Analysis of Industrial Gas Turbine Blade

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Abstract – The *Gas Turbine rotatory blades undergo a power generation process continuously with high temperature and high-pressure gases, which generates a lot of stress on the blades. This paper holistically presents the design, steady-state thermal and modal analysis using ANSYS differentiating between two chosen materials namely Inconel 718 and Titanium Ti-6Al-4V.*

Key Words: Gas Turbine, Steady-State Thermal Analysis, Modal Analysis, ANSYS, FEM, Turbine Blades

1.INTRODUCTION

The two of the most common applications of gas turbine in modern industries are Gas Turbo Generator and Gas Turbo Compressor. In a gas turbo generator turbine powerplant there is a generator, to generate electricity the generator needs a prime mover which is the gas turbine. The gas turbine transforms the chemical energy in the fuel (e.g., Natural Gas) into mechanical energy. The mechanical energy generated by the turbine exit shaft is transferred through a gear box to the generators' shaft. This type of electricity generally has low or medium level of voltage, to convert it into high voltage a step-up transformer is used.

In modern gas turbines to transform the chemical energy of fuel gas into mechanical energy the fuel should be burnt in the combustion chamber of a gas turbine. Air is let in to the gas turbine through an air intake and mixed with a proper amount of natural gas. The ratio of air and gas is determined based on the specific heating value of the gas, quality of air, amount of moisture and altitude from sea level. The ignition system makes the initial sparks providing the required heat. When the fire is stabilized in the combustion chamber the ignition system is shut down. The most critical process in a gas turbine performance is to manage the combustion and generate a proper amount of high-pressure exhaust gas. This exhaust gas is supplied to the turbine which rotates the turbine blades and then rotating the turbine shaft. The air is prone to contamination which can affect the combustion process or even harm the system degrading the overall performance, the screening and filtration are basic initial steps for inlet air. The draft pressure and temperature of the air and the fuel are also monitored with the help of proper instrumentation.

The turbine air compressor an axial compressor comprising of multi-stages of blades mounted radially on the turbine inlet shaft. The two materials for the turbine blade were selected upon extensive research and were found to be the most suitable for high temperature, high frequency and high rotational speed blades. The materials are Inconel 718 and Ti-6Al-4V. The designing of the blade is carried out in Solidworks 2019 and analysis in ANSYS 2019 and 2020.

Table -1: Material Properties

Properties	Unit	Inconel 718	Ti-6Al-4V
Density	g/cm^3	8.19	4.43
Young's Modulus	MPa	2E05	1.14E05
Poisson's Ratio		0.31	0.342
Tensile Yield Strength	MPa	1069	1100
Tensile Ultimate Strength	MPa	1375	900
Thermal Conductivity	W/mK	11.2	6.7

2. Analysis

Analysis of the turbine blade is carried out in ANSYS 2019 and 2020. The blade is analyzed at 3500 rpm kept constant throughout the analysis. The elemental step of the analysis procedure is defining the mesh. The method for meshing is tetrahedrons. Later on, the boundary conditions are added. The properties for the materials are defined in the software as mentioned in table-1.

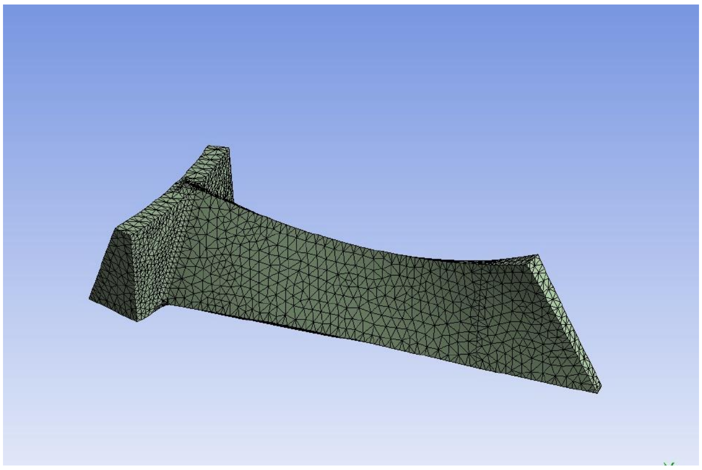

Fig -1: Meshed Model of Turbine Blade

2.1 Steady-State Thermal Analysis

The initial temperature, root temperature, turbine blade temperature is defined as 23°C, 300°C and 1200°C respectively for both Inconel 718 and Ti-6Al-4V alloy. The results are in terms of total heat flux and directional heat flux.

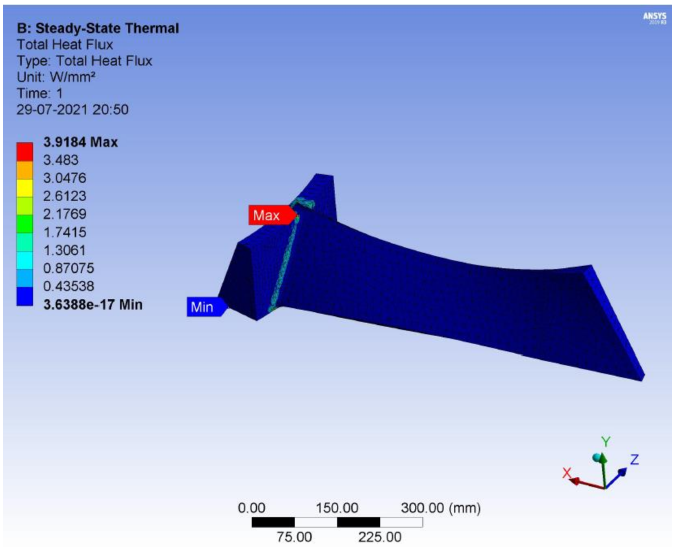

Fig -2: Total Heat Flux for Ti-6Al-4V

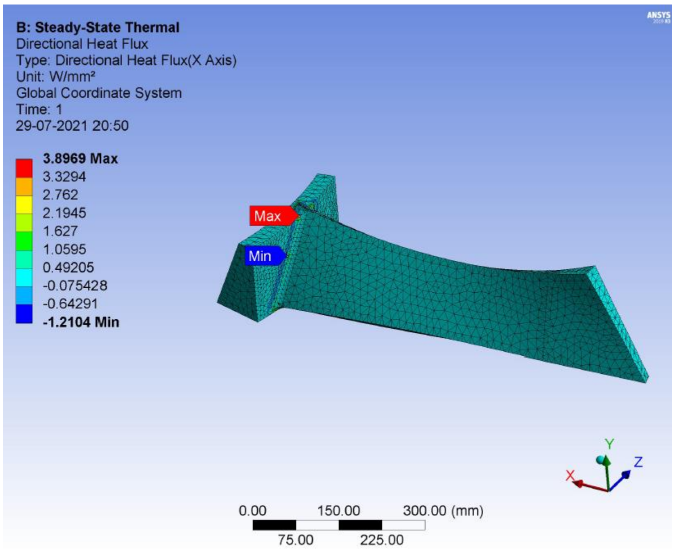

Fig -3: Directional Heat Flux for Ti-6Al-4V

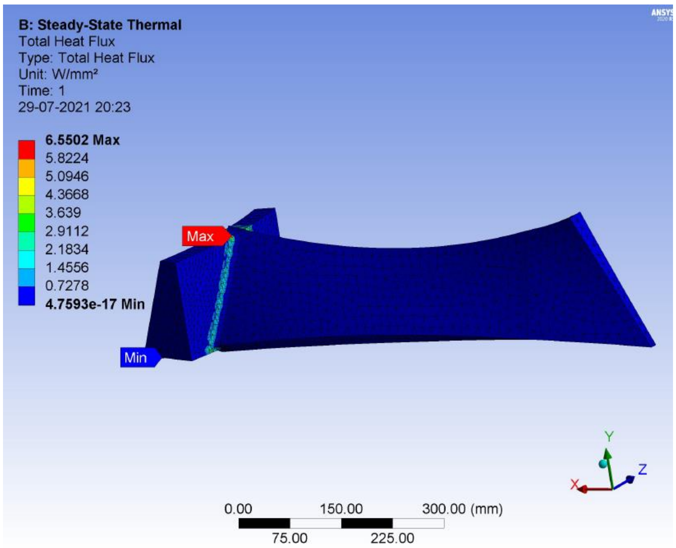

Fig -4: Total Heat Flux for Inconel 718

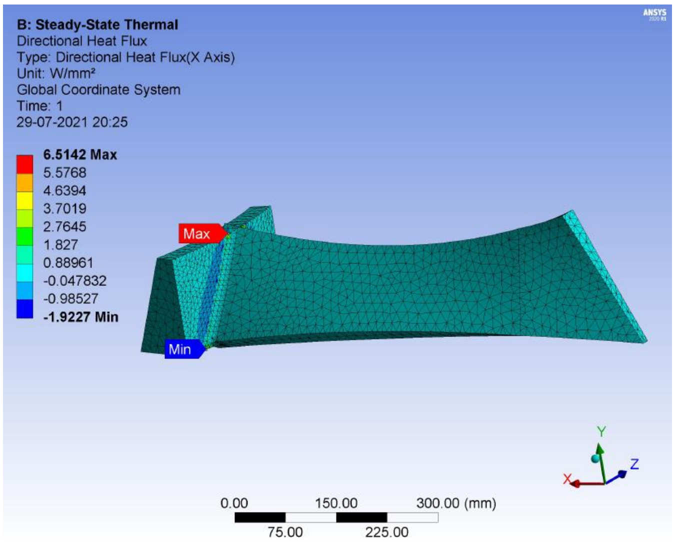

Fig -5: Directional Heat Flux for Inconel 718

2.2 Modal Analysis

The total deformation from modal analysis for Ti-6Al-4V is established at frequencies 100.14Hz, 246.11Hz, 419.76Hz and for Inconel 718 is carried out at 99.174Hz, 241.11Hz, 411.66HZ.

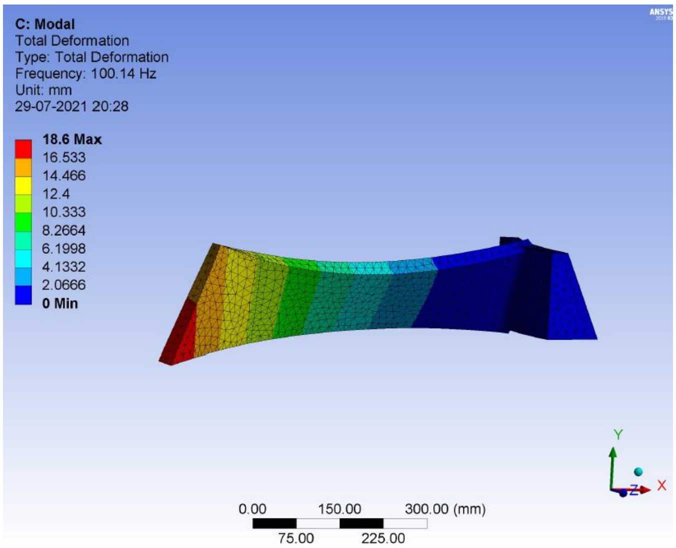

Fig -6: Total deformation for Ti-6Al-4V at 100.14Hz

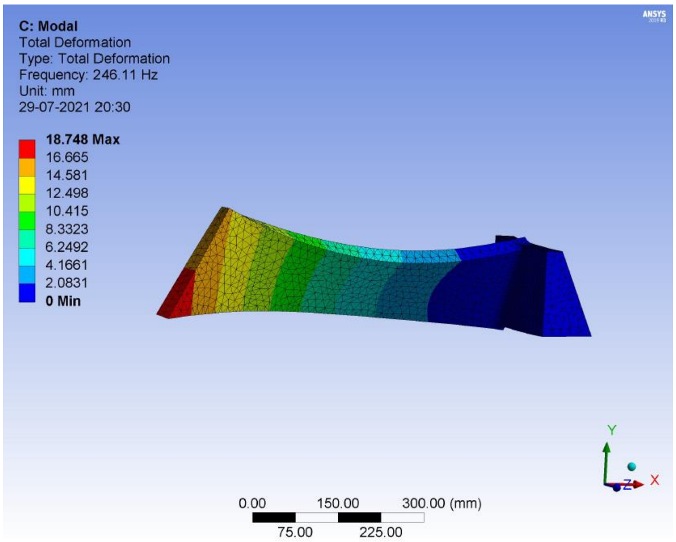

Fig -7: Total deformation for Ti-6Al-4V at 246.11Hz

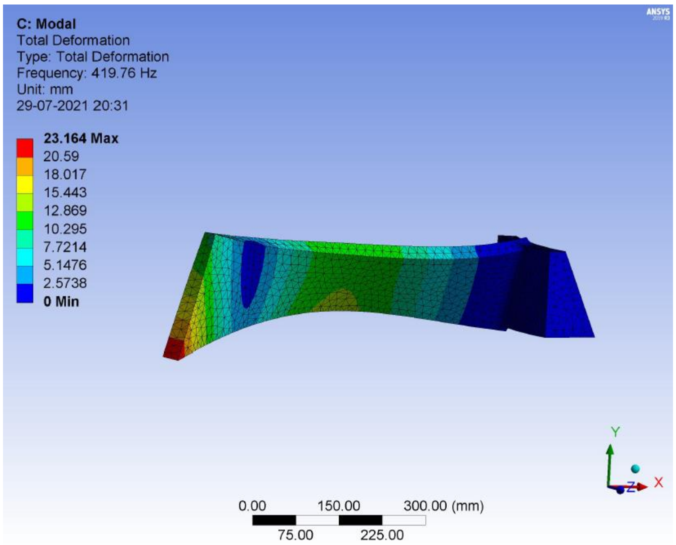

Fig -8: Total deformation for Ti-6Al-4V at 419.76Hz

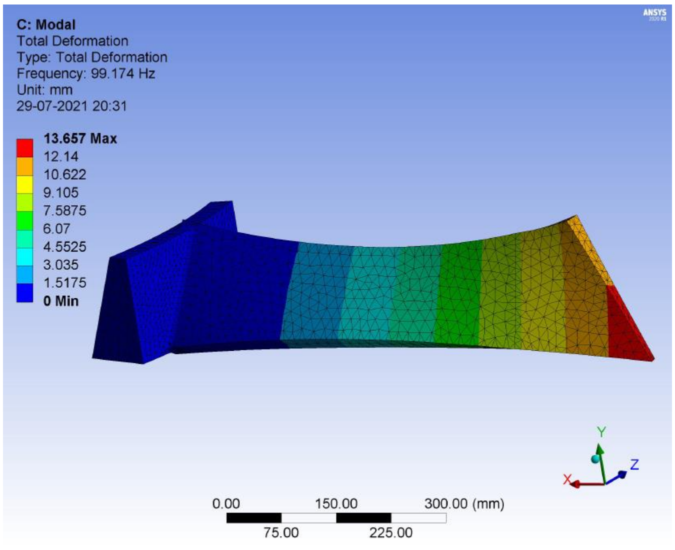

Fig -9: Total deformation for Inconel 718 at 99.174Hz

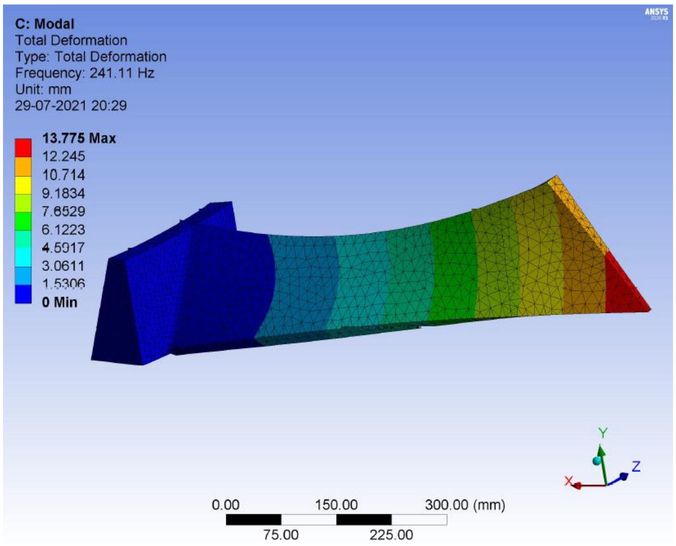

Fig -10: Total deformation for Inconel 718 at 241.11Hz

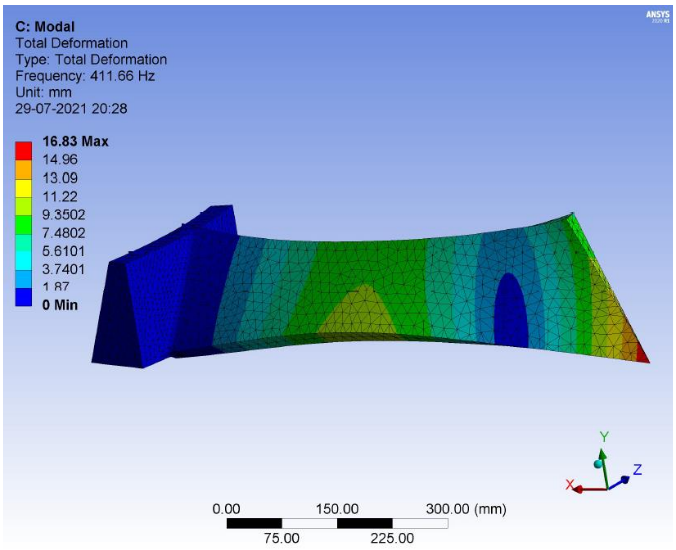

Fig -11: Total deformation for Inconel 718 at 411.66Hz

3. RESULTS

3.1 Ti-6Al-4V

The results for steady-state thermal analysis show maximum total heat flux to be 3.9184 W/mm² and maximum directional heat flux to be 3.8969 W/mm². The total deformation from modal analysis at 100.14Hz, 246.11Hz, 419.76Hz is 18.6mm, 18.748mm, 23.164mm respectively.

3.2 Inconel 718

The results for steady-state thermal analysis show maximum total heat flux to be 6.5502 W/mm² and maximum directional heat flux to be 6.5124 W/mm². The total deformation from modal analysis at 99.174Hz, 241.11Hz, 411.66Hz is 13.657mm, 13.775mm, 16.83mm respectively.

Table -2: Steady-State Thermal Analysis Results

Parameter	**Unit**	**Inconel 718**	**Ti-6Al-4V**
Total Heat Flux	W/mm²	6.5502	3.9184
Directional Heat Flux	W/mm²	6.5124	3.8969

Table -3: Modal Analysis Ti-6Al-4V Results

Frequency (Hz)	**Total Deformation (mm)**
100.14	18.6

246.11	18.748
419.76	23.164

Table -4: Modal Analysis Inconel 718 Results

Frequency (Hz)	Total Deformation (mm)
99.174	13.657
241.11	13.775
411.66	16.83

4. CONCLUSIONS

It is observed from the above results that both the materials are giving considerable results. The value of total heat flux for a material relies upon the thermal conductivity of the material. In the steady-state thermal analysis result, the total heat flux for Ti-6Al-4V is around 40% lesser than that of Inconel 418. So, Ti-6Al-4V material gives better results than the Inconel 718. The total deformation for all the 3 modes is increasing for the both of the materials, but the Inconel 718 has less deformation compared to Ti-6Al-4V at almost same frequencies. If cost is not a major condition for selection of material, then Ti-6Al-4V must be chosen otherwise Inconel 718 is a better choice.

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