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STRUCTURAL AND THERMAL ANALYSIS OF STEAM TURBINE CASING

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Abstract – *Steam turbine is a superb primum mobile to convert heat of steam to energy. Of all heat engines and prime movers the turbine is nearest to the perfect and it's wide employed in power plants and altogether industries wherever power is required for method. In addition, the realization of critical turbine components need improved design and materials, which offer all possibilities for a cost effective and flexible service. High thermal stress gradients were found at the region of casing where fatigue cracks were detected during engine operation. 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 V5-R20 software. Boundary conditions were given on the finite element model through ANSYS.*

Key Words: Steam turbine casing, Structural Analysis. 3-D model, CATIA, Thermal expansion, FEM, Turbine rotor, start up cycles, ANSYS

1. INTRODUCTION

1.1 Principle Of Steam Turbine:

The steam energy is converted mechanical work by expansion through the turbine. The expansion takes place through a series of fixed blades (nozzles) and moving blades each row of fixed blades and moving blades is called a stage. The moving blades rotate on the central turbine rotor and the fixed blades are concentrically arranged within the circular turbine casing which is substantially designed to withstand the steam pressure.

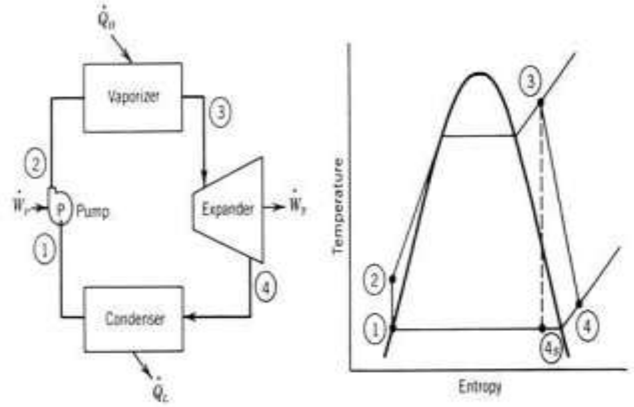


Fig -1.1: Working of Steam Power plant and its cycle

Fig –1.2 : Steam turbine casing

1.2: VARIOUS PARTS OF STEAM TURBINE

a) Nozzle: The nozzle expands steam of comparatively low velocity and high static pressure within considerable increase in velocity. The nozzle is so positioned as to direct the flow of steam into the rotor passage.

b) Diffuser: It is a mechanical device that is designed to control the characteristics of steam at the entrance to a thermodynamic open system. Diffusers are used to slow the steam's velocity and to enhance its mixing into the surrounding steam. In contrast, a nozzle is often intended to increase the discharge velocity and to direct the flow in one particular direction.

Flow through nozzles and diffusers may or may not be assumed to be adiabatic. Frictional effects may sometimes be important, but usually they are neglected. However, the external work transfer is always assumed to be zero. It is also assumed that changes in thermal energy are significantly greater than changes in potential energy and therefore the latter can usually be neglected for the purpose of analysis.

c) Blades Or Buckets: The blades or buckets form the rotor flow passage and serves to change the direction and hence the momentum of the steam received in the stationary nozzles.

d) Guide Or Guide blades: Often a turbine is arranged with a series of rotor flow passages. Intervening between the blades comprising the rotor passages are rows of stationary guide blades. The purpose of this guide is to reverse the direction of steam leaving the preceding moving blade row so that general direction of steam leaving the preceding moving blade rows is similar. If guide blades were not provided, opposing force would be exerted on the rotor which would largely negate each other.

e) Casing Shell Or Cylinder: The turbine enclosure is generally called the casing although the other two names are in common use. The nozzle and guide are fixed on casing, which in addition to confining the steam serves as support for the bearings. Sometimes the word cylinder is restricted as a cylindrical form attached to inside of the casing to which the guides are fixed.

f) Shaft, Rotor, Spindle: These terms are applied to the rotating assembly which carries the blades.

g) Disc Or Wheel: The moving blades are attached to the disc which in turn is keyed to the shaft.

h) Diaphragm: The diaphragm which is fixed to the cylinder or casing contains the nozzle and serves to confine the steam flow to nozzle passage.

i) Packing: Packing in the form of carbon rings minimizes the leaking in the annular space between the diaphragm and shaft.

j) Thrust Bearings: Usually a combination of Kingsbury and collar types absorbs the axial forces.

k) Exhaust Hood: The exhaust hood is the portion of the casing which collects and delivers the exhaust steam to exhaust pipe or condenser.

l) Steam Chest: The steam chest is the supply chamber from which steam is admitted to the nozzles.

m) Governor: The governing system may be designated to control steam flow so as to maintain constant speed with load fluctuations to maintain constant pressure with variation of demand for processed steam or both.

n) Throttle Or Stop Valves: The throttle and stop valves are located in the steam supply line to the turbine. The stop valve is hydraulically operated quick opening and shutting valves designed to be either fully opened or shut. On small turbines the stop valves may be manually operated but in any case is intended for emergency use or when fully shut down. The throttle valve is used in smaller turbines in addition to stop valve as a means of regulating steam flow during the starting or stopping the operation.

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.

1.3 :INTRODUCTION TO CATIA:

Program that can combine between drawing and design, animation and simulation production and Manufacturing, Without need to use more than one program, to produce a single project, Until found everything I need in the most comprehensive program on earth "CATIA". This program, which change my point of view in the science of mechanical drawing, where it became more easy, more flexible and more accurate.

MODULES IN CATIA

CATIA consists of modules each Module specialized in specific design field, And I will review now the most famous of these modules:

Fig 1.6 : Some of CATIA Modules

1.4: INTRODUCTION TO ANSYS

ANSYS is general-purpose finite element analysis (FEA) software package. Finite Element Analysis is a numerical method of deconstructing a complex system into very small pieces (of user-designated size) called elements. The software Implements equations that govern the behavior of these elements and solves them all; creating a comprehensive explanation of how the system acts as a whole. These results then can be presented in tabulated, or graphical forms. This type of analysis is typically used for the design and optimization of a system far too complex to analyze by hand. Systems that may fit into this category are too complex due to their geometry, scale, or governing equations.

ANSYS is the standard FEA teaching tool within the Mechanical Engineering Department at many colleges. ANSYS is also used in Civil and Electrical Engineering, as well as the Physics and Chemistry departments. ANSYS provides a cost-effective way to explore the performance of products or processes in a virtual environment. This type of product development is termed virtual prototyping. With virtual prototyping techniques, users can iterate various scenarios to optimize the product long before the manufacturing is started. This enables a reduction in the level of risk, and in the cost of ineffective designs. The multifaceted nature of

ANSYS also provides a means to ensure that users are able to see the effect of a design on the whole behavior of the product, be it electromagnetic, thermal, mechanical etc.

1.11.1: Steps In Finite Element Analysis:

STEP 1:

First the domain is represented as finite elements. This is called descritization of domain. Mesh generation programs called processors, help in dividing the structure.

STEP 2:

Formulate the properties of each element in stress analysis. It means determining the nodal loads associated with all element deformation stress that is allowed.

STEP 3:

Assemble elements to obtain the finite element model of the structure.

STEP 4:

Apply the known loads, nodal forces in stress analysis. In stress analysis the support of the structure has to be specified.

STEP 5:

Solve simultaneous line algebraic equations to determine nodal displacements in the stress analysis.

STEP 6:

Postprocessors help the user to sort the output and display in the graphical output form.

A typical finite element model is comprised of nodes, degrees of freedom, elements material properties, externally applied loads and analysis type.

The finite element method is a numerical analysis technique for obtaining approximate solutions to a wide range of engineering problems.

2. LITERATURE REVIEW

Naresh Kumar Doneti , Spoorthi Gopagoni, Tariku Achamyeleh[1], This paper provides examples on how the concept has been realized within various design aspects and features, all with an underlying target to produce steam turbines that meet all named market requirements at competitive prices. **Gayatri Choudhary,Nishita Kispotta,Dhaneshwari Sidar etc.all [2],** has worked on design consideration, design checks and sensitivity analysis to achieve the design criteria to fulfill the structural requirement for mechanical integrity. 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. **Mohamed Rehan Z, Dr. Shivarudhraiah [3] ,** has been worked on design and analysis of a steam turbine**.** Bleed is amount of steam output from turbine through pipe and exit from final stage of turbine. This bleed enters to feed water heater (low and high) and deaerator to increase unit efficiency. The bleed steam is actually the steam which has already performed work on turbine blades. Design and analysis of bleed and more particularly to a device for carrying a store such as a steam, and provided with means for positively ejecting the store from the bleed pocket. **A. Sudheer Reddy, MD .Imran Ahmed, T. Sharath Kumar etc. all [4],** dicussed on working of a steam turbine**.** Steam turbine is an excellent prime mover to convert heat energy of steam to mechanical energy. In power generation mostly steam turbine is used because of its greater thermal efficiency and higher power-to-weight ratio. **Laxminarayan.k , Dr.M.Venkatarama Reddy , Dr.Kumar [5],** In their present work, one such analysis is carried out to evaluate the contact pressure in a high pressure steam turbine casing. The shape and design of a steam turbine casing depends on key sensitivity parameters like bolt pre-tensions, contact pressure and thickness of casing which determine the structural integrity of the casing. The preset work reviews a recent structural integrity assessment carried out on a high-pressure turbine inner casing that had suffered from temper embrittlement Conventional design of a steam turbine casing is considered**. Ms. Mohini R. Kolhe , Prof. A. D. Pachchhao, Prof. H.G.Nagpure [6],** presented a paper on a review of the past work done in the field of steady state and transient thermal analysis of steam turbine rotor using finite element method. The analysis of transient thermal stress values that are produced while the turbine is running are the key factors of study while designing the next generation turbines. The temperature gradients that can be established in the transient state are generally higher than those that occur in the steady-state and hence thermal shock is important factor to be considered relative to ordinary thermal stress. The rotor of steam turbine is subjected to temperature variations in short periods of time due to the start and stop cycles of the turbine. This causes sudden changes in the temperature with transient thermal stresses being induced into the turbine rotor. The estimate of thermal stresses induced in the turbine rotor is important in determining the start up cycle of a steam turbine. The transient effect is due to the changes in the material properties like Density, Specific heat and Young's Modulus. **J.Ramesh, C.Vijaya Bhaskar Reddy, Dr. B. Jayachandraiah [7],** In this work the thermo mechanical analysis of steam turbine casing will be established by finite element method. 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. **Dhanush Naik J B, Dr. Kiran Kumar P [8],** has been done a contact pressure analysis of steam turbine casing under static loading condition. Steam turbine is a device used to covert thermal energy (Steam) into mechanical energy, then after converted to Electrical energy.

3. DESIGN AND ANALYSIS

We have been supplied with the .igs file of the Steam turbine Casing; I have designed the Steam turbine Casing according to the dimensions supplied to me in CATIA V5. The following figures show the development of the design in the CATIA.

3.1 : Isometric Projection and its FV & TV :

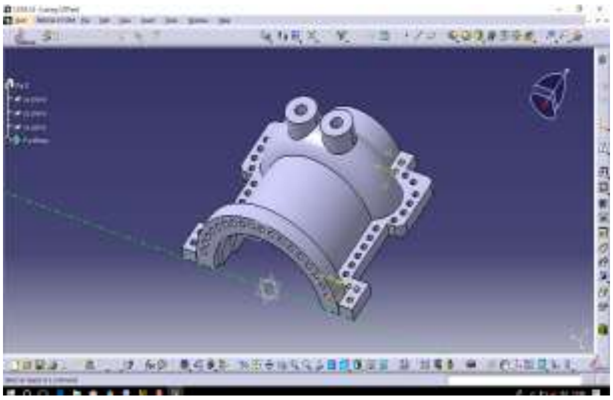


Fig 3.1: Isometric Projection of turbine casing model in CATIA V5

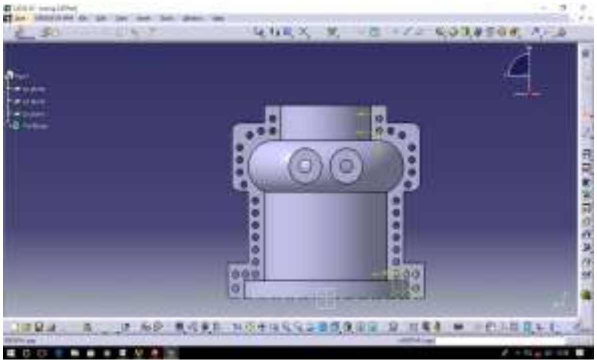


Fig3.2 : Top view of turbine casing

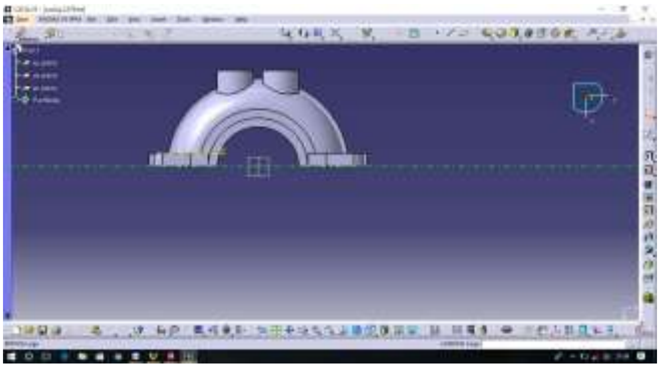


Fig3.3 : Front view of turbine casing

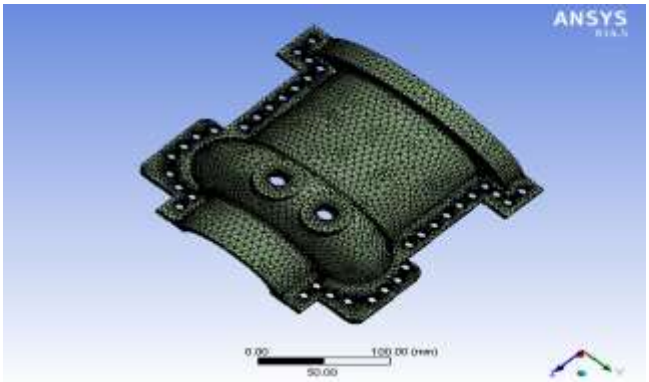


Fig3.4 : Mesh Generation in ANSYS

3.2 : Material Selection for Steam Turbine Casing : After the design the material selection plays a vital role in the analysis. In this present work we are selected Inconel625, Inconel 718, Nikhil 325.

Initially assumed ambient condition outside the casing i.e 22^0c and convection mode of heat transfer is applied to the casing. Also the Inner surface temperature is 320^0c for the safe design.

S. No	Material	Density kg/ mm^3	Thermal Conductivity (w/mm ^oC)	Specific Heat (mJ/Kg ^oC)	Youngs modulus (MPa)	Poissoins Ratio (μ)
1.	Inconel 625	8.4e-5	1.14e-2	4.46e5	2.5e5	0.30
2.	Inconel 718	8.19 e-6	1.12e-2	4.35e-5	2.08e 5	0.25
3.	Nickel 325	8.9e-6	9e-2	4.4e5	2.32 e^5	0.32

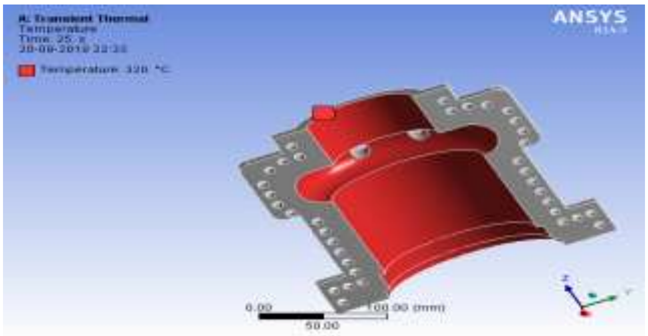


Fig 3.5 : Temperature applied to the Casing Inner surface

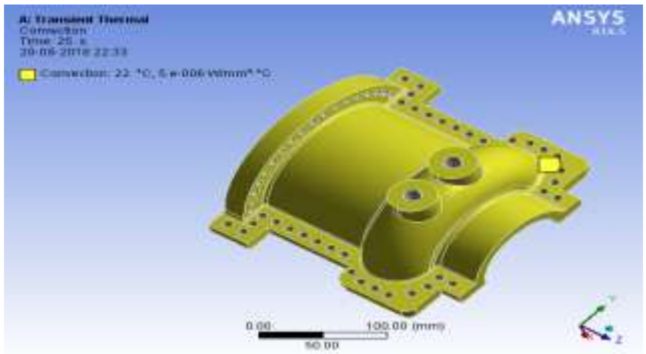


Fig3.6: Convection applied to the Casing Top surfaces

3.1 OBSERVATIONS :

3.1.1 : The Temperature and Heat flux Distribution of piston **with different materials** for one second has been observed. also the temperature and heat flux distributions by time (1s) is shown graphically.

Case 1 : A) Temperature Distribution when Casing material as Inconel 625:

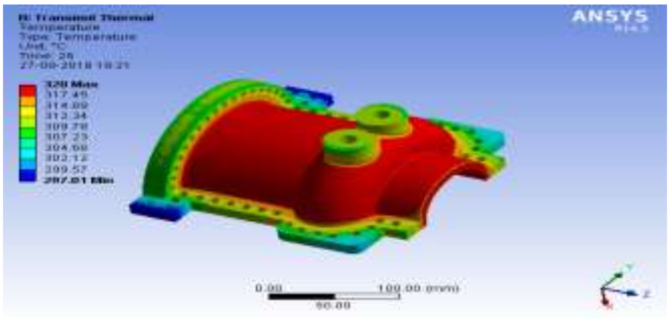
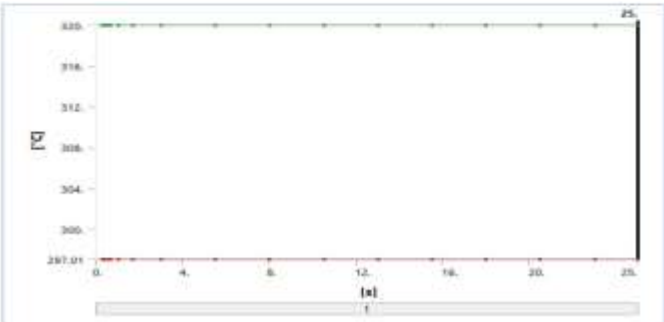


Fig.3.7 : Temperature Distribution when Casing material as Inconel 625



GRAPH 3.1 : Time Vs Temperature when Casing material is Inconel-625

B) Heat Flux Distribution when Casing material as Inconel 625:

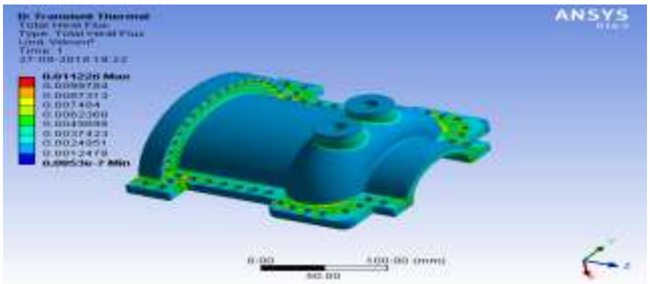
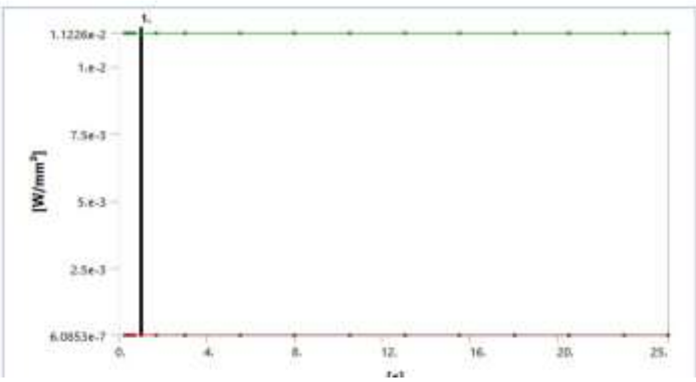


Fig 3.8 : Heat Flux Distribution when Casing material as Inconel 625



GRAPH 3.2 : Time Vs Heat Flux when Casing material is Inconel-625

Case 2 : A) Temperature Distribution when Casing material as Inconel 718:

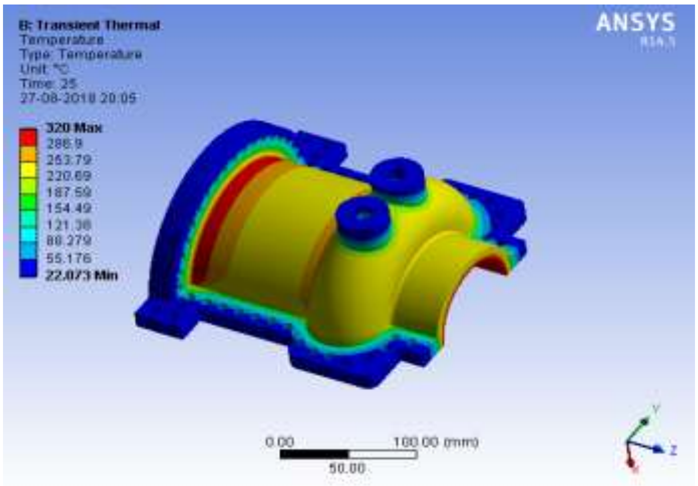
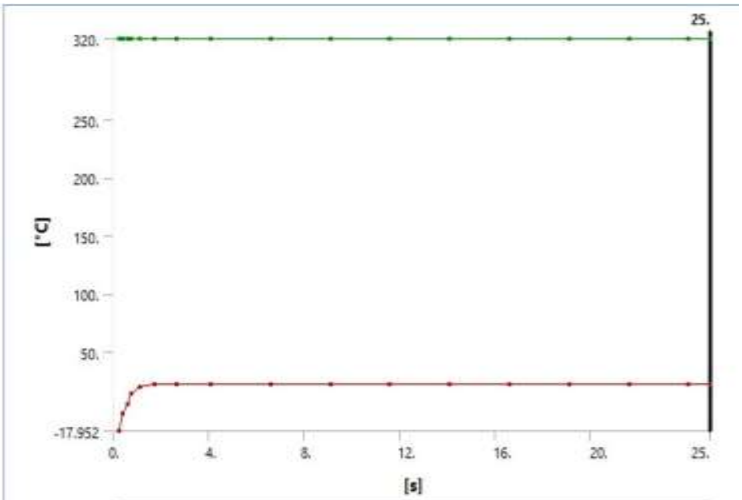


Fig. 3.9 : Temperature Distribution when Casing material as Inconel 718



GRAPH 3.3 : Time Vs Temperature when Casing material is Inconel-718

B) Heat Flux Distribution when Casing material as Inconel 718 :

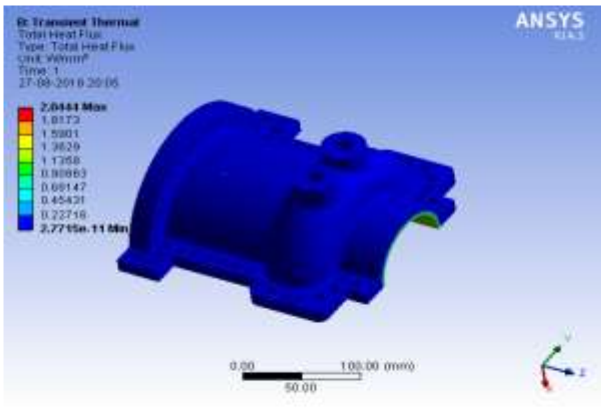
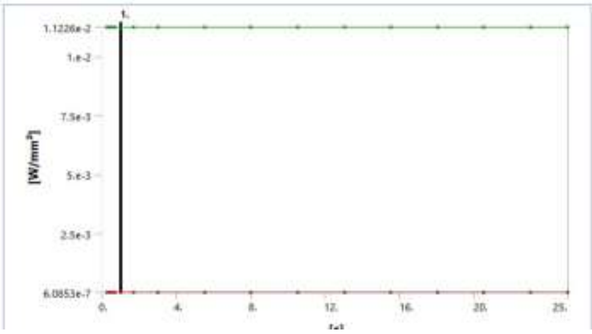


Fig 3.10 : Heat Flux Distribution (outer surface)when Casing material as Inconel 718



GRAPH 3.4 : Time Vs Heat Flux (outer casing)when Casing material is Inconel-718

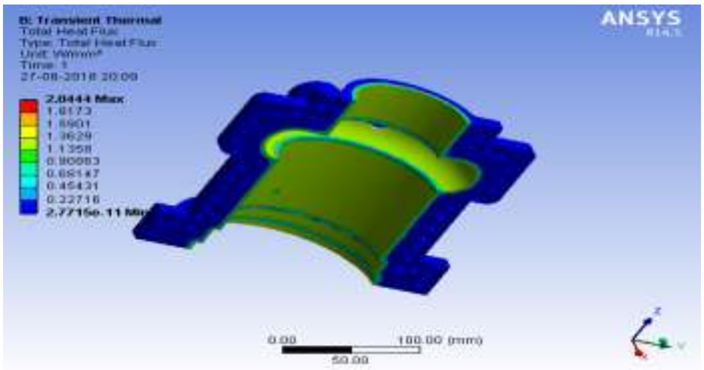
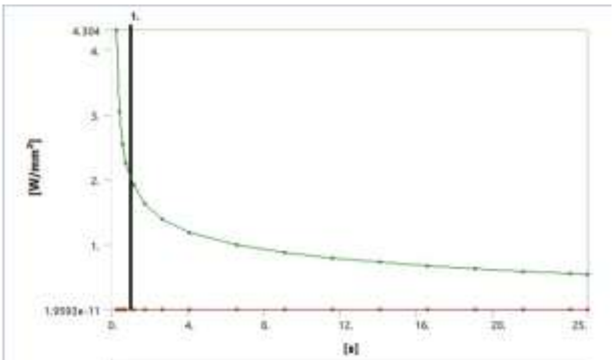


Fig 3.11 : Heat Flux Distribution (Inner surface)when Casing material as Inconel 718



GRAPH 3.5 : Time Vs Heat Flux (Inner casing)when Casing material is Inconel-718

Case 3 : A) Temperature Distribution when Casing material as Nickel 325 :

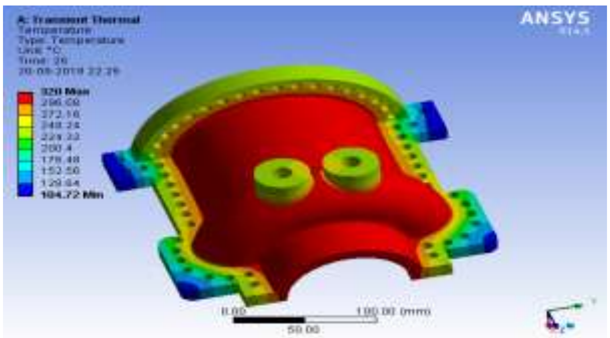
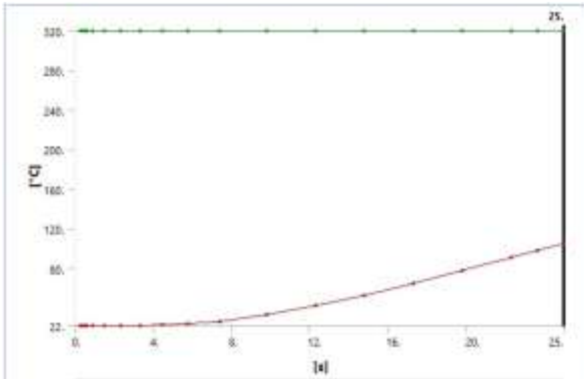


Fig.3.12 : Temperature Distribution when Casing material as Nickel 325



GRAPH 3.6 : Time Vs Temperature when Casing material is Nickel -325

B) Heat Flux Distribution when Casing material as Nickel-325 :

S.No	Material	Max value (w/mm²)	Min value (w/mm²)
1.	Inconel 625	0.01126	6.685e-7
2.	Inconel 718	2.044	2.7715e-11
3.	Nickel 325	7.854	1.555e-7

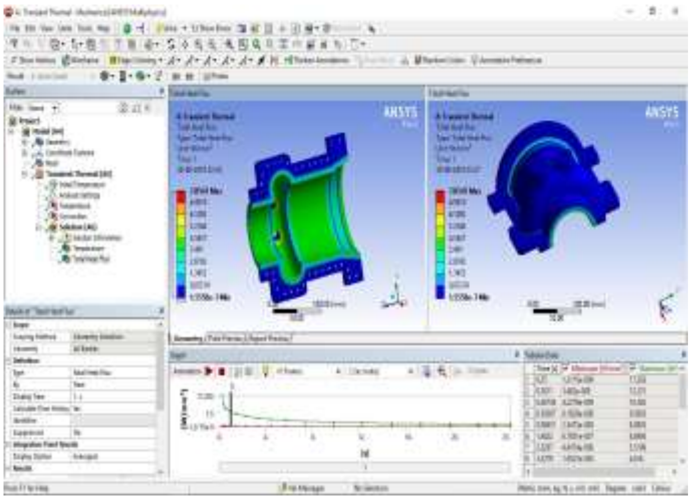
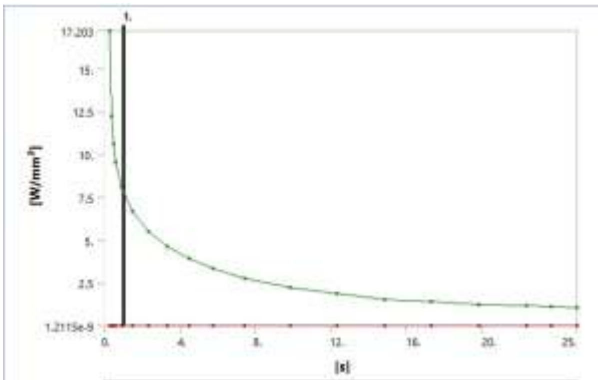


Fig. 3.13 : Heat Flux Distribution(Inner & Outer)when Casing material as Nickel-325



GRAPH 3.7 :Time Vs Heat Flux (Inner & outer casing)when Casing material is Nickel-325.

4. CONCLUSIONS AND FUTURE SCOPE

In this present work i selected ,Inconel 625, Inconel 718 **and Nickel 325** materials are used as Casing materials. Also tested the heat flux distribution and temperature distribution with different Casing materials from the above mentioned materials.

At the initial stage the temperature applied to the casing inside as 320^0c and outside casing as 22^0c and the convection het transfer distribution was observed as fallows.

The Temperature and Heat flux Distribution of piston **with different materials** for one second has been observed. also the temperature and heat flux distributions by time (1s) is shown graphically.

Table 4.1 : Comparison of Heat Flux distribution with Different materials:

conclusions :

- The casing made with Inconel 625 , Inconel 718 was not providing much heat distribution at any instant.
- similarly, The piston made with Titanium alloy without coating also not providing much heat distribution at any instant.
- The maximum heat flux distribution obtained when **Al-Alloy** is piston material and **Mg-Zr-O_3** as coating material which is equal to **71.513 W/mm^2**.
- so the Mg-Zr-O_3 Coating material is preferable compared other.

Future scope:

The test can be extended by selecting more different piston materials those are very much convective in nature.

This work can be extended by selecting suitable coating materials other than Ni-Cr-Al and Mg-Zr-O_3.

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BIOGRAPHIES

Am veldi kanakaraju completed master of technology in wits, Warangal.

I am Nalla suresh working as an assistant professor since last three years in wits , Warangal.

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