

Static and Thermal Analysis of Impeller Blade in Compressor of Turbocharger

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Abstract

This paper borders around analysis of compressor blade. The Impeller blade is a rotating part which imparts highly pressurized air. Impeller blade is critical part of turbocharger which has shown increasing growth of failure damaging assembly. It deals with Static and thermal analysis of Impeller blade which is made up of INCONEL N06230 to estimate its performance. The causes of failure for blade have also been found out. The investigation has been done using Solid Works 2012 and ANSYS 10.0 software. Solid Works 2012 is used for modeling of compressor blade and analysis has been done by ANSYS10.0 software.

An attempt has been made to investigate the effect of induced stresses, pressure and temperature on the Impeller blade. A structural analysis has been carried out to investigate the stresses and displacements of the Impeller blade. A thermal analysis has been carried out to investigate the thermal gradient and thermal stress.

Keywords: ANSYS, FEA, INCONEL N06230, Impeller blade, Solid Works

I. INTRODUCTION

Centrifugal compressor produces highly compressed air needed for efficient combustion. High pressure is achieved by

imparting kinetic energy to the air in the impeller, and then this kinetic energy converts into pressure in the diffuser. Centrifugal compressor consists of a

stationary casing containing an impeller, which rotates and imparts kinetic energy to the air and a number of diverging passages in which the air decelerates. The deceleration converts kinetic energy into static pressure. This process is known as diffusion, and the part of the centrifugal compressor containing the diverging passages is known as the diffuser. Air enters the impeller eye and is whirled around at high speed by the vanes on the impeller disc. After leaving the impeller, the air passes through a diffuser in which kinetic energy is exchanged with pressure. Energy is imparted to the air by the rotating blades, thereby increasing the static pressure as it moves from eye radius r_1 to tip radius r_2 . The remainder of the static pressure rise is achieved in the diffuser.

2. FINITE ELEMENT ANALYSIS OVERVIEW

Finite element analysis (FEA) involves solution of engineering problems using computers. Engineering structures that have complex geometry and loads, are either very difficult to analyze or have no theoretical solution. However, in FEA, a structure of this type can be easily analyzed. Commercial FEA programs, written so that a user can solve a complex engineering problems without knowing the

governing equations or the mathematics; the user is required only to know the geometry of the structure and its boundary conditions. FEA software provides a complete solution including deflections, stresses and reactions.

FEA is divided in 3 steps:

2.1 Pre-processing:

Using a CAD program the structure is modeled. A model consists of several elements that collectively represent the entire structure. The geometry of the structure, the constraints, loads and mechanical properties of the structure are defined. Thus, in pre-processing, the entire structure is completely defined by the geometric model. The structure represented by nodes and elements is called mesh.

2.2 Solution:

This phase can be performed in the Model Solution task of the simulation application, or in an equivalent external finite element solver. Model Solution can solve for linear and Nonlinear static, dynamics, buckling, heat transfer, and potential flow analysis problems.

2.3 Post-processing:

CAD program is utilized to manipulate the data for generating deflected shape of the structure, creating stress plots, animation. Graphical representation of the results is useful in understanding behavior of the structure.

3. MODELLING AND MESHING OF COMPRESSOR

3.1 Modelling by using SolidWorks 2012:

Modelling of compressor is done on SolidWorks 2012 software as shown in figure.3.1. Compressor consist of 18 number of blades. Modelled is saved in IGES format which is later used for analysis purpose.

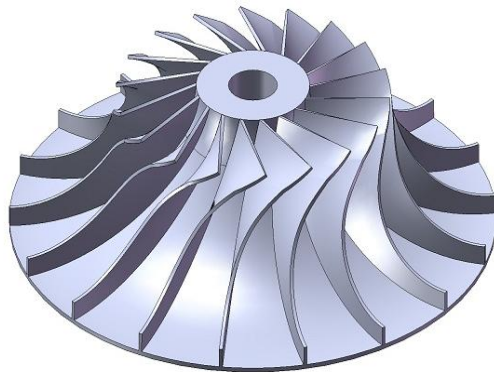


Figure: 1

3.2 Meshing in ANSYS 10:

Compressor model is imported in ANSYS, and is meshed properly in Mechanical APDL ANSYS to divide it into elements and nodes. Tetramesh is used for turbine blade, and element size length is 6 mm.

Quality checks and mesh optimization for elements were also performed taking into consideration of aspect ratio, distortion, stretch.

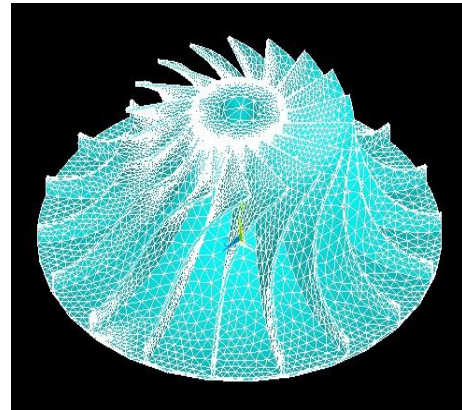


Figure: 2

Solid 187 3D 10-node structural element is used.

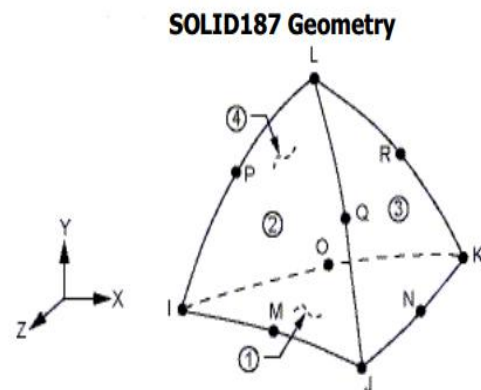


Figure: 3

SOLID187 Input Summary:

Nodes: I, J, K, L, M, N, O, P, Q, R.

Degrees of Freedom: UX, UY, UZ.

Material Properties: EX, E, EZ, ALPX, ALP, ALPZ, PRXY, PRYZ, PRXZ, DENS, GXY, GYZ, GXZ, DAMP.

Surface Loads: Pressures -face1 (J-I-K), face2 (I-J-L), face3 (J-K-L), face4 (K-I-L).
Body Loads: Temperatures -T(I), T(J), T(K), T(L), T(M), T(N), T(O), T(P), T(Q), T(R). Body force densities: The element values in the global X, Y, and Z directions

4. RESULTS AND DISCUSSION

Staic analysis has been carried out to predict stress and displacement. Figure

4.1-4.6 shows result for von mises stress, Stress in X-Direction, Stress in Y-Direction, Stress in Z-Direction, Displacement vector sum and Displacement in Y- Direction.

Thermal analysis has been carried out to predict results. Figure 4.7-4.8 shows result for thermal gradient and thermal stress.

Table 3 5 Inconel N06230 properties

INCONEL N06230	Properties
Tensile strength(N/mm ²)	841
Yield strength(N/mm ²)	428
Density(kg/m ³)	8910
Poisson's ratio	0.34
Modulus of elasticity(N/mm ²)	211500
Specific heat(J/kg-°C)	410
Thermal conductivity(W/m-k)	9.80

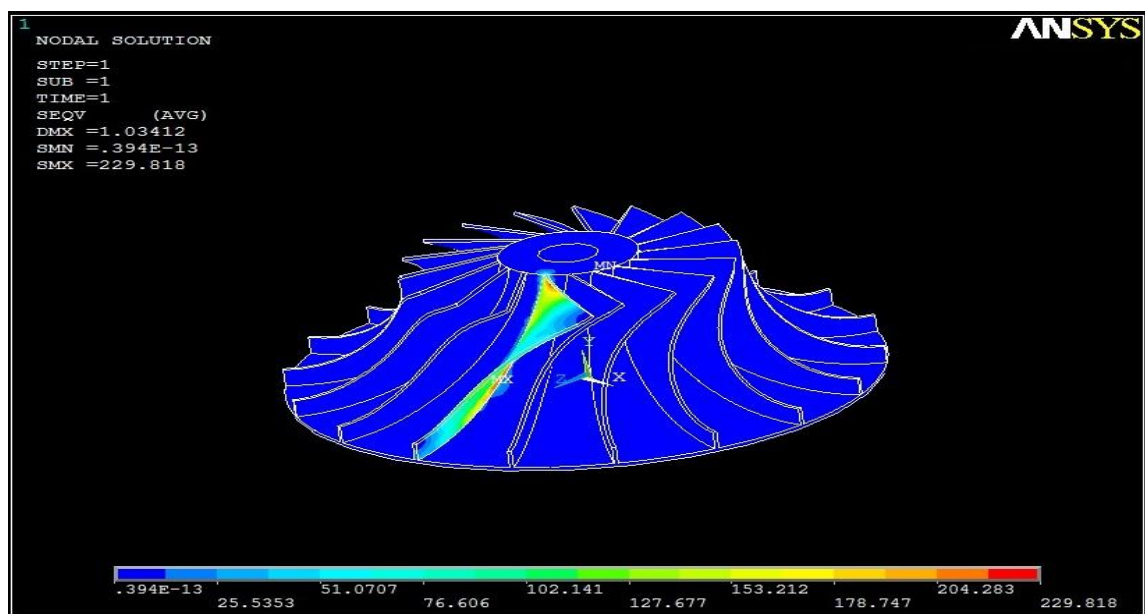


Fig. 4.1 Von mises stress

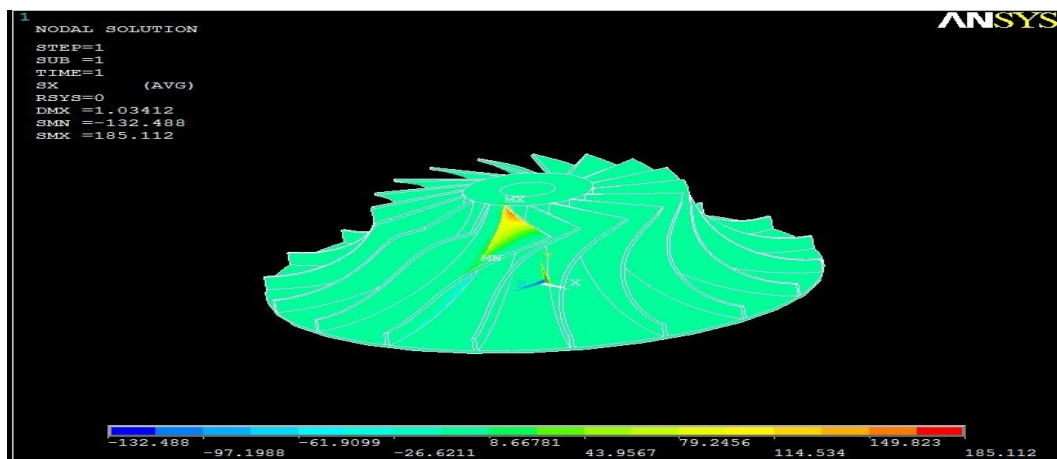


Fig.4.2 X-Component Stress

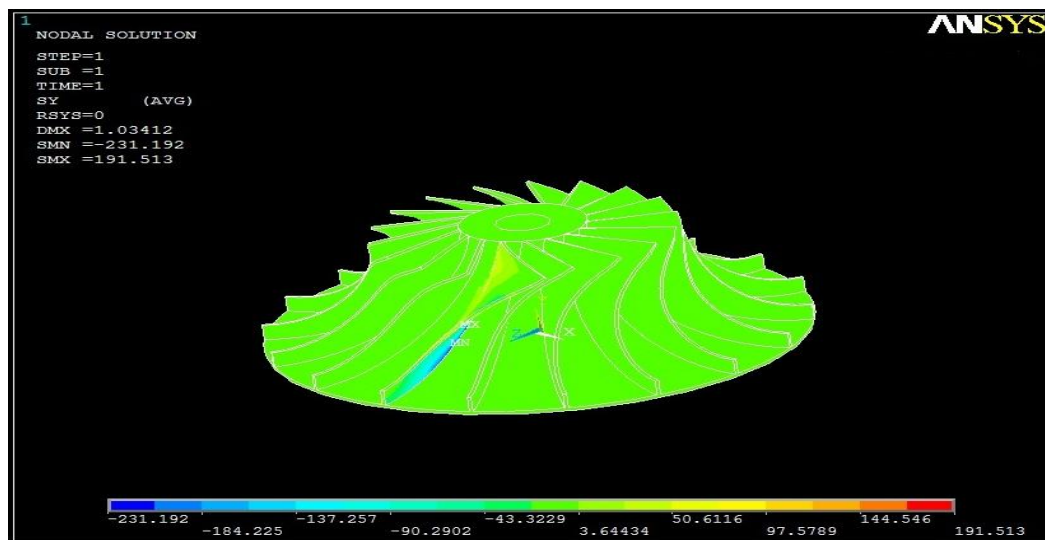


Fig. 4.3Y-Component stress

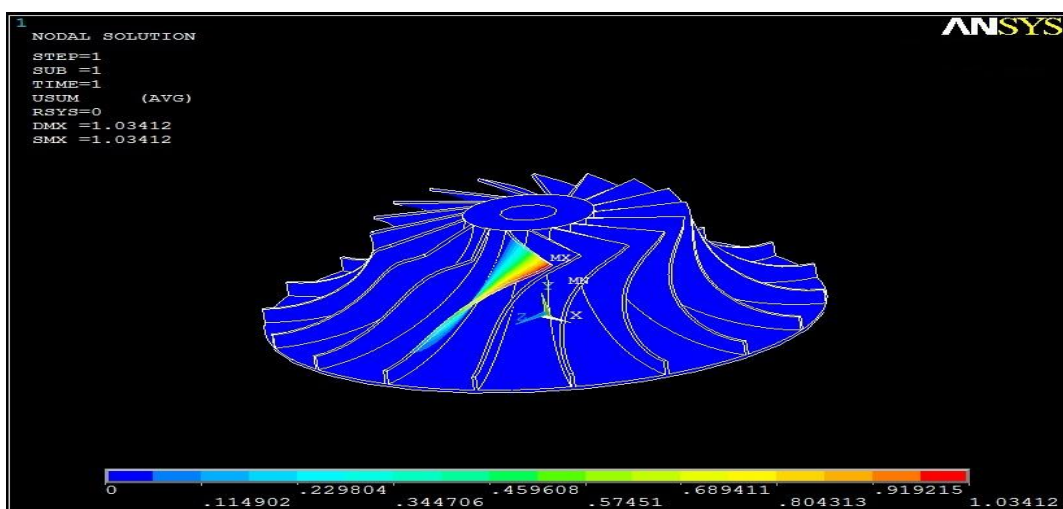


Fig.4.4 Vector sum displacement

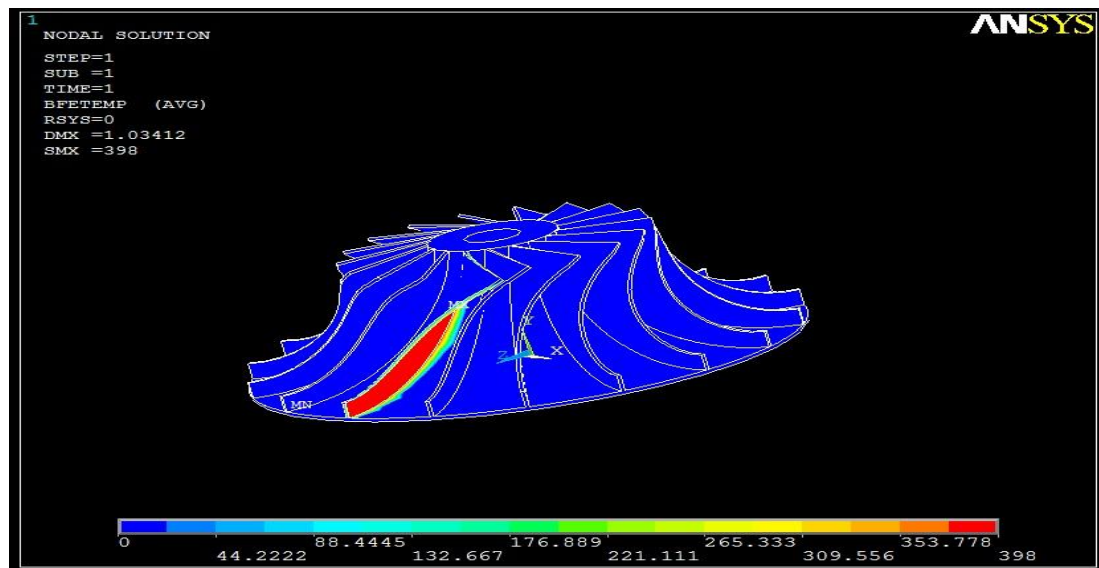


Fig.4.5 Temperature distribution

Table 4.0 Results for compressor analysis

INCONEL N06230	Properties
Displacement vector sum (mm)	1.03699
Von mises stress (MPa)	272.71
X-Component Stress (MPa)	185.112
Y-component Stress (MPa)	191.513

CONCLUSION

Compressor rotor assembly is more vulnerable to failure due to structural and thermal load.

- Distribution of stress along blade was studied by software and it shows that critical region of compressor blade which is between hub and blade requires careful attention.
- Maximum deformation occurs at tip section of blade.
- Periodic maintenance is necessary to satisfy prescribed conditions of turbocharger like clearances, balancing, exhaust gas temperature to avoid vibrations.
- The rotor imbalancing need to look upon critically while carrying out analysis because change in

thickness of blade seriously imbalance rotor causing rpm of rotor to be fluctuating and whirling of shaft.

- Structural and thermal analysis is carried out and maximum stress induced is within safe limit.

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