© 2014 IJEDR | Volume 2, Issue 4 | ISSN: 2321-9939

Examine the Effect of Speed on Stress and Displacement of Pico Hydro Turbine Blade for Different Materials Using FEA Software

[1]Urvinkumar Rameshbhai Patel, [2]Devendra Ashokbhai Patel, [3]Ankit Desai
[1]Assistant Professor, [2]Assistant Professor, [3]Assistant Professor
[1]Mechanical Engineering Department,
Chhotubhai Gopalbhai Patel Institute of Technology, Bardoli, Surat, India

---

***Abstract* - The aim of this paper is to examine the stress and displacement for pico turbine blades. The engineer's work is to design blades that can operate safely in harsh environments and be able to avoid failure and deformation of blades. This requires in-depth finite element modeling and structural analysis. Due to shape of the blade it is not possible to calculate the stresses of rotor blade using analytical method. Hence ANSYS, a solid modeling & a finite element package is used to calculate the stresses for rotor blades. The results were analyzed for runner and found location of several critical sections subjected to high stress concentration at hub section. Analysis shows that the maximum stress is produced at hub and blade joint section which is safe up to speed limit 5000 rpm.**

***Index Terms* - Finite element analysis (FEA), pico turbine, stress, runner blade**

I. INTRODUCTION

Pico hydro is defined as water power output capacity up to 5 kW. The name was given by Nigel Smith because it needs some different ways of thinking to micro, mini and larger hydropower. There are much more sites where people have a source of falling water but do not have electricity. For these rural communities, pico hydro is the solution of lowest-cost technology for generating electricity. It is essential to analyse the turbine which is of very small scale power production. This is done by the powerful tool Finite Element Analysis (FEA).

Today the finite element method (FEM) is considered as one of the well-established and convenient technique for the computer solution of complex problems in different fields of engineering: civil engineering, mechanical engineering, nuclear engineering, biomedical engineering, hydrodynamics, heat conduction, geo-mechanics, etc. From other side, FEM can be examined as a powerful tool for the approximate solution of differential equations describing different physical processes.

The success of FEM is based largely on the basic finite element procedures used. The formulation of the problem in variation form, the finite element discretization of this formulation and the effective solution of the resulting finite element equations. These basic steps are the same whichever problem is considered and together with the use of the digital computer present a quite natural approach to engineering analysis.

Structural stress and displacement analysis

The structural stress analysis will be conducted in ANSYS for Different speeds of runner ranges from 1000 to 5000 rpm, the runner material will be taken as aluminum, Nitronic and Chromium. The maximum stress and maximum displacement will be observed.

Similarly flow simulation of turbine assembly done in ANSYS at constant head of 2m, different flow rates and different speeds of runner. The maximum stress and displacement produced in runner blade is observed. The present work includes the simulation (structural analysis) of pico turbine subjected to centrifugal stresses due to rotational speed. ANSYS'11, a solid modeling & a finite element package are used to calculate the stresses for complex geometry of rotor blades.

Turbine Design data

Table: 1 Pico turbine design data [6]

Turbine type	Propeller turbine
Number of blades	4
Blade Shape	Flat
Tip Diameter, Dt	130 mm
Hub to tip ratio, Dh/Dt	0.55
Operating head, H	2 m
Operating flow rate, Q	25 L/s
Target rotation speed, N	1500 rpm
Forecasted power (1500 rpm, 25 L/s)	255 W
Stagger angle, ξ	71°

Outer radius of stator guide vanes, r_{GV}	100 mm
Height of stator guide vanes, h_{GV}	52 mm
Stator guide vane angle, α_{GV}	72.3°
Draft tube inlet radius	71 mm
Draft tube exit radius	150 mm
Draft tube length	0.4 m

Modelling and meshing

The turbine data are concluded from [6]. Geometric model of axial turbine components are shown in fig. 1, which is modeled in Pro-E software. The digital images of assembly components and meshing of turbine runner are shown in fig. 1 & 2.

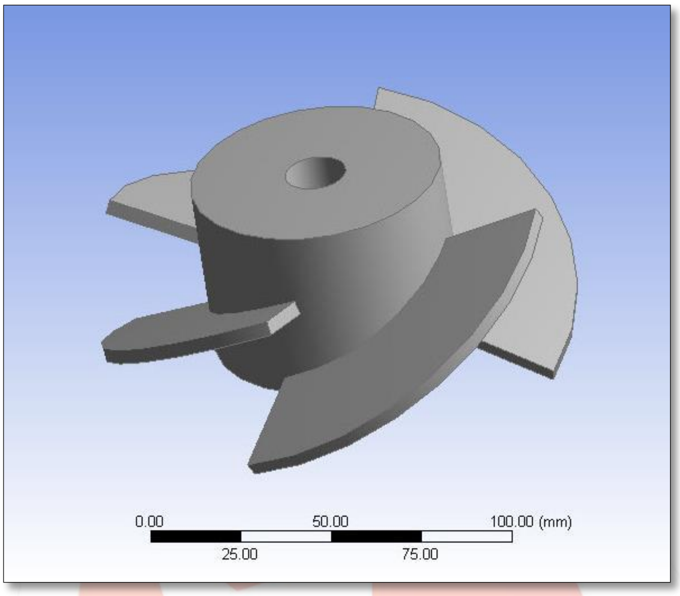

Fig. 1 geometry of runner of pico turbine

Structural boundary conditions namely displacement restraints on the front and rear face of the shaft bore edges of rotor, while angular velocity (centrifugal load) on rotor blade model. Rotational speed of axial fan rotor = 1000 rpm to 5000 rpm having interval of 1000 rpm.

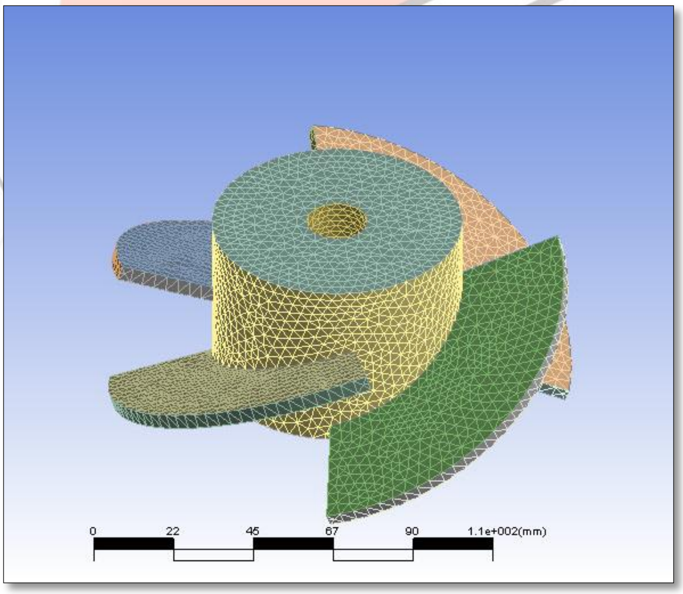

Fig. 2 Meshing of turbine runner blade

The runner materials are selected as aluminum, Nitronic and 13Cr4Ni having physical properties as shown in table: 2.

Table: 2 Material Properties[7-9]

Sr No.	Property	Aluminum	Nitronic	13Cr4Ni
1	Young's Modulus (GPa)	717	181	206
2	Density (kg/m^3)	2795	7610	7700
3	Poison's Ratio	0.33	0.298	0.288
4	Yield Strength (MPa)	448.159	717	580

II. RESULTS AND DISCUSSION

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 impulse turbine.

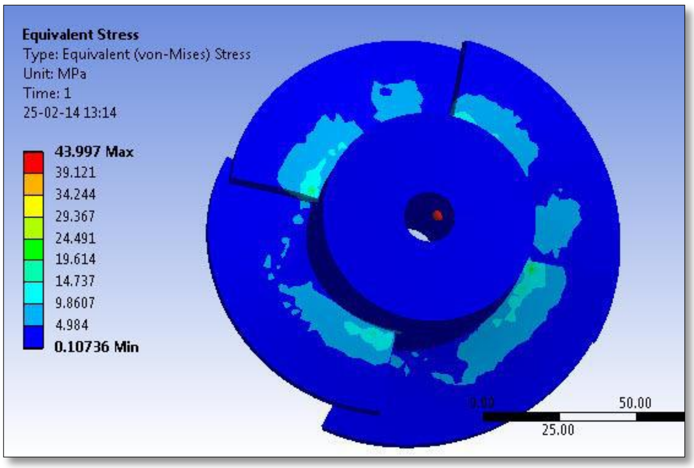

Fig. 3 Centrifugal stress analysis results of axial flow turbine rotor blade

The fig. 3 displays the stresses developed for the aluminum rotor considering a speed of 5000 rpm. Similar steps were performed by taking different material i.e. Nitronic and 13Cr4Ni and calculating the stresses at different speed ranging from 1000 rpm to 5000 rpm with an increment at speed of 1000 rpm. Results which are obtained from FE analysis are described in below table: 3.

Table 3. Maximum stresses at various speeds for different materials

Speed (RPM)	Maximum Stress (MPa)		
	Aluminium	Nitronic	13Cr4Ni
1000	0.439900	1.215200	1.234600
2000	1.759900	4.861100	4.938500
3000	3.959800	10.937000	11.112000
4000	7.039600	19.444000	19.754000
5000	10.999000	30.382000	30.886000

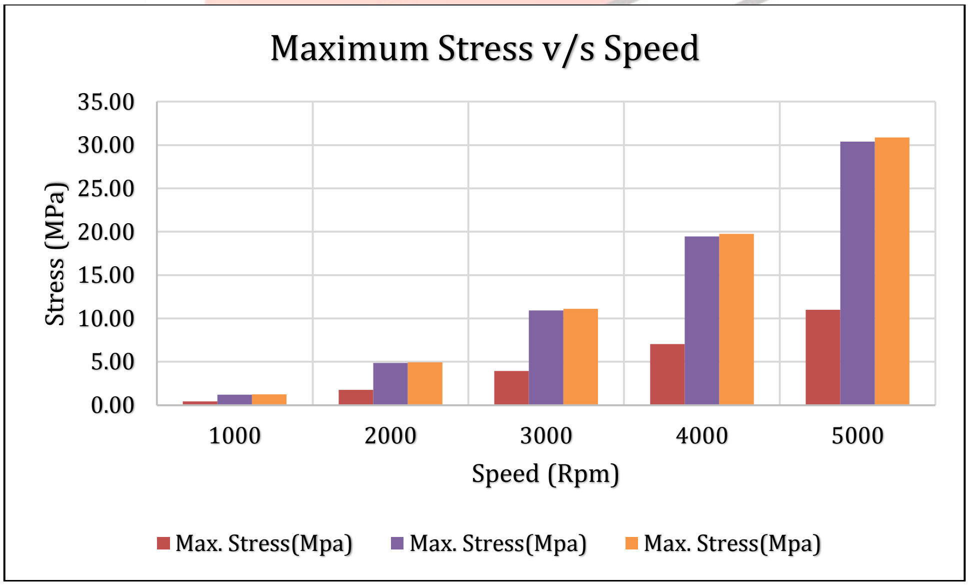

Fig. 4 Maximum stress for different materials of runner at various speeds

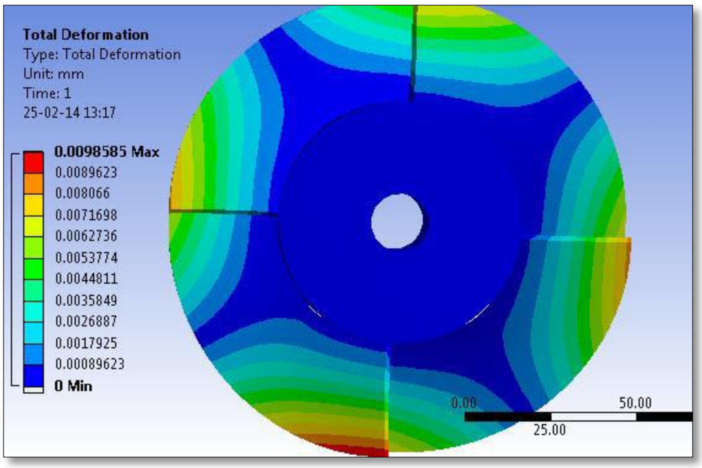

Fig. 5 Maximum deformation analysis of axial flow pico turbine rotor blade

Figure. 4 displays the deformation developed for the material of Aluminium runner considering a speed of 1000 rpm. The table. 4 displays the results obtained by analyzing turbine blades of different materials.

Table 4. Maximum displacement at various speeds for different materials

Speed (RPM)	Maximum Displacement (mm)		
	Aluminium	Nitronic	13Cr4Ni
1000	0.000394	0.000430	0.000383
2000	0.001575	0.001721	0.001361
3000	0.003549	0.003872	0.003451
4000	0.006309	0.006884	0.006134
5000	0.009859	0.010756	0.009585

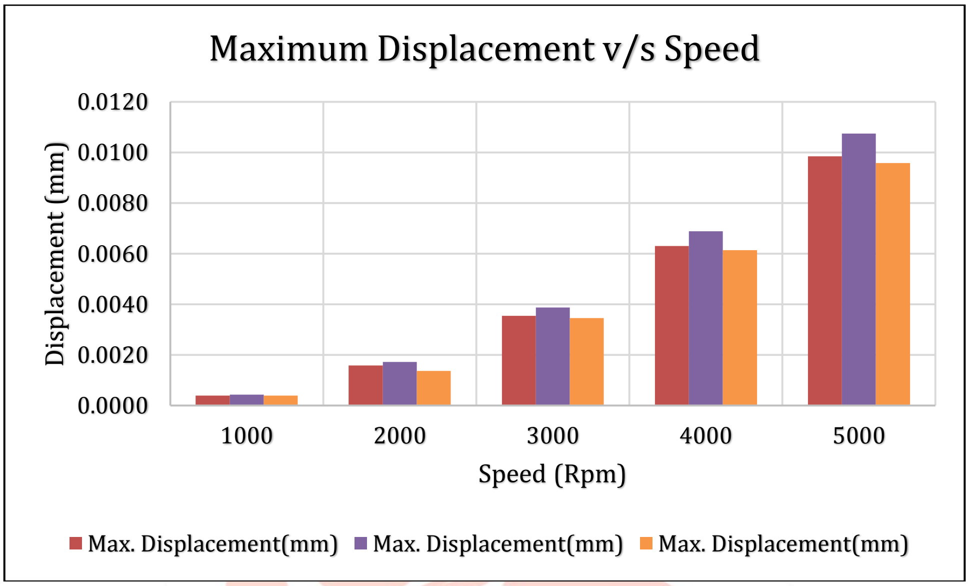

Fig. 6 Maximum displacement for different materials of runner at various speeds

III. CONCLUSION

Deformation and stress results are discussed as follows:

- It is clearly seen that as the speed of rotor is increases the stress and displacement also increases for different materials of turbine runner blade.
- table:3 indicates that, at maximum speed of 5000 rpm the maximum stresses generated in Aluminium, Nitronic and 13Cr4Ni is 10.999000 MPa, 30.382000 MPa and 30.886000 MPa respectively.
- Also from table:4, it has been observed that deformation at maximum speed of 5000 rpm is 0.009859 mm for Aluminium, 0.010756 mm for Nitronic and 0.009585 mm for 13Cr4Ni.
- The Von-mises stresses are seems to be safe at blade section up to 5000 rpm.
- Analysis shows that the stress is secure in the range of 1000 to 5000 rpm for this design.
- 13Cr4Ni is acceptable material for application purpose in pico turbine blades because it deforms less compared to other materials. The material selection can be vary according to the applications of components where they are being use.

REFERENCES

[1] V.Ramamurti and S.Sreenivasamurthy, (1980), Dynamic stress analysis of rotating twisted and tapered blades. J.strain analysis, vol. 15, No.3, pp.117-126.
[2] V.Omprakash and V.Ramamurti, (1989), Dynamic stress analysis of rotating turbomachinery bladed-disc system, J.computer and structure, vol. 32, No.2, pp.477-488.
[3] SureshBabu G, Raviteja Boyanapalli, (2013), Identification of critical speeds of turbine blade along with stress stiffing and spin softening effects, International Journal of Innovative Technology and Exploring Engineering (IJITEE), ISSN: 2278-3075, Volume-2, Issue-5
[4] S.L. Dixon, A textbook of Fluid Mechanics, Thermodynamics of Turbo machinery
[5] Ziaei Rad, (2005), finite element, modal testing and modal analysis of a radial flow impeller, Iranian Journal of Science & Technology, Transaction B, Engineering, Vol. 29, No. B2
[6] Bryan Patrick Ho-Yan, Master of Applied Science Thesis, Design of a Low Head Pico Hydro Turbine for Rural Electrification in Cameroon, University of Guelph, April, 2012
[7] http://www.suppliersonline.com/propertypages/nitronic60.asp#mechanicl
[8] http://www.steel-grades.com/Steel-grades/High-alloy/13cr-4ni.html
[9] http://www.aluminiumdesign.net/why-aluminium/properties-of-aluminium.html