Static, Thermal and CFD Analysis of Bleeder in Steam Turbine Casing Using Ansys

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Abstract - *The goal of this project is to provide a tool for steam-powered store transportation as well as a technique to completely eject the store from the bleed pocket. It is now more necessary than ever to have a casing and unharness mechanism that can completely expel a storage. The static and thermal loads on this shop may drive it to violently contact the bleed pocket structure once the steam from a contemporary high-performance rotary engine is discharged before falling far from the pocket. Bleed is the volume of steam produced by a rotary engine that leaves the engine's end through a pipe. This leak increases the effectiveness of the device by feeding both the deaerator and the heater (low and high). The steam that has previously operated on a rotary engine's blades is known as bleed steam. Today, we have the choice of either heating feed water with the steam or condensing it in a condenser. Most crucially, a tool for moving a store like a steam train and giving means to totally expel the store from the bleed pocket. It is getting more crucial to have a casing and unlock device that can entirely eject a store. Steam from a contemporary, improved rotary engine may be forced by the static and thermal hundreds on this shop to aggressively contact the bleed pocket structure before dissipating far from the pocket.*

Key Words: Bleeder, Turbine casing, Deaerator, Steam turbine casing.

1.INTRODUCTION

A steam turbine is a machine that uses pressurized steam to generate heat that drives a rotating output shaft to carry out mechanical work. In 1884, Sir Charles Parsons developed its modern manifestation.

As of 1996, steam turbines accounted for around 90% of all energy produced in the United States. Since they create rotational motion, steam turbines are particularly well suited to be used to drive an electrical generator. Using a variety of stages to expand the steam brings about a closer match with the optimal reversible expansion procedure. It is a key factor in the increase in thermodynamic efficiency of the steam turbine. The Rankine cycle drives the steam turbine.

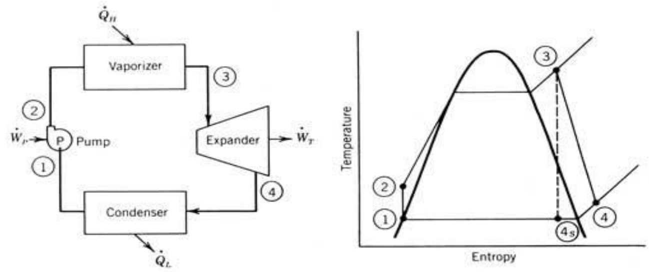

Fig-1.1 Working of Steam Power plant and its cycle

1.1 Types of Turbines
Impulse Turbine

Fixed nozzles on impulse turbine direct the steam flow into high-velocity jets. These jets have high kinetic energy, which is transformed as the steam jet changes direction into shaft rotation by the bucket-shaped rotor blades. Only the stationary blades experience a pressure drop, resulting in a net increase in steam velocity throughout the stage. The steam's pressure decreases from the inlet pressure to the exit pressure as it passes through the nozzle (atmospheric pressure, or more usually, the condenser vacuum). Steam expands at such a high ratio that it leaves the nozzle at a very rapid rate. A significant amount of the steam's maximum exit velocity is carried away by the moving blades. The carry over velocity or departing loss is the term used to describe the energy loss caused by this higher exit velocity.

Reaction Turbine

The rotor blades in the reaction turbine are placed in convergent nozzle configurations. This type of turbine makes use of the reaction force produced as the steam accelerates through the nozzles formed by the rotor. Steam is directed onto the rotor by the fixed vanes of the stator. It leaves the stator as a jet that fills the entire circumference of the rotor. When compared to the blades' speed, the steam then reverses the course and picks up speed. With steam accelerating through the stator and decelerating through the rotor, there is a pressure drop across both the stator and the rotor. There is no net change in steam velocity across the stage, but there is a reduction in pressure and temperature, representing the effort done in moving the rotor.

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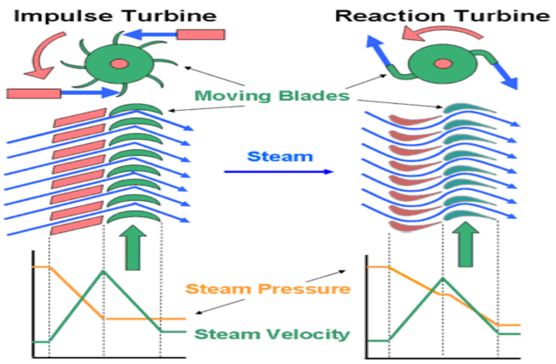

Fig-1.2 Types of Turbines

1.2 Steam turbine casing

These configurations include cross compound, tandem compound, and single casing turbines. The simplest design, single casing units attach a generator to a single casing and shaft. When two or more casings are directly coupled together to power a single generator, A cross compound turbine arrangement features two or more shafts not in line driving two or more generators that often operate at different speeds. Many large applications often employ a cross compound turbine.

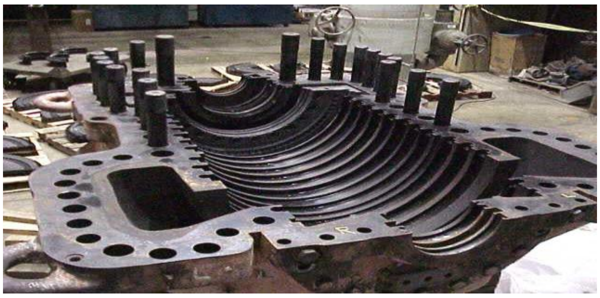

Fig-1.3 Steam Turbine Casing

1.2 Flange

A flange is an external or internal ridge, or rim (lip), for strength, as the flange of an iron beam such as an I-beam or a T-beam; or for attachment to another object, as the flange on the end of a pipe, steam cylinder, etc., or on the lens mount of a camera; or for a flange of a rail car or tram wheel.

Fig-1.4 Flanges

1.3 Working of Steam Turbine

When a high energy fluid (one with high pressure and temperature) travels over a series of rotor blades, the blades absorb the fluids energy and begin to rotate, it transforms thermal energy in the fluid to mechanical energy.

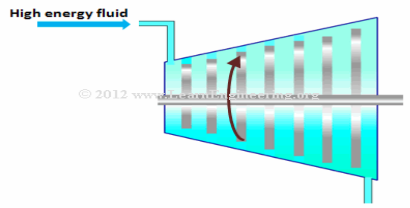

Fig-1.5 Movement of steam

So, series of such blade which eventually transform thermal energy are the most vital part of a steam turbine. Among these rotor sets it would be obvious if you looked closely at one of the blades that a blade is a collection of airfoil cross sections from bottom to top. Such airfoils produce low pressure at the bottom and high pressure at the top as flow passes through them.

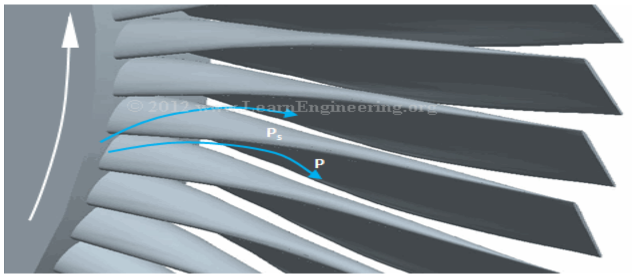

Fig-1.6 Pressure Observed by blades

The blade will rotate because of the resultant force in an upward direction caused by pressure differential. Therefore, a portion of the fluid energy will be converted into the mechanical energy of the blade. We shall closely examine energy linked with a fluid before examining energy transmission from fluid to blade.

1.4 Bleed

Bleed is the quantity of steam that leaves the turbine's final stage through a pipe. This bleed enters to feed the deaerator and water heater (low and high), increasing the efficiency of the unit.

The steam that has already worked on turbine blades is what is known as "bleed steam". Now the only choice left is whether to use the steam to heat the feed water or to condense it in the condenser. The first approach won't provide us with any useful energy because the heat will be transferred to cooling water before being released into the atmosphere via cooling towers.

The second approach is most suitable since it allows us to heat feed water using the latent heat of steam. As a result, efficiency is not being lost much. Please be aware that a greater portion of efficiency would have been lost if the extractions had been made from the Main Steam line. However, this never occurs anyplace.

Fig-1.7 Bleed Pocket

1.5 Application of Steam Bleed

- Scales in the steel industry can be removed using it. About 12bars of pressure is needed to remove scales.
- It can be utilized in the sugar industry for drying purposes. About 5bars of pressure is needed.
- It can be utilized for drying purposes in the paper industry. About 8 bars are needed for this application.
- In the pulp industry, it is employed. For this application, 4bars of pressure are needed.
- It is used in the cement industry to dry cement. The needed pressure is roughly 14 bar.

2. Design of Model

Designed Model in Catia V5r17

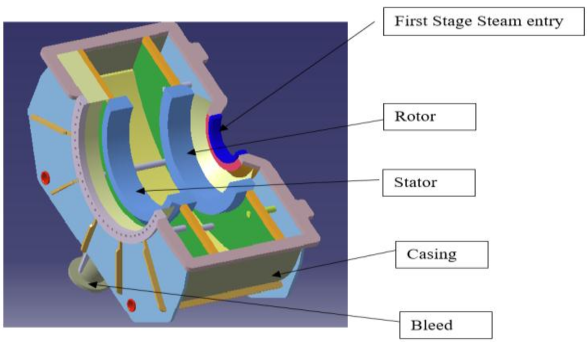

Fig-2.1 Model in CATIA

3. Analysis and Results of Casing and Bleed

3.1 Structural Analysis

Mesh Generation

The purpose of structural analysis is to ascertain how loads affect actual structures and the parts that make them up. This kind of research is applicable to all load-bearing structures, including buildings, bridges, automobiles, equipment, furniture, clothes, soil layers, prostheses, and biological tissue.

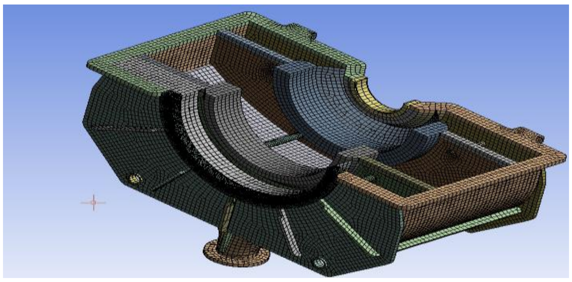

Fig-3.1 Meshing

Generating meshes for structural analysis. Quadra mesh is the chosen mesh type. No clarification is offered. The mesh quality improves with higher convergence rates. It indicates that the right answer was found more quickly. A poor mesh may miss several significant events, such as the boundary layer that occurs during fluid flow. The convergence of the solution or the rate of convergence may not take place in this circumstance.

Steady State

According to systems theory, a system in steady state has several properties that remain constant across time. This indicates that the partial derivative with respect to time is zero for those system attributes p:

$$\frac{\partial p}{\partial t} = 0$$

Different views of bleed in casing of a turbine with meshing

These of different views of bleed cut out

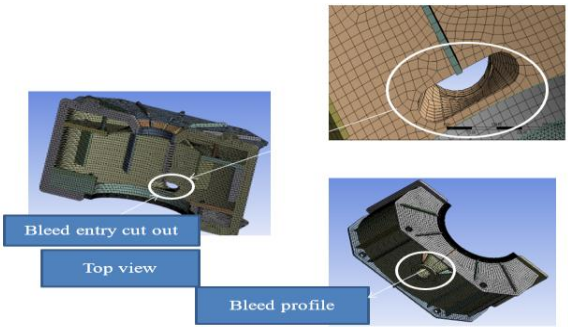

Fig-3.2 Fig.3.2 Views of Bleed profile

Numerical Approach

Calculation for diameter of Steam turbine bleeder

Data:

Casing of the turbine extraction at the exhaust stage for a 30 MW turbine.
Flow - 10 TPH – 2.78 kg/s
Specific Volume – 0.26570 m3/kg
Velocity – 40 m/s
Area = (flow x specific volume)/velocity
Area = (2.87 x 0.26570)/40 = 18451.4 mm^2
$d^2 = (4 \times 18451.4)/\pi$
d = 153.3 mm = 6.04 inch

NOTE: Flanged fittings and 7-inch pipe flanges must be used in accordance with ASME Standard 16.5 Class 300.

Boundary Constraints for Steam Turbine Bleed Application

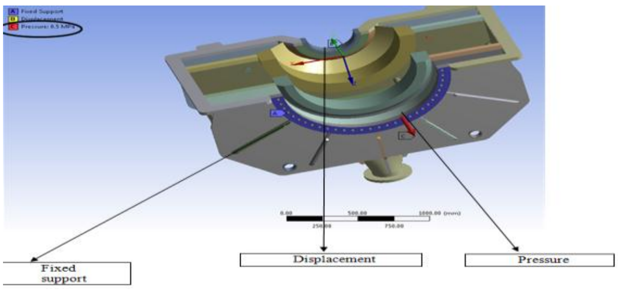

Fig-3.3 Applying Boundary Conditions

The figure illustrates the use of boundary conditions in the analysis of bleed's static structural design. Assuming that steam is moving in the Y direction, the displacement is provided at point B. The pressure for the bi-phasic analysis is shown in Point C of the above figure. At point A, fixed support is provided.

Results of the structural analysis of bleed

Equivalent Stress

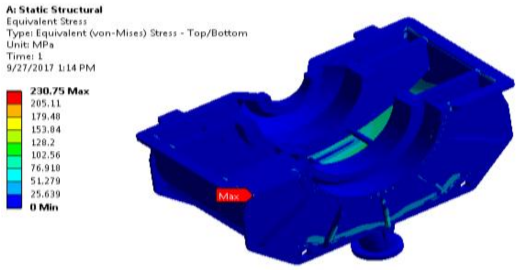

Fig-3.4 Equivalent stress

The casing in this figure's corresponding stress. Red indicates the maximum stress distribution, which is 230.75MPa.

Total Deformation

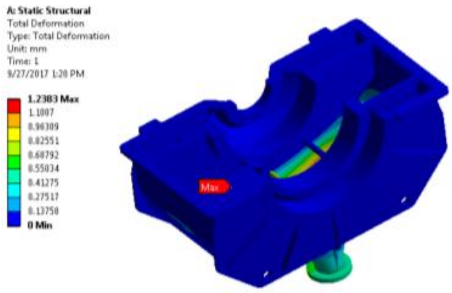

Fig-3.5 Deformation

The casing in this figure's corresponding stress. Red indicates the maximum stress distribution, which is 230.75MPa.

Maximum principal stress and Minimum principal stress

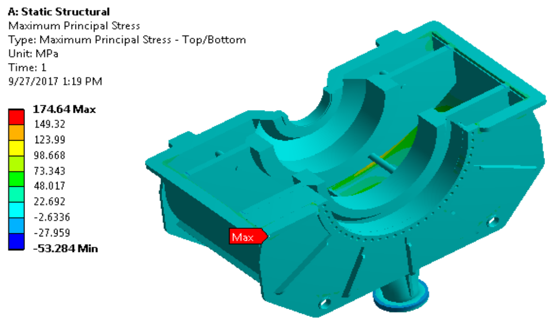

Fig.-3.6 Maximum Principal stress

The max principal stress in the casing as determined by steady state analysis about 174.64MPa is represented in red area.

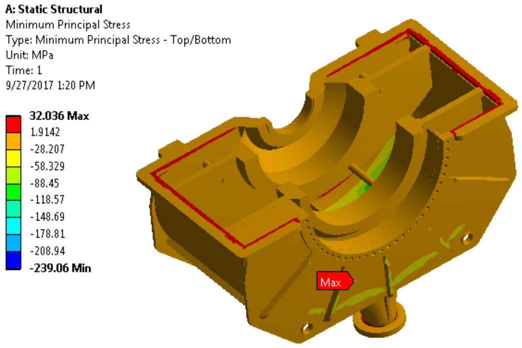

Fig-3.7 Minimum Principal stress

In steady state analysis, this figure shows the minimum principal stress in the casing. Is about 32.036MPa and it is indicated in red.

3.2 Structural Analysis of casing

Determine how loads affect actual structures and their constituent components using structural analysis

Application of Boundary conditions

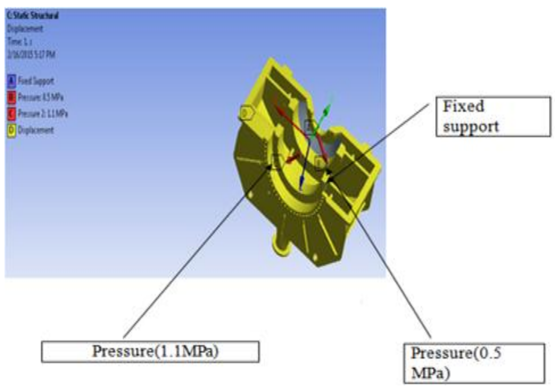

Fig-3.8 Applying Boundary Conditions.

The figure illustrates the use of boundary conditions for the static structural analysis of casing. At point A, fixed support is provided. For phasic analysis, the pressure of 0.5 MPa is indicated at point B in the above diagram. At point C, a pressure of 1.1 MPa is stated. The displacement is recorded as a point in the Y direction since steam is believed to travel in this direction

Static Structural Analysis's Results

Equivalent Stress

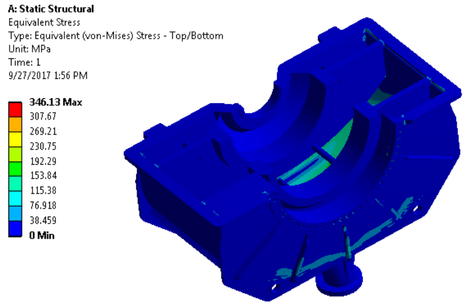

Fig-3.9 Equivalent stress

In steady state analysis and the equivalent stress, this figure illustrates the stress distribution in the casing. About 346.13MPa of equivalent stress exists

Total deformation

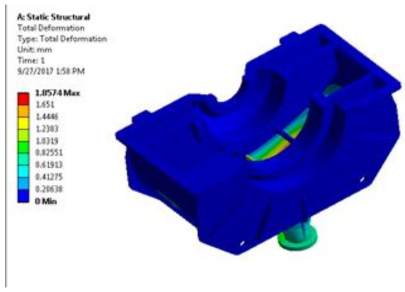

Fig-3.10 Deformation

In the above figure red color indicates overall deformation in the casing. Obtained maximum deformation is 1.8574mm.

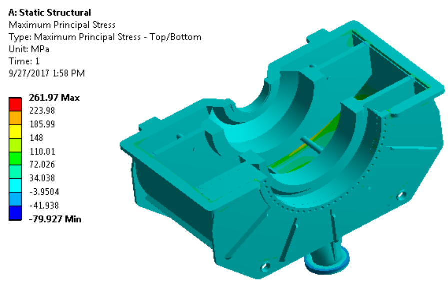

Fig.-3.11 Maximum Principal stress

This figure displays the casing's maximum principal stress. The 261.97Mpa maximum principal stress is depicted in red.

3.3 Thermal Analysis

A subfield of materials science called thermal analysis examines how a material's properties vary with temperature.

Thermal Analysis for Casing

Thermal Analysis at Steady State

Boundary Conditions Applications:

1. A - 225°C – Temperature 1
2. B - 235°C – Temperature 2
3. C – 1.9 x e^{-004} W/mm^2 °C, Convection which is 22°C.
4. D - 245°C – Temperature 3

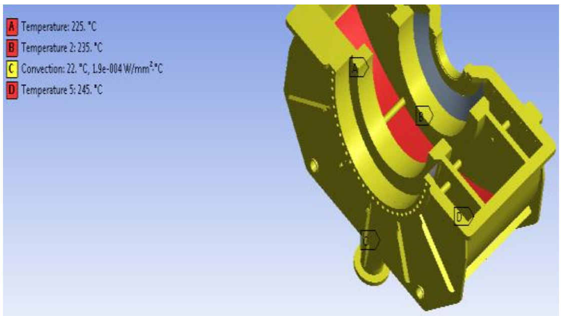

Fig-3.12 Apply Boundary Conditions

The figure demonstrates how boundary conditions are used for the casing's steady state thermal analysis. For phasic analysis, point A in the preceding diagram indicates a temperature of 225°c. Point B indicates a temperature of 235 °C. Due to the assumption that steam will proceed in the direction of Y, the displacement is given at point

Total deformation

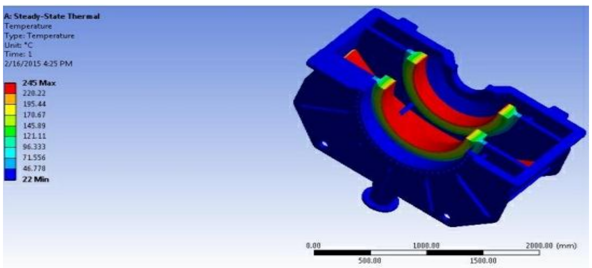

Fig-3.13 Temperature variation

The temperature change in the casing from the beginning of the steam entry to the end is represented by this figure. The red color represents the maximum temperature of 245°C.

3.4 Thermal Analysis of Bleed

Boundary Conditions Application

1. A - 225°C
2. B - 1.9 x e^{-004} W/mm^2 °C, Convection is 22°C.

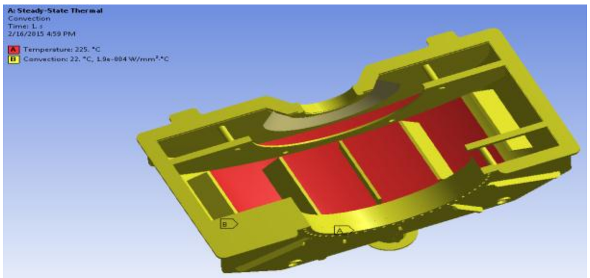

Fig-3.14 Application of Boundary Conditions

Results of Thermal Analysis of Bleed

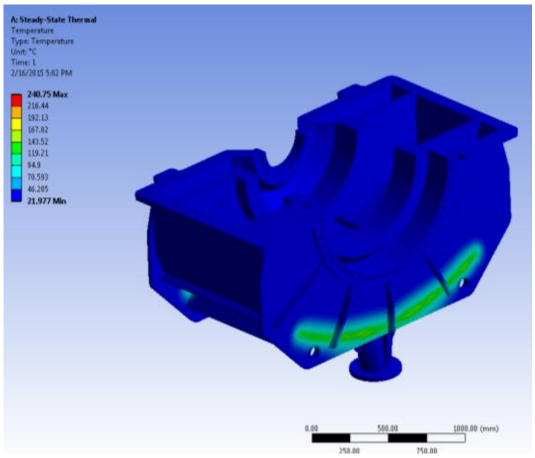

Fig.-3.15 Temperature of steam flow

The temperature of the steam flow in the bleed is shown in this figure from the start of the steam entrance to the finish. The maximum temperature is shown by red, which is 240.75°C. The steam temperature that is escaping from the bleed pocket is around 100°C in temperature.

3.5 Transient Thermal Analysis

In the field of materials science known as "transient thermal analysis", the characteristics of materials are examined as they change over time.

Boundary Conditions

1. A - 350°C -Temperature 1
2. B - 300°C – Temperature 2

This analysis examined by time variation

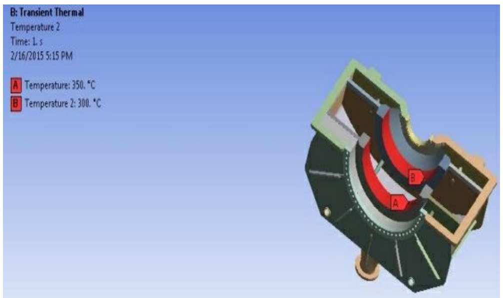

Fig-3.16 Applying Boundary Conditions

Result of Transient Thermal Analysis

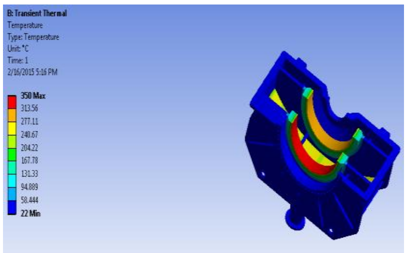

Fig-3.17 Transient result in casing

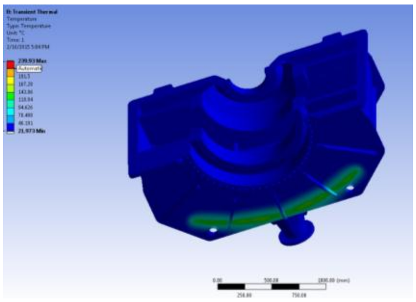

Fig-3.18 Transient result in bleed

The temperature will be at its peak in the beginning, initially assumed to be 350°c, according to the findings of the transient thermal study of the casing, figure 3.17 Figure 3.18 shows a bleed pocket's transient thermal analysis. Approximately 100°C of steam is entering the bleed pocket.

3.6 Flange Analysis

Design of Flange

- Contact type: Surface to surface contact pairings have frictionless connections.
- Fine mesh is necessary: Fillet flange, Bolt hole, Shank corners and blot head.
- Load consideration: Bolt pretension is 49000N, Pressure is 15 MPa
- Stress on flange causes the joint to split = Pressure x Area = 15 x 122954.18 = 344312.7 N

Table -1: Properties

Material	Young's Modulus (E) MPa	Poisson's Ratio	Thermal Conductivity Y KW/mm/°C	Co-efficient of linear exp. (α) mm/ °C	Allowable Stress MPa
Flange (A 182 F11)	170000	0.3	0.047	1.2 e-5	248.2
Bolt (IS 1364)	170000	0.3	0.047	1.2 e-5	723.9
Gasket (S316)	164000	0.2	0.02	0.3 e-5	206.8

Table -2: Flange dimensions as per ASME std. 16.5 Class 300

Particulars	Dimension (mm)
Outer diameter	318
Inner diameter	171
Raised face diameter	216
Thickness of flange	37
Bolt size	M20
P.C.D of flange	270
No. of bolts	12
Bolt hole diameter	23

Flange Meshing

- Mesh: Element type used: tetrahedron
- Element size: body sizing: 10mm (fine mesh)
- For hole: refinement factor: 1(fine mesh)
- For fillet: edge sizing: no. of divisions: 100 divisions (fine mesh)

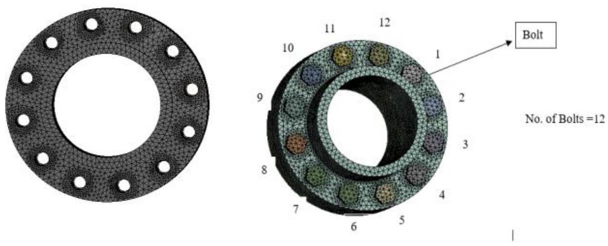

Fig-3.19 Meshing of flange elements

Flange Analysis Results

Flange Structural Analysis

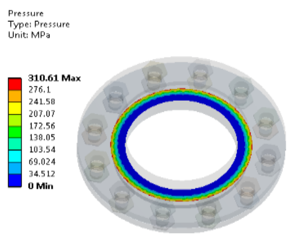

Fig-3.20 Contact pressure without-gasket

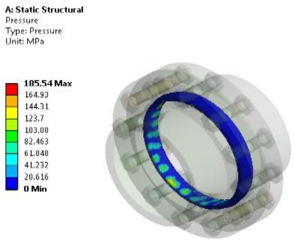

Fig-3.21 Contact pressure with gasket

The maximum contact pressure in the absence of gasket is found to be 310.61Mpa as shown in figure 3.20 and in presence of gasket will be 185.54Mpa as shown in figure 3.21.

Thermal Analysis of Flange

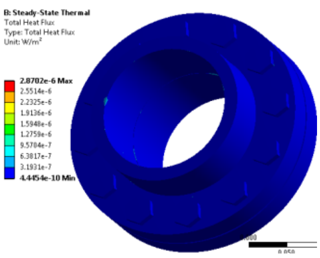

Fig-3.22 Variation of Total Heat Flux (Steady State)

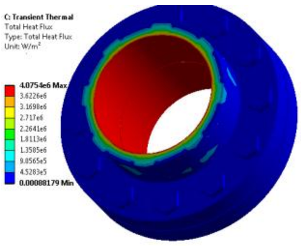

Fig-3.23 Variation of Total Heat Flux (Transient Thermal)

The variation of total heat flux is greater in transient thermal state when compared to steady state.

3.7 Bolt Pretension

In simple terms, it is the amount of force applied to a bolted joint to keep them together and prevent relative motion between the parts. Therefore, the clamp load must be greater than the load that the joint must support to prevent the joint from coming undone. There are a few tables that would provide us with values dependent on diameter (also depends on the grade). The torque is calculated using the following formula:

$$T = K \times D \times P$$

Were.

T = Torque, in-lb

K = coefficient of friction, 0.20 for dry and 0.15 for lubricated joint. (Values may vary a little bit)

D = bolt nominal diameter, in mm

P = clamp load, lb

The bolt's threads bend when we apply torque (may be 4-5). We determine the clamp load in this way. And in the industry, torque is measured by angular displacement (could be easily calculated from the pitch). It provides us with a strain value, which allows us to establish accurate clamp loads. One important element is that bolts are never coated, according to industry. After some time, the paint would start to peel off, and we would lose a significant amount of clamp load, which would cause the joint to loosen.

We must also be careful not to overtighten the bolt. If we exceed the bolt's yield, it can cause the joint to deform. Of course, under torquing would cause the joint to loosen, and along with that, we might experience some fretting, which would accelerate the failure of the component.

The used bolts have a very high yield. Values in the 150 KSI range are normal. Therefore, when applying clamp load, we do not want the bolt head to gradually deform the parent material, since this would also lead to a loss of clamp load and a loose joint. We always use toughened washer because of this.

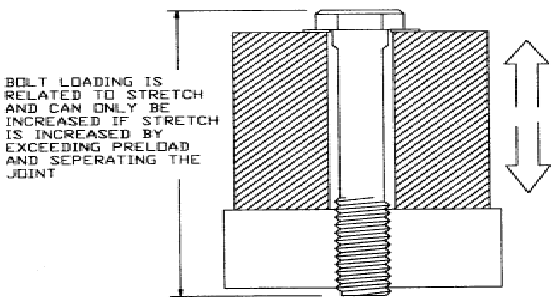

Fig-3.24 Bolt loading

Applying Bolt Pretension load

In the past, it was challenging to integrate pretension stresses from the installation torque of tightening the bolt to an analysis of a fastened flange. Analysts can more readily characterize known axial loads or adjustments to bolt bodies or cylinder faces by using the bolt pretension load option in ANSYS.

When putting a bolt body under a bolt pretension load, a coordinate system is needed. The Z-axis of the coordinate system must be the direction of the bolt axis.

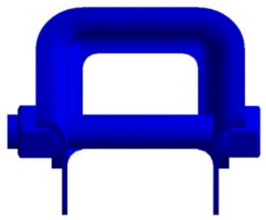

Fig-3.25 Pretension Load

There are 4 bolt pretension load options, they are

1. Load: gives the bolt a compressive axial load (T=Dx0.2xF)
2. F = Axial Load; D= Diameter of bolt; T= Torque.
3. Adjustment: gives the bolt a compressive axial displacement.
4. Lock: Preload displacement is fixed for upcoming load step.
5. Open: opens the bolt load to stop the bolt from being loaded at a certain point of the load.
6. Note: For the purpose of providing a bolt pretension load, contact settings are crucial.

   - $P_1 > P_2(1-k)$

     Where, P_1 = Pretension of bolts

     P_2 = External load

     k = 0.1 for ground surface

   - Checking for joint separation for with metallic gasket.

     $P_1 < A_b \times Y_b$

     Where A_b = Area of the bolt

     Y_b= Yield strength of bolt material

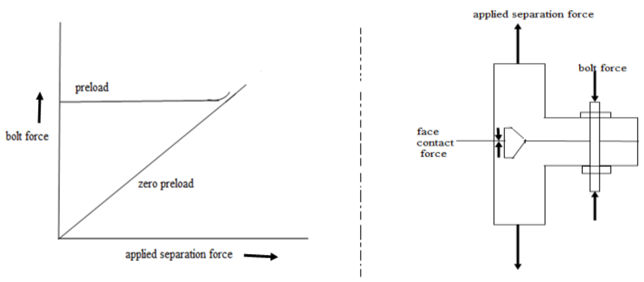

Fig-2.36 Graph of bolt force and direction of load

Apply Bolt Load

Bolt faces or bodies should be loaded if they are cylindrical. If the load is applied to a cylindrical face, the software will slice the body mesh at the centroid of the loaded face and create pretension elements in the direction of the cylinder axis. The software slices the body mesh at the origin of the local coordinate system when a load is applied to a body and creates pretension elements along the local coordinate system's Z-axis.

Contact Settings

There should be bonding between the bolt shaft and nut. Change the contact pairings along the bolt's length to No Separation or Frictionless if you want the two components to pass one another. Bonded contact may prevent the appropriate deformation of the bolt pretension.

Mesh Settings

To ensure that the mesh can be correctly separated in the axial direction of the bolt, it is crucial to choose a small enough mesh on the face or body that supports the bolt pretension stresses.

Results of Deformation in Bolts

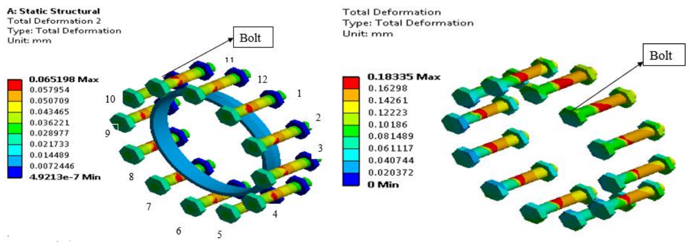

Fig-3.27 Results of deformation in bolts

The deformation in the absence of gasket is found to be 0.18335mm and in presence of gasket will be 0.065198mm as shown in figure 3.27

Stresses in Bolts

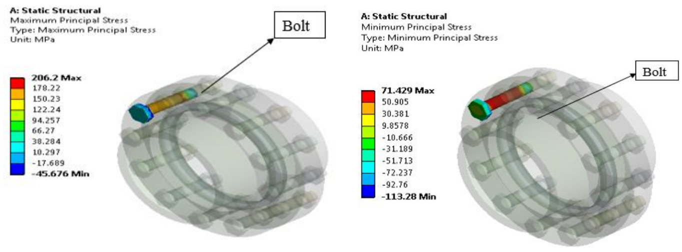

Fig-3.28 Bolts evolved a maximum stress and a minimum principal stress

The maximum and minimum principal stress are shown in red color that is 206.2Mpa and 71.429Mpa.

3.8 Computational Fluid Dynamics Analysis

Computational fluid dynamics is a branch of fluid mechanics that use numerical methods and algorithms to solve and analyse problems involving fluid flows. The interaction of liquids and gases with surfaces governed by boundary conditions is modelled using computers. High-speed supercomputers enable the development of better solutions. Software that increases the precision and speed of difficult modelling situations, such as transonic or turbulent flows, is still being developed. In a wind tunnel, such software is first experimentally validated; full-scale testing, such as flight tests, serves as the final stage in the validation process

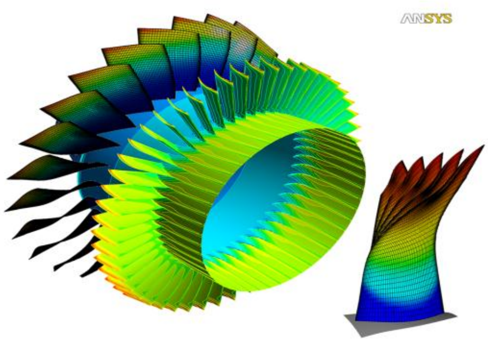

Fig-3.29 CFD view

Meshing

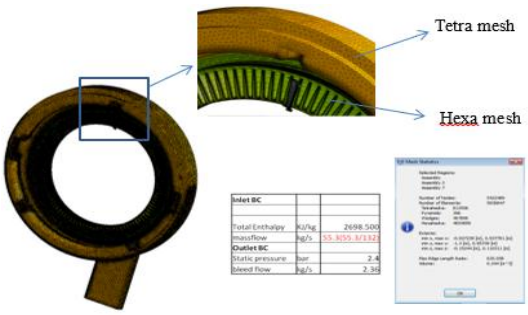

Fig.-3.30 Meshing

There are 132 nozzles, with a flow rate of 55.3/132, and we have applied a mass flow of 0.418kg/sec for each nozzle. Between the nozzle and blade and between the blade and cavity, we have used a stage interface.

Results of Computational fluid dynamics

Pressure Analysis In CFD

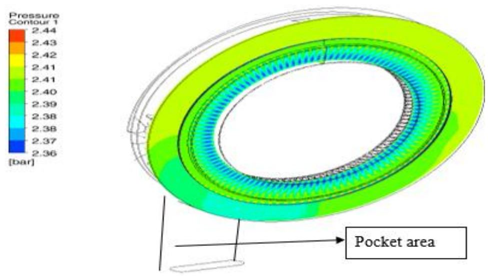

Fig-3.31 Pressure analysis

In the figure, steam is shown applying pressure as it enters the bleed pocket through the shell. 2.44bar is the maximum pressure that might possibly exist. 2.40 bar is the pressure at which steam enters the bleed pocket.

Velocity Analysis in CFD

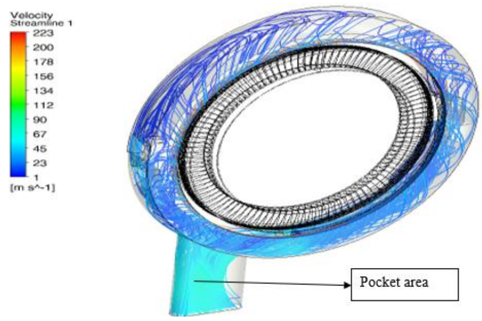

Fig-3.32 Velocity analysis

Before emerging from the bleed pocket, the steam rotates 360 degrees. Blue color indicates the flow. Steam moves through the bleed pocket at a 55 m/s speed.

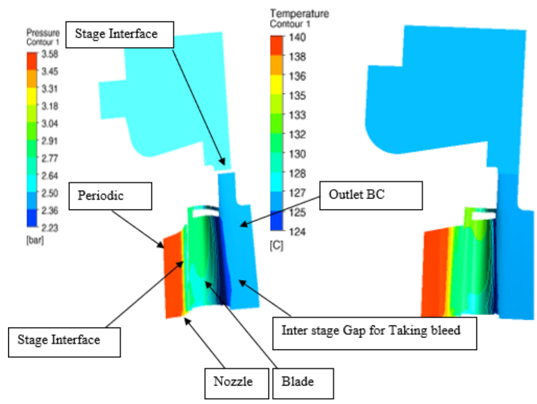

Fig-3.33 Variation of temperature and pressure on nozzles, blades and at interstage

Results After Solving

Area = (Flow x Specific volume) / Velocity

Area = (2.36 x 0.71966) / 55

Diameter of the bleed (d) = 7.8 inch

Numerical Approach Results

Diameter of bleed (d) = 7.6 inch

4. CONCLUSIONS

1. Designing a bleed in steam turbine with a specific dimension is the goal of the work presented in the report. To investigate the various elements and applications of steam turbine bleed, a thorough literature review was conducted. The various parts of the bleed were created utilising a method that was deemed suitable. For creating parts with various types of operations, CATIA is widely utilised. Finally, in the CATIA Assembly part, each component is put together to form a complete turbine, after which it is all tested in Ansys V14.5.

2. Due to their numerous applications, Bleed, which are still relatively new on the market, are garnering a lot of interest. A complex engineering product like bleed is always being developed. Before the bleed is ready for market consumption, there is still much design work to be done. The design process must take into consideration a variety of additional aspects in order to be suitable for actual applications. The production of such complex forms at microscopic sizes is another topic of ongoing research. Even greater bleed could be produced with more investigation into the design and manufacturing process.

- Casing and bleed pocket structural analysis is investigated. to evaluate how loads affect the casing.
- We have examined how the thermal analysis of the casing and bleed pocket varies over time and then when time is absent.
- Computational fluid dynamics is used to measure flow.

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