FINDING THE BEST ROTATIONAL SPEED AFFECTING THE STRESSES ANALYSIS FOR GAS TURBINE BLADES SUBJECTED TO CENTRIFUGAL FORCES

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ABSTRACT

By the current research the first stage rotor blade of a two-stage gas turbine has been analyzed and by using several different speeds ranging from 7500 to 11500, stress analysis and finding the best speed and less stress. The finite element method (FEM) has now become a very important agent of engineering analysis. Its truth is reflected in its popularity between engineers and designers pertinence to nearly all the engineering majors.

AUTOCAD software is used to model it. analysis is performed by ANSYS14.5 software. The ANSYS program was used14.5 to find the stresses raised on the gas turbine blades by cutting the blade into 11 slides and a distance between one slice and another (9.536mm), and then it was subjected to five different speeds and calculated the stress values and the values confirmed that the best speed with the least effective stress is 7500r.p.m.

KEYWORDS: Stress Analysis, Turbine Blade, Super Alloy X, ANSYS Software

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INTRODUCTION

Gas turbines are used for electrical power generation. Today, gas turbines are one of the most prevalent ones used power generating technologies. Before gas turbine engine components are released into service, they are usually tested. This testing is performed during the component development stage and during certification and improvement stages of the gas turbine engine development process. The spin rig test could also be performed under a life extension study to estimate the real fatigue life of hot section engine components [1].

Gas turbines play a major role in the power generating units. The main function of the blades in gas turbines is imparting energy to, or extracting it, from a fluid stream. This paper mainly deals with the modeling and analysis of gas turbine blades. The design data for a turbine blade is obtained using Reverse Engineering technique. Using the data so obtained, a model of the turbine blade is created in ANSYS F.E.A. [5].

Turbine Blade

The rotating blades of turbo machine are very important components and the main reason for turbo machine collapse is failure of turbine blade. Failure of a turbine blade could lead to disastrous physical and economic consequences. Hence, suitable turbo machine blade design plays a pivotal role in the proper working of turbo machine. Turbine blades are the most substantial part of a gas turbine [6]. It must resist (a) high operating temperatures, (b) high tensile stress resulting from the centrifugal force at different rotating speeds (c) bending stress resulting from the equivalent impulse load of the fluid operating at a particular distance from the cantilever blade setting .

Auto CAD Soft Ware

AUTO CAD is mechanical design software that takes advantage of Microsoft Windows' familiar Graphical user interface. It is an easy-to-learn tool that allows designers to quickly draw mechanical shapes, parts and dimensions and producing detailed models and drawings [6].

Finite Element Method

The finite element method (FEM) has presently turn out a very substantial factor of engineering analysis. The FEM configured the turbine blade model for analysis using a compound system of points or nodes linked into a lattice known as mesh. The nodes were coordinated at a specific density throughout the model. The geometry of the gas turbine blade is modeled in AUTOCAD and then imported into ANSYS for meshing. The airfoil profile of the rotor blade was produced on the XZ plane with the help of key points defined by the coordinates. Then a number of splines were fitted through the key points, creating the 2D airfoil shape. The geometry of the blade was meshed with the element type used for Tetrahedron 10 nodes. It has 3 degrees of freedom per node, that is, clarification in three direction X,Y and Z were used. The blade dimensions are given in Table (1) the gas turbine blade geometrical models created in ANSYS and meshed gas Turbine blade using ANSYS (14.5). The steps employed in the course of the analysis are as follows;

- Creating a three dimensional model in AUTOCAD software 2014
- Import the AUTOCAD model in ANSYS 14.5 software as shown in figure (1).
- Mesh the imported model in ANSYS (234064) nodes and (136575) elements shown in figure (2).
- Apply boundary conditions as shown in figure (3).
- Solve the system equations to find out the unknowns.
- Validation of solutions obtained with the operating conditions as shown in figure (4).

Table 1: Dimensions of the Blade

Total Length of Blade	Length of Root	Length of Airfoil	Length of Hollow
157mm	62mm	95mm	52.1mm

Table 2: Material Properties for Turbine Blade Analysis X Alloy

Young's Modulus (Gpa)	Density (kg/m ³)	Poisson's Ratio	Thermal conductivity (w/mk)	Thermal expansion(°c)	Yield strength (Mpa)	Melting temperature (°c)
210	7780	0.3	22	10E-6	1175	1370

Figure 1

Figure 2

Figure 3

Figure 4

LITERATURE REVIEW

Gopinath Chintalaa, She used a reverse engineering (RE) technique to make a solid gas turbine blade sample and then resolve this sample in ANSYS finite element analysis. Five various materials were applied. It was found that Ti is the best material for gas turbine blades to withstand centrifugal forces and it was taken into account in this study because it takes possession of prominent properties in structural constancy when exposure to differ temperatures and stress loads, and it also takes possession of maximum strength at rising temperatures [2].

Tomas Misek, Zdenek Kubin, A turbine blade made of steel with a length of 1220 mm and a rotational speed of 3000 rpm was developed. The mechanical strength of the blade made was proven by the rotational at high-speed test. The vibrations test show that there were no reverberation points near their fated speed. An outstanding match is reached for the

calculated and measured original frequencies which grant dependability in the numerical FE model. The application of LSB48 in an actual rotor must be well examined from the perspective of the coupled rotor blade frequencies since natural frequencies are always influenced by the rotor arranging [3].

John.V, T.Ramakrishna Gas turbine blades cooling has been studied for two different alloy materials, N 155 and Inconel 718 It has been found that Inconel 718 has bestead thermal properties as the blade temperatures and resulting thermal stresses are lower. It was found that the design of the cooling passages in the blades reduces the trouble of overheating and thermal stress. When analyzing 4 different models with differ number of holes, it is concluded that the blade sample with 13 holes is the superior [4].

Kottha Srinivas, Mr. M.Prasad, A rotary blade model was constructed for a gas turbine, followed by a static structural analysis and thermal analysis. In static structural analysis Mpa pressure is applied by assigning four various materials such as: stainless steel, titanium alloy, and Inconel Maximum stress, strain & deformations are obtained titanium is showing least stress values compared to stainless steel and Inconel[5].

R.D.Prasad, Behera Ravi Teja, M.S.S. Srinivasa, The temperature has important effect on the von Mises stress in the turbine blade. Maximum protraction and temperatures are spotted at the blade tip section and minimum protraction and temperature difference at the base of the blade. The thermal stresses are prevalent in the analysis compare to the Pressure and Centrifugal forces. Distortion progressively growing straight along the blade from the base to the tip bit of the blade [6].

RESULTS & DISCUSSION

Figure (5) shows the effect of the Max. principle stress resulting from centrifugal forces at different speeds shown in (a-b-c-d-e). It has been observed that stress values increase with increasing speed, so the speed of 7500 r.p.m is affected by much lower stress compared to the other velocities, as shown in table No.(3) and that figure (6) shows the path of Max. principle stress along the blade for different speed.

Table 3: Maximum Values of Max. Principle Stress (MPa) at Different Speed

Speed (r.p.m)	Max. Principle Stress (MPa)										
7500	768.94	280.24	232.71	210.1	177.9	203	166	127	113.5	112	90..7
8500	987.67	359.96	298.9	269.8	228.5	261	213.5	164	146	143	117
9500	1234	450	373	337	285	326	266	205	182	180	146
10500	1507	549	456	412	349	399	326	250	223	220	178
11500	1808	659	547	494	418	479	391	300	267	363	213

Figure 5: Max. Principle Stresses in Turbine Blades Resulting from Centrifugal Forces at Different Speeds: (a), (b), (c), (d), (e).

Figure 6: Shows Comparison of Maximum Principle Stresses for Five Different Speed used in this Study.

Figure No.(7) and contains the pictures (a-b-c-d-e) represent the Min. principle stress caused by the centrifugal forces resulting from the different speeds. It was observed that the stress is higher at the base of the blade and gradually decreases to the tip of the blade as shown in table (4) and that figure (8) shows the path of Min. principle stress along the blade for different speed, but the stress concentration is at the trailing edge and the least is at the leading edge.

Table 4: Maximum Values of Min. Principle Stress (MPa) at Different Speed

Speed (r.p.m)	Min. Principle Stress (MPa)										
7500	111	16	3	1.8	1.44	1.3	7.6	12.6	13.2	20	3.8
8500	143	21	4.2	2.3	1.9	1.67	9.8	16.2	17	25.5	4.85
9500	178	26	2.1	5.2	2.9	2.32	12.3	20	21.2	31.8	6.1
10500	217	32	6.4	3.44	2.8	2.54	15	25	25.8	39	7.4
11500	260	38	7.6	4.5	3.4	3.2	17.99	29.6	30.99	46.6	8.88

Figure 7: Min. Principle Stresses in Turbine Blades Resulting from Centrifugal Forces: (a), (b), (c) (d), (e) at Different Speeds.

Figure 8: Shows Comparison of Minimum Principle Stresses for Five Different Speed used in this Study.

Figure No.(9), which contains pictures (a-b-c-d-e) representing shear stress, as the highest shear stress value in the first level at the base of the blade and the lowest rate at the top of the blade, as shown in Table No. (5), and that figure (10) shows the path of Max. shear stress along the blade for different speed, and that less Shear stress value at speed 7500 rpm.

Table 5: Maximum Values of Max. Shear Stress (MPa) at Different Speed

Speed (r.p.m)	Max. Shear Stress (MPa)										
7500	393	140	116	105	89	106	83	70	61	60	58
8500	505	180	150	140	114	136	106	84	78	70	60
9500	630	225	187	169	143	170	133	105	97	87.5	96
10500	770	275	215	206	174	208	162	128	119	107	118
11500	924	329	274	247	209	249	191	153	143	128	140

Figure 9: Max. Shear Stresses in Turbine Blades Resulting from Centrifugal Forces: (a), (b), (c) (d), (e).

Figure 10: Shows Comparison of Maximum Shear Stresses for Five Different Speed used in this Study.

Figure (11) which contains the shapes (a-b-c-d-e), represents the normal stress as the highest normal stress value in the first level and its concentration at the base of the blade and the lowest rate at the top of the blade, as shown in table No. (6), and that figure (12) shows the path of normal stress along the blade for different speed.

At the highest value at the base of the blade and gradually reduced to the top of the blade, but the optimum speed with the lowest normal stress at 7500 rpm.

Table 6: Maximum Values of Max. Normal Stress (MPa) at Different Speed

Speed (r.p.m)	Max. Normal Stress (MPa)										
7500	743	280	232	209	177	203	162	124	87	65	4.6
8500	892	360	298	269	228	261	208	160	112	84	5.9
9500	1192	449	371	336	284	326	260	199	140	104	7.36
10500	1457	548.7	454	410	348	399	318	243	171	128	8.9
11500	1748	658	545	492	417	478	381	291	205	153	10.8

Figure 11: Max. Normal Stresses in Turbine Blades Resulting from Centrifugal Forces: (a), (b), (c) (d), (e).

Figure 12: Shows Comparison of Maximum Normal Stresses for Five Different Speed used in this Study.

Figure (13) which contains the shapes (a-b-c-d-e), represents the equivalent stress, as the highest equivalent stress value in the first level and its concentration at the base of the blade and the lowest value at the top of the blade, as shown in table No. (7), and the figure (14) shows the path of equivalent stress along the blade for different speed represented The highest value at the base of the blade and gradually reduced to the top of the blade, and this indicates that the highest centrifugal forces at the base of the blade and the lowest at the top of the blade, but the ideal velocity with the lowest equivalent stress at speed is 7500 rpm.

Table 7: Maximum Values of Max. Von Mises Stress (MPa) at Different Speed

Speed (r.p.m)	Max. Von mises stress (MPa)										
7500	698	277	233	210	178	208	157	115	109	108	118
8500	896	356	299	270	229	267	201	148	140	138	151
9500	1120	445	373	337	285	339	252	185	175	172	189
10500	1368	543	456	412	349	408	307	226	214	211	231
11500	1641	652	547	494	418	489	369	271	257	253	277

Figure 13: Max. Von Mises Stresses in Turbine Blades Resulting from Centrifugal Forces: (a), (b), (c) (d), (e).

Figure 14: Shows Comparison of Maximum Von Mises Stresses for Five Different Speed used in this Study.

CONCLUSIONS

- Five different velocities (7500,8500,9500,10500,11500) were used to find pressures resulting from the effect of centrifugal forces at this different speed. The results showed that the stresses (maximum and minimum principle stress, shear stress, normal stress, Von mises stress) have the least effect on gas turbine blades at centrifugal forces resulting from speed 7500 rpm, as the centrifugal forces increase with increasing speed and then the resulting stress increases By increasing the centrifugal forces resulting from the increase in speed, the ideal speed of the blade made of the alloy used in the current research is at 7500 rpm, which is at the safety level of the turbine system.
- It was deduction that the stresses generated by the centrifugal forces (normal stress, von misses stress, maximum and minimum principle stress) were centered at the base of airfoil from the back.

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