International Journal of Scientific & Engineering Research Volume 11, Issue 6, June-2020
ISSN 2229-5518

DESIGN & DYNAMIC ANALYSIS OF AERO TURBINE DISC

R.Karthigeyan[1], Shivasharanayya Swamy[2]
[1]M. Tech Student, Machine Design Dept., REVA University, Bangalore
[2]Assoc.Professor, School of Mechanical Engineering, REVA University, Bangalore

Abstract— This study summarizes the design and analysis of Gas turbine blade, as turbine discs have numerous applications in the aerospace industry, such as in liquid rocket engines. In this study, the stresses and deformations of a turbine disc were studied. The goal was to highlight the stress and deformation distribution to assist in the design of a disc as well as to demonstrate the importance of using finite element (FE) analysis in simulating an actual design case. CATIA is used for design of solid model and ANSYS software for analysis for F.E. model generated. The stresses and deformations developed as a result of the disc operating conditions at high rotational speeds. Applying boundary conditions of displacement constraints. Static and dynamic stress analyses results were determined and FOS was tabulated based on material properties.

Index Terms— FOS, Gas Turbine blade CATIA, FE.

1 INTRODUCTION

Quite a few studies involving marginal separation between rotor and nozzle have been conducted in recent years, and for a variety of turbo machinery applications. Much of the previous work is briefly summarized in the following section to provide an overview. Only a few studies, however, were found to straight relevance to the present study.

Every axial flow compressor has a boundary in its mass flow, at both higher and lower side for a specific speed called its operating range, within which it can operate successfully. The extreme rate is called choke limit. The peak efficiency point is generally stated as the design point. The lowest mass flow rate at which the compressor can run steadily is called the stall point.

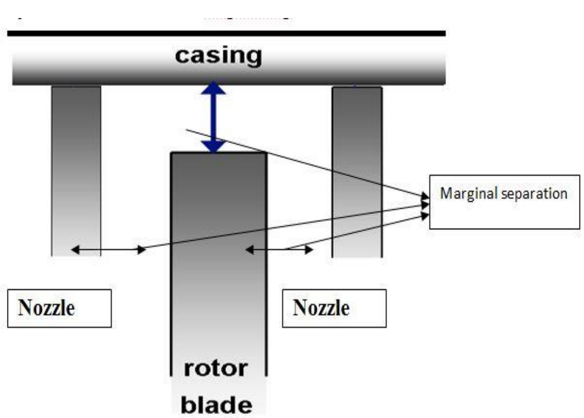


Fig. 1.1: Rotor Casing Assembly of the Gas Compressor

The above figure shows marginal separation of nozzles and rotor. The complex field of turbine /compressor blade vibration has long been in need of developed tools to help predict the reliability of blading.

The gas turbine is a device that burns fuel to provide energy to generate a moving flow of air, and to extract valuable power or generate useful thrust from that movement. The compressor would source all the air required by the turbine.

Its main function is to source sufficient air to please the necessities of the combustion burners. The compressor need increase in the pressure of mass of air received from the air inlet duct and then release it to the burners.

The shape of the stator blades are designed based on the absolute velocity vector at the inlet and exit of the rotor blade. The blade themselves be can arranged to achieve just a change in the direction of the fluid velocity, in which case blade passage area is constant, or change in the static enthalpy(or pressure) through a varying area passage. In latter case the stator blade passage will act as a nozzle in compressor.
To acquire a high pressure of order 4 to 10 bar of working fluid where fuel is constantly burnt with compressed air to yield a steam of hot.

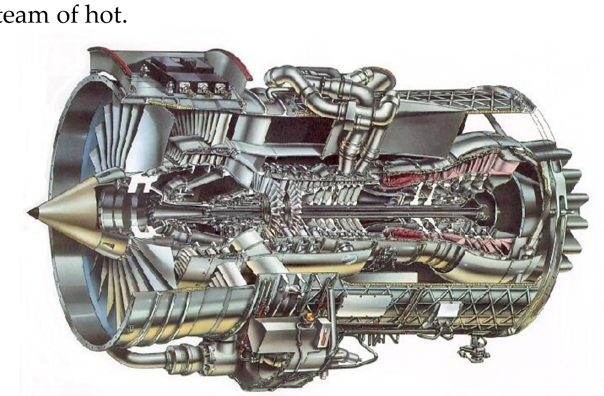


Fig. 1.2: Gas Turbine

One way to proceed is enhancements of methods in the engineering development areas. The aim is to improve the engineering design process to a large extend. Concurrent simultaneous engineering is the key word for these activities in the past. The complex blade design process is one key part of that.

Aerodynamic blade design process

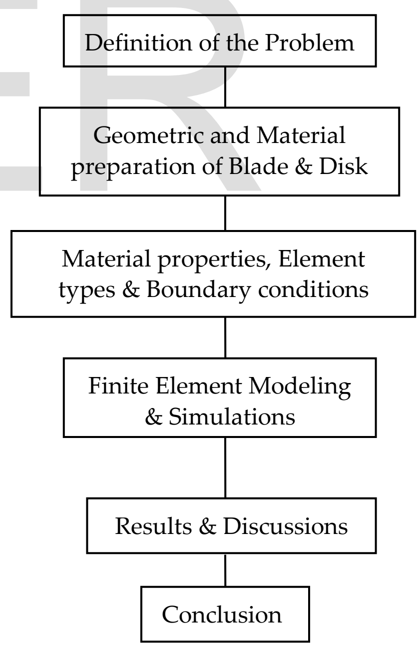
The blade geometry design process usually plays an imperative role in the advance and verification of an innovative gas turbine or aero engine. It is the innermost eye of most design iterations and henceforth taking into account the great number of dissimilar blades requisite for a multistage Compressor or turbine is a serious cost aspect.

In the low pressure turbine area people understood the positive outcome of relaxing for the steadiness of the boundary layer and enlarged blade loading.

2 LITERATURE REVIEW

Teju. V et al. [1] have conducted studies on design and stresses analyze a turbine blade of a jet engine, an examination for the usage of new materials. In the work turbine blade was designed with two different materials so-called as Inconel 718 and Titanium T-6. **Amr Elhefny et al.** [2] have conducted studies on analysis of turbine disc. In the work, the stresses and displacements developed as a outcome of the disc operating conditions at high rotational speeds and thermal grades were examined using two types of heat transfer modes—conduction and convection. **John. V et al.** [3] have conducted studies on the design and analysis of Gas turbine blade, CATIA was used for design of solid model and ANSYS software for analysis for F.E. model produced. The main aim of the study was to have the natural frequencies and mode shapes of the turbine blade. **Chaitanya Krishna Patsa et al.** [4] have conducted studies on the design and analysis of Gas turbine blade in which the study agrees to inspect steady state thermal & structural performance of the blade for Monel-400, Haste alloy -x & Inconel 625 materials. Lastly concluding the best suitable material. **Kalapala prasad et al.** [5] have conducted studies on structural and thermal analysis of the first stage hallow rotor blade of a two-stage gas turbine using ANSYS and material used was Titanium alloy, Stainless steel alloy, Aluminum2024 alloy, Inconel625 alloy and haste alloy. Deflection detected was minimum in the case of Titanium alloy and stainless steel alloy. **B.T.Naik et al.** [6] have conducted studies on design and analysis of Gas turbine blade. The structural analysis and performance of the blade for materials N155, Inconel625, Titanium were associated. Lastly concluding the best suitable material. **Lucjan Witek** [7] has conducted studies on failure analysis of turbine disc of an aero engine, from the visual examined of the fractured surface; there was a remark on beach marks, typical of fatigue failure. A non-linear finite element method was used. The computation was completed with excessive rotational speed. **R.A. Claudio** [8] has conducted studies on the gas turbine disc. Finite element analysis were resultant from a plain disc of no cracks and for geometry with two types of cracks, both at the notch root of the blade insert and situated in the corner and in the center (central crack), fatigue life predictions were studied. **Nageswara Rao Muktinutalapati et al.** [9], Materials for Gas Turbines – An Overview, Advances in Gas Turbine Technology. **www.special.metals.com** [10], the INCONEL alloy 718 material's physical and chemical properties were referred from http://www.specialmetals.com/assets/smc/documents/inconel_alloy_718.pdf. **G.J. Nie et al.** [11] Stress analysis and material tailoring in isotropic linear thermo-elastic incompressible functionally graded rotating discs of variable thickness**,** Composite Structures, thermal behavior information was studied. **C.L. Clark** [12]**,** High Temperature Alloys**,** Pitman, material properties was noted. **A.R. Ragab et al.** [13], Engineering Solid Mechanics**,** CRC Press, Boca Raton, the application of boundary conditions was studied in the Textbook of Solid Mechanics. **P.P. Benham et al.** [14] Mechanics of Engineering Materials, material properties was noted. **S. S. Rao [15],** The Finite Element method in Engineering, the type of meshing being employed is this study is taken from this textbook.

3 METHODOLOGY



4 FINITE ELEMENT SIMULATION

4.1 Work Material

In this study work, material chromium steel is selected. It has many advantages as compared to other materials used for mold steel, there is no need of subsequent heat treatments. Chromium steel is stronger, harder and abrasion resistant material allowing a longer life. In the presence of chromium, the alloy enhances the toughness and hardness, corrosion resistance and good machinability and the properties of chromium-steel alloy is shown in the Table.

Table: 4.1 Properties of the Material used for the Model

Material	Chromium-Steel (X28CrMoNiV49)	
Density at room temperature, ϱ	7.7×10^{-9}	kg/mm^3
Modulus of elasticity, E	2.1×10^5	Mpa
Yield Strength, σ_y	585	Mpa
Tangent Modulus, E_T	5500	Mpa
Operating Speed	6920 rpm = 724.75 rad/sec	
Poisson's Ratio, μ	0.3	
Factor of Safety, FOS	1.68	

4.2 Model Structure

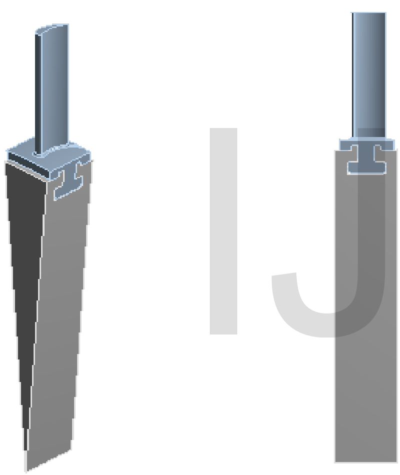


Fig. 4.1: Isometric views of Blade, Disc, Bladed Disc Assembly

It is a single sector Blade and Rotor Disc assembly with a single T-root. It has a Disc sector angle. The Front view and Isometric view of Blade and Rotor Disc assembly is shown above figure.

4.3 Meshed Model

The Bladed Disc assembly geometry model is meshed effectively. The mesh is mix of triangle and quadrilateral elements, which is said to be a good mesh. Which effectively absorbs the stress and strain produced in the geometry model upon subjected to load. Meshed blade and disc are shown in figure.

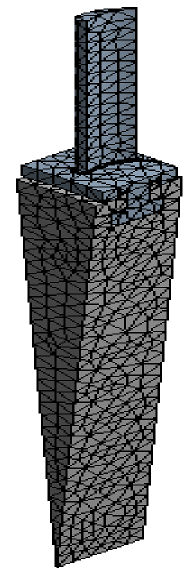


Fig. 4.2: Tetrahedron Meshed Model of Single Bladed Disk

4.4 Boundary Conditions

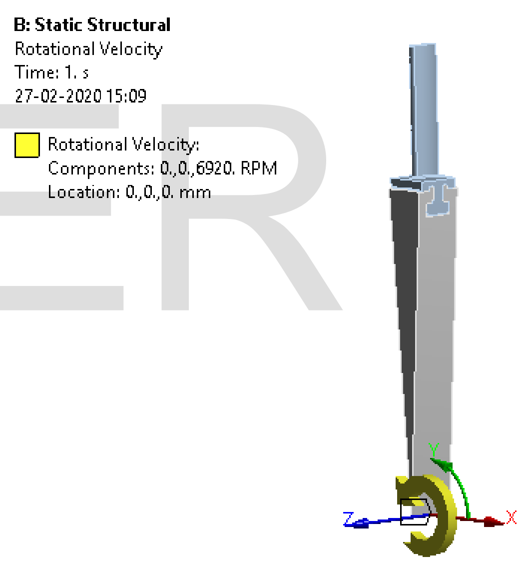


Fig. 4.3: Rotational Boundary condition

& the displacement Costraint for the model is given a free displacement in Y-direction (radial direction) and constrained to "0mm" in other directions.

5 RESULTS AND DISCUSSION

5.1 Static Analysis Results

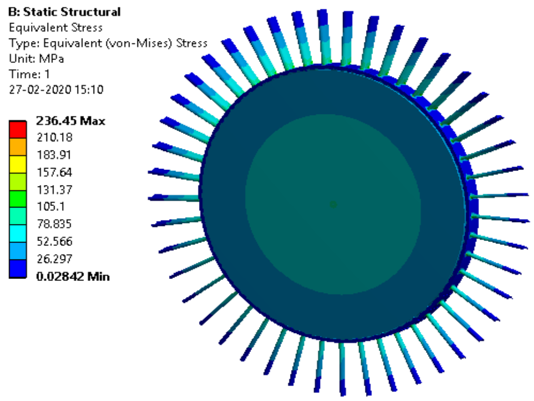


Fig. 5.1: The Von-Mises stress is found to be maximum at the fillet region of T-root region and is equal to 236.45 Mpa.

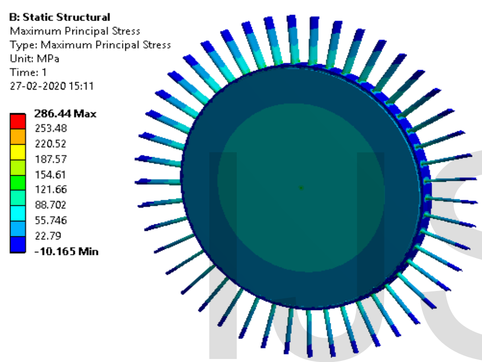


Fig. 5.2: Maximum principal stress is 286.44 Mpa is found at fillet region of T-root blade

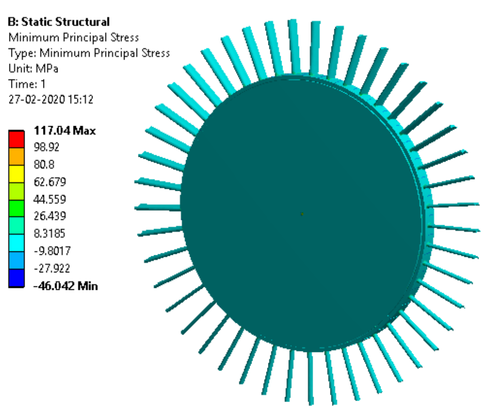


Fig. 5.3: Minimum principal stress is 117.04 Mpa is found at fillet region for the applied load condition

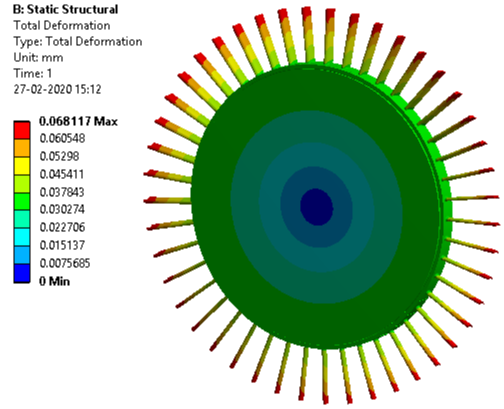


Fig. 5.4: The deformation is found to be maximum at the tip of the blade. Maximum Total deformation is 0.06811 mm for the applied load condition.

6 CONCLUSION

- Linear static structural analysis has been carried out to estimate the von misses stress, at critical regions of blade and disc and it is found that **von-misses stress**/ equivalent stresses of **236.45 Mpa**, found to be less than the yield strength of the material, hence the design is **safe.**
- Linear static structural analysis has been carried out to estimate the **maximum principal stress**, at critical regions of blade and disc and it is found that maximum principal stresses of **286.44 Mpa**, found to be less than the yield strength of the material, hence the design is **safe.**
- The estimation of **minimum principal stress,** at critical regions of blade and disc is found to be **117.41 Mpa**, found to be less than the yield strength of the material, hence the design is **safe**.
- The estimation of **deformation** at critical regions of blade and disc is found to be **0.068mm,** falling under the **permissible limits.**

7 REFERENCES

[1] Theju V, Uday P S, PLV Gopinath Reddy, C.J. Manjunath, "Design and Analysis of Gas Turbine Blade", International Journal of Innovative Research in Science, Engineering and Technology, Vol. 3, Issue 6, June 2014

[2] Amr Elhefny, Guozhu Liang, "Stress and deformation of rocket gas turbine disc under different loads using finite element modeling", School of Astronautics, Beihang University, Beijing 100191, China, accepted 23 October 2012 Available online 21st March 2013.

[3] V. John, T. Ramakrishna, "The design and analysis of gas turbine blade", International Journal of Advanced Research and Studies, Vol. 2, No.1, Dec 2012, E-ISSN2249–8974

[4] Chaitanya Krishna Patsa, Subhani Mohammed, "Structural Analysis of Super Alloy Gas Turbine Blade using FEA", IJERT, ISSN: 2278-0181, Vol. 3 Issue 1, January – 2014

[5] Kalapala Prasad, V S S Venkatesh, "Design and analysis of first stage 22omw Gas Turbine Rotor Blade", ISSN: 2248-9622, Vol. 6, Issue 5, (part-4) May 2016, pp.01-04

[6] B.T. Naik, "Analysis of Gas Turbine Rotor Blade by Using F.E.M", International Journal and Magazine of engineering, Technology, management and Research, ISSN: 2348-4845

[7] Lucjan Witek, Failure analysis of turbine disc of an aero engine, Science Direct, Vol. 13, Issue 1, January 2006, Pages 9-17

[8] R.A. Claudio, C.M. Branco, E.C. Gomes, J. Byrne., "Life Prediction of a Gas Turbine Disc using the finite element method", Department of Mechanical Engineering, EST/Instituto Politécnico de Setúbal Campus do IPS, Estefanilha, 2914-508 Setúbal, AS JORNADAS DE FRACTURA – 2002

[9] Nageswara Rao Muktinutalapati, VIT University, India, Chapter-13, Materials for Gas Turbines – An Overview, Advances in Gas Turbine Technology, Intechopen Nov2011, ISBN: 978-953-307-611-9.

[10] Material property Inconel 718 [online], Available: http://www.specialmetals.com/assets/smc/documents/inconel_alloy_718.pdf

[11] G.J. Nie, Stress analysis and material tailoring in isotropic linear thermoelastic incompressible functionally graded rotating discs of variable thickness, Composite Structures, 92 (3) (2010), pp. 720-729 Article

[12] C.L. Clark, High Temperature Alloys, Pitman, New York (1993) Google Scholar

[13] A.R. Ragab et al., Engineering Solid Mechanics, CRC Press, Boca Raton, FL (1999), Google Scholar

[14] P.P. Benham et al., "Mechanics of Engineering Materials", John Wiley and Sons, New York (1987), Google Scholar

[15] S. S. Rao, "The Finite Element method in Engineering", BH Publications New Delhi, 3rd Edition, 1999.