International Journal of Multidisciplinary Engineering in Current Research - IJMEC
Volume 9, Issue 5, May-2024, http://ijmec.com/, ISSN: 2456-4265

DESIGN AND ANALYSIS OF AIRCRAFT JET ENGINE TURBINE BLADE USING ANSYS WORKBENCH

Abhijit Chowdary, Mohd Sultan Ali, B. Chandrakanth, Mohd Azher Hussain Taj, Mr. Mohd Hafeez

Dept. of Mechanical Engineering, SVITS, Mahbubnagar, Telangana, India.

Abstract: *This paper summarizes the design and analysis of Aircraft Jet Engine Turbine Blade, Catia is used for design and analysis is done using Ansys Workbench for model generated by applying boundary condition; this paper also includes specific post processing and life assessment of blade. We take an opportunity to present this report on "Design and Analysis of Aircraft Jet Engine Turbine Blade" and put before readers some useful information regarding this project. Drawn by list of priorities progress in the design and structural analysis of Aircraft Jet Engine Turbine Blade is reviewed and presented for generating huge performance. This project is motivated by the key role of blades in the performance of jet engine turbine. The fundamentals of the associated physics are emphasized. Recent developments and advancements have led to an increase and improvement in blade aerodynamics, stability and reliability. This article is intended as a high-level review of design of the blade environment and current state of structural design to aid further research in developing new and innovative blade technologies.*

INTRODUCTION

General Description

A turbine is a rotary mechanical device that extracts energy from a fluid flow and converts it into useful work. The work produced by a turbine can be used for generating electrical power when combined with a generator. A turbine is a turbo machine with at least one moving part called a rotor assembly, which is a shaft or drum with blades attached. Moving fluid acts on the blades so that they move and impart rotational energy to the rotor. Early turbine examples are windmills and waterwheels.

DOI: https://doi-ds.org/doilink/05.2024-81888763

Gas, steam, and water turbines have a casing around the blades that contains and controls the working fluid. Credit for invention of the steam turbine is given both to Anglo-Irish 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. Hero of Alexandria demonstrated the turbine principle in an aeolipile in the first century AD and Vitruvius mentioned them around 70 BC.

Operation Theory

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.

Reaction turbines develop torque by reacting to the gas or fluid's pressure or mass. The pressure of the gas or fluid changes as it passes through the turbine rotor blades. A pressure casement is needed to contain the working fluid as it acts on the turbine stage(s) or the turbine must be fully immersed in the fluid flow (such as with wind turbines). The casing contains and directs the working fluid and, for water turbines, maintains the suction imparted by the draft tube. Francis turbines and most steam turbines use this concept. For compressible working fluids, multiple turbine stages are usually used to harness the expanding gas efficiently. Newton's third law describes the transfer of energy for reaction turbines. Reaction turbines are better suited to higher flow velocities or applications where the fluid head (upstream pressure) is low.

In the case of steam turbines, such as would be used for marine applications or for land-based electricity generation, a Parsons-type reaction turbine would require approximately double the number of blade

DOI: https://doi-ds.org/doilink/05.2024-81888763

rows as a de Laval-type impulse turbine, for the same degree of thermal energy conversion. Whilst this makes the Parsons turbine much longer and heavier, the overall efficiency of a reaction turbine is slightly higher than the equivalent impulse turbine for the same thermal energy conversion.

Uses

- A large proportion of the world's electrical power is generated by turbo generators.
- Turbines are used in gas turbine engines on land, sea and air.
- Turbochargers are used on piston engines.
- Gas turbines have very high-power densities (i.e. the ratio of power to mass, or power to volume) because they run at very high speeds. The Space Shuttle main engines used turbo pumps into the engine's combustion chamber. The liquid hydrogen turbo pump is slightly larger than an automobile engine.
- Turbo expanders are used for refrigeration in industrial processes.

LITERATURE SURVEY

A turbine blade is the individual component which makes up the turbine section of a gas turbine or steam 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 that can be categorized as internal and external cooling, and thermal barrier coatings. Blade fatigue is a major source of failure in steam turbines and gas turbines. Fatigue is caused by the stress induced by vibration and resonance within the operating range of machinery. To protect blades from these high dynamic stresses, friction dampers are used.

In a gas turbine engine, a single turbine section is made up of a disk or hub that holds many turbine blades. That turbine section is connected to a compressor section via a shaft (or "spool"), and that compressor section can either be axial or centrifugal. Air is compressed, raising the pressure and temperature, through the compressor stages of the engine. The temperature is then greatly increased by combustion of fuel inside the combustor, which sits between the compressor stages and the turbine stages. The high-temperature and high-pressure exhaust gases then pass through the turbine stages. The turbine stages extract energy from this flow, lowering the pressure and temperature of the air and transfer

DOI: https://doi-ds.org/doilink/05.2024-81888763

the kinetic energy to the compressor stages along the spool. This process is very similar to how an axial compressor works, only in reverse.

Environment and failure modes

Turbine blades are subjected to stress from centrifugal force (turbine stages can rotate at tens of thousands of revolutions per minute (RPM)) and fluid forces that can cause fracture, yielding, or creep failures. Additionally, the first stage (the stage directly following the combustor) of a modern gas turbine faces temperatures around 2,500 °F (1,370 °C),[10] up from temperatures around 1,500 °F (820 °C) in early gas turbines.[11] Modern military jet engines, like the Snecma M88, can see turbine temperatures of 2,900 °F (1,590 °C).[12] Those high temperatures can weaken the blades and make them more susceptible to creep failures. The high temperatures can also make the blades susceptible to corrosion failures.[8] Finally, vibrations from the engine and the turbine itself can cause fatigue failures.

Materials

A key limiting factor in early jet engines was the performance of the materials available for the hot section (combustor and turbine) of the engine. The need for better materials spurred much research in the field of alloys and manufacturing techniques, and that research resulted in a long list of new materials and methods that make modern gas turbines possible. One of the earliest of these was Nimonic, used in the British Whittle engines.

A turbine blade with thermal barrier coating

Another major improvement to turbine blade material technology was the development of thermal barrier coatings (TBC). Where DS and SC developments improved creep and fatigue resistance, TBCs improved corrosion and oxidation resistance, both of which became greater concerns as temperatures increased.

DOI: https://doi-ds.org/doilink/05.2024-81888763

The first TBCs, applied in the 1970s, were aluminide coatings. Improved ceramic coatings became available in the 1980s. These coatings increased turbine blade temperature capability by about 200 °F (90 °C). The coatings also improve blade life, almost doubling the life of turbine blades in some cases.

Most turbine blades are manufactured by investment casting (or lost-wax processing). This process involves making a precise negative die of the blade shape that is filled with wax to form the blade shape. If the blade is hollow (i.e., it has internal cooling passages), a ceramic core in the shape of the passage is inserted into the middle. The wax blade is coated with a heat-resistant material to make a shell, and then that shell is filled with the blade alloy. This step can be more complicated for DS or SC materials, but the process is similar. If there is a ceramic core in the middle of the blade, it is dissolved in a solution that leaves the blade hollow. The blades are coated with a TBC, and then any cooling holes are machined.

OBJECTIVES AND METHODOLOGY

The objective of this project work is to successfully develop a design and analyze of a Jet Turbine Blade. The mechanism is to be reliable, simple, cost-effective and practically feasible. The aim of this Jet Turbine Blade is to provide constrained thermodynamic optimization, so as to enable the required measurement in the Jet Turbine Blade. This system is also supposed to enhance the comfort temperature and the favorable conditions.

The methodology adopted to use standard and presently used components in design rather than to design all components from ground up. The advantage of this method is that, you do not have to spend ridiculous amount level in testing the integrity of each part as they have already proved their worth in real world applications.

Initially the design was adopted from an already existing Jet Turbine Blade and minor changes were made to suite our purpose, first devised was based on using the fluid between the wall, this mechanism was later taken in testing phase due to following conditions.

1. Heat transfer of a Jet Turbine Blade has been obtained for proper material.

2. Pressure on the Jet Turbine Blade has been obtained.

DOI: https://doi-ds.org/doilink/05.2024-81888763

3. Carry out design and optimization of counter flow Jet Turbine Blade.

Due to these conditions, the design was changed and a fully new design was defined. The model also uses the same mechanism setup. The software to be used in design is Catia V5 and testing of design is Ansys.

GEOMETRICAL METHODOLOGY OF THE PROJECT

The aircraft gas turbine engine is based on deterministic calculations of low-cycle fatigue and previous field experience with similar engines. It is probable that no two engine companies determine the life of their engines in the same way or apply the same experience and safety factors to their designs. Davis and Stearns and Halila et al. discuss the mechanical and analytical methods and procedures for turbine engine and high-pressure turbine design. The designs of the engine components are based on life predictions by using material test curves that relate life in cycles or time (hrs.) as a function of stress. Six criteria for failure were presented:

(1) Stress rupture
(2) Creep
(3) Yield
(4) Low-cycle fatigue (LCF)
(5) High-cycle fatigue (HCF)
(6) Fracture

Mechanics. Not mentioned as probable failure modes and/or cause for removal of rotating engine components in Refs. And are oxidation, corrosion, and erosion (wear).

DESIGN METHODLOGY OF JET TURBINE BLADE

Introduction to CATIA

CATIA (Computer Aided Three-dimensional Interactive Application) is a multi-platform CAD/CAM/CAE commercial software suite developed by the French company Dassault Systems. Written in the C++ programming language, CATIA is the cornerstone of the Dassault Systems product

DOI: https://doi-ds.org/doilink/05.2024-81888763

lifecycle management software suite. CATIA competes in the high-end CAD/CAM/CAE market with Cero Elements/Pro and NX (Unigraphics).

CATIA can be applied to a wide variety of industries, from aerospace and defense, automotive, and industrial equipment, to high tech, shipbuilding, consumer goods, plant design, consumer packaged goods, life sciences, architecture and construction, process power and petroleum, and services. CATIA V4, CATIA V5, Pro/ENGINEER, NX (formerly Unigraphics), and Solid Works are the dominant systems.

Modeling of Jet Turbine Blade in CATIA V5

This Jet Turbine Blade is designed using CATIA V5 software. This software used in automobile, aerospace, consumer goods, heavy engineering etc. it is very powerful software for designing complicated 3d models, applications of CATIA Version 5 like part design, assembly design. The same CATIA V5 R20 3d model and 2d drawing model is shown below for reference. Dimensions are taken from. The design of 3d model is done in CATIA V5 software, and then to do test we are using below mentioned software's.

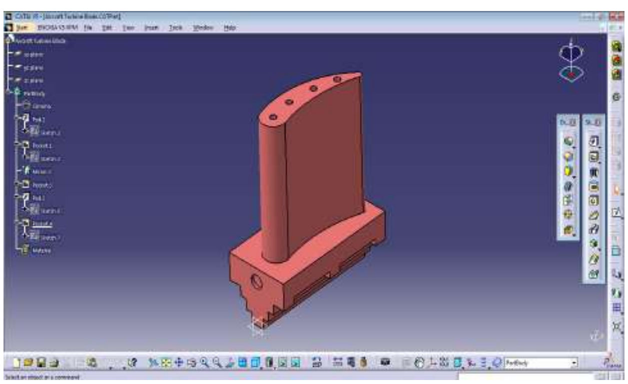

Fig: Model design in CATIA-V5

DOI: https://doi-ds.org/doilink/05.2024-81888763

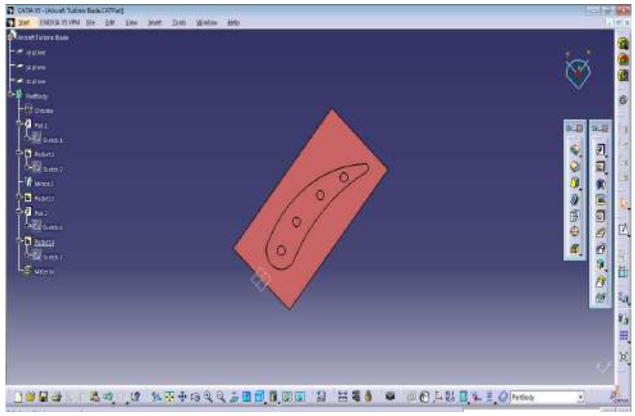

Fig: Model arrangement of working area / mechanism in CATIA-V5

ANALYSIS OF JET TURBINE BLADE

Procedure for Analysis Using ANSYS:

The analysis of the Jet Turbine Blade is done using ANSYS. For compete assembly is not required, is to carried out by applying moments at the circulation of the fluid location along which axis we need to mention. Fixing location is bottom legs.

Preprocessor

In this stage the following steps were executed:

- **Import file in ANSYS window**

  File Menu > Import> STEP > Click ok for the popped-up dialog box > Click Browse" and choose the file saved from CATIAV5R20 > Click ok to import the file

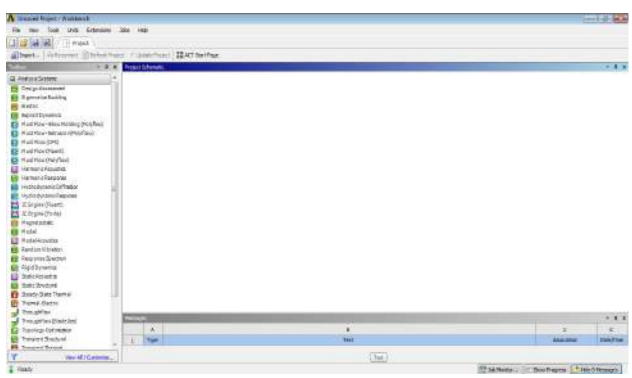

Fig: Import panel in Ansys Fluent.

Meshing:

DOI: https://doi-ds.org/doilink/05.2024-81888763

International Journal of Multidisciplinary Engineering in Current Research - IJMEC
Volume 9, Issue 5, May-2024, http://ijmec.com/, ISSN: 2456-4265

Mesh generation is the practice of generating a polygonal or polyhedral mesh that approximates a geometric domain. The term "grid generation" is often used interchangeably. Typical uses are for rendering to a computer screen as finite element analysis or computational fluid dynamics. The input model form can vary greatly but common sources are CAD, NURBS, B-rep and STL (file format). The field is highly interdisciplinary, with contributions found in mathematics, computer science, and engineering.

Three-dimensional meshes created for finite element analysis need to consist of tetrahedral, pyramids, prisms or hexahedra. Those used for the finite volume method can consist of arbitrary polyhedral. Those used for finite difference methods usually need to consist of piecewise structured arrays of hexahedra known as multi-block structured meshes. Meshing is an integral part of the computer-aided engineering (CAE) simulation process. The mesh influences the accuracy, convergence and speed of the solution. Furthermore, the time it takes to create a mesh model is often a significant portion of the time it takes to get results from a CAE solution. Therefore, the better and more automated the meshing tools, the better the solution. From easy, automatic meshing to a highly crafted mesh, ANSYS provides the ultimate solution. Powerful automation capabilities ease the initial meshing of a new geometry by keying off physics preferences and using smart defaults so that a mesh can be obtained upon first try. Additionally, users are able to update immediately to a parameter change, making the handoff from CAD to CAE seamless and aiding in up-front design. Once the best design is found, meshing technologies from, ANSYS provide the flexibility to produce meshes that range in complexity from pure hex meshes to highly detailed Hybrid meshes. It has a range of meshing tools that cater to nearly all physics. While the meshing technologies were developed to meet specific needs.

RESULTS AND DISCUSSION

Structural Analysis Results of Ti-6Al-4V Alloy Turbine Blade

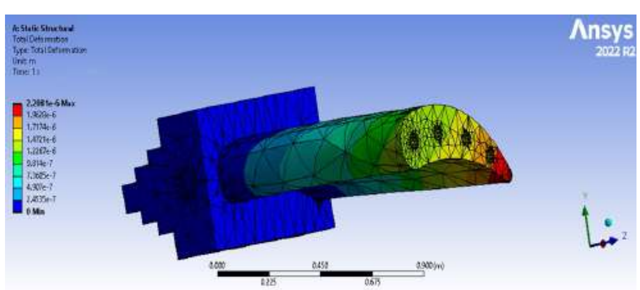

Fig Total Deformation for Ti-6Al-4V Alloy Turbine Blade

DOI: https://doi-ds.org/doilink/05.2024-81888763

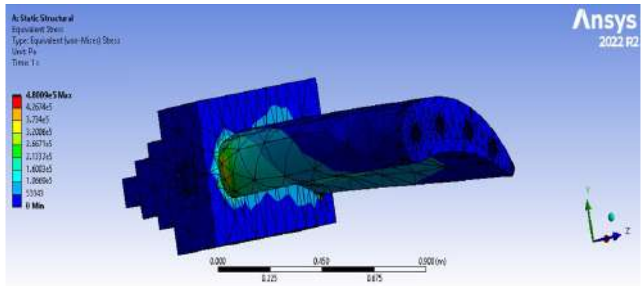

Fig Von-Mises Stress for Ti-6Al-4V Alloy Turbine Blade

Analysis Type	Results	Ti-6Al-4V Alloy
Structural Analysis	Total Deformation (in m)	2.2081e-06
	Equivalent Von Mises Stress (in Pa)	4.8009e+05

Tab: Structural Analysis Results of Ti-6Al-4V Alloy

Structural Analysis Results of Inconel 718 Nickel Based Super Alloy Material Turbine Blade

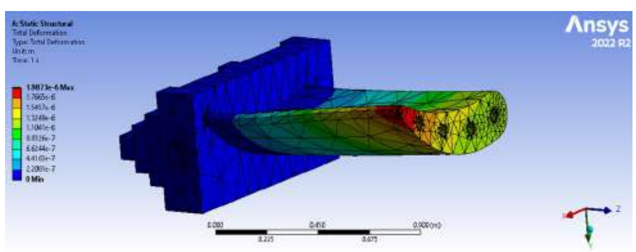

Fig Total Deformation for Inconel 718 Nickel Based Super Alloy Material Turbine Blade

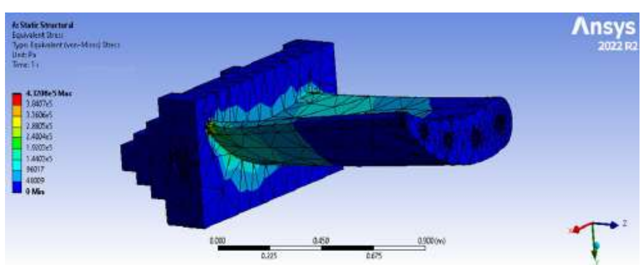

Fig Von-Mises Stress for Inconel 718 Nickel Based Super Alloy Material Turbine Blade

Analysis Type	Results	Inconel 718 Alloy

DOI: https://doi-ds.org/doilink/05.2024-81888763

Structural	Total Deformation (in m)	1.9873e-06
	Equivalent Von Mises Stress (in Pa)	4.3208e+05

Tab: Structural Analysis Results of Inconel 718 Nickel Based Super Alloy Material

CONCLUSION

It can be seen from the above result that, our objective to find the Structural Analysis of a Jet Engine Turbine Blade in a curve has been successful. As shown above figures the displacement of the Jet Engine Turbine Blade design is meshed and solved using Ansys and Maximum displacement is observed which is very less.

This is showing us that clearly each component is having minor displacement. Maximum Von Mises Stress at the fixing location is appeared (Minimum Stress which is acceptable).

The value which is very less compared to yield value; this is below the yield point. The Structural are the results that we approach in Ansys workbench. The analysis result of the Jet Turbine Blade has to withstand a force caused by falling and incurring results around it.

Structural Analysis Results

Analysis Type	Results	Ti-6Al-4V Alloy	Inconel 718 Alloy
Structural Analysis	Total Deformation (in m)	2.2081e-06	1.9873e-06
	Equivalent Von Mises Stress (in Pa)	4.8009e+05	4.3208e+05

Therefore, according to the above results we can state that Inconel 718 Nickel Based Super Alloy Material is having minimum deformation of 1.9873e-06 m compared to Ti-6Al-4V Alloy and load applied on it.

DOI: https://doi-ds.org/doilink/05.2024-81888763

After completing the meshing of Jet Engine Turbine Blade Model next is to do analysis based on the application. So, the model which is analyzed and mention in the Ansys software to get accurate results as per the conditions. The design of the Jet Engine Turbine Blade model is analyzed flawlessly in analysis as well. Design Study is passed the FEA and can sustain the applied load for the Jet Engine Turbine Blade.

REFERENCES

- Frazier, 2014; Melchels et al., 2012; Optimizing 3D Printed Concrete Structures Using Topology Optimization
- Morrow et al., 2007; Serres et al., 2011; Environmental comparison of process and conventional machining implementing life cycle assessment
- Huang et al., 2013; Energy and emissions saving potential of additive manufacturing: the case of lightweight aircraft components
- Immarigeon et al., 1995; Lightweight materials for aircraft applications
- Energy data Connection (EIA), 2014; Economic and environmental assessment of deconstruction strategies using building information modelling
- Dornfeld, 2010; Advanced monitoring of machining operations
- Dornfeld, 2010; Allwood et al., 2011; Leveraging Manufacturing for a Sustainable Future
- Harrysson, 2012; Frazier, 2014; Energy and emissions saving potential of additive manufacturing: the case of lightweight aircraft components
- Kobryn et al., 2006; Additive manufacturing of aerospace alloys for aircraft structures
- Diary of Organizing genuine science and Thermo guaranteed science
- Doing the South African improvement achievement progress guide - The control of a collection achievement clarification for intermixing of ampleness Willie Bouwer Du Preez, Deon J De Mix
- Daniel G. Backman, James C. Williams. (1992) Advanced Materials for Aircraft Engine Applications. JSTOR, 255, 1082-1087.
- Jureczko, M.; Pawlak, M.; Mezyk, A. Optimization of wind turbine blades. J. Mater. Proc. Technol. 2005, 167, 463–471.
- Habali, S.M.; Saleh, I.A. Local design, testing and manufacturing of small mixed airfoil wind turbine blades of glass fiber reinforced plastics Part I: Design of the blade and root. Energy Convers. Manag. 2000, 41, 249–280.

DOI: https://doi-ds.org/doilink/05.2024-81888763