Annals of R.S.C.B., ISSN:1583-6258, Vol. 24, Issue 2, 2020, Pages. 1875 - 1891
Received 20 October 2020; Accepted 04 December 2020.

Structural & Thermal Analysis of Gas Turbine Blade by Using Ansys

Nallappan M#1, Malarkannan#2, vinothkumar v.s#3

l,3,Assistant Professor, Department of Aeronautical Engineering ,

Dhanalakshmi Srinivasan College of Engineering and Technology, India

2, Assistant Professor, Department of Mechanical Engineering , Dhanalakshmi Srinivasan College of Engineering and Technology, India

[1]nallappan2486@gmail.com

[2]malarkannan.mech@dscet.ac.in

[3]vsvinotharo@gmail.com

Abstract:
Withstanding of gas turbine blades for the elongations is a major consideration in their properties because they are subjected to high tangential, axial, centrifugal forces during their working conditions. Several methods have been suggested for the better enhancement of the mechanical properties of blades to withstand these extreme conditions. This project summarizes the modeling and analysis of Gas turbine blade, on which CREO 2.0 is used for design of solid model of the turbine blade and ANSYS 14.0 software is used for model meshing of the blade and applying the boundary condition.This project specifies how the program makes effective use of the ANSYS and applies boundary conditions to examine steady state thermal & structural performance of the blade for N 155 & Inconel 725 materials. Finally found the best suited material among the TWO from the report generated after analysis. From this the results are stated and reported.

Keywords:Gas turbine blade,CREO,thermal, structural,Inconel 725

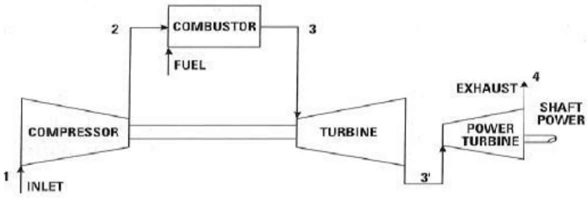
1. INTRODUCTION

The purpose of turbine technology are to extract the maximum quantity of energy from the working fluid to convert it into useful work with maximum efficiency by means of a plant

Annals of R.S.C.B., ISSN:1583-6258, Vol. 24, Issue 2, 2020, Pages. 1875 - 1891
Received 20 October 2020; Accepted 04 December 2020.

having maximum reliability, minimum cost,
minimum supervision and minimum starting time. 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.

To get a high pressure of order 4 to 10 bar of working fluid where fuel is continuously burnt with compressed air to produce a steam of hot, fast moving gasas shown in figure 1[1].



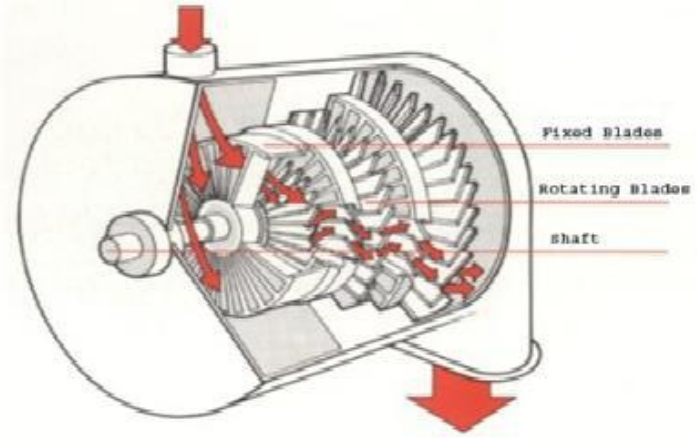
This gas stream is used to power the compressor that supplies the air to the engine as well as providing excess energy that may be used to do other work, which is essential for expansion a compressor, is required. The quantity of the working fluid and speed required are more so generally a centrifugal or an axial compressor is required. The turbine drives the compressor so it is coupled to the turbine shaft. If after compression the working fluid were to be expanded in a turbine, then assuming that there were no losses in either component, the power developed by the turbine can be increased by increasing the volume of working fluid at constant pressure or alternatively increasing the pressure at constant volume.

Either of these may be done by adding heat so that the temperature of the working fluid is increased after compression. To get a higher temperature of the working fluid a combustion chamber is required where combustion of air and fuel takes
place giving temperature rise to the working fluid. Gas turbines have been constructed to work on the following: -oil, natural gas, coal gas, producer gas, blast furnace and pulverized coal.

The engine consists of three main parts.

1. The Compressor section
2. The Combustion section (the combustor).
3. The turbine (and exhaust) section.

The Turbine compressor usually sits at the front of the engine. There are two main types of compressor, 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 as shown below in figure 2 [1], [2].



Turbine Blade Coupled to Centrifugal Compressor

Turbine Blade

The rotor blades of the turbo machine are very critical components and reliable operation of the turbo machine as a whole depends on their repayable operation. The major cause of break down in turbo machine is the failure of rotor blade. The failure of the rotor blade may lead to catastrophic consequences both physically and economically. Hence, the proper design of the turbo machine blade plays a vital role in the proper functioning of the turbo machine as shown in figure 4[1].

Turbine Blade

A good design of the turbo machine rotor blading involves the following:

1. Determination of geometric characteristics from gas dynamic analysis.

2. Determination of steady loads acting on the blade and stressing due to them.
3. Determination of natural frequencies and mode shapes.
4. Determination of unsteady forces due to stage flow interaction.
5. Determination of dynamic forces and life estimation based on the cumulative damage fatigue theories[3]

Due to corrosion and corrosion deposits turbine blades fail. To protect it from corrosion, the uses of pack-aluminized coatings are used. The main elements used are aluminum, nickel, and chromium[1], [5].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 ringsof fixed and moving blades, to get a high pressure of order of 4 to 10 bar of working fluid which is essential forexpansion a compressor is required. The quantity of working fluid and speed required are more, so generally a centrifugal or axial compressor is required. The turbine drive the compressor so it is coupled to the turbine shaft, If after compression the working fluid were to be expanded in a turbine, then assuming that there were no losses in either component,

John.vet.al(3) studied on the design and analysis of Gas turbine blade, CREO is used for design of solid model and ANSYS software for analysis for F.E.model generated, by applying boundary condition, this paper also includes specific post-processing and life assessment of blade .HOW the program makes effective use of the ANSYS pre-processor to mesh complex turbine blade geometries and apply boundary conditions. Here under we presented how Designing of a turbine blade is done in CREO with the help of co-ordinate generated on CMM.And to demonstrate the preprocessing capabilities, static and dynamic stress analysis results, generation of Campbell and Interference diagrams and life assessment. The principal aim of this paper is to get the natural frequencies and mode shafe of the turbine blade.

V.RagaDeepuet.al(4) Studied on a Gas turbine is a device designed to convert the heat energy of fuel in to useful work such as mechanical shaft power. Turbine Blades are most important components in a gas turbine power plant. A blade can be defined as the medium of transfer of energy from the gases to the turbine rotor. The turbine blades are mainly affected due to static loads. Also the temperature has significant effect on the blades. Therefore the coupled (static and thermal) analysis of turbine blades is carried out using finite element analysis software

ANSYS.

In this paper the first stage rotor blade of the gas turbine is created in CREO V5 R15 Software. This model has been analysed using ANSYS 11.0. The gas forces namely tangential, axial were determined by constructing velocity triangles at inlet and exist of rotor blades. After

containing the heat transfer coefficients and gas forces, the rotor blade was then analysed using ANSYS 11.0 for the couple field (static and thermal) stresses.

Methodology

4.1 Details of Turbine blade

D=1308.5 mm, N=3426 Rpm, L=117mm, d=2mm

Chemical Composition

INCONEL 725

Cr	Ni	Mo	Nb (+Ta)	Ti	C	Mn	Si	P	S	Fe	Al
22.5	59	9.5	4	1.7	0.03	0.35	0.20	0.015	0.01	Bal	0.35

N 155

C	Mn	Si	S	P	Cr	Ni	Co	Mo	W	Cb(+Ta)	N
0.16	2.00	1.00	0.03	0.05	22.5	21.0	21.00	3.5	3.0	1.25	0.2

i. MATERIAL PROPERTIES

	N 155	INCONEL 725
Density (kg/m3)	8249	8310
Young’s modulus (MPa)	143000	204000
Poisson’s ratio	0.34	0.31
Yield stress (MPa)	550	917
Thermal conductivity (W/m-K)	20.0	21.2
Melting Point 0C	1354	1343

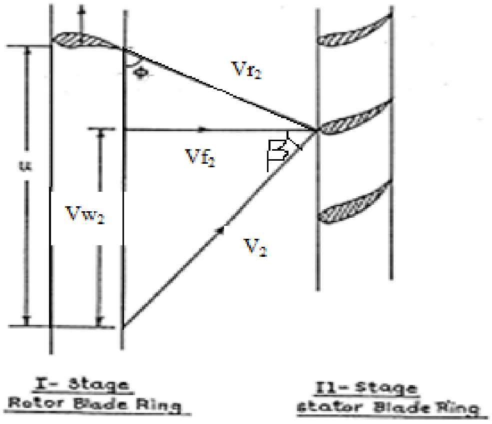
ii. Evaluation of Gas Forces on the Rotor Blades

Gas forces acting on the blades of the rotor in general have two components namely tangential (Ft) and axial (Fa). These forces result from the gas momentum changes and from pressure differences across the blades. These gas forces are evaluated by constructing velocity triangles at inlet and outlet of the rotor blades. The rotor blades considered for analysis are untwisted and same profile is taken throughout the length of the blade. If the gas forces are assumed to be distributed evenly then the resultant acts through the centroid of the area[1], [2].

iii. Evaluation of Gas Forces on the First Stage Rotor Blade

At the inlet of the first stage rotor blades,
Absolute flow angle α = 23.850
Absolute velocity V1 = 462.21 m/s
The velocity triangles at inlet of first stage rotor blades were constructed
Diameter of blade mid span D = 1.3085 m
Design speed of turbine N = 3426 rpm
Peripheral speed of rotor blade at its mid span, U =ΠDN/60

From the velocity triangles in figure 9 we get,
Whirl velocity Vw1= 422.74 m/s
Flow Velocity Vf1= 186.89 m/s
Relative velocity, Vr1= 265.09 m/s
Blade angle at inlet, θ = 135.017 0
At the exit of the first stage rotor blades,
Flow velocity, Vf2 = 180.42 m/s
Relative flow angle, Φ = 37.88 0
The velocity triangles at the exit of the first stage rotor blades as were constructed
From the velocity triangles we get,
Whirl velocity, Vw2 = 2.805 m/s
Relative velocity, Vr2 = 293.83 m/s



Exit Velocity Triangles of I-Stage Rotor Blades

The gas forces and power developed in the first stage rotor blades were evaluated using the equations that were

used for first stage rotor blades.

Tangential force Ft = 248.199 Newton

Axial force Fa = 3.82 Newton.

Power developed P = 6.991 mega watts.

Centrifugal force Fc = 38038.73 Newton

The turbine blade is subjected to rotational speed of 3426 rpm and firing temperature of 619^0C. Factor of safety is 1.6.

iv. Convective Heat Transfer Coefficients over the Blade Surfaces

The flows over suction and pressure side of rotor blade as shown in figure .

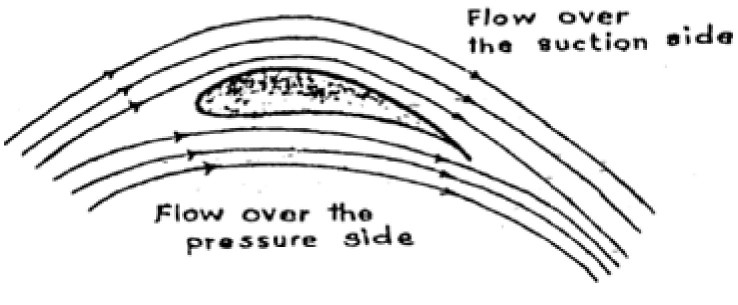


Figure : Gas Flows over Suction and Pressure Side of Rotor Blade at temperature of 619^oC

Convective Heat Transfer Coefficients on Suction side of Rotor Blades hs = 379.92 w/m2 k.

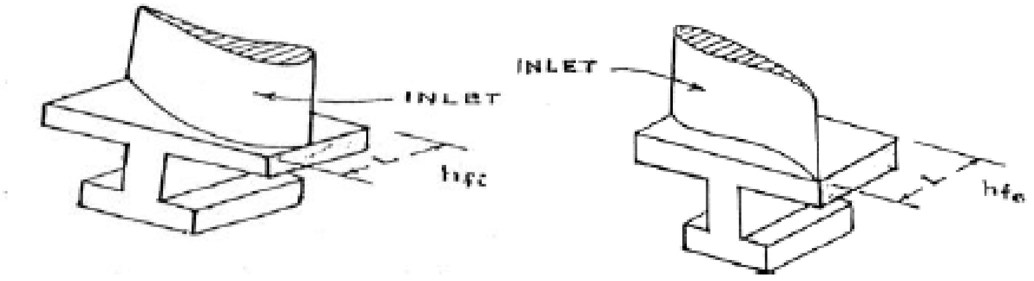
Convective Heat Transfer Coefficients on the Pressure side of rotor blade hp = 284.95 w/m2k

[1], [2],[15].

Q Heat Flow Rate =h_{gas}x A X Dt = 379.92 x 0.0072368 x 619-30 = 1619.4 W

v. Evaluation of Convective Heat Transfer Coefficient (hr)

Convective Heat Transfer Coefficient (hr) on the Two Rectangular Faces at inlet and Exit of Rotor Blades as shown in figure



Inlet and Exit of the Rotor Blade

Convective heat transfer coefficients on the rectangular face at inlet

hfi = 231.195 w/m2 K.

Convective heat transfer coefficients on the rectangular face at exist

hfe = 224.73 w/m2K

vi. Structural Analysis of a Gas Turbine Rotor Blade

Element Type 1: Solid 185 3D 8-nodes Structural Solid Element

Element type 2: Solid70 3D 8-nodes Thermal Solid Element

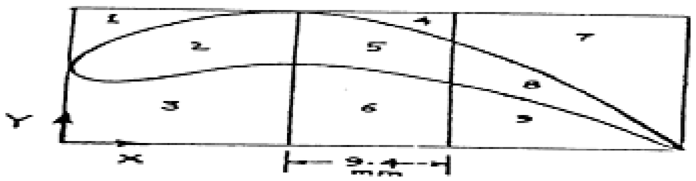
Young’s Modulus of Elasticity (E)

Poisson ratio (μ)

Density (ρ)

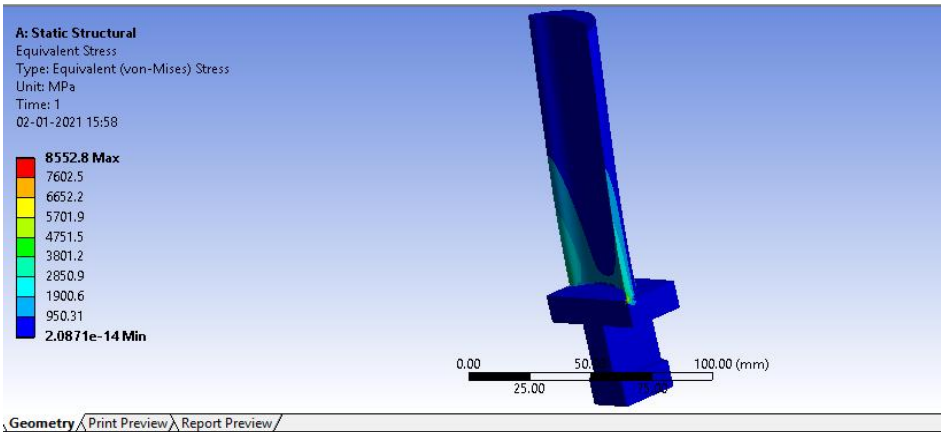
Coefficient of thermal expansion (α)

The aero foil profile of the rotor blade was generated on the XY plane with the help of key points defined by the coordinates as shows in table. Then a numberof splines were fitted through the key points. A rectangle of dimensions 49*27 mm was generated as shown in figure



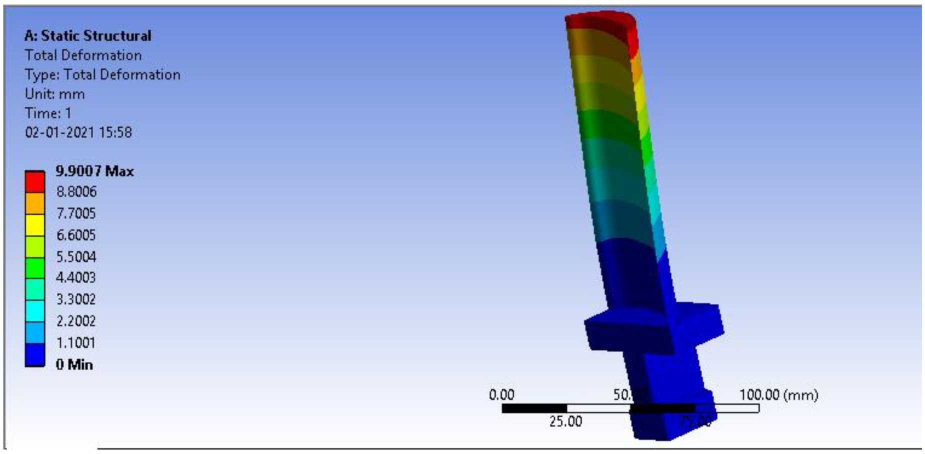
Boundary of Aero Foil Section

NO.	X	Y	NO.	X	Y
1	0.00	0.00	20	49	0.00
2	2.6	17.3	21	49	27.00
3	5.85	21	22	0.00	27.00
4	10	25	23	19.8	0.00
5	14.8	26.6	24	1.00	13.6
6	22.9	25.3	25	29.2	0.00
7	28	22.2	26	29.2	27.00
8	33.4	18.5	27	19.8	27.00
9	38	14.4	28	15.2	27.00
10	42	10.9	29	18.08	27.00
11	45.5	5.70	30	49.00	0.27E-1
12	49.00	0.00	31	48.90	0.288E-1
13	6.18	12.4	32	29.2	12.49
14	11.2	14.4	33	19.8	26.62
15	16.18	15.5	34	19.8	15.12
16	21.1	14.9	35	29.2	21.25
17	26	13.6	36	0.00	0.30E-1
18	38.2	8.77	37	19.8	0.30E-1
19	45	3.95	38	19.8	15.12



A: Static Structural
Equivalent Stress
Type: Equivalent (von-Mises) Stress
Unit: MPa
Time: 1
02-01-2021 15:58

Equivalent von-misses Stress of N 155



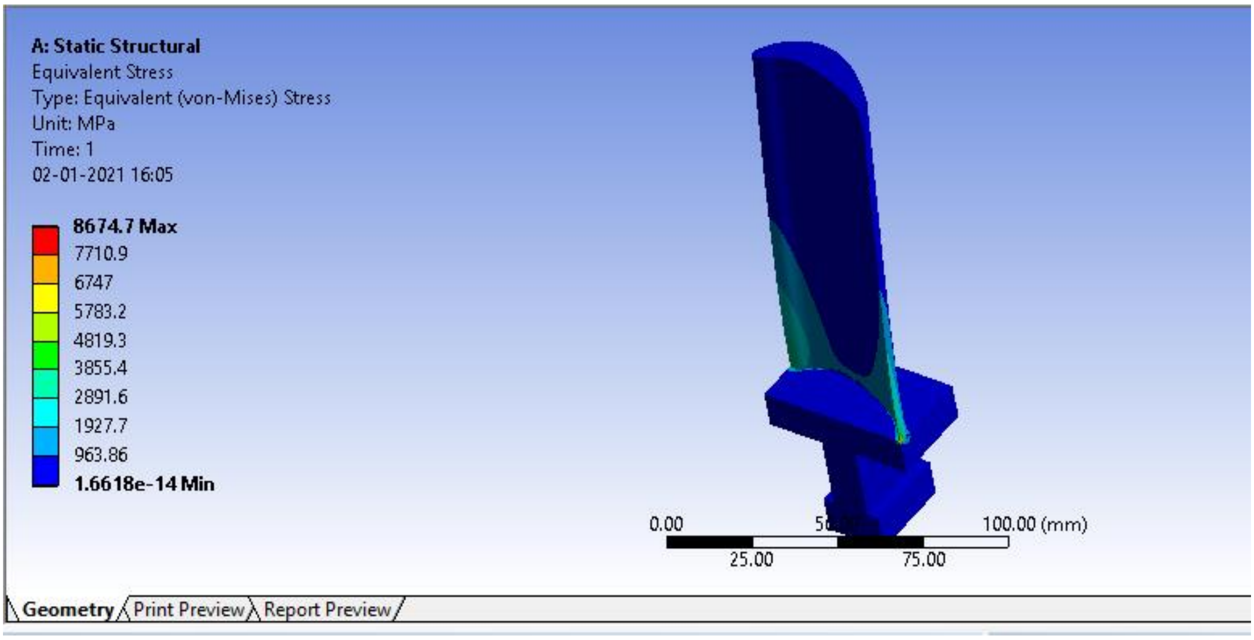
A: Static Structural
Total Deformation
Type: Total Deformation
Unit: mm
Time: 1
02-01-2021 15:58

Total deformation

Results

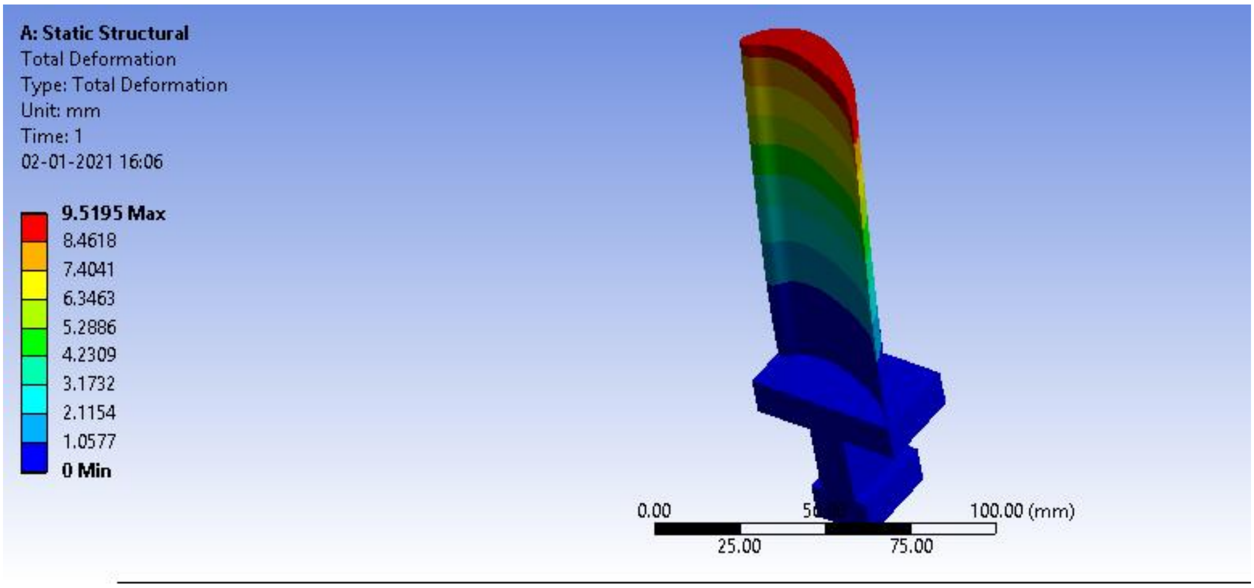
Object Name	*Equivalent Stress*	*Total Deformation*
State	Solved	
Scope		
Scoping Method	Geometry Selection	
Geometry	All Bodies	
Definition		
Type	Equivalent (von-Mises) Stress	Total Deformation
Integration Point Results		
Display Option	Averaged	
Results		
Minimum	2.0873e-014 MPa	0. mm
Maximum	8552.8 MPa	9.9007 mm

<u>RESULTS OF INCONEL 725</u>



A: Static Structural
Equivalent Stress
Type: Equivalent (von-Mises) Stress
Unit: MPa
Time: 1
02-01-2021 16:05

Equivalent von-misses Stress of INCONEL 725



Deformation of INCONEL 725

Object Name	*Part 1*
State	Meshed
Graphics Properties	
Visible	Yes
Transparency	1
Material	
Assignment	INCONEL 725
Nonlinear Effects	Yes
Thermal Strain Effects	Yes
Bounding Box	
Length X	165. mm
Length Y	49.487 mm
Length Z	27.067 mm
Properties	
Volume	74959 mm³
Mass	0.61616 kg
Centroid X	39.817 mm
Centroid Y	1.505 mm
Centroid Z	-2.6203 mm

Moment of Inertia Ip1	111.18 kg·mm²
Moment of Inertia Ip2	1376.8 kg·mm²
Moment of Inertia Ip3	1443.7 kg·mm²
Statistics	
Nodes	75875
Elements	45077
Mesh Metric	None

Results

Object Name	*Equivalent Stress*	*Total Deformation*
State	Solved	
Scope		
Scoping Method	Geometry Selection	
Geometry	All Bodies	
Definition		
Type	Equivalent (von-Mises) Stress	Total Deformation
Results		
Minimum	**1.6618e-014 MPa**	**0. mm**
Maximum	**8674.7 MPa**	**9.5195 mm**

STEADY STATE THERMAL ANALYSIS USING ANSYS SOFTWARE

Asteady-statethermalanalysiscalculatestheeffectsofsteadythermalloadsonasystemorcomponent.Engineer/analysts oftenperformasteady-stateanalysisbeforeperformingatransient thermalanalysis,tohelpestablishinitialconditions.Asteady-stateanalysisalsocanbethelaststepofatransient thermalanalysis performed afteralltransient effectshavediminished.

Steady-statethermalanalysis is usedtodeterminetemperatures,thermalgradients,heatflowrates,andheatfluxesinanobjectthatarecausedbythermalloadsthatdonotvaryovertime.Suchloadsincludethefollowing:

- Convections

- Radiation
- Heatflowrates
- Heatfluxes(heatflowperunitarea)
- Heatgeneration rates(heatflowperunitvolume)
- Constanttemperatureboundaries

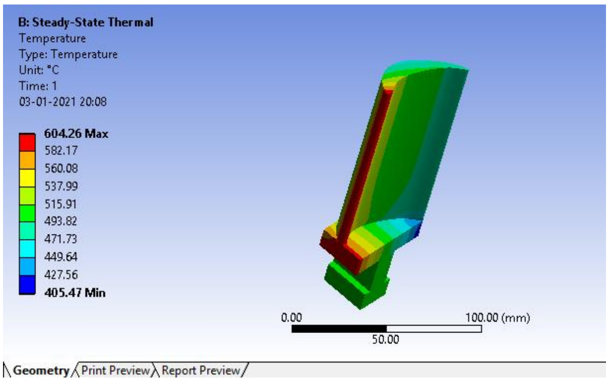
Asteady-statethermalanalysismaybeeitherlinear,withconstant materialproperties;ornonlinear,withmaterialproperties thatdependontemperature.Thethermalproperties ofmostmaterialdovarywithtemperature,sotheanalysisusuallyisnonlinear.Includingradiationeffectsalsomakestheanalysisnonlinear.

The procedure forperformingathermalanalysisinvolvesthreemaintasks:

- Build the model.
- Applyloadsandobtainthesolution.
- Reviewtheresults

9.Results of Thermal Analysis

○ **Thermal RESULTS OF N155**



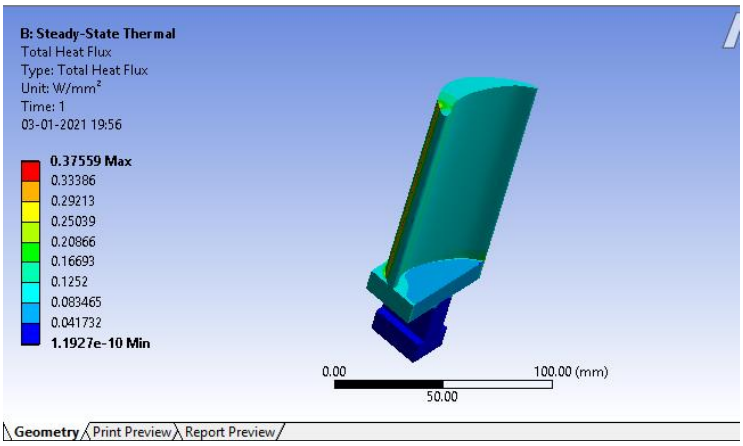
B: Steady-State Thermal
Temperature
Type: Temperature
Unit: °C
Time: 1
03-01-2021 20:08

TEMPERATURE

Results

Object Name	*Temperature*
State	Solved
Scope	
Scoping Method	Geometry Selection

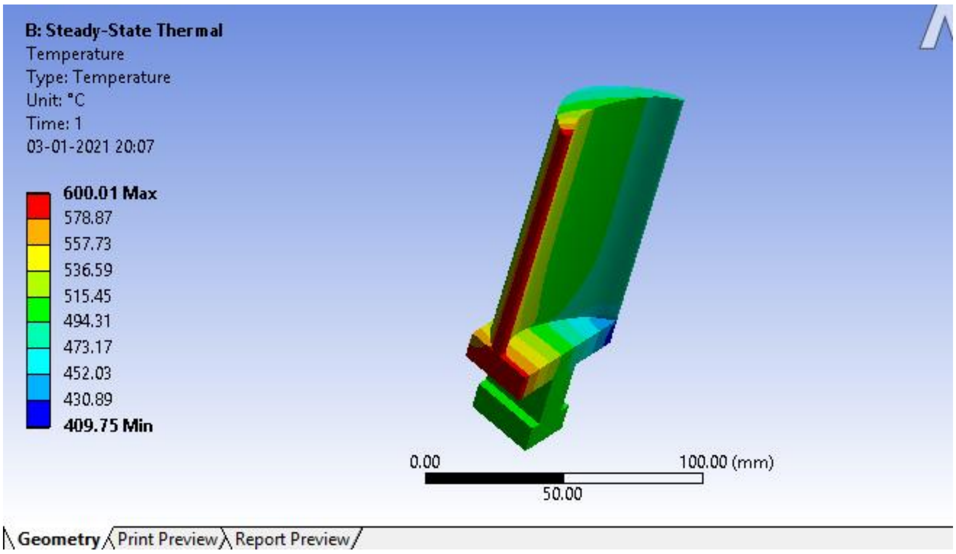
Geometry	All Bodies
Definition	
Type	Temperature
By	Time
Display Time	Last
Calculate Time History	Yes
Identifier	
Suppressed	No
Results	
Minimum	405.47 °C
Maximum	604.26 °C
Information	
Time	1. s
Load Step	1
Substep	1
Iteration Number	1



B: Steady-State Thermal
Total Heat Flux
Type: Total Heat Flux
Unit: W/mm^2
Time: 1
03-01-2021 19:56

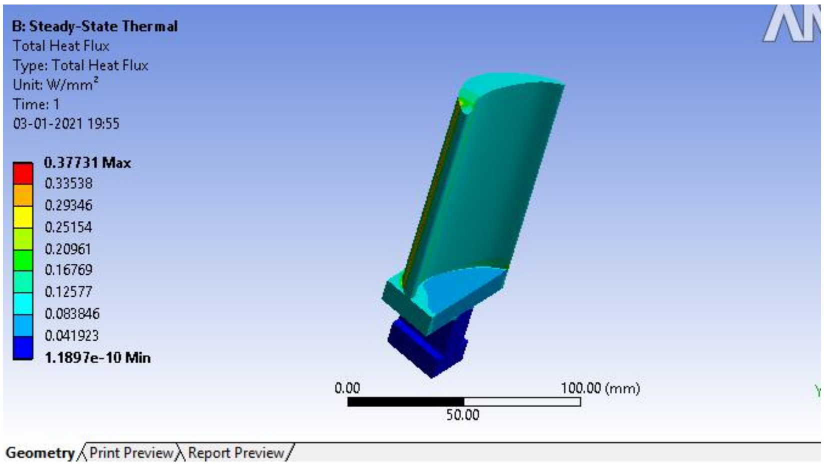
TOTAL HEAT FLUX

Results	
Minimum	**1.1927e-010 W/mm^2**
Maximum	**0.37559 W/mm^2**



TEMPERATURE

Object Name	*Temperature*
Results	
Minimum	**409.75 °C**
Maximum	**600.01 °C**



Results	
Minimum	**1.1897e-010 W/mm²**
Maximum	**0.37731 W/mm²**

RESULTS & DISCUSSIONS

Structural Analysis

From the results of static structural gas turbine blade, Theanalysed value compared with both material the inconnel 725 results obtained values are less in deformation and more in stress compared with N155.

Thermal analysis:

The temperature variation obtained as shown in fig. From figure, it is observed that the temperature variations of materials are varying from 600 ^{o}C to 604 ^{0}C throughout the blade and the variation is linear along the path from both inside and outside of the blade.

CONCLUSION

The finite element analysis for structural and thermal anaysis of gas turbine rotor blade is carried out using ansys 14.0. The temperature has a significant effect on the overall turbine blades. Maximum elongations and temperatures are observed at the blade tip section and minimum elongation and temperature variations at the root of the blade. Maximum stresses are observed at the root of the turbine blade and upper surface along the blade roots two different materials of construction i.e., N-155 and Inconel 725 materials. It is found that the temperature has a significant effect on the overall stresses induced in the turbine blades. The blade temperatures attained induced are lesser for Inconel 725 material, less in deformation and more in stress compared with N155. as it has better thermal and structural properties.

REFERENCES

1)S.Gowreesh, N.Sreenivasalu Reddy andN.V.Yogananda Murthy. “CONVECTIVE HEAT TRANSFER ANALYSIS OF a AERO GAS TURBINE BLADE USING ANSYS”, International journal of Mechanics of solids, vol4, No.1, March 2009

2) P.Kauthalkar, Mr.DevendraS.Shikarwar, and Dr.Pushapendra Kumar Sharma. “ANLYSIS OF THERMAL STRESES DISTRIBUTION PATTERN ON GAS TURBINE BLADE USING ANSYS”, International journal ofEngineering Education and technology, Vol.2, No.3, Nov 2010.

3) John.V, T.Ramakrishna. “THE DESIGN AND ANALYSIS OF GAS TURBINE BLADE”, International Journal of Advanced Research andStudies, Vol 2, No.1, Dec 2012.

4) V.RagaDeepu, R.P.KumarRopichrla. “DESIGN AND COUPLED FIELDANALYSIS OF

FIRST STAGE GAS TURBINE ROTOR BLADES", International journal of Mathematics and Engineering, Vol 13, No.2, Pages: 1603-1612.

5) S.S.Rao,"The Finite Element method in Engineering", BH Publications New Delhi, 3rd Edition, 1999.

6) R D V Prasad , G Narasa Raju , M S S Srinivasa Rao , N Vasudeva Rao "STEADY STATE THERMAL & STRUCTURAL ANALYSIS OF GAS TURBINE BLADE COOLING SYSTEM".

7)V. Veeraragavan "EFFECT OF TEMPERATURE DISTRIBUTION IN 10C4/60C50 GAS TURBINE BLADE MODEL USING FINITE ELEMENT ANALYSIS".

8) H.S.Manohar **,** Finite Element Method ,first edition.

9) Jack D Mattingly, "Elements of Propulsion: Gas Turbine and Rockets

10) Timoshenko, "STRENGTH OF MATERIALS PART 1" third edition