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Structural Analysis of Gas Turbine Blade

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Abstract –*Blades of gas turbine are responsible for extracting energy from the high temperature and high pressure gases.Gas turbine blade operated at high temperature provides better efficiency and maximum work output. The present paper deals with structural analysis of gas turbine blade. The analysis was carried out to know the mechanical stresses and deformation experienced by the gas turbine rotor blade. Solid model of turbine blade is created by using SOLIDWORKS20 software. The turbine blade is analyzed for its' structural performance due to the loading condition using ANSYS 16.2 software to study the variation of stresses on gas turbine blade for aluminium alloy, titanium alloy and magnesium alloy material. Among this three materials Titanium alloy has maximum equivalent stress 7.53×10^5 N/m^2 and minimum deformation of 2.33×10^{-5} m.*

Key Words: *Gas turbine blade, Mechanical stresses, Deformations, Materials, Structural Analysis.*

1. INTRODUCTION

The gas turbine obtains its power by utilizing the energy from burnt gases which is at the high temperature and pressure. Power was obtained by expanding them through the several rings of fixed and moving blades. The turbine is responsible for driving the compressor so it is coupled to the turbine shaft. After compression, the working fluid was expanded in a turbine. Then it was assumed that there were no losses in both component and the power developed by the turbine can be increased by increasing the volume of working fluid at constant pressure or alternatively increasing the pressure at constant volume. Else it may be done by adding heat so that the temperature of the working fluid is increased after compression. For getting higher combustion, chamber is required where combustion of air and fuel takes place and giving temperature rise to the working fluid. The turbine escapes energy from the exhaust gas. Work deals with structural analysis of gas turbine blade. The analysis was carried out to understand the mechanical stresses and deformation. This was experienced by the gas turbine rotor blade and includes the parameters such as the gas forces which are assumed to be distributed evenly. The tangential and axial force acts through the centroid of the blade and the centrifugal force acts through the centroid of the blade in radial direction.

2. LITERATURE REVIEW

V. NagaBhushana *et.al*[1] worked on the turbine blade under evaluation belongs to the first stage rotor blade of a two - stage gas turbine. The turbine blade data was obtained by using CMM. 3D solid model is created by using CATIA V5R21software. The turbine blade is analyzed for its thermal and structural performance due to the loading condition and the temperature gradients using ANSYS 14.0. Maximum stresses are observed near the root of the turbine blade and maximum temperatures are observed at the blade tip sections. Also minimum temperature is observed at the root of blade. P. V. Krishnakanth *et.al.*[2] specified how the program makes effective use of the ANSYS pre-processor to analyze the complex turbine blade geometries and then apply boundary conditions to know steady state thermal & structural performance of the turbine blade for N 155, Hastealloy x & Inconel 625 material. Inconel 625 has better thermal properties. V. Nagabhushan Rao*, et.al*.[3] generated profile by using CATIA V5R21software. The turbine blade is analysed for its thermal as well as structural performance. It was observed that there was no evidence of rubbing marks on the tip section of turbine blade which indicates the elongation of the blade is within the safe limit. The stresses induced in the turbine blade which is to be made up of super alloy and Nimonic 80A alloy are within the safe limits. Theju V. et.*al* [4] made an attempt to investigate the effect of temperature and induced stresses on the turbine blade. A thermal analysis has been carried out to investigate the direction of the temperature flow which has been developed due to the thermal loading. A structural analysis has been carried out to know the stresses and displacements of the turbine blade. An attempt is also made to suggest the best material for a turbine blade by comparing the results obtained for two materials i.e. Inconel 718 and titanium T6. Inconel 718 is considered as a best material after analysis. S. Alka *et.al*[5] designed blade in such a way that it produce maximum rotational energy by directing the flow of the gas along its surface. The blades are made at specific angles to incorporate the net flow of gas over it. Catia is the standard 3D product design, featuring industry-leading productivity tool that promote best practices in design. Over a static structural analysis silicon carbide is better material for gas turbine blade. Mehdi Tofighi Naeem *et.al*[6]carried out microstructural analysis of all elements that had great influence on the failure initiation. The failure analysis of a gas turbine with first and second stage blades made up of nickel-based alloy was checked. Accumulated service time of these blades is more than 10 years. This investigation was carried out by mechanical as well as metallurgical analysis.

From analysis it is observed that blade failure was not directly related to the centrifugal and gas loading. M. Mirzaei, R. Karimi[7] gave idea about stress analysis and life assessment of the gas turbine blade. With the assumption of occurrence of small-scale creep and thermal-fatigue during each start-stop cycle. The crack tip parameters were calculated by using the energy domain integral method. An incremental crack growth scheme was considered. The total life for the growth of 0.5mm surface crack to 5mm through-thickness crack was calculated. G.D.Ujade and M.B.Bhambere[8] reviewed on paper of various analysis done on turbine blades and various factors which made impact on turbine blade. On analysing four different models with varying no of holes, it is observed that the blade model with 13 holes is best suited. N.Suresh and T.L.Rakesh babu [9] gave an idea about variation of stresses for gas turbine blade for graphite and titanium materials.Nickel alloys with titanium and graphite with partially stabilized cobalt coating is more beneficial due to low stress, displacement, low cost and easy for manufacturing. K.Hari Brahmaiah and M.Lava Kumar[10] analysed gas turbine blade through the cooling holes by using CFD software FLUENT. On evaluating the graphs which are to be drawn for total heat transfer rate and temperature distribution.The blade with 13 holes is considered as optimum. Steady state thermal and structural analysis was carried out by using ANSYS software with different blade materials of Chromium steel and Inconel718.

3. MATERIAL AND METHOD

3.1 MODELLING OF GAS TURBINE BLADE.

The gas turbine blade geometry is created by using co-ordinates. This Co-ordinate are imported into solid works20 software from UIUC –NACA4412. Chord length for turbine blade model is 250 m.

Table-1: Co-ordinates for creating profile

X	Y
0	0
2.6	17.3
5.85	21
10	25
14.8	26.6
22.9	25.3
28	22.2
33.4	18.5
38	14.4
42	10.9
45.5	5.7
49	0
6.18	12.4
11.2	14.4
16.18	15.5
21.1	14.9
26	13.6
38.2	8.77
45	3.95
49	0
49	27
0	27
19.8	0
1	13.6
29.2	0
29.2	27
19.8	27
15.2	27
18.08	27
49	2.70×10^{-2}
48.9	2.88×10^{-2}
29.2	12.49
19.8	26.62
19.8	15.12
29.2	21.25
0	3.00×10^{-2}

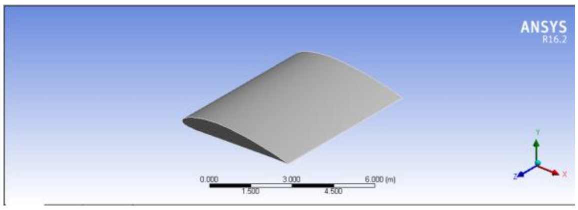

Fig.1 Model of gas turbine blade.

Type of meshing used for gas turbine blade during analysis process in Ansys16.2 is tetrahydral meshing. Sizing for meshing is fine.

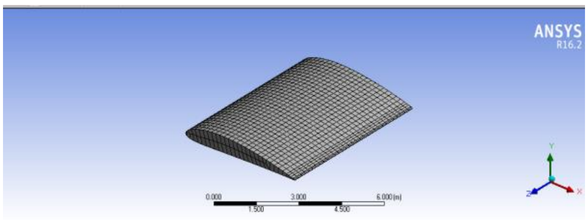

Fig.2 Meshing model of turbine blade

3.2 FINITE ELEMENT METHOD

The stress analysis of gas turbine blade in the field of gas turbine engineering is invariably complex. It is also for many of the problems; it is extremely difficult to obtain analytical solutions. The finite element method is a numerical analysis technique for obtaining approximate solutions of the problem. It has now become a very important and powerful tool for numerical solution of engineering problems. The method being used for the analysis of structures, solids of complex shapes and complicated boundary conditions based problems. The betterment in computer technology and highspeed electronic computers enables complex problems to model easily. Various researches did lot of work to develop analysis of gas turbine rotor blade using finite element analysis method.

3.3 FINITE ELEMENT ANALYSIS OF GAS TURBINE BLADE.

The turbine blade is analyzed for its structural performance due to the loading condition. Static analysis was carried out to know the mechanical stresses and deformations experienced by the gas turbine rotor blades. It includes the parameters such as the gas forces which are assumed to be distributed evenly. Also the tangential and axial forces act through the centroid of the blade. The centrifugal force acts through the centroid of the blade in the radial direction.

Table-2: Forces applied on blade

	Tangential force (Ft)	Axial Force (Fa)	Centrifugal force (Fc)
Aluminum alloy	80312.869 N	250 N	980 N
Titanium alloy	159453 N	250 N	980 N
Magnesium alloy	62125 N	250 N	980 N

4. RESULT AND DISCUSSION.

The structural finite element analysis was performed for the turbine blade using ANSYS 16.2 software. Three materials such as Titanium alloy, aluminum alloy, Magnesium alloy are the material which are used in the manufacturing of marine gas turbine blade have been considered for the analysis under same operating conditions. Titanium alloy has maximum equivalent stress 7.53×10^{5} N/m^{2} and minimum deformation of 2.33×10^{-5} m.

4.1 Aluminum alloy

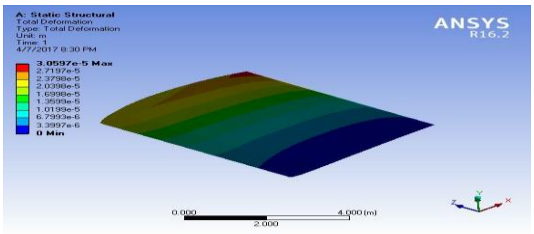

Fig.3 Total deformation on aluminum alloy

Fig.3 shows the deformations in the turbine blade made up of Aluminum Alloy due to the forces. Maximum deformations are 3.05×10^{-5} m observed at the blade tip sections and minimum elongations at the root of the blade.

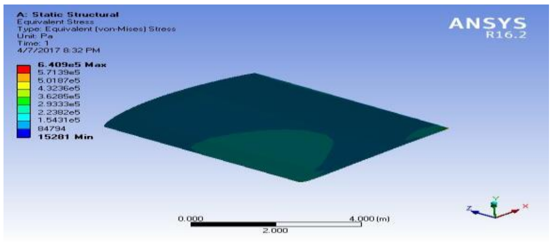

Fig.4 Stress distribution on aluminum alloy

Fig.4 indicates the stress distribution in the turbine blade made up of aluminium alloy due to mechanical loads. Stress distribution increases from leading edge to trailing edge. Maximum equivalent stress observed is 6.409×10^{5} N/m^{2}.

4.2 Titanium alloy

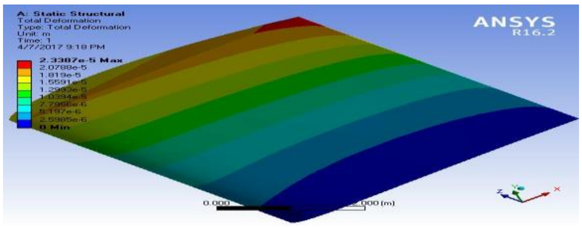

Fig.5 Total deformation on Titanium blade.

Fig. 5 shows the deformations in the turbine blade made of Titanium Alloy due to forces. Maximum deformations 2.33×10^{-5}m is observed at the blade tip section and minimum at the root of the blade.

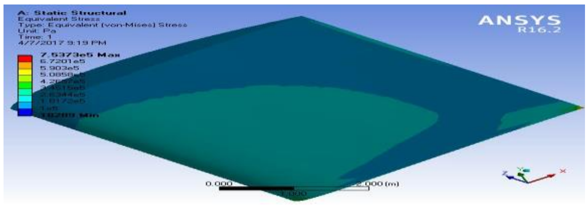

Fig.6.Stress distribution on titanium blade alloy

Fig.6 indicates the stress distribution in the turbine blade made up of titanium alloy due to mechanical loads. Stress distribution increases from leading edge to trailing edge. Maximum equivalent stress observed is 7.53×10^{5} N/m^{2}.

4.3 Magnesium alloy

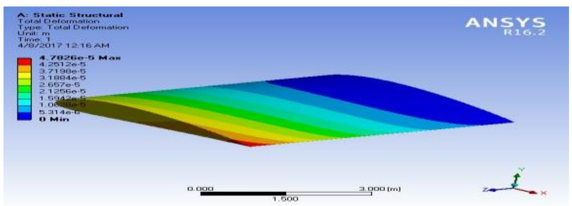

Fig.7 Total deformation on magnesium blade.

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Fig.7 shows the deformations in the turbine blade made of magnesium alloy due to forces. Maximum deformations 4.78×10^{-5} m of observed at the blade tip .sections and minimum elongations at the root of the blade.

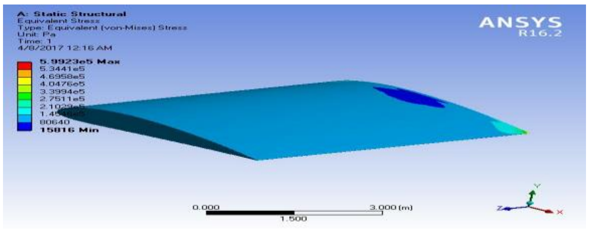

Fig.8 stress distribution on magnesium alloy

Fig.8 indicates the stress distribution in the turbine blade made up of magnesium alloy due to mechanical loads. Stress distribution increases from leading edge to trailing edge. Maximum equivalent stress observed is 5.99×10^{5} N/m^2.

Results from above analysis are tabulated as follows:

Table-3: Results

Material	Maximum equivalent stress (N/m^2)	Maximum Deformation(m)
Aluminum alloy	6.409×10^{5}	3.05×10^{-5}
Titanium alloy	7.53×10^{5}	2.33×10^{-5}
Magnesium alloy	5.99×10^{5}	4.78×10^{-5}

5. CONCLUSIONS

Three materials such as aluminum alloy, Titanium alloy, Magnesium alloy used for manufacturing of turbine blades of a gas turbine engine are meant for marine application, and they have been selected. The turbine blade model profile is generated by using SOLIDWORKS20 software. The turbine blade is analyzed for its structural performance due to the loading condition in ANSYS16.2. Magnesium alloy has maximum deformation as compared to other two materials. But maximum equivalent stress for magnesium alloy is 5.99×10^{5}N/m^2. Aluminum alloy has maximum deformation 3.05×10^{-5}m and maximum equivalent stress is 6.409×10^{5}N/m^2. Titanium alloy has maximum equivalent stress and minimum deformation as compared to the other two materials. Maximum equivalent stress for titanium alloy is 7.53×10^{5} N/m^2 and deformation is 2.33×10^{-5} m. Hence, Titanium alloy is more beneficial than aluminum alloy and magnesium alloy, due to maximum equivalent stress and minimum deformation.

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