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Analysis of Failure Gas Turbine Blade

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Abstract—*Gas turbine blades operate under extreme thermal, mechanical, and aerodynamic stresses, making them susceptible to malfunctions such as creep, fatigue, oxidation, erosion, and foreign object damage (FOD). This study investigates the failure mechanisms of gas turbine blades, analyzing the causes, effects, and possible mitigation strategies to improve performance and durability. A detailed metallurgical and mechanical analysis is conducted on failed turbine blades using techniques such as scanning electron microscopy (SEM), energy-dispersive X-ray spectroscopy (EDS), hardness testing, and microstructural evaluation. Additionally, finite element analysis (FEA) and computational fluid dynamics (CFD) simulations are performed to assess stress distribution, thermal gradients, and aerodynamic forces acting on the blades. The results indicate that high-temperature creep, thermal fatigue, and material degradation due to oxidation and hot corrosion are the primary causes of blade malfunction. The presence of micro cracks, erosion due to particulate impact, and improper cooling mechanisms further accelerate blade failure. To mitigate these issues, advanced thermal barrier coatings (TBCs), improved cooling channel designs, high-performance super alloys, and optimized maintenance schedules are recommended. This research provides critical insights into enhancing turbine blade life, reducing downtime, and improving overall efficiency in gas turbine operations, ultimately contributing to cost savings and reliability in power generation and aerospace industries.*
Keywords—*ANSYS, Helicopter rotor spar design, Composite material, FEM, Metal matrix composite.*

I. INTRODUCTION

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. Blades of wind turbines and water turbines are designed to operate in different conditions, which typically involve lower rotational speeds and temperatures. The temperature will be increase and decrease suddenly in the turbine blades and it will cause problems to the blades.

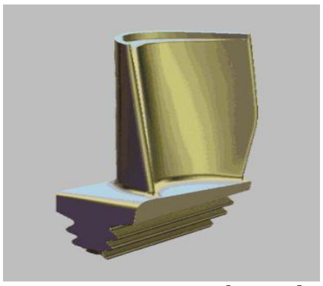


Fig 1.1 Gas Turbine Blade

The fig 1.1 is the diagram of a gas turbine blade. 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 the kinetic energy to the compressor stages along the spool. This process is very similar to how an axial compressor works, only in reverse.

a. Failures in gas turbine blade

Turbine blades are subjected to very strenuous environments inside a gas turbine. They face high temperatures, high stresses, and a potential environment of high vibration. All three of these factors can lead to blade failures, potentially destroying the engine, therefore turbine blades are carefully designed to resist these conditions. 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 turbine faces temperatures around 2,500 °F (1,370 °C), up from temperatures around 1,500 °F (820 °C) in early gas turbines. Modern military jet engines, like the Snecma M88, can see turbine temperatures of 2,900 °F (1,590 °C).

Fig 1.2: Failed Stator Blades

Those high temperatures weaken the blades and make them more susceptible to creep failures. The high temperatures can also make the blades susceptible to corrosion failures. Finally, vibrations from the engine and the turbine itself (see blade pass frequency) can cause fatigue failures is an engineering simulation software provider founded by software engineer John Swanson. It develops general-purpose finite element analysis and computational fluid dynamics software. While ANSYS has developed a range of computer-aided engineering (CAE) products, it is perhaps best known for its ANSYS Mechanical and ANSYS Multiphysics products.

II. ANSYS

ANSYS Mechanical and ANSYS Multiphysics software are non exportable analysis tools incorporating pre-processing (geometry creation, meshing), solver and post-processing modules in a graphical user interface. These are general-purpose finite element modeling packages for numerically solving mechanical problems, including static/dynamic structural analysis (both linear and non-linear), heat transfer and fluid problems, as well as acoustic and electro-magnetic problems.

ANSYS Mechanical technology incorporates both structural and material non-linearities. ANSYS Multi physics software includes solvers for thermal, structural, CFD, electromagnetics, and acoustics and can sometimes couple these separate physics together in order to address multidisciplinary applications. ANSYS software can also be used in civil engineering, electrical engineering, physics and chemistry.

ANSYS, Inc. acquired the CFX computational fluid dynamics code in 2003 and Fluent, Inc. in 2006. The CFD packages from ANSYS are used for engineering simulations. In 2008, ANSYS acquired An soft Corporation, a leading developer of high-performance electronic design automation (EDA) software, and added a suite of products designed to simulate high-performance electronics designs found in mobile communication and Internet devices, broadband networking components and systems, integrated circuits, printed circuit boards, and electromechanical systems. The acquisition allowed ANSYS to address the continuing convergence of the mechanical and electrical worlds across a whole range of industry sectors.

III. ANALYSIS PROCEDURE

The 3D model of the blade is designed by using pro-e software and it is converted as IGES format.
The IGES (Initial Graphic Exchange System) format is suitable to import in the ANSYS Workbench for analyzing
Open the ANSYS workbench
Create new geometry File – import external geometry file – generate

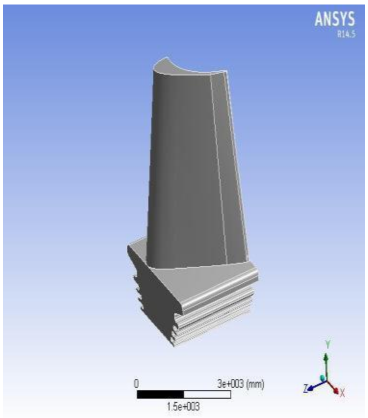


Fig 2.1 :Geometric view of model in workbench

Project – new mesh

Defaults – physical preference – mechanical

Advanced – relevance center – fine

Project – convert to simulation – yes

Select the all solid in geometry tree

Definition – material – new material

New material – right click – rename –Nickel super alloy

Enter the value of the young's modulus, poisons ratio, density, thermal conductivity and specific heat etc.

New analysis – transient thermal

Transient thermal – right click – insert – temperature

Select the faces

Geometry – apply

Temperature in°c

Solution – insert the temperature and total heat flux,

Repeat the above steps for incoloy A 286

Right click the solution icon in the tree – solve

IV. RESULTS AND DISCUSSION

The model designed in Pro-E is analysed using the Ansys v11.The analysing is carried out with the "Nickel super alloy" and the "Incoloy A-286". The table 4.1 and 4.2 shows the material property of both material taken here

Thermal conductivity	11.1 w/mk
Coefficient of Expansion	12.8 щm/mºc
Density	8190 kg/m^3
Specific heat	435 J/Kgk
Electrical Resistivity	128.9 microhm-cm

Table 4.1: mechanical properties of Nickel Super Alloy

Thermal conductivity	12.7 w/mk
Coefficient of Expansion	16.4 ɰm/m°c
Density	2870 kg/m^3
Specific heat	419 J/Kgk
Electrical Resistivity	910 microhm-cm

Table 4.2: mechanical properties of Incoloy A-28

V. ANALYSIS OF NICKEL SUPER

ALLOY 5.1.1 LOADING CONDITIONS

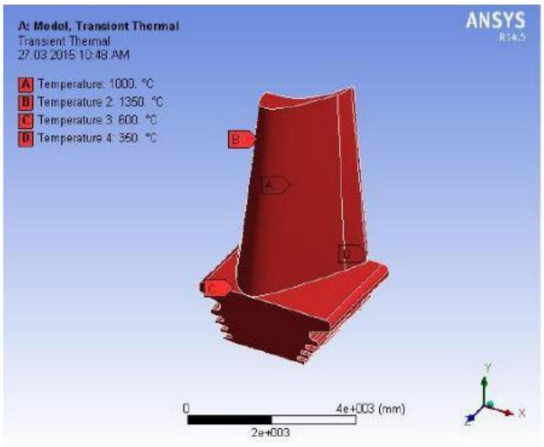


Fig 5.1: Loading Conditions for Nickel Super Alloy

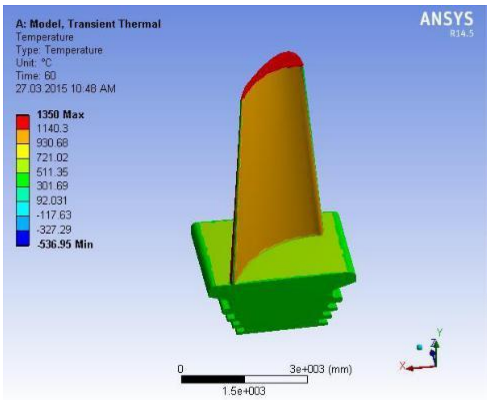


Fig 5.3: Temperature Distribution for Nickel Super Alloy

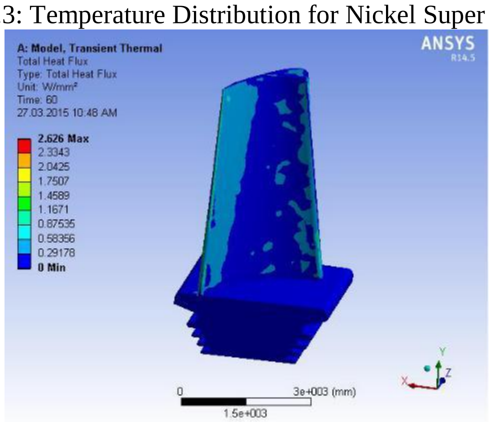


Fig 5.4: Total Heat Flux for Nickel Super Alloy

Fig 5.1, 5.2, 5.3, 5.4 shows the analysis of the Nickel super alloy by various temperature

ANALYSIS OF INOLOY A-286

The material properties are applied in the software while doing the analysis of the materials.

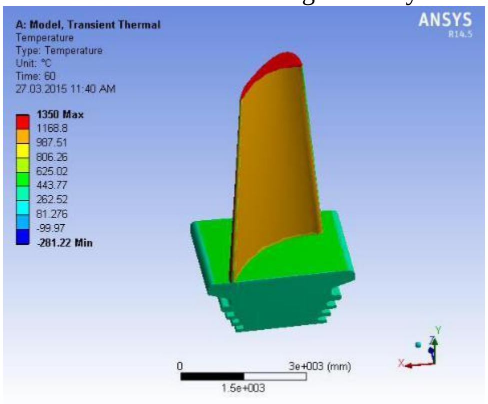
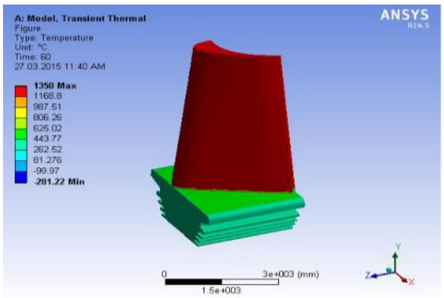


Fig 5.2: Temperature Distribution for Nickel Super Alloy



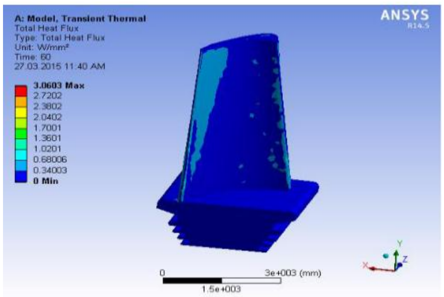


Fig 5.5: Temperature Distribution for Incoloy A-286

RESULTS FOR NICKEL SUPER ALLOY

NICKEL SUPER ALLOY	MINIMUM	MAXIMUM
TEMPERATURE ^{0}C	-536.95	1350
TOTALHEATFLUX (W/mm^2)	**0**	2.62

Table 5.1results for Nickel super alloy

RESULTS FOR INCOLOY A-286

INCOLOY A-286	MINIMUM	MAXIMUM
TEMPERATURE ^{0}C	-281.22	1350
TOTALHEATFLUX (W/mm^2)	**0**	3.06

Table 5.2 results for Incoloy A-286

By changing the temperature of both of the material it is found that the properties of the both material is different and the Incoloy A-286 is better than the Nickel super alloy.the value obtained from the analysis is plotted in the above table (Table no 5.1 and 5.2).

CONCLUSION

Here we study about the heat and mass transfer concept preferably gets knowledge about heat transformation. Analyzing results from testing the gas turbine blade under temperature are listed in the Table. Analysis has been carried out by nickel super alloy and incoloy A 286. The results such as temperature distribution.

FUTURE WORK

Created 3D model of gas turbine blade has been analyzed using nickel super alloy and another material with the help of ANSYS workbench software to find deformation, stress and strain values. To know about the most suitable material to make the turbine blade which is having the good heat flux over the whole body profile of the turbine blade. To analyse that if there is any deformation occur in the blade root if it has been made of different materials. That is the root and the blade profile is made up of two different material then analyzing to know if there is any deformation will occur to the root and tip.

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