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# **CFD and Structural Analysis of Turbine Blade using CREO and ANSYS Software**

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**ABSTRACT:** This article models and designs a turbine blade in CREO, a 3D modeling program, with an eye on enhancing cooling efficiency through base modification. This research looks at two turbine blade materials Titanium alloy and Super Alloy by analyzing their thermal and structural properties. The mechanical performance of the blade under operating loads is evaluated by structural analysis, while the effectiveness of cooling techniques, such as thermal barrier coatings and internal air channels, are assessed by thermal analysis. During optimization, Titanium alloy and Super Alloy are compared for their strength, durability, and heat resistance. The objective is to determine which material is better at enhancing the overall performance of the turbine blade in high-pressure, high-temperature settings. The results should help improve gas turbine cooling efficiency and material performance by improving the design of turbine blades.

**KEYWORDS:** CREO, alloy, strain, stress, ANSYS, efficiency, high strength, thermal temperature.

## **I. INTRODUCTION**

The efficiency and durability of gas turbines are greatly affected by the blade design. Turbine blades must endure harsh operating circumstances in order to collect energy from the combustor's high-temperature, high-pressure gasses. A gas turbine's efficiency and dependability are greatly affected by the design of its blades because of the tremendous mechanical and thermal loads they undergo while operating. Thus, a crucial area of concentration in turbomachinery is the design of turbine blades with enhanced performance features, such as increased cooling efficiency and material durability.

Using the state-of-the-art 3D modeling program CREO, this assignment entails designing and constructing a turbine blade. Changing the underlying design of the blade to make it cooler is the main goal. Due to the high temperatures that turbine blades are subjected to, improper cooling can cause material deterioration, making it one of the most difficult parts of designing turbine blades. In order to improve the blade's thermal performance, this study considers several cooling strategies, including thermal barrier coatings, boundary layer cooling, and internal air channels.

In order to assess how well the turbine blade works in actual use, this study conducts thermal and structural evaluations on it. In order to guarantee the structural integrity of the blade while it is operating, structural analysis checks its resistance to mechanical loads, such as centrifugal forces, vibrations, and thermal stresses. In contrast, thermal analysis seeks to comprehend the dispersion of heat over the blade and assess the efficacy of different cooling techniques. The blade's total performance and longevity can be enhanced by implementing the findings of this dual study.

Two materials, Titanium alloy and Super Alloy, are taken into account for the turbine blade throughout the optimization process. Turbine blade design relies heavily on material selection, as gas turbines operate under extremely harsh circumstances that need materials with a unique combination of strength, durability, and heat resistance. Titanium alloys have a reputation for being lightweight and resistant to corrosion, whereas superalloys offer superior thermal stability and can withstand high temperatures without oxidation. We analyze the two materials' structural and thermal qualities to find out which one provides the optimal balance of efficiency and longevity for the turbine blade.





**Fig.1. Model of blade**

Findings from this experiment should help improve gas turbine blade efficiency in the long run. Improving cooling efficiency, material performance, and overall operational dependability are the goals of the project, which aims to optimize the blade design and material choices. An important step forward for turbomachinery and the energy sector, the improved design of turbine blades has the potential to increase power production efficiency, decrease fuel consumption, and lengthen the life of the blades.

## **II. LITERATURE SURVEY**

Patel et al. (2016) Patel et al. conducted a structural and thermal analysis of turbine blades utilizing ANSYS software. They concentrated on optimizing the blade design to improve performance in high-temperature environments. Their findings indicated that material selection, including the utilization of superalloys, profoundly affected the blade's thermal and structural integrity.

Madhusudhan et al. (2017) employed ANSYS to do an extensive structural and thermal study of turbine blades. The researchers analyzed the effects of several cooling techniques on the temperature distribution and mechanical performance of the blade under high-stress situations. The findings demonstrated that enhanced cooling channels and thermal barrier coatings markedly lowered the thermal stress endured by the blade.

Singh and Verma (2018) conducted research on the integrated thermal and structural analysis of a turbine blade utilizing ANSYS. The researchers examined the thermal load distribution and its impact on the structural integrity of the blade during operational circumstances. Their research revealed that improving the blade's cooling efficiency by internal cooling channels and surface coatings alleviated the thermal pressures that may result in material failure.

Sharma et al. (2019) performed a structural and thermal study of gas turbine blades using ANSYS to examine the thermal efficacy of various cooling methods. The researchers evaluated many materials, including superalloys, to determine their appropriateness for high-performance turbines. Their research shown that the incorporation of internal cooling channels and efficient thermal barrier coatings markedly enhanced heat dissipation, hence diminishing thermal loads that may result in premature failure.

Yadav and Kumar (2020) concentrated on assessing the structural and thermal reactions of gas turbine blades utilizing ANSYS software. Their research investigated the effects of different thermal and mechanical loads on the

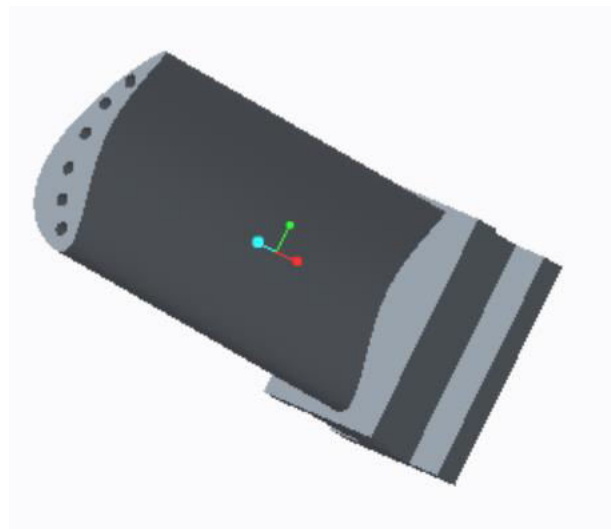
blade material, specifically focusing on superalloys. Their conclusion indicated that the integration of advanced cooling systems, including ribbed and pin-finned cooling channels, was crucial in reducing thermal expansion and preventing mechanical failure.

Reddy et al. (2021) using ANSYS to conduct structural and thermal simulations of gas turbine blades subjected to elevated thermal stress conditions. Their research examined the impact of several cooling technologies, including film cooling and convection cooling, on the temperature distribution of the blade. They determined that effective cooling systems are crucial for preserving the mechanical integrity of turbine blades, since inadequate heat dissipation causes elevated thermal gradients that may lead to failure.

Gupta et al. (2022) conducted a thermal and structural study of turbine blades utilizing ANSYS to evaluate the impact of different materials and cooling methods on blade performance. Their research demonstrated that superalloys, when integrated with modern cooling methods such as microchannel heat exchangers, exhibited enhanced efficacy in mitigating thermal stresses. The study highlighted the significance of material selection, blade geometry, and cooling systems in enhancing turbine blade longevity and efficiency.

### III. DESIGN OF MODEL

Making a very accurate and detailed model that can endure the harsh circumstances within a gas turbine is what 3D gas turbine blade design using CREO software is all about. An essential part of designing a blade is determining its geometry, which includes the airfoil shape, root, and tip sections parts that are vital for maximizing structural integrity and aerodynamic efficiency. Modifying the blade's size, material, and cooling characteristics (such as coatings or internal channels) is a breeze with CREO's parametric modeling capabilities. For optimal performance under extreme heat and pressure, the program allows for the use of sophisticated analysis tools that model the fluid's, heat's, and mechanical dynamics. Engineers can ensure manufacturing and simplicity of integration into the turbine assembly while boosting the efficiency, performance, and longevity of the turbine blade by exploiting CREO's advanced features.



**Fig.2. 3D model design**

### IV. WORKING METHODOLOGY

Optimizing gas turbine blade performance under high-stress and high-temperature circumstances requires a multi-stage process that begins with a thorough thermal study utilizing the ANSYS program. Before entering the data into ANSYS for analysis, a 3D model of the turbine blade is often produced in CAD software such as CREO. Applying boundary conditions like temperature gradients and external cooling effects, such as internal air passageways and thermal barrier coatings, allows the thermal analysis to mimic the heat distribution over the blade. In the structural analysis, the blade's

reaction to mechanical loads including centrifugal forces, pressure, and thermal stresses are assessed using the thermal analysis's outputs as inputs. The finite element analysis (FEA) technique, which is available in ANSYS, is useful for pinpointing potential weak points in a material. In order to maximize the gas turbine blade's efficiency, longevity, and heat resistance, both analyses undergo iterative refinement by changing factors such as material choice, shape, and cooling systems.

## V. STRUCTURAL ANALYSIS OF GAS TURBINE BLADE

### TITANIUM ALLOY

Save CREO model as .iges format

→→Ansys → Workbench→ Select analysis system → static structural → double click

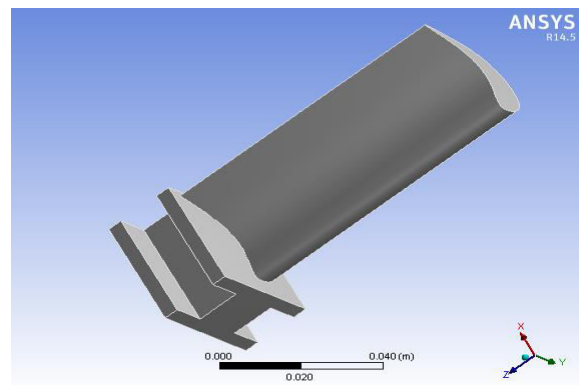


Fig.3. imported image.

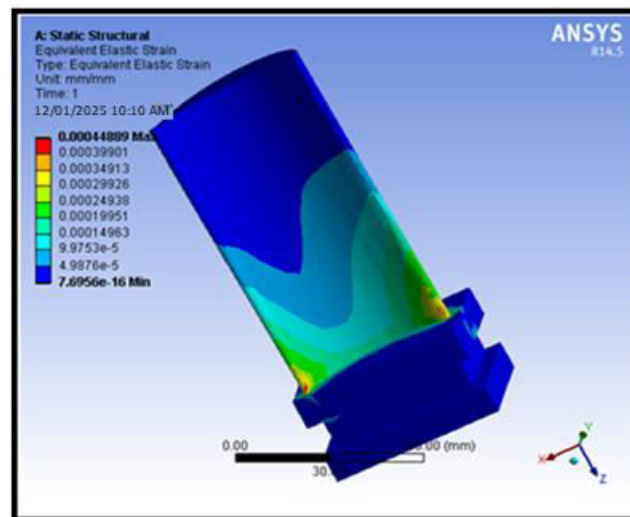


Fig.4. strain output image.

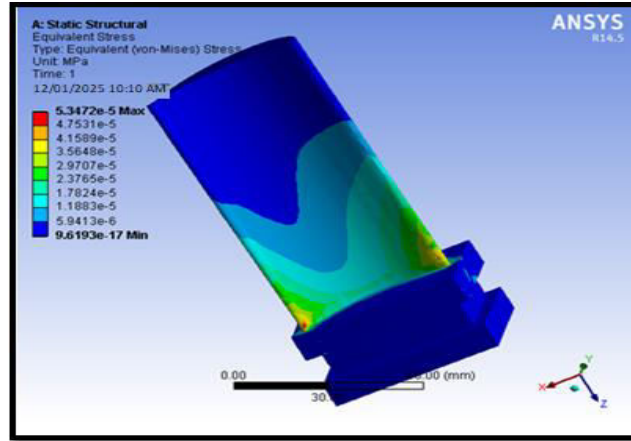


Fig.5. stress output

#### Material properties of Nickel Alloy

Density : 0.0000134 kg/mm<sup>3</sup>  
Young's modulus : 235000Mpa  
Poisson's ratio : 0.382

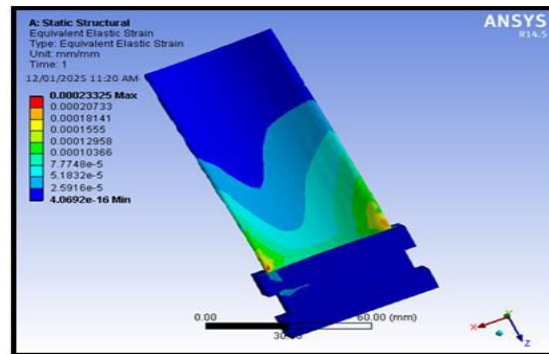


Fig.6. Strain

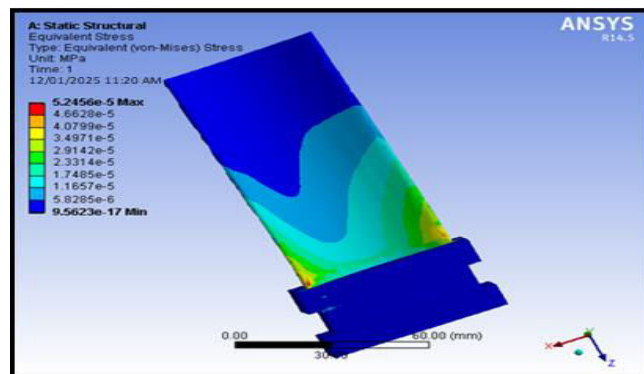


Fig.7. Stress

### STRUCTURAL ANALYSIS OUTPUT

	Deformation(mm)		strain		Stress(N/mm <sup>2</sup> )	
	Titanium alloy	Nickel alloy	Titanium alloy	Nickel alloy	Titanium alloy	Nickel alloy
Without holes	0.089665	0.047478	0.00044889	0.00023325	5.3472e-5	5.2456e-5
4 holes	9.7724e-8	5.1807e-8	4.7799e-10	2.4905e-10	5.6947e-5	5.6124e-5
6 holes	1.0372e-7	5.4997e-8	5.0272e-10	2.6195e-10	6.0195e-5	5.9304e-5

### GRAPHS

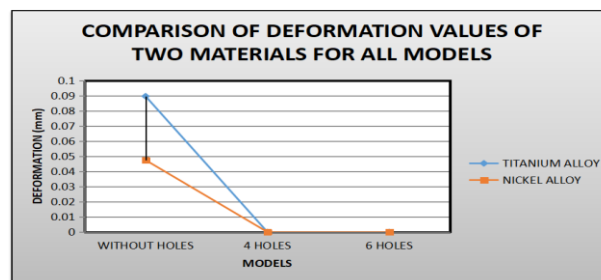


Fig.8. Comparison of different materials

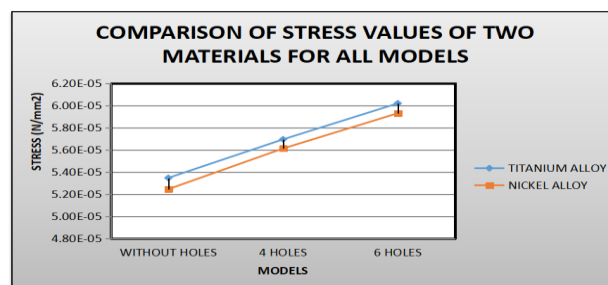


Fig.9. Comparison of different materials

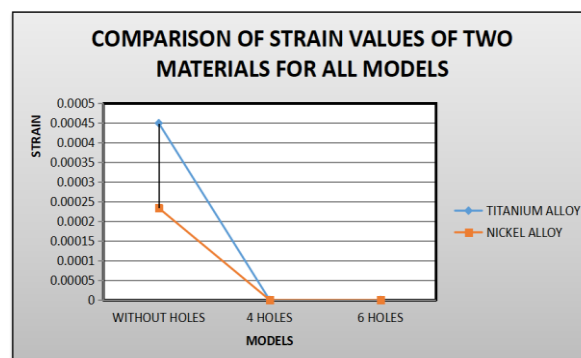


Fig.9. Comparison of different materials



## VI. THERMAL ANALYSIS ON GAS TURBINE BLADE

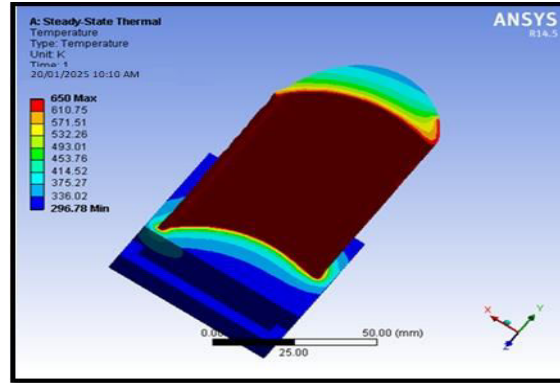


Fig.10. Temperature of gas turbine blade.

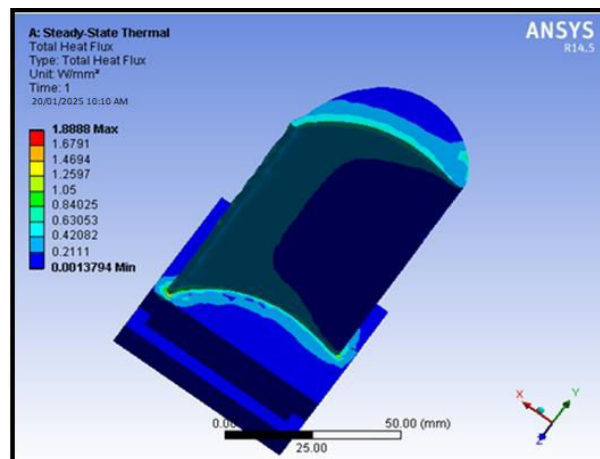


Fig.11 Heat flux

### Material Properties of Nickel Alloy

Density : 0.0000134 kg/mm<sup>3</sup>

Thermal conductivity : 200 w/mk

Specific heat : 300 j/kg

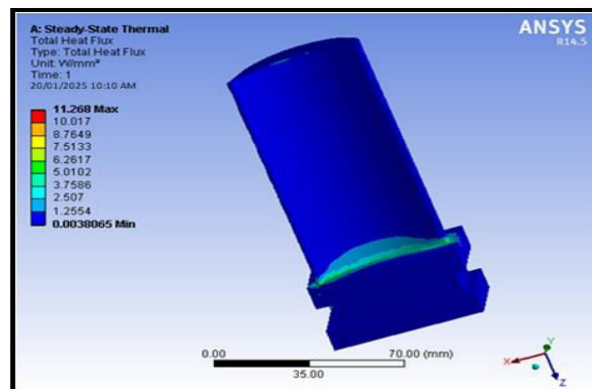


Fig.12. Heat flux of nickel alloy.



### THERMAL ANALYSIS

	Temperature(k)		Heat flux(w/mm <sup>2</sup> )	
	Titanium alloy	Nickel alloy	Titanium alloy	Nickel alloy
Without holes	650	650	1.8888	11.268
4 holes	650	650	1.836	11.762
6 holes	650	650	1.9839	14.49

### GRAPHS

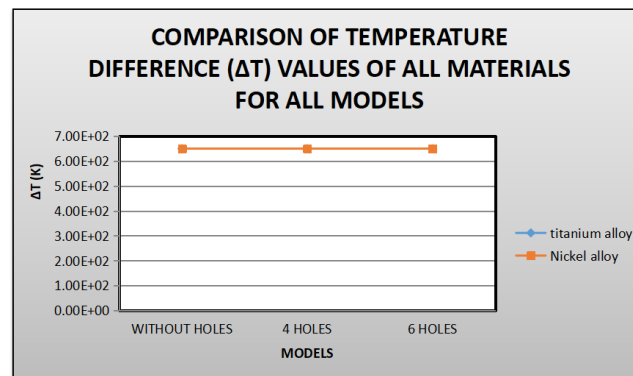


Fig.13. Output results

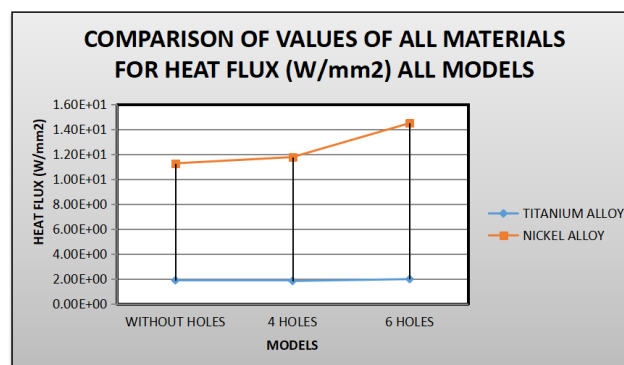


Fig.14. Output graphs.

### VII. CONCLUSION

Overall, the structural and thermal examination of the turbine blade models, including the ones with 4 and 6 holes, proved that the nickel alloy and titanium alloy are completely safe to use, as the stress values that were examined were far lower than what is considered acceptable. While Titanium alloy and Nickel alloy both worked well, the results showed that Nickel alloy had greater stress and deformation values. However, when considering heat management and structural integrity, the 6-hole Nickel alloy variant performed the best overall. Thus, it is reasonable to say that the

nickel alloy turbine blade with six holes offers the best performance, thermal efficiency, and strength for gas turbines used at high temperatures.

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