IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

Effect Of Different Turbine Blade Materials On The Performance Of Jet Engine Turbine

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Abstract:

The design of the turbine blade was delicate. The experimental test of turbine blade structure is delicate and more precious process. In this present work, a detailed design of turbine blade structure modeling done by using CATIA V5 R20 software. The static stress analysis is carried out to find the stresses of the turbine blade structure for different paraphernalia. The stresses are estimated with the help of ANSYS structural analysis software. One of the important structural factors of the aircraft is turbine blade which controls the machine. The turbine blade, which is mounted in the turbine section of the aircraft spurt machine. The material used in the Turbine blade is nickel predicated superalloy, which as high- strength admixture and high strength- to- weight rate and excellent fatigue resistance. The use of emulsion paraphernalia in the spurt machine of aircraft is getting further common, the sedulity demand for predicting and minimizing the product and conservation cost is rising. Still, the selection for the design and associated manufacturing process in the early design stage is so far largely experience and knowledge predicated and partly a political decision which creates a high cost. There is, therefore, a need to develop an approach for the optimal design of turbine blade structure subject to design conditions, paraphernalia, manufacturing process, and bearing in mind the cost constraints in the early stages of development. In order to gain a high-strength material, trials were made to make the turbine blade as light as possible as well as with a high structural strength These tasks are considered in the order and manner in which the inventor must handle them. Within these task areas, the critical aspects of the structural, performance, and physical boundary conditions that the structure design must satisfy are presented and the detailed procedure for modeling the turbine blade structure is also presented. The model is also exported into the analysis software to conduct the analysis. The analysis on the turbine blade model is conducted representing that the model when an advanced material analogous as titanium alloy and Inconel 625 is considered including nickel and chromium to check the strength. The idea is to give high-strength material that can perform in the turbine section where high temperature is there and high forces are acting on the turbine blade.

1. INTRODUCTION

1.1.JET ENGINE:

A jet engine stands as a remarkable example of a reaction engine that produces a fast-moving jet, generating thrust through the powerful mechanism of jet propulsion. While this definition can extend to various propulsion systems, including rockets, water jets, and hybrid engines, it is important to note that the term "jet engine" primarily signifies internal combustion airbreathing engines such as turbojets, turbofans, ramjets, or pulse jets. In essence, these are sophisticated examples of internal combustion engines. Airbreathing jet engines are designed with efficiency in mind, featuring a rotor compressor that harnesses power from a turbine. This system utilizes the surplus energy to create thrust via a propelling nozzle, operating based on the well-established Brayton thermodynamic cycle. This advanced technology is vital for jet aircraft, enabling them to cover long distances with ease. Historically, early jet aircraft relied on turbojet engines, which unfortunately demonstrated inefficiency in subsonic flight. Yet, the advancement of aviation technology has led to the widespread adoption of high-bypass turbofan engines in contemporary subsonic jets. These engines not only enhance speed but also deliver exceptional fuel efficiency, far surpassing traditional piston and propeller engines over long travel distances. Furthermore, in pursuit of high-speed performance, certain air-breathing engines, such as ramjets and scramjets, leverage the vehicle's speed to achieve thrust, eliminating the need for a mechanical compressor. This innovation marks a significant leap in the evolution of jet propulsion technology.

TURBINE BLADE-

A turbine blade is an essential component of a gas turbine's turbine section, playing a vital role in harnessing energy from the high-temperature, high-pressure gas produced by the combustor. These blades are often the critical factor in optimizing gas turbine performance. To endure the extreme conditions they face, turbine blades are crafted from advanced materials like superalloys, employing a range of effective cooling methods categorized as internal or external, complemented by thermal barrier coatings. Blade fatigue is a major challenge that can lead to failures in both steam and gas turbines, primarily due to the stresses induced by vibrations and resonance within the operational range of the machinery. To protect these vital components from excessive dynamic stresses, friction dampers are strategically implemented, ensuring not only enhanced durability but also improved overall efficiency and reliability of the turbine system.

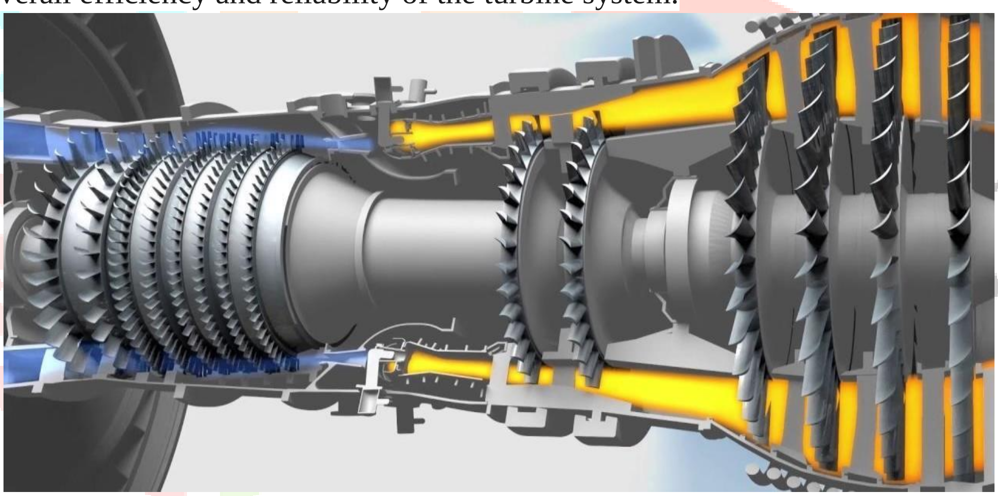

FIG.1.TURBINE SECTION

Blades of wind turbines and water turbines are uniquely engineered to thrive in lower rotational speeds and temperatures, distinguishing them from the high-performance demands of gas turbine engines. In a gas turbine engine, each turbine section features a robust disk or hub that accommodates numerous turbine blades. This crucial section connects seamlessly to a compressor section through a shaft, commonly known as a "spool," which may be either axial or centrifugal. As air flows through the compressor stages, it undergoes compression that significantly increases both pressure and temperature. This process is further intensified by the combustion of fuel in the combustor, strategically positioned between the compressor and turbine stages. The resulting high-temperature, high-pressure exhaust gases then enter the turbine stages, where the turbines extract energy from this dynamic flow. This process effectively reduces the exhaust pressure and temperature while efficiently transferring kinetic energy back to the compressor stages via the spool, thereby functioning similarly to an axial compressor but in reverse. Different types of engines exhibit varying numbers of turbine stages, with high-bypass ratio engines often boasting the most stages. This crucial variation directly impacts the design strategies for turbine blades at each stage. Many gas turbine engines implement a twin-spool design, comprising a high-pressure spool and a low-pressure spool. Some configurations even utilize a three-spool design, incorporating an intermediate pressure spool between high- and low-pressure spools. The high-pressure turbine faces the hottest and highest-pressure air, while the low-pressure turbine endures cooler, lower-pressure air. These contrasting environmental conditions necessitate tailored designs for turbine blades, focusing on materials and cooling techniques, even as the aerodynamic and thermodynamic principles remain consistent across the board. Under the demanding conditions present in gas and steam turbines, the blades confront extreme temperatures, significant stresses, and the potential for high vibrations. In steam turbines, these blades are vital components of power plants, converting the linear motion of high-temperature, high-pressure steam into the rotary motion essential for driving the turbine shaft, thus playing a pivotal role in efficient energy generation.

A critical obstacle in the early evolution of jet engines was the inadequate performance of materials in the hot section, particularly within the combustor and turbine. This realization ignited a fervent quest among researchers for superior materials, resulting in groundbreaking advancements in alloys and manufacturing techniques. The introduction of Nimonic marked one of the first significant successes, playing a pivotal role in the British Whittle engines. The advent of superalloys in the 1940s, coupled with revolutionary methods such as vacuum induction melting in the 1950s, dramatically elevated the temperature limits that turbine blades could endure. Moreover, advancements like hot isostatic pressing refined the alloys utilized in these critical components, significantly enhancing their performance and reliability. Today, state-of-the-art turbine blades incorporate nickel-based superalloys enriched with chromium, cobalt, and rhenium, pushing the boundaries of efficiency and dependability in modern engine technology. In addition to these alloy advancements, the development of directional solidification (DS) and single crystal (SC) production methods has been transformative. These techniques markedly improve the blades' strength against fatigue and creep by aligning grain boundaries in a single direction (DS) or entirely eliminating them (SC). The pursuit of SC technology initiated in the 1960s with Pratt and Whitney took a decade to realize in practice. The pioneering use of directional solidification was exemplified in the J58 engines of the SR-71, exemplifying the remarkable progress in turbine blade technology.

FIG.2.TURBINE BLADE

A significant leap forward in turbine blade material technology is the development of thermal barrier coatings (TBC). While advancements in Directionally Solidified (DS) and Single Crystal (SC) materials have enhanced creep and fatigue resistance, TBCs specifically tackle corrosion and oxidation concerns—issues that have become critical as operating temperatures have soared. The inaugural TBCs, introduced in the 1970s, utilized aluminide coatings, but the 1980s saw a breakthrough with advanced ceramic coatings. These innovations have elevated the temperature endurance of turbine blades by approximately 200 °F (90 °C) and have nearly doubled their lifespan, a testament to their effectiveness. Most turbine blades are expertly crafted through investment casting, also known as lost-wax processing. This meticulous method involves creating an accurate negative die of the blade shape, which is then filled with wax. For blades with internal cooling passages, a ceramic core is strategically inserted. After coating the wax model with a heat-resistant material to form a protective shell, the shell is filled with the blade alloy. While this process is more complex for DS or SC materials, the fundamental approach remains consistent. Once the ceramic core is dissolved, the blade is left hollow, a critical feature for efficiency. Following this, the blades receive a TBC coating, and any cooling holes are machined with precision. The future lies in Ceramic Matrix Composites (CMC), where fibers are embedded in a matrix of polymer-derived ceramics, offering substantial advantages over traditional superalloys. CMCs stand out for their lightweight design and exceptional high-temperature capabilities. Specifically, SiC/SiC composites, which incorporate a silicon carbide matrix reinforced by silicon carbide fibers, can endure operating temperatures 200°-300 °F higher than nickel superalloys. GE Aviation has already demonstrated the potential of SiC/SiC composite blades in the low-pressure turbine of its F414 jet engine, paving the way for next-generation performance in aviation technology.

List of turbine blade materials:

- U-500 This material was used as a first stage (the most demanding stage) material in the 1960s and is now used in later, less demanding, stages.
- Rene 77
- Rene N5
- Rene N6
- PWA1484
- CMSX-4
- CMSX-10
- Inconel
- IN-738 – From 1971 to 1984, GE relied on IN-738 as a premier first-stage blade material, until it was succeeded by GTD-111. Today, IN-738 serves effectively as a second-stage material, showcasing its strong legacy. Designed specifically for land-based turbines, it emphasizes performance over aircraft gas turbines.
- GTD-111 Blades crafted from directionally solidified GTD-111 are now integral to many GE Energy gas turbines in the first stage, while those made from equiaxed GTD-111 excel in later stages.
- EPM-102 (MX4 (GE), PWA 1497 (P&W)) represents an innovative single crystal superalloy, a product of collaboration between NASA, GE Aviation, and Pratt & Whitney for the ambitious High Speed Civil Transport (HSCT). Even though the HSCT program was ultimately canceled, the alloy remains a strong candidate for future applications by both GE and P&W.
- Nimonic 80a is a proven choice for turbine blades on the Rolls-Royce Nene and de Havilland Ghost.
- Nimonic 90 was successfully utilized in the Bristol Proteus.
- Nimonic 105 found its role in the Rolls-Royce Spey.
- Nimonic 263 was essential in the combustion chambers of the Bristol Olympus, powering the iconic Concorde supersonic airliner.

2. OBJECTIVE:

1. The temperature and pressure inside the turbine are high, so high thermal resistance and high strength material are used.
2. The purpose is to study the material properties and compare the results. Materials like Titanium allow, Inconel 625, Ceramic, Nickel and chromium.

3. DIMENSIONS OF TURBINE BLADE:

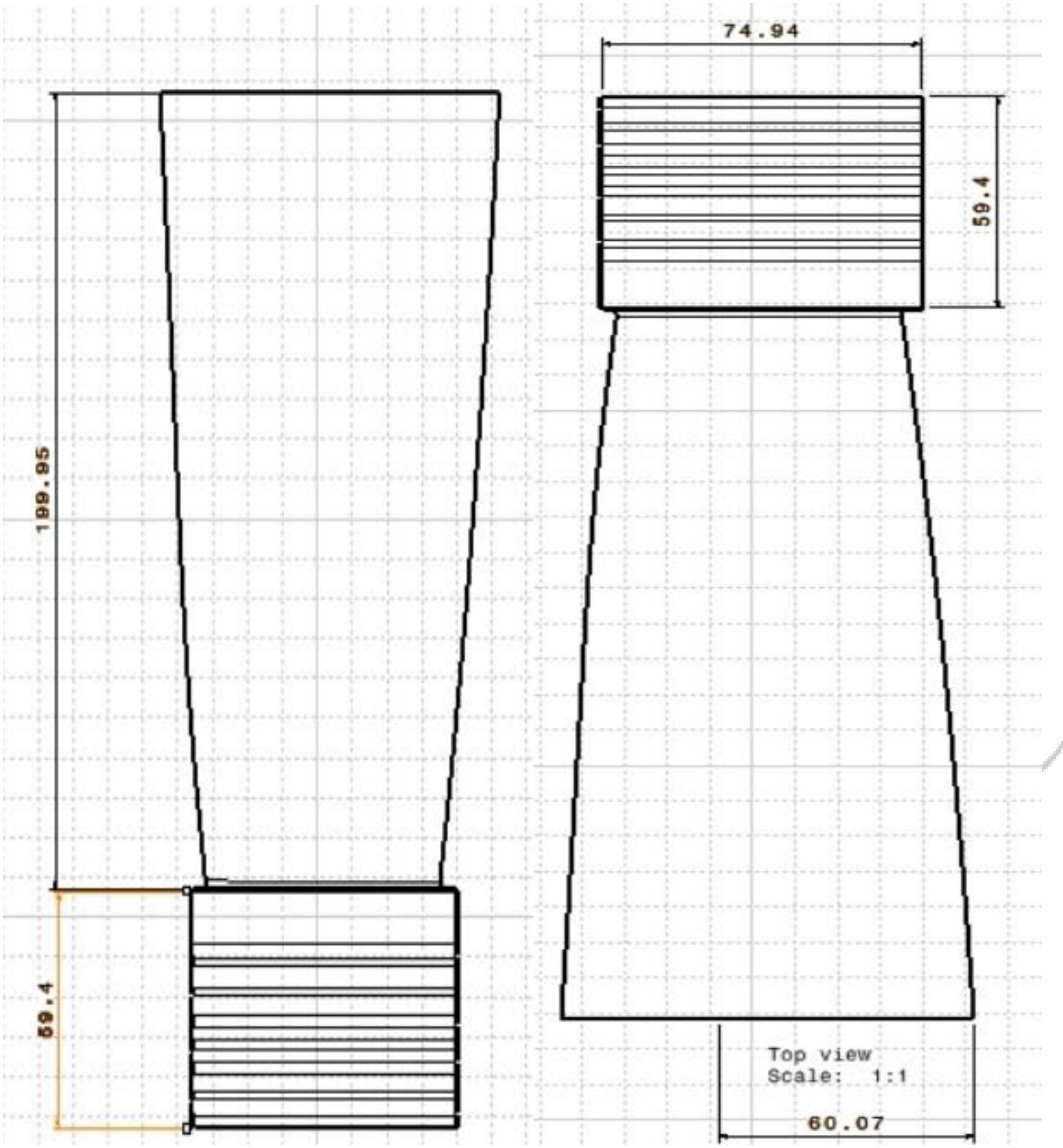

FIG.3.Top view of turbine blade

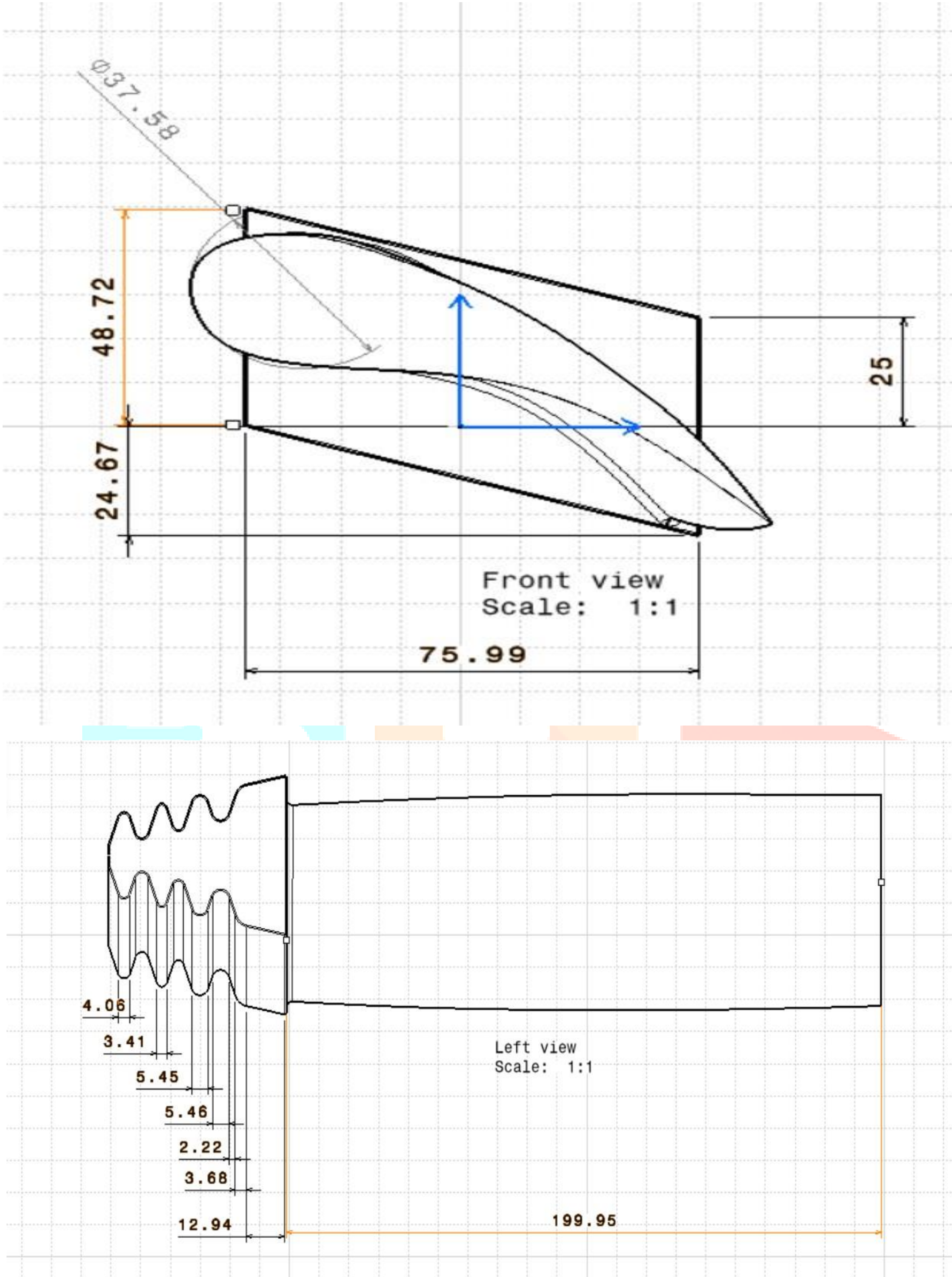

Fig 4: Front view of turbine blade

Materials Selection for Turbine Blade:

The Turbine blade of the jet engine is used for further study. The materials used in our project are titanium allow, Inconel 625, ceramic, nickel and chromium. Optimization through mass takes place due to changes in material and its properties.

•TITANIUM ALLOY:

Titanium alloys are alloys that contain a mixture of titanium and other chemical elements.

Properties:

The beta-phase titanium is more ductile, while alpha-phase titanium is stronger but less ductile, largely due to the increased slip planes found in the bcc structure of the beta-phase compared to the hcp structure of the alpha-phase. Alpha-beta-phase titanium exhibits mechanical properties that are intermediate between the two phases. When titanium dioxide is formed at high temperatures, it dissolves in the metal with a significant energy requirement. This process implies that most titanium, unless meticulously purified, contains a considerable amount of dissolved oxygen, making it comparable to a Ti–O alloy. Though oxide precipitates can enhance strength, they are less responsive to heat treatment and can greatly reduce the toughness of the alloy. While many alloys have titanium as a minor component, they are generally categorized based on the predominant element, so they aren't typically labeled as "titanium alloys." On its own, titanium is a robust and lightweight metal—stronger than typical low-carbon steels yet 45% lighter, and twice as strong as weaker aluminum alloys while being 60% heavier. Titanium exhibits exceptional resistance to corrosion in seawater, which makes it ideal for marine applications like propeller shafts and rigging. Additionally, titanium and its alloys are extensively utilized in aerospace applications, such as airplanes, missiles, and rockets, where high strength, low weight, and heat resistance are crucial. Due to its biocompatibility, titanium is also employed in medical applications, including artificial joints, screws, plates for fractures, and various biological implants. Titanium alloy has a density of 4620 kg/m³, Young's Modulus of 96000 MPa, Poissons ratio of 0.36, and melting point of 1933 °C.

Table no.01. Titanium alloy properties

Material	DENSITY (Kg/m^3)	Young's Modulus(Mpa)	Poissons ratio	Melting point(°C)
Titanium alloy	4620	96000	0.36	1933

Uses:

Titanium is used regularly in aviation for its resistance to corrosion and heat, and its high strength-to-weight ratio. Titanium alloys are generally stronger than aluminium alloys, while being lighter than steel.

• INCONEL 625:

Inconel Alloy 625 (UNS designation N06625) stands out as a premier nickel-based superalloy, revered for its outstanding strength and remarkable resistance to high temperatures. This exceptional material is indispensable in applications that demand unwavering durability and stability in the most extreme environments. Its specially engineered composition not only allows it to maintain its strength but also provides superior resistance to oxidation and corrosion. As a result, Inconel 625 is the ideal choice for various industrial applications, particularly in turbine components and chemical processing equipment, ensuring longevity and reliability in critical operations.

Properties:

Inconel 625 has a density of 7850 kg/m³, Young's Modulus of 2E+05 MPa, Poissons ratio of 0.3, and melting point of 1350 °C.

Table no .02. Inconel properties

Material	DENSITY (Kg/m^3)	Young's Modulus(Mpa)	Poissons ratio	Melting point(°C)
INCONEL625	7850	2E+05	0.3	1350

Uses:

Seawater components, Flare stacks, Aircraft ducting systems, Fabrication with Inconel 625, Specialized seawater equipment, Chemical process equipment, Turbine shroud rings, Engine thrust-reverser systems, Jet engine exhausts systems, Boiler furnaces

• CERAMIC (Al203):

Ceramics represent an incredible category of materials, renowned for their hardness, brittleness, heat resistance, and corrosion resistance. These remarkable materials are created through the careful shaping and high-temperature firing of inorganic, nonmetallic substances like clay. Some of the most familiar examples of ceramics include earthenware, porcelain, and brick. The journey of ceramics began with humanity's earliest masterpieces in pottery—functional pots, vessels, and intricate figurines crafted from pure clay or combined with other materials like silica, which were hardened and sintered through fire. Over time, techniques advanced, allowing for the glazing and firing of ceramics, resulting in smooth, vibrant surfaces that significantly reduce porosity by utilizing glassy, amorphous coatings atop crystalline substrates. Today, ceramics have evolved beyond simple household items, encompassing a vast array of domestic, industrial, and construction products, while also leading to cutting-edge materials in advanced ceramic engineering, including innovative applications in semiconductors. Embracing ceramics means harnessing a blend of timeless tradition and modern technology.

Properties :

The physical properties of any ceramic material are fundamentally shaped by its crystalline structure and chemical composition. Solid-state chemistry underscores the vital link between microstructure and essential properties, including localized density variations, grain size distribution, porosity types, and the presence of second phases. These factors are critically correlated with key ceramic attributes such as mechanical strength, as described by the Hall-Petch equation, along with hardness, toughness, dielectric constant, and the optical qualities of transparent ceramics. Ceramography stands as a vital discipline dedicated to the meticulous preparation, examination, and evaluation of ceramic microstructures. The assessment and characterization of these microstructures are conducted at spatial scales that align with those in the cutting-edge field of nanotechnology, spanning from tens of ångstroms (Å) to tens of micrometers (μm). This range effectively bridges the gap between the minimum wavelength of visible light and the resolving power of the human eye. The intricate microstructure encompasses grains, secondary phases, grain boundaries, pores, micro-cracks, structural defects, and hardness micro-indentations. Each of these components significantly impacts the bulk mechanical, optical, thermal, electrical, and magnetic properties of the ceramic. Furthermore, the characteristics of the microstructure often reveal critical insights into the fabrication methods and processing conditions employed, making this understanding indispensable for advancing ceramic material applications.

Mechanical properties:

The significance of mechanical properties cannot be overstated in structural, building materials, and textile fabrics. In contemporary materials science, fracture mechanics has proven to be an essential tool for enhancing the mechanical performance of materials and components. By applying the principles of stress and strain—especially the theories of elasticity and plasticity—this field addresses the microscopic crystallographic defects in real materials to predict the macroscopic mechanical failures that may arise. Alongside it, fractography plays a crucial role in uncovering the underlying causes of failures and validating theoretical predictions through real-world evidence. Ceramic materials, typically bonded through ionic or covalent means, exhibit a notorious propensity to fracture before any plastic deformation occurs, resulting in reduced toughness. Moreover, the porous nature of these materials exacerbates the situation, as pores and microscopic flaws act as stress concentrators that further diminish toughness and tensile strength. This combination often leads to catastrophic failures, starkly contrasting the more ductile failure modes seen in metals. While ceramics can display some degree of plastic deformation, their rigid crystalline structures allow for only a limited number of slip systems for dislocations to move through, causing them to deform very slowly. Thankfully, advancements in ceramic material development have introduced ceramic matrix composite materials. By embedding ceramic fibers and applying specific coatings that create fiber bridges across cracks, these composites substantially enhance fracture toughness. A prime example of this innovation can be found in ceramic disc brakes, which utilize these advanced materials crafted through specialized manufacturing processes. The result is a noteworthy marriage of durability and performance that can revolutionize applications in various industries. Ceramic has a density of 3980 kg/m^3, Young's Modulus of 4.13E+05 MPa, Poissons ratio of 0.33, and melting point of 2369 °C.

TABLE NO 03. Ceramic properties

Material	DENSITY (Kg/m^3)	Young's Modulus(Mpa)	Poissons ratio	Melting point(°C)
CERAMIC	3980	4.13E+05	0.33	2369

Uses:

Ceramic knife blades are an exceptional choice, as they remain sharp far longer than traditional steel blades, offering ongoing efficiency and performance in the kitchen. However, it's important to note that they are more brittle, making them susceptible to breaking if mishandled

Carbon-ceramic brake disks are an outstanding option for vehicles, designed to effectively resist brake fade even under high-temperature conditions. This means you can count on consistent performance and enhanced safety during intense driving scenarios.

"Advanced composite ceramic and metal matrices" have been engineered specifically for contemporary armored fighting vehicles, providing exceptional resistance to penetration from shaped charges (HEAT rounds) and kinetic energy penetrators. This innovative design ensures enhanced protection for crew and equipment, making it a critical advancement in military technology.

Advanced composite ceramic and metal matrices have been designed for most modern armored fighting vehicles because they offer superior penetrating resistance against shaped charges (HEAT rounds) and kinetic energy penetrators. In addition, ceramics such as alumina and boron carbide have been used in ballistic armored vests to repel high-velocity rifle fire. Such plates are commonly known as small arms protective inserts (SAPIs). Similar materials are also used to protect the cockpits of some military airplanes due to their low weight.

• **NICKEL:**

Nickel is a chemical element with the symbol Ni and atomic number 28. It is a silvery-white, lustrous metal with a slight golden tinge. Belonging to the transition metals, nickel is known for its hardness and ductility.

Properties:

Nickel is an exceptional silvery-white metal with a subtle golden hue, capable of achieving a brilliant polish. Notably, it stands out as one of only four elements—alongside iron, cobalt, and gadolinium—that exhibit magnetic properties at or near room temperature. With a Curie temperature of 355 °C (671 °F), nickel loses its magnetism when heated beyond this point. Structurally, nickel exhibits a face-centered cubic unit cell, characterized by a lattice parameter of 0.352 nm, which correlates to an atomic radius of 0.124 nm. Remarkably, this crystal arrangement remains stable under pressures exceeding 70 GPa. As a member of the transition metals, nickel displays impressive hardness, malleability, and ductility. Additionally, it boasts relatively high electrical and thermal conductivity, setting it apart among its peers. While ideal crystals can reach a compressive strength of 34 GPa, this is typically not observed in bulk material due to dislocation formation; however, it has been achieved in Nickel nanoparticles, showcasing its potential in advanced applications.

Nickel has a density of 8902 kg/m³, Young's Modulus of 2.2E+05 MPa, Poissons ratio of 0.31, and melting point of 1739 °C.

Table 04. Nickel properties

MATERIAL	DENSITY (Kg/m^3)	Young's Modulus(Mpa)	Poissons ratio	Melting point(°C)
NICKEL	8902	2.2E+05	0.31	1739

Uses:

Nickel plays a vital role in a wide array of both industrial and consumer products, making it an essential element in our daily lives. Its applications include stainless steel, which is renowned for its durability; alnico magnets found in various electronics; and coinage that endures the test of time. Nickel is also crucial in rechargeable batteries, providing reliable energy storage, and is used in electric guitar strings and microphone capsules to enhance performance. Additionally, it serves as a protective plating on plumbing fixtures, ensuring longevity. Special alloys like permalloy, elinvar, and invar rely on nickel for their unique properties. Widely considered an alloy metal, nickel significantly boosts the tensile strength, toughness, and elastic limit in nickel steels and nickel cast irons. It even imparts a green tint in glass, showcasing its versatility. Embracing nickel is not just about using a metal; it's about harnessing a powerhouse that enhances countless products around us.

- **CHROMIUM:**

Chromium, represented by the symbol Cr and holding the atomic number 24, stands as the pioneering element in group 6. This remarkable transition metal boasts a striking steely-grey hue, along with a lustrous, hard, and brittle composition. The exceptional corrosion resistance and impressive hardness of chromium metal make it a highly sought-after material in various industries

Properties:

Chromium stands out as the fourth transition metal on the periodic table, showcasing a captivating electron configuration of [Ar] 3d5 4s1. It is notably the first element in the periodic table where its ground-state electron configuration defies the Aufbau principle. This is a fascinating phenomenon that reappears with other elements like copper, niobium, and molybdenum later on. The primary reason for this is the repulsion between electrons within the same orbital due to their similar charges. In earlier elements, the energy cost of promoting an electron to a higher energy level is generally too high to offset the benefits of reducing interelectronic repulsion. However, when it comes to 3d transition metals, the energy gap between the 3d subshell and the higher 4s subshell is minimal. Additionally, the more compact nature of the 3d subshell means that the repulsion among 4s electrons is less severe compared to that among 3d electrons. Consequently, this minimizes the energetic cost involved in promoting electrons and maximizes the energy released from the process—making the promotion of one or even two electrons to the 4s subshell a favorable reality. Notably, this type of promotion occurs for nearly all transition metals, with the exception of palladium. Furthermore, chromium marks the beginning of the 3d series where its 3d electrons start to venture closer to the nucleus, resulting in a diminished contribution to metallic bonding. This decrease is reflected in its lower melting and boiling points compared to the preceding element, vanadium, along with a reduced enthalpy of atomisation. In terms of reactivity, chromium(VI) serves as a powerful oxidising agent, distinguishing itself from the oxides of molybdenum(VI) and tungsten(VI). With a density of 7190 kg/m³, a Young’s Modulus of 2.45E+05 MPa, a Poisson’s ratio of 0.2, and an impressive melting point of 1907 °C, chromium’s unique properties make it a remarkable element worthy of attention.

Table no.05. Chromium properties

MATERIAL	DENSITY (Kg/m^3)	Young’s Modulus(Mpa)	Poissons ratio	Melting point(°C)
CHROMIUM	7190	2.45E+05	0.2	1907

Uses:

The remarkable properties of chromium, particularly its ability to form stable metal carbides at grain boundaries, greatly enhance the strength and corrosion resistance of steel, making it an essential alloying element. High-speed tool steels feature a chromium content ranging from 3 to 5%, which contributes to their durability and performance. When added to iron in concentrations exceeding 11%, chromium transforms it into stainless steel—the leading corrosion-resistant metal alloy. This process typically involves introducing ferrochromium to molten iron. Furthermore, nickel-based alloys benefit from the formation of discrete, stable carbide particles at the grain boundaries, resulting in enhanced strength. A prime example is Inconel 718, which contains 18.6% chromium and is renowned for its exceptional high-temperature properties, making it a preferred choice in jet engines and gas turbines over conventional structural materials. The significance of chromium is highlighted in ASTM B163, which endorses its use for condenser and heat exchanger tubes, while its application in high-strength castings at elevated temperatures is governed by ASTM A567. AISI type 332 is specifically designed to withstand conditions that typically lead to carburization, oxidation, or corrosion. Incoloy 800 is lauded for its stability and ability to maintain an austenitic structure, even after prolonged exposure to extreme temperatures. Additionally, Nichrome is widely utilized as resistance wire in heating elements for toasters and space heaters. These diverse and critical applications underscore the strategic importance of chromium in modern materials engineering..

DESIGN AND ANALYSIS SOFTWARES USED:

Steps for modeling:

OPENING A NEW FILE

➢ Press on Start ➢ Choose Mechanical Design -> Part Design

➢ Enter the part name -> click Ok

➢ First, create the 2D model in part design from the cross-section. Then, pad the 2D model to create the 3D model.

➢ The airfoil-like structure is created in 2D, and then the remaining design is developed in 3D.

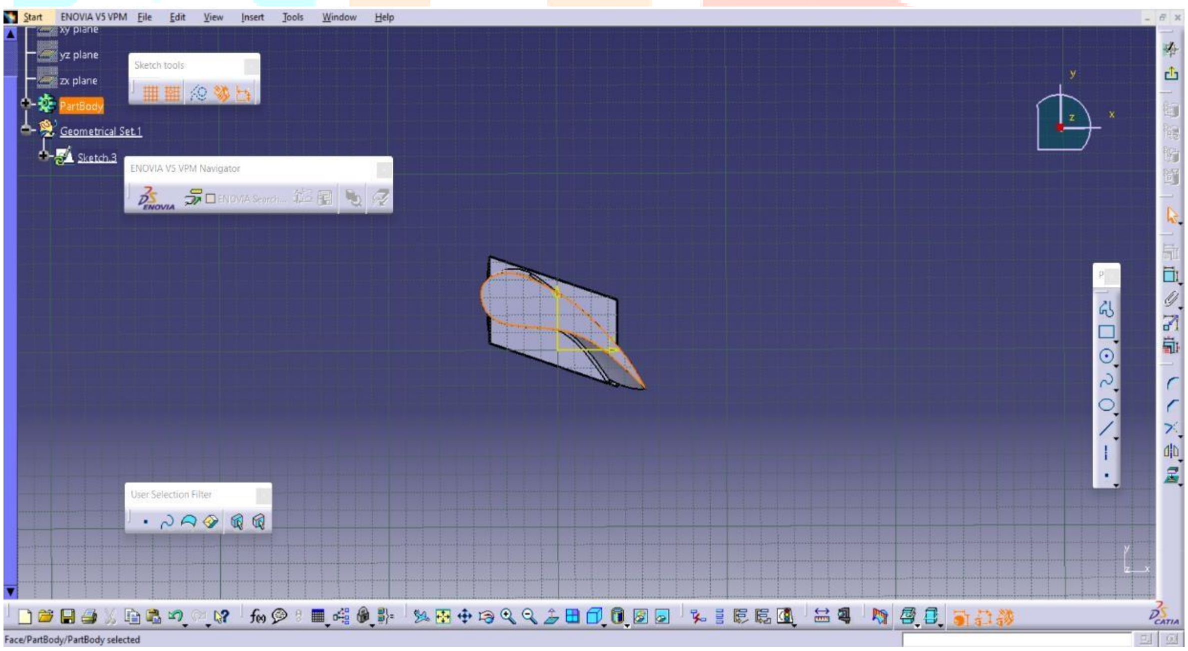

Fig.5. Top view of turbine blade

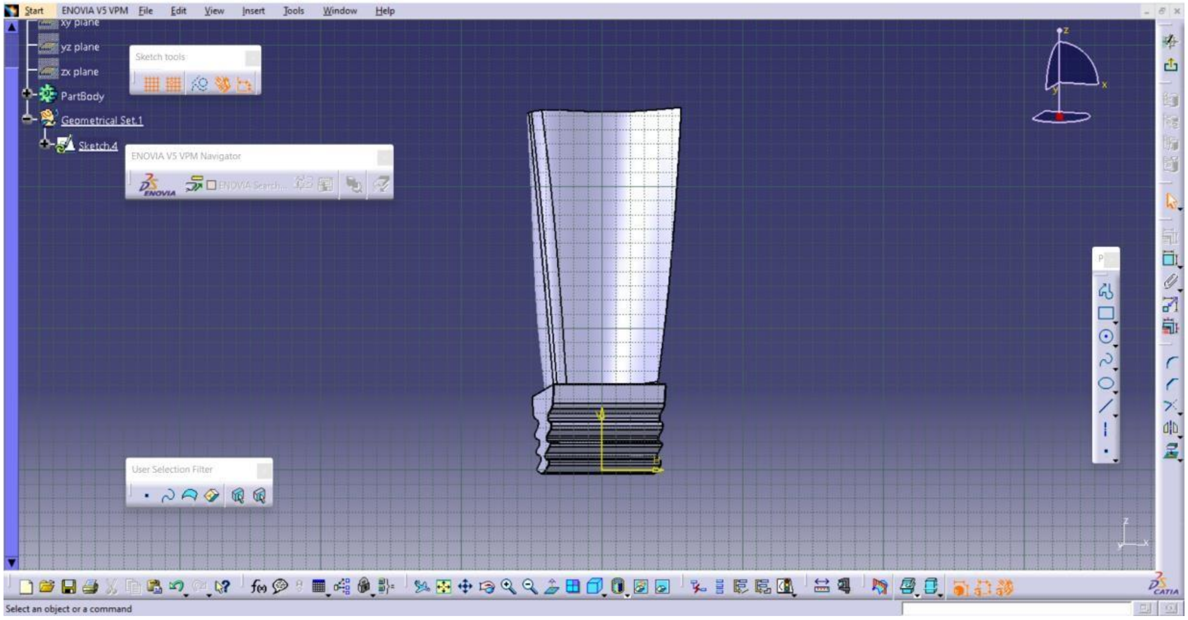

Fig.6.Front view of turbine blade

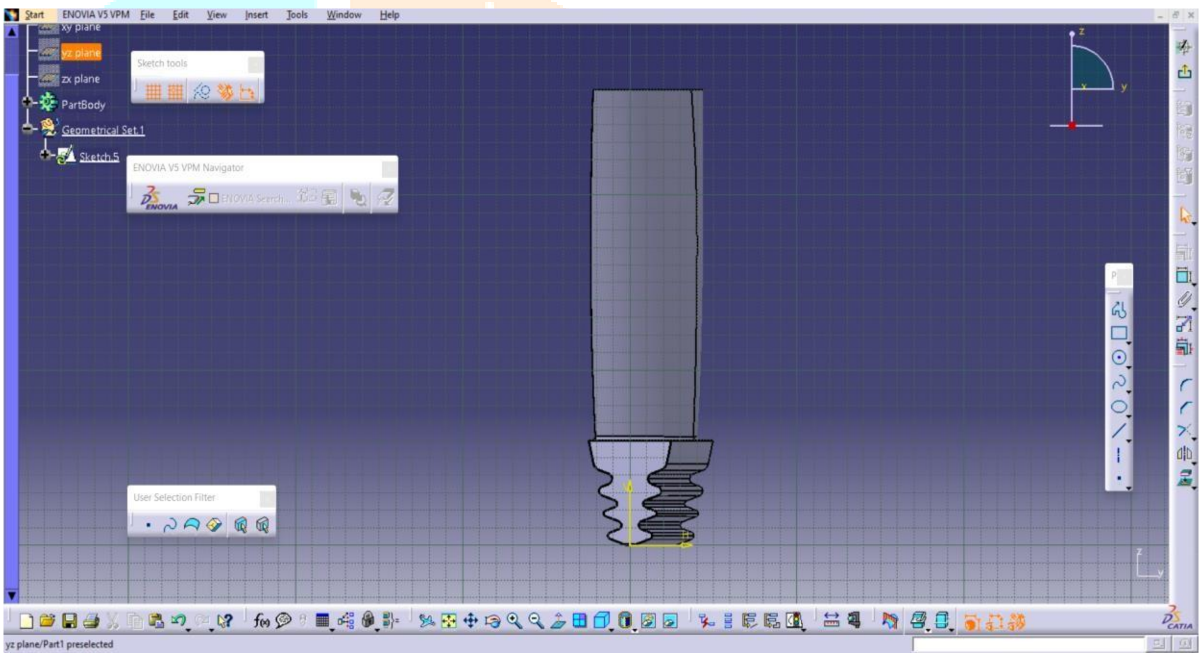

Fig.7.Side view of turbine blade

Final Design of turbine blade :

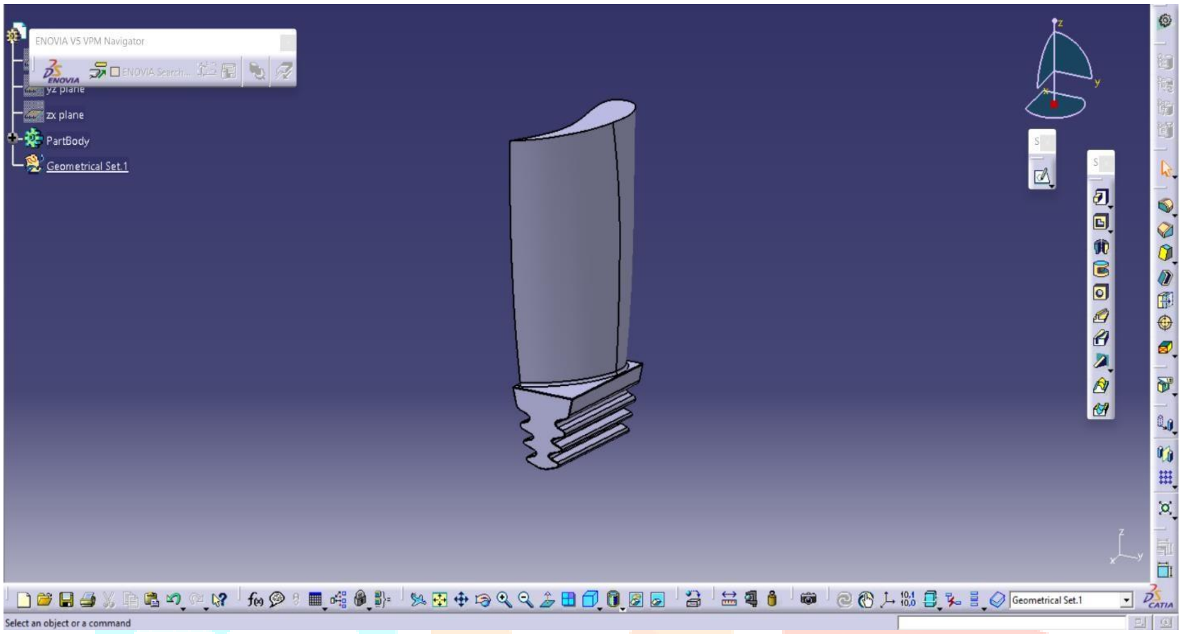

FIG.8. Turbine blade

Steps for analysis:

- The catia design is imported to ansys workbench.
- The catia file is saved in Igs format then it is imported to ansys.

Boundary Conditions:

- Type of load: Assuming force due to air as load (air loads) which is acting on the turbine.
- Direction of load: Air flow acting perpendicular to the edge of the turbine blade.
- Fixed Support: Fixed support is applied to the root of the turbine blade.

Properties Applied to Materials:

All the properties for the materials are given by ANSYS Engineering Data Sources (i.e. all the properties such as Young's Modulus, Poisson's Ratio, etc are taken from ANSYS itself).

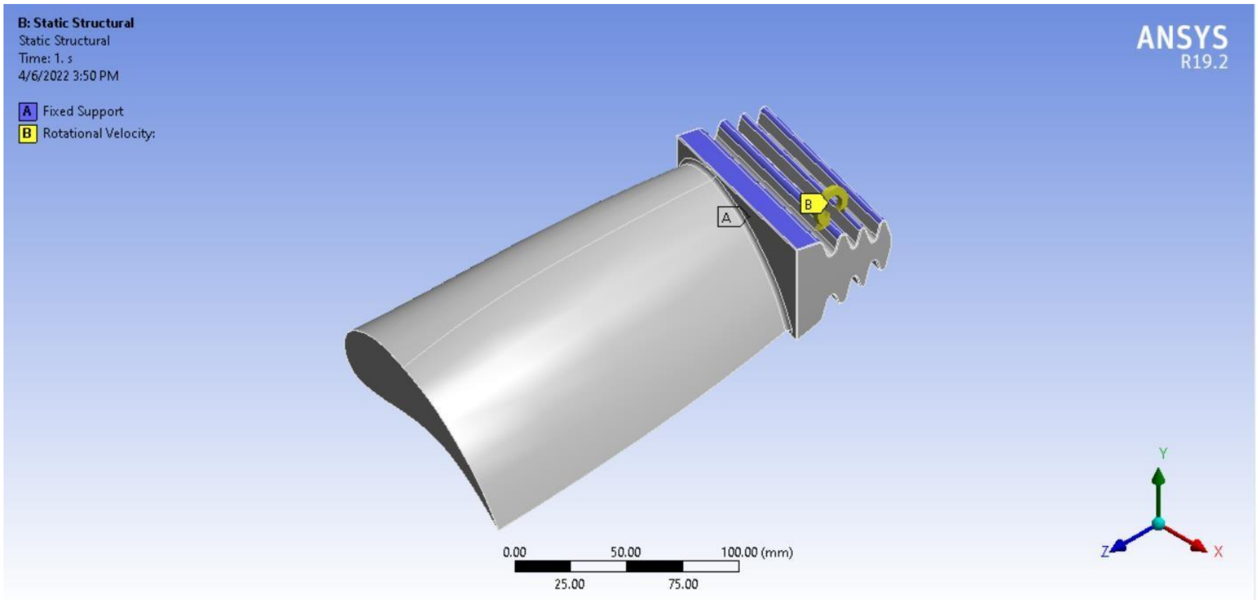

Fig 9: Boundary Conditions Applied to the Turbine Model

ANALYSIS AND RESULTS

Now the model is imported in ANSYS for static analysis

1. Effective Steps to Conduct Analysis in ANSYS Workbench:
   Begin by launching ANSYS Workbench through Start → Programs → ANSYS 19.2 → ANSYS Workbench. Next, double click on Static Structural (ANSYS) to kick-start your analysis.
2. Access Engineering Data, edit it to add the necessary materials, and then return to your project. Right-click on Geometry, import the geometry, and browse to select your CAD file.
3. Right-click on Model, choose Edit, and a new mechanical window will conveniently open for you.
4. Expand the Geometry Tree, select the relevant Part, and assign the appropriate material for your analysis.
5. Choose a point, edge, or face; right-click and seamlessly insert the loading condition (fixed, rotational velocity, etc.) that meets your requirements.
6. Click on Mesh, adjust the settings from coarse to fine for an optimal mesh, and then right-click on Mesh to generate it.
7. Navigate to Solution and click Solve to progress your analysis.
8. Insert a variety of results such as maximum principal stress, equivalent stress, total deformation, and directional deformation. Right-click on Solution, resolve all, and click on each specific result to visualize your findings effectively.

9. Finally, choose Print View to produce a printed version of your results, or opt for Report Generate to create a comprehensive report of your analysis session.

Meshing of turbine blade in ANSYS:

- All the properties such as Young's Modulus and Poisson's ratio is given as per standard values.
- Meshing is completed using Hex Dominant Mesh (i.e. forming square, rectangular and few triangular elements).
- Each element size on the entire surface meshing is taken as 1mm and fine mesh is completed.

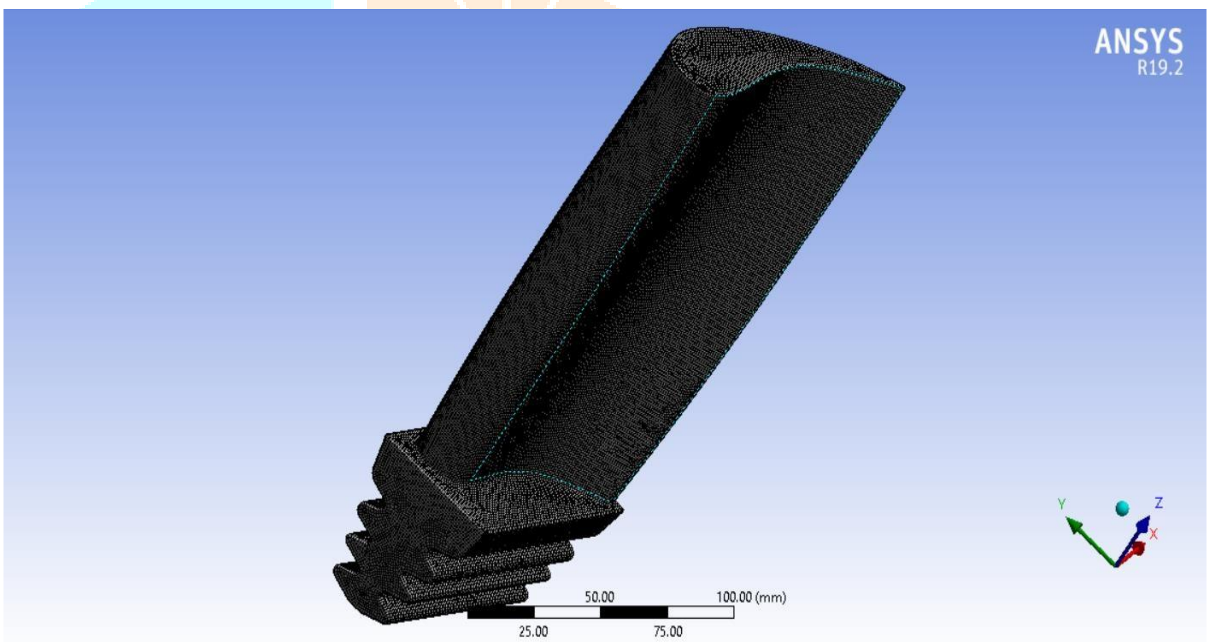

Fig 10: Meshing of Turbine Blade Model

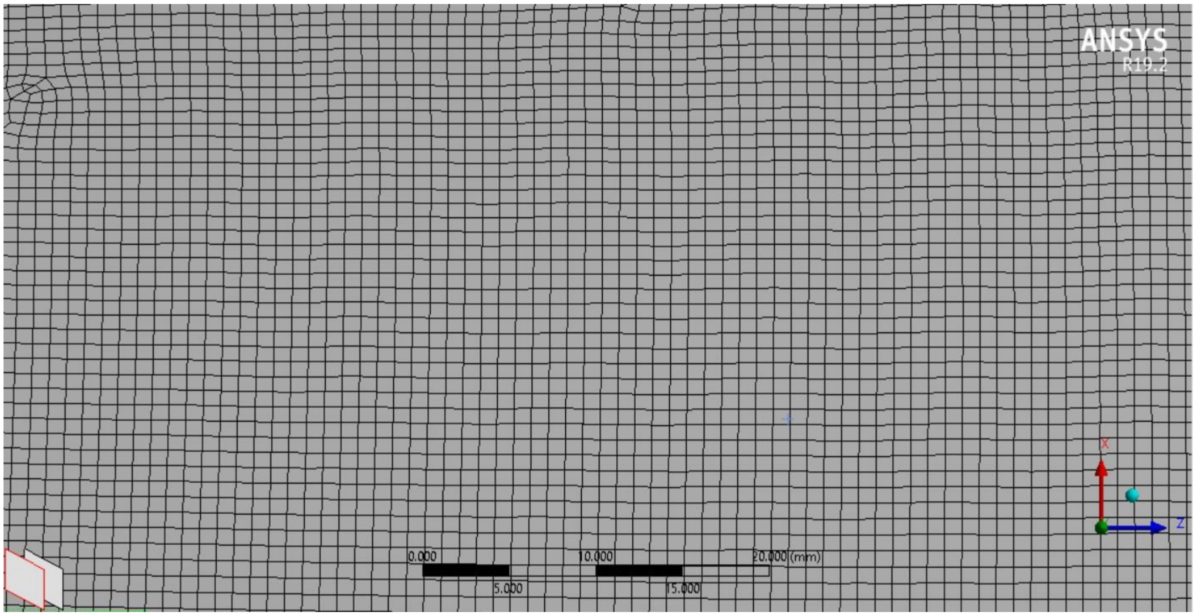

Fig 11: Zoomed Mesh Model of turbine blade Surface

1.For TITANIUM ALLOY Material:

Table : Properties of Titanium

Material	DENSITY (Kg/m^3)	Young's Modulus(Mpa)	Poissons ratio	Melting point(°C)
Titanium alloy	4620	96000	0.36	1933

Table 7: Geometrical Properties of turbine blade (Titanium)

Type	Define By	X Component
Rotational velocity	Components	500 rad/s (ramped)

Turbine blade Structural Analysis Results (Titanium):

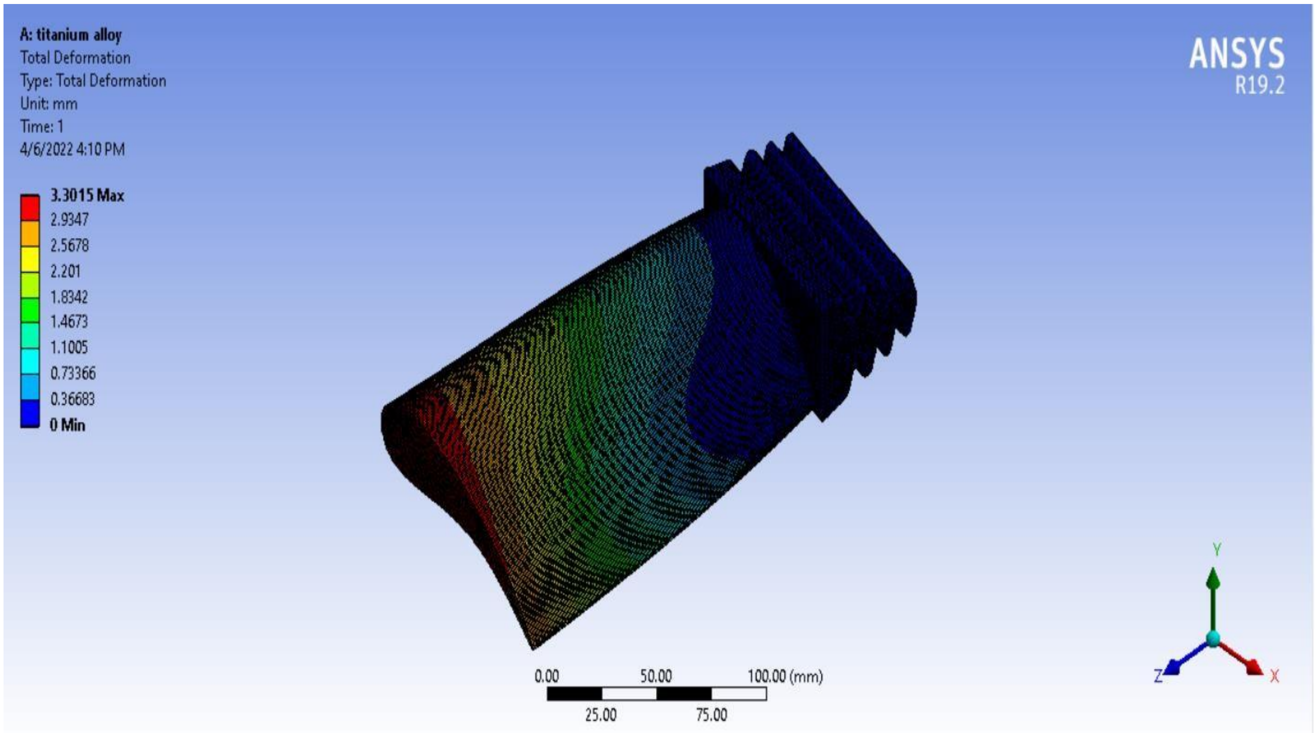

Fig 12: Total Deformation (Titanium)

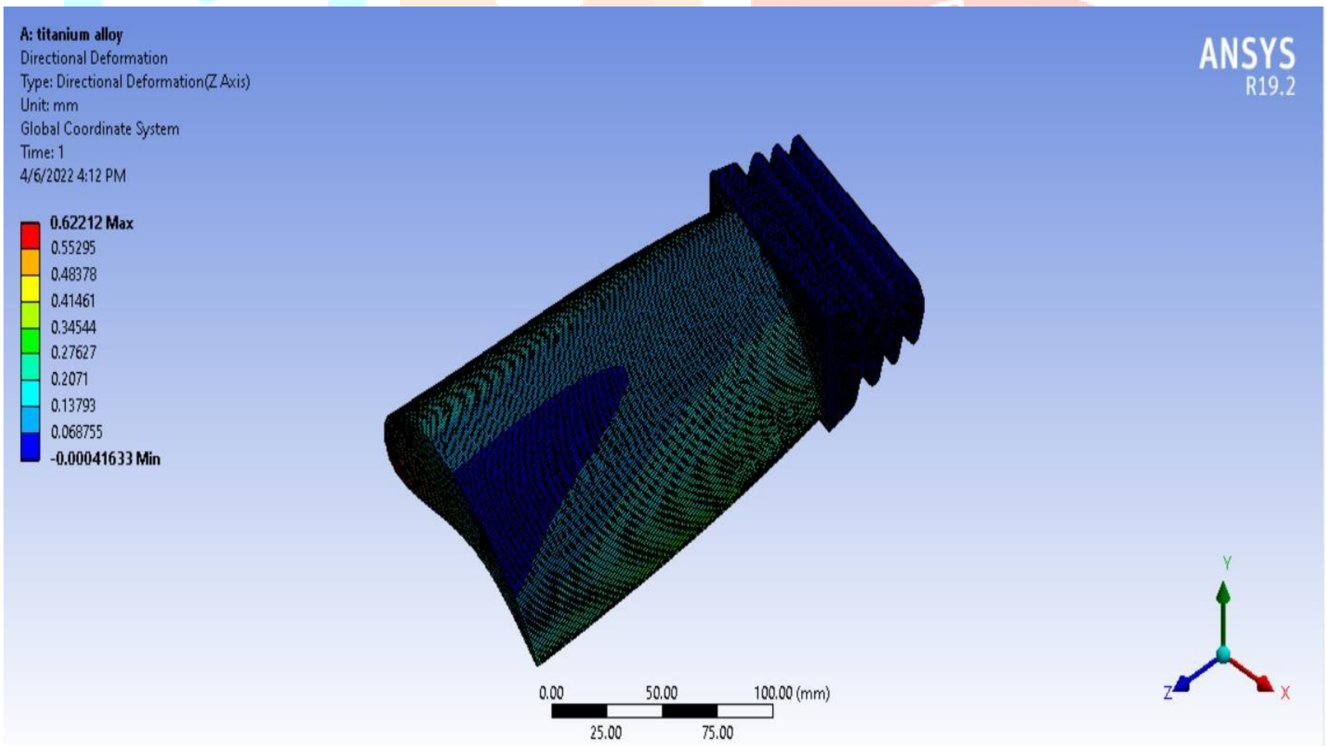

Fig 13: Directional Deformation in X-axis

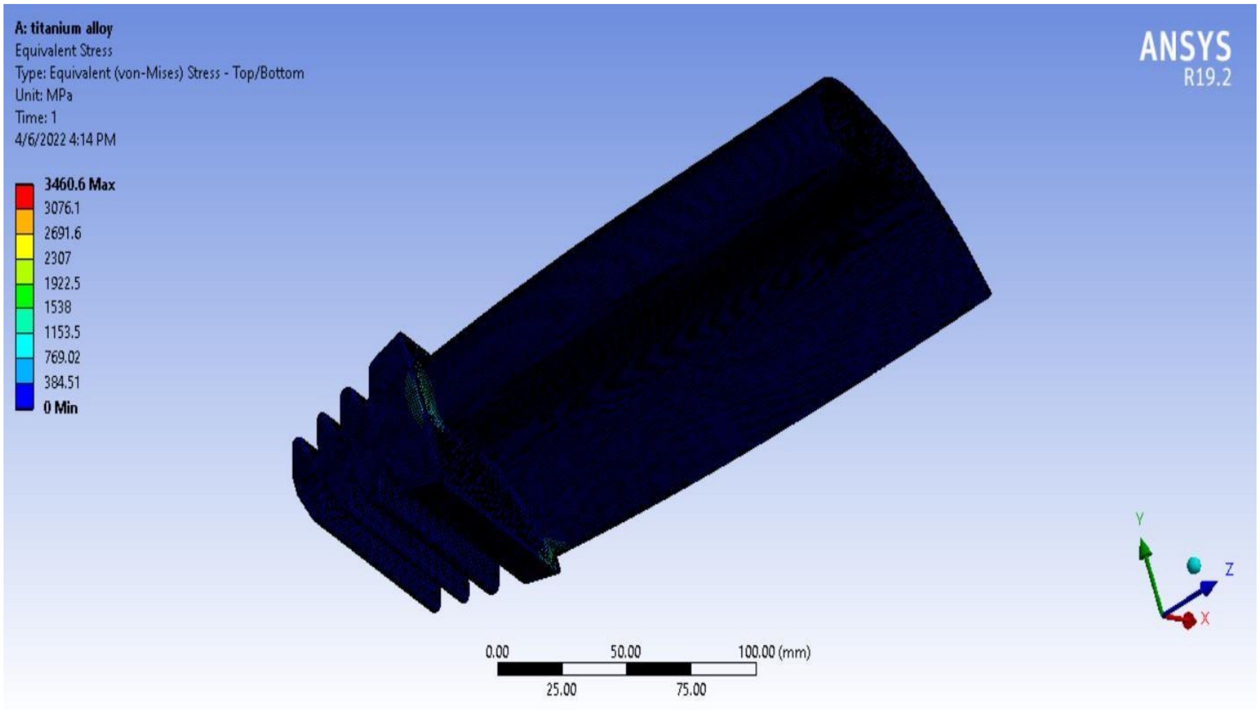

Fig 14: Equivalent (von-mises) Stress

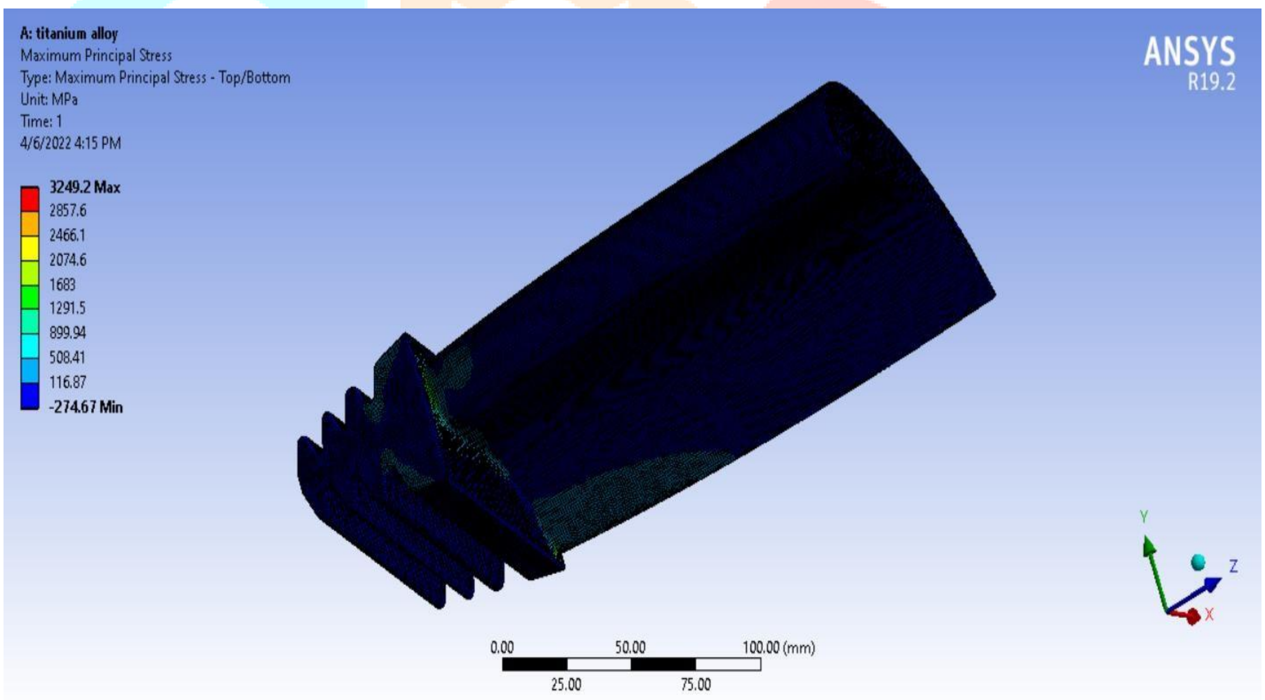

Fig 15: Maximum Principal Stress

Results of turbine blade Structural Analysis (Titanium) :

TABLE 8. Results of turbine blade Structural Analysis (Titanium)

Object Name	**Total Deformation**	**Directional Deformation**	**Maximum Principal Stress**	**Equivalent Stress**
Minimum	0 mm	-4.1633e-004 mm	-274.67 MPa	0. MPa
MAXIMUM	3.3015 mm	0.62212 mm	3249.2 MPa	3460.6 MPa
AVERAGE	1.0394 mm	0.17566 mm	33.871 MPa	45.589 MPa

TABLE 8.Results of turbine blade Structural Analysis (titanium)

2.For INCONEL 625 Material :

Table: Properties of INCONEL 625

Material	DENSITY (Kg/m^3)	Young's Modulus(Mpa)	Poissons ratio	Melting point(°C)
INCONEL625	7850	2E+05	0.3	1350

Table: Force on turbine blade (INCONEL 625)

Type	**Define By**	**X Component**
Rotational velocity	Components	500 rad/s (ramped)

Results of turbine blade Structural Analysis (INCONEL 625):

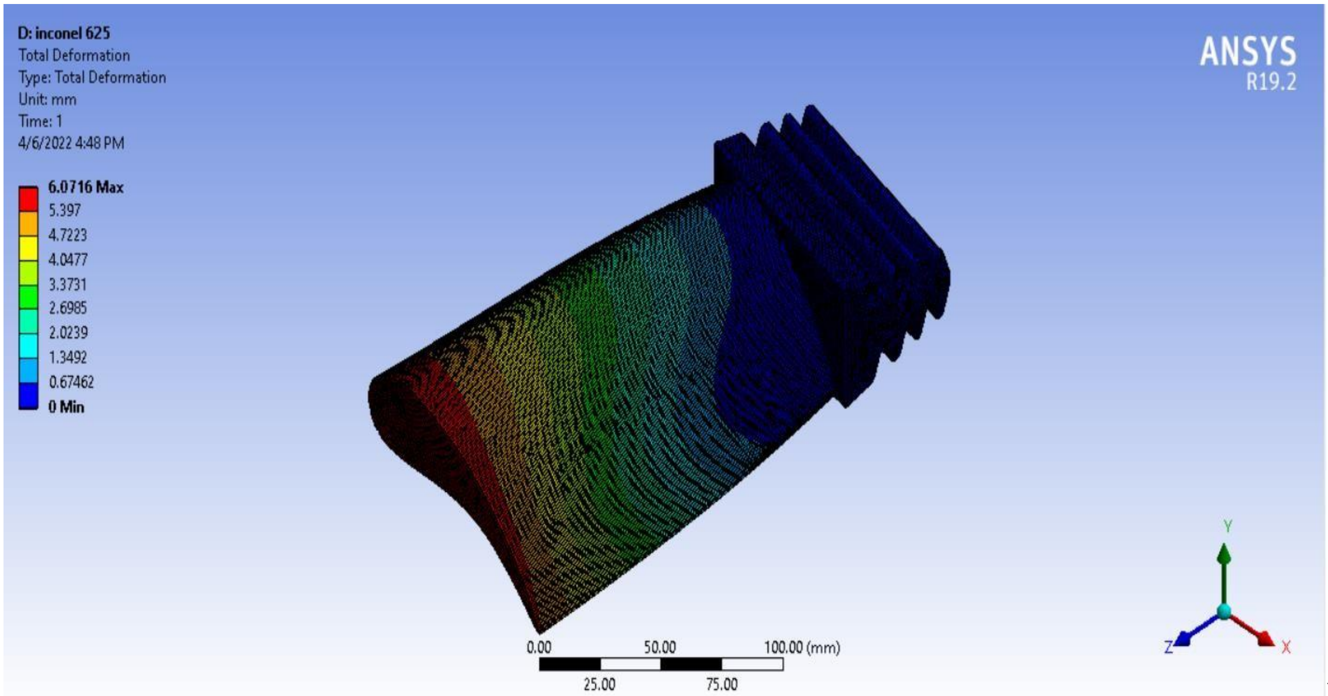

Fig 16: Total Deformation

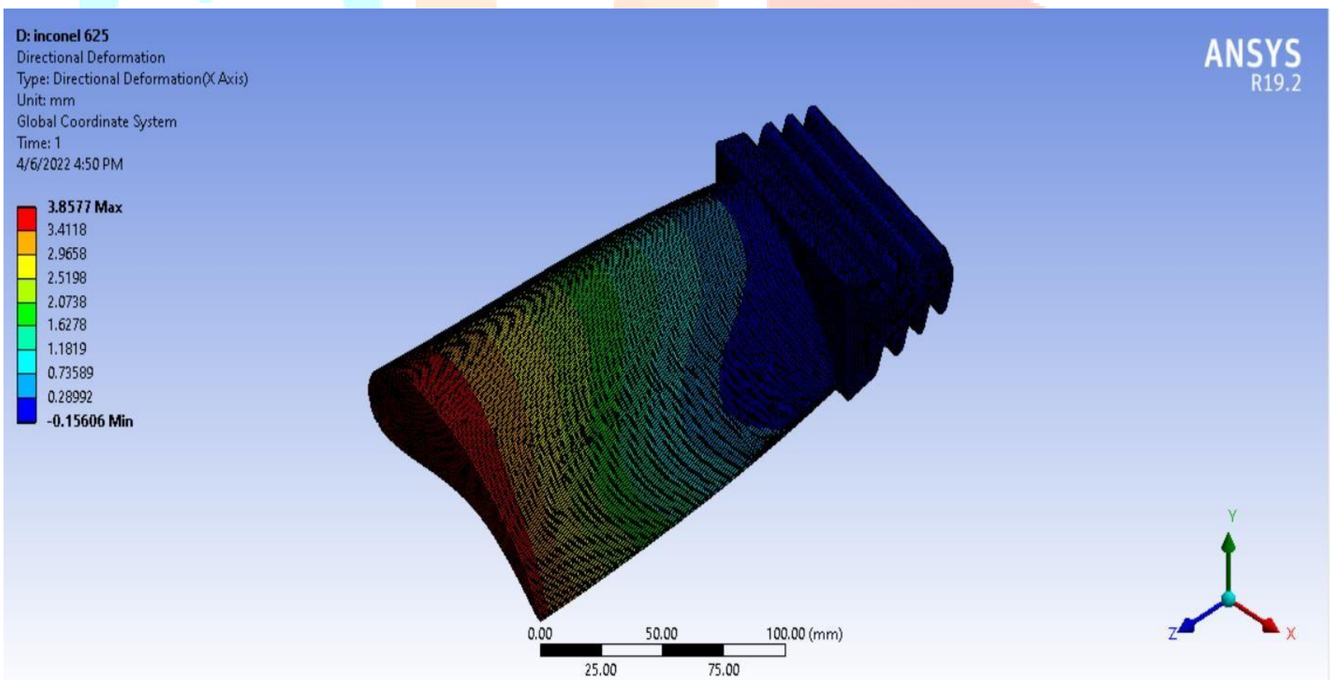

Fig 17: Directional Deformation

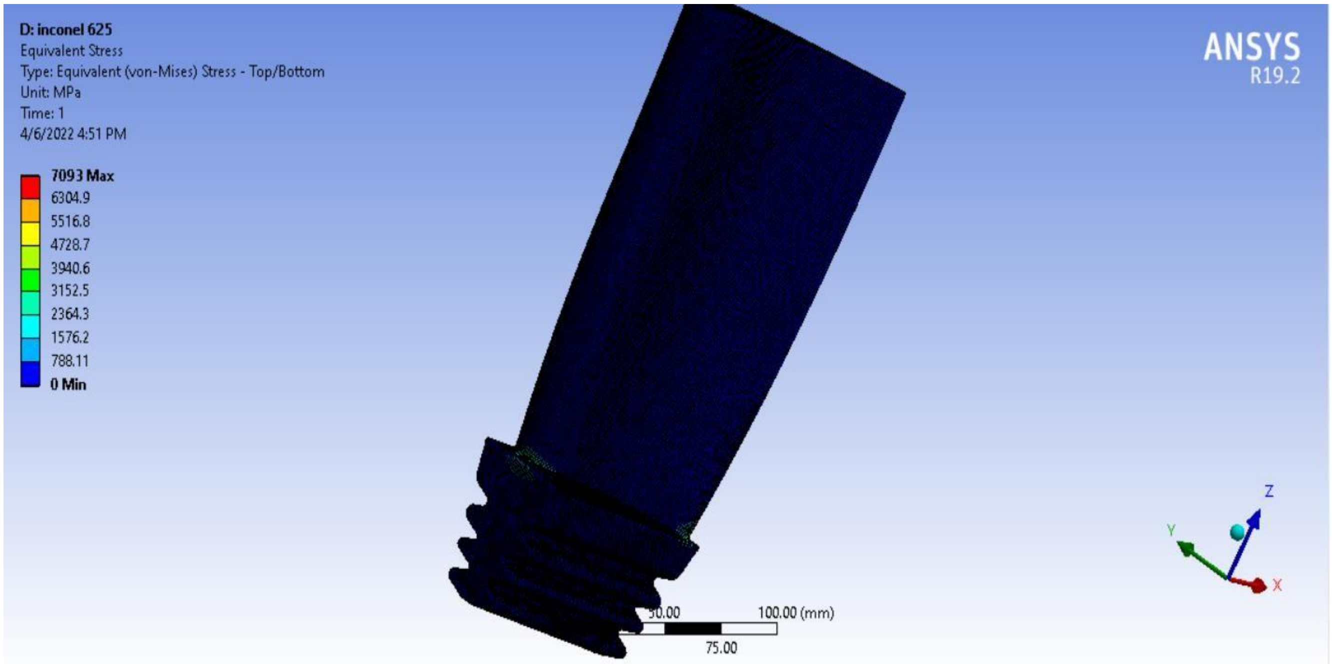

Fig 18: Equivalent (von-mises) Stress

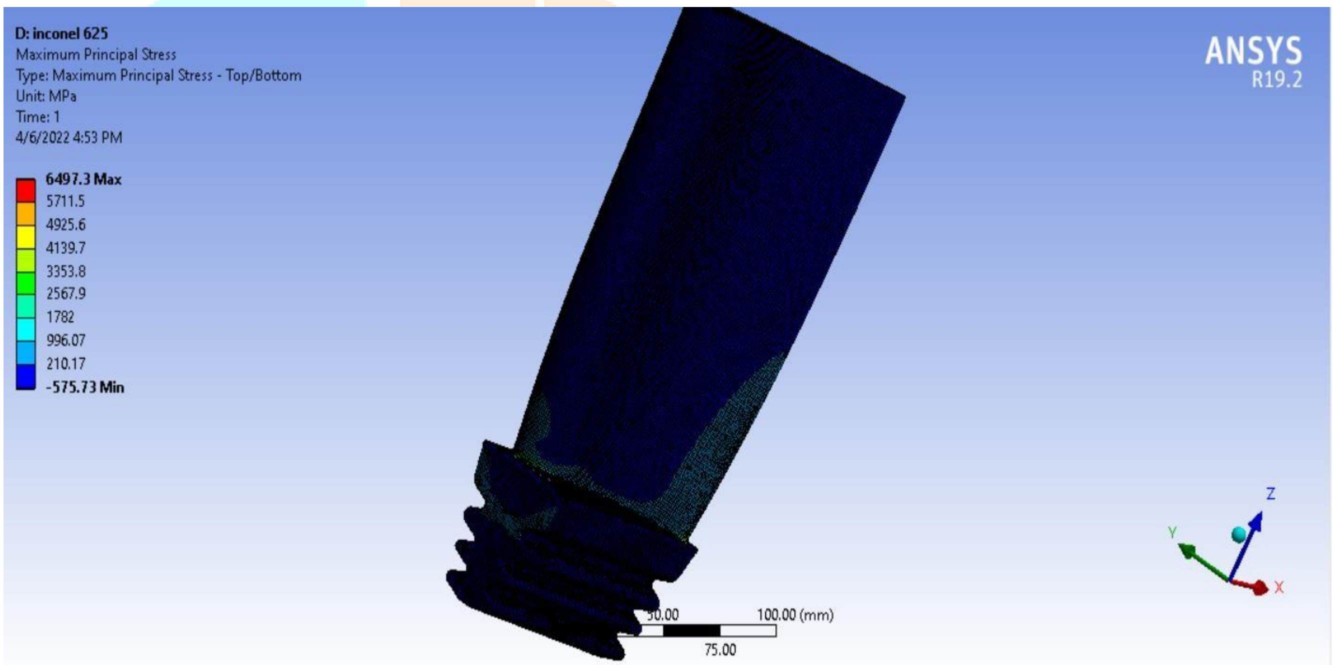

Fig 19: Maximum Principal Stress

Results of Turbine Blade Structural Analysis (Inconel 625)

Table 9: Results of turbine blade Structural Analysis (Inconel 625)

Object Name	Total Deformation	Directional Deformation	Maximum Principal Stress	Equivalent Stress
Minimum	0 mm	-0.15606 mm	-575.73 MPa	0. MPa
MAXIMUM	6.0716 mm	3.8577 mm	6497.3 MPa	7093. MPa
AVERAGE	1.9752 mm	1.2211 mm	64.263 MPa	87.803 MPa

3. For CERAMIC (Al203) Material;

Table 2: Geometrical Properties of Turbine Blade (CERAMIC)

Material	DENSITY (Kg/m^3)	Young's Modulus(Mpa)	Poissons ratio	Melting point(°C)
CERAMIC	3980	4.13E+05	0.33	2369

Table 3: Force on turbine blade (INCONEL 625)

Type	Define By	X Component
Rotational velocity	Components	500 rad/s (ramped)

Results of turbine blade Structural Analysis (CERAMIC) ;

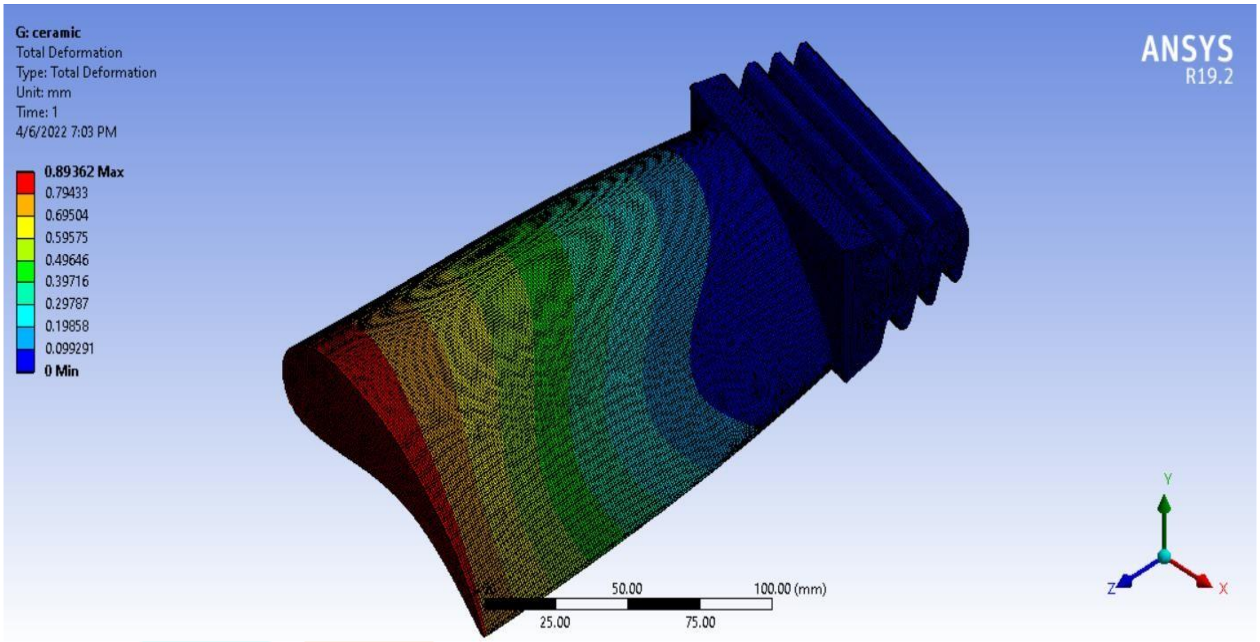

FIG 20. Total Deformation

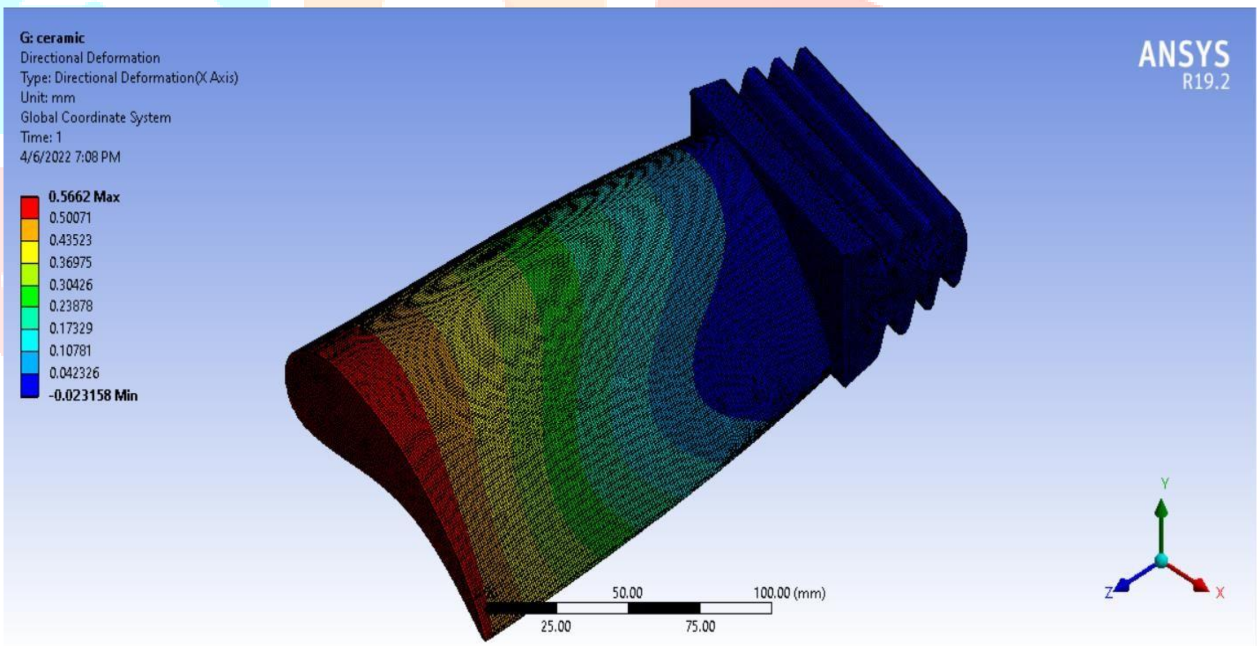

FIG 21. Directional deformation

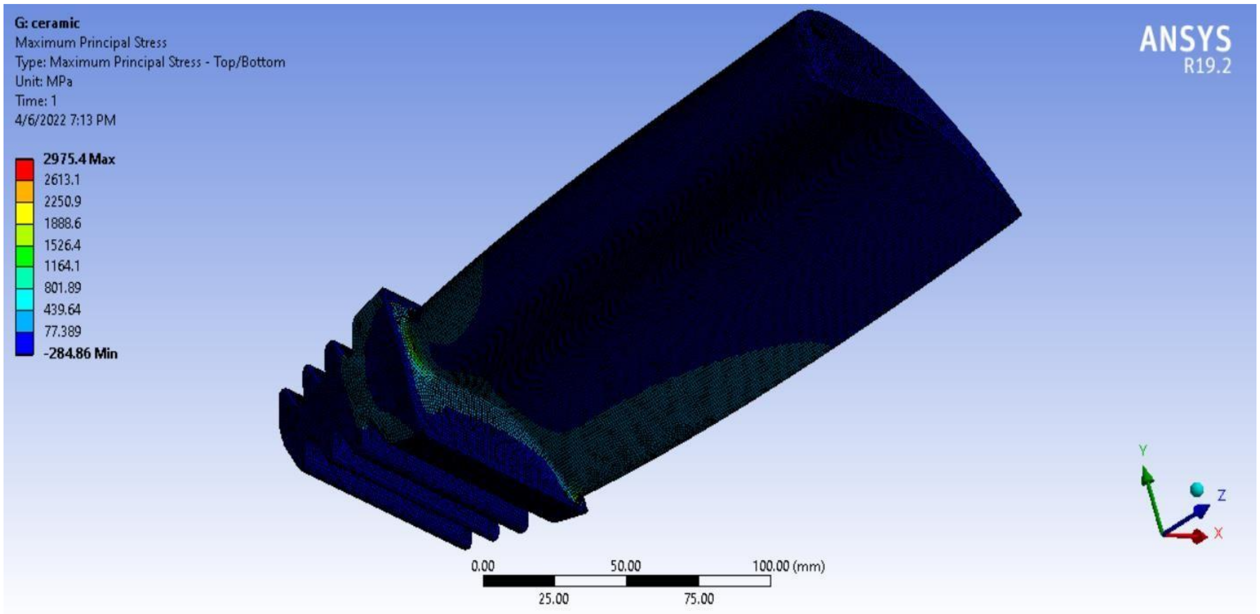

FIG 22. Maximum principal stress

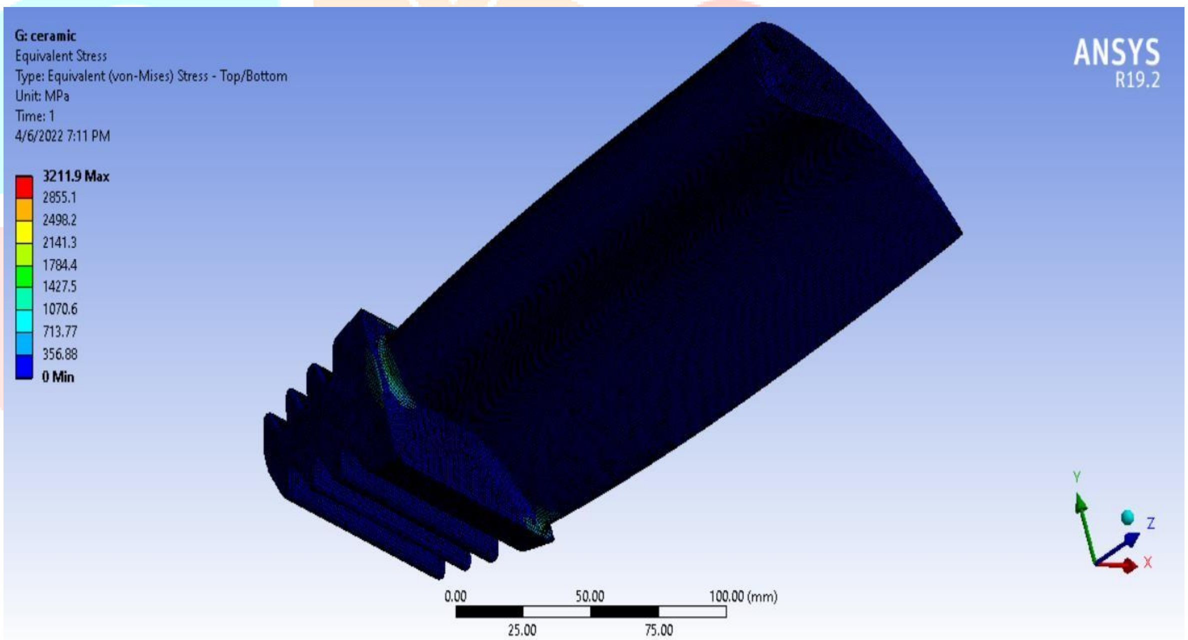

FIG 23. Equivalent stress

Results of Turbine Blade Structural Analysis (CERAMIC)

Table 10: Results of turbine blade Structural Analysis (CERAMIC)

Object Name	Total Deformation	Directional Deformation	Maximum Principal Stress	Equivalent Stress
Minimum	0 mm	-2.3158e-002 mm	-284.86 MPa	0. MPa
MAXIMUM	0.89362 mm	0.5662 mm	2975.4 MPa	3211.9 MPa
AVERAGE	0.28973 mm	0.17848 mm	30.625 MPa	41.698 MPa

4. For NICKEL Material;

Table: Geometrical Properties of Turbine Blade (NICKEL):

MATERIAL	DENSITY (Kg/m^3)	Young's Modulus(Mpa)	Poissons ratio	Melting point(°C)
NICKEL	8902	2.2E+05	0.31	1739

Table: Force on turbine blade (NICKEL) :

Type	Define By	X Component
Rotational velocity	Components	500 rad/s (ramped)

Results of turbine blade Structural Analysis (NICKEL) ;

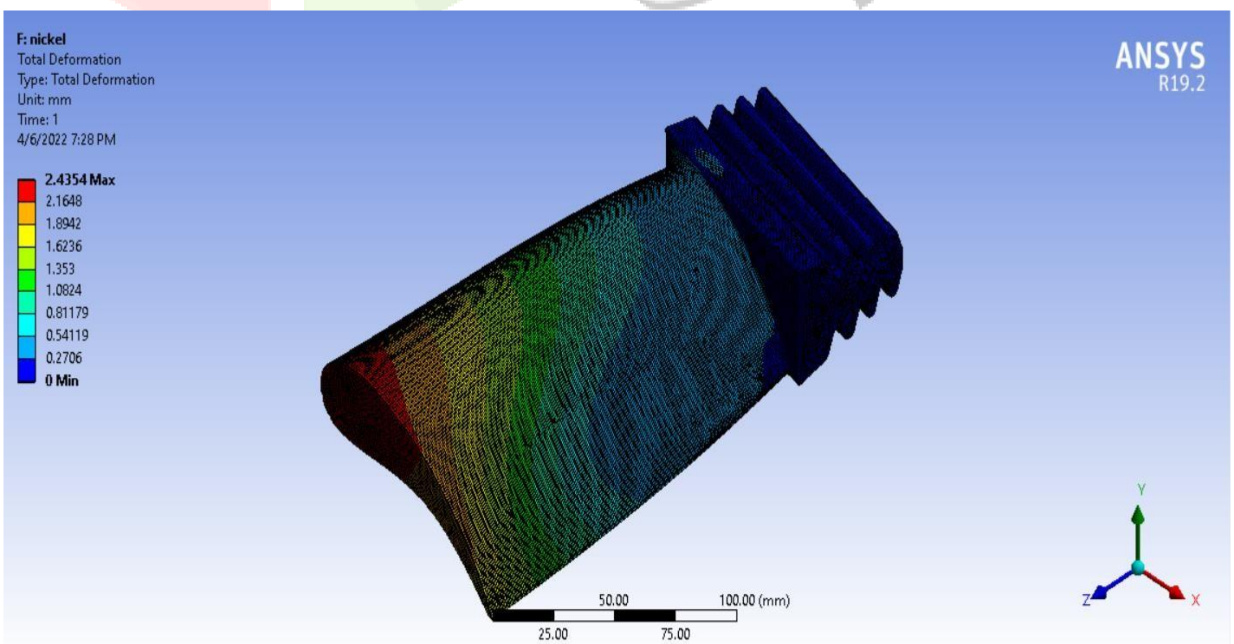

FIG 24. Total deformation

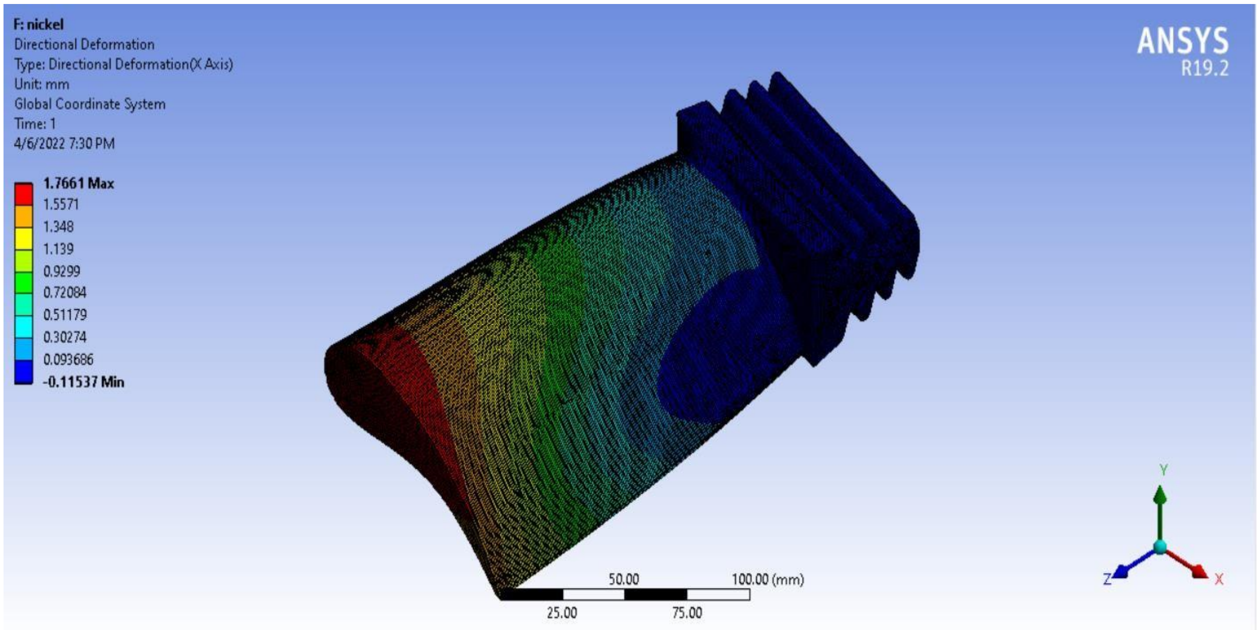

FIG 25. Directional Deformation

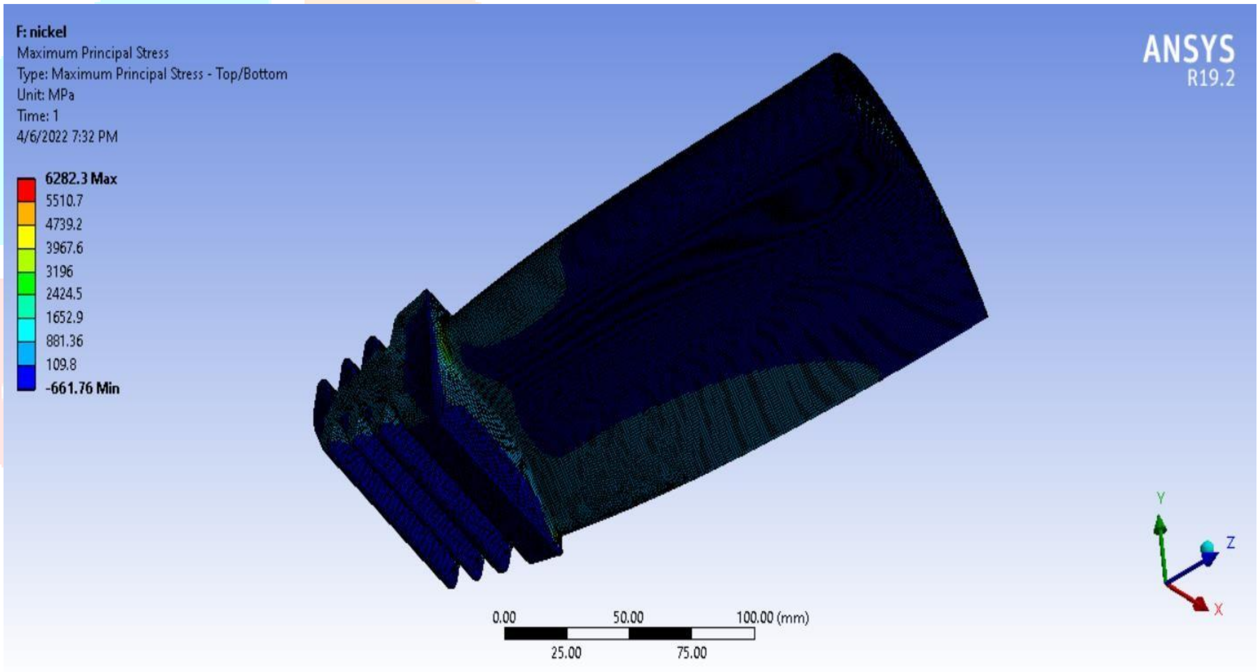

FIG 26. MAXIMUM DEFORMATION

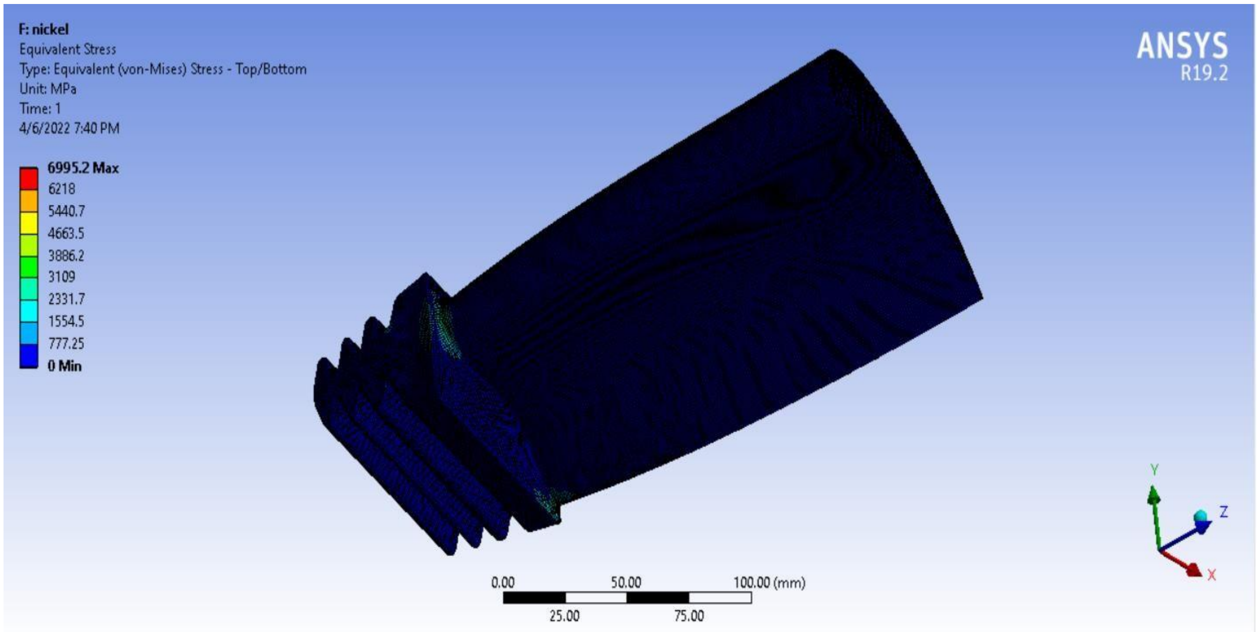

FIG 27. EQUIVALENT STRESS

Results of Turbine Blade Structural Analysis (NICKEL)

Table 11: Results of turbine blade Structural Analysis (NICKEL)

Object Name	Total Deformation	Directional Deformation	Maximum Principal Stress	Equivalent Stress
Minimum	0 mm	-0.11537 mm	-661.76 MPa	0. MPa
MAXIMUM	2.4354 mm	1.7661 mm	6282.3 MPa	6995.2 MPa
AVERAGE	0.76024 mm	0.51336 mm	76.496 MPa	108.31 MPa

5. For CHROMIUM Material;

Table: Geometrical Properties of Turbine Blade (CHROMIUM) :

MATERIAL	DENSITY (Kg/m^3)	Young's Modulus(Mpa)	Poissons ratio	Melting point(°C)
CHROMIUM	7190	2.45E+05	0.2	1907

Table: Force on turbine blade (CHROMIUM) :

Type	Define By	X Component
Rotational velocity	Components	500 rad/s (ramped)

Results of turbine blade Structural Analysis (CHROMIUM) ;

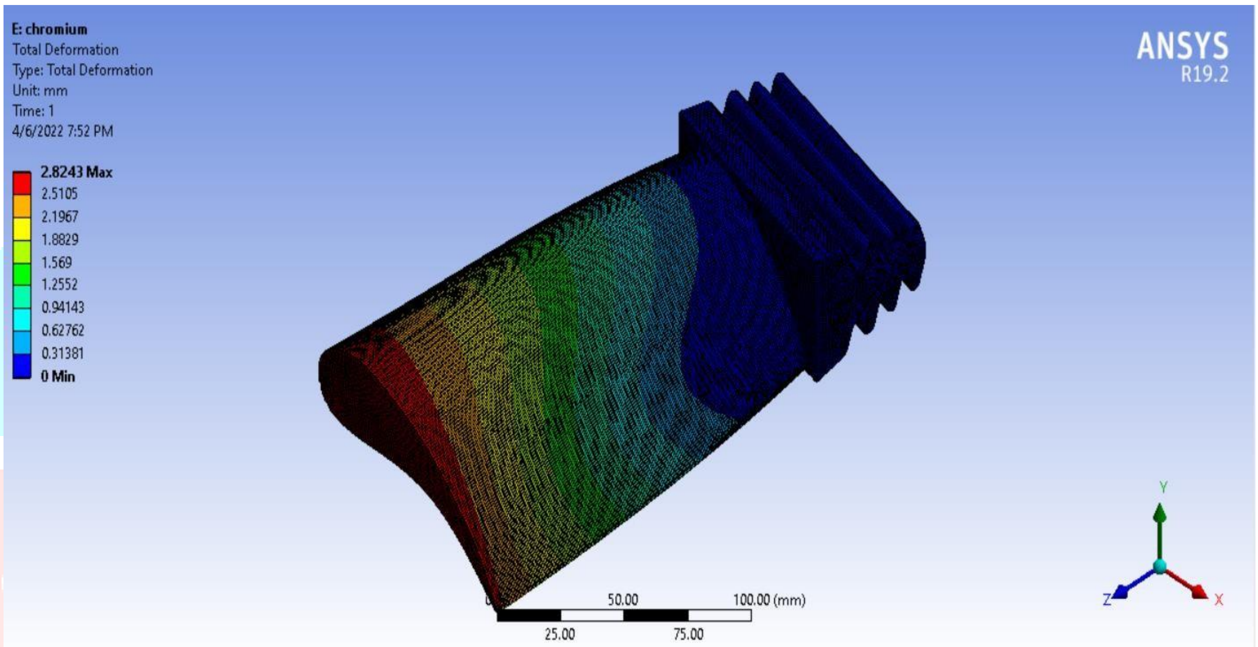

FIG 28. Total deformation

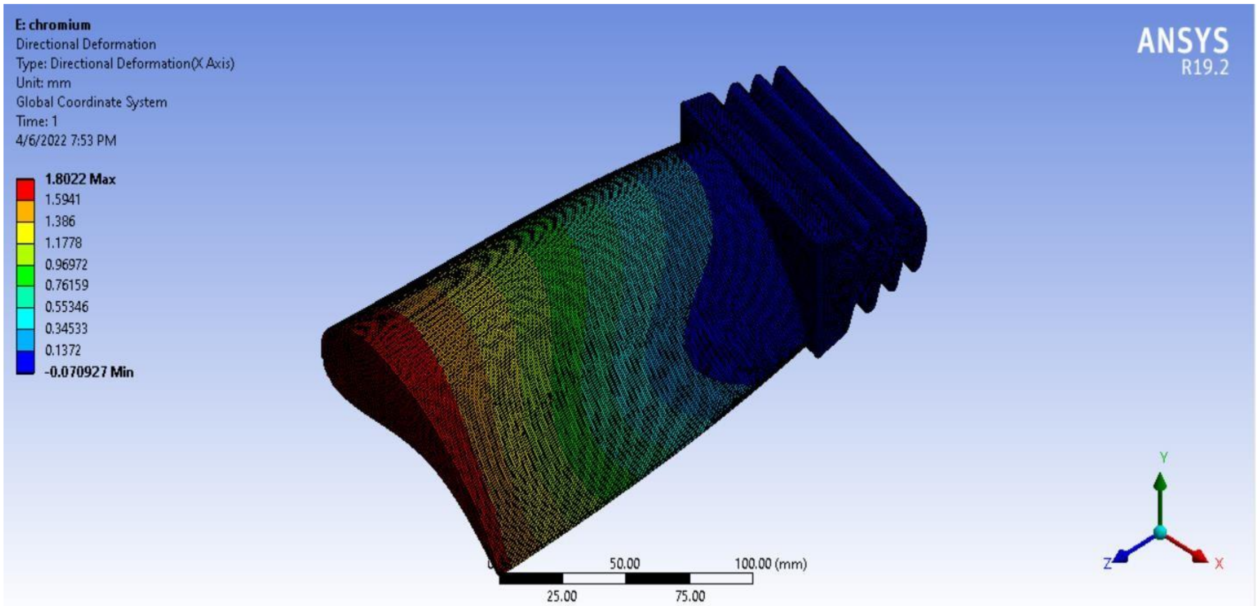

FIG 29. Directional deformation

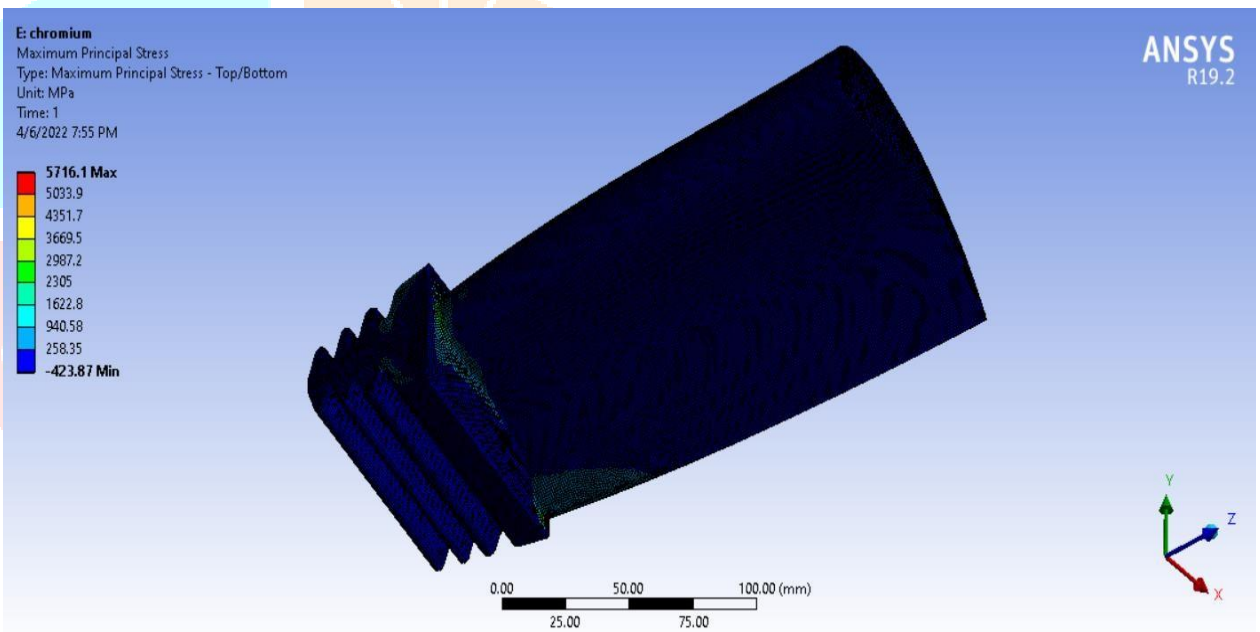

FIG 30. Maximum stress

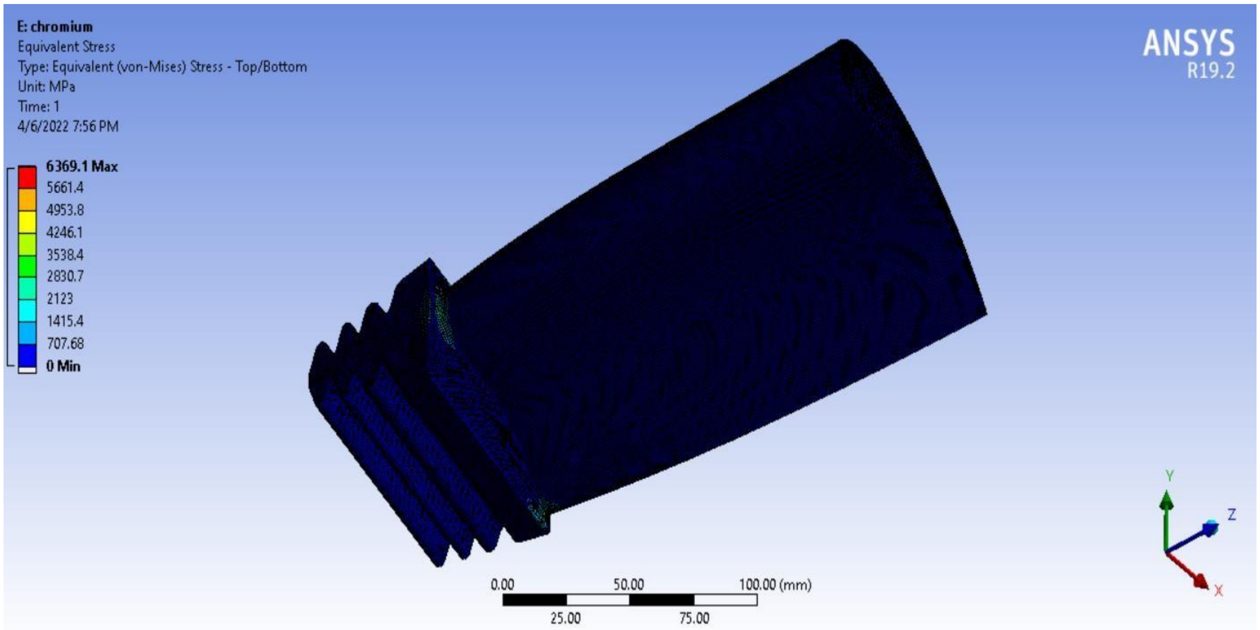

FIG 31. Equivalent stress

Results of Turbine Blade Structural Analysis (CHROMIUM)

Table 12: Results of turbine blade Structural Analysis (CHROMIUM)

Object Name	Total Deformation	Directional Deformation	Maximum Principal Stress	Equivalent Stress
Minimum	0 mm	-7.0927e-002 mm	-423.87 MPa	0. MPa
MAXIMUM	2.8243 mm	1.8022 mm	5716.1 MPa	6369.1 MPa
AVERAGE	0.92339 mm	0.5741 mm	55.369 MPa	75.778 MPa

FINAL RESULTS AND DISCUSSION:

Table 13: Final result of all materials:

Materials	TOTAL DEFORMATION	DIRECTIONAL DEFORMATION	MAXIMUM PRINCIPLE STRESS	EQUIVALENT STRESS
TITANIUM ALLOY	3.3015 mm	0.62212 mm	3249.2 MPa	3460.6 MPa
INCONEL 625	6.0716 mm	3.8577 mm	6497.3 MPa	7093. MPa
CERAMIC	0.89362 mm	0.5662 mm	2975.4 MPa	3211.9 MPa
NICKEL	2.4354 mm	1.7661 mm	6282.3 MPa	6995.2 MPa
CHROMIUM	2.8243 mm	1.8022 mm	5716.1 MPa	6369.1 MPa

The following results show Total deformation, Directional deformation, Maximum principle stress, and Equivalent stress. Titanium alloy has high strength and other properties of titanium are also suitable for turbine blade so titanium is used for turbine blade design.The total deformation of titanium is 3.3015 mm. Which is almost maximum deformation. Inconel 625 is also used in turbine blade because it has best thermal properties but it has less strength as compared to titanium. But Inconel is suitable for high thermal conditions. The total deformation of the Inconel is 6.0716 mm which is maximum. Nickel is also high strength material. The total deformation of nickel is 2.4354 mm which is less as compared to titanium. Chromium is also high strength material. The total deformation of Chromium is 2.8243 which is almost same as compared to nickel. Ceramic which has high strength and better thermal properties. The ceramic used in the software is Aluminum oxide (Al203) which has less deformation as compared to other material and also it has high thermal properties. The Ceramic material is the suitable material for turbine blades as per this research.

CONCLUSION :

- In the current research, application of TITANIUM ALLOY, INCONEL 625, CERAMIC , NICKEL, AND CHROMIUM is evaluated for the design
- Structural analysis is carried out on the Turbine blade for TITANIUM ALLOY, INCONEL 625, CERAMIC , NICKEL AND CHROMIUM materials.
- Total deformation, Directional deformation, Equivalent Von-Mises stress and Maximum Principal stress are the results obtained from analysis.
- From the test results obtained, shows potential application of Ceramic over other materials for turbine blades.

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