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Structural Analysis of Gas Turbine Rotor Blade at Different Pressure Loads

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ABSTRACT

In the present work the first stage rotor blade of a two-stage gas turbine has been analyzed for structural, thermal using ANSYS 19.3 which is powerful Finite Element Software. In the process of getting the thermal stresses, the temperature distribution in the rotor blade has been evaluated using this software. From different materials H13, ALSI 316L, ALSI 10mg that has been considered for the purpose analysis. The turbine blade along with the groove is considered for static, thermal, modal analysis. The blade is modeled with the 3D-Solidworks. The geometric model of the blade profile is generated with splines and extruded to get a solid model. It is observed that the Maximum temperatures observed at the blade tip section are linearly decreasing from the tip of the blade to the root of the blade section. The present used material for blades is chromium steel. In this thesis, it is replaced with ceramic matrix composites, H13, ALSI 316L, ALSI 10mg.

Keywords: Gas Turbine, Structural Analysis, Thermal Analysis, Modal, Finite Element Analysis.

1. INTRODUCTION

1.1 TURBINE

A **turbine** is a rotary engine that extracts energy from a fluid flow and converts it into useful work.The simplest turbines have one moving part, a rotor assembly, which is a shaft or drum with blades attached. Moving fluid acts on the blades, or the blades react to the flow, so that they move and impart rotational energy to the rotor. **Gas**, **steam**, and **water** turbines usually have a casing around the blades that contains and controls the working fluid. Credit for invention of the steam turbine is given both to the British engineer Sir Charles Parsons (1854–1931), for invention of the reaction turbine and to Swedish engineer Gustaf de Laval (1845–1913), for invention of the impulse turbine. Modern steam turbines frequently employ both reaction and impulse in the same unit, typically varying the degree of reaction and impulse from the blade root to its periphery.A working fluid contains potential energy (pressure head) and kinetic energy (velocity head). The fluid may be compressible or incompressible. Several physical principles are employed by turbines to collect this energy.

1.2 TYPES OF TURBINES

1. 2.1 Steam Turbine

A **steam** turbine is a device that extracts thermal energy from pressurized steam and uses it to do mechanical work on a rotating output shaft. Its modern manifestation was invented by Sir Charles Parsons in 1884. Because the turbine generates rotary motion, it is particularly suited to be used to drive an electrical generator – about 90% of all electricity generation in the United States is by use of steam turbines. The steam turbine is a form of heat engine that derives much of its improvement in thermodynamic efficiency through the use of multiple stages in the expansion of the steam, which results in a closer approach to the ideal reversible process.

Fig: 1.1 Steam Turbine

1.1.2 Gas Turbine

A **gas turbine**, also called a combustion turbine, is a type of internal combustion engine. It has an upstream rotating compressor coupled to a downstream turbine, and a combustion chamber in-between.Gas turbines are sometimes referred to as turbine engines. Such engines usually feature an inlet, fan, compressor, combustor and nozzle (possibly other assemblies) in addition to one or more turbines.

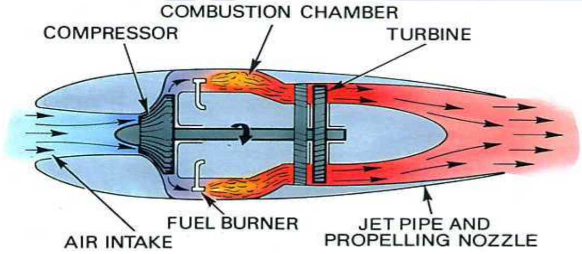


Fig: 1.2 Gas Turbine

1.1.3 Shrouded Turbine

Shrouded turbine, many turbine rotor blades have shrouding at the top, which interlocks with that of adjacent blades, to increase damping and thereby reduce blade flutter. In large land-based electricity generation steam turbines, the shrouding is often complemented, especially in the long blades of a low-pressure turbine, with lacing wires. These wires pass through holes drilled in the blades at suitable distances from the blade root and are usually brazed to the blades at the point where they pass through. Lacing wires reduce blade flutter in the central part of the blades. The introduction of lacing wires substantially reduces the instances of blade failure in large or low-pressure turbines.

1.1.4 Contra-Rotating Turbine

Contra-rotating, also referred to as **coaxial contra-rotating**, is a technique whereby parts of a mechanism rotate in opposite directions about a common axis, usually to minimize the effect of torque.Examples include some aircraft propellers, resulting in the maximum power of a single piston or turbo-prop engine to drive two propellers in opposite rotation.

Contra-rotating propellers are also common in some marine transmission systems, for large speed boats with planning hulls. Two propellers are arranged one behind the other, and power is transferred from the engine via planetary gear transmission. The configuration can also be used in helicopter designs, where similar issues and principles of torque apply.

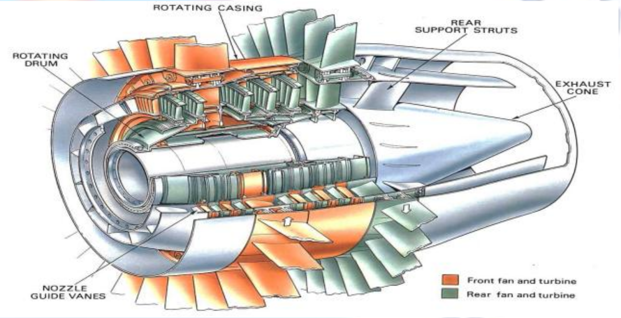


Fig: 1.3 Contra Rotating Turbines

1.1.5 Stator Less Turbine

Stator less turbine, multi-stage turbines have a set of static (meaning stationary) inlet guide vanes that direct the gas flow onto the rotating rotor blades. In a stator less turbine the gas flow exiting an upstream rotor impinges onto a downstream rotor without an intermediate set of stator vanes (that rearrange the pressure/velocity energy levels of the flow) being encountered.

1.1.6Ceramic Turbine

Ceramic turbine, Conventional high-pressure turbine blades (and vanes) are made from nickel-based alloys and often utilize intricate internal air-cooling passages to prevent the metal from overheating. In recent years, experimental ceramic blades have been manufactured and tested in gas turbines, with a view to increasing Rotor Inlet Temperatures and/or, possibly, eliminating air cooling. Ceramic blades are more brittle than their metallic counterparts and carry a greater risk of catastrophic blade failure. This has tended to limit their use in jet engines and gas turbines, to the stator (stationary) blades.

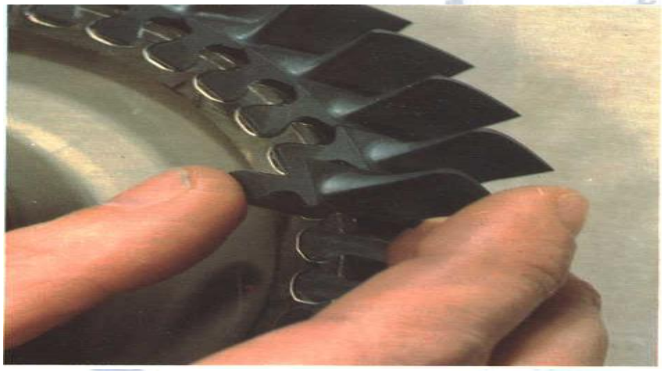


Fig: 1.4 Ceramic Turbine

1.2 GAS TURBINE ENGINE

The gas turbine engine was first developed some forty years ago and by the early 1950s it was a commonplace power unit for both military and civil aircraft. However, in more recent years the gas turbine has become the prime power unit in many diverse applications including military and commercial land transport and marine propulsion systems. It is in the latter role where the greatest number of corrosion problems occurs, these being particularly severe within the turbine section of engines usedin ships, hovercraft and helicopters.A simple gas turbine is comprised of three main sections: **a compressor**, **a combustor** and **a turbine**. The gas turbine operates on the principle of the **Brayton** cycle where compressed air is mixed with fuel and burned under constant pressure conditions. The resulting hot gas is expanded through a turbine to perform work.

A **compressor** is a mechanical device that increases the pressure of a gas by reducing its volume. Compressors are similar to pumps: both increase the pressure on a fluid and both can transport the fluid through a pipe. As gases are compressible, the compressor also reduces the volume of a gas. Liquids are relatively incompressible; while some can be compressed, the main action of a pump is to pressurize and transport liquids.

A **combustion chamber** is the part of an engine in which fuel is burned. Energy is added to the gas stream in the combustor, where fuel is mixed with air and ignited. In the high-pressure environment of the combustor, combustion of the fuel increases the temperature. The products of the combustion are forced into the turbine section.

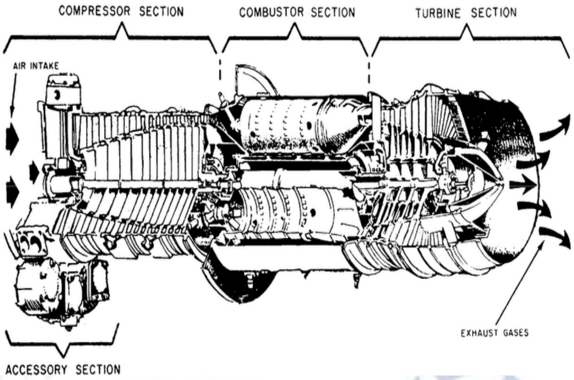


Fig: 1.5 Gas Turbine Engine

A **turbine** is a rotary engine that extracts energy from a fluid flow and converts it into useful work.

The simplest turbines have one moving part, a rotor assembly, which is a shaft or drum with blades attached. Moving fluid acts on the blades, or the blades react to the flow, so that they move and impart rotational energy to the rotor.

1.2.1 Working Cycle

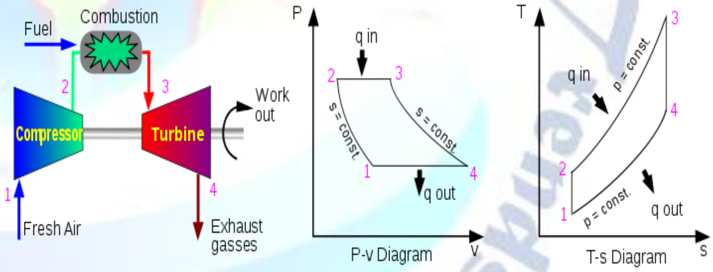


Fig: 1.6 Working Cycle

The **Brayton cycle** is a thermodynamic cycle that describes the workings of the gas turbine engine, basis of the air breathing jet engine and others. It is named after George Brayton (1830–1892), the American engineer who developed it, although it was originally proposed and patented by Englishman John Barber in 1791.[1] It is also sometimes known as the Joule cycle. The Ericsson cycle is similar but uses external heat and incorporates the use of a regenerator.The working cycle of the gas turbine engine is like that of the four-stroke piston engine. However, in the gas turbine engine, combustion occurs at a constant pressure, whereas in the piston engine it occurs at a constant volume. Both engine cycles show that in each instance there is induction, compression, combustion and exhaust. These processes are intermittent in the case of the piston engine whilst they occur continuously in the gas turbine. In the piston engine only one stroke is utilized in the production of power, the others being involved in the charging, compressing and exhausting of the working fluid.In contrast, the turbine engine eliminates the three 'idle' strokes, thus enabling more fuel to be burnt in a shorter time; hence it produces a greater power output for a given size of engine.

Due to the continuous action of the turbine engine and the fact that the combustion chamber is not an enclosed space, the pressure of the air does not rise, like that of the piston engine, during combustion but its volume does increase. This process is known as heating at constant pressure. Under these conditions there is no peak or fluctuating pressures to be withstood, as is the case with the piston engine with its peak pressures more than 1,000 lb. per sq. in. It is these peak pressures which make it necessary for the piston engine to employ cylinders of heavy construction and to use high octane fuels, in contrast to the low octane fuels and the light fabricated combustion chambers used on the turbine engine.

The working cycle upon which the gas turbine engine functions is, in its simplest form, represented by the cycle shown on the pressure volume diagram in fig. 2-2. Point A represents air at atmospheric pressure that is compressed along line AB. From B to C heat is added to the air by introducing and burning fuel at constant pressure, thereby considerably increasing the volume of air. Pressure losses in the combustion chambers (Part 4) are indicated by the drop between B and C. From C to D the gases resulting from combustion expand through the turbine and jet pipe back to the atmosphere. During this part of the cycle, some of the energy in the expanding gases is turned into mechanical power by the turbine; the remainder, on its discharge to atmosphere, provides a propulsive jet. Because the turbo-jet engine is a heat engine, the higher the temperature of combustion the greater is the expansion of the gases. The combustion temperature, however, must not exceed a value that gives a turbine gas entry temperature suitable for the design and materials of the turbine assembly.The improvements of the gas turbine cycle have historically been aiming at increasing the efficiency, lowering the investment cost, and reducing environmental emissions. To increase efficiencies, turbine designers have worked to increase firing temperatures without damaging the turbines. However, firing turbines beyond the threshold temperatures of their components threaten their integrity and reliability. Development of advanced cooling techniques and improving materials are two major strategies of solving this problem. The improvements of the individual efficiencies of the main gas turbine components like the compressor and turbine have also helped in increasing the gas turbine efficiency. In addition, improved efficiency can be achieved by modifications to the original simple cycle to recover heat from the turbine exhaust.

2. LITERATURE REVIEW

The word "**turbine**" was coined in 1822 by the French mining engineer Claude Burdin from the Latin turbo, or vortex, in a memoir, "Des turbines hydraulic ques our machines rotatories à grandevitesse" (Hydraulic turbines or high-speed rotary machines), which he submitted to the Academia royal des sciences in Paris. Benoit Fourneyron, a former student of Claude Burdin, built the first practical water turbine [1].

The purpose of turbine technology is 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 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 gas as shown in figure 1[2].

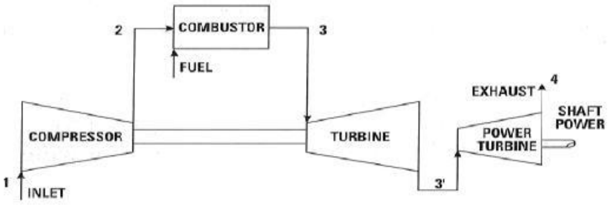


Figure 2.1 Gas Turbine Simple Open Cycles

The Turbine compressor usually sits at the front of the engine. There are two main types of compressors, the centrifugal compressor and the axial compressor.

The compressor will draw in air and compress it before it is fed into the combustion chamber. In both types, the compressor rotates, and it is driven by a shaft that passes through the middle of the engine and is attached to the turbine as shown below in figure 2 [2], [3].Gas turbine fuel systems are similar for all Turbines. For the most common fuels, which are natural gas, LNG (liquid natural gas), and light diesel, the fuel system consists of: A fuel delivery system, Fuel nozzles, Fuel additives (to deal with vanadium), Fuel washing (to deal with sodium and potassium Salts) and Modifications to the fuel delivery system [4].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].

In this there is a group of iron-base alloys, the iron-chromium-nickel alloys known as stainless steels, which do not rust in sea water, are resistant to concentrated acids and which do not scale at temperatures up to 1100°C. It is this largely unique universal usefulness, in combination with good mechanical properties and manufacturing characteristics, which gives the stainless steels their raison d'être and makes them an indispensable tool for the designer.

The usage of stainless steel is small compared with that of carbon steel but exhibits a steady growth, in contrast to the constructional steels. Stainless steels as a group are perhaps more heterogeneous than constructional steels, and their properties are in many cases relatively unfamiliar to the designer. In some ways stainless steels are an unexplored world but to take advantage of these materials will require an increased understanding of their basic properties [6]. With beta stabilizers this group has high harden ability and high strength, but also a higher density. Titanium alloys use in aero engines, Automotive, Airframes and road transport, Dental alloys, geothermal plant, Marine and Military hardware [7].

The finite element method (FEM) has now become a very important tool of engineering analysis. Its versality is reflected in its popularity among engineers and designers belonging to nearly all the engineering disciplines. [8] Whether a civil engineer designing bridges, dams or a mechanical engineers designing auto engines, rolling mills, machine tools or an aerospace engineer interested in the analysis of dynamics of an aero plane or temperature rise in the heat shield of a space shuttle or a metallurgist concerned about the influence of a rolling operation on the microstructure of a rolled product or an electrical engineer interested in analysis of the electromagnetic field in electrical machinery-all find the finite element method handy and useful[9].

It is not that these problems remained 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 solve an engineering problem mathematically, always try simplified formulation to overcome the various complexities involved in exact mathematical formulation. In the modern technological Environment, the conventional methodology of design cannot compete with the modern trends of

Computer Aided Engineering (CAE) techniques [10], the constant search for new innovative design in the engineering field is a common trend. To build highly optimized products, this is the basic requirement of today for survival in the global market. All round efforts were put forward in this direction. Software professionals and technologists have developed various design packages [11].

The finite element method is a numerical analysis technique for obtaining approximate solutions to a wide variety of engineering problems. In engineering problems there are some basic unknowns. If they are found, the behavior of the entire structure can be predicted. The basic unknowns or the field variable which are encountered in engineering problems are displacement in solid mechanics [12].

The finite procedure reduces such unknowns to a finite number by dividing the solution region into small parts called elements as shown in figure 6 and by expressing the unknown field variable in terms of assumed approximating functions within each element. The approximating functions are defined in terms of field variable specified called nodes or nodal point [13]. Thus, in the finite element analysis the unknowns are field variables of the nodal points. Once these are found the field variable at any point can be found by using interpolation functions.

3. INTRODUCTION TO TURBINE BLADE

A **turbine blade** is the individual component which makes up the turbine section of a gas turbine. The blades are responsible for extracting energy from the high temperature, high pressure gas produced by the combustor. The turbine blades are often the limiting component of gas turbines. To survive in this difficult environment, turbine blades often use exotic materials like super alloys and many different methods of cooling, such as internal air channels, boundary layer cooling, and thermal barrier coatings.

Fig: 3.1 Turbine Blades

3.1 MATERIALS

Since the design of turbo machinery is complex, and efficiency is directly related to material performance, material selection is of prime importance. Gas and steam turbines exhibit similar problem areas, but these problems areas are of different magnitudes. Turbines components must operate under a variety of stress, temperature, and corrosion conditions. Compressor blades operate at relatively low temperatures but are highly stressed. The combustor operates at a relatively high temperature and low-stress conditions. The turbine blades operate under extreme conditions of stress, temperature, and corrosion. These conditions are more extreme in gas turbines than in steam turbine applications. As a result, the material selection for individual components is based on varying criteria in both gas and steam turbines.A design is only as efficient as the performance of the selected component materials. The combustor liner and turbine blades are the most critical components in existing high-performance, long-life gas turbines. The extreme conditions of stress, temperature and corrosion make the gas turbine blade a material challenge. Other turbine components present operational problem areas, but to a lesser degree. For this reason, gas turbine blade metallurgy will be discussed for solutions to problem areas. Definition of potential solutions will also relate to other turbine components.

The interaction of stress, temperature, and corrosion yield a complex mechanism that cannot be predicted by existing technology. The required material characteristics in a turbine blade for high performance and long life include limited creep, high-rupture strength, resistance to corrosion, good fatigue strength, and low coefficient of thermal strains. The failure mechanism of a turbine blade is related primarily to creep and corrosion and secondarily to thermal performance, long life, and minimal maintenance.The development of new materials as well as cooling schemes has seen the rapid growth of the turbine firing temperature leading to high turbine efficiencies. The stage 1 blade must withstand the most severe combination of temperature, stress and environment; it is generally the limiting component in the machine. Fig 2 shows the trend of firing temperature and blade alloy capability.

4. SOLIDWORKS

SolidWorks is a solid modeling computer-aided design (CAD) and computer-aidedengineering(CAE) computer program that runs on Microsoft Windows. SolidWorks is published by Dassault Systemes.More than 3,246,750 product designers and engineers worldwide, representing 240,010 organizations, use SOLIDWORKSto bring their designs to life–from the coolest gadgets to innovations that deliver a bettertomorrow.Dassault systems SOLIDWORKS Corp. offers complete 3D software tools that let you create, simulate, publish, and manage your data. SOLIDWORKS products are easy to learn and use and work together to help you design products better, faster, and more cost-effectively. SOLIDWORKS'focus on ease-of-use allowsmoreengineers, designers and other technology professionals than ever before to take advantage of 3D in bringing their designs tolife.

- It is headquartered at Waltham, Massachusetts, USA.
- The latest version of SolidWorks'was released on 19thSeptember, 2016 as SolidWorks2017.

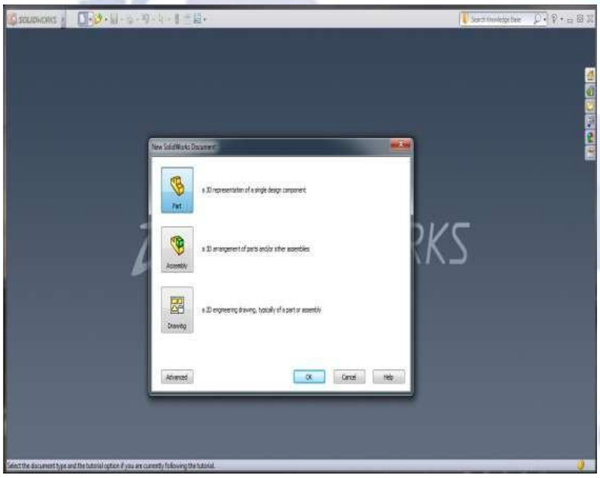
SolidWorks partners with third party developers toadd functionality in niche market applications likefinite element analysis, circuit layout, tolerance checking, etc.

SolidWorks has also licensed its 3D modelingcapabilities to other CAD software vendors, notablyANVIL.

4.2 HISTORY

SolidWorks Corporation was founded in December 1993 by Massachusetts Institute ofTechnology graduate Jon Hirschtick.Hirschtickused $1 million he had made while a member of the MIT Blackjack Team to set up the company. Initially based in Waltham,Massachusetts,United States, Hirschtickrecruited a team of engineers with the goal of building 3D CAD software that was easy-to-use, affordable, and available on the Windows desktop. Operating later from Concord, Massachusetts, SolidWorks released its first product SolidWorks 95, in November 1995. In 1997 Dassault, best known forits CATIA CAD software, acquired SolidWorks for $310 million in stock.[5]Jon Hirschtickstayed on board for the next 14 years in various roles. Under his leadership, SolidWorks grew to a $100 million revenuecompany.SolidWorks currently markets several versions of the SolidWorks CADsoftware in addition to eDrawings, a collaboration tool, and DraftSight, a 2D CAD product.SolidWorks was headed by John McEleney from 2001 to July 2007 and JeffRay from 2007 to January 2011. The current CEO is Gian Paolo Bassi from Jan 2015. Gian Paolo Bassi replaces Bertrand Sicot, who ispromoted VicePresidentSales of Dassault Systèmes' Value Solutions saleschannel.

4.3 THE SOLIDWORKSMODEL

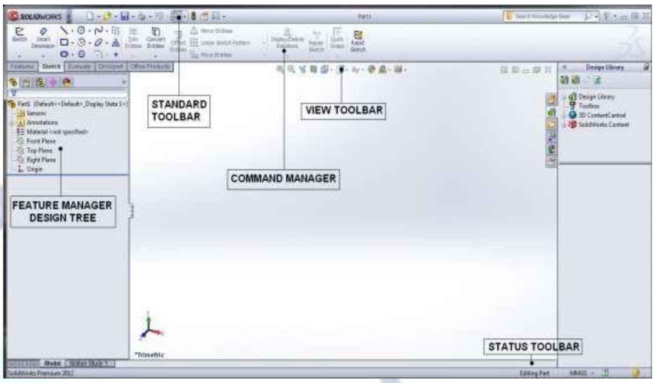


The SolidWorks model is made up of:

- **Parts** -2D design (Sketch), 3D design (Features) , Part design consider in the part designsection.
- **Assemblies** - Assembling of two or more than two parts considered in thissection.
- **Drawings**- Designing with standards is considered in the drawingsection.

4.4 SOLIDWORKS USERINTERFACE

The interfaceis nativeWindowsinterface, and such behaves in the same manner as other Windowsapplications.



4.5 DESIGN OF GAS TURBINE BLADE

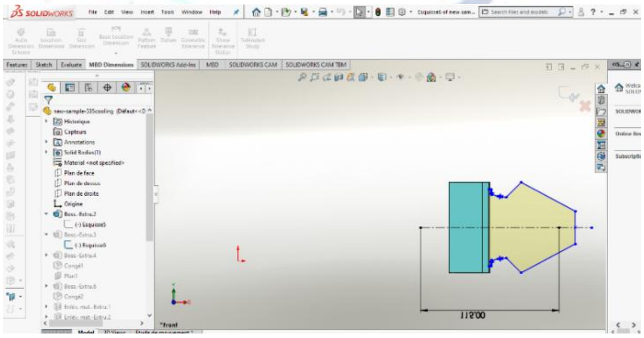


Fig.no.4.1 2d sketch of body

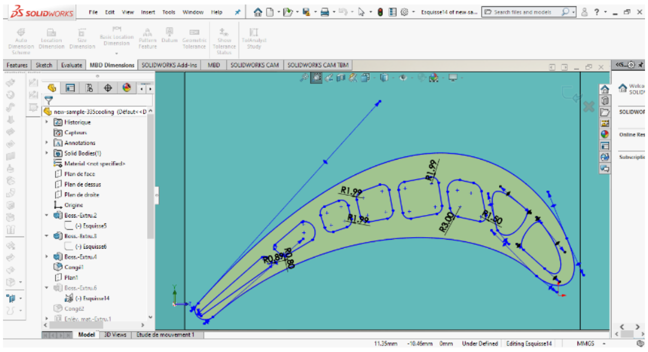


Fig.no.4.2 blade shape in 2d

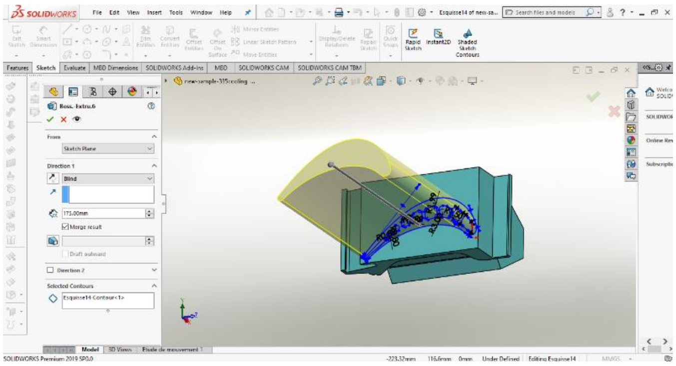


Fig.no.4.3 using extrude boss.

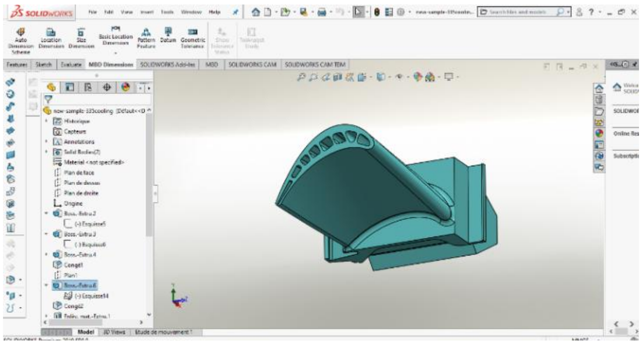


Fig.no.4.4 design of gas turbine blade

5. ANALYSIS

The essential idea in fem is that the body or structure may be separated into littler components of limited measurements called "Finite Elements". The first body or the structure is then considered as a gathering of these components associated at a limited number of joints called "nodes" or "nodal points". Basic capacities are approximated the relocations over each limited component. Such accepted capacities are called "shape capacities". This will speak to the uprooting within the component as far as the remit Element technique is a scientific apparatus for illuminating common and fractional at the hubs of the components. The Final differential comparison because it is a numerical instrument, it can take care of the unpredictable issue that can be spoken to in differential mathematical statement from. The use of FEM is boundless as respects the arrangement of commonsense configuration issues.FEM has good efficiency to solve problems and cost critical problems as the cost for computing power is high.The finite element method can be utilized to solve problems in the following areas:

- Structural analysis
- Thermal analysis
- Vibrations and dynamics
- Buckling analysis
- Acoustics
- Fluid flow simulations
- Crash simulations.
- Mould flow simulations

Now a days, even the simplest of products rely on the finite element method for design evaluation. This is on account of contemporary configuration issues normally can't be understood as precisely and inexpensively utilizing some other system that is at present accessible. Physical testing was the standard in the years passed by, however now it is just excessively costly and tedious too.

ESSENTIAL CONCEPTS: The limited component technique depends on building an entangled article with basic squares or driving a confounded item into little and sensible pieces. Use of this basic thought can be discovered all over the place in ordinary life and buildings. The philosophy of FEA can be explained with a small example such as measuring the area of a circle.

- Area of one triangle: Si=1/2*R2*sin θI.
- Area of the circle: SN=1/2*R2*N*Sin (2∏/N) →∏R2 as N→∞.
- Where N= total number of triangles (elements)

To calculate the area of circle without using conventional formula, one of the approach could be dividing the area into number of equal segments. The area of each triangle multiplied by the number of such segments gives the total area of the circle.

5.2 A BRIEF HISTORY OF THE FEM:

WHO?

The reference credited is to Courant (Mathematician), Turner (aircraft industry), Clough (California University), Martin (aircraft industry), Argyris (German university), etc. However, it was probably established by several pioneers independently.

WHEN?

- Initial idea in mathematical terms was put in 1940s.
- Application to simple engineering problems in 1950s.
- Implementation in large computers in 1960s.
- Development of pre and post processors in 1980s.
- Analysis of large structural problems in 1990s.

WHERE?

Implementation and application were mainly in aircraft industry and automobile sectors (large and fast computers were available only in these industries).

WHAT?

Field problems in the form matrix of organizing large numbers of algebraic equations are used and matrix equations are solved. Differential equations are changed into an algebraic form. Blocks with different geometry are hooked together for creating complex geometry of the engineering problem.

WHY?

The advantage of doing FEM analysis is that it is simple to change the geometry, material and loads recomputed stresses for modified product rather than build and test. The method can be used to solve almost any problem that can be formulated as a field problem. The entire complex problem can be cast as a larger algebraic equation by assembling the element matrices within the computer and solved.

5.3 MESHING:

MESHING: Before lattice the model and even before building the model, it is essential to consider whether a free work or a mapped cross section is proper for the examination. A free work has no limitations as far as component shapes and has no predefined example connected to it. Contrast with a free work, a mapped cross section is confined if the component shape it contains and the pattern of mesh. Mapped area mesh contains either quadrilateral or just triangular components, while a mapped volume cross section contains just hexahedron components. If we need this kind of lattice, we must form geometry as an arrangement of genuinely normal volumes and/or regions that can acknowledge a mapped network.

5.4 STRUCTURAL STATIC ANALYSIS:

The load effects can be calculated on a structure by ignoring the damping and inertia effects, such as those caused by time varying loads can be calculated by structural static analysis. Steady equivalent loads like steady inertia loads and time varying loads are included in Static analysis. Static analysis is utilized to decide the removals, burdens, strains and powers in structures or segments brought about by burdens that don't instigate noteworthy dormancy and damping impacts. Enduring stacking and reaction conditions are accepted, i.e. the stress and the structure's reactions are expected to differ gradually as for time. The kinds of load can be applied in static analysis include:

- Force and pressure application on body.
- Steady state inertial forces.
- Displacement.
- Thermal behavior.

Create a study defining its analysis type and options.

If needed, define parameters of your study. A parameter can be a model dimension, material property, force value, or any other input.

6. RESULTS FO GAS TURBINE BLADE

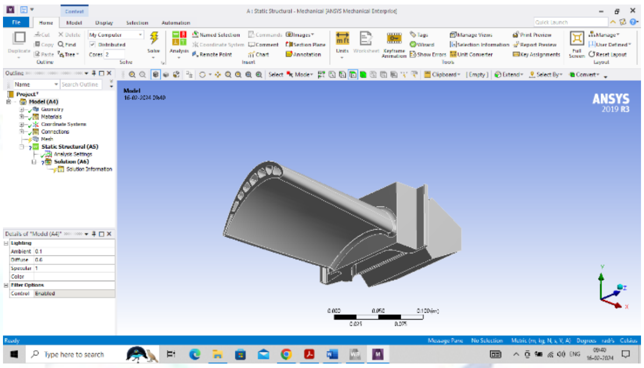


Fig.no.6.1 imported file in Ansys

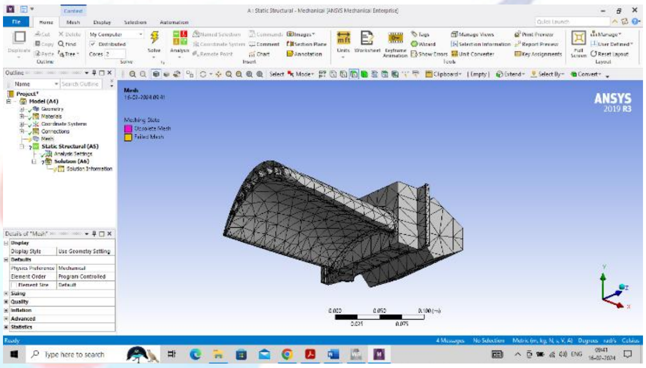
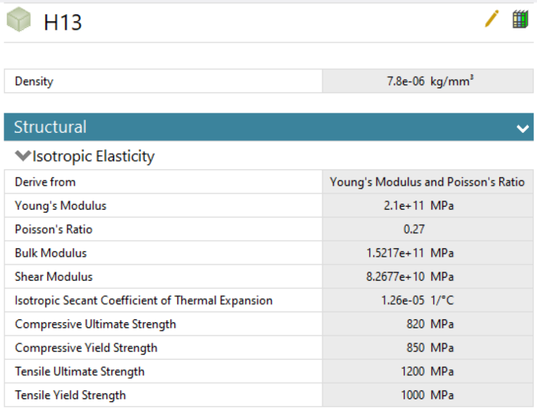


Fig.no.6.2 meshed component

6.1 H13



H13

Density	7.8e-06 kg/mm³
Structural	
Isotropic Elasticity	
Derive from	Young's Modulus and Poisson's Ratio
Young's Modulus	2.1e+11 MPa
Poisson's Ratio	0.27
Bulk Modulus	1.5217e+11 MPa
Shear Modulus	8.2677e+10 MPa
Isotropic Secant Coefficient of Thermal Expansion	1.26e-05 1/°C
Compressive Ultimate Strength	820 MPa
Compressive Yield Strength	850 MPa
Tensile Ultimate Strength	1200 MPa
Tensile Yield Strength	1000 MPa

Table 6.1 mechanical properties of H13

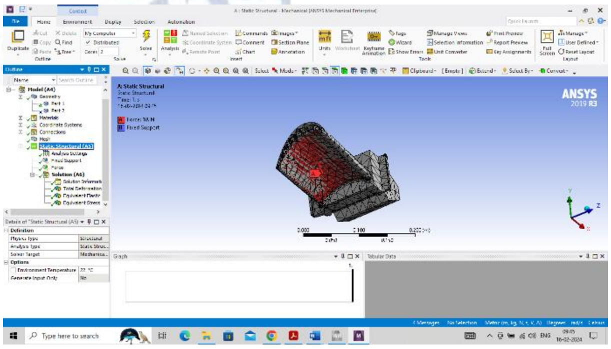


Fig.no.6.3 boundary conditions

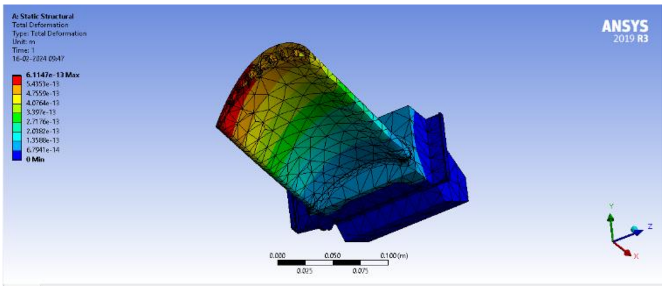


FIG.NO.6.4 total deformation

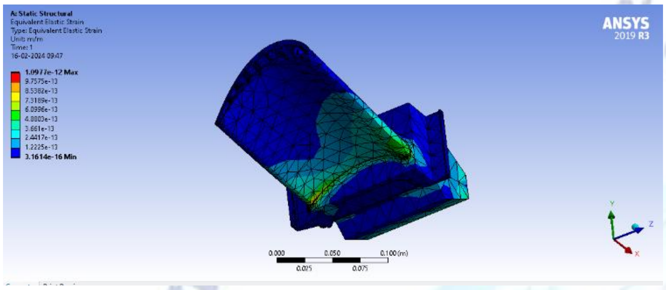


Fig.no.6.5 elastic strain

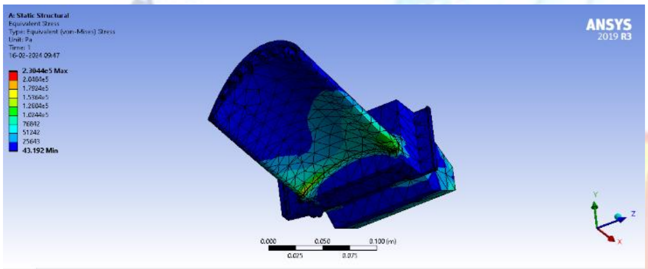
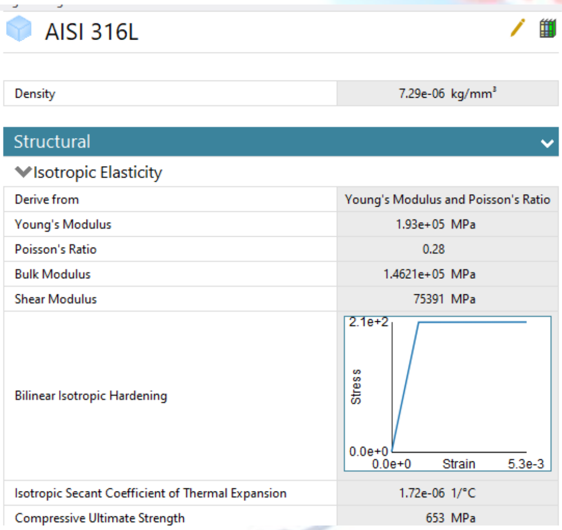


Fig.no.6.6 equivalent stress

6.2 ALSI 316L



AISI 316L

Density	7.29e-06 kg/mm³

Structural

Isotropic Elasticity

Derive from	Young's Modulus and Poisson's Ratio
Young's Modulus	1.93e+05 MPa
Poisson's Ratio	0.28
Bulk Modulus	1.4621e+05 MPa
Shear Modulus	75391 MPa
Bilinear Isotropic Hardening	
Isotropic Secant Coefficient of Thermal Expansion	1.72e-06 1/°C
Compressive Ultimate Strength	653 MPa

TABLE 6.2 ALSI 316L mechanical properties

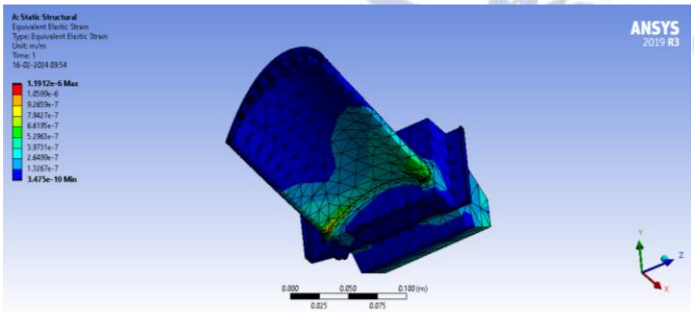


Fig.no.6.7 total deformation

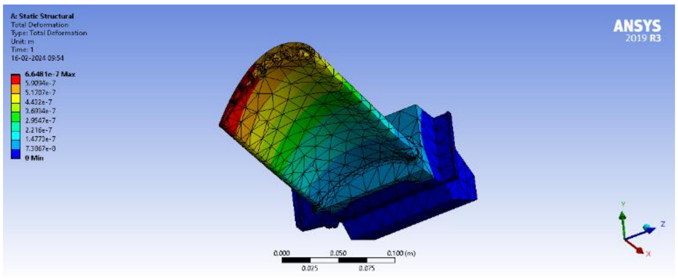


Fig.no.6.8 elastic strain

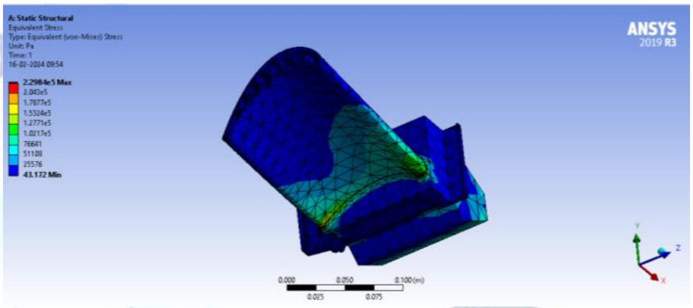
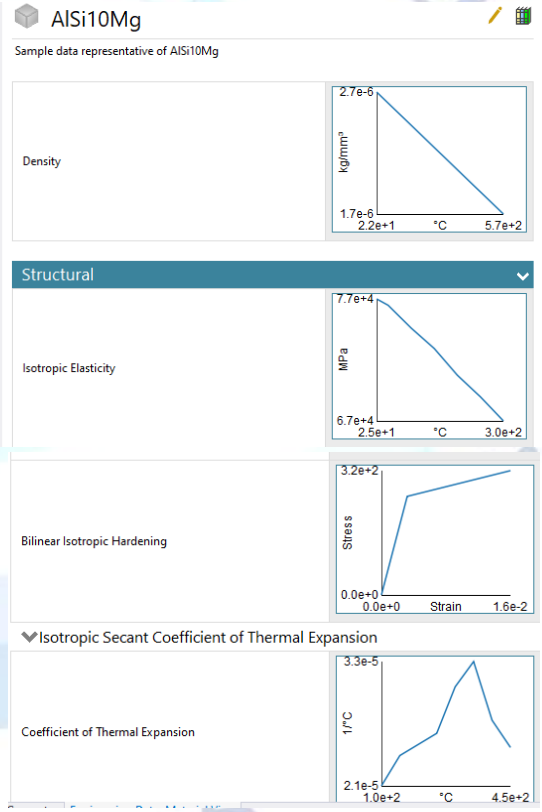


Fig.no.6.9 equivalent stress

6.3 ALSI 10mg



AlSi10Mg

Sample data representative of AlSi10Mg

Density

Structural

Isotropic Elasticity

Bilinear Isotropic Hardening

Isotropic Secant Coefficient of Thermal Expansion

Coefficient of Thermal Expansion

TABLE 6.3 ALSI 10mfg mechanical properties

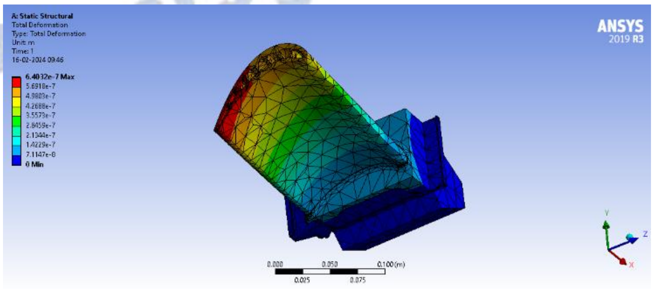


Fig.no.6.10 Total deformation

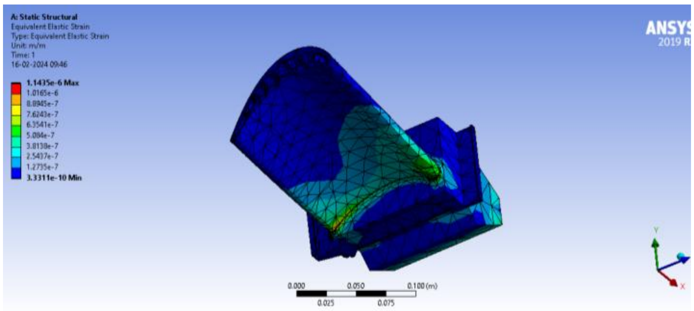


Fig.no.6.11 elastic strain

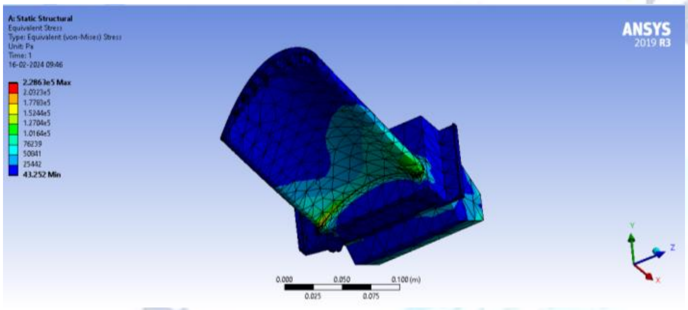


Fig.no.6.12 equivalent stress

Materials	Total Deformation (m)		Equivalent Elastic Stain		Equivalent Stress (Pa)	
	Min.	Maximum	Minimum	Maximum	Minimum	Maximum
AIML 1OMG	0	6.6481e-007	3.475Ee-010	1.1912e-006	43.172	2.298e+005
AIML 316L	0	6.1147e-013	3.1614e-016	1.0977e-012	43.192	2.3044e+005
Carbon epoxy	0	6.4032e-007	3.3311E-010	1.1435E-006	43.252	2.2863E+005

Table 6.7 Results of all materials

7. CONCLUSION

In this project a turbine blade is designed in SOLIDWORKS software. The gas turbine blades are designed both the cooling methods, the film cooling in external cooling and convection cooling in internal cooling. The turbine blade with convection cooling for 4 holes is modeled. By observing the static analysis results, stress values are less for ceramic matrix composite material, and compared to the turbine blade models convection cooling 6 holes blade has less stress compared with external cooling gas turbine blade by observing the thermal analysis results the heat flux values are more for ALSI 10mg. so it can be concluded the ALSI 10mg composites material.

Conflict of interest statement

Authors declare that they do not have any conflict of interest.

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