A Research on Evaluation of Small Wind Turbine Blades of Different Thicknesses

Rushikesh V. Godse, Haribhau G. Phakatkar, Sandip A. Kale

Abstract*: Designing a new small wind turbine of required capacity needs new blade design. Wind turbine blade passes through three design steps such as functional design, aerodynamic design and strength design. Strength design can be carried out using static or dynamic conditions. In this research work a blade is designed for 5m rotor diameter using glass fiber reinforced plastic. Three blades of 3 mm. 4 mm and 5 mm thickness are modelled and analyzed using Finite Element Analysis software. The main body is analyzed using 2D and blade root is analyzed using 3D approach. The results obtained are studied to understand the stress distribution on the front as well as the back surface of the blade. Also, the deformation of all three blade models is analyzed.

Index Terms*: Finite element analysis, small wind turbine, static strength, wind turbine blade.

I. INTRODUCTION

Wind power has attracted many researchers in this new century again [1, 2]. Larger wind turbines are installed significantly worldwide and contributed as a major renewable energy source. Small wind turbines are used for low power generation and installed in low wind regions. Still, small wind turbines are in development stage. People are not using small wind turbines considerably. Only a few countries have installed and using these small wind turbines. Worldwide, very few manufacturers are involved in the manufacturing of small wind turbines. Design and development of the following components are the important stages during the development small wind turbines,

- Wind turbine blade
- Yawing system
- Generator
- Charge controller
- Tower

The first component facing the wind to produce mechanical power is the blade [3, 4]. There is a considerable need to design and develop the blades as per the required capacity of the wind turbine. Development of wind turbine blade passes through following process [2, 3],

- Calculation of blade length based on the power output required.
- Selection of airfoil or design of new airfoil. In case of new airfoil design, computational and experimental testing of airfoil.
- The aerodynamic design of the blade using simulation software
- Strength design of blade includes selection of material and dimensions.
- If acceptable, manufacturing of blade
- Else repeat iterations as per requirement

The broad theme of this paper is the strength design of the blade for small wind turbine. The wind turbine blade is subjected to edgewise and flap-wise bending. It is required to sustain the cyclic flap-wise bending, which is more dominant than the edgewise bending. Hence, it is required to design the blade to withstand against cyclic flap-wise bending. Strength design of wind turbine blade is done on the basis of static or dynamic strength using computational or experimental techniques [6, 7]. This research work is focused on static strength design of a small wind turbine blade using the computational technique. In this work, a blade for 5000 mm rotor diameter is considered for static strength analysis.

II. METHODLOGY

As the blade is hollow from inside and the thickness is negligible compared to other two dimensions that is the length and width of blade. Here, one can use 2D geometry and the root body as a 3D geometry. In ANSYS the blade body is considered as a surface body with three different thickness 3 mm, 4 mm and 5 mm and the root body as a solid body. The blade model is meshed with considering all the quality criteria of meshing in ANSYS. In this geometry, the root body consist of four holes for bolting arrangement with hub. These four holes are set as fixed supports. The blade is fixed at the root. Finite element analysis of all three models is carried out.

The different material options for small wind turbines are,

- Wood,
- Aluminium,
- Glass fiber reinforced plastic and
- Carbon fiber reinforced plastic
- Natural Fiber with reinforced plastic

Some researchers are using a sandwich of glass and carbon fiber reinforced plastic

Revised Manuscript Received on June 10, 2019.

Rushikesh V. Godse, Mechanical Engineering Department, Trinity College of Engineering and Research, Savitribai Phule Pune University, Pune, India.
Haribhau G. Phakatkar, Mechanical Engineering Department, Trinity College of Engineering and Research, Savitribai Phule Pune University, Pune, India
Sandip A. Kale, Mechanical Engineering Department, Trinity College of Engineering and Research, Savitribai Phule Pune University, Pune, India.

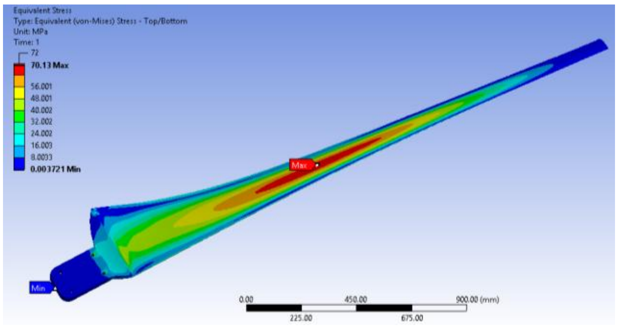
[8 - 10]. In this research work glass fiber reinforced plastic is considered for the blade.

III. FEA ANALYSIS

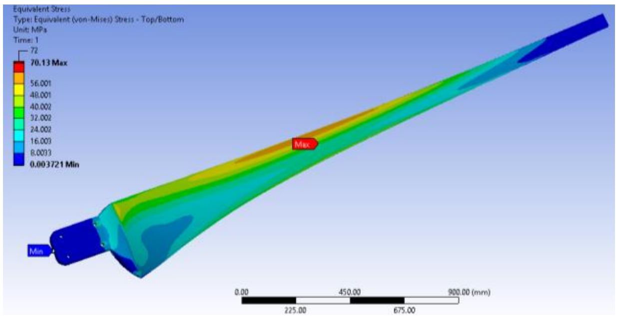
This section comprises of results obtained from Finite Element Analysis. The static structural analysis is plotted in terms of deformation and maximum von-misses stresses.

A. The stresses induced in the Blade

Stress distribution for front and back surface for the blade of 3 mm thickness is shown in Fig. 1 (a) and Fig. 1 (b) respectively. In this paper, the wind turbine blade surface facing the wind flow is termed as front face and opposite surface is termed as the back face of the blade. The maximum stress observed on front surface is 70.13 Mpa and on the back surface of the blade is 60 Mpa.



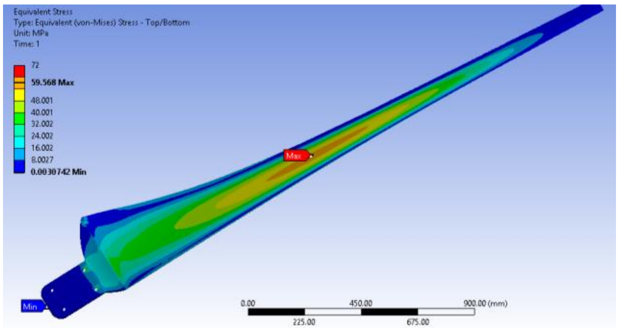
(a) Front Face



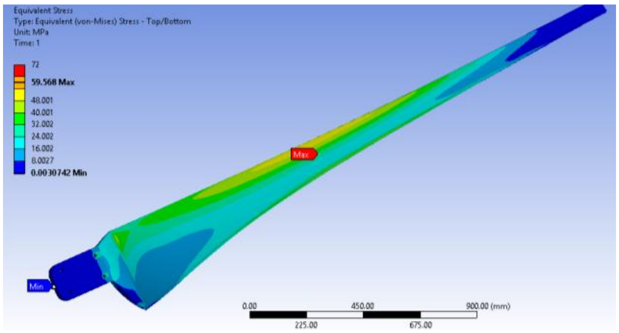
(b) Back Face

Fig. 1. Stress plot for the blade (t = 3 mm)

Stress distribution for front and back surface for the blade of 4 mm thickness is shown in Fig. 2 (a) and Fig. 2 (b) respectively. The maximum stress observed on front surface is 59.59 Mpa and on the back surface of the blade is 51 Mpa.



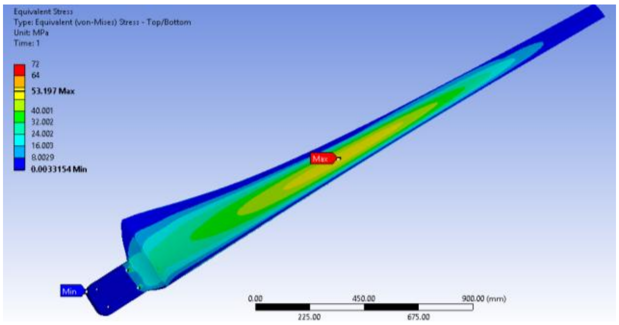
(a) Front Face



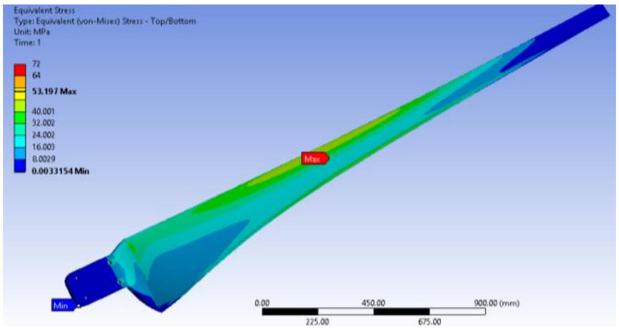
(b) Back Face

Fig. 2. Stress plot for the blade (t = 4 mm)

Stress distribution for front and back surface for the blade of 5 mm thickness is shown in Fig. 3 (a) and Fig. 3 (b) respectively. The maximum stress observed on front surface is 53.20 Mpa and on the back surface of the blade is 45 Mpa.



(a) Front Face



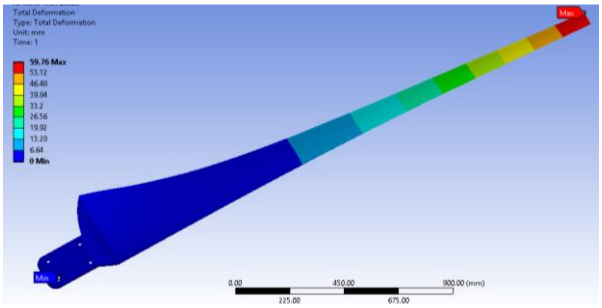
(b) Back Face

Fig. 3. Stress plot for the blade (t = 5 mm)

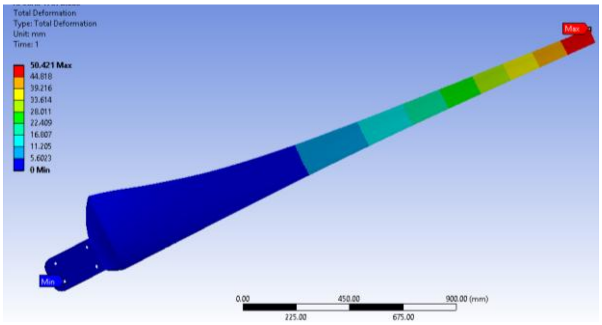
B. Blade Deformation

The deformation for the blades of 3 mm, 4 mm and 5 mm thickness are shown in Fig. 4 (a) Fig. 4 (b) and Fig. 4 (c) respectively.

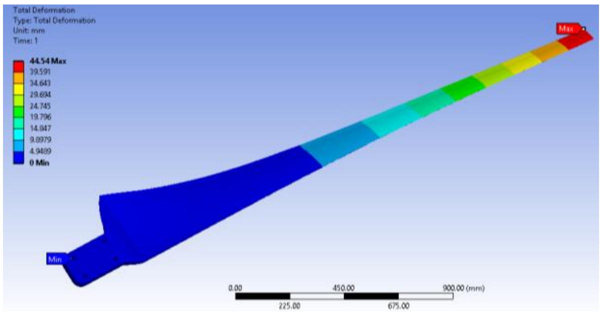
Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication



(a) Deformation of the blade (t = 3 mm)



(a) Deformation of the blade (t = 4 mm)



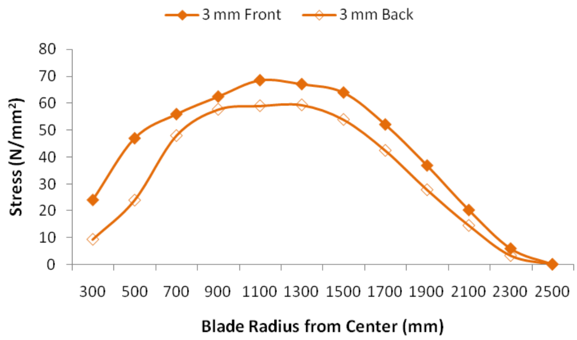
(a) Deformation of the blade (t = 5 mm)

Fig. 4. Blade Deformations

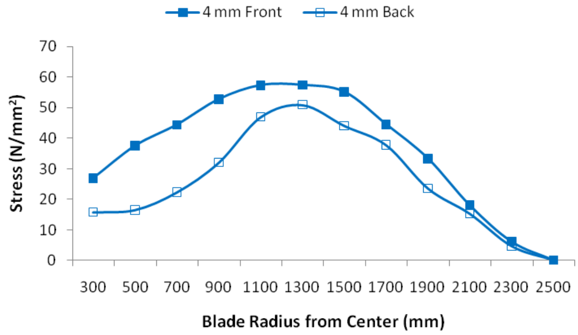
IV. RESULTS AND DISCUSSION

This section presents a comparative evaluation of the stresses and deformation of blades of different thicknesses. Fig. 5 presents the graph of stresses induced on front and back faces of the blades for considered thicknesses. For all thicknesses, the stresses induced in the back faces are lower than that of the front face. Up to the mid span of the blade this difference is significant and reducing after the mid span. It is observed that for the all cases the front faces of the blades are subjected to maximum stress values between the distance of 900 to 1500 mm from rotor center. In all cases for the back face the mid span of the leading edge is subjected to more stresses compared to other regions. A spar can be inserted in the mid span region to reduce the stress values further.

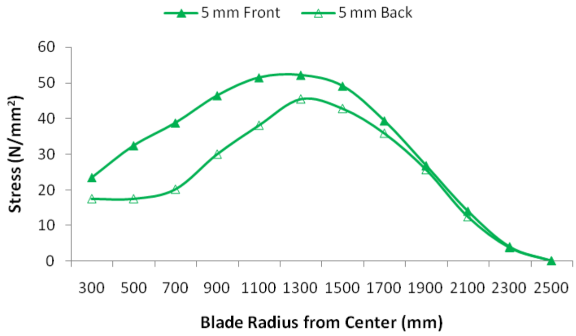
From Fig. 6., Fig. 7 and Fig. 8 it is observed that stress and deformation values are reduced with increases in the blade thickness and it is obvious too. The range of difference in stress values at both faces, when thickness is changed from 3 to 4 mm is higher than when the thickness is changed from 4 to 5 mm.



(a) Stress plot for blade (t = 3 mm)



(b) Stress plot for the blade (t = 4 mm)



(c) Stress plot for the blade (t = 5 mm)

Fig. 5. Stress plot for front and back face along the length

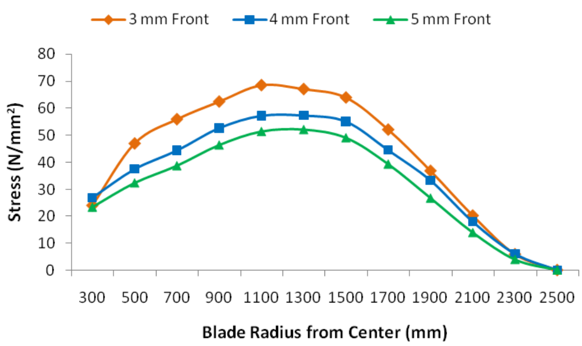


Fig. 6. Comparative Stress plot for front faces

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

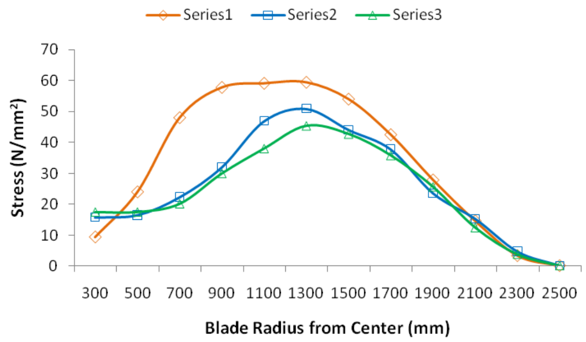


Fig. 7. Comparative Stress plot for back faces

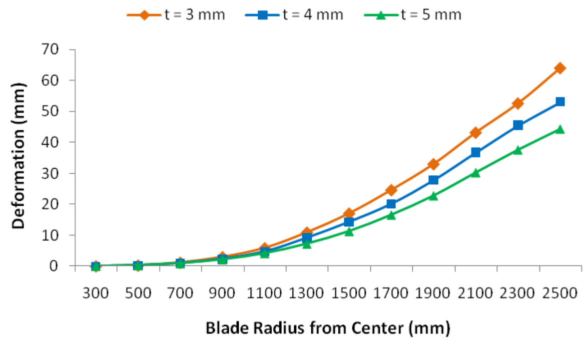


Fig. 8. Deformation of blade for different thicknesses

V. CONCLUSION

On the basis of finite element analysis results for the three blade models, following conclusions are drawn.

- For all thicknesses, the stresses induced in the back faces are lower than that of the front face. Up to the mid span of the blade this difference is significant and reducing after the mid span.
- It is observed that for the all cases the front faces of the blades are subjected to maximum stress values between the distance of 900 to 1500 mm from rotor center. In all cases for the back face the mid span of the leading edge is subjected to more stresses compared to other regions. A spar can be inserted in the mid span region to reduce the stress values further.

REFERENCES

1. S. A. Kale, Jagadeesh Hugar, "Static Strength Design of Small Wind Turbine Blade Using Finite Element Analysis and Testing", ASME 2015 International Mechanical Engineering Congress and Exposition, Houston, Texas, USA, November 13-19, 2015, SBN: 978-0-7918-5740-3, pp. V04BT04A041; 4 pages
2. David Wood, "Small Wind Turbines: Analysis, Design, and Application", Springer-Verlag London , 2011, pp.
3. Mahasidha Birajdar , S. A. Kale, S.N. Sapali, "Effects of Design Parameters on Aerodynamic Performance of New Profile Small Wind Turbine Blades", ASME 2015 International Mechanical Engineering Congress and Exposition, Houston, Texas, USA, November 13-19, 2015, ISBN: 978-0-7918-5747-2, pp. V07BT09A049; 8 pages
4. Horizon Gitano-Briggs, "Low Speed, Wind Turbine Design", In in Wind Power, Rupp Carriveau, IntechOpen, 2012, DOI: 10.5772/53141, pp. 267-283
5. Mahasidha R. Birajdar and Sandip A. Kale, " Comparison of New Designed Small Wind Turbine Airfoils and Blade Performance Using Different Techniques', International Journal of Energy, Environment, and Economics, ISSN- 1054-853X, Vol. 24, Issue 1, pp. 75-85
6. J. J. Heijdra , M. S. Borst And D. R. V. Van, "Wind turbine blade structural performance testing", In Advances in Wind Turbine Blade Design and Materials, Woodhead Publishing Limited, 2013, pp. 432-445.
7. H. Soker, "Loads on wind turbine blades", In Advances in Wind Turbine Blade Design and Materials, Woodhead Publishing Limited, 2013, pp. 29-58.
8. Sandip A. Kale, Swanand R. Kulkarni, Suraj D. Shravagi and Ganesh P. Bharambe, Materials for Small Wind Turbine Blades, Chapter 3 in Renewable Energy and Sustainable Development, 2015, ISBN: 978-1-63463-429-8, pp.43-54.
9. Sandip A. Kale, Sham H. Mankar and Santosh P. Masal, "Weight and Cost Reduction of A Small Wind Turbine Blade", IEEE Sponsored 2nd International Conferences for Convergence of Technology (I2CT), Pune, India, 08 April -09 April 2017
10. P. D. Clausen and F. Reynal, "Design, manufacture and testing of small wind turbine blades", In Advances in wind turbine blade design and materials, Woodhead Publishing Limited, 2013, pp. 413-431

Published By:
Blue Eyes Intelligence Engineering & Sciences Publication