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# Design and Thermal Analysis of Steam Turbine Blade

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**Abstract –** *the steam turbine is one of the most excellent prime movers in to the mechanical energy due the essential for steam turbine blades, the many multifunction used and for the more applications .the reduction the stresses and increasing the fatigue of life in major concern is high temperature, various technic has used for the increasing the fatigue that is one technic has the axial hole along with blade spam. The thermal using ANSYS 16.2 workbench this software is popularity of the finite element analysis in different types of loading with based material properties modules with different holes in turbine blades.*

***Key Words***:

**Thermal Analysis, Steam Turbine moving Blades, FEA,**

**Geometrical/Material Optimization.**

## 1. INTRODUCTION

The development days steam turbine moving blades major part of the steam consumption are subjected to the dissimilar types loading such as steam the inertia of centrifugal forces, due to the is forces varieties of stresses are encouraged in the moving blade. Stress and strain mapping on the moving blades, the present paper the static and dynamic behaviour of the moving blades and the basic problem in steam turbine blade increasing the life of the turbine with increasing the holes in the blades .the present paper involving the stress scrutiny of a typical blade made up in nickel alloy that is subjected in the centrifugal forces, the study result show that the centrifugal loading .here the in case of effected thickness , twist and taper of the blade was considered for the deter ermine the von-mises stresses, deformation in Z-direction was determine using the finite element analysis software. The solid bricks 20 –node element are used.

### 1.1 Components of Steam Turbine

The part of the steam turbine is casing the most its fixed in the across the blades, that which have the working fluid have the unique direction, the portion part of the blades is the very high temperature the blades will sucked the energy, then the combustor will produce the high pressure turbine and its blades will have very limiting component. The guide blade carrier is the steam condensing the steam turbine where taking factor of correct angle getting in to the moving blades here we are going to use the guides that would be guide blade they are going to be fixed. And particular rotor it has rotary mechanical machinery who's who main aim to extract energy condensing the fluid factors finally to the used full work the generation of main power electricity.

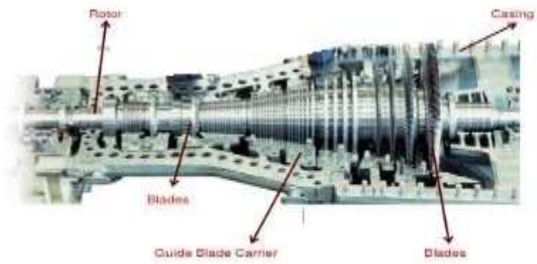



**Figure 1 component of steam turbine**

### 1.2 Impulse and reaction bleeding

The differentiation of the impulse and reaction blading taking the concept of the flow of the steam through one stage of fixed along with the moving blades. While in the impulse turbine which will results in the drop of the pressure drop and gets accumulated across the fixed blades and get affected to the nozzles. Finally, these nozzles move the steam with an optimum at a high velocity.

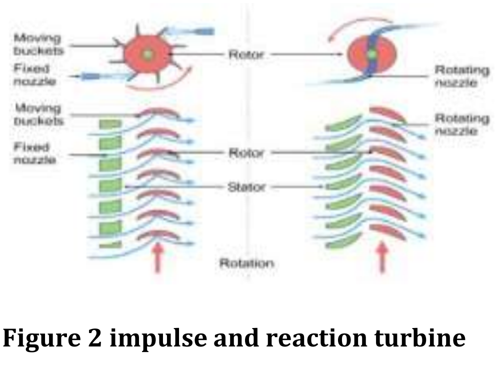



**Figure 2 impulse and reaction turbine**

## 2. METHODOLOGY

The main purpose of the turbine technology are to extract maximum quality of energy from the working fluid to convert it in to the use full work with maximum efficiency by means of a plant having maximum reliability, minimum cost minimum supervision and minimum starting time .the steam turbine its power utilizing the energy by burn the fluid and air which is high temperature and high pressure by expanding through the several rings ad fixed moving blades.to get a high pressure of order some high working fluid.

**What is the solution?**

In the solution phase of the analysis, the computer take over analysis simulation over equations that is finite element method generates

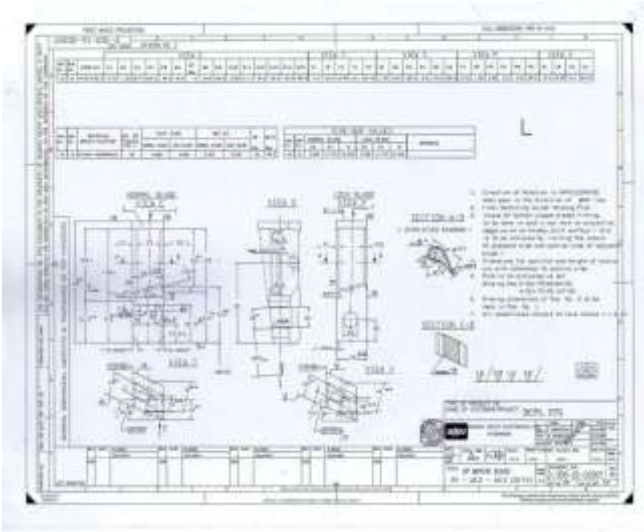


**Figure 3 turbine blade sheet (reference by Triveni)**

### 2.1 Design of Steam Turbine Blade with Hole

We are going to consider the existing design (0.5mm holes) and for thermal analysis of the size of the holes of the blades where the thermal capacity is increased. The blade which is designed with 5 holes of 0.5mm is found to be optimum solution Ceramic matrix composites wherever the fibers area unit embedded in a ceramic matrix, area unit essentials increasing to This blade is hollow a ceramic core within form for these particular is inserted in the center. This blade is surrounded with this heat-resistant material the create this shell, so that shell is stuffed under this blade alloy. That step will be a lot of sophisticated for materials, however the method is analogous.

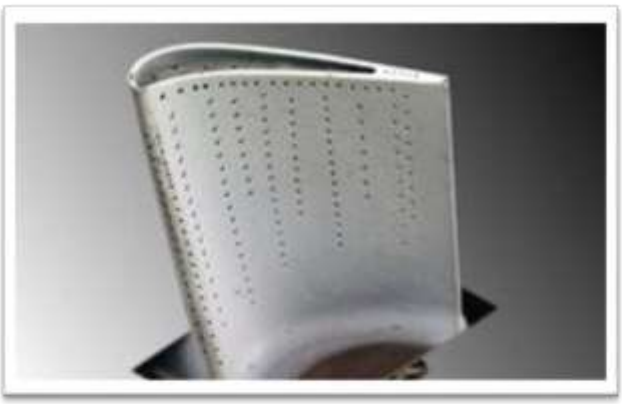


**Figure 4 steam turbine blades with holes**

### 2.2. Specification of steam turbine blade with holes

**D=1300.5 mm, N=7600 rpm, L=116mm, d=12mm, Holes Dia 0.5mm**

- The steam turbine rotor blade inlet temperature is 16200/ 900°C
- Rotor blade outlet temperature is 1478°C.
- Total thermal heat flux for copper is 2.6453MW/ $m^2$
- Total thermal heat flux for titanium is 0.9927 $MW/m^2$
- Total thermal heat flux for nickel is 1.9559 $MW/m^2$.

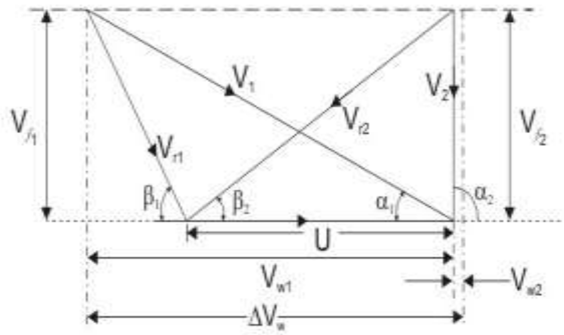



**Figure 5 velocity profile of steam turbine blade with hole**

### 2.3. Choice of Steam Turbine Blade

The choice made here is going to be depending upon the factors like very important is rotor blades etc, the steam which is going to be incident upon there also again and get the deflection of the gas through an very factors consideration are the specified angle where the consideration are done with the result obtained as the minimum loss.

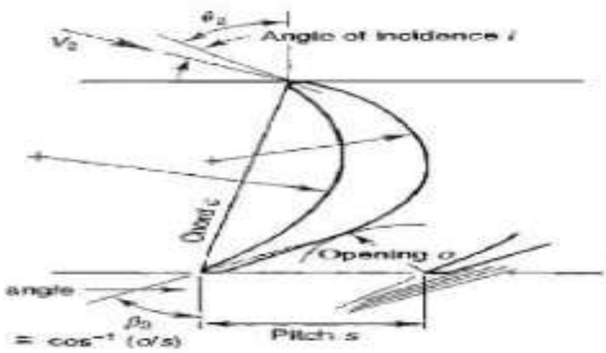



**Figure 6 convectional; steam turbine of the choice of blade angle**

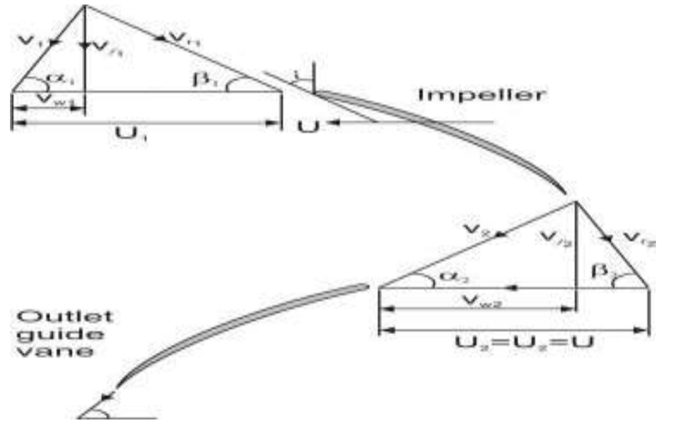



**Figure 7 velocity diagrams for steam turbine blade**

For steam $\mathbf{V=\sqrt{2\Delta h}}$

**1 Peripheral Velocity of Blade**

$$U=\frac{\pi DN}{60}=\frac{\pi\times1308.5\times7600}{60}=955.06\ m/s \ldots\ldots\ldots\ldots(1)$$

**2 Applying for Continuity Equation for Nozzle Outlet**

$$\pi DC_n\, e_1 \sin\alpha_1 = MV$$

$$M=\frac{\pi(2.4)\times0.3\times687.5\times0.342}{42.46}=12.53\ kg/s \ldots\ldots\ldots(2)$$

**3 Applying Continuity Equation for Blade Outlet**

$$\pi DC_n\, Cr_2 \sin\beta_2 = MV$$

$$C_U=\frac{POWER\times1000}{M\times U}=500.3\ m/s \ldots\ldots\ldots\ldots(3)$$

**4 In The Velocity Diagram**

**As per Based on Diagram**

$C_2 = 230$ m/s

$C_{r2} = 350$ m/s

$C_{r1} = 250$ m/s

$$\text{Now } \Delta=\frac{C_1^2-C_2^2}{2\times1000\times\eta b}=\frac{500^2\times0.81\times250^2}{2\times1000\times0.94}=106.6\ Kj/kg$$

$$\Delta=\frac{C_{r2}^2-C_{r1}^2}{2\times1000\times\eta b}=\frac{350^2-0.81\times250^2}{2\times1000\times0.94}=38.33\ KJ/Kg \ldots\ (4)$$

**5 Heat Drop in Stage**

**= 1814.7 Kj/Kg ………………………………… (5)**

**6 The Outlet Angle of Moving Blades**

**$(\beta_2)=20^\circ$**

**…………………………………………………(6)**

**7 Degree of Reaction**

$$\frac{\Delta_b}{\Delta_n+\Delta_b}=\frac{38.33}{1814.7}=21.06\ \% \ldots\ldots\ldots\ldots(7)$$

**8 Gross Efficiency**

$$=\frac{397.93\times620.80}{100(1814.7)}=82.53\%$$

**……………………………………………(8)**

**9 Blade efficiency ($\eta_b$)**

$$=\frac{2(620.80)397.93}{40.26^2}=87.5\ \%\text{ with hole}\ldots\ldots\ldots\ldots(9)$$

**2.4. Catia Design**

The geometric modeling of steam turbine blade angle with holes and type cross-sections is done using Catia. The three-dimensional model of the steam turbine blade shown in below figure

**Figure 8 Catia module steam turbine blade inlet heat with holes**

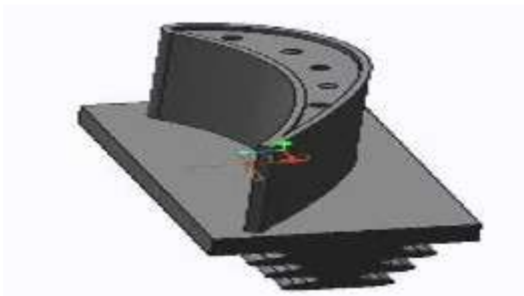


**Figure 9 Catia module heat distributions in blade hole**

**2.4 Ansys Design**

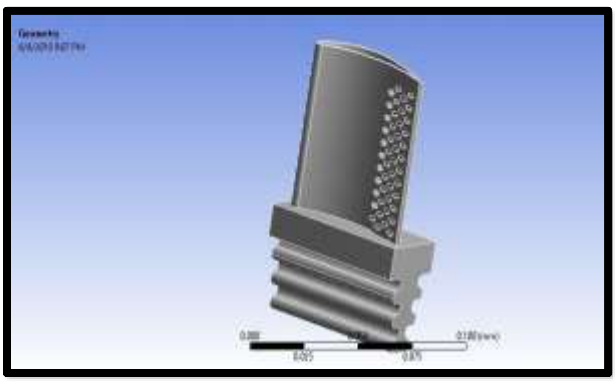


**Figure 10 geometry input in Ansys**

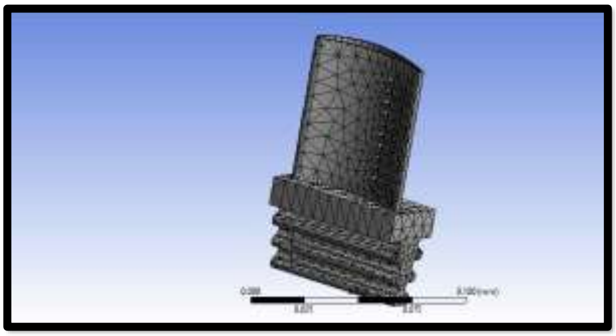


Figure 11 mess generation in Ansys

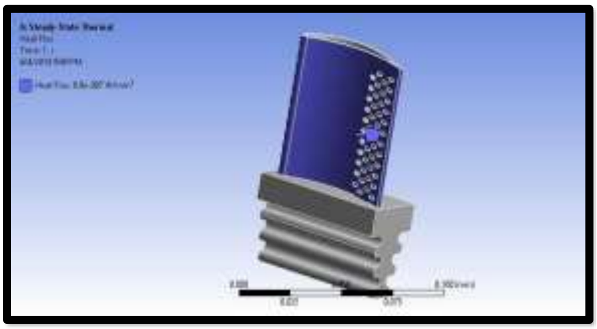


Figure 12 steady state thermal Heat Flux W/mm$^2$

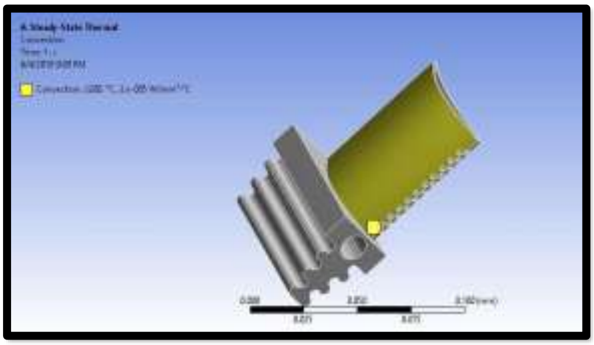


Figure 13steady sate thermal convection w/mm$^2$

**2.5 Properties of Material**

**Titanium Alloy**

Table 1 properties of titanium alloy

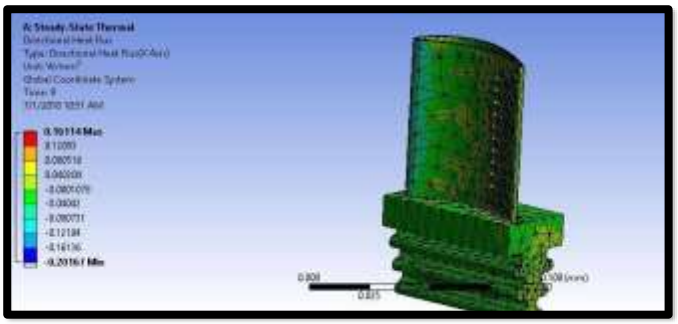
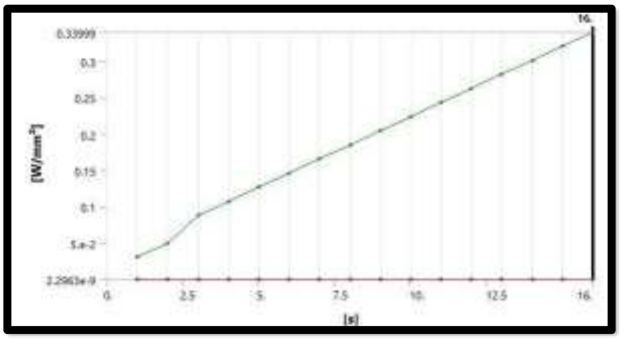


Figure14 steady state direction of heat flux in w/mm$^2$




graph 1 direction of heat flux in w/mm$^2$vs. specific entropy kj/kg

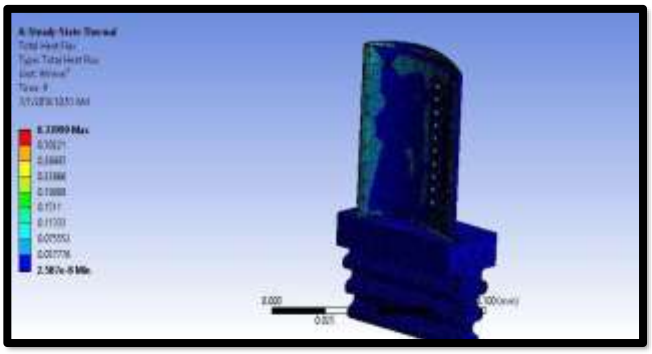


Figure 15 steady state thermal total heat fluxes in w/mm$^2$

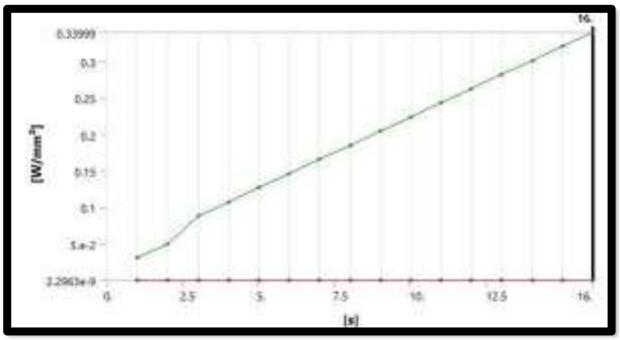



Figure 22 steady state thermal temperatures in $^0$c

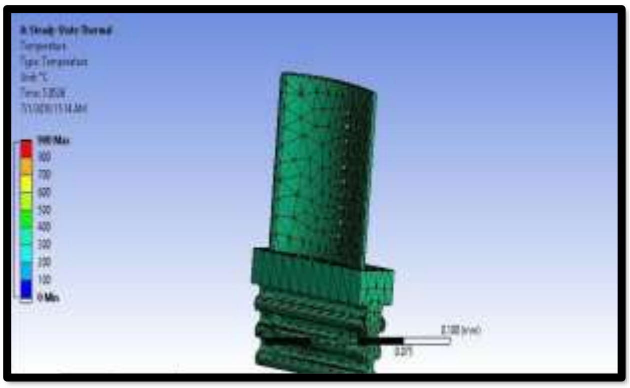
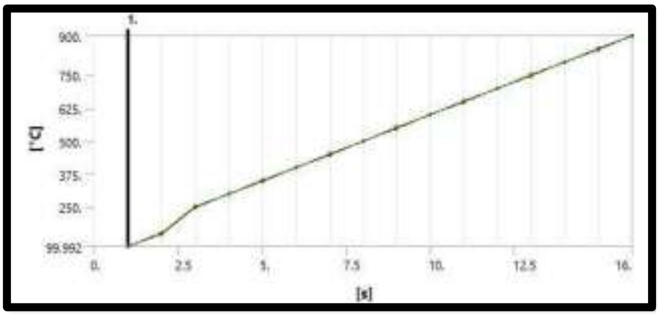


Figure16 steady state thermal temperatures $^0$c



Graph3 temperature in$^0$c vs. specific entropy kj /kg

**2.6 Nickel alloy**

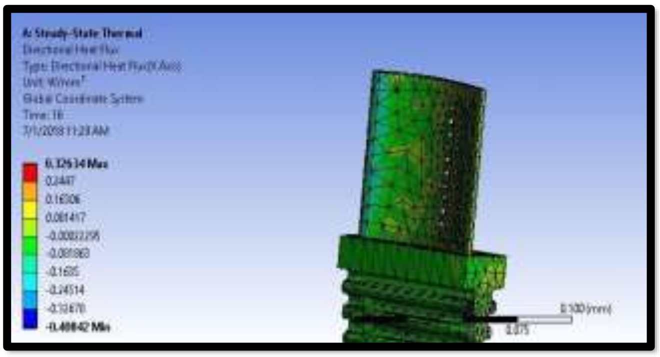
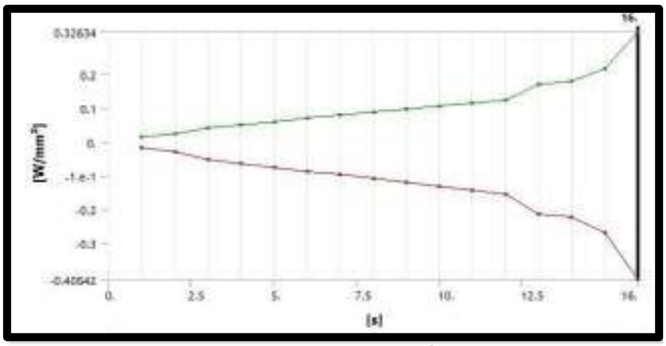


Figure 17 steady state thermal directional heat fluxes in w/mm$^2$



Graph 4 directional heat flux w/ mm$^2$vs. specific entropy kj/kg

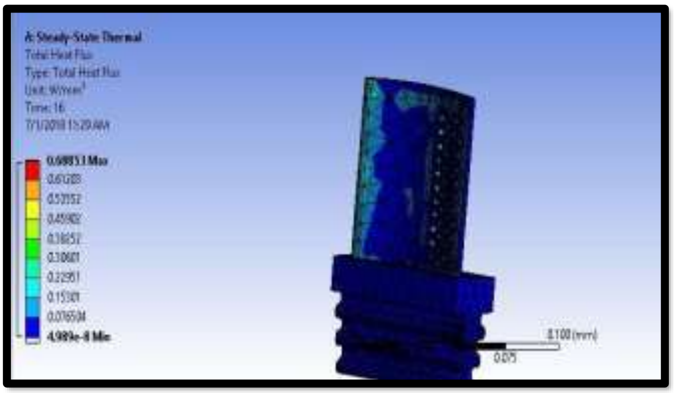
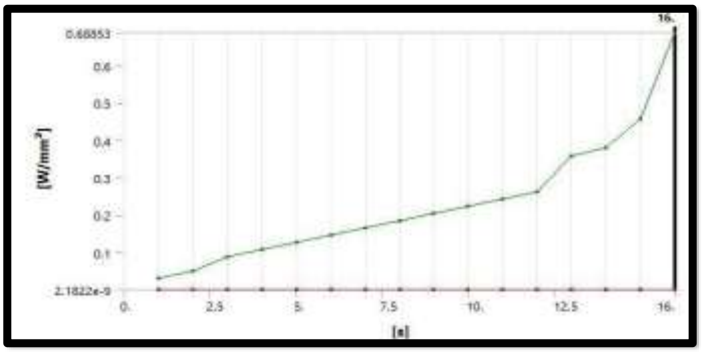


Figure 18 steady state thermal total heat fluxes in w/mm$^2$



Graph 5 total heat flux w/mm$^2$vs. specific entropy kj/kg

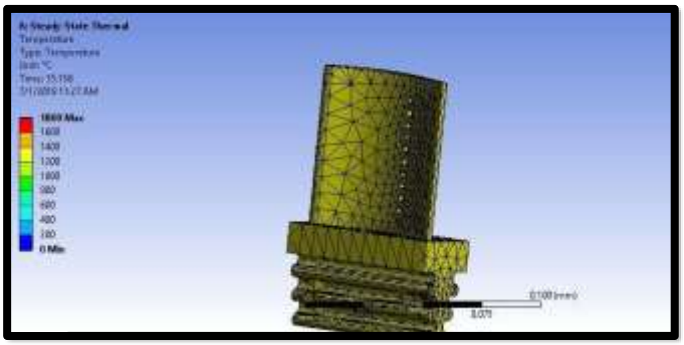
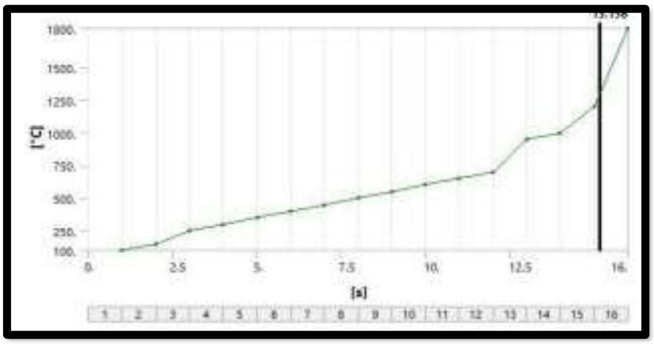


Figure 19 steady state thermal temperatures in $^0$c



Graph6 temperatures in $^0$c vs. specific entropy kj/kg

## Aluminum Alloy

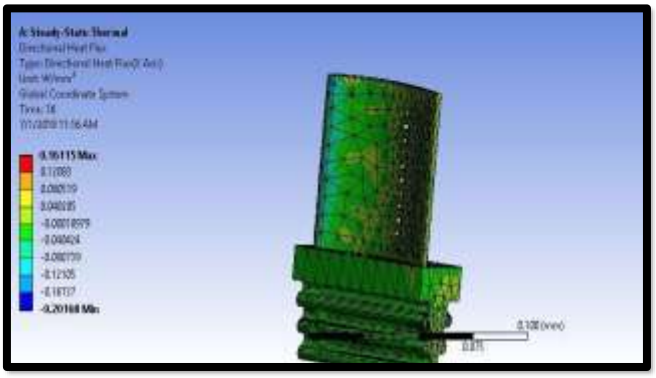
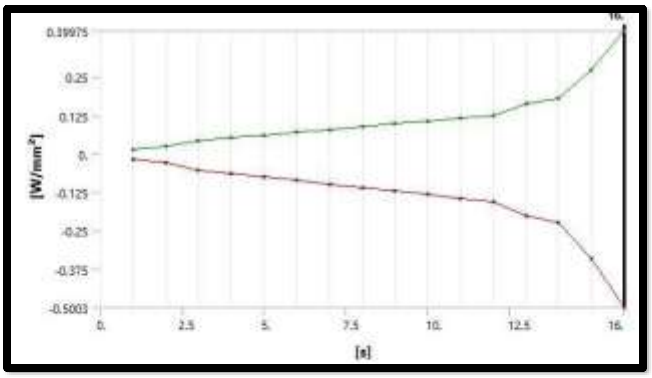


Figure20 steady state direction of heat flux w/mm$^2$




Graph 7 directional heat fluxes in w/mm$^2$vs specific entropy in kj/kg

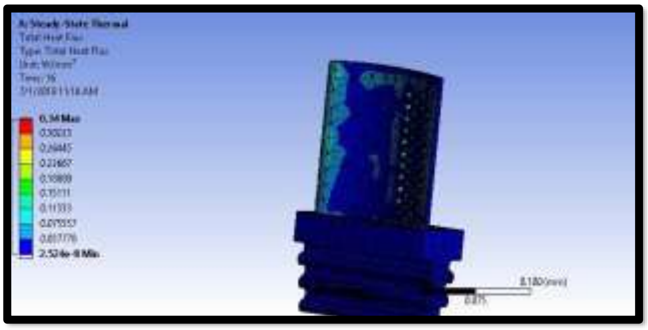
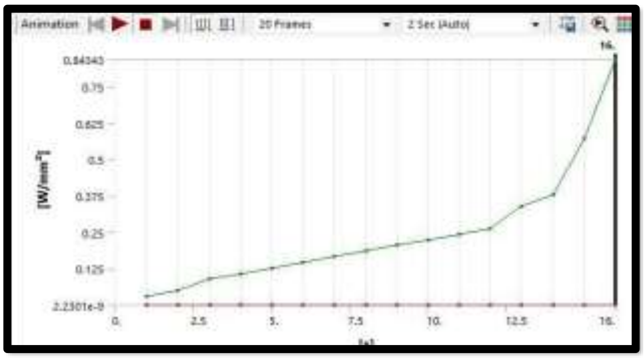


Figure 21 steady state thermal total heat fluxes in w/mm$^2$



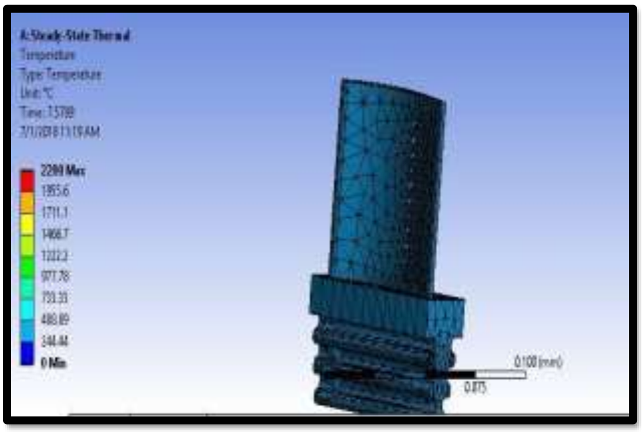
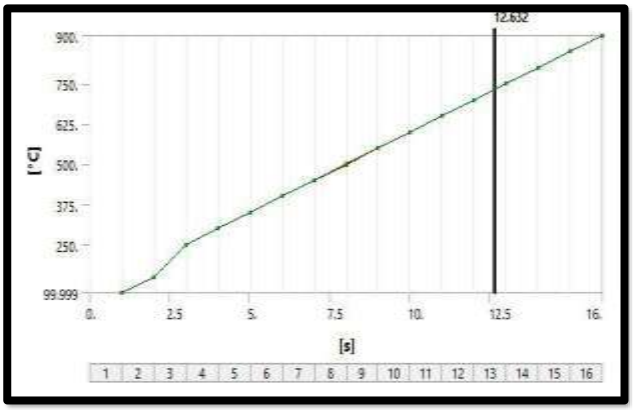



Figure 22 steady state thermal temperatures in $^0$c




Graph 8 temperature in (t)$^0$c vs specific entropy (s)in kj/kg

## 3. RESULT AND COMPARISON

**Table 1 theoretically result of titanium, nickel and aluminum alloys**

| Material | Total Heat Flux | Directional Heat Flux | Temperature |
|---|---|---|---|
| Titanium Alloy | 0.3399 | 0.16114 | 900 |
| Nickel Alloy | 0.68853 | 0.32634 | 1800 |
| Aluminum Alloy | 0.3400 | 0.16115 | 2200 |

**Table 2 blade specification with and without holes**

| Blade specification | Equivalent stress | Cyclic life | Damage | Sensitivity |
|---|---|---|---|---|
| Blade Without holes | 209.48 N/mm$^2$ | 6.53E5 | 46234 | 3.26E5 |
| Blade with 2mm holes | 159.18 N/mm$^2$ | 7.30E5 | 16884 | 1E5 |
| Blades with 4mm holes | 164.19 N/mm$^2$ | 6.214E5 | 3654 | 1E6 |
| Blades with 5mm holes | 134,15 N /mm$^2$ | 5.703E5 | 39456 | 4.76E5 |

### 3.1 Graphical Results

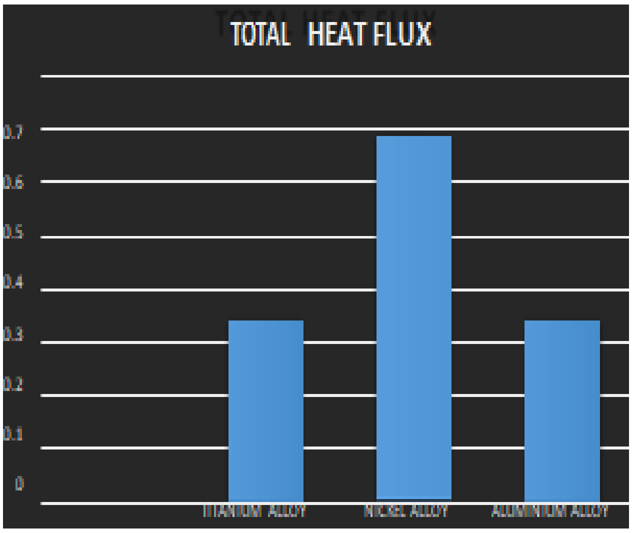



**Chart 1 graph of directional for total heat flux**

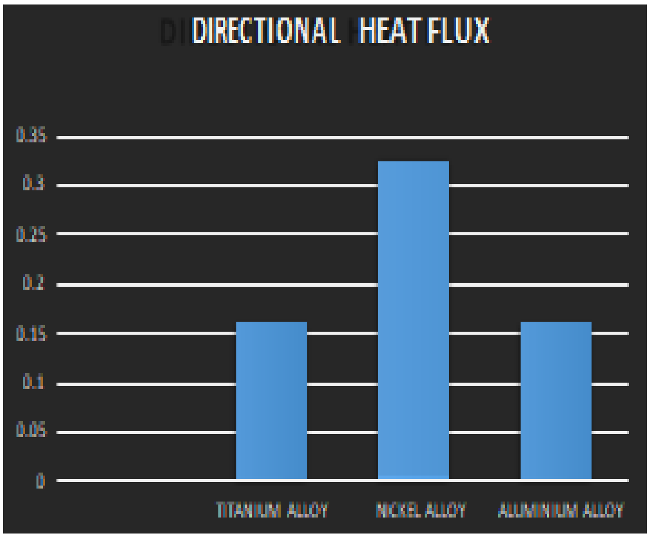



**Chart 2 graph of directional for directional heat flux**

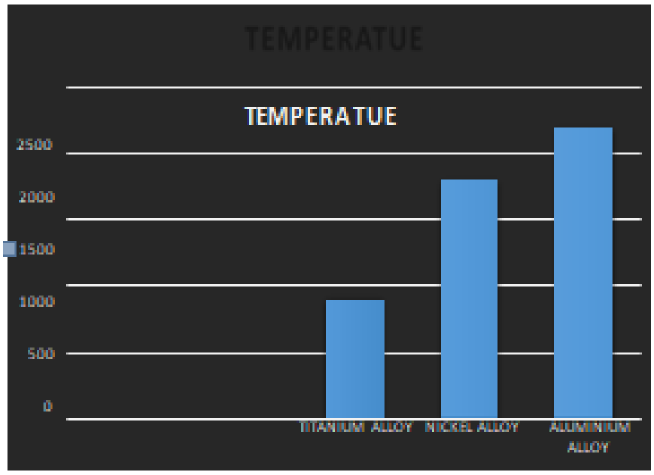



**Chart 3 graph of directional for temperature**

## 4. CONCLUSION

From the applied data it is found that titanium alloy is found to show that considering the Total heat flux the value is stable when compared with the remaining applied material. The dissipated heat temperature is comparably low when compared with other parameters and hence a stable performance is achieved the holes created supposed to show good response, in reducing the heat and also overcome the creep in edges that creates blow holes. Nickel is found to be the second choice and bit non-economical but the temperature is low when compared to aluminum alloy material. The blade design of Triveni Turbine Company is found to be used titanium as the main blade material as per also the results show the supportive performance.

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