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# THERMAL AND STRESS ANALYSIS OF A GAS TURBINE ROTAR BLADE

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**Abstract:** The objective of this project is to design and stresses analyse a turbine blade of a jet engine. An Investigation for the usage of new materials is required. In the present work turbine blade was designed with two different materials named as Inconel 718 and Titanium T-6. An attempt has been made to investigate the effect of temperature and induced stresses on the turbine blade. A thermal analysis has been carried out to investigate the direction of the temperature flow which is been develops due to the thermal loading. A structural analysis has been carried out to investigate the stresses, shear stress and displacements of the turbine blade which is been develop due to the coupling effect of thermal and centrifugal loads. An attempt is also made to suggest the best material for a turbine blade by comparing the results obtained for two different materials (Inconel 718 and titanium T6). Based on the plots and results Inconel718 can be consider as the best material which is economical, as well as it has good material properties at higher temperature as compare to that of Titanium T6.

**Index Terms** – Titanium T-6, Centrifugal, Inconel 718, Thermal Loading.

## 1.INTRODUCTION

A gas turbine is a device that converts the energy stored in a gas, such as compressed air and fuel, into mechanical energy, which can then be used to drive a generator for electricity production or to propel an aircraft. It works by compressing air, mixing it with fuel, igniting the mixture, and then expanding the hot, high-velocity exhaust gases through a turbine, which spins a shaft. A gas turbine essentially brings together air that it compresses in its compressor module, and fuel, that are then ignited. Resulting gases are expanded through a turbine. That turbine's shaft continues to rotate and drive the compressor which is on the same shaft, and operation continues.

Its modern manifestation was invented by sir Charles parsons in 1884.A system of angled and shaped blades arranged on a rotor through which steam is passed to generate rotational energy. Today, normally used in power stations. A device for converting energy of high-pressure steam (produced in a boiler) into mechanical power which can be used to generate electricity. Equipment unit flown through System, used to convert the energy of the steam into rotational energy. Gas turbines could play a key role in the future power generation market addressing issues of producing clean, efficient, affordable, and fuel-flexible electric power. Numerous projections estimate that gas turbines will comprise a significant portion of the required generation capacity in the 21st century. Novel advanced gas turbine cycle modifications intended to improve the basic Brayton cycle performance and reduce pollutant emissions are currently under development or being investigated by gas turbine manufacturers and Research and Development (R&D) organizations. Preliminary conceptual analyses of advanced cycles indicate that it may be possible to achieve an improved combination of efficiency, emissions, and specific power output which in turn should reduce the power generation equipment cost basis.

## DEFINITION OF GAS TURBINE

A gas turbine is a device that converts the energy of a pressurized gas, typically air, into rotary motion to generate power. It operates by compressing incoming air, mixing it with fuel, igniting the mixture, and then allowing the high-speed exhaust gases to drive a turbine. This turbine is connected to a shaft that can be used to power machinery or a generator.

## BASIC OF GAS TURBINE

A gas turbine or gas turbine engine is a type of continue flow internal combustion engine. The main parts common to all gas turbine engines form the power-producing part (known as the gas generator or core) and are, in the direction of flow:

- A rotating gas compressor
- A combustor
- A compressor-driving turbine.

## 2.REVIEW OF LITERATURE

**Thermal and Structural Analysis of a Gas Turbine Casing Using Finite Element Method Chanduri Rajendra Prasad** - Gas turbines are becoming increasingly used as power generators for a wide variety of applications around the world. With such wide range of applications, it is necessary to improve the designs on continual basis for increased efficiency, reliability, availability and cost reduction. Gas turbine casings are generally of thin wall design to reduce thermal inertia to enable quick start up and shut downs. The main objective of the present investigation is to analyses the temperature distribution; stresses developed throughout the turbine casing using finite element method concept. In this paper, steady state thermal and structural analysis on a gas turbine casing of 26.82 MW capacity is carried out using ANSYS software with increased working gas temperatures and reduced outside casing thickness than the existing operating conditions. The outcome of the present work can be used for changing the operating conditions of the gas turbine to higher parameters or for resolving any machining deviations.

## REVIEW OF STRUCTURAL AND THERMAL ANALYSIS OF GAS TURBINE BLADE G D Ujade1\* and M B Bhambere

The gas turbine obtains its power by utilizing the energy of burnt gases and the air which is at high temperature and pressure by expanding through the several rings of fixed and moving blades. Since the turbine blades are working at high temperature and pressure there are extreme stresses developed on turbine blades. The first centrifugal stresses act on the blade due to high angular speeds, and second is thermal stresses that arise due to temperature gradient within the blade material. The present paper is review of various analyses done on turbine blades and there are various factors effects on turbine blade. This paper will be helpful for those who are working in the area of power plants.

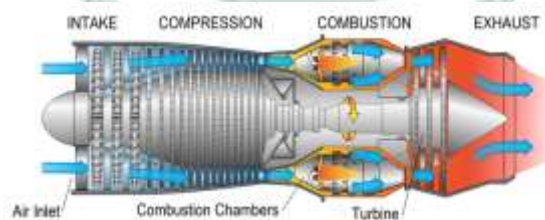
## 3.CONSTRUCTION

### Construction of Gas Turbine

A gas turbine is an engine where fuel is continuously burnt with compressed air to produce a stream of hot, fast-moving gas. This gas stream is used to power the compressor that supplies the air to the engine as well as providing excess energy that may be used to do other work. Turbine compressor usually sits at the front of the engine. There are two main types of compressors, the centrifugal compressor and the axial compressor. The compressor will draw in air and compress it before it is fed into the combustion chamber. In both types, the compressor rotates and it is driven by a shaft that passes through the middle of the engine and is attached to the turbine.

A gas turbine, often referred to as a jet engine, is a powerful and versatile mechanical device used in various applications, including aircraft propulsion, power generation, and industrial processes. It operates on the principle of compressing and combusting air with fuel to produce high-speed exhaust gases that drive a turbine, converting energy into useful mechanical work. This efficient technology plays a crucial role in modern transportation and energy production.

The gas turbine stands as a rotary internal combustion engine, serving as a streamlined alternative to traditional reciprocating piston engines. It represents a straightforward method for generating power, characterized by its distinctive ability to compress ambient air and introduce heat via the combustion of fuel within a designated combustion chamber, commonly referred to as a combustor.



**Fig :1 Gas Turbine Engine**

A gas turbine engine, a type of continuous flow internal combustion engine, is constructed with three main components: a compressor, a combustion chamber, and a turbine. The compressor draws in and compresses air, which then mixes with fuel and is ignited in the combustion chamber. The resulting hot, high-pressure gas expands through the turbine, spinning its blades and driving both the compressor and a generator.

### Compressor

- The compressor is a rotating assembly of blades that increases the pressure and temperature of the incoming air.
- It can be a centrifugal compressor (for smaller turbines) or an axial compressor (for larger turbines).

### Combustion Chamber

- This section is where fuel is injected and burned with the compressed air.
- The combustion process generates high-temperature, high-pressure gas.
- Various combustion chamber designs exist, including can-type, annular, and can-annular configurations.

### Turbine

- The turbine is a rotating assembly of blades that converts the thermal energy of the hot gas into rotational work.

- This rotational work is used to drive the compressor and, in some cases, a generator to produce electricity.
- The turbine also has a stationary part (stator) that directs the hot gas flow.
- Other important aspects of gas turbine construction.

**Auxiliary Systems**

- Gas turbines also have auxiliary systems like fuel pumps, control systems, cooling systems, and lubrication systems.

**Casing**

- The turbine is housed within a casing, which serves as a pressure vessel and provides structural support.

**Materials**

- Gas turbines are typically made of high-strength, heat-resistant materials like stainless steel and nickel alloys.

**Cooling**

- Cooling systems are often used to keep critical components at safe operating temperatures.

**4.TABULATION ANALYSIS**

**Tabulation of Gas Turbine Blade**

By using standard assumptions, theoretical calculations are made to obtain the dimensions of the blade geometry. The design parameters are given in table.

Parameter	Value	Unit
Blade Height, H	0.081833	M
Chord Width, C	0.02727	M
Pitch, s	0.02264	-
No. of Blade	69	-
Blade inlet angle, B2	18.3°	Deg
Blade inlet angle, b3	54.56°	Deg
Mean Radius	0.2475	M

**Table.1: Design parameters**

Design and CERO Modelling:

The 3D model is created using the software CREO; it is shown in fig



**Fig.2: Model of Turbine Blade**

**Details of Turbine Blade Material**

The turbine blade is subjected to rotational speed of 10800 rpm and firing temperature of 6190C. Factor of safety is 1.6.

PROPERTIES	UNITS	INCONEL 718	TITANIUM T6
Young’ Modulus	Mpa	2E5	1.06E5
Density	Kg/m^3	8193.3	4420
Poisson’s Ratio	-	0.31	0.3
Tensile yield Strength	Mpa	1069	530
Allowable Stress	Mpa	641.8	318
Allowable Shear stress	Mpa	385.08	190.8
Specific Heat	J/kg-k	556.85	527.5

**Table.2: Details of Turbine Blade Material**

### 5.RESULT ANALYSIS

- Analysis of Gas Turbine Blade
- Structural Analysis of Turbine Blade

#### Total Deformation of Turbine Blade

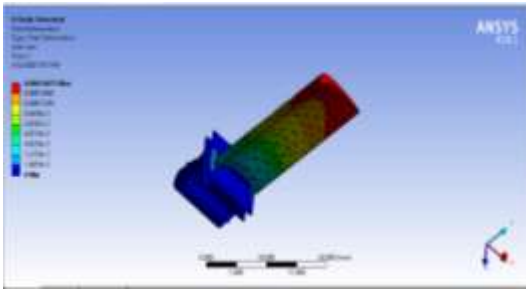


Fig.3: Total Deformation of Titanium T6

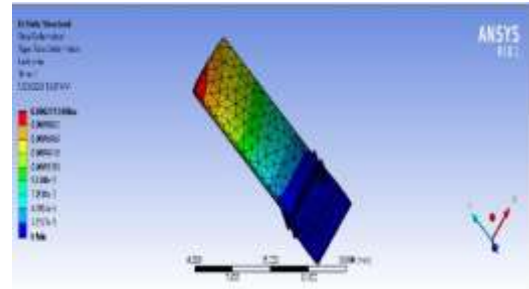


Fig.4: Total Deformation of Inconel 718

#### Strain of Turbine Blade

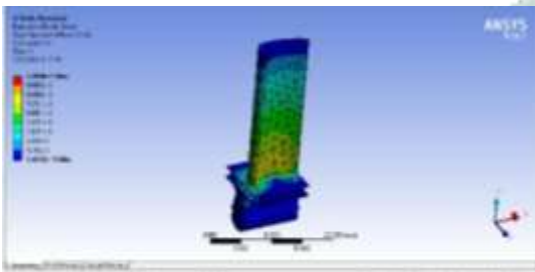


Fig .5: Strain of Titanium T6

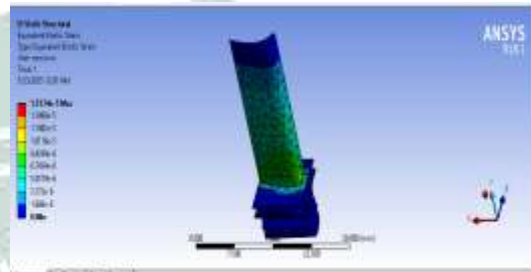


Fig.6: Strain of Inconel 718

#### Stress of Turbine Blade

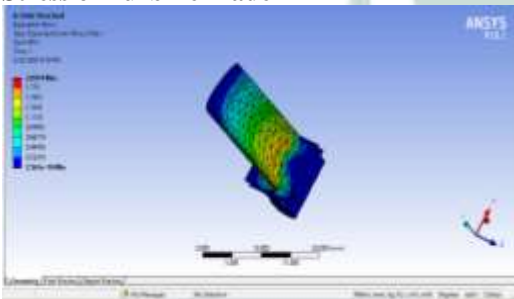


Fig.7: Stress of Titanium T6

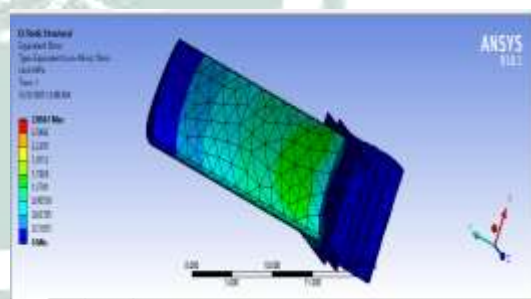


Fig :8: Stress of Inconel 718

#### Thermal Analysis of Turbine Blade Directional Heat Flux

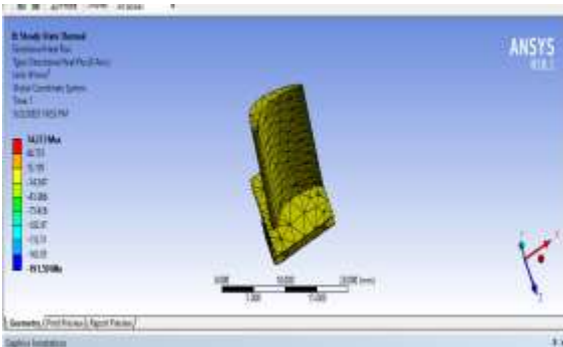


Fig.9: Directional Heat Flux of Titanium T6

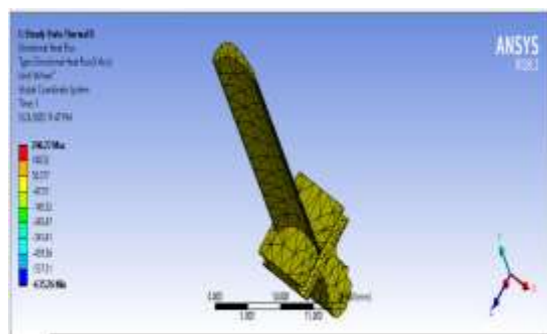
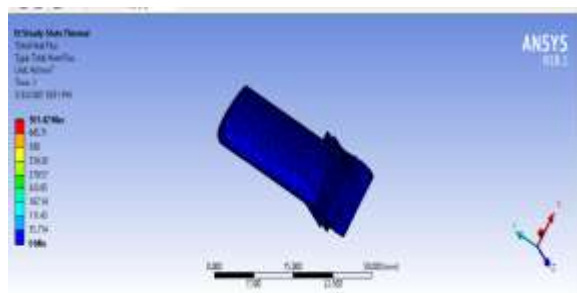
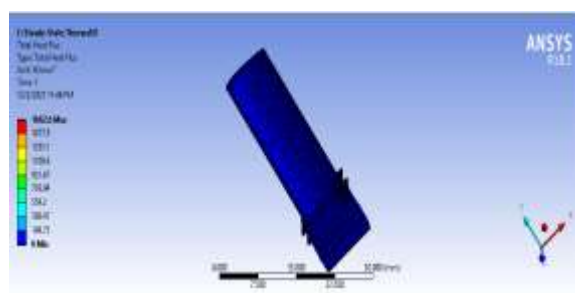


Fig.10: Directional Heat Flux of Inconel 718

**Total Heat Flux of Turbine Blade**

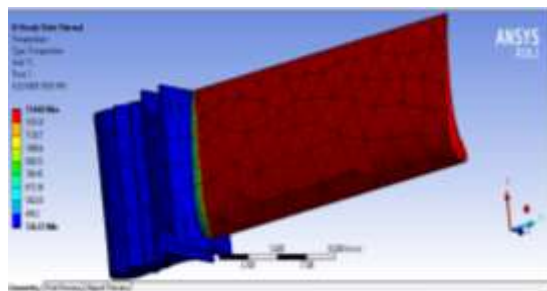


**Fig.11: Total Heat Flux of Titanium T6**

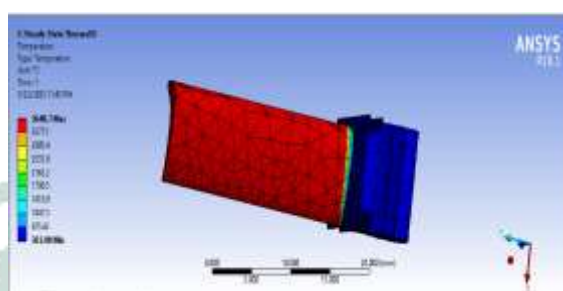


**Fig.12: Total Heat Flux of Inconel 718**

**Temperature of Turbine Blade**



**Fig.13: Temperature of Titanium T6**



**Fig.14: Temperature of Inconel 718**

The temperatures obtained from the thermal analysis are imported to structural analysis. The Centrifugal forces acting on the blade are considered as loads in structural analysis. Thermal expansion of Titanium-T6 is lesser as compare to that of Inconel 718; due to this property of the materials the expansion of the Titanium T6 is lesser as compare to that of Inconel 718.

**6.SUMMARY OF RESULT**

**Results**

**Comparison of Results**

Parameter	Titanium Alloy < Br > (Files 6-8)	Inconel 718 < Br > (Files 22-24)	Best Material
Total Deformation	Max: 0.214mm	Max: 0.120mm	Inconel 718 (Less Deformation)
Equivalent Strain	Max: 0.001098	Max: 0.000615	Inconel 718 (Lower Strain)
Von Misses Stress	Max: 521.36 Mpa	Max: 417.98 Mpa	Inconel 718(Lower Stress)

**Table. 3: Comparison Of Result**

**Summary**

Inconel 718 performs better under the same loading condition, showing

44% less Deformation

44% less Strain

20% less Stress

This indicates higher stiffness, better fatigue resistance and superior mechanical performance.

Parameter	Titanium T6	Inconel 718	Remarks
Max Temperature (C)	1344.9	3648.7	Inconel 718 with stands much higher temperature.
Min Temperature (C)	336.12	303.98	Titanium retains more residual heat.
Directional Heat Flux (Max) W/mm^2	74.273	246.27	Inconel 718 conducts more heat directionally.
Directional Heat Flux (Min) W/mm^2	-191.59	-635.26	Larger variation in Inconel 718.
Total Heat Flux (max) W/mm^2	501.42	1662.6	Inconel 718 handles more over all heat.
Total Heat Flux (Min) W/mm^2	0	0	Same for both (baseline)

**Table. 4: Summary**

## 7.CONCLUSION

- Inconel 718 Performs better in terms of mechanical strength and thermal resistance.
- It with stands higher temperature and conducts more heat, making it suitable for high temperature – applications such as turbine blades, exhaust system and high-pressure environments.
- Recommendation: Use Inconel 718 for critical application demanding high thermal endurance and mechanical stability.
- It is also seen Inconel 718 have good material properties at higher temperature has compare to that of the titanium T6.

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