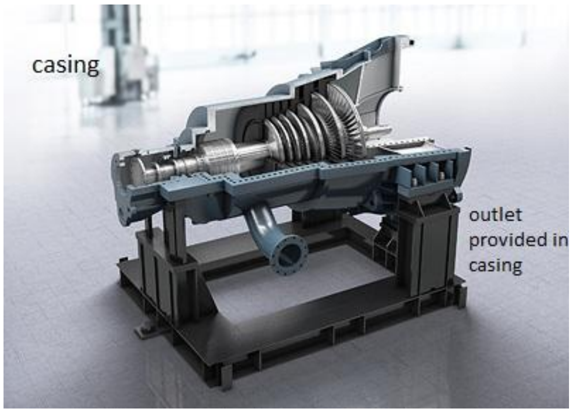

Fig.1 Steam Turbine Bleed Pocket

1.1 Types of Casings

1.1.1 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 housesboth the inlet and exhaust connections. The bearing housings areeither 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.

1.1.2 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.


Fig.2 Section view of actual casing

II. LITERATURE REVIEW

[1]MalagaudaPatil and Arvind Maddebihal.IJIRSET,"Steady State Thermal Analysis of Steam Turbine Casing"The highly impactful character of a steam turbine is its safety and reliability when compared to the other prime movers. The steam turbine is subjected to a variable loads in terms of pressure and blade speed or torque being the issuable ones. It is observed that the steam turbine casing is subjected to a very high pressure load and strain due to blade speed at start-ups and shut downs. The impact is higher at the start of the generator. Hence in this paper an effort is made to understand the impact of these loads through the steady state analysis being carried out for the turbine. The inputs for the analysis were obtained from a standard turbine model of 10 MW capacity with avg. RPM of 6750 and working at pressure of 65 bar. The finite element method was adopted to carry out the analysis. Using ANSIS, the finite element model was developed and the boundary conditions were convection, radiation, heat fluxes and heat flow rate. From the analysis it was observed that, 1. The steady state analysis can be used to obtain the resultant (Von mises) stresses within the casing. 2. If the thermal gradient through thickness if high enough then it might lead to cracking in the casing.

[2] Laxminarayana.k et al, in this paper was to estimate the contact pressure between both lower casing and upper of casing so that there should not be any leakage in the steam turbine. During operating condition steam turbine casings are subjected to very high pressure and temperature which results in stress and strain distribution. If the contact pressure is not achieved as per the standards then it leads to leakage of steam which causes explosion of casing. Pretension in bolt is considered to archive a solid contact between the casings. Boundary conditions are connected in the supports and bolting areas. From the analysis they reason that the stress produced in the casing is well within maximum allowable stress and approved the examination allowable stress and approved the examination of analytical calculation of contact pressure with FEM result.

[3] J. Ramesh at. El, In this paper the author has tried to understand the transient conditions that developed during the start-ups and shut of a steam turbine. It is established through experiments that the high pressure if responsible for the non-uniform stress and strain distribution through the casing. The finite element method is used to understand the extent of the stress generated. Software CATIA was used to develop the FE model of the turbine and Analysis is carried out. The paper carries out the details of the analysis of the creep and stresses developed at high temperatures and the thermal stresses developed at the start ups of the turbines. The maximum deformations were calculated at the inner surfaces with experimentally available data including the Cold starts which served as the boundary condito0ns to the model. The Von-mises stresses and the deformations were calculated and evaluated with the experimental data. The results obtained were very similar to the previously mentioned paper about steady state analysis of a steam turbine, MalagaudaPatil and Arvind Maddebihal.

III. CALCULATION OF BLEED DIAMETER

For 30 MW steam turbine casing extraction at low pressure stage.
Flow =10TPH (tones per hour) = 10/3.6 kg/sec.
Specific volume =0.26580 m^3/kg.
Velocity = 40m/sec.
Area X velocity = flow X specific volume
d = 153.311mm = 6.03 inch
NOTE: 6 inch pipe flanges and flanged fittings to be used as per ASME standard 16.5 class 300.

IV. GEOMETRIC MODEL

The modelling of bleeder in steam turbine casing is carried out in NX-CAD 11 software.

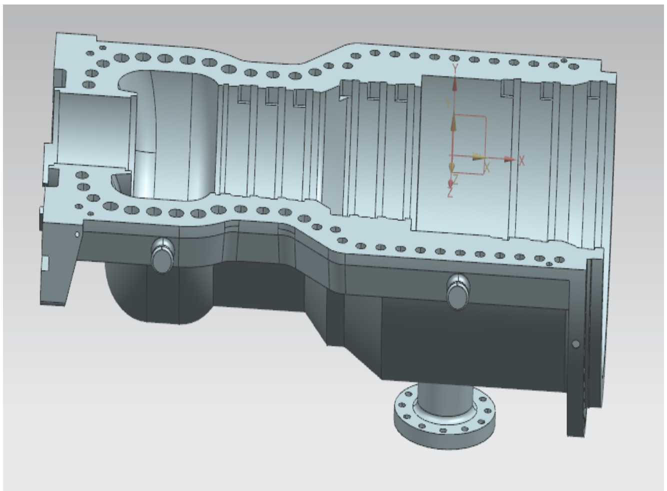

Fig.3 Geometric model of bleeder in casing

V. STEADY-STATE STRESS ANALYSIS

In this analysis physical quantity such as temperature and pressure are consider.We are preparing bleeder in multistage steam turbine casing for worst condition loading.
The maximum inlet steam pressure: 5mpa;
The maximum inlet steam temperature: 360℃;
The assumptions which are made while modelling the process are given below.

- The steam turbine has upper and lower half casing are consider to be symmetric.
- 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 static and thermal loading.
- The thermal conductivity of the material used for the analysis is uniform throughout.

5.1 Material properties

The material of casing is used chromium steel. Its contain 12 % chromium and its chemical name is X22CrMoV12-1.This material is widely used in manufacturing of turbine casings and blades because of its better strength, high temperature and Corrosive resisting properties which are suited for steam turbine environmental conditions.

Description	Steam turbine casing
material	Chromium steel
Young's modulus (Mpa)	1.9E5
Density (kg/m3)	7800
Poisson's ratio	0.28
Thermal conductivity(w/MGk)	24
Yield stress (Mpa)	670
Ultimate tensile strength (Mpa)	880

5.2 Mesh generation:
The size of the elements influences the accuracy of the solutions, the smaller the radial dimension of the elements, the better the stress and strain. The model is meshed with an element size of 20 mm and Tetrahedrons method is used for meshing. Face meshing is used to the bleeder to obtain structural mesh. The Number of nodes is 396397 and the Number of elements is 257143.

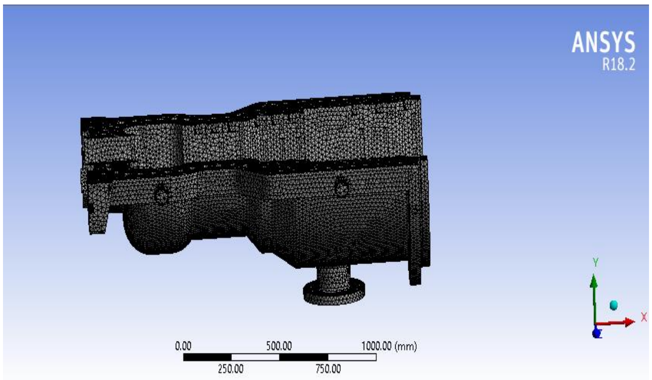

Fig.4 Meshing/Discretisation of Steam Turbine Casing

5.3 Boundary conditions:

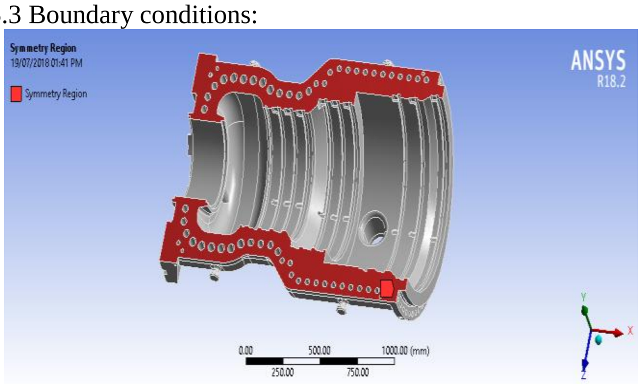

Fig.5 Symmetric boundary condition

Before doing analysis we need to Appling Symmetric boundary condition along y-axis. Here red colure shows the symmetric boundary region. Because the steam turbine has upper and lower half casing are consider to be symmetric.

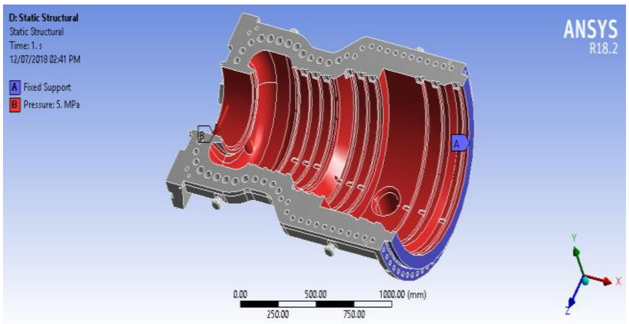

Fig.6 Static boundary conditions

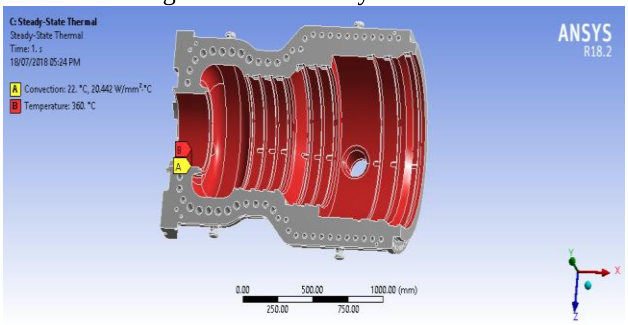

Fig.7 Thermal boundaries conditions

The boundary condition need to be specified before solving any engineering problem. It specifies the specific boundary within which problem need to be solved.Here fixed support is applied at the one end of the casing which is being attached to the condenser and the maximum inlet pressure of 5 Mpa is applied at the inner casing. Figure 4.11 represents the temperature which developed inside the casing which is the result of temperature developed due to the inner steam. High temperature steam is the cause of thermal stresses inside the casing. A temperature of 360ºC is applied inside the casing to know the effect of temperature on casing and due to that convention is applied over the temperature of the inner casing with the film coefficient of steam is 20.442 w/mm2 cº.

VI. FINITE ELEMENTS RESULTS

The outcome of the finite element analysis done on the bleeder of steam turbine casing model is found in terms of Von-Mises Stress or equivalent stress, total deformation, maximum principal stress and factor of safety.

6.1 Von-Mises Stress:

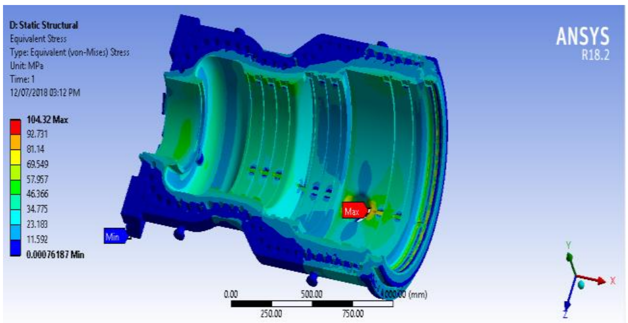

Fig.8 Von-Mises Stress

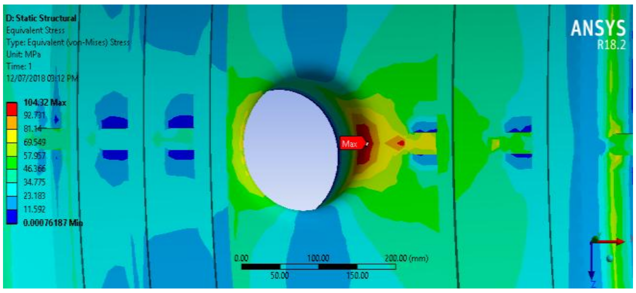

Fig.9 detail view of Von-Mises Stress

Von Mises stress is the average stress developed for the casing under static thermal load condition, which is shown in Figure 8 & 9.The maximum von-mises stress value is obtained at bleed pocket which is 104.32Mpa. The yield stress for chromium steel is 670 MPa. Since the von-mises stress is within the yield stress the design is safe.

6.2 Total deformation:

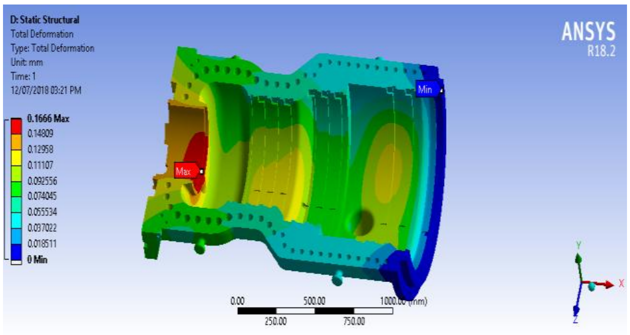

Fig.10 Total deformation

The casing can undergo deformation due to the massive pressure and temperature. The chances of deformation have to be evaluated to check safety of design. Figure 10 represents the total deformation of casing model. A total deformation of 0.1666mm is observed due to the combined effect of pressure & temperature.

6.3 Maximum principal stress:

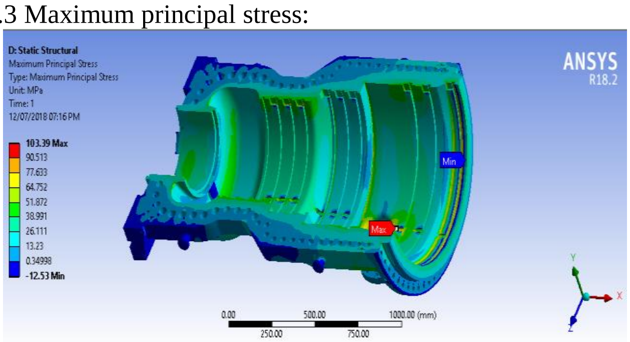

Fig.11 Maximum principal stress

Figure 11 represents the total principal stress developed due to the application of inner temperature and pressure. The maximum principal stress is obtained at bleed pocket which is 103.39MPa. The yield stress for chromium steel is 670 MPa. Since the maximum principal stresses is within the yield stress the design is safe.

6.4 Minimum principal stress:

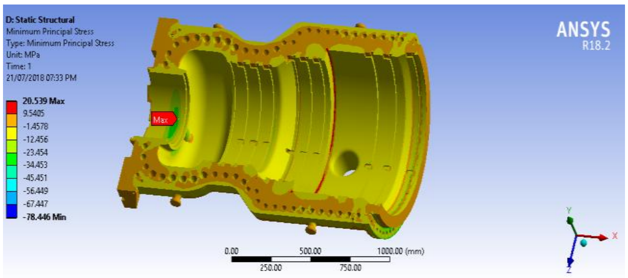

Fig 12 Minimum principal stress

Fig 12 represents the Minimum Principal Stress developed in the casing under inner pressure and temperature. A minimum principal stress of 20.539 is observed. The yield stress for chromium steel is 670 MPa. Since the Minimum Principal stress is within the yield stress the design is safe.

6.4 Factor of safety:

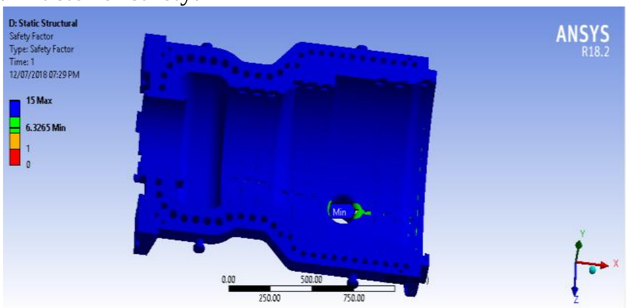

Fig.12Factor of safety

Factors of Safety are a part of engineering design and for structural engineering expressed as is a term describing the load carrying capacity of a system beyond the expected or actual loads. For designing the Turbine components at static the F.O.S must be 6 or more. From the analysis factor of safety obtained is 6.3265, so designcriteria is safe.

VII. CONCLUSION

In this work, thesteady state stress analysis we observed that the maximum stress obtained at bleed pocket which is less than yield stress of chromium steel. Hence our design is safe. The F.O.S for typical turbine components under static conditions should be not less than 6, in the present work F.O.S for bleeder in steam turbine casing obtained is 6.3265, so designcriteria is safe.

The work presented is a basic attempt at design of bleeder in multistage steam turbine casing. Bleeding in steam turbine attracting wide range due to their varied applications. Bleed is a continuous process so a lot of work is need to be done on the design aspects before the bleed can be readily available in market. And the extracted steam could be utilized in processing industries.

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