

MODELLING AND FINITE ELEMENT ANALYSIS OF GAS TURBINE BLADES

Submitted in partial fulfillment of the requirements for the
award of Bachelor of Engineering in Mechanical Engineering

By

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**DEPARTMENT OF MECHANICAL ENGINEERING
SCHOOL OF MECHANICAL ENGINEERING**

SATHYABAMA

**INSTITUTE OF SCIENCE AND TECHNOLOGY
(DEEMED TO BE UNIVERSITY)**

**Accredited with Grade "A" by NAAC | 12B Status by UGC | Approved by AICTE
JEPPIAAR NAGAR, RAJIV GANDHI SALAI, CHENNAI - 600 119**

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BONAFIDE CERTIFICATE

This is to certify that this Project Report is the bonafide work of K SURIYA (37150188), M SYED MUDASIR (37150190) who carried out the project entitled “MODELLING AND FINITE ELEMENT ANALYSIS OF GAS TURBINE BLADE” under my supervision.

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Internal Examiner

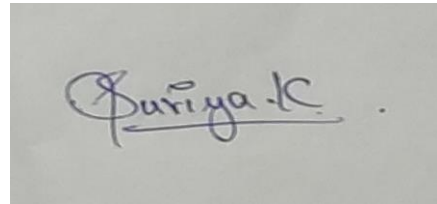
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DECLARATION

I K SURIYA hereby declare that the Project Report entitled **MODELLING AND FINITE ELEMENT ANALYSIS OF GAS TURBINE BLADE** done by me under the guidance of Mr. R. KUMAR SUBRAMANIAN is submitted in partial fulfillment of the requirements for the award of Bachelor of Engineering in Mechanical Engineering.

DATE:

PLACE:

A rectangular box containing a handwritten signature in blue ink. The signature appears to be 'Suriya K.' with a horizontal line underneath the name.

SIGNATURE OF THE CANDIDATE

ACKNOWLEDGEMENT

I am pleased to acknowledge my sincere thanks to Board of Management of SATHYABAMA for their kind encouragement in doing this project and for completing it successfully. I am grateful to them.

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ABSTRACT

Withstanding of turbine blades for the elongations may be a major consideration in their properties because they're subjected to high tangential, axial, centrifugal forces during their working conditions. Several methods are suggested for the higher enhancement of the mechanical properties of blade to face up to 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 with the help of the spline and extrude options ANSYS 14.0 software is used for model meshing of the blade and thereby 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.

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LIST OF SYMBOLS AND ABBREVIATIONS

F_a	AXIAL FORCE
F_c	CENTRIFUGAL FORCE
F_t	TANGENTIAL FORCE
E	YOUNG'S MODULUS
D	DEFLECTION
M	POISSON'S RATIO
S	STRESS
L	LENGTH
D	DIAMETER OF SHAFT
N	SPEED OF TURBINE IN RPM
A	COEFFICIENT OF THERMAL EXPANSION
Re	REYNOLD'S NUMBER
Nu	NUSSELT NUMBER
Pr	PRANDTL NUMBER
V	VELOCITY
V_w	WHIRL VELOCITY
V_f	FLOW VELOCITY
V_r	RELATIVE VELOCITY

h_s	CONVECTIVE HEAT TRANSFER CO-EFFICIENT IN SUCTION SIDE
h_p	CONVECTIVE HEAT TRANSFER CO-EFFICIENT IN PRESSURE SIDE
H_r	HEAT TRANSFER CO-EFFICIENT
$h_{f_{inlet}}$	CONVECTIVE HEAT TRANSFER CO-EFFICIENT AT INLET
$h_{f_{exit}}$	CONVECTIVE HEAT TRANSFER CO-EFFICIENT AT EXIT
LNG	LIQUID NATURAL GAS
FEM	FINITE ELEMENT METHOD
CMM	COORDINATE MEASURING MACHINE

1. INTRODUCTION

1.1 GENERAL

The purpose of turbine technology are to extract the utmost quantity of energy from the working fluid to convert it into useful work with maximum efficiency by means of a plant having maximum reliability, minimum cost, minimum supervision and minimum beginning. The turbine obtains its power by utilizing the energy of burnt gases and therefore the air which is at heat and pressure by expanding through the several rings of fixed and moving blades. To get a high of order 4 to 10 bar of working fluid where fuel is continuously burnt with compressed gas to supply a steam of hot, fast moving gases shown in figure 1.1.

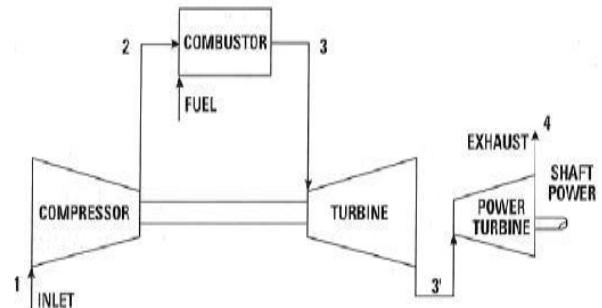


FIG: 1.1: GAS TURBINE AND ITS BLOCK DIADRAM.

This gas stream is employed to power the compressor that supplies the air to the engine also as providing excess energy which will be wont to do other work, which is important for expansion a compressor, is required. The speed and the quantity of the working fluid required are high so commonly a centrifugal or an axial compressor is required.

The turbine drives the compressor so it's coupled to the turbine shaft. If after compression the working fluid were to be expanded during a turbine, then assuming that there have been no losses in either component, the facility developed by the turbine

can be increased by increasing the quantity of working fluid at constant pressure or alternatively increasing the pressure at constant volume.

Either of those could also be done by adding heat in order that the temperature of the working fluid is increased after compression. To get a better 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 are constructed to figure on the following: -oil, gas, coal gas, air gas, furnace and pulverized coal.

1.2 ESSENTIAL PARTS OF GAS TURBINE

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 are generally located at the front of the engine. There are two main sorts of compressor, the centrifugal compressor and therefore the axial compressor. The compressor will attract air and compress it before it's fed into the combustion chamber. In both types, the compressor rotates and it's driven by a shaft that passes through the center of the engine and is attached to the turbine as shown below in fig.1.2.

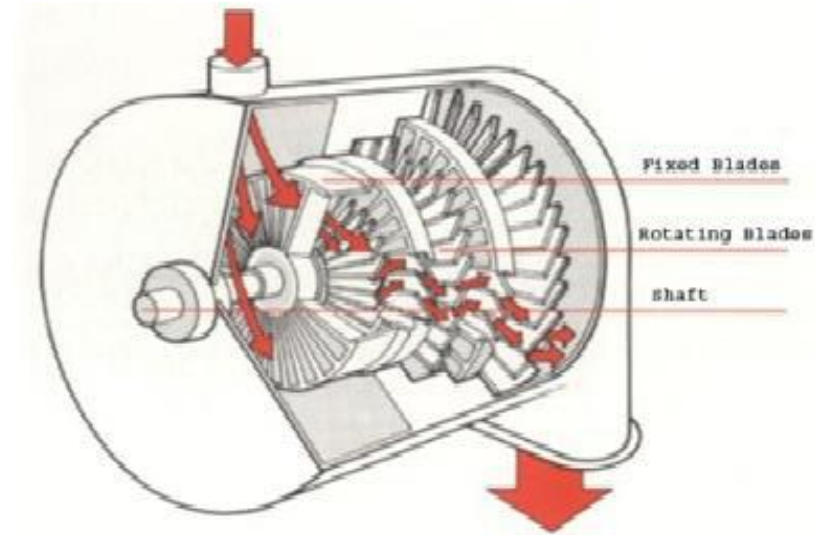


FIG: 1.2: TURBINE BLADE COUPLED TO CENTRIFUGAL COMPRESSOR

1.3 FUEL FOR GAS TURBINE POWER PLANT

Gas turbine fuel systems are familiar to all the Turbines. For the foremost common fuels, which are gas, LNG (liquid natural gas), and lightweight diesel, the equipment consists: A fuel delivery system, Fuel nozzles, Fuel additives (to deal with vanadium), Fuel washing (to affect sodium and potassium Salts) and Modifications to the fuel delivery system.

1.3.1 NATURAL GAS

Natural gas comprises over 80% methane with minimum amounts of ethane, propane, butane, and heavier hydrocarbons. It may also include CO₂, nitrogen, and hydrogen. There are a plethora of blends of gas available worldwide.

1.4 TURBINE BLADE

The rotor blades of the turbine are very difficult components and reliable operation of the turbine as a whole depends on their repayable operation. The major explanation for break down in turbo machine is that the failure of rotary wing. The failure of the rotary wing may cause 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 1.3.



FIG: 1.3: TURBINE BLADE

1.4.1 DESIGN FACTOR OF GAS TURBINE BLADES

A good design of the turbine rotor blading involves the following:

1. Determination of geometric characteristics from gas dynamic analysis.
2. Determination of steady loads working 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 supported the cumulative damage fatigue theories.

1.4.2 PRODUCTION OF BLADES

Blades could also be considered to be the guts of turbine and every one other member exist for the sake of the blades. Without blade there would be no power and therefore the slightest fault in blade would mean a discount in efficiency and dear repairs. The following are a number of the methods adopted for production of blades.

1.4.2.1 Rolling: Sections are rolled to the finished size and used in conjunction with packing pieces. Blades manufactured by this method don't fail under combined bending and force.

1.4.2.2 Machining: Blades are also machined from rectangular bars. This method has more or less has an equivalent advantage as that of first. Impulse blade is manufactured by this technique.

1.4.2.3 Forging: Blade and vane sections having airfoil sections are manufactured by specialist techniques.

1.4.2.4 Extrusion: Blades are sometimes extruded and the roots are left on the subsequent machining. This technique is not reliable as rolled sections, because of narrow limits imposed on the composition of blade material.

1.5 TURBINE BLADE COOLING

Unlike steam turbine blading's, gas turbine blading's need cooling. The objective of the blade cooling is to stay the metal temperature at a secure level to make sure an extended creep life and low oxidation rates. Although it's possible to chill the blades by liquid using thermo syphon and warmth pipe principal, but the universal method of blade cooling is by cool air or working fluid flowing through internal passage within the blades. The mean rotor blade temperature is about 3500C below the prevailing gas temperature after efficient blade cooling as shown below in figure 1.4.



FIG: 1.4: TURBINE BLADE COOLING

Due to corrosion and its deposits turbine blades may fail. To prevent it from corrosion, the uses of pack-aluminized coatings are used. The major elements used are aluminum, nickel, and chromium.

The turbine obtains its power by utilizing the energy of burnt gases and therefore the air which is at heat and pressure by expanding through the several rings of fixed and moving blades, to urge a high of order of 4 to 10 bar of working fluid which is important for expansion a compressor is required. The speed and quantity of working fluid required are high, so commonly a centrifugal or axial compressor is required. The turbine drive the compressor so it's coupled to the turbine shaft, If after compression the working fluid were to be expanded during a turbine, then assuming that there were no losses in either component, the facility developed by the turbine are often increased by increasing the quantity of working fluid at constant pressure or alternatively increasing the pressure at constant volume. Either of there may be done by increasing heat so that the working fluid temperature is increased after compression. To get a better 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. The turbine escapes energy from the exhaust gas. Like the compressor, turbine are often centrifugal or axial. In each type the fast paced exhaust gas is sued to spin the turbine, since the turbine is attached to an equivalent shaft because the compressor at the front of the engine, and therefore the compressor will turn together, the turbine may extract only enough energy to show the compressor.

The remaining of the exhaust gas is left to exit the rear of the engine to supply thrust as in a pure jet engine. Or extra turbine stages could also be went to turn other shafts to power other machinery like the rotor of a helicopter, the propellers of a ship or electrical generators in power stations. The present paper deals with the primary type is centrifugal stresses that 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 finite element analysis of turbine blade mainly consider of the following two sorts: Structural and thermal analysis. The analysis is administered under steady state conditions using ANSYS software. The study has been conducted with three different materials N155, & Inconel 725.

1.6 APPLICATION OF GAS TURBINE

The following are the applications of gas turbine as shown in figure 1.5.

- 1.** Land Applications
- 2.** Space Applications
- 3.** Marine application



FIG: 1.5: APPLICATIONS OF GAS TURBINE

2. LITRATURE SURVEY

2.1. CONVECTIVE HEAT TRANSFER ANALYSIS OF AN AERO GAS TURBINE BLADE USING ANSYS

S.Gowreesh et.al(1) studied on the primary stage rotary blade of a two stage turbine has been analyzed for structural, thermal, modal analysis using ANSYS 11.0.which may be a powerful Finite Element Method software. The temperature distribution within the rotor blade has been evaluated using this software. The design features of the turbine segment of the turbine are taken from the preliminary design of an influence turbine for maximization of an existing turbo reaction propulsion engine. It has been felt that a detail study are often administered on the temperature effects to possess a transparent understanding of the combined mechanical and thermal stresses.

2.2. ANALYSIS OF THERMAL STRESSES DISTRIBUTION PATTERN ON GAS TURBINE BLADE USING ANSYS

Kauthalkar et.al (2) the scope of gas turbine technology is to produce, high quantity of energy from the working fluid and to convert it into useful work with high efficiency. That means, the turbine having maximum reliability, minimum cost, minimum supervision and minimum beginning. The turbine get its power by utilizing the energy of hot gases and the air. This is at heat and pressure by expanding through the several rings of fixed and moving blades. A high of order 4 to 10 bar of working fluid which is important for expansion, a compressor is required. The speed and the quantity of working fluid required are high so commonly a centrifugal or axial compressor is required. The turbine drives the compressor so it's coupled to the turbine shaft.

2.3. THE DESIGN AND ANALYSIS OF GAS TURBINE BLADE

John.v et.al (3) studied on the planning and analysis of turbine blade, CREO is employed for design of solid model and ANSYS software for analysis for F.E.model generated, by applying boundary condition, this analysis consists certain post-processing and life evaluation 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. It is to demonstrate the preprocessing qualities, 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 safe of the turbine blade.

2.4. DESIGN AND COUPLED FIELD ANALYSIS OF FIRST STAGE GAS TURBINE ROTOR BLADE

V.Raga Deepu et.al (4) Studied on a turbine may be a device designed to convert the warmth energy of fuel into work like mechanical shaft power. Turbine Blades are most essential parts in a gas turbine power plant. A blade are often defined because 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 special notable effect on the blades. Therefore the coupled (static and thermal) analysis of turbine blades is administered using finite element analysis software ANSYS. In this paper the primary stage rotary wing of the turbine is made in CREO V5 R15 Software. This model has been analyzed using ANSYS 11.0. The gas forces like tangential, axial were determined by constructing velocity triangles at inlet and exist of turbine blades. After containing the heat transfer coefficients and gas forces, the rotary wing was then analyzed using ANSYS 11.0 for the couple field (static and thermal) stresses.

3. EXSISTING AND PROPOSED SYSTEM

3.1 COMPUTER AIDED ANALYSIS

The model is created and analyzed using CREO and ANSYS. For automatic mesh generation and node selection is employed. The structural, thermal modal modules of ANSYS 11.0 are used for the analysis of the turbine blade. The turbine blade was analyzed for mechanical stresses, temperature distribution, combined mechanical and thermal stresses and radial elongations, natural frequencies and mode shapes. The blade is then analyzed series with thermal analysis previous structural analysis. The model is discretized using 8 noded plane element (plane 82) & solid 95 3D 20-nodes structural solid element.

3.2 FINITE ELEMENT METHOD

The finite element method (FEM) has now become a really important tool of engineering analysis. Its versality is reflected in its popularity among engineers and designers belonging to just about all the engineering disciplines. Whether an engineer designing bridges, dams or a mechanical engineers designing auto engines, rolling mills, machine tools or an engineer curious about analysis of dynamics of an aero plane or temperature rise within the protective covering of an area shuttle or a metallurgist concerned about the influence of a rolling operation on the microstructure of a rolled product or an engineer curious about the analysis of the electromagnetic field in electrical machinery-all find the finite element method handy and useful. It's not that these issues remains unproved before the finite element method came into vogue; rather this method has become popular due to its relative simplicity of approach and accuracy of results. Traditional methods of engineering analysis, while attempting to unravel an engineering problem mathematically, always go for simplified formulation so as to beat the varied complexities involved in exact mathematical formulation. In the

fashionable technological Environment the traditional methodology of design cannot compete with the modern trends of Computer Aided Engineering (CAE) techniques. The constant look for new innovative design within the engineering field may be a common trend. To build highly optimized product, this is often the essential requirement of today for survival within the global market. All round efforts were suggested during this direction. Software professional and technologists have developed several design packages.

3.3 EXSISTING SYSTEM

TABLE: 3.1: MATERIAL PROPERTIES OF N155

PROPERTIES	UNITS	N155
DENSITY	Kg/m ³	8249
YOUNG'S MODULUS	MPa	143000
POISSON'S RATIO	NO UNITS	0.34
YIELD STRESS	MPa	550
THERMAL CONDUCTIVITY	W/mK	20.0
MELTING POINT	⁰ C	1354

TABLE: 3.2: CHEMICAL COMPOSITION OF N155

NICKEL (Ni)	21
CHROMIUM	22.5
MOLYBDENUM	3.5
NIOBIUM,TANTALUM	1.25
TUNGSTEN	3
NITROGEN	0.2
CARBON	0.16
MANGANESE	2
SILICON	1
PHOSPHOROUS	0.04
SULPHUR	0.03
COBALT	21
IRON	BALANCE

3.4 PROPOSED SYSTEM

TABLE: 3.3: CHEMICAL COMPOSITION OF INCONEL 725

NICKEL (Ni)	59
CHROMIUM	22.5
MOLYBDENUM	9.5
NIOBIUM	4.0
TITANIUM	1.7
ALUMINIUM	0.35
CARBON	0.03
MANGANESE	0.35
SILICON	0.20
PHOSPHOROUS	0.015
SULPHUR	0.010
IRON	BALANCE

TABLE: 3.4: MATERIAL PROPERTIES OF INCONEL 725

PROPERTIES	UNITS	INCONEL 725
DENSITY	Kg/m ³	8310
YOUNG'S MODULUS	MPa	204000
POISSON'S RATIO	NO UNITS	0.31
YIELD STRESS	MPa	917
THERMAL CONDUCTIVITY	W/mK	21.2
MELTING POINT	⁰ C	1343

4. ANALYSIS OF GAS TURBINE BLADE

4.1 EVALUATION OF GAS FORCE

Tangential (F_t) and axial (F_a) are the two gases commonly acting on the rotor blades of the turbine. These are the resultant forces from the gas momentum changes and from pressure differences across the blades. These gas forces are determined by the construction of velocity triangles at inlet and outlet of the turbine blade. The rotor blades referred for analysis were untwisted and same profile is taken throughout the length of the blade. If the gas forces are considered to be supplied evenly then the resultant force acts through the centroid of the area.

At the inlet of the first stage turbine rotor blades,

Absolute flow angle $\alpha = 23.850$

Absolute velocity $V_1 = 462.21 \text{ m/s}$

The velocity triangles at the inlet of primary stage rotor blades were constructed

Blade mid span diameter $D = 1.3085 \text{ m}$

Design speed of turbine $N = 3426 \text{ rpm}$

Peripheral speed of rotary blade at its mid span, $U = \pi DN/60$

From the speed triangles in figure 9 we get,

Whirl velocity $V_{w1} = 422.74 \text{ m/s}$

Flow Velocity $V_{f1} = 186.89 \text{ m/s}$

Relative velocity, $V_{r1} = 265.09 \text{ m/s}$

Blade angle at inlet, $\theta = 135.017^\circ$

At the exit of the primary stage rotor blades,

Flow velocity, $V_{f2} = 180.42 \text{ m/s}$

Relative flow angle, $\Phi = 37.88^\circ$

The velocity triangles at the exit of the first stage rotor blades as were constructed

From the velocity triangles Fig.4.1, we get,

Whirl velocity, $V_{w2} = 2.805 \text{ m/s}$

Relative velocity, $V_{r2} = 293.83 \text{ m/s}$

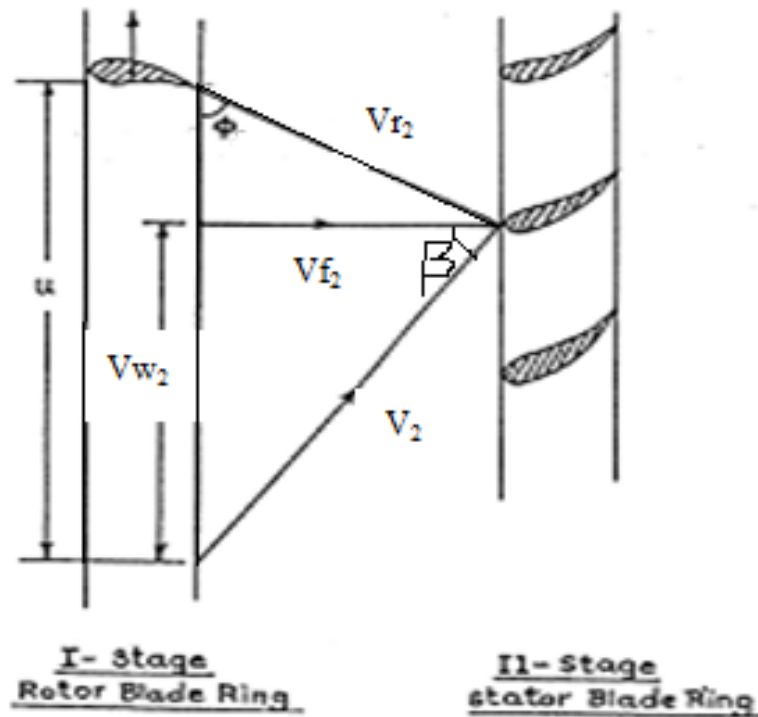


FIG: 4.1: EXIT VELOCITY TRIANGLE OF I STAGE ROTOR BLADE

The gas forces and power developed within the first stage rotor blades were evaluated using the equations that were used for first stage rotor blades.

Tangential force $F_t = 248.199$ Newton

Axial force $F_a = 3.82$ Newton.

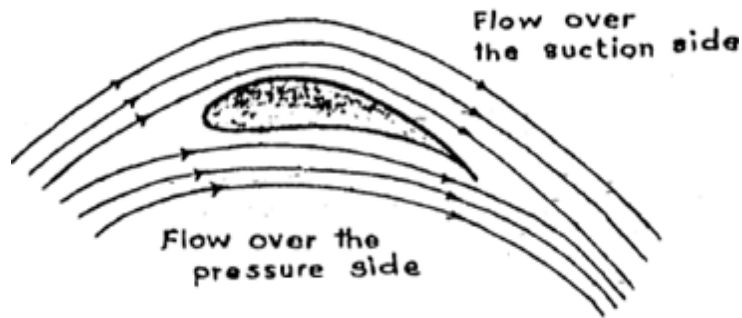
Power developed $P = 6.991$ megawatts.

Centrifugal force $F_c = 38038.73$ Newton

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

4.1.1 CONVECTIVE HEAT TRANSFER

The flows over suction and pressure side of rotor blade as shown in figure.4.2.



**FIG: 4.2: GAS FLOW OVER SUCTION AND PRESSURE SIDE OF ROTOR BLADE
AT TEMPERATURE OF 619° C**

Convective Heat Transfer Coefficients on Suction side of Rotary turbine Blades

$$h_s = 379.92 \text{ w/m}^2 \text{ k.}$$

Convective Heat Transfer Coefficients on the Pressure side of Rotary turbine Blades

$$h_p = 284.95 \text{ w/m}^2 \text{K.}$$

$$Q \text{ Heat Flow Rate} = h_{\text{gas}} \times A \times \Delta t = 379.92 \times 0.0072368 \times 619 - 30 = 1619.4 \text{ W}$$

Convective Heat Transfer Coefficient (hr) on the Two Rectangular Faces at inlet and Exit of Rotor Blades as shown in figure 4.3.

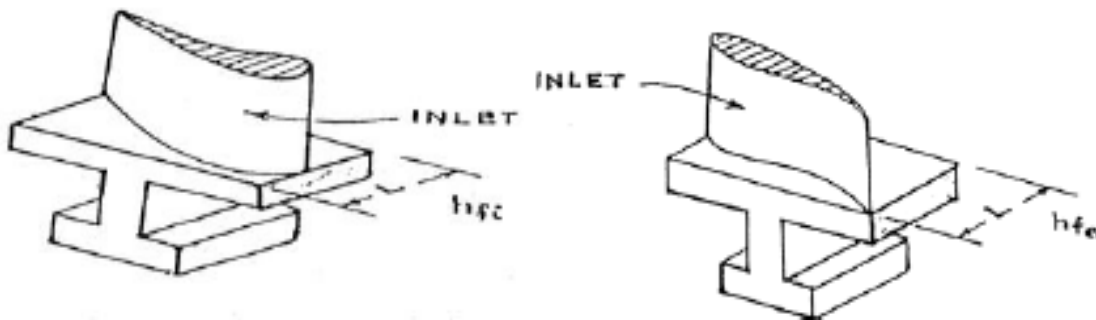


FIG: 4.3: INLET AND EXIT OF THE ROTOR BLADE

Convective heat transfer coefficients on the rectangular face at inlet of turbine Blades

$$hf_{\text{inlet}} = 231.195 \text{ w/m}^2 \text{ K.}$$

Convective heat transfer coefficients on the rectangular face at exist of turbine Blades

$$hf_{\text{exit}} = 224.73 \text{ w/m}^2 \text{ K}$$

4.2 STRUCTURAL ANALYSIS OF GAS TURBINE ROTOR BLADE

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 4.1. Then variety of splines were fitted through the key points. A rectangle of dimensions 49*27 mm was generated as shown in fig4.4.

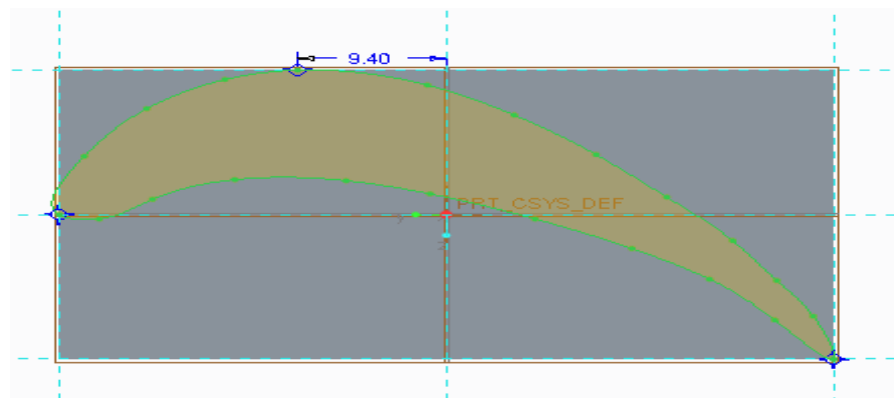


FIG: 4.4: Boundary of Aero Foil Section

TABLE: 4.1: LIST OF KEYPOINTS

S.NO	X	Y	S.NO	X	Y
1	0.00	0.00	20	49	0.00
2	2.6	17.3	21	49	27.0
3	5.85	21	22	0.00	27.0
4	10	25	23	19.8	0.0
5	14.8	26.6	24	1.0	13.6
6	22.9	25.3	25	29.2	0.0
7	28	22.2	26	29.2	27.0
8	33.4	18.5	27	19.8	27.0
9	38	14.4	28	15.2	27.0
10	42	10.9	29	18.08	27.0
11	45.5	5.70	30	49.0	0.27E-1
12	49.0	0.00	31	48.9	0.288E-1
13	6.18	12.4	32	29.2	12.49
14	11.2	14.4	33	19.8	26.62
15	16.1	15.5	34	19.8	15.12
16	21.1	14.9	35	29.2	21.25
17	26	13.6	36	0.0	0.30E-1
18	38.2	8.7	37	19.8	0.30E-1
19	45	3.9	38	19.8	15.12

Using splines and features 9 different areas were generated as volumes. In the shape and size option, the amount of element edges along the lines surrounding the areas 1 to 9 was specified. In the attribute option element type 1 and material type 1 were assigned to the 2 areas. Areas 1 to m9 were extruded upwards within the positive Z direction through a height of 5mm. After extrusion, the rectangular block as shown as in figure.4.5 was generated.

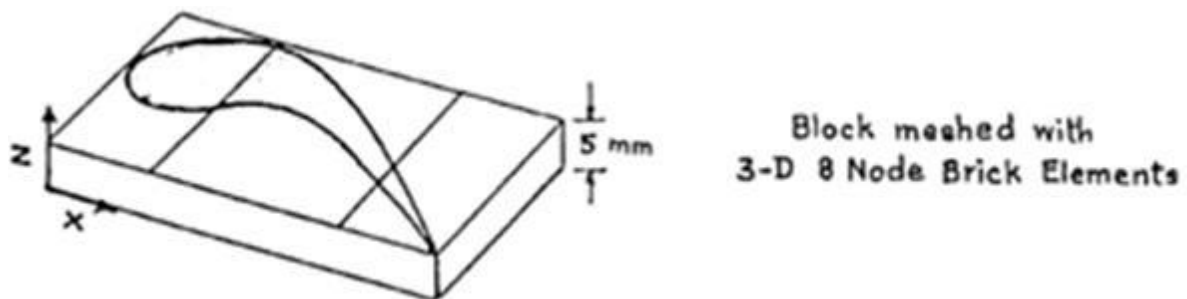


FIG: 4.5 3D 8 NODE BRICK ELEMENT

Again using the extrusion option, the shaded area as shown in figure.4.6 was extruded upwards through the blade height (117 mm) along the positive Z direction, Areas 4,5,6 were extruded downwards along the negative direction through a distance 14.5 mm. The model was generated as shown in figure.4.7 by use in the preprocessor of ANSYS14.

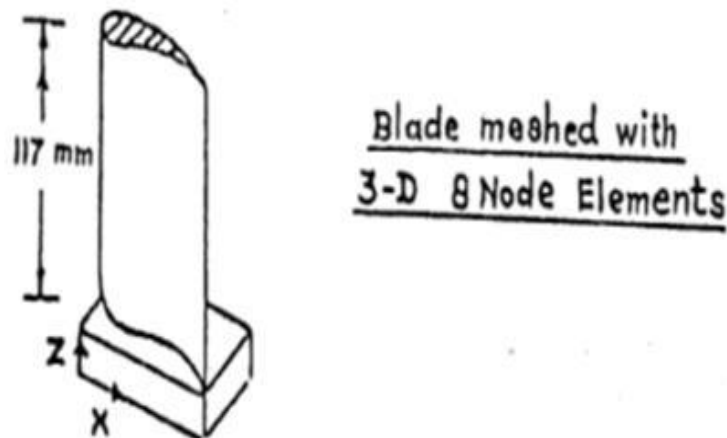


FIG: 4.6 EXTRUDED 3D 8 NODE ELEMENT

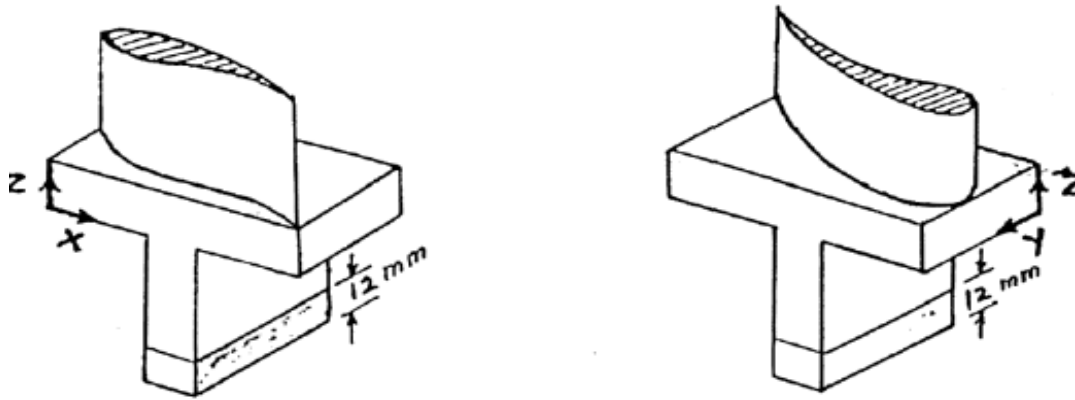


FIG: 4.7 VOLUME OF ROTOR BLADE

The shaded areas shown below in figure 16 were extruded along the X-direction through a distance of 3.8 mm using the mesh option all the areas were meshed with Brick 8-node 185 element as shown in figure.4.8

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 given below. Then a variety of splines were fitted through the key points. A rectangle of dimensions 49 X 27 mm.

4.2.1 3D MESHED MODEL OF TURBINE BLADE

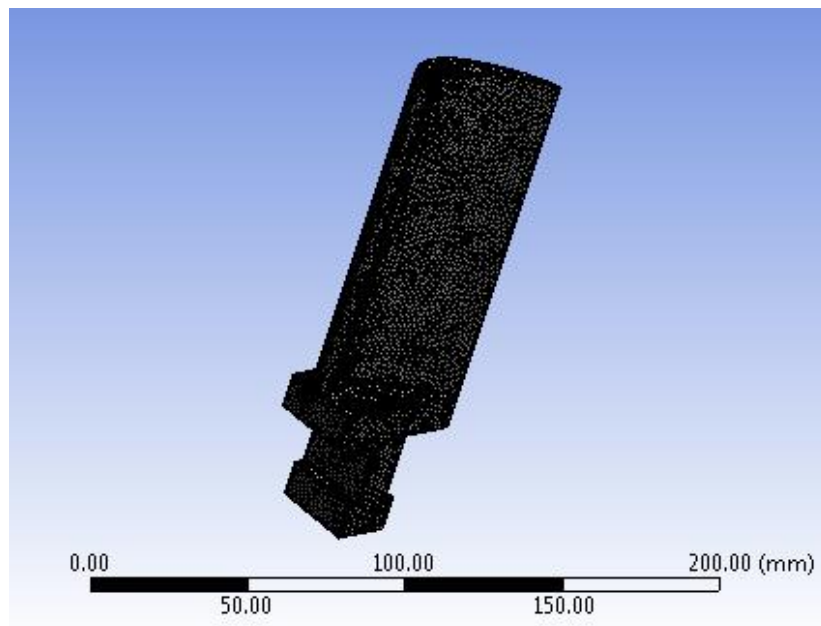


FIG: 4.8 3D MESHED MODEL OF TURBINE BLADE

TABLE. 4.2 STATISTICS OF MESHED BLADE

Statistics	
Nodes	75875
Elements	45077
Mesh Metric	None

4.2.2 LOADS AND BOUNDARY CONDITIONS

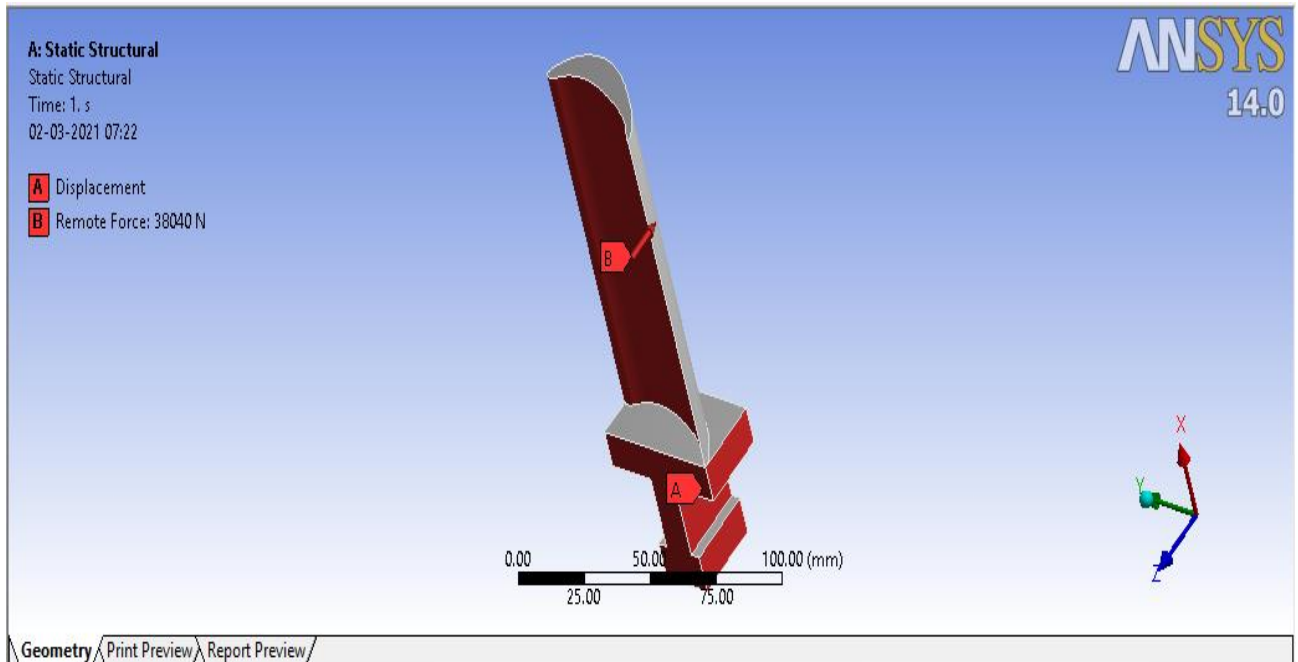


FIG: 4.9 TURBINE BLADE WITH LOADS AND BOUNDARY CONDITIONS

TABLE: 4.3: LOADS AND BOUNDARY CONDITIONS

Object Name	Displacement	Remote Force
State	Fully Defined	
Scope		
Scoping Method	Geometry Selection	
Geometry	8 Faces	1 Face
Coordinate System		Global Coordinate System
X Coordinate		70.5 mm
Y Coordinate		1.6788 mm
Z Coordinate		1.1169 mm
Location		Defined
Definition		
Type	Displacement	Remote Force
Define By	Components	
Coordinate System	Global Coordinate System	
X Component	0. mm (ramped)	-248.2 N (ramped)
Y Component	0. mm (ramped)	-3.82 N (ramped)
Z Component	0. mm (ramped)	-38039 N (ramped)
Suppressed	No	
Behavior		Deformable
Advanced		
Pinball Region		All

4.3 STEADY STATE THERMAL ANALYSIS

A steady-state thermal analysis calculates the consequences of steady thermal loads on a system or component. Engineer/analysts constantly perform a steady-state thermal analysis before performing a transient thermal analysis, to assist establish initial conditions. A steady-state analysis can also be the last step of a transient thermal analysis performed in any case transient effects have diminished. Steady-state thermal analysis is employed to work out temperatures, thermal gradients, heat flow rates, and warmth fluxes in an object that are caused by thermal loads that do not vary over time. Such loads include the following:

- Convections
- Radiation
- Heat flow rates
- Heat fluxes (heat flow per unit area)
- Rate of heat generation (heat flow per unit volume)
- Constant temperature boundaries

A steady-state thermal analysis could also be either linear, with static material properties; or nonlinear, with material properties that based on the temperature. In thermal properties most of the material do vary with temperature, therefore the analysis is generally nonlinear. Including radiation effects also makes the analysis nonlinear.

The following are the three steps to perform a thermal analysis:

- Build the model.
- Apply loads and obtain the solution.
- Review the results.

4.3.1 THERMAL LOAD AND BOUNDARY CONDITIONS

TABLE: 4.4: THERMAL LOAD AND BOUNDARY CONDITIONS

Object Name	Convection	Convection 2	Heat Flow
State	Fully Defined		
Scope			
Scoping Method	Geometry Selection		
Geometry	2 Faces		
Definition			
Type	Convection		Heat Flow
Film Coefficient	231.19 W/m ² ·°C (ramped)	224.73 W/m ² ·°C (ramped)	
Ambient Temperature	30. °C (ramped)		
Suppressed	No		
Define As			Heat Flow
Magnitude			1619.4 W (ramped)

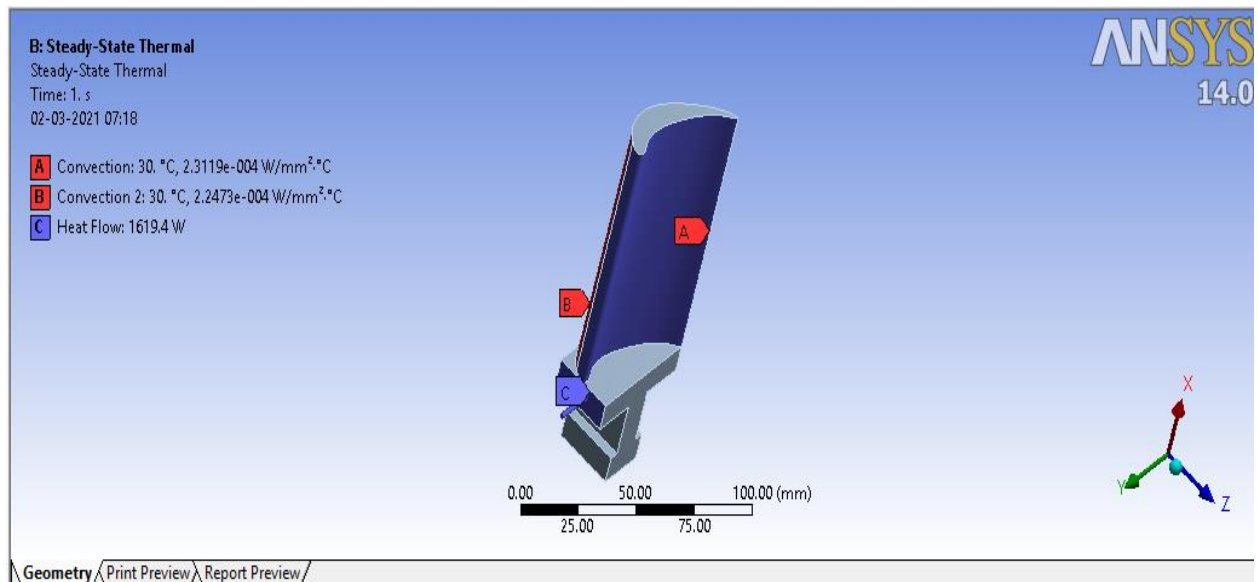


FIG: 4.10 TURBINE BLADE WITH THERMAL LOAD AND BOUNDARY CONDITIONS

4.4 CFD ANALYSIS

Computational Fluid Dynamics (CFD) is the process of mathematically modeling a physical phenomenon involving fluid flow and solving it numerically using the computational prowess. ... A mathematical model of the physical case and a numerical method are used in a CFD software tool to analyze the fluid flow.

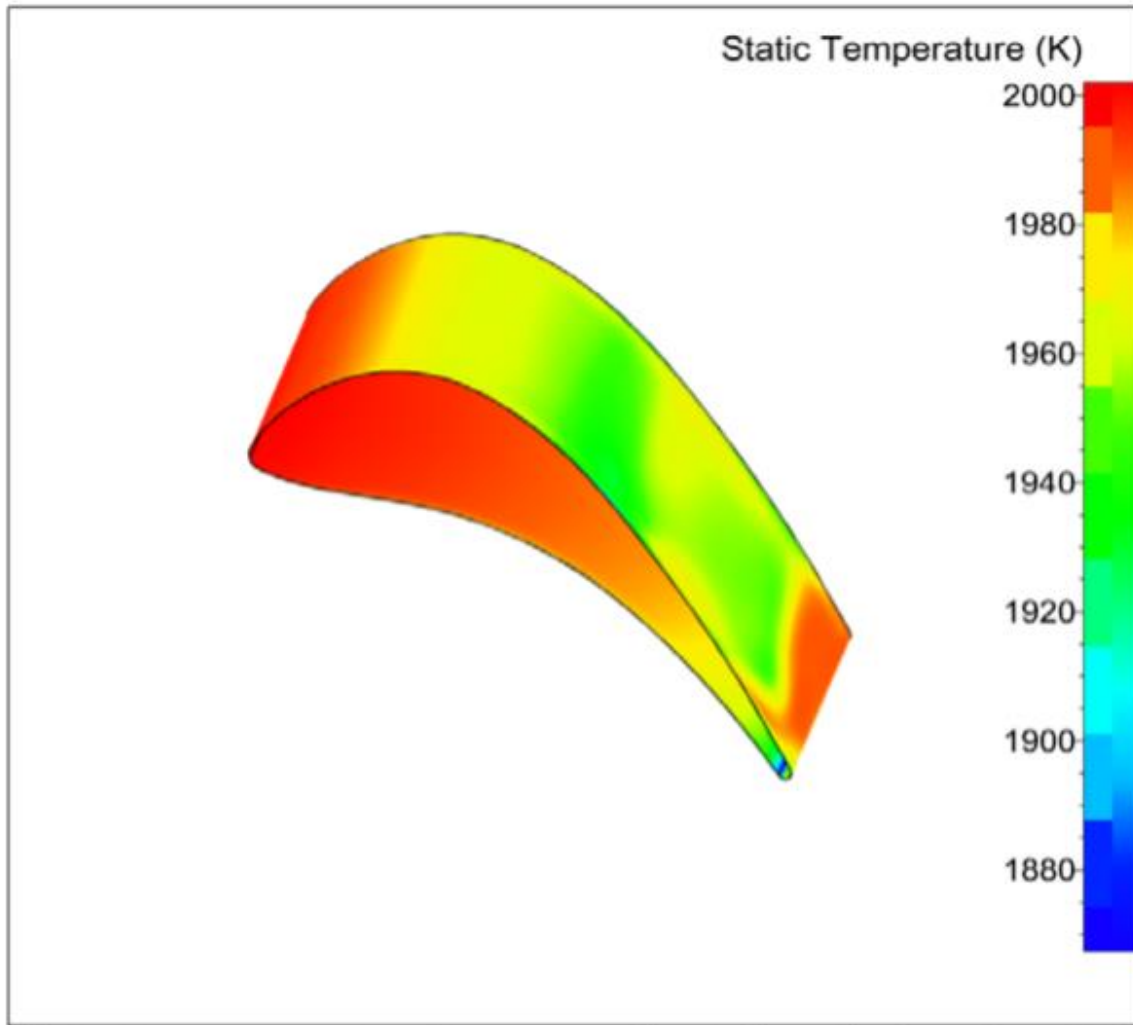


FIG 4.11 TEMPERATURE GRADIENT OF N155

Minimum temperature –1880 K

Maximum temperature –2000 k

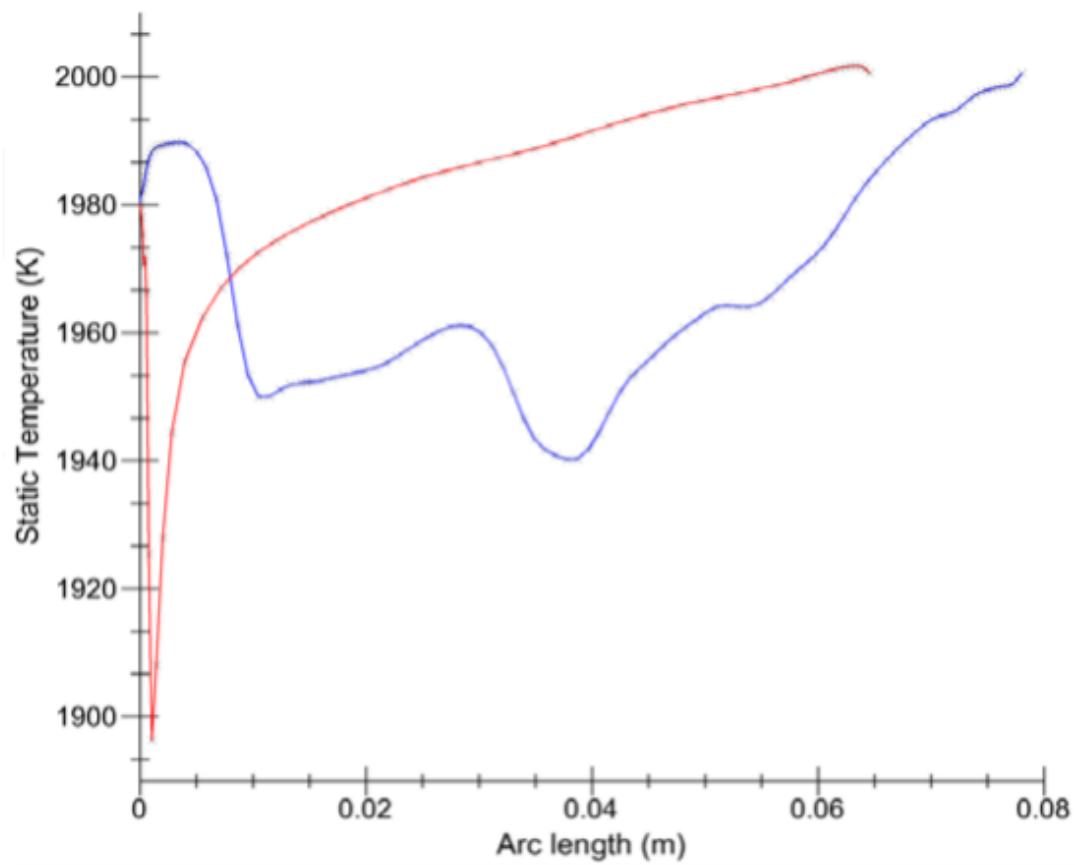


FIG 4.12 GRAPHICAL ANALYSIS OF N155

Minimum temperature – 1940 K

Maximum temperature – 2000 k

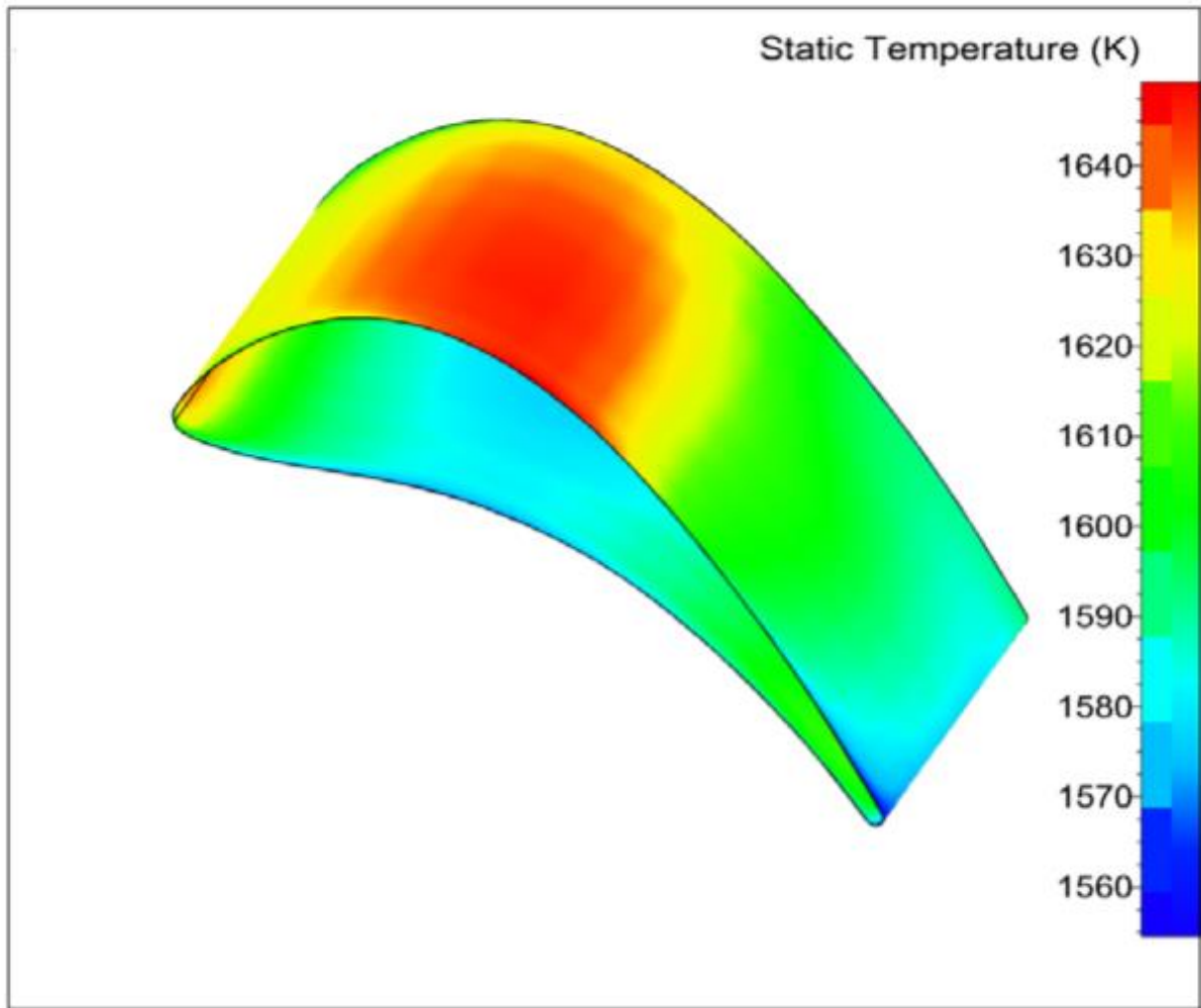


FIG 4.13 TEMPERATURE GRADIENT OF INCONEL 725

Minimum temperature –1560 K

Maximum temperature –1640 k

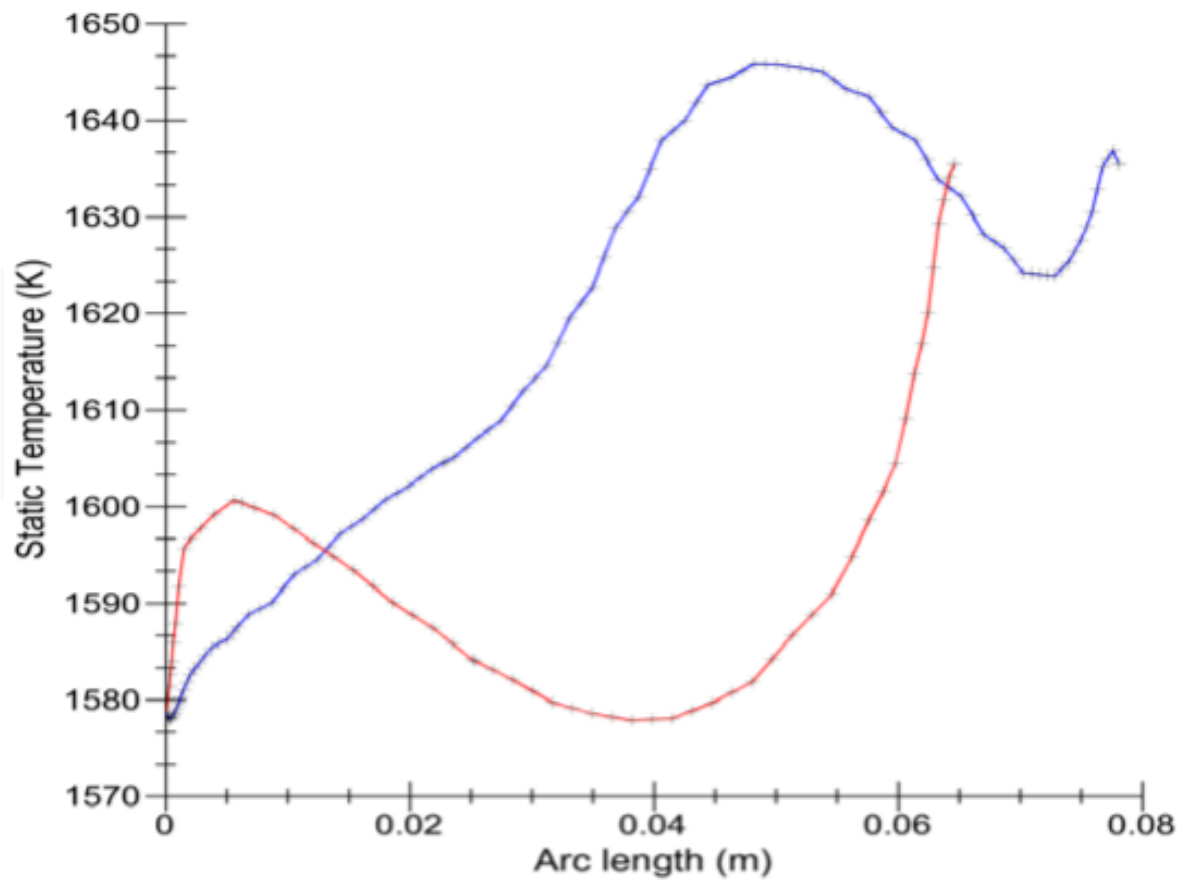


FIG 4.14 GRAPHICAL ANALYSIS OF INCONEL 725

Minimum temperature – 1578 K

Maximum temperature – 1645 k

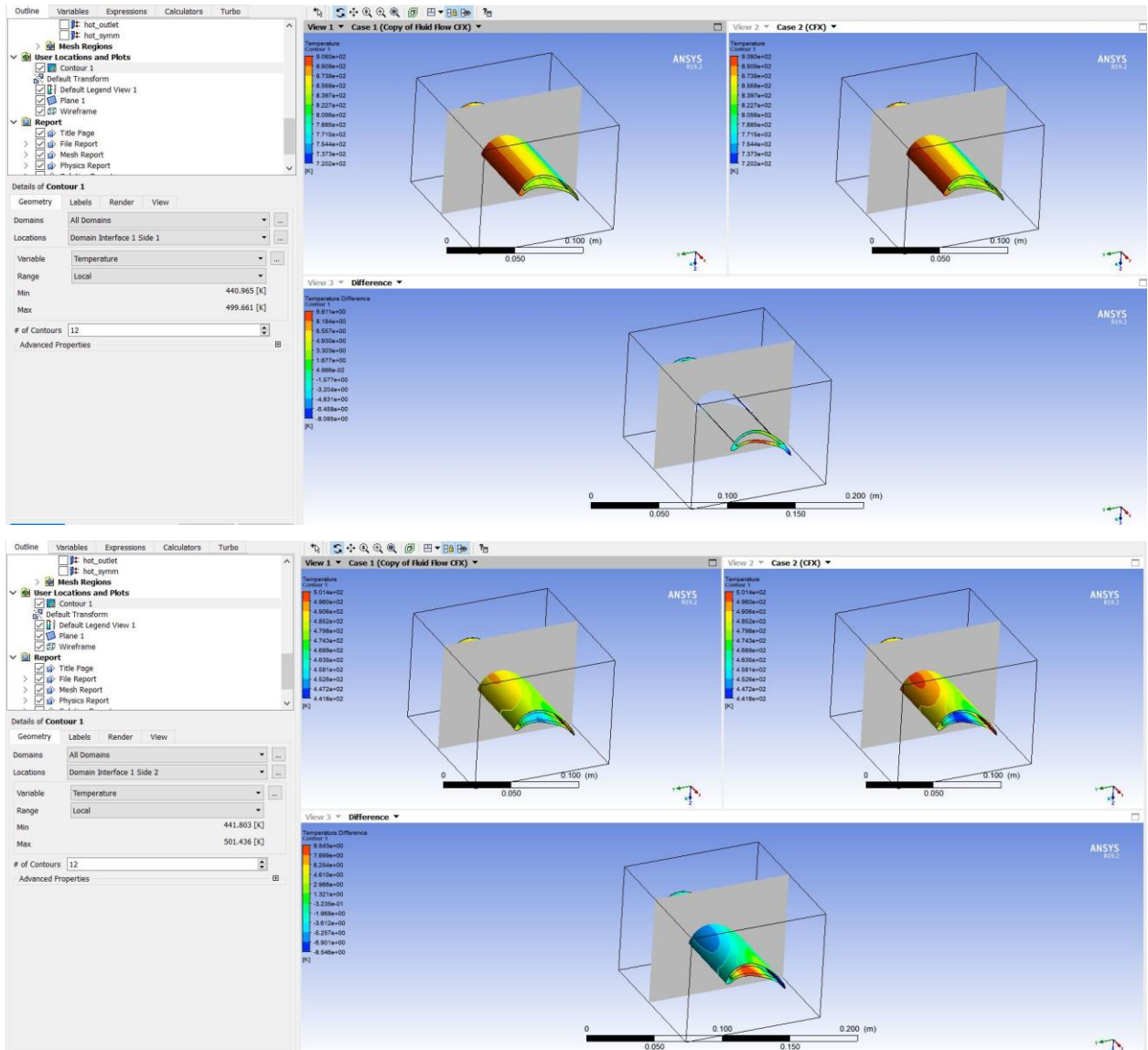


FIG 4.15 HOT INTERFACE – TEMPERATURE COMPARISON BETWEEN INCONEL 725 AND N155

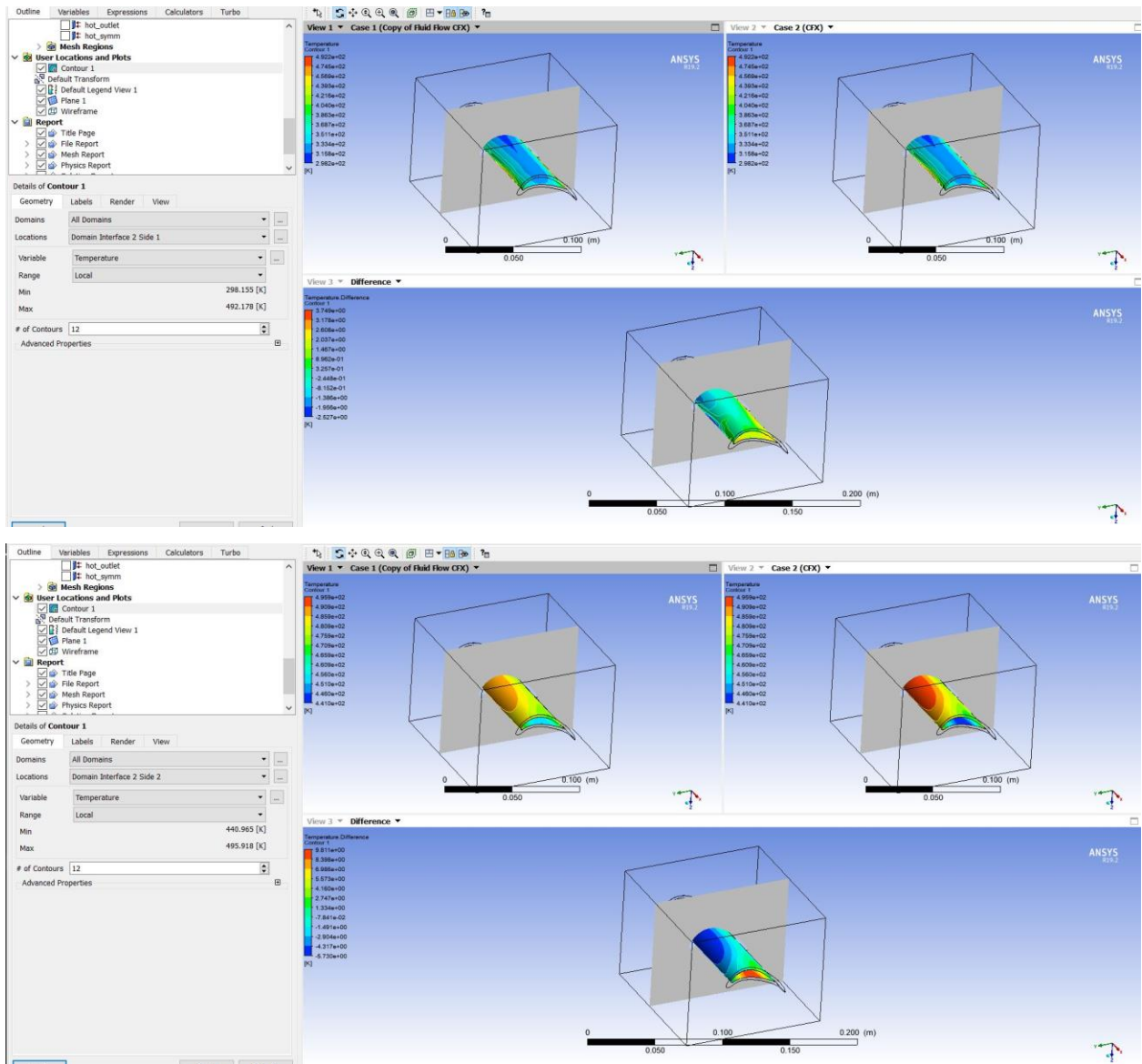


FIG 4.16 COLD INTERFACE – TEMPERATURE COMPARISON BETWEEN N155 AND INCONEL 725

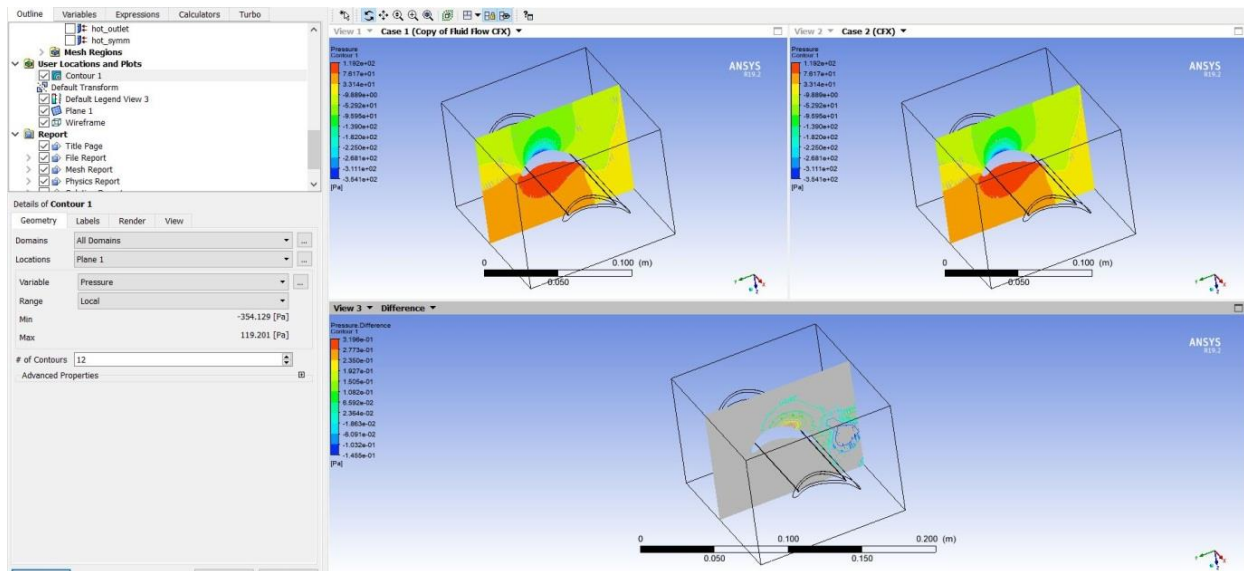


FIG 4.17 PLANE – PRESSURE COMPARISON BETWEEN INCONEL 725 AND N155

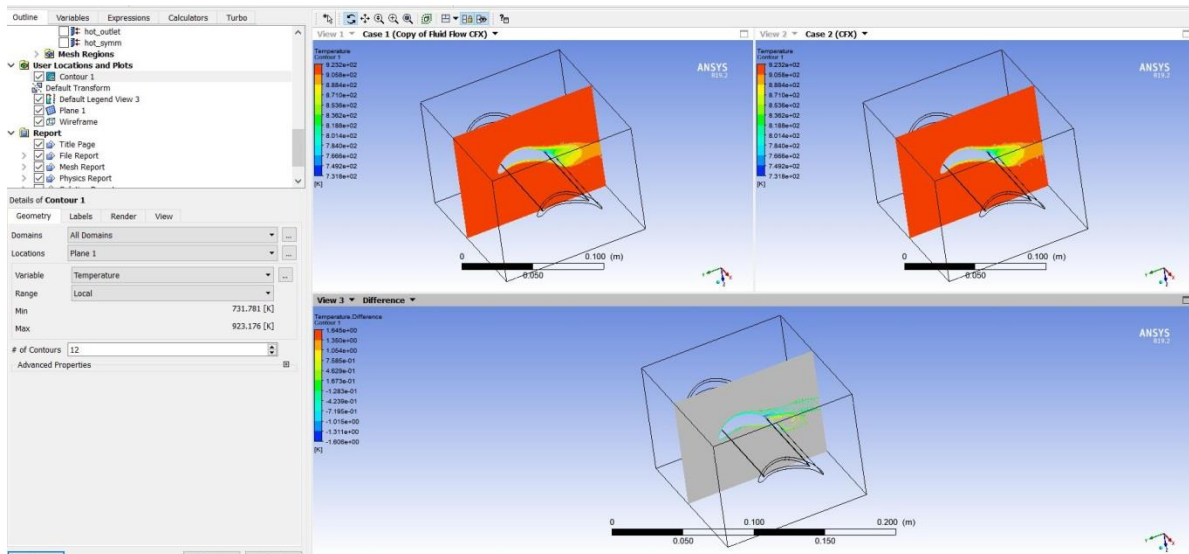


FIG 4.18 PLANE – TEMPERATURE COMPARISON BETWEEN INCONEL725 AND N155

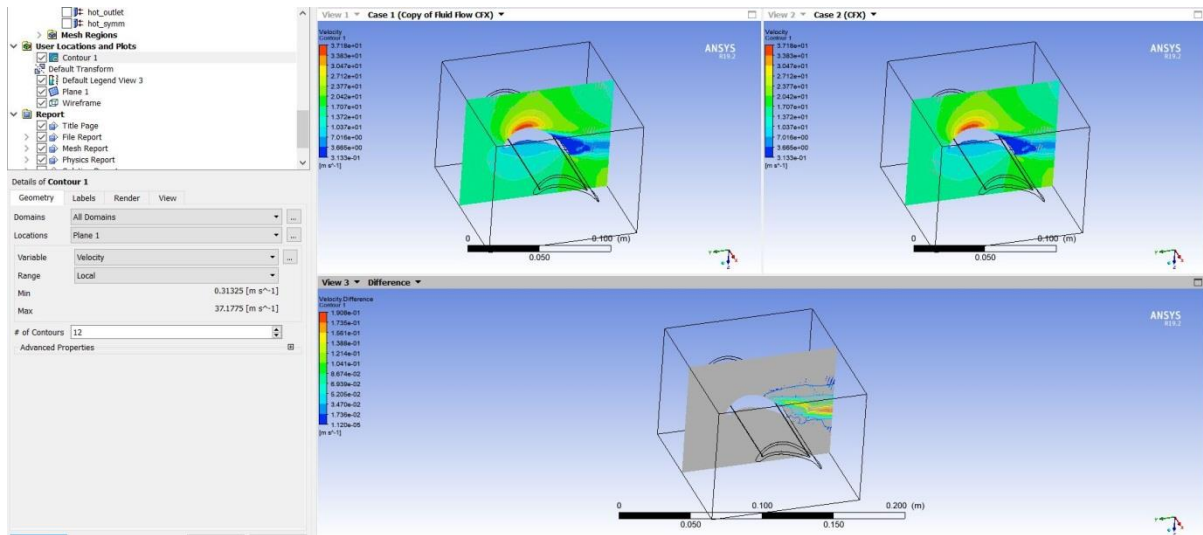


FIG 4.19 PLANE – VELOCITY COMPARISON BETWEEN INCONEL725 AND N155

5. RESULTS AND DISCUSSION

5.1 STRUCTURAL ANALYSIS OF N155

TABLE. 5.1 STATISTICS OF N155

Object Name	<i>Part 1</i>
State	Meshed
Graphics Properties	
Visible	Yes
Transparency	1
Material	
Assignment	N155
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 mm ³
Mass	0.61834 kg
Centroid X	39.817 mm
Centroid Y	1.505 mm
Centroid Z	-2.6203 mm
Moment of Inertia Ip1	111.58 kg·mm ²
Moment of Inertia Ip2	1381.7 kg·mm ²
Moment of Inertia Ip3	1448.8 kg·mm ²
Statistics	
Nodes	75875
Elements	45077
Mesh Metric	None

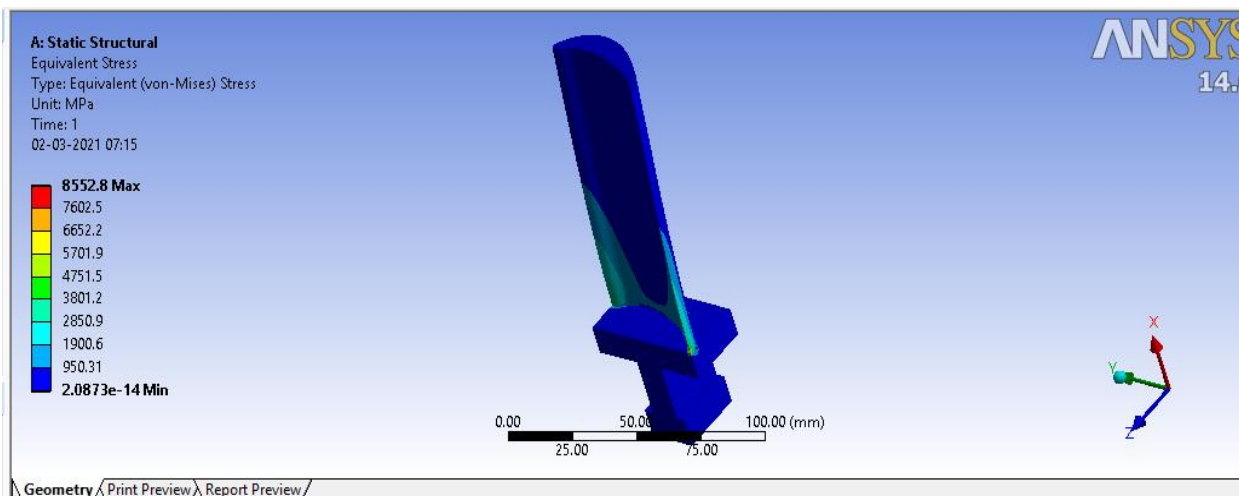


FIG: 5.1: EQUIVALENT VON MISES STRESS OF N155

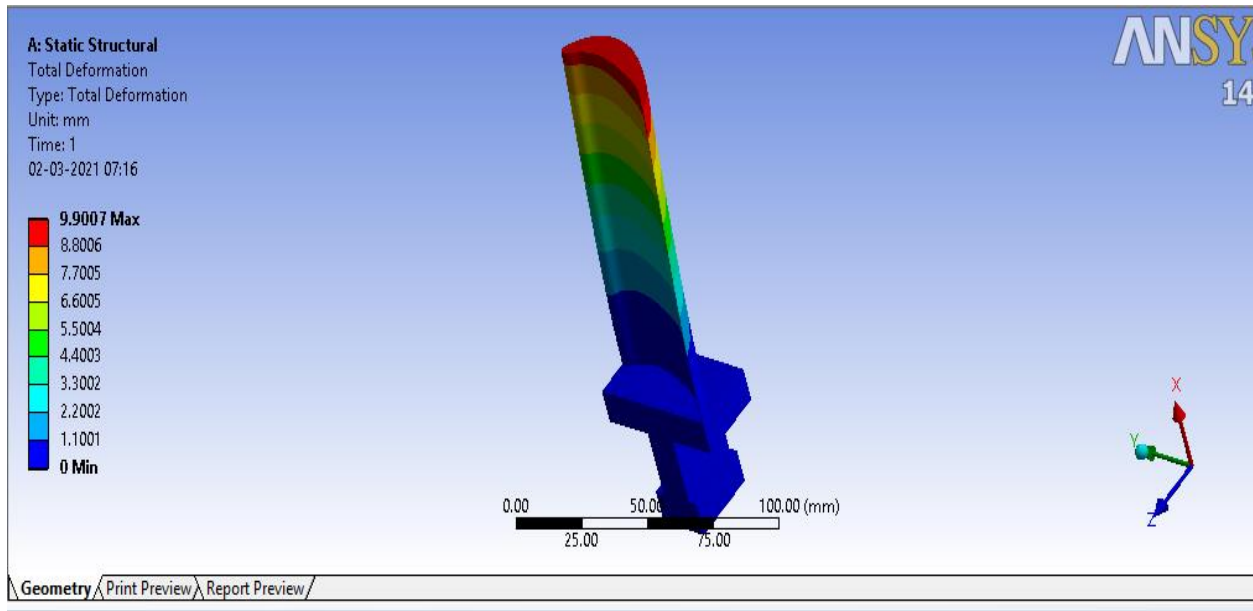


FIG: 5.2: TOTAL DEFORMATION OF N155

TABLE: 5.2: RESULTS OF N155

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

5.2 STRUCTURAL ANALYSIS OF INCONEL 725

TABLE. 5.3 STATISTICS OF INCONEL 725

Object Name	<i>Part 1</i>
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 mm ³
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·mm ²
Moment of Inertia Ip2	1376.8 kg·mm ²
Moment of Inertia Ip3	1443.7 kg·mm ²
Statistics	
Nodes	75875
Elements	45077
Mesh Metric	None

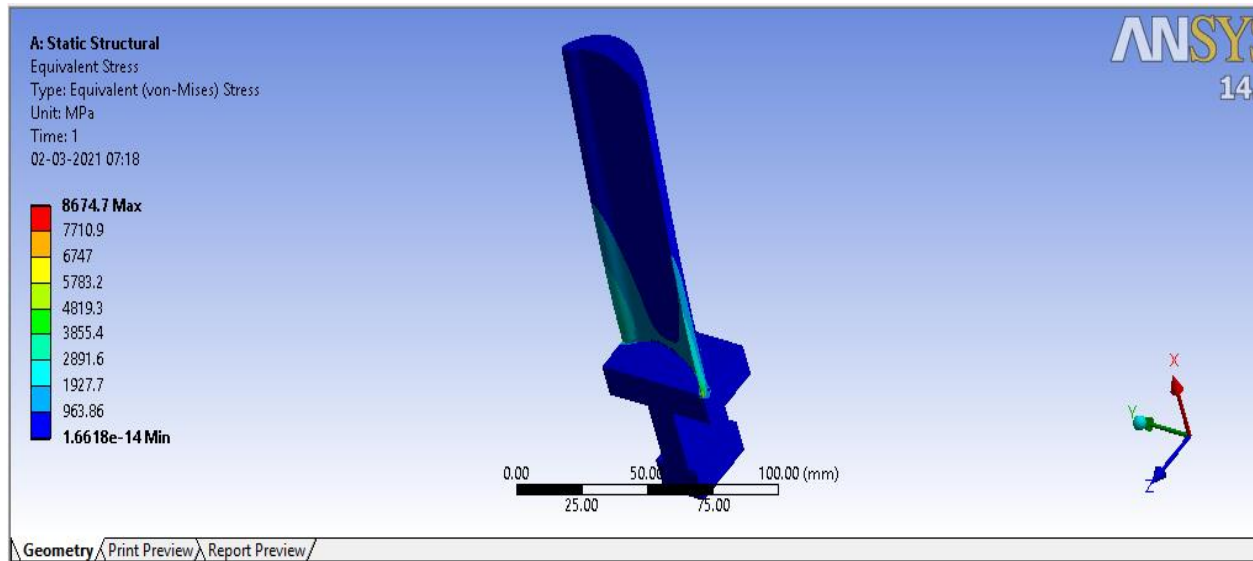


FIG: 5.3: EQUIVALENT VON MISES STRESS OF INCONEL 725

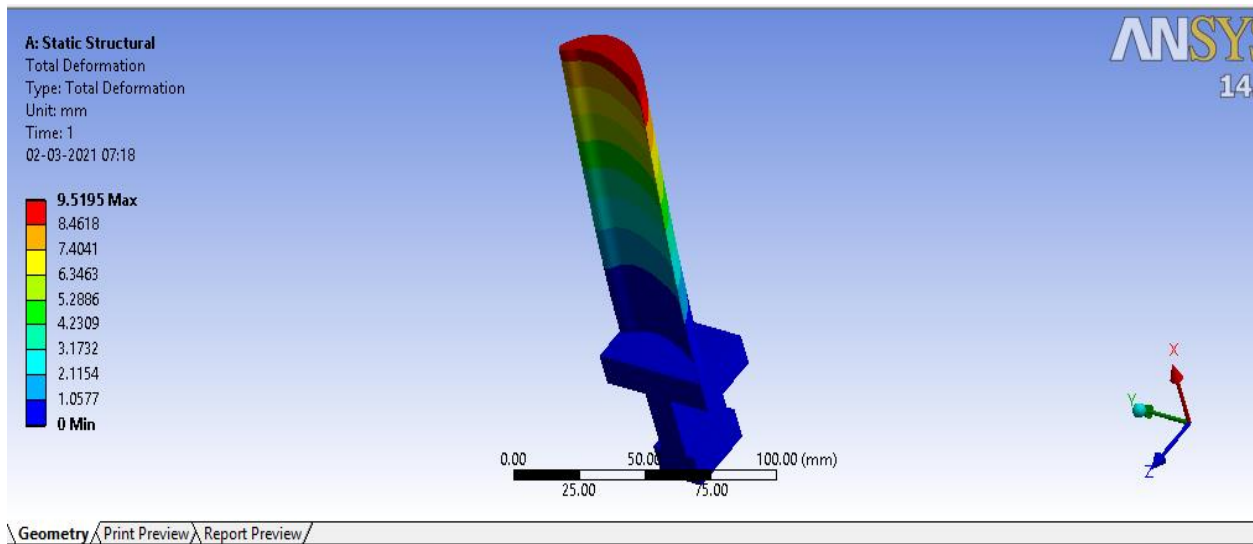


FIG: 5.4: TOTAL DEFORMATION OF INCONEL 725

TABLE: 5.4: RESULTS OF INCONEL 725

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

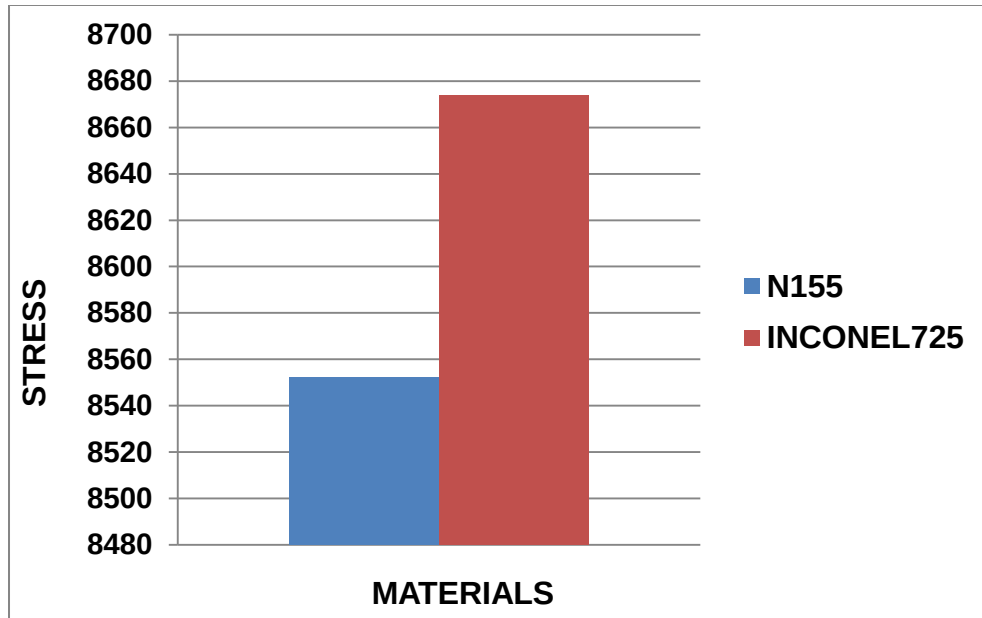


FIG: 5.5: GRAPHICAL ANALYSIS OF STRESSES

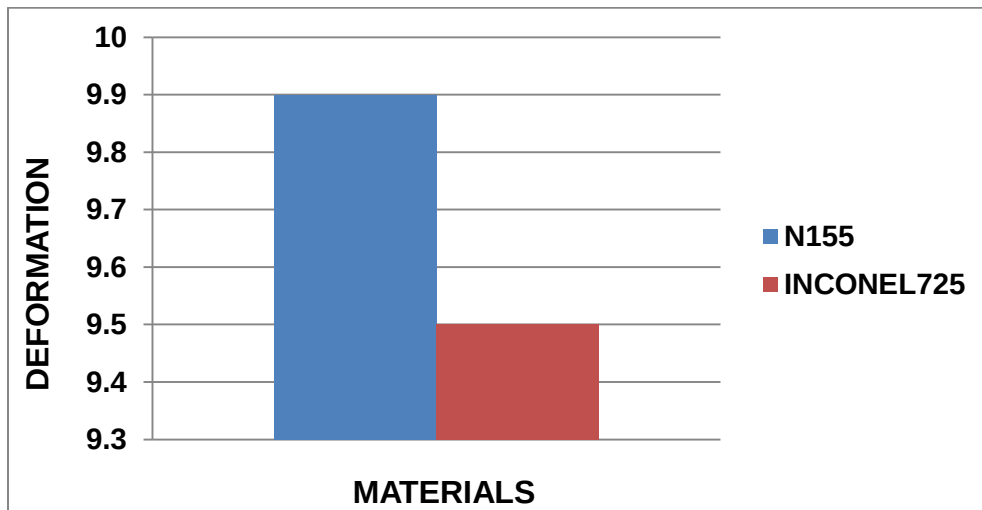


FIG: 5.6: GRAPHICAL ANALYSIS OF DEFORMATION

5.3 THERMAL ANALYSIS OF N155

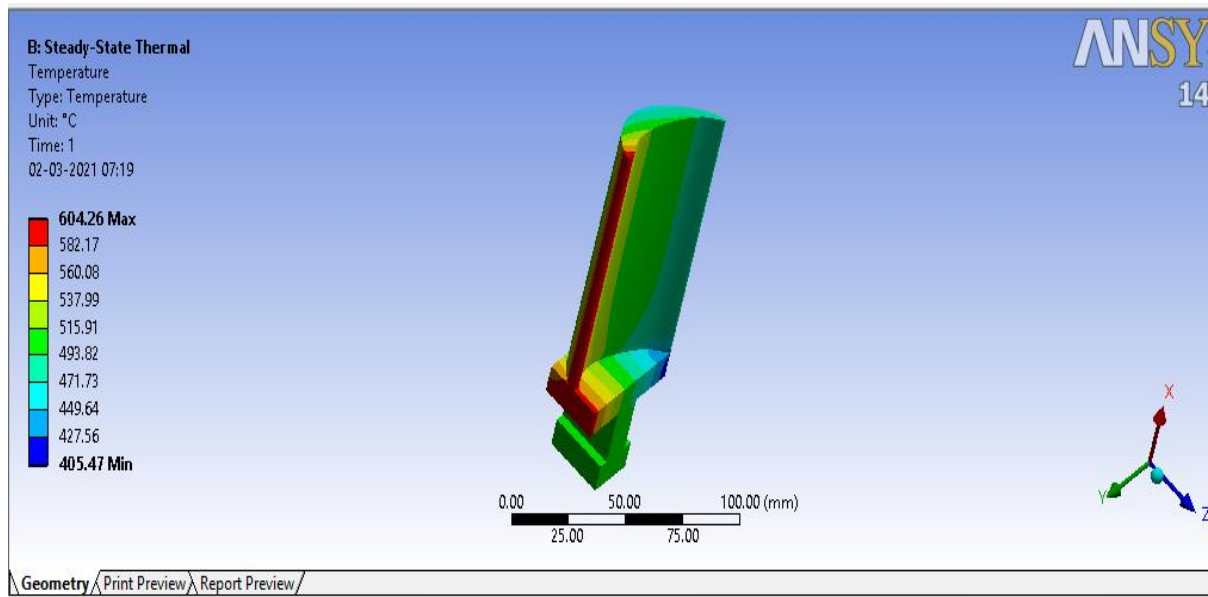


FIG: 5.7: TEMPERATURE OF N155

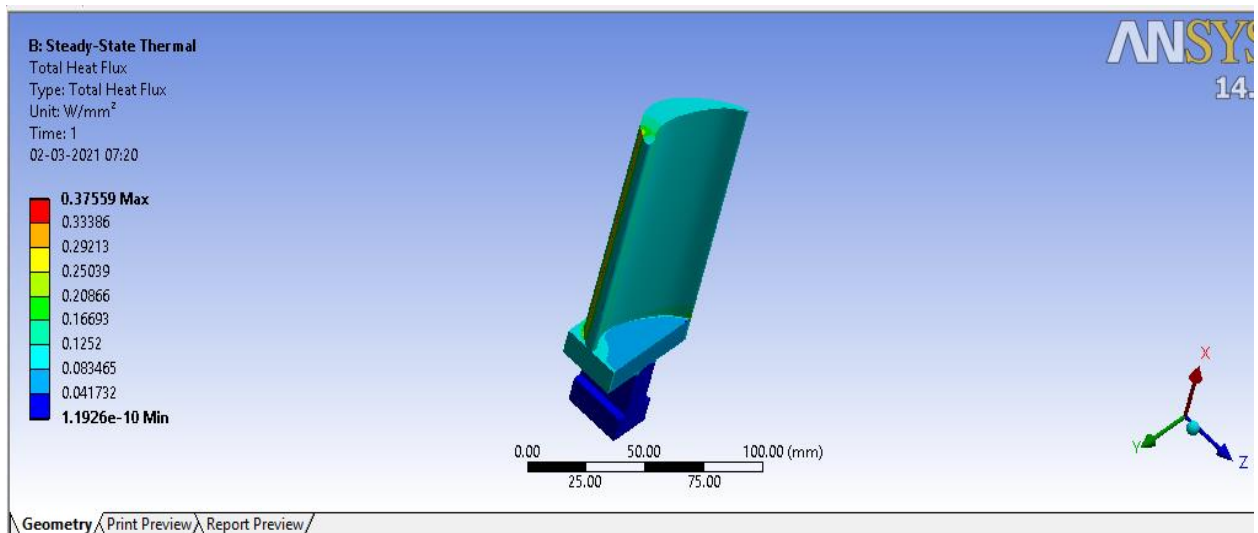


FIG: 5.8: TOTAL HEAT FLUX OF N155

TABLE.5.5 THERMAL ANALYSIS OF N155

Object Name	<i>Temperature</i>
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
Sub step	1
Iteration Number	1

5.4 THERMAL ANALYSIS OF INCONEL 725

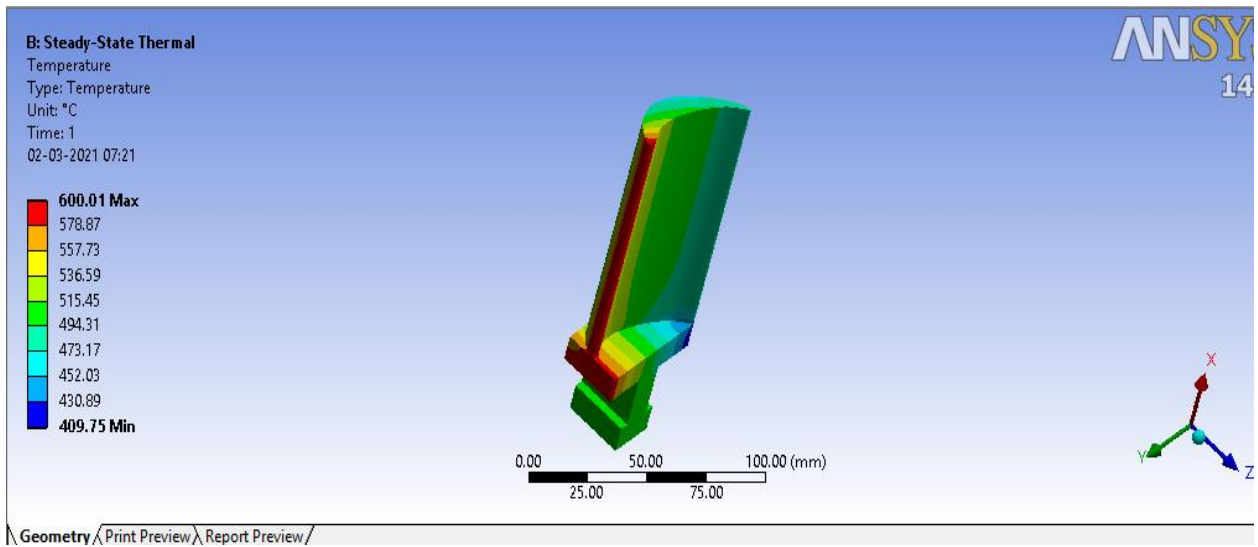


FIG: 5.9: TEMPERATURE OF INCONEL 725

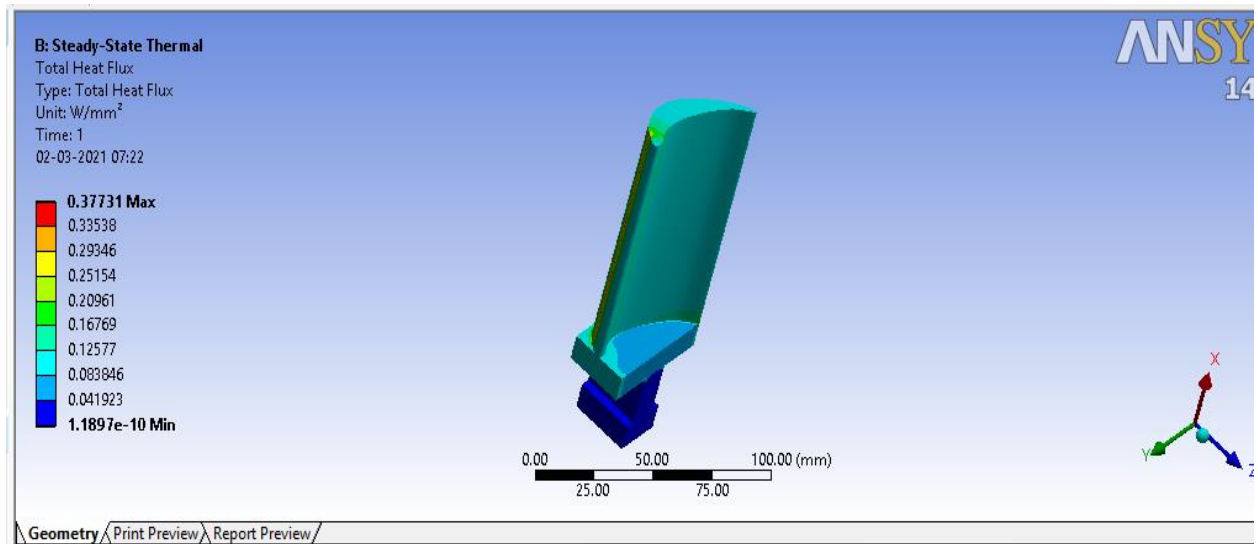


FIG: 5.10: TOTAL HEAT FLUX OF INCONEL 725

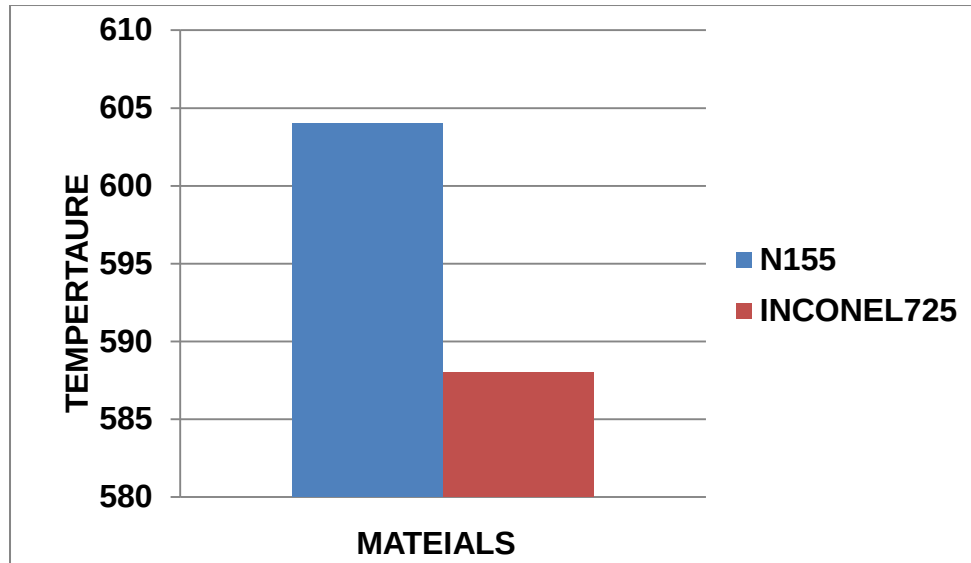


FIG: 5.11: GRAPHICAL ANALYSIS OF TEMPERATURE

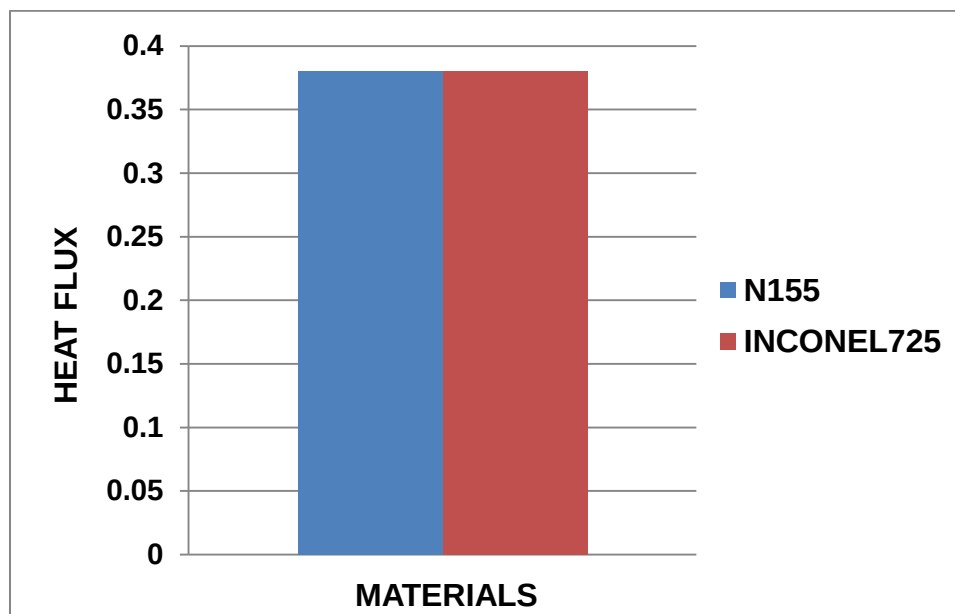


FIG: 5.12: GRAPHICAL ANALYSIS OF HEAT FLUX

5.5 DISCUSSION

TABLE.5.6 FINAL RESULTS OF THE MATERIALS

MATERIAL	Equivalent Von- misses Stress (Mpa)	Deformation (mm)	Temperature (°C)	Total Heat Flux (W/mm²)
N155	8552	9.9	604	0.38
INCONEL 725	8674	9.5	600	0.38

5.5.1 Structural Analysis

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

5.5.2 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 oC to 604 °C throughout the blade and the variation is linear along the path from both inner and outer side of the blade.

6. CONCLUSION

The finite element analysis for structural and thermal analysis of turbine rotary blade is administrated using ANSYS 14.0. The temperature features a significant effect on the general turbine blades. Maximum elongations and temperatures are observed at the blade tip section and minimum elongation and temperature variations at the basis 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.

6.1 REFERENCES

1. S.Gowreesh, N.Sreenivasalu Reddy and N.V.Yogananda Murthy. "CONVECTIVE HEAT TRANSFER ANALYSIS OF AN AERO GAS TURBINE BLADE USING ANSYS", International journal of Mechanics of solids, vol4, No.1, March 2009(ppt55-62).
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3. John.V, T.Ramakrishna. "THE DESIGN AND ANALYSIS OF GAS TURBINE BLADE", International Journal of Advanced Research and Studies, Vol 2, No.1, Dec 2012.
4. V.Raga Deepu, R.P.Kumar Ropichrla. "DESIGN AND COUPLED FIELD ANALYSIS 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.