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REVIEW ARTICLE

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STATIC AND DYNAMIC ANALYSIS ON COMPRESSOR BLADE

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ABSTRACT

The Compressor is a device that pressurizes a working fluid/gas/steam. The energy level of the fluid increases as it flows through the compressor due to the action of the compressor blades which exert a torque on the fluid. Compressor blades compress the gas, which flows from the inlet and leaves the gas with higher temperature and pressure to the outlet. Loads imposed upon the components of compressors result in compressor blade stresses, which vary considerably over the operational envelope of the compressor edge of the blade stresses, which is important in evaluating the operational limits of the compressor in terms of compressor speed and total pressure combinations. The consequence of a single blade failure is catastrophic in terms of severe damage to the remaining rotor and stator blades and to the compressor, and in terms of the extensive time required to replace the damaged parts. The data were analyzed to determine the total blade stresses, dynamic stresses, and the static stresses.

This project is to design and conduct analysis to the compressor blade. CATIA is used to design the solid model and ANSYS for analysis. However the program makes effective use of the ANSYS Pre-processor to mesh complex compressor blade geometries and apply boundary conditions.

The objective of the current task is to perform the Static analysis and Dynamic analysis to know the stress and strain at the high temperature zone of the compressor blade.

Keywords: Compressor blade, Design, CATIA, ANSYS, Static analysis, Dynamic analysis.

INTRODUCTION

The evolution is a balanced integration, economic, aerodynamic, structural, dynamic, noise, aesthetic consideration, which are known to be machine type and size dependent. The design of a modern compressor blade includes choices of blade number, airfoils, chord and twist distributions, and materials. The justification for each of these choices often includes conflicting considerations that need to be prioritized. Some obvious blade design trends resulting from increased compressor size include lower blade solidity, increased airfoil thickness, and maximum lift coefficient, along with incremental increases in tip speed. Limits that govern these trends needs to understand in order to achieve a minimum cost-of-energy design.

Many problems in engineering and applied science are governed by differential or integral equations. The solutions to these equations would provide an exact, closed form solution to the particular problem being studied. However, complexities in the geometry, properties and in the boundary conditions that are seen in most real-world problems usually means that an exact solution cannot be obtained or even obtained it will not be in a reasonable amount of time. Current product design cycle times imply that engineers must obtain design solutions in a 'short' amount of time.

The Finite Element Method (FEM) is one such approximate solution technique. The FEM is a numerical procedure for obtaining approximate solutions to many of the problems encountered in engineering analysis. In the FEM, a complex region defining a continuum is discretised into simple geometric shapes called elements. The properties and the governing relationships are mathematically in terms of unknown values at specific points in the elements called nodes. An assembly process is used to link the individual elements to the given system.

When the effects of loads and boundary conditions are considered, a set of linear or nonlinear algebraic equations is usually obtained. A solution of these equations gives the approximate behavior of the system.

2. OBJECTIVE OF THE PROJECT

1. To design the compressor blade
2. By studying the design, applying the Finite Element Modelling for the blade
3. Conduct the linear static and dynamic analysis to the blade.

3. FINITE ELEMENT ANALYSIS

A commercial FEA process consists of these 3 steps

- Pre -processor
- Processor
- Post-processor

Pre-processor - Input data describe geometry, material properties, loads and boundary condition. Software can automatically prepare much of the FE mesh, but must be given direction to the type of the element and the mesh density desired. That is the analyst must select the desired formulation that suits the mathematical model and state how large the element size should be in selected portions the FE model.

Processor- Software's automatically generates matrices that describe the behavior of each element, combines these matrices into the large single matrix equation that represent the FE structure, and solves this equation to determine values of field qualities of nodes. Substantial additional calculations are required if behavior is non-linear or time dependent.

Post processor - FEA solution and quantities derived from it are listed or graphically displayed. This set up is also automatic, except that the analyst must tell the software the list is displayed to prepare. In stress analysis, the typical display includes deformed shape, with deformations exaggerated and probably animated, and stress of various types on various planes.

The below figure shows the basic general process in the analysis of any typical product.

4. ANALYSIS

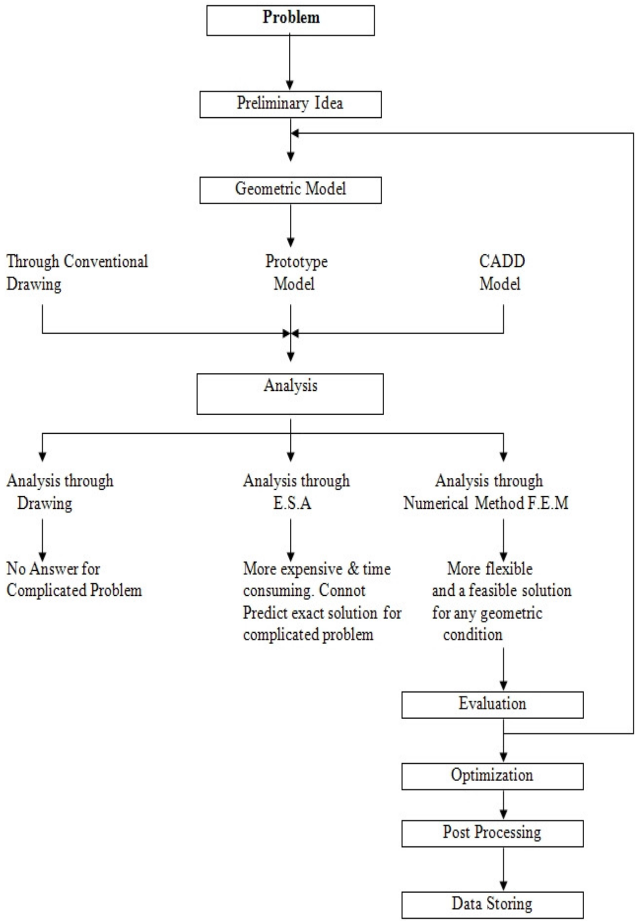

Fig 4.1 Analysis of typical product

5.FINITE ELEMENT ANALYSIS OF COMPRESSOR BLADE

5.1 Modelling

The modelling process is divided into two steps.

1. Geometric Modelling
2. Finite Element Modelling

5.1.1 Geometric Modelling

Geometric modeling phase is to represent the geometry in terms of points, lines, curves, surfaces, volumes. The geometric model stores enough information to fully describe the boundaries, surfaces and topology of the object. During present work geometric model is constructed by using Catia V5.

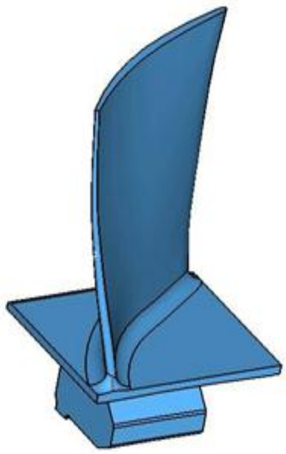

Fig 5.1: compressor blade

5.1.2 Finite Element Modeling

Here the geometric model is used in generating Finite element model by meshing the area using the appropriate elements from ANSYS library. The density of mesh is decided depending upon the accuracy of the result required. So the geometric model was meshed with fine elements at the constraint and at airfoil region. The geometry is meshed with tetrahedral element of first order in terms of explicit topology.

5.2 Mesh Generation

Meshing means dividing the component into smaller components or elements. The meshing is done using Hyper mesh v10 software. Tetrahedral elements were generated according to the quality specifications. Hypermesh Pre & ANSYS as post processing software are used. The reason for using tetrahedral elements is that the compressor blade is a solid component and to any solid part it is compulsory to use tetrahedral elements and also this helps in time consuming.

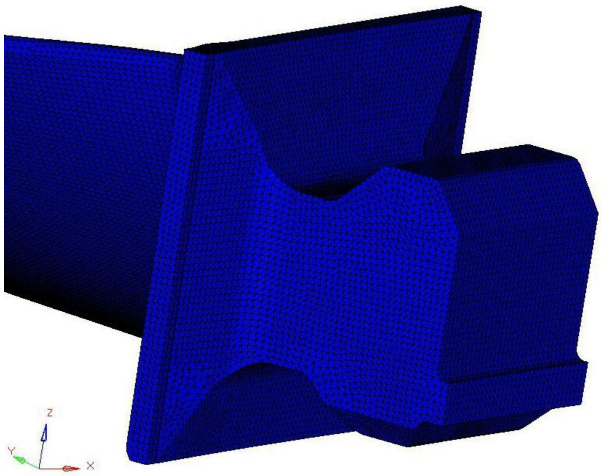

Fig 5.2: Meshed compressor blade

5.2.1 Load and Boundary Condition

The loading condition that is applied to the compressor blade is shown in the below table.

Sl. no	Condition	Pressure in ksi	Temperature in F	Speed in rpm
1	SLTO	10-20	70-200	3500
2	CRITICAL SPEED	30-40	70-250	4500
3	RED LINE	40-50	70-350	6000

Table 5.1 Loading conditions for the compressor Blade

Boundary condition included Contact/fixation at the pivot region in the radial, tangential and axial direction the engine i.e. in all 6 degrees of freedom.

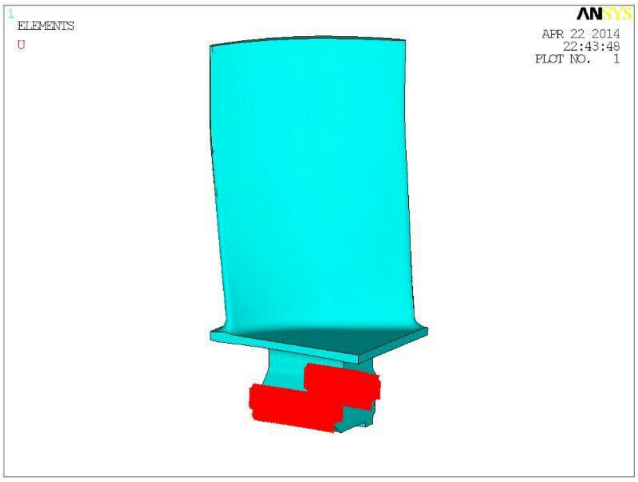

Fig 5.3 Boundary conditions applied to the compressor blade

5.3 ANALYSIS

The analysis is carried out using ANSYS 11. The reason behind using this software is that, the compressor blade is the place where the temperature is high when compared to other regions and ANSYS is the simulation software which gives accurate results than other related software's.

5.3.1 Static Analysis:

A static analysis calculates the effects of the steady loading condition of a structure while ignoring inertia and damping effects, such as those caused by time-varying loads. A static analysis can however include steady inertia loads (such as gravity and rotational velocity), and time-varying loads that can be approximated as static equivalent loads.

Static analysis is used to determine the displacements, stresses, strains and forces in structures or components caused by loads that do not induce significant inertia and damping effects. Steady loading and response conditions are assumed; that is, the loads and the structure's response are assumed to vary slowly with respect to time.

In static analysis, we are doing analysis of tensile stress and displacement in all (X, Y, Z) directions. And also conducting von misses stress. The flowing figures shows the analysis.

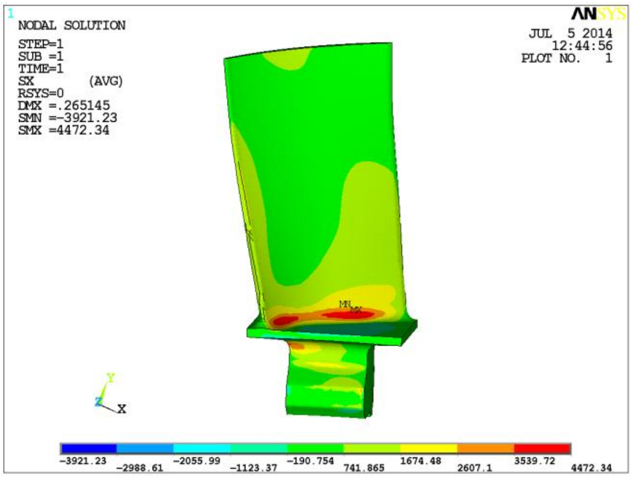

Fig 5.4 Static analysis-Displacement along X-axis

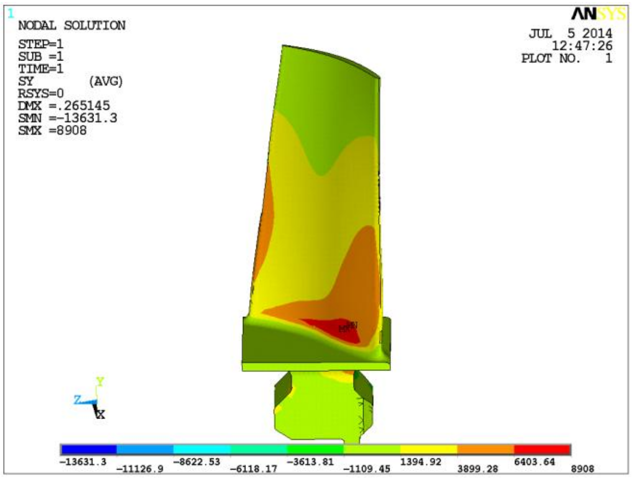

Fig 5.5 Static analysis-Displacement along y-axis

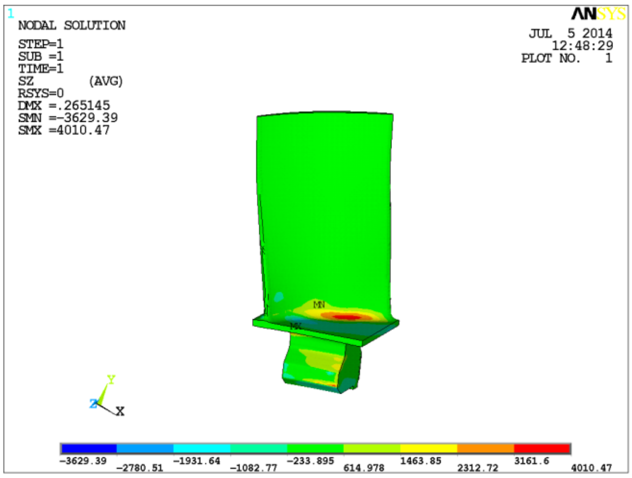

Fig 5.6 Static analysis-Displacement along z-axis

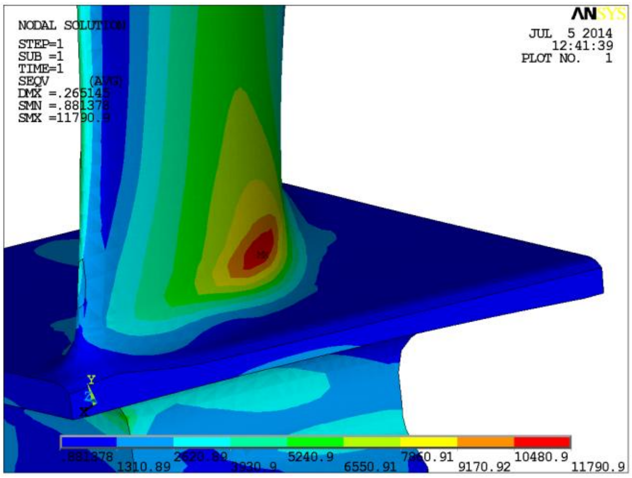

Fig 5.7 Von misses stress

5.3.2 Modal Analysis

Modal analysis is defined as the study of the dynamic characteristics of a mechanical structure. The dynamic behavior of mechanical structures is typically done using a linear system modeling approach.

Modal analysis is the process of determining all the modal parameters, which are then sufficient for formulating a mathematical dynamic model. So we do the modal analysis and extract the frequency for different mode shapes and input these values in order to arrive at the appropriate Campbell diagram which indicates the percentage by which the structure is in proximity to resonance and at what harmonic.

In modal analysis the blade is not constrained to any of the degree of freedom; that is, the analysis is with, into the blade as it is in the space and the blade is made to run for the displacement and von misses stress by applying loads and the results are noted down. If the values in column time/frequency shows zeros or nearer value to the 1st six values, then the result is correct. The below figure shows the results of modal analysis.

Material of the blade: Ti-6Al-4V
Density: 4.43g/cc
Young's modulus: 113.8Gpa
Poisson's ratio: 0.3

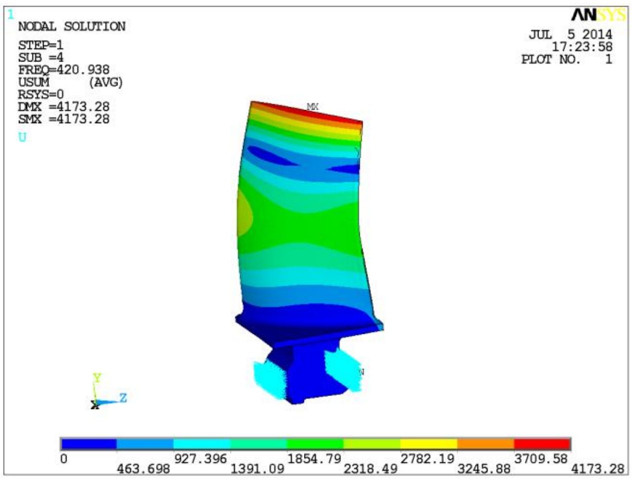

Fig 5.8 Modal analysis-max displacement

5.3.3 Free Free analysis

Free free analysis computes the natural frequencies and mode shapes of a structure. The natural frequencies are the frequencies at which a structure will tend to vibrate if subjected to a disturbance. For example, the strings of a piano are each tuned to vibrate at a specific frequency. The deformed shape at a specific natural frequency is called the mode shape. Normal modes analysis is also called real eigen value analysis.

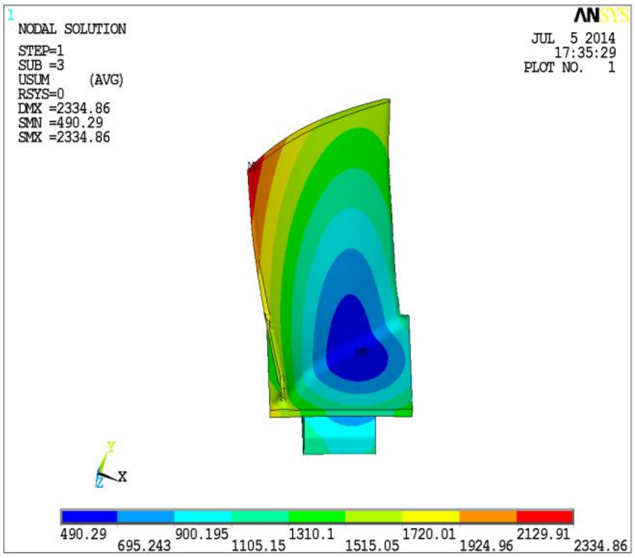

Fig 5.9: Free Free analysis- max displacement

6. RESULTS

6.1. Static analysis

- Along X-axis: U max=4.472mm
  U min=-3.921mm
- Along X-axis: U max=8.908mm
  U min=-1.3631mm
- Along Z- axis: U max=4.010mm
  U min=-3.629mm
- Von mises stress=11.790ksi

6.2. Modal analysis

MODEL FREQUENCES	
Set	Time/ Frequency
1	0.0101
2	0.0255
3	0.0299
4	0.0420
5	0.0654
6	0.0896

6.3. Free Free analysis

MODAL FREQUENCIES	
Set	Time/ Frequency
1	0
2	0
3	0
4	6.58E-05
5	2.01E-04
6	2.68E-04

CONCLUSION

- Static and Dynamic analysis are carried out
- The max displacement for all the cases is reported
- The model analysis is carried out and the 1st six modes are rigid body motions
- The max stresses are compared with the yield strength of the material and the stresses are below the yield strength.

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