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Finite Element Analysis of Axial Flow Turbine

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ABSTRACT: It is quite common that every component so designed will be affecting from various deformations and irregularities which may lead to generation of various stresses. So, it is very much essential to analyze the component for various stresses that are to be developed. Here, the analysis of various stresses in axial flow turbine is being done at and stress concentration is determined in the vicinity of blades of Turbine. The Material INCONEL 718 Material is Used .This alloy is made of Niobium, Chromium & Nickel.

The main objective is to find out the Displacement, Equivalent and Fatigue stresses in the blades when subjected to structural and thermal Loads.

Structural system of axial flow turbine can be easily analyzed using finite element analysis techniques. From these techniques the FEA is done in order to find out the stresses in the existing turbine for the given loads and boundary conditions using Finite Element Analysis Software ANSYS Workbench. This entire work is done in various steps like firstly modeling the turbine in SOLIDWORKS software and importing the geometry into the ANSYS software for process of analysis. Here five types of analysis are being done namely, static structural analysis, transient thermal analysis, structural to thermal coupled analysis, fatigue analysis and modal analysis.

The conclusions thus extracted from these analyses are the numerical values of stress concentrations, displacement, thermal stress, various modes of failure for different natural frequencies, and its life in cycles and safety factor. And it is found out that maximum stress is 194.61MPa, and in the thermal to structural coupled analysis the maximum stress is 217.65MPa. The other stresses outside the localized stress region are well within the yield strength value 1035Mpa, the life of the turbine chosen is 1×10^6 cycles. Hence the Axial Flow Turbine is safe.

KEY WORDS: Solid works and ANSYS 14.0 (ANSYS WORKBENCH)

I. INTRODUCTION

A machine for producing continuous power in which a wheel or rotor, typically fitted with vanes, is made to revolve by a fast-moving flow of water, steam, gas, air, or other fluids is called a turbine. A turbine, from the Greek $\tau\upsilon\rho\beta\eta$, $tyrb\bar{e}$, ("turbulence"), is a rotary mechanical device that extracts energy from a fluid flow and converts it into useful work. A turbine is a turbo machine with at least one moving part called a rotor assembly, which is a shaft or drum with blades attached. Moving fluid acts on the blades so that they move and impart rotational energy to the rotor. Early turbine examples are windmills and waterwheels.

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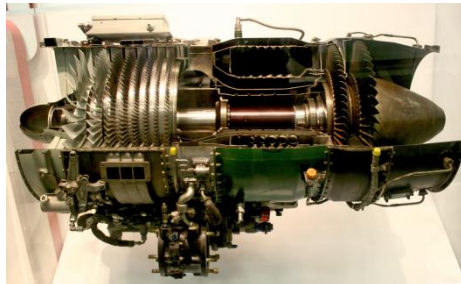


Fig.1.1, A typical axial-flow gas turbine turbojet, the J85, sectioned for display. Flow is left to right, multistage compressor on left, combustion chambers centre, two-stage turbine on right.

II. MATERIAL PROPERTIES

The physical properties of the material such as elastic modulus, Poisson's ratio, coefficient of thermal expansion etc. vary with the temperature. As the disk is subjected to severe thermal gradients, the nonlinear nature of the properties should also be taken into account. Generally, the density of the material is constant throughout the disk even under a wide range of temperatures. Poisson's Ratio has only an insignificant effect on the stress distribution. Accurate stress calculations would therefore require accurate data of the elastic properties of the disk material.

The Material INCONEL 718 Material is Used .This alloy is made of Niobium, Chromium & Nickel

Table 2.1 Properties

Temp/Properties	30 °C	200 °C	350 °C	500 °C	650 °C
Young's Modulus(E) GPa	207.7	194.6	186.5	178.3	170.6
Ultimate Strength (σ_u) Mpa	1240	1161	1201	1117	1067
Yield Strength (σ_y) Mpa	1035	969	1002	932	890
Thermal Conductivity (K) W/mk	11.7	14.90	16.27	18.17	19.73
Thermal Expansion (α) $e^{-6}/^{\circ}C$	12.42	13.32	13.95	14.40	14.76
Specific Heat (C_p) J/kg k	418.6	460.5	502.4	544.3	586.2
Density (ρ) Kg/m ³	8220				

III. PROCEDURE AND GEOMETRY

This project was done in ANSYS Workbench software by designing the model of the turbine in the SOLIDWORKS software and importing this model into ANSYS for analysis of various stress generated in it. The main aim of this project is to find out the stresses developed in the turbine when it is subjected to structural and thermal loads.

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Here the material chosen for the turbine is INCONEL 718; this alloy is made of Niobium, Chromium & Nickel. This model is then fine meshed and applied various boundary conditions and a pressure of 0.9 bars and a rotational velocity of 15000rpm is given for finding stresses in static structural analysis. A temperature of 30°C applied in the shaft and bottom of the rim and a temperature of 300°C applied in outer rim and all blades for thermal analysis. This is extended to structural to thermal coupled analysis. Later modal analysis is done for finding 6 modes of failure for their respective natural frequencies at 15000rpm. Finally fatigue tool is incorporated in fatigue analysis to find out the life of the turbine, damage and safety factor. Once all the numerical values are obtained from all the analysis it is evident that design of turbine is in safe limits.

Solid Works Design of Turbine:

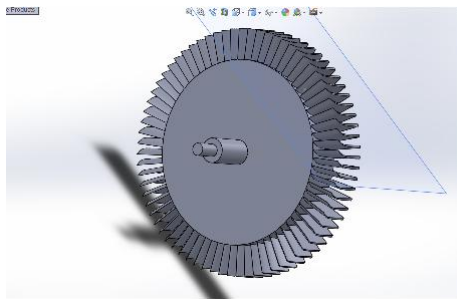


Fig. 3.1 Model of a turbine

APPLICATION OF LOAD AND BOUNDARY CONDITIONS

- The Rotational velocity is applied to all bodies is 15000 RPM.
- Remote displacement that is Rotation in Z direction is free and other Degree of freedom is fixed.
- This remote displacement support is applied both ends of the shaft.
- Pressure load is applied on the faces of all the bodies' i.e. 0.9 bar.

The temperature is applied in the shaft and bottom of the rim as 30°C. Temperature is applied in outer rim and all blades as 300°C.

IV. SOLUTIONS

STATIC ANALYSIS:

This analysis is used to determine the displacements, stresses etc., under static loading conditions, both in linear and non linear static analyses. Non linearities include plasticity, stress stiffening, large deflection, large strain, hyper elasticity, contact surfaces, and creep.

Here the results of static structural analysis are total displacement of turbine and equivalent stresses i.e. von-mises stress generated in the turbine.

SOLUTION OF STATIC STRUCTURAL ANALYSIS:

After the model was imported and meshed, the analysis was done by applying remote displacement supports at both ends of the shaft. Pressure load is applied on the faces of the all bodies that are 0.9 bars with rotational velocity of 15000rpm. The results were found out to be;

Von Mises stress:

Maximum stress --- 194.61MPa

Minimum stress --- 0.25375MPa

Total deformation:

Maximum --- 0.11724 mm

Minimum --- 6.8243×10^{-5} mm.

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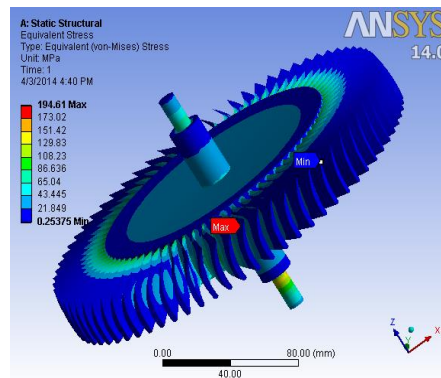


Fig. 4.1. Equivalent Stress plot in static analysis

TRANSIENT THERMAL ANALYSIS

An analysis in which Thermal calculates temperatures and heat fluxes in your model at different times in response to specified heat loads and subject to specified prescribed temperatures and/or convection conditions.

Transient thermal analysis determines temperatures and other thermal quantities that vary over time. Engineers commonly use temperatures that a transient thermal analysis calculates as input to structural analyses for thermal stress evaluations. Many heat transfer applications-heat treatment problems, nozzles, engine blocks, piping systems, pressure vessels, etc.-involve transient thermal analyses.

A transient thermal analysis follows basically the same procedures as a steady-state thermal analysis. The main difference is that most applied loads in a transient analysis are functions of time.

Boundary conditions;

- The temperature is applied in the shaft and bottom of the rim as 30°C.
- Temperature is applied in outer rim and all blades as 300°C.

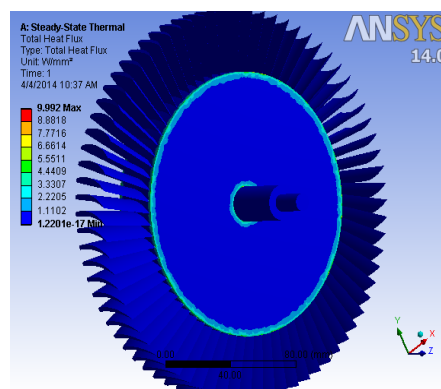


Fig.4.2 .Total Heat Flux plot in thermal analysis

THERMAL TO STRUCTURAL COUPLED ANALYSIS:

A thermal analysis follows basically the same procedures as a steady-state thermal analysis. The main difference is that most applied loads in a transient analysis are functions of time. This analysis is done by considering the temperature effects coupled with static structural analysis. The results obtained from the thermal analysis are coupled at the solution phase to structural analysis and combined results are analyzed.

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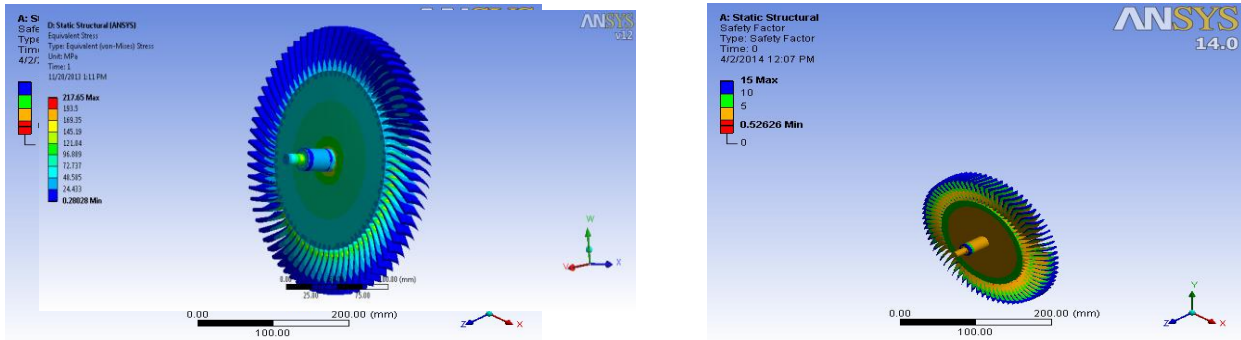


Fig. 4.3 Equivalent Stress plot in static analysis

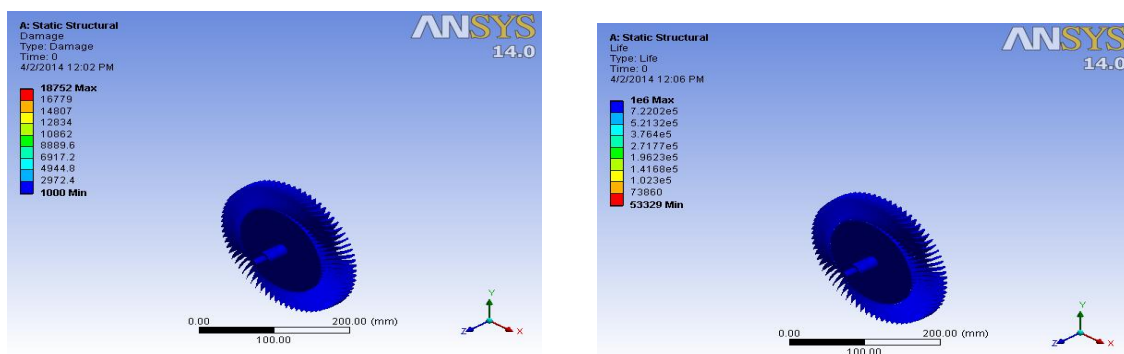
- **Boundary conditions:**
- Turbine Blade structural and thermal loading conditions
 - Pressure – 0.9 bars
- Temperature - 30⁰C on shaft and outer rim; 300⁰C on all blades and inner side of rim.
- Rotational velocity - 15000rpm.

SOLUTION OF THERMAL TO STRUCTURAL COUPLED ANALYSIS

- **Total deformation**
- Maximum---0.32646mm
- Minimum---4.57 x 10⁻⁵ mm
- **Equivalent (von- Mises) stresses**
- Maximum---217.65 MPa Minimum--- 0.280 MPa
- **Overall temperature**
- Maximum---300.14⁰C
- Minimum---30⁰C

FATIGUE ANALYSIS:

Fatigue is a failure caused by application of repetitive load by the process of initiation of cracks and growth in simple terms “life of structure when it is subjected to repetitive loads”. In this analysis one can determine the life of the



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component along with the damage and safety factor. Solutions and plots of safety factor, life & damage as shown figure 4.4, 4.5, 4.6.

V. CONCLUSIONS

The Displacement, Equivalent and Fatigue stresses has been found out in the blades of axial flow turbine when it is subjected to structural and thermal Loads at given boundary conditions.

VI. LITERATURE REVIEW

There were many papers which took the chances of doing the analysis of turbine like “Determination of Stress Concentration Factors of a Turbine Rotor Using Finite Element Analysis”. Journal of Mechanical Engineering, Vol. ME 40, No. 2, December 2009. Transaction of the Mech. Eng. Div., The Institution of Engineers, Bangladesh, by R. Nagendra Babu, K.V.Ramana and K.Mallikarjuna Rao.

“Coupled Thermal-Structural Analysis of a Turbine Rotor Using ANSYS for Finding Out Remnant Life”; The International Journal of Science and Technology by Srikanth Bashetty, Parthasarathy Garre.

“Determination Of Stress Concentration Factor In Steam Turbine Blade By Finite Element Method”; ISSN 2278 – 0149 www.ijmerr.com Vol. 2, No. 3, July 2013; The International Journal of Mechanical Engineering and Robotics Research by Sandip G Ghugal, Rajendra K Pohane and Sandeep M Pimpalgaonkar.

“Transient Thermal Analysis of a Steam Turbine Rotor”; International Journal of Engineering Research and Applications (IJERA) ISSN: 2248-9622 www.ijera.com Vol. 2, Issue 3, May-Jun 2012, pp.2248-2252 2248 | by Shilpa P. Bhorkar, Dr. A.V. Vanalkar.

“Theoretical Analysis of Gas Turbine Blade By Finite Element Method”; B. Deepanraj, P. Lawrence and G. Sankaranarayanan.

“Thermal Analysis of a Gas Turbine Rotor Blade by Using Ansys”; International Journal of Engineering Research and Applications (IJERA) ISSN: 2248-9622 Vol. 2, Issue 5, September- October 2012, pp.2021-2027 2021 by G.Narendranath, S.Suresh.

These projects paved us a way for finding the displacement and fatigue stress on turbine when structural and thermal loads are applied.

REFERENCES

- [1] “Determination of Stress Concentration Factors of a Turbine Rotor Using Finite Element Analysis”. Journal of Mechanical Engineering, Vol. ME 40, No. 2, December 2009. Transaction of the Mech. Eng. Div., The Institution of Engineers, Bangladesh, by R. Nagendra Babu, K.V.Ramana and K.Mallikarjuna Rao.
- [2] “Coupled Thermal-Structural Analysis of a Turbine Rotor Using ANSYS for Finding out Remnant Life”; The International Journal of Science and Technology by Srikanth Bashetty, Parthasarathy Garre.
- [3] “Determination Of Stress Concentration Factor In Steam Turbine Blade By Finite Element Method”; ISSN 2278 – 0149 www.ijmerr.com Vol. 2, No. 3, July 2013; The International Journal of Mechanical Engineering and Robotics Research by Sandip G Ghugal, Rajendra K Pohane and Sandeep M Pimpalgaonkar.
- [4] “Transient Thermal Analysis of a Steam Turbine Rotor”; International Journal of Engineering Research and Applications (IJERA) ISSN: 2248-9622 www.ijera.com Vol. 2, Issue 3, May-Jun 2012, pp.2248-2252 2248 | by Shilpa P. Bhorkar, Dr. A.V. Vanalkar.
- [5] “Theoretical Analysis of Gas Turbine Blade by Finite Element Method”; B. Deepanraj, P. Lawrence and G. Sankaranarayanan.
- [6] “Thermal Analysis of a Gas Turbine Rotor Blade by Using Ansys”; International Journal of Engineering Research and Applications (IJERA) ISSN: 2248-9622 Vol. 2, Issue 5, September- October 2012, pp.2021-2027 2021 by G.Narendranath, S.Suresh.
- [7] “Machine Design by R S Kurmi”.
- [8] www.ansys.com.
- [9] www.wikipedia.com.
- [10] www.google.co.in.