INTERNATIONAL JOURNAL OF RESEARCH
In Advanced Engineering Technologies

Volume 6, Issue 2 JULY 2017

DESIGN AND ANALYSIS OF GAS TURBINE BLADE

[1] **Kottha Srinivas,** [2] **Mr. M.Prasad**
[1] PG Scholar, Department of MECH, **Methodist COLLEGE of Engineering & Technology.**
Abids, Hyderabad – 500 001.
[2] Assistant Professor, Department of MECH, **Methodist COLLEGE of Engineering & Technology.**
Abids, Hyderabad – 500 001.

Abstract

A gas turbine used in power generation by converting kinematic energy into mechanical energy by rotors. The rotors has to withstand high temperatures, pressure, stresses and strains during compression and expansion in turbine and it has to increase thermal efficiency. The life of the blade is also important by avoiding fatigue. Solidworks software is used to model it. Meshing, analysis is performed by Ansys 14.5 software. Rotors cooling methods are also analyzed to improve convection and decrease temperatures on blades. Deformations are analyzed by static structural analysis. Thermal stresses and strains results by software are compared for different materials. This analysis is done to introduce new innovated materials into real-time application on existing or new products to increase efficiency and life.Structural load like Pressure analysis is done at required areas to choose a best material. Vibrational frequency in turbine are also estimated by modal analysis.

Fig: Gas turbine blade with rotor

1. Introduction:

Gas turbines are used for power generation. Today, gas turbines are one of the most widely-used power generating technologies. Gas turbines are a type of internal combustion (IC) engine in which burning of an air-fuel mixture produces hot gases that spin a turbine to produce power. It is the production of hot gas during fuel combustion, not the fuel itself that the gives gas turbines the name. Gas turbines can utilize a variety of fuels, including natural gas, fuel oils, and synthetic fuels. Combustion occurs continuously in gas turbines, as opposed to reciprocating IC engines, in which combustion occurs intermittently.

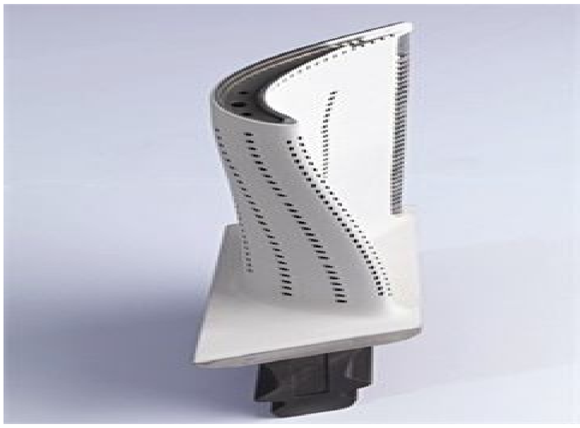


Fig: Gas turbine rotor blade

2. How does a gas turbine works:

Gas turbines are comprised of three primary sections mounted on the same shaft: the compressor, the combustion chamber (or combustor) and the turbine. The compressor can be either axial flow or centrifugal flow. Axial flow compressors are more common in power generation because they have higher flow rates and efficiencies. Axial flow compressors are comprised of multiple stages of rotating and stationary blades (or stators) through which air is drawn in parallel to the axis of rotation and incrementally compressed as it passes through each stage. The acceleration of the air through the rotating blades and diffusion by the stators increases the pressure and reduces the volume of the air. Although no heat is added, the compression of the air also causes the temperature to increase.

The compressed air is mixed with fuel injected through nozzles. The fuel and compressed air can be pre-mixed or the compressed air can be introduced directly into the combustor. The fuel-air mixture ignites under constant pressure conditions and the hot combustion products (gases) are directed through the turbine where it expands rapidly and imparts rotation to the shaft. The turbine is also comprised of stages, each with a row of stationary blades (or nozzles) to direct the expanding gases followed by a row of moving blades. The rotation of the shaft drives the compressor to draw in and compress more air to sustain continuous combustion. The remaining shaft power is used to drive a generator which produces electricity. Approximately 55 to 65 percent of the power produced by the turbine is used to drive the compressor. To optimize the transfer of kinetic energy from the combustion gases to shaft rotation, gas turbines can have multiple compressor and turbine stages.

Because the compressor must reach a certain speed before the combustion process is continuous or self-sustaining – initial momentum is imparted to the turbine rotor from an external motor, static frequency converter, or the generator itself. The compressor must be smoothly accelerated and reach firing speed before fuel can be introduced and ignition can occur. Turbine speeds vary widely by manufacturer and design, ranging from 2,000 revolutions per minute (rpm) to 10,000 rpm. Initial ignition occurs from one or more spark plugs (depending on combustor design). Once the turbine reaches self-sustaining speed – above 50% of full speed – the power output is enough to drive the compressor, combustion is continuous, and the starter system can be disengaged.

3. Gas Turbine Working Principle

Gas turbine engines derive their power from burning fuel in a combustion chamber and using the fast flowing combustion gases to drive a turbine in much the same way as the high pressure steam drives a steam turbine.

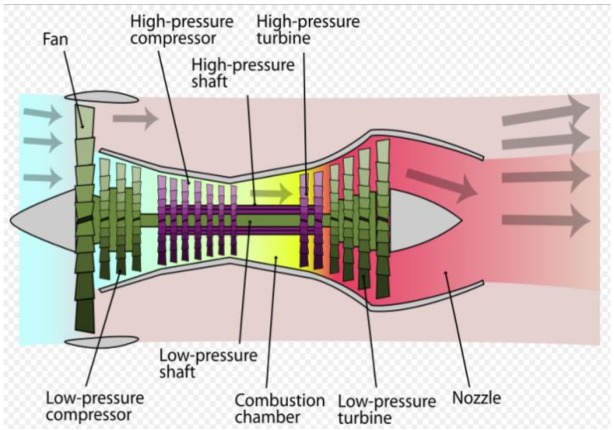


Fig: gas turbine combustion

One major difference however is that the gas turbine has a second turbine acting as an air compressor mounted on the same shaft. The air turbine (compressor) draws in air, compresses it and feeds it at high pressure into the combustion chamber increasing the intensity of the burning flame.

It is a positive feedback mechanism. As the gas turbine speeds up, it also causes the compressor to speed up forcing more air through the combustion chamber which in turn increases the burn rate of the fuel sending more high pressure hot gases into the gas turbine increasing its speed even more. Uncontrolled runaway is prevented by controls on the fuel supply line which limit the amount of fuel fed to the turbine thus limiting its speed.

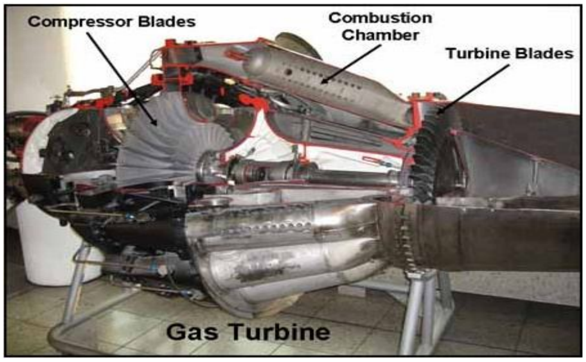


Fig: Gas turbine

The thermodynamic process used by the gas turbine is known as the Brayton cycle. Analogous to the Carnot cycle in which the efficiency is maximized by increasing the temperature difference of the working fluid between the input and output of the machine, the Brayton cycle efficiency is maximized by increasing the pressure difference across the machine. The gas turbine is comprised of three main components: a compressor, a combustor, and a turbine. The working fluid, air, is compressed in the compressor (adiabatic compression - no heat gain or loss), then mixed with fuel and burned by the combustor under constant pressure conditions in the combustion chamber (constant pressure heat addition). The resulting hot gas expands through the turbine to perform work (adiabatic expansion). Much of the power produced in the turbine is used to run the compressor and the rest is available to run auxiliary equipment and do useful work. The system is an open system because the air is not reused so that the fourth step in the cycle, cooling the working fluid, is omitted.

Gas turbines have a very high power to weight ratio and are lighter and smaller than internal combustion engines of the same power. Though they are mechanically simpler than reciprocating engines, their characteristics of high speed and high temperature operation require high precision components and exotic materials making them more expensive to manufacture.

4. Solidworks

Solid Works is mechanical design automation software that takes advantage of the familiar Microsoft Windows graphical user interface.

It is an easy-to-learn tool which makes it possible for mechanical designers to quickly sketch ideas, experiment with features and dimensions, and produce models and detailed drawings.

Introduction to Solidworks:

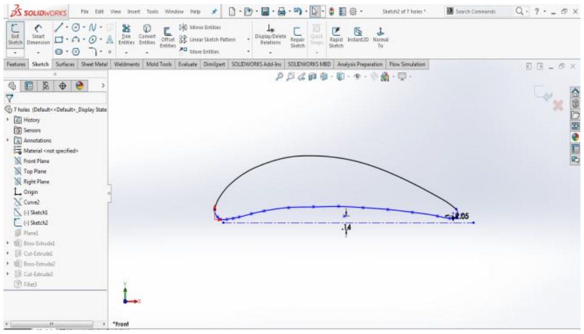
Solidworks mechanical design automation software is a feature-based, parametric solid modeling design tool which advantage of the easy to learn windows ^{TM} graphical user interface. We can create fully associate 3-D solid models with or without while utilizing automatic or user defined relations to capture design intent.

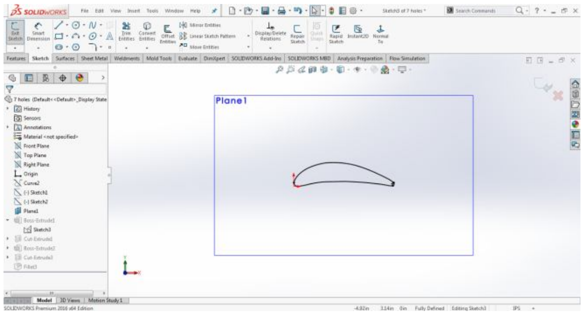
Parameters refer to constraints whose values determine the shape or geometry of the model or assembly. Parameters can be either numeric parameters, such as line lengths or circle diameters, or geometric parameters, such as tangent, parallel, concentric, horizontal or vertical, etc. Numeric parameters can be associated with each other through the use of relations, which allow them to capture design intent.

5. Design procedure of Gas Turbine Blade

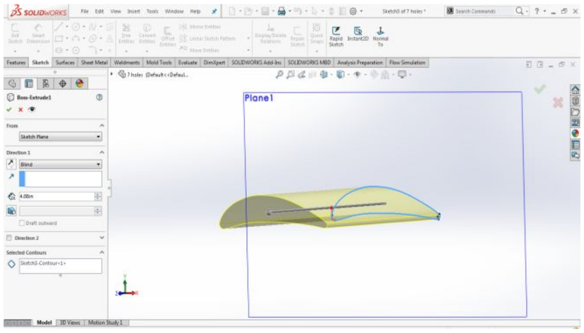
For designing the gas turbine blade the following procedure has to be follow

Go to features and select curves and coordinates as follows

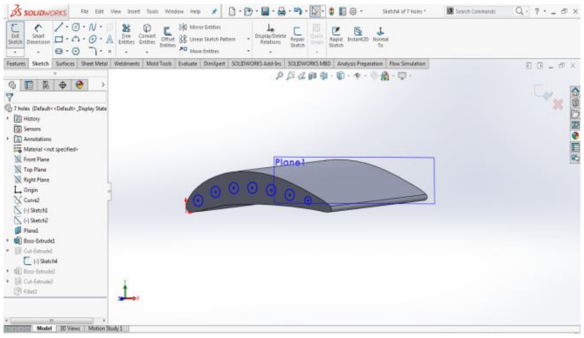




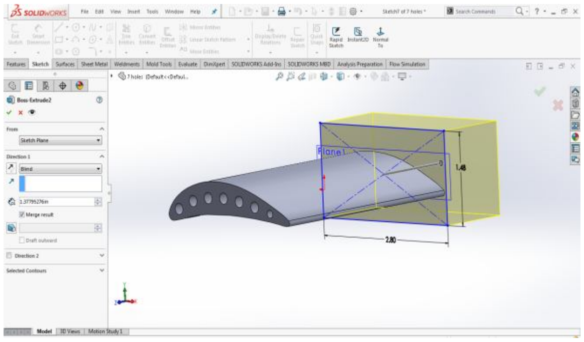
Now go to features and extrude it as follows

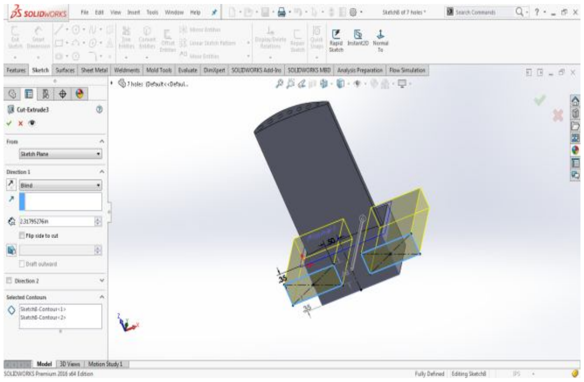


Draw the sketch as follows

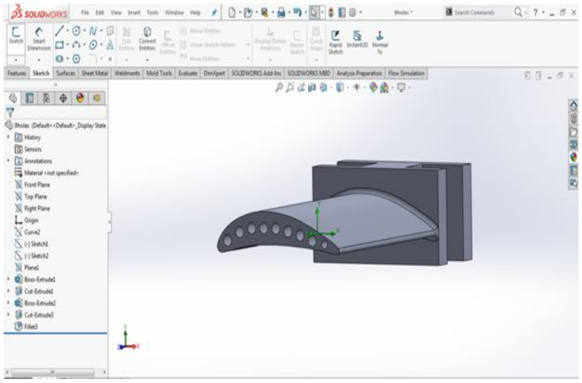


Draw the sketch as follows to make extrude

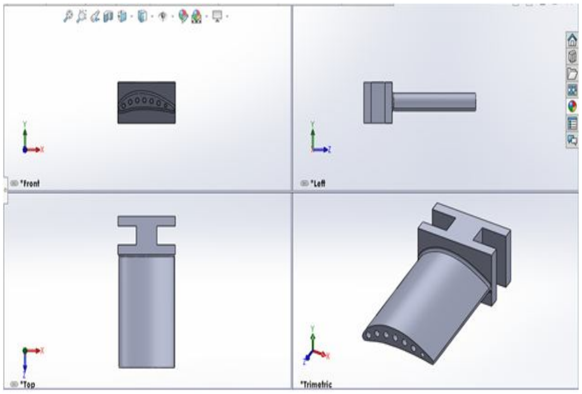




Gas turbine rotor blade



Four views of gas turbine rotor blade



6. Finite Element Analysis:

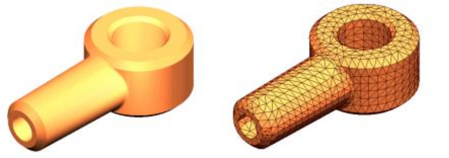
Introduction:

Finite Element Analysis (FEA) is a computer-based numerical technique for calculating the strength and behaviour of engineering structures. It can be used to calculate deflection, stress, vibration, buckling behaviour and many other phenomena. It also can be used to analyze either small or largescale deflection under loading or applied displacement. It uses a numerical technique called the finite element method (FEM).

Basic Concepts of Analysis:

Meshing:

The software uses the Finite Element Method (FEM). FEM is a numerical technique for analyzing engineering designs. FEM is accepted as the standard analysis method due to its generality and suitability for computer implementation. FEM divides the model into many small pieces of simple shapes called elements effectively replacing a complex problem by many simple problems that need to be solved simultaneously.



CAD model of a part

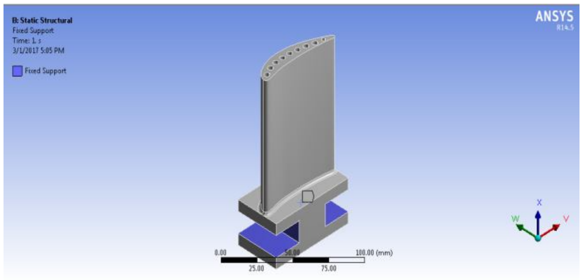
Model subdivided into small pieces (elements)

Material data:

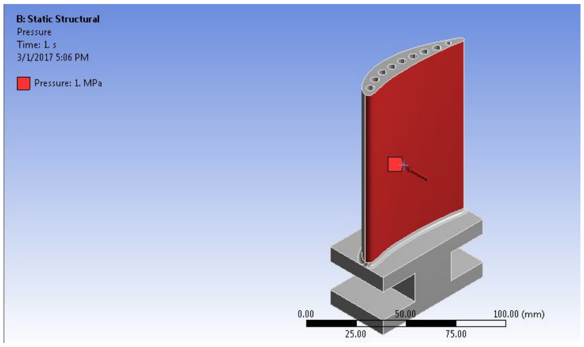
Material	Density (kg/m³)	Young's modulus (pa)	Poison's ratio	Bulk modulus (pa)	Shear modulus (pa)	Thermal conductivity (W/m⁰C)
Stainless steel	7750	1.93E+11	0.31	1.693E+11	7.3664E+10	15.1
Titanium alloy	4620	9.6E+10	0.36	1.1429E+11	3.529E+10	21.9
Inconel	8440	2.05E+10	0.28	1.553E+18	8.0078E+17	9.7

7. Structural analysis on Gas Turbine

Fixed support

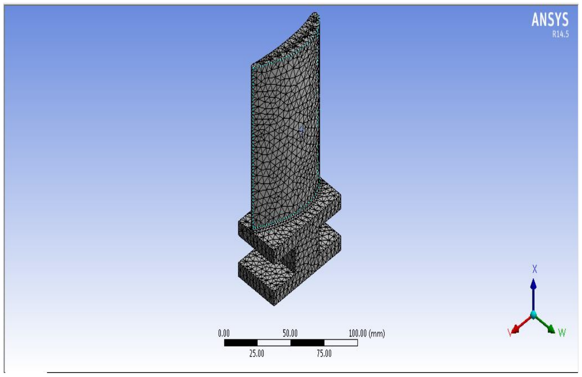


Pressure (1 MPA)



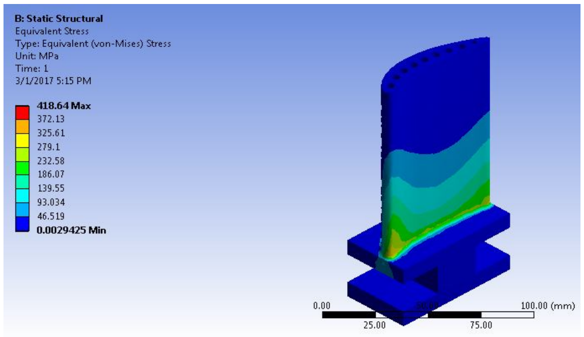
Meshing

Size: fine

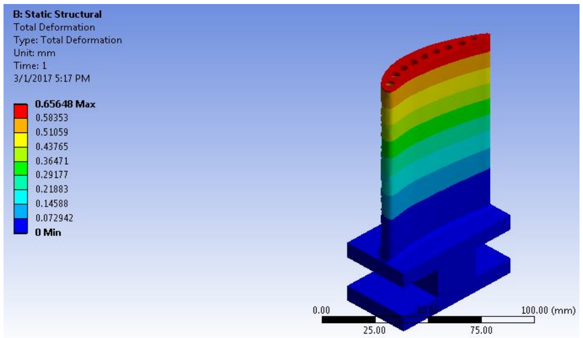


Material: Stainless Steel

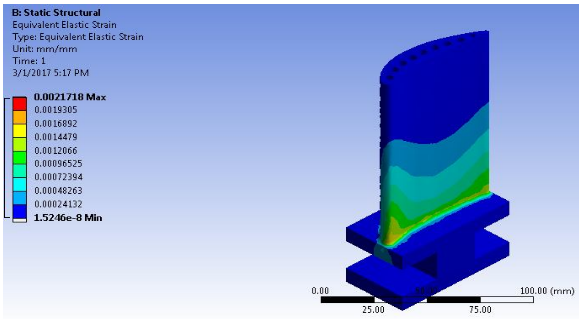
Maximum stress



Total deformation

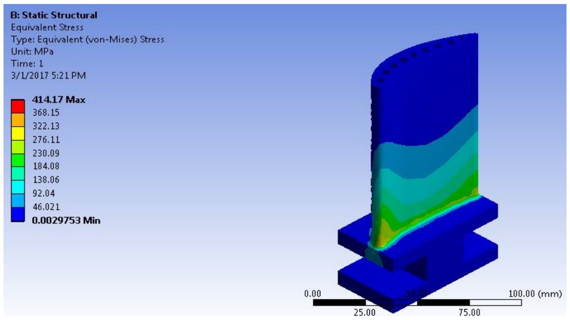


Maximum strain

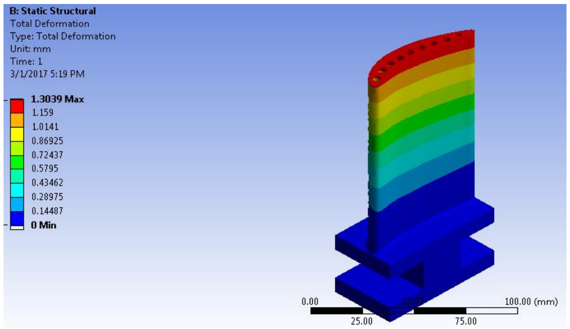


Material: Titanium alloy

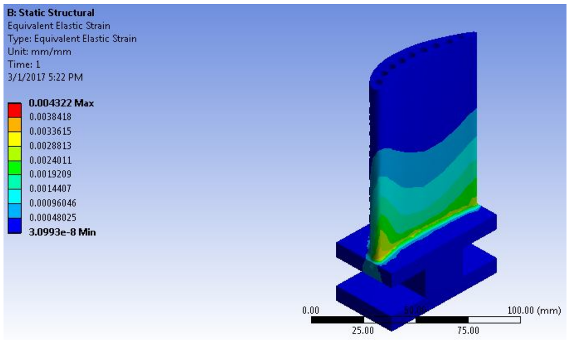
Maximum stress



Total deformation

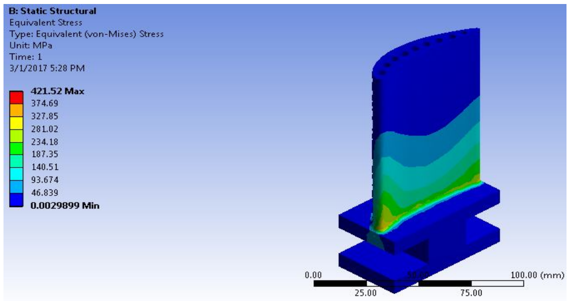


Maximum strain

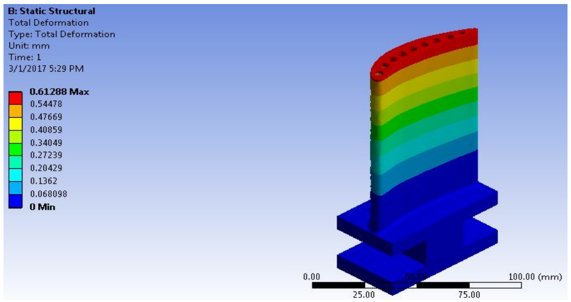


Material: Inconel (Nickel 625 Alloys)

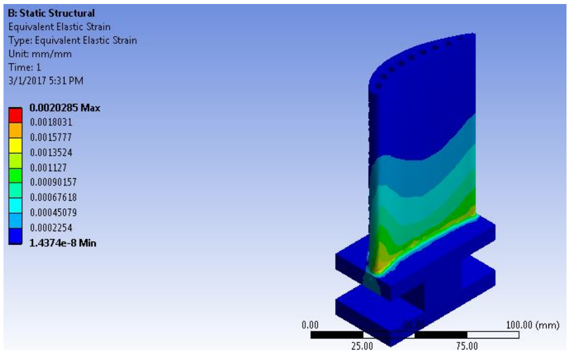
Maximum stress



Total deformation

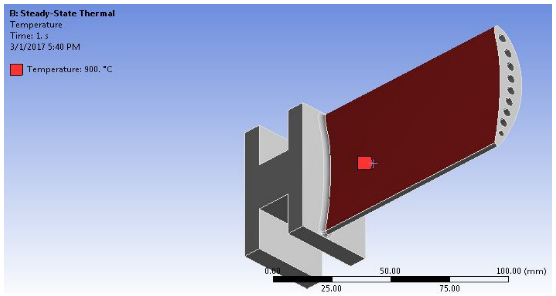


Maximum strain

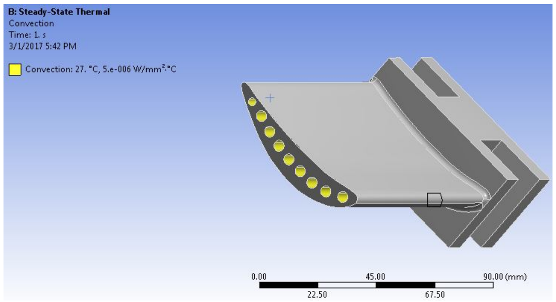


8. Steady State Thermal Analysis on Gas Turbine Rotor Blade

Temperature (900 c)

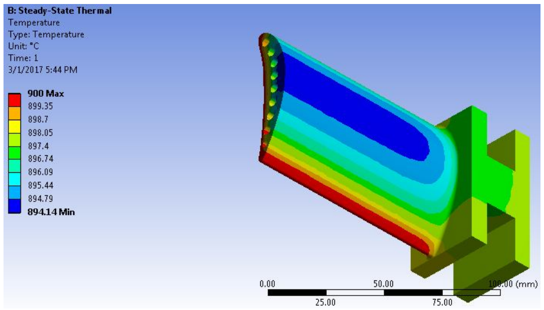


Convection (27 c)

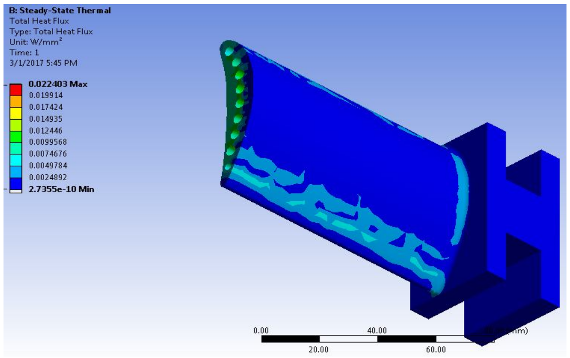


Material: Stainless Steel

Temperature Distribution

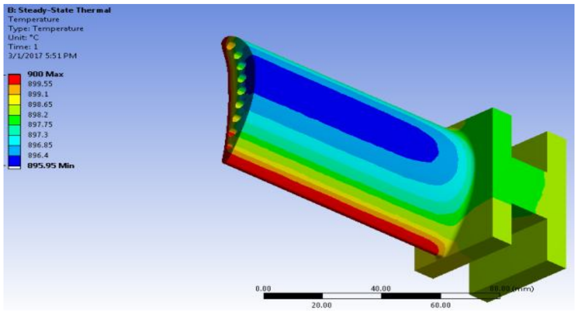


Total Heat Flux

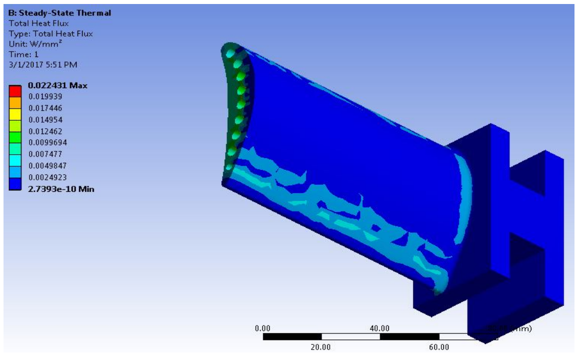


Material: Titanium Alloy

Temperature Distribution

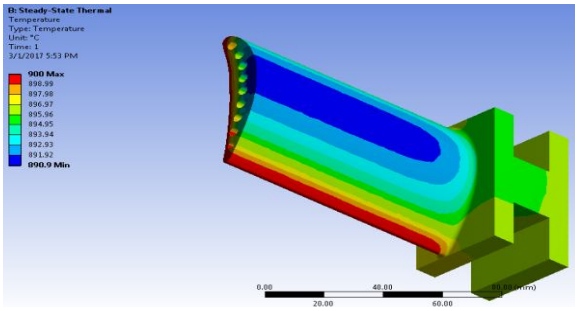


Total Heat Flux

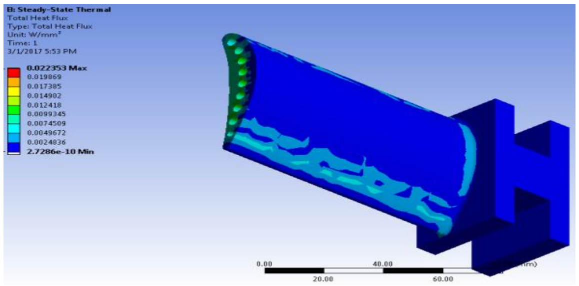


Material: Inconel (Nickel 625 Alloys)

Temperature Distribution



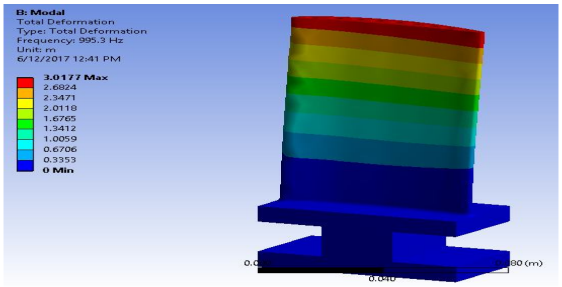
Total Heat Flux



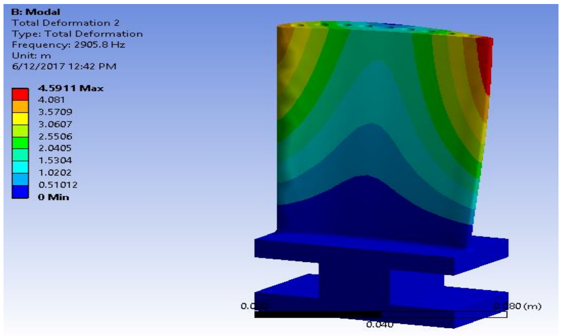
10. Dynamic (Modal) Analysis

Material: Stainless Steel

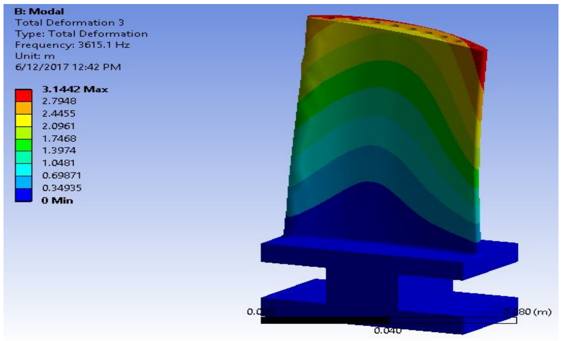
Mode-1



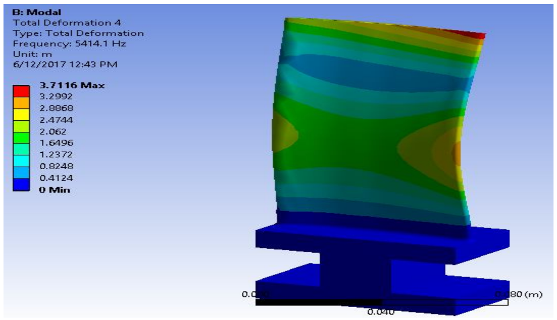
Mode-2



Mode-3

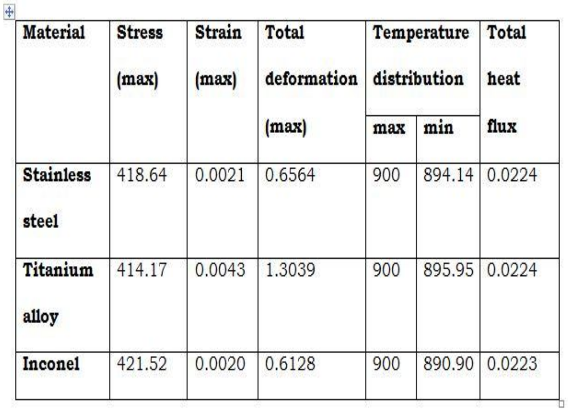


Mode-4



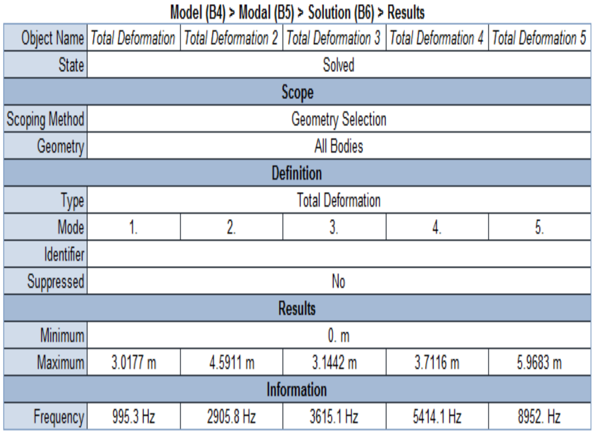
11. Results

Experimental Results



Material	Stress (max)	Strain (max)	Total deformation (max)	Temperature distribution		Total heat flux
				max	min	
Stainless steel	418.64	0.0021	0.6564	900	894.14	0.0224
Titanium alloy	414.17	0.0043	1.3039	900	895.95	0.0224
Inconel	421.52	0.0020	0.6128	900	890.90	0.0223

MODAL Analysis Results



Model (B4) > Modal (B5) > Solution (B6) > Results

Object Name	*Total Deformation*	*Total Deformation 2*	*Total Deformation 3*	*Total Deformation 4*	*Total Deformation 5*
State	Solved				
Scope					
Scoping Method	Geometry Selection				
Geometry	All Bodies				
Definition					
Type	Total Deformation				
Mode	1.	2.	3.	4.	5.
Identifier					
Suppressed	No				
Results					
Minimum	0. m				
Maximum	3.0177 m	4.5911 m	3.1442 m	3.7116 m	5.9683 m
Information					
Frequency	995.3 Hz	2905.8 Hz	3615.1 Hz	5414.1 Hz	8952. Hz

12. Conclusion

- Modeling and analysis on gas turbine rotor blade is done.
- Static structural analysis and thermal analysis are done.
- In static structural analysis 1 mpa pressure is applied by assigning four various materials such as stainless steel, titanium alloy, and inconel
- Maximum stress, strain & deformations are obtained titanium is showing least stress values compared to stainless steel and inconel
- Inconel (Nickel 625 Alloy) showing least strain value as well as least deformation value compare to titanium & stainless steel.
- In steady state thermal analysis maximum temperature is given as 900^0C and convection through holes is 27^0C
- Temperature distribution and total heat flux values are studied and tabulated. Max heat dissipation that is cooling is done by inconel materials followed by stainless steel.
- Decreased failure rates by stress analysis and thermal analysis.

References:

[1] Gowreesh, S., Sreenivasalu Reddy, N. and Yogananda Murthy, NV. 2009. Convective Heat Transfer Analysis of a Aero Gas Turbine Blade Using Ansys, International Journal of Mechanics

and Solids. 4: 39-46.

[2] Facchini, B. and Stecco. S.S. 1999. Cooled expansion in gas turbines: a comparison of analysis methods, Energy Conversion and Management. 40: 1207-1224.

[3] Mohammad, H., Albeirutty., Abdullah, S., Alghamdi., Yousef, S. Najjar. 2004. Heat transfer analysis for a multistage gas turbine using different blade-cooling schemes, Applied Thermal Engineering. 24: 563-577.

[4] Mahfoud, K. and George, B. 1997. Computational study of turbine blade cooling by slot-injection of a gas, Applied Thermal Engineering. 17: 1141-1149.

[5] Moyroud, F., Fransson, T. and Jacquet-Richardet, G. 2002. A comparison of two finite element

reduction techniques for mistuned bladed-disks, Journal of Engineering for Gas Turbines and Power. 124: 942-953.

[6] Giovanni, C., Ambra, G., Lorenzo, B. and Roberto, F. 2007 Advances in effusive cooling techniques of gas turbines, Applied Thermal Engineering. 27: 692-698.

[7] Cun-liang, L., Hui-ren, Z., Jiang-tao, B. and Du-chun, X. 2010. Film cooling performance of converging slot-hole rows on a gas turbine blade, International Journal of Heat and Mass Transfer. 53: 5232-5241.

[8] Zhang, JJ.,Esat, II. and Shi, YH. 1999. Load Analysis with Varying Mesh Stiffness, Computers and Structures. 70: 273-280.

[9] Hildebrabd, FB. 1997. Introduction to Numerical Analysis, McGraw-Hill, New York.

[10] MoussaviTorshizi, SE.,YadavarNikravesh, SM. and Jahangiri, A. 2009. Failure analysis of gas turbine generator cooling fan blades, Engineering Failure Analysis. 16: 1686-1695.

[11] Cleeton, JPE., Kavanagh, RM. and Parks, GT. 2009. Blade cooling optimisation in humid-air and steam-injected gas turbines, Applied Thermal Engineering. 29: 3274-3283.

[12] Krishnamoorthy, C. 1994. Finite Element Analysis Theory and Programming,Tata McGraw-Hill, New Delhi.

[13] Martin, HC. and Carey, GF. 2006. Introduction to the Finite Element Analysis,McGraw Hill Publishing Co Ltd, New Delhi.