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Design and Fatigue Analysis of Turbine Rotor Blade by Using F.E.M

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ABSTRACT:

The first stage rotor blade of the gas turbine has been analyzed for the static and thermal stresses resulting from the tangential, axial and centrifugal forces. The gas forces namely tangential, axial were determined by constructing velocity triangles at inlet and exist of rotor blades. The rotor blade was then analyzed for the temperature distribution. For obtaining temperature distribution, the convective heat transfer coefficients on the blade surface exposed to the gas have to feed to the software.

After containing the temperature distribution, the rotor blade was then analyzed for the combined mechanical and thermal stresses and also the fatigue life. Gas turbine is an important functional part of many applications. Reducing the stresses and increasing the fatigue life is the major concern since they are in high temperature environment. Various techniques have been proposed for the increase of fatigue life and one such technique is to have axial holes along the blade span.

Finite element analysis is used to analyze thermal and structural performance due to the loading condition, with material properties of N155, NIMONIC 80A & INCONEL 600 We are analyzed to find out the optimum number of holes for good performance. Counter plots for stresses for design 7 holes and for fatigue sensitivity it is found that when the number of holes of the blades is increased, the stresses are reduced and no. of cycles are increased.

Thus, the blade configuration with 7 holes of 2mm size is found to be optimum solution. This project specifies how the program makes effective use of the ANSYS workbench pre-processor to analysis the complex turbine blade geometries.

CHAPTER-1
INTRODUCTION:
1.1Basic introduction:

Turbo machine rotor blades are subjected to different types of loading such as fluid or gas forces, inertia loads and centrifugal forces. Due to these forces various stresses are induced in the rotor blades. So stress and strain mapping on a rotor blade provide a vital information concerning the turbo machine design and lead to the detection of critical blade section. Analysis of static and dynamic behavior of a rotor blade is a basic problem in aero elasticity of turbo machine blades. The present paper deals with the stress analysis of a typical blade made up of nickel super alloy, which is subjected to centrifugal loading. The analysis results show that stress is severed due to centrifugal forces compared that due to dynamic gas forces. Here in this case the effect of thickness, twist and taper of the blade was considered as the root of the blade where generally failure is occurring. The various blade shapes viz. Rectangular, argues with some angle twist, taper aerofoil are taken into consideration. In this paper linear static analysis for determining von-Moses stresses, deformation in Z direction was determined using Finite element analysis software. The Solid brick 20-node element is used.

CHAPTER-2
LITERATURE REVIEW
2.1 Literature survey:

Qianand Dutta [1] implemented with the mathematical formulation of the turbine blade design. Using B-spline to represent the turbine blade, using the diffusion equation to generate material composition variation, using finite element method to solve the constrained diffusion equation.

Naeem et al. [2] carried out the failure analysis of gas turbine blades made of nickel-base alloy in two discrete sections, they are Mechanical and Metallurgical By using Ansys workbench software and metallurgical investigation was carried out by using visual examination. Dhopade andNeely [3] investigated the effects of low cycle and the effects of high cycle fatigue interaction on the aerodynamic and structural behavior of a blade. A numerically based analysis through the interaction of CFD and FEM referred to Fluid- structure interaction. Bhatti et al. [4] Focused on the transient heat transfer characteristics, centrifugal and thermal stresses arising in the disk. Maximum stresses obtained are found to be within the yield strength of materials .

CHAPTER-3
METHODOLGY OF TURBINES
3.1introduction:

Turbines can be classified into four general types according to the fluids used: water, steam, gas, and wind. Although the same principles apply to all turbines, their specific designs differ sufficiently to merit separate descriptions.A water turbine uses the potential energy resulting from the difference in elevation between an upstream water reservoir and the turbine-exit water level (the tailrace) to convert this so-called head into work. Water turbines are the modern successors of simple waterwheels, which date back about 2,000 years. Today the primary use of water turbines is for electric power generation.

The greatest amount of electrical energy comes, however, from steam turbines coupled to electric generators. The turbines are driven by steam produced in either a fossil-fuel-fired or a nuclear-powered generator. The energy that can be extracted from the steam is conveniently expressed in terms of the enthalpy change across the turbine. Enthalpy reflects both thermal and mechanical energy forms in a flow process and is given by the sum of the internal thermal energy and the product of pressure time's volume. The available enthalpy change through a steam turbine increases with the temperature and pressure of the steam generator and with reduced turbine-exit pressure. The energy available in wind can be extracted by a wind turbine to produce electric power or to pump water from wells.

Wind turbines are the successors of windmills, which were important sources of power from the late middle Ages through the 19th century.

3.2 GAS TURBINES:

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, which is essential for expansion a compressor, is required. The quantity of ten working fluids and speed required are more so generally a centrifugal or axial compressor is required.

The turbine drives the compressor so it is coupled to the turbine shaft. If after compression the working fluid were to be expanded in a turbine, then assuming that there were no losses in either component, the power developed by the turbine can be increased by increasing the volume of the working fluid at constant pressure or alternatively increasing the pressure at constant volume. Either of these may be done by adding heat so that the temperature of the working fluid is increased after compression. To get a higher temperature of the working fluid a combustion chamber is required where combustion of air and fuel takes place giving temperature rise to the working fluid.

3.3 Construction of Gas Turbine Rotor and their Components:
Gas turbines have been constructed to work on the following: -oil, natural gas, coal, gas, producer gas, blast furnace and pulverized coal.

3.4 Open cycle gas turbine:
A gas turbine is an engine where fuel is continuously burnt with compressed air to produce a stream of hot, fast moving gas. This gas stream is used to power the compressor that supplies the air to the engine as well as providing excess energy that may be used to do other work.

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The engine consists of three main parts: The Compressor, Combustor and Turbine compressor usually sit at the front of the engine. There are two main types of compressor, 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. The combustor is where fuel is added to the compressed air and burnt to produce high velocity exhaust gas as shown.

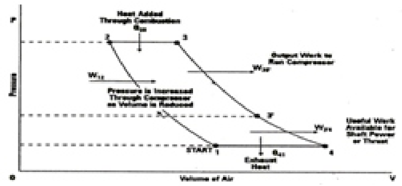

Fig. Indicator diagram of gas turbine

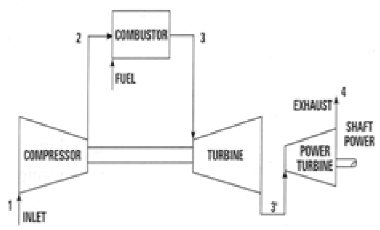

Fig. 3.2 Simple Open Cycle Gas Turbine

The turbine extracts energy from the exhaust gas. The turbine can, like the compressor, be centrifugal or axial. In each type the fast moving exhaust gas is used to spin the turbine. Since the turbine is attached to the same shaft as the compressor at the front of the engine they will turn together. The turbine may extract just enough energy to turn the compressor. The rest of the exhaust gas is left to exit the rear of the engine to provide thrust as in a pure jet engine. Or extra turbine stages may be used to turn other shafts to power other machinery such as the rotor of a helicopter, the propellers of a ship or electrical generators in power stations.

CHAPTER-4
Turbine Blades
4.1Shape of Blade:

The airfoil shape of the blade helps to generate lift by taking advantage of the Bernoulli Effect described above. Gas turbine blade designers have experimented with many different airfoil shapes over the years in an effort to find the perfect shape that will perform well in a range of high speeds. Even minor changes in this blade shape can dramatically affect the power output and noise produced by a gas turbine. To get some ideas of different airfoils used in airplane wings and wind turbine blades, research the United States National Advisory Committee for Aeronau¬tics (NACA). This group was responsible for designing a wide range of airfoils in the 1940's.

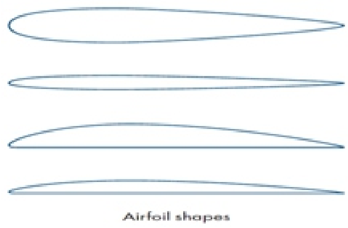

Fig. 4.1 Airfoil shapes

4.2 Assembly of Rotor Blade:

A sleeve assembly provided between a hot gas path and a disc cavity in a turbine engine includes an annular outer wing member extending from an axially facing side of a rotor structure towards an adjacent non-rotating vane assembly, and a plurality of fins extending radially inwards from the outer wing member and extending towards the adjacent non-rotating vane assembly .The fins are arranged such that a space having a component in a circumferential direction is defined between adjacent fins. Rotation of the fins during operation of engine effects a pumping of air from the disc cavity towards the hot gas path to assist in limiting hot working gas leakage from the hot gas path to the disc cavity by forcing the hot working gas away from sleeve assembly. The sleeve is intermediate to the power shaft which is fitted to the shaft and power shafts rotates at high respective speeds leads to generation of power

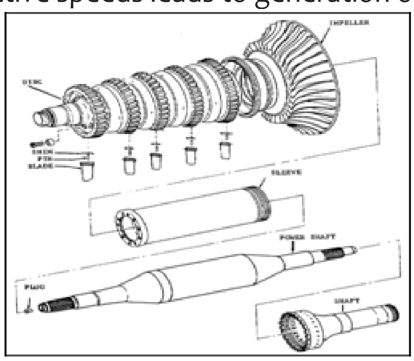

Fig .4.2 Assembly of rotor blade

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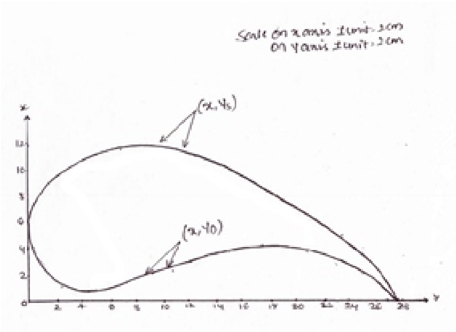
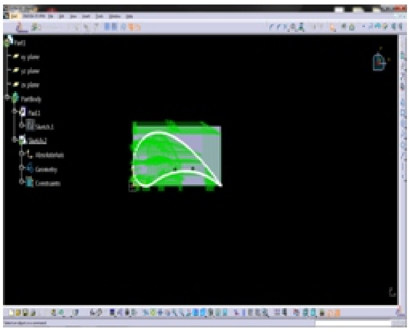
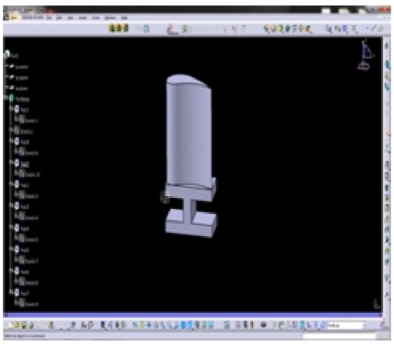


Rotor blade profile

CHAPTER-5
MODELING
5.1 Introduction to CATIA :

CATIA is one of the world's leading high-end CAD/CAM/CAE software packages. CATIA (computer aided three dimensional interactive application) is a multi-platform PLM/CAD/CAM/CAE commercial software suite developed by Dassault systems and marketed worldwide by IBM. CATIA is written in the C++ programming language. CATIA provides open development, architecture through the use of interfaces, which can be used to customize or develop applications. The applications in programming interfaces supported visual basic and C++ programming languages.

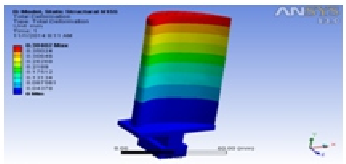


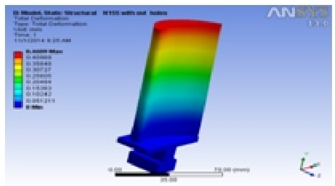


CHAPTER-6
ANALYSIS
6.1 INTRODUCTION TO ANSYS

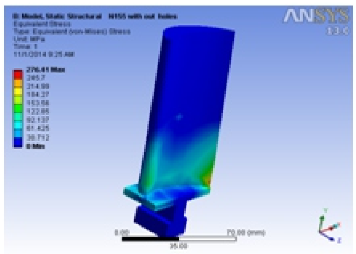
ANSYS is an engineering simulation software provider founded by software engineer John Swanson. It develops general-purpose finite element analysis and computational fluid dynamics software. While ANSYS has developed a range of computer-aided engineering (CAE) products, it is perhaps best known for its ANSYS Mechanical and ANSYS Multi-physics products.

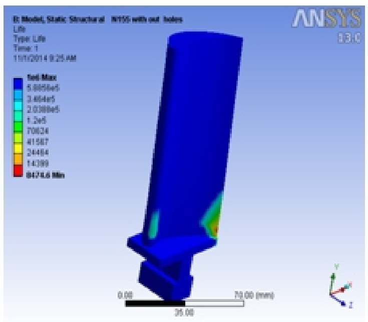
Material -1 (N155)
STATIC STRUCTURAL:
TOTAL DEFORMATION





Equivalent stress





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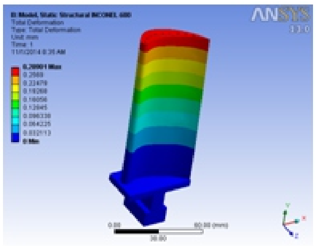
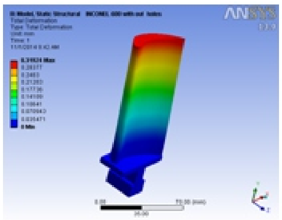
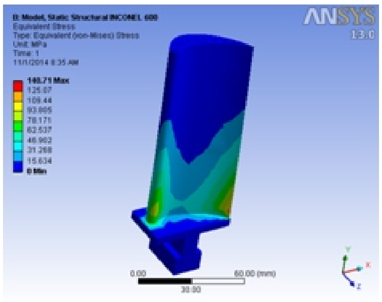
Material-2 (INCONEL 600)

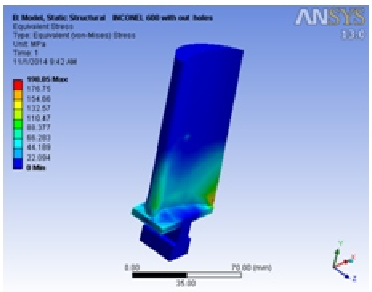
TOTAL DEFORMATION



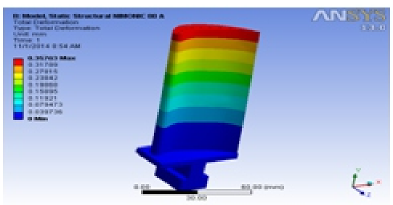


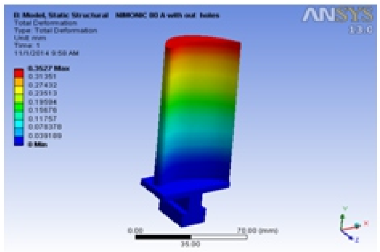
EQUIVALENT STRESS





Material-3 (NIMONIC 80 a)
TOTAL DEFORMATION





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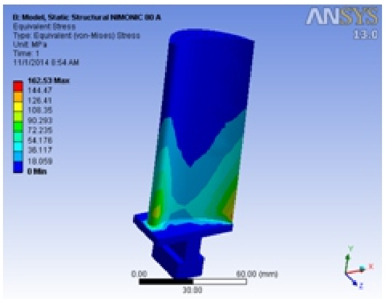

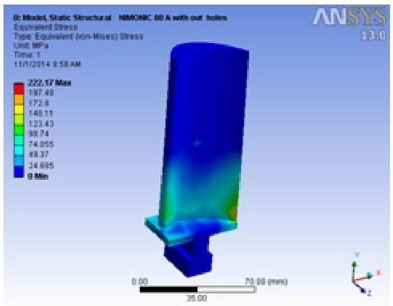

CHAPTER-7
CONCLUSION:

The following parameters are concerned for the profile of a blade with and without holes in which N155 and INCONEL 600, NIMONIC 80A materials are characterized with respect to shear stress temperatures, direction of heat flux, total deformation, equivalent stress, and normal stress and safety factors. From above results INCONEL 600 has life (93121) is more than other than N155&NIMONIC 80 A and shear stresses is low compared with other materials and damage is decreased and life increased while giving with holes to the blade. Hence optimization gives the better results. (WITH HOLES)

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