

Analysis of Stress Distribution on the Gas Turbine Compressor Wheel Due To the Centrifugal Forces



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ABSTRACT

We all know that COMPRESSOR in a gas turbine assembly one among the 6 major sections. The compressor which pressurizes the inlet air (gas), plays an active role in increasing the efficiency of the turbine, in that compressor wheel forms a significant part in the compressor section.

The work developed by the exhaust gases passing through the turbine, 65 to 70% is used to run the compressor and remaining 30 to 35% is used to generate the electric energy. Compressor and turbine wheels mounted on a single shaft rotate at the same speed. Due to its own mass and the buckets mounted on it, dynamic stresses are induced on the compressor wheel while rotation. Thus, in addition special care is paid to design and it is advisable to analyze it for real life situation. But in this project we are mainly concerned on structural static linear stress analysis.

Since the compressor wheel involves complex properties and boundary conditions, which analytical methods fail to analyze hence, numerical methods need to be employed which provide approximate, but acceptable solutions. Finite Element Method is one such technique applied for boundary value problems and it is integrated with high speed digital computer becomes a powerful tool to analyze complex domine with relative ease.

ANSYS is one of the upgraded software implementing FEM. Using ANSYS, the compressor wheel is analyzed for structural linear stress analysis and the results are received.

INTRODUCTION TO GAS TURBINES:

Gas turbines have been used for electricity generation for many years. In the past, their use has been generally limited to generating electricity in periods of peak electricity demand. Gas turbines are ideal for this application as they can be started and stopped quickly enabling them to be brought into service as required to meet energy demand peaks. However, their previously small unit sizes and their low thermal efficiency restricted the opportunities for their wider use for electricity generation.

Here are two basic types of gas turbines - aeroderivative and industrial. As their name suggests, aeroderivative units are aircraft jet engines modified to drive electrical generators. These units have a maximum output of 40 MW. Aeroderivative units can produce full power within three minutes after start up. They are not suitable for base load operation. Industrial gas turbines range in sizes up to more than 260 MW. Depending on size, start up can take from 10 to 40 minutes to produce full output. Over the last ten years there have been major improvements to the sizes and efficiencies of these gas turbines such that they are now considered an attractive option for base-load electricity generation. Industrial gas turbines have a

lower capital cost per kilowatt installed than aeroderivative units and, because of their more robust construction, are suitable for base load operation.

WORKING PRINCIPLE AND COMPONENTS OF GAS TURBINE:

Gas turbines use the hot gas produced by burning a fuel to drive a turbine. They are also called combustion turbines or combustion gas turbines. The main components of a gas turbine are an air compressor, several combustors (also called burners) and a turbine. The air compressor compresses the inlet air (raises its pressure). Fuel is mixed with the high pressure air in burners and burnt in special chambers called combustors. The hot pressurised gas coming out of the combustors is at very high temperature (up to 1350° C). This gas then passes through a turbine, giving the turbine energy to spin and do work, such as turn a generator to produce electricity.

As the turbine is connected to its compressor, the compressor uses some (about 60%) of the turbine's energy. Because some of its heat and pressure energy has been transferred to the turbine, the gas is cooler and at a lower pressure when it leaves the turbine. It is then either discharged up a chimney (often called a stack) or is directed to a special type of boiler, called a Heat Recovery Steam Generator (HRSG), where most of the remaining heat energy in the gas is used to produce steam.

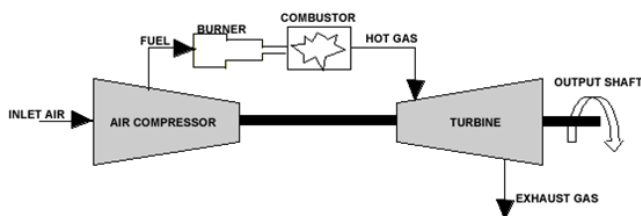


DIAGRAM OF TYPICAL LARGE GAS TURBINE

CYCLE OF OPERATION:

The gas turbine (Brayton) cycle is one of the most efficient cycles for the conversion of gas fuels to mechanical power or electricity. The use of distillate liquid fuels, usually diesel, is also common where the cost of a gas pipeline cannot be justified. Gas turbines

have long been used in simple cycle mode for peak lopping in the power generation industry, where natural gas or distillate liquid fuels have been used, and where their ability to start and shut down on demand is essential. Gas turbines have also been used in simple cycle mode for base load mechanical power and electricity generation in the oil and gas industries, where natural gas and process gases have been used as fuel. Gas fuels give reduced maintenance costs compared with liquid fuels, but the cost of natural gas supply pipelines is generally only justified for base load operation. More recently, as simple cycle efficiencies have improved and as natural gas prices have fallen, gas turbines have been more widely adopted for base load power generation, especially in combined cycle mode, where waste heat is recovered in waste heat boilers, and the steam used to produce additional electricity.

The efficiency of operation of a gas turbine depends on the operating mode, with full load operation giving the highest efficiency, with efficiency deteriorating rapidly with declining power output. Today's base load efficiency for natural gas-fired turbines is in the range of 36% (LHV) for large scale turbines (169-200+ MWe) to 25% or less (1 MWe range). The efficiency is related to the firing temperature in the combustion chamber and the turbine entry temperature. The larger turbines generally feature higher temperatures as market opportunities, and pressures, are more influential at these scales.



DESCRIPTION OF THE PROBLEM

AIM:

To study the stress distribution on the compressor wheel due to the centrifugal forces.

MATERIAL PROPERTIES:

Material	:	B50A368-S10(HY19467)
Strain hardening Modulus	:	2.1 E+05
Density	:	7.85E-10
Poission's ratio	:	0.3

FINITE ELEMENT DETAILS:

Software used	:	ANSYS
Element type	:	8 node axi-symmetric element (NTKP=3 NORDER=2)
Total number of elements:		851
Total number of nodes	:	989

BOUNDARY CONDITIONS:

As the component is axi-symmetric no constrains are required. However, to ensure that there are no rigid body motions in axial direction, one node is fixed in axial direction.

LOAD CASES:

1. Centrifugal forces.

ANSYS:

It is a finite element software package. It is very extensively used and is recognized as the most powerful engineering design and analysis software. It is registered trademark of SAS IP Inc.

ANSYS is general purpose software, which can be used for almost any type of finite element analysis virtually in any industry automobiles, aerospace, railways, machinery, electronics, sporting goods, power generation, power transmission and biomechanics. "General purpose" also refers to the fact that the software can be used in all disciplines of engineering-structural, mechanical, electrical,

electromagnetic, electronic, thermal, fluid and bio-medical.

ANSYS program can be run either in interactive mode or batch mode. Interactive mode, as its name implies, is where designer constantly interacts with the computer. When the command is issued the ANSYS program processes it and indicates what it did. In case of a mistake, corrective action can right away be taken. Interactive mode allows the designer to use convenient features such as graphic displays, on line help, menu system and graphics picking.

ANSYS finite element analysis software enables engineers to perform the following tasks:

1. Build computer models or transfer CAD models of structures, products, and components systems.
2. Apply operating loads or other design performance conditions.
3. Study physical responses such as, stress levels, temperature distributions or the impact of electromagnetic fields.
4. Optimize a design early in the development process to reduce production costs.
5. Do prototype testing in environments where it otherwise would be undesirable or impossible.

The ANSYS program has a comprehensive graphical user interface (GUI) that give easy interactive access to program functions. Commands, documentation and reference material. A system helps users navigate through the ANSYS program. Users can input data using the mouse, keyboard or the combination of both.

AXISYMMETRIC MODEL:

The deformation of the distribution of stress in solid of revolution that is deformed symmetrically with respect to its axis of the revolution is of great practical importance. The deformation being symmetrical with respect to the axis of revolution, it is most convenient to employ cylindrical coordinate's r , and z and to take the z -axis along the axis of symmetry. In these circumstances, the components of the displacement vector and of the stress tensor will all be independent

of the angle . Revolving bodies like flywheel can be analyzed by introducing centrifugal forces in the body force.

PRACTICAL LIST OF INDUSTRIES IN WHICH ANSYS IS USED:

1. Aerospace
2. Automotive
3. Biomedical
4. Electronics
5. Bridges & Buildings

Applicable ANSYS product: applicable products are determined by the discipline and complexity of the problem.

VARIOUS STAGES IN FINITE ELEMENT ANALYSIS:

1. PREPROCESSING:

- (a). Create model geometry.
- (b). Define material properties.
- (c). Choose element type.
- (d). Define geometric constraints.
- (e). General finite element mesh.

2. SOLUTION:

- (a). Apply boundary conditions.
- (b). Apply loads.
- (c). Solve for unknowns.

3. POST PROCESSING:

- (a). Review results like displacements, stress, reactions, etc.....
- (b). Check validity of solution.

MODELLING PROCEDURE INVOLVED IN ANALYSIS OF COMPRESSOR WHEEL UNDER DIFFERENT STRUCTURAL LOADINGS THROUGH ANSYS.

1.PRE PROCESSING:

1. Creation of the model through key points:-
Join the key points using the line command
Mainmenu>preprocessor>modeling>create>lines>straight line.

Forming the area

Mainmenu>preprocessor>modeling>create>areas>arbitrary>by lines.

Select the lines between which area is to be formed.

2. Defining element type:-

(a). Element type> add> structural solid(select quad node 42)>ok.

(b). Element type>options>element behaviour-axisymmetric.

3. Defining material properties:-

Materialproperties>materialmodels>structural>linear>elastic>isotropic>specify material number>OK.

Enter the value of corresponding material density.

4. Meshing:-

Meshing >mesh tool>global (smart size=3)>mesh>pick all>OK

2. SOLUTION:

1. Applying loads:-

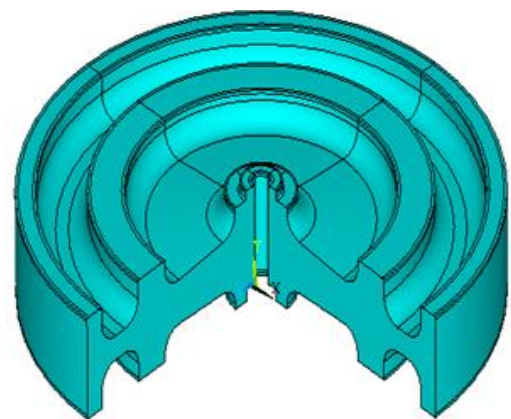
Solution>defineloads>apply>structural>displacement>on areas>pick all>apply displacement on areas (select the direction)>enter the displacement value>APPLY.

2. Solving:-

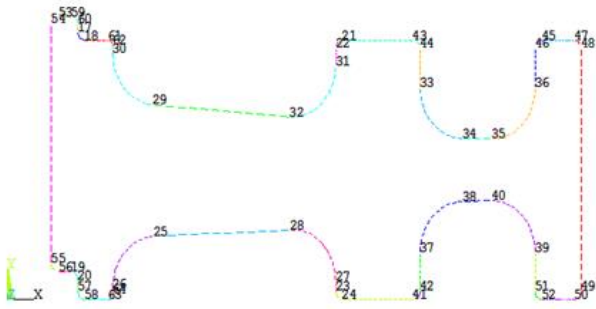
Solution>solve>current L.S.

3. GENERAL POST PROCESSING:

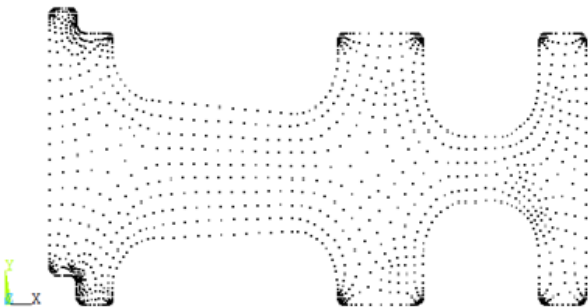
Plot results>nodal solution>stress>von mises stress>OK.



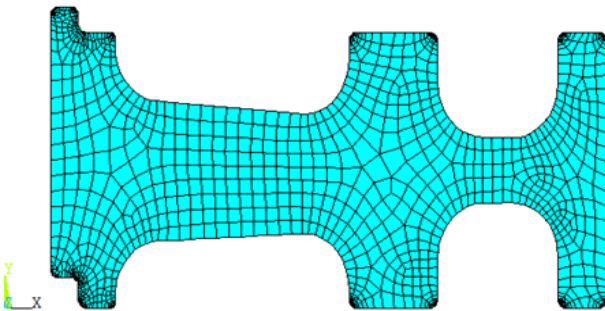
Imported geometry of compressor wheel



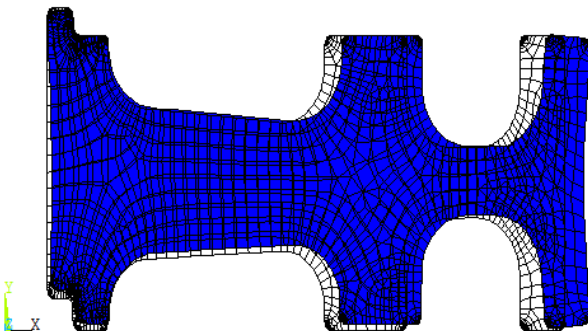
Lines in FEM of compressor wheel



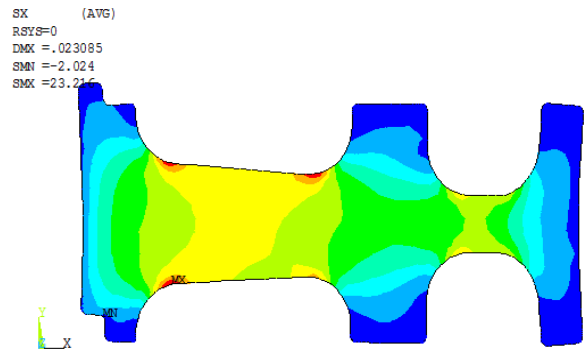
Nodes in FEM of compressor wheel



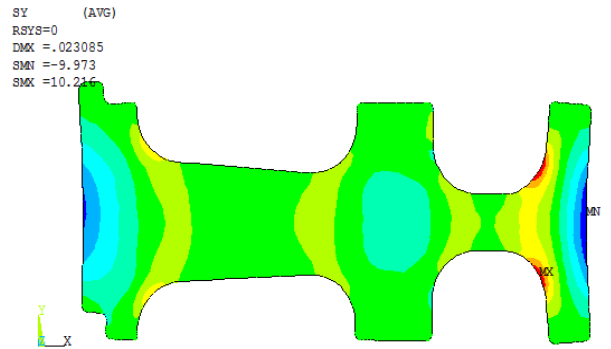
Mesh of compressor wheel



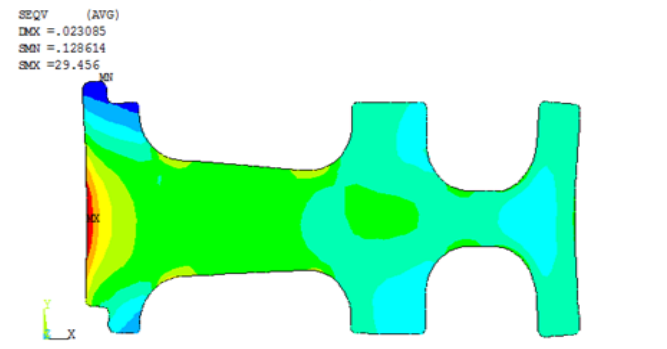
Displacement



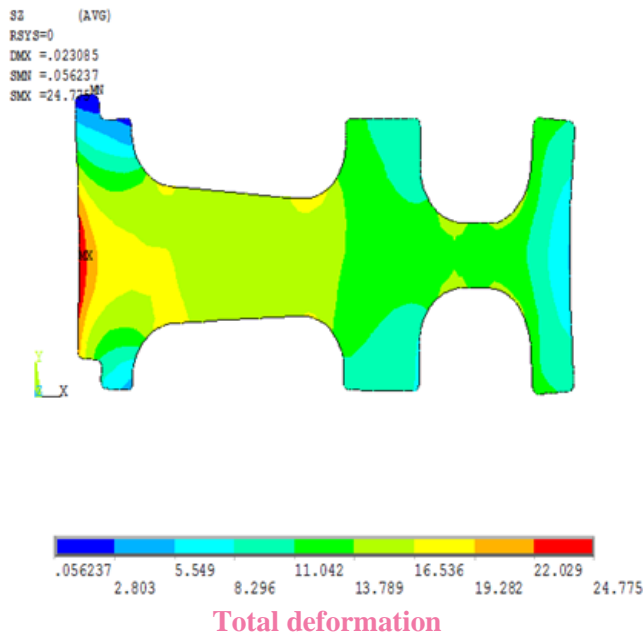
Nodal Solution-x direction



Nodal Solution-y direction



Nodal Solution- z direction



well below safe design values. Thus, displacements and stresses are within the limits of allowable values. Hence, the design is safe statically and modally and thus it is clear for manufacturing process.

REFERENCES

1. Advanced Strength of Material-J.P.DEN HARTOG
2. The Finite Element Method-O.C.ZEINKEIEWICZ
3. Introduction to FEM-TIRUPATHI.CHANDRAPUTLA
4. Finite Element Procedures-KLAUS-JURGEUS BATHE
5. Introduction to FEM-E.HINTON and D.R.OWEN

RESULTS AND CONCLUSIONS

RESULTS

In the static and modal analysis of the model, after the modeling part and after giving the required inputs, the solution part is executed. If there are no errors in the model developed, then the solution is done.

The excellent results are obtained are as follows

1. It is obtained that the maximum stress along the radial direction i.e, stress in Z direction is

$$\text{Max} 24.735 \text{ kg / cm}^2$$

$$\text{Min} 0.056237 \text{ kg / cm}^2$$

2. It is observed that the equivalent stress or vonmises stresses also on the application of centrifugal force is

$$\text{Max} 29.456 \text{ kg / cm}^2$$

$$\text{Min} 0.128614 \text{ kg / cm}^2$$

and observed that maximum displacement is at rim side and minimum displacement is at hub side

CONCLUSIONS:

The analysis of compressor wheel for Frame-6 ,2 stage 40MW Gas Turbine is carried out for static and modal analysis. The maximum displacement is 0.660343mm and maximum stress is 6.4 E – 05 N/mm², which are