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THERMAL PERFORMANCE OF GAS TURBINE BLADE WITH AND WITHOUT INTERNAL COOLING

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Abstract— Gas turbines are mostly used in power generation, aerospace, and industrial applications. By providing internal Cooling in the gas turbine blade, therefore, the heat transfer rate improves. The cooling air is passed into the rib-enhanced serpentine passages into the blades to achieve inter cooling. Internal cooling heat transfer improves by the application of Impinging jets, pin fins, and dimples. To achieve maximum heat transfer, the internal Cooling path to be optimized so currently existing design of the gas turbine blade is replaced with the new design. In this paper, a turbine blade (with and without cooling) is designed and modeled in Creo 2.0 software. The materials used for the Gas turbine blade are Titanium, Nickel and Inconel 625. The CFD Simulation is done. The pressure distribution, velocity, temperature distribution, mass flow rate, and heat transfer rate are more for the Reynolds numbers $12x10^5$ compared with $9x10^5$, 10x105, and $11x10^5$.

Keywords- Gas turbine blade; internal cooling; CFD; Reynolds number

1. INTRODUCTION

In recent years, with more economic gas turbine engines, the gas temperature generated is more than the metal parts permissible temperature. Air foils are frequently cooled using air by passing through internal passage. If the thermal environment is tremendously severe then internal cooling is used in combination with film cooling. By raising the inlet temperature of the gas entering into the turbine will impact the thermal performance of the power generation plant. Hot parts like combustors, rotor blades and stator vanes are refurbished or replaced repeatedly because of due to high temperature of combustion gases, thermal loads and damages. Therefore, high performance is obtained to be counterbalanced by maintenance costs.

To achieve optimum thrust to weight ratios and higher cycle performance required to raise the inlet temperature also results in a rise of turbine parts temperature which will impact to decline the life of the components. An amount of cooling flow that is present in the compressor already will be fed into the internal passage of turbine airfoil will tend to maintain high inlet temperatures. By using this technique, we can attain a high inlet temperature while maintaining the low temperature at turbine metal parts. Appropriate internal coolant passages design is perilous to upholding the life of the component which will affect the cycle efficiency. So, a precise estimate of 3D flow and heat transfer rate within the blade is vital. This empowers the design to attain low blade temperatures by maintaining a nominal flow of cooling air from the compressor.

2. LITERATURE SURVEY

Thomas J. Martinet al. [1] has investigated the high inlet temperatures and turbine blade integrity in the turbine blade are obtained by maintaining the maximum temperature in the turbine blade. Dieter Bohnet al. [2], made the study on the cooling effectiveness increases with the declining pressure level of a steam source when the supplied cooling potential is maintained at constant. With the rise in steam mass flow, the outcome of the overall thermal performance of the combined cycle is satisfactory. Mohammad H. Albeiruttyet al. [3], the results are stated that high efficiency is observed when steam is used as a cooling medium compared to air. Sergio Amaral et al. [4], proposed in his experimental study, the turbine blade without cooling channels observed huge thermal stresses (263 MPa) in between hub and blade and for with cooling is raised to 369 MPa at hub leading edge. Sethunathanet al. [5] his study, the gas turbine blades at the trailing edge region the heat transfer effective was numerically investigated and also pressure drops and heat transfer for the two-pass rectangular channel. Shian Li et al. [6] founded that through experimental study is20%~43% side-wall heat transfer coefficients higher is observed at passage without ribs compare with ribs on opposite walls. The rib's length will affect heat transfer and friction. Thermal performance and friction factors are high for the sidewall with continuous ribs when compared to truncated ribs. The pressure loss is observed low for the truncated ribs and high for side wall with continuous ribs. Mohammad Hamdanet al. [7] As we knew that Reynolds's number is directly proportional to heat transfer, in this case, experimental results explained that when the cooling fluid is passing through the swirl chamber, the heat transfer increases with the increment of jet Reynolds number. L. Zhang et al. [8] observed for a 17% turbulence intensity, the maximum local Nusselt number increment on the pressure surface (at X/C = —0.2) is about 2 times that of the no-grid 0.7 percent turbulence intensity case.

3. BOUNDARY CONDITIONS

The NACA 6412 downloaded and points are imported to the Creo to draw the turbine blade profile.
For CFD analysis Input parameters of Pressure and temperature values are taken from the "DESIGN AND ANALYSIS OF GAS TURBINE INTERNAL COOLING PASSAGE"

- Pressure = 904kpa
- Temperature = 1374k for the outer surface of the blade and 653 k for cooling fluid
- Material properties (Titanium, Nickel alloy, Inconel 625 and Air) are taken from the matweb.com

4. MODELING & DRAFTING IN CREO 2.0

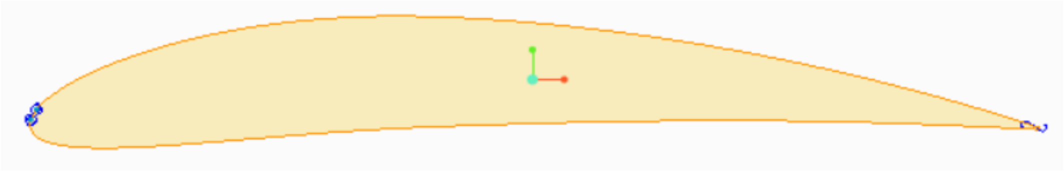


Figure 1: NACA 6412 blade profile

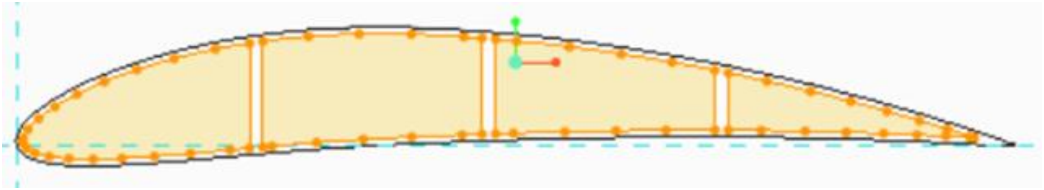
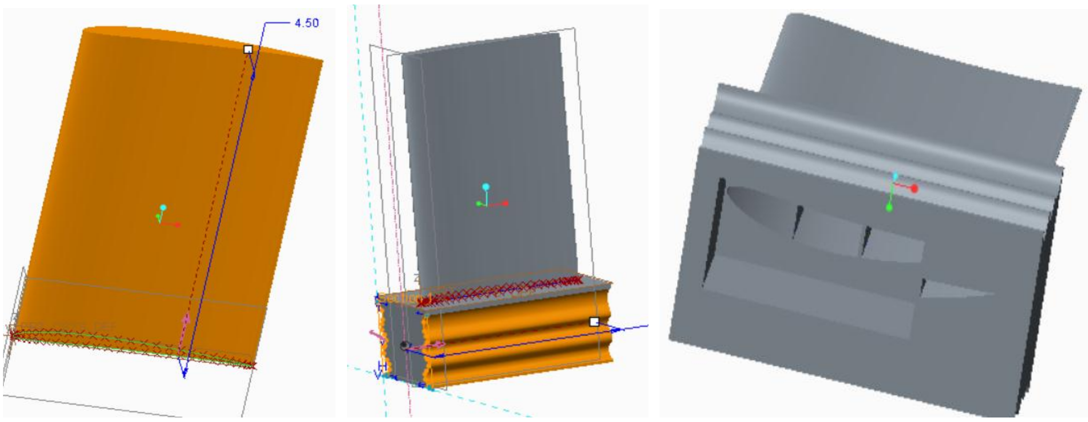


Figure 2: NACA 6412 blade profile with cooling ribs



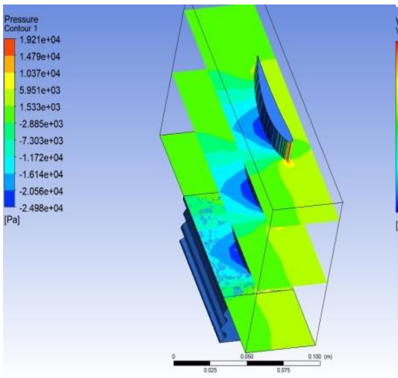
(a) (b) (c)

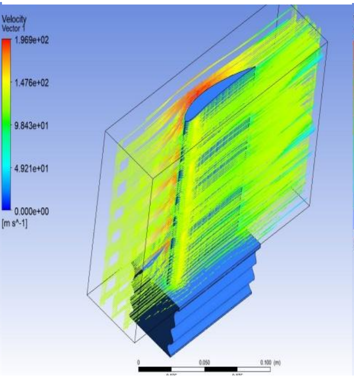
Figure 3: (a) height of the gas turbine blade (b) complete 3D model of the original gas turbine blade (c) cooling ribs to the blade

5. RESULTS & DISCUSSIONS

CFD Simulation was done for the original gas turbine blade with standard material and a modified blade with cooling ribs. The input parameters are considered from the journal mentioned in boundary conditions. For the modified gas turbine blade, cooling ribs are considered and different materials were assumed.

- **The following results for the original gas turbine blade**





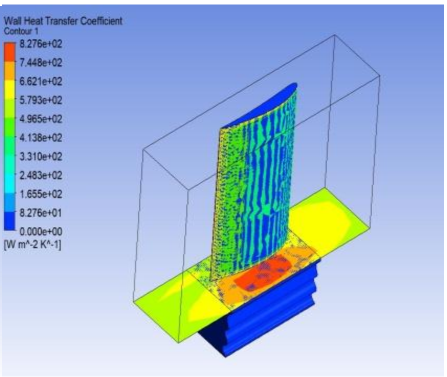


Figure 4: - Pressure Figure 5: - velocity Figure 6: - wall heat transfer coefficient

The pressure counters were observed in fig4. At top to bottom of the blade edge, pressure is high and observed with red colour indication. The pressure is low at the side of the blade which is observed with blue colour on the plane but in the bottom plane more area of low pressure is observed. Pressure is always indirectly proportional to velocity. The velocity is high at the side of the blade where the pressure is low. The high heat transfer coefficient is more at the surface of the turbine observe in figure 6.

- **The following results for the Modified with internal cooling of a gas turbine blade**

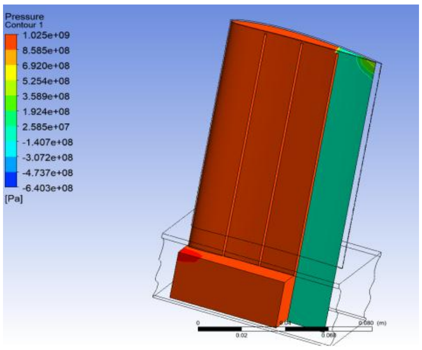


Figure 7: - pressure

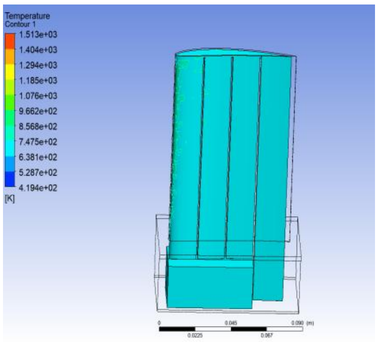


Figure 8: - temperature

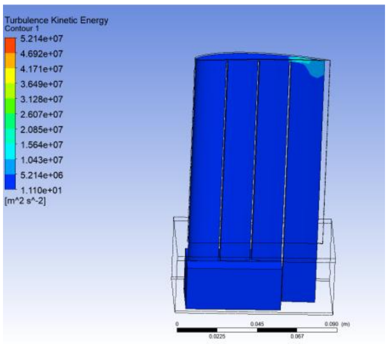


Figure 9: - kinetic energy

The maximum pressure was observed in internal fluid flow see fig7 and minimum was at exit of the coolant fluid. The internal fluid is carrying 747.5k temperature inside the turbine blade which can improve the life of the blade.

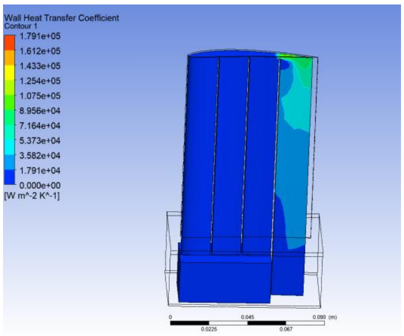


Figure 10: - wall heat transfer coefficient

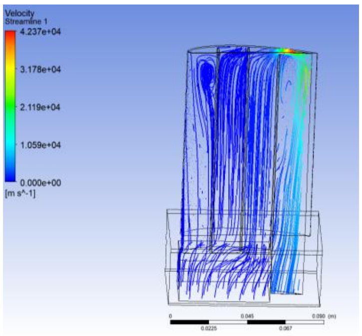


Figure 11: - velocity

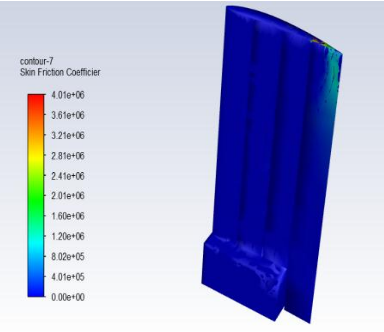
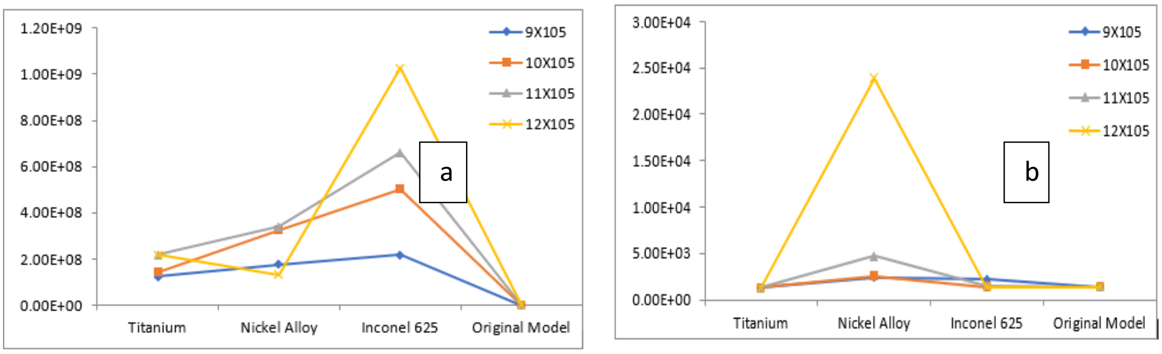


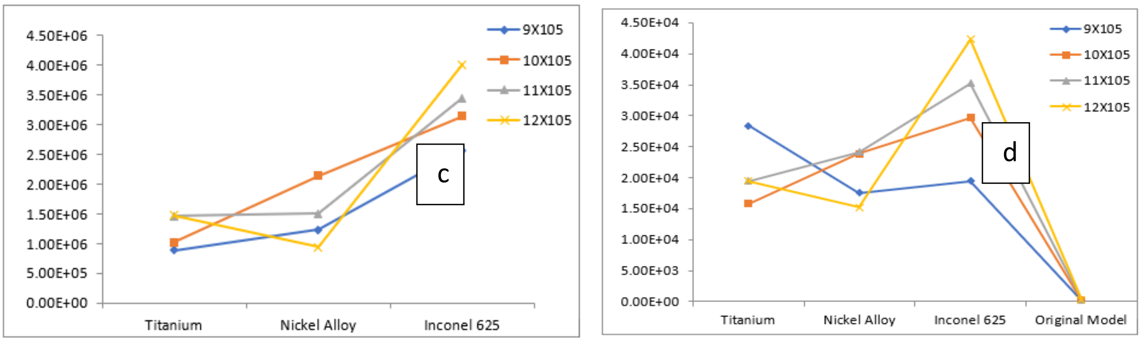
Figure 12: - skin friction coefficient

The wall heat transfer coefficient is more the internal cooling turbine blade (fig10) when compare to the original turbine blade (Fig6).



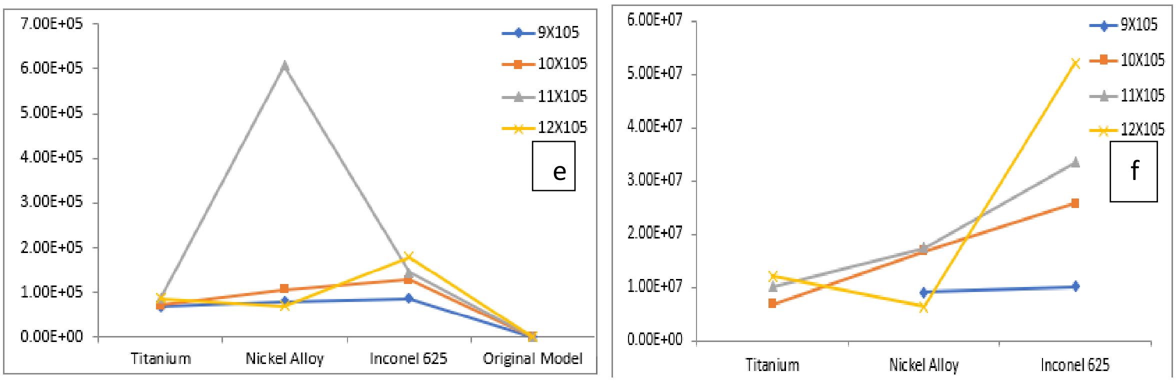
Graph (a) – Comparison of Pressure with different materials used in the Modified Model and Original Model with titanium at different Reynolds numbers.
(b) – Comparison of Temperature with different materials used in Modified Model and Original Model with titanium at different Reynolds numbers.

(a)From the above graph, it is observed that the Pressure value is increasing at 12X10^{5}Reynolds number for Inconel 625 material and decreasing at 9X10^{5}Reynolds number for original Model with Titanium of blade when compared with remaining Materials. (b)From the above graph, it is observed that the Temperature value is increasing at 12X10^{5}Reynolds number for Nickel Alloy material and Decreasing at 9X10^{5}Reynolds number for Titanium material of blade when compared with remaining Materials and Original Model.



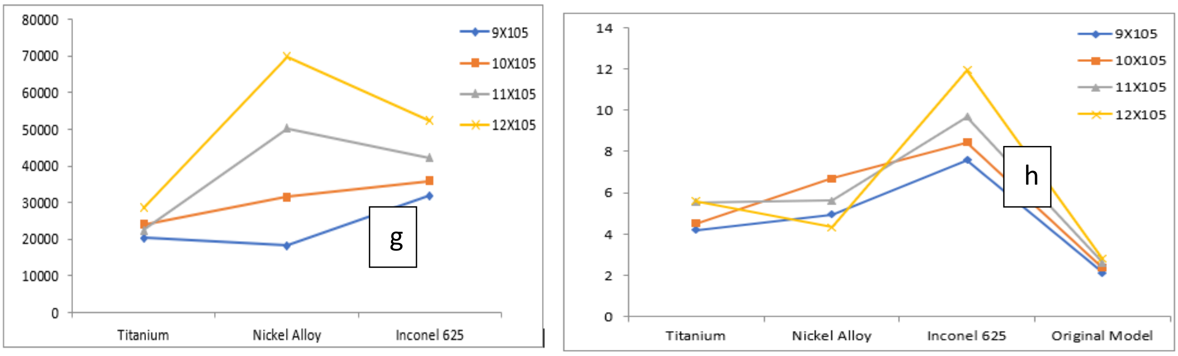
Graph (c) – Comparison of Velocity with different materials used in Modified Model and Original Model with titanium at different Reynolds numbers. (d) – Comparison of Skin Friction Coefficient with different materials used in Modified Model at different Reynolds numbers.

(c) From the above graph, it is observed that the Velocity value is increasing at 12X10^5 and 9X10^{5}Reynolds number for Inconel 625, Titanium materials and Decreasing at all Reynolds number for Original Model with Titanium material of blade when compared with remaining Materials. (d) From the above graph, it is observed that the Skin Friction Coefficient value is increasing at all Reynolds numbers for Inconel 625 material and Decreasing at 12X10^{5}Reynolds number for Nickel Alloy material of blade when compared with remaining Materials.



Graph (e) – Comparison of Wall Heat Transfer with different materials used in Modified Model and Original Model with Titanium at different Reynolds numbers. (f) – Comparison of Kinetic Energy with different materials used in Modified Model at different Reynolds numbers

(e) From the above graph it is observed that the Wall Heat Transfer value is increasing at 11X10^5 Reynolds numbers for Nickel Alloy material and decreasing at 9X10^5 Reynolds number for Original Model with Titanium material of blade when compared with remaining Materials. (f) From the above graph, it is observed that the Kinetic Energy value is increasing at all Reynolds numbers for Inconel 625 material and Decreasing at 12X10^5 Reynolds number for Nickel Alloy material of blade when compared with remaining Materials.



Graph (g) – Comparison of Mass Flow Rate with different materials used in Modified Model and Original Model with Titanium at different Reynolds numbers. (h) – Comparison of Total Heat Transfer rate with different materials used in the Modified Model at different Reynolds numbers.

(g) From the above graph, it is observed that the Mass Flow Rate value is increasing at 12X10^5 Reynolds numbers for Inconel 625 material and decreasing at 9X10^5 Reynolds number for Original Model with Titanium material of blade when compared with remaining Materials. (h) From the above graph it is observed that the Total Heat Transfer rate value is increasing at 12X10^5, 11X10^5 Reynolds numbers for Nickel Alloy material and Decreasing at 9X10^5, Reynolds number for Nickel Alloy material of blade when compared with remaining Materials.

6. CONCLUSIONS

From the results, we can conclude that,

- The pressure value is increasing at 12X10^5 Reynolds number for Inconel 625 material and Decreasing at 9X10^5 Reynolds number for original Model
- The Skin Friction Coefficient value is increasing at all Reynolds numbers for Inconel 625 material and decreasing at 12X10^5 Reynolds number for Nickel Alloy material of blade when compared with remaining Materials.
- Kinetic Energy value is increasing at all Reynolds numbers for Inconel 625 material and Decreasing at 12X10^5 Reynolds number for Nickel Alloy material of blade when compared with remaining Materials
- The mass Flow Rate value is increasing at 12X10^5 Reynolds numbers for Inconel 625 material
- Total Heat Transfer rate value is increasing at 12X10^5, 11X10^5 Reynolds numbers for Nickel Alloy material and Decreasing at 9X10^5, Reynolds number for Nickel Alloy material of blade when compared with remaining Materials.

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