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Research Paper

FE ANALYSIS OF RUNNER BLADE FOR WELLS TURBINE

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One of the major sources of stress arising in turbo machinery blades are centrifugal loads acting at any section of aerofoil. According to this phenomenon stress evaluation of blade attachment region in the disc has to be performed in order to avoid the blade failure. This paper summarizes FE analysis of wells turbine blade, on which Pro- E is used for deign of solid model of the turbine blade with the help of the spline and extrude options ANSYS 11.0 Software is used analysis of FE model generated by meshing of the blade using the solid brick element present in the ANSYS software itself and thereby applying the boundary condition. Then ANSYS pre processor to analyse the complex geometries and performance of the blade for different materials. Finally stating the best suited material among the three from report generated after analysis. Result can be compared with mechanical properties of turbine blade materials.

Keywords: Wells turbine rotor, FEA, Aerofoil, Stress, Different material

INTRODUCTION

Scientists have been investigating and defining different methods for power extraction from the wave motion. These devices utilize the principle of Oscillating Water Column (OWC). OWC based wave energy power plant convert into low pressure pneumatic power in form of bi-direction of air flow. Then wells turbine currently uses around world for wave energy power generation. Wells turbine introduced Dr. A. A. Wells in 1976. The Wells turbine was proposed as a form of self-rectifying axial flow air turbine which is suitable for wave energy conversion in OWC. There are many reports which investigate the performance of the Wells turbine both on the starting and running characteristics. According to these results, however, the Wells turbine has inherent Disadvantages: lower efficiency, poorer starting, higher noise level and higher axial thrust in comparison with conventional turbines.

In order to overcome these drawbacks and to determine the optimum turbine geometry,

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various researches have conducted studies and published papers in relation to the rotor blade profile for the Wells turbine. According to previous studies, symmetrical airfoil of NACA four digit series is preferable one, especially it has been shown that the NACA four digit series with thickness ratio of approximately 20% is recommended one for the rotor blade.

Importance of FEM

The Finite Element Method (FEM), sometimes referred to as Finite Element Analysis (FEA), is a computational technique used to obtain approximate solutions of boundary value problems in engineering. Simply stated, a boundary value problem is a mathematical problem in which one or more dependent variables must satisfy a differential equation everywhere within a known domain of independent variables and satisfy specific conditions on the boundary of the domain. Boundary value problems are also sometimes called field problems. The field is the domain of interest and most often represents a physical structure. The field variables are the dependent variables of interest governed by the differential equation. The boundary conditions are the specified values of the field variables (or related variables such as derivatives) on the boundaries of the field. Depending on the type of physical problem being analyzed, the field variables may include physical displacement, temperature, heat flux, and fluid velocity to name only a few.

A General Procedure for Finite Element Analysis

Certain steps in formulating a finite element analysis of a physical problem are common to all such analysis, structural, heat transfer, fluid flow, or some other problem. These steps are embodied in commercial finite element software packages and are implicitly incorporated. The steps are described as follows.

Pre-Processing

The pre-processing step is, quite generally, described as defining the model and includes:

Step 1: Define the geometric domain of the problem.

Step 2: Define the element type(s) to be used.

Step 3: Define the material properties of the elements.

Step 4: Define the geometric properties of the elements (length, area, and the like).

Step 5: Define the element connectivity's (mesh the model).

Step 6: Define the physical constraints (boundary conditions).

Step 7: Define the loadings.

Solution

During the solution phase, finite element software assembles the governing algebraic equations in matrix form and computes the unknown values of the primary field variable(s). The computed values are then used by back substitution to compute additional, derived variables, such as reaction forces, element stresses, and heat flow. As it is not uncommon for a finite element model to be represented by tens of thousands of equations, special solution techniques are used to reduce data storage requirements and computation time. For static, linear problems, a wave front solver, based on Gauss elimination, is commonly used.

Post Processing

Analysis and evaluation of the solution results is referred to as post processing. Postprocessor software contains sophisticated routines used for sorting, printing, and plotting selected results from a finite element solution. Examples of operations that can be accomplished include:

1. Sort element stresses in order of magnitude.
2. Check equilibrium.
3. Calculate factors of safety.
4. Plot deformed structural shape.
5. Animate dynamic model behaviour.
6. Produce color-coded temperature plots.

Importance of Finite Element Analysis in Turbo Machinery

Turbo machinery blades are usually exposed to very hostile operating conditions and failure of a single blade may lead to major secondary damage of the machine. This explains why the vibration characteristics of turbo machine blades have been studied in such great detail. Most investigations have dealt with axial-flow turbo machines rather than radial-flow ones. This is mainly due to the fact that the former category has been, possibly used extensively in aircraft propulsion, which is perceived to be a more critical application. However, greater knowledge of the vibration behaviour of radial-flow impellers will be useful for optimizing their fatigue-life and efficiency resulting in increased performance and applicability.

PROBLEM DEFINITION AND PRESENT WORK

The present work includes the simulation (structural analysis) of axial turbine subjected to centrifugal stresses due to rotational speed. Due to complicated shape of the blade it is not possible to calculate the stresses of rotor blade using analytical method. Hence Pro-E 5.0, a solid modeling and a finite element package are used to calculate the stresses for complex geometry of rotor blades. Stress analysis can be viewed by postprocessor phase of ANSYS'11.

It is applied to the design of wells turbine rotor with blade. A streamline curvature method is used for the solution of the meridional flow and a singularity method is utilized for the blade-to-blade flow.

The Four type rotor blades are radially set between two coaxial cylindrical wall surfaces. The outer-diameter is D0 = 0.298 m and the inner diameter is Dh = 0.208 m.

MODELLING AND MESHING

The modelling of wells turbine has been done in Sheet metal module of commercial software Pro-E 5.0 then the geometry made in the Pro-E 5.0 parametric is converted in to the step file (.stp format) and then it is import in the ANSYS for the meshing and the boundary conditions.

The geometry is drafted based on the dimensions of geometric design parameters. The rotor with one blade geometry is 3-dimensionally modelled then meshed properly to divide it into elements and nodes. Finite element model was generated using free meshed 4 nodes quadratic tetrahedral element due to their flexibility in curved and complex shapes, which has three degrees of freedom per node, i.e., translation in x, y, z directions were used. Quality checks and mesh optimization for elements were also performed

Figure 1: Geometry Model of One Blade Rotor

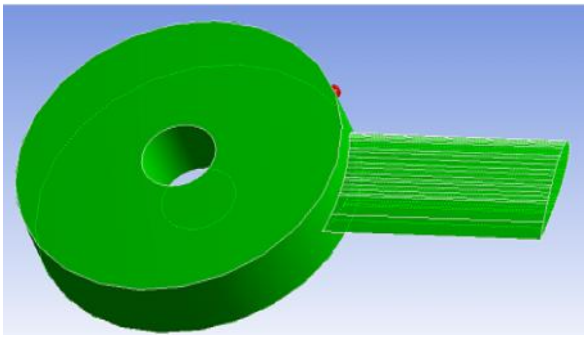


Figure 2: FE Model with Meshing

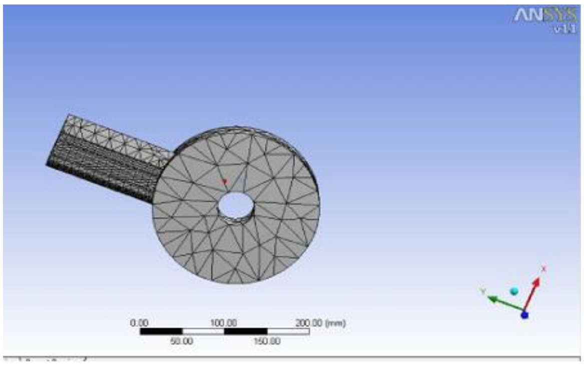
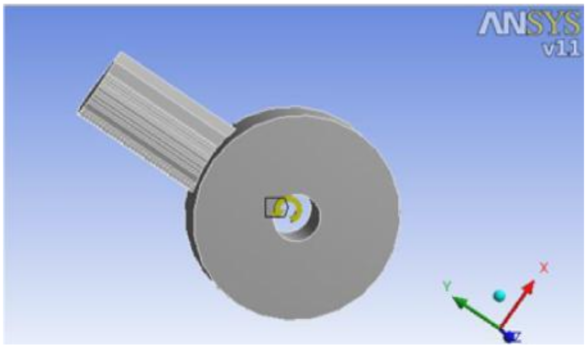


Figure 3: Wells Turbine Rotor Blade with Boundary Conditions on It



taking into consideration of aspect ratio, distortion, stretch. For analysis work, geometric and FE models with meshing for rotor with blade is presented as following images:

The Structural boundary conditions for the simulation are shown in Figure 4 at rotational Speed ranging from 1000 rpm to 5000 rpm whereas the material properties was changes by keeping all dimensions same as provides in data. Also applied to fixed support.

ANALYSIS RESULT

The results obtained are presented in the form of counter maps and profiles of radial elongation, mechanical stresses on blade surface for the rotor blade of axial flow wells turbine.

Above figure displays the stresses developed for the Aluminium rotor considering a speed of 5000 rpm. Similar steps were

Figure 4: Equivalent Stress Analysis Results on Wells Turbine Rotor Blade at 5000 rpm

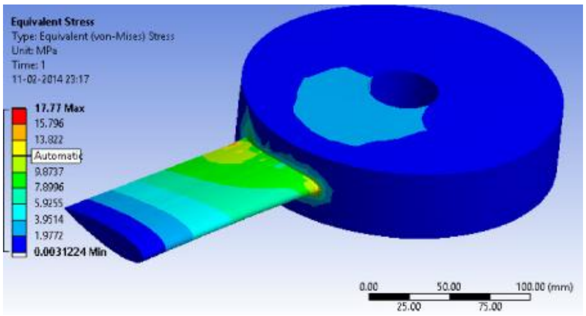


Figure 5: Centrifugal Stress Total Deformation Analysis Results on Wells Turbine Rotor Blade

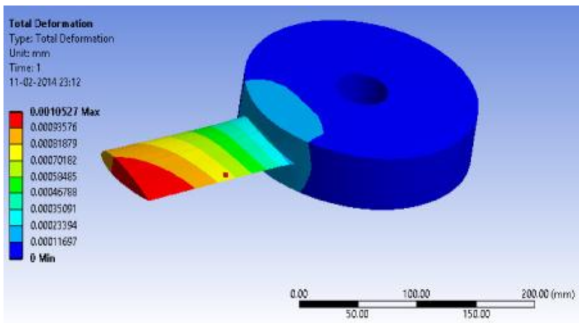


Table 1: Maximum Stresses and Total Deformation at Various Speeds for Different Material

Speed (rpm)	Equivalent Stress (Mpa)			Total Deformation (mm)		
	Aluminum	Inconel	S.S.310A	Aluminum	Inconel	S.S.310A
1000	0.915	2.682	2.627	0.0011	0.0011	0.0011
2000	3.662	10.728	10.509	0.0043	0.0043	0.0043
3000	8.239	24.137	23.646	0.0096	0.0096	0.0096
4000	14.646	42.911	42.038	0.017	0.0171	0.00171
5000	22.885	67.048	65.684	0.0266	0.268	0.0268

Figure 6: Maximum Stresses for Rotor at Various Speeds for Different Material

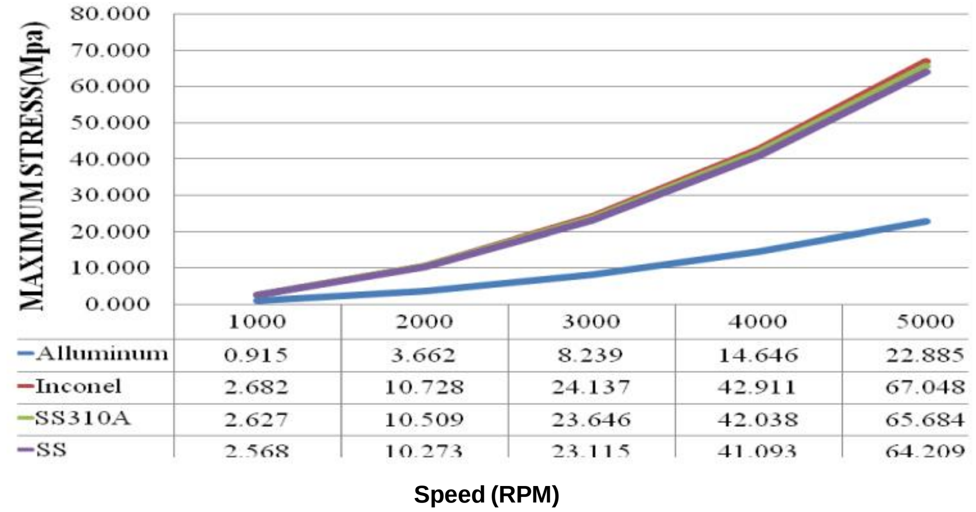
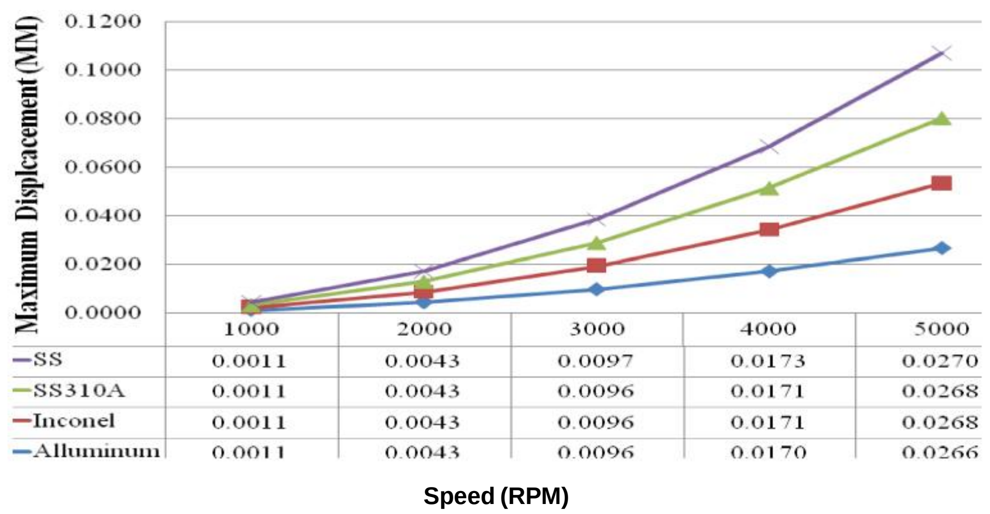


Figure 7: Maximum Displacements for Rotor at Various Speeds for Different Material



performed by taking different material and calculating the stresses at different speed ranging from 1000 rpm to 5000 rpm with an increment at speed of 1000 rpm.

DISCUSSION

From post processing results on graphics screen and graphs shown above, Displacement and stress results are discussed as bellows:

1. Maximum stresses are observed at hub section of rotor blade as shown in Figure 5 and the stresses are found to be in safe limit.
2. Maximum stress developed at maximum speed of 5000 rpm for Inconel, SS310A and Aluminium is 67.048 Mpa, 65.684 Mpa, and 22.885 Mpa respectively as shown in Figure 6.
3. From Figure 6 stresses developed in the rotor increases linearly as the same increment of speed for different rotor materials.
4. As the speed increases, maximum stress increases very high in Inconel and SS310A. But the little increase of maximum stress in aluminium as speed increase.

CONCLUSION

FE structural analysis of wells turbine blades using Pro-E software ANSYS serves as mechanical design tool. The analyzed results intimated several critical blade joint between rotor blade and hub, which are highly stressed causing blade failure so that joint requires much attention and careful determination. The von-mises stresses are found to be in safe limit up to 5000 rpm for wells turbine. Also as the speed of rotor is increased the stress and displacement also increases so for the high speed rotor much attention is required for material selection.

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