Static Structural and Dynamic Properties
Examination of Savonius VAWT Blades Made of Aluminum using Ansys

C.Thangavel, A.Jegan, M.Saravanan

Abstract: This paper studies the potential for installing roof-mounted Vertical Axis Wind Turbine (VAWT) systems on house roofs with the goal of maximizing the efficiency and reducing the cost and weight of the turbine. The efficiency of the wind turbine depends on the material, shape and angle of the blade. So material of the turbine blade is an important factor in the design of wind turbine. Most of the wind turbine blades are made of mild steel and stainless steel which has more density. It has huge weight, more high corrosion and less fatigue strength. The steel can be replaced by aluminum material to reduce the weight, to improve corrosion resistance, to make them more affordable, efficient, durable and sustainable. In this paper, Aluminum material was used to design savonius wind blades of 1 m height and 0.5 m chord length with 4 different arc radii.

CAD modeling software Solid Works was used to model wind blade and static structural and modal analysis of the Aluminum blade was done by using ANSYS Workbench software. This size of turbine can be most suitable for small houses in urban areas to produce electricity.

Key Words: VAWT, Savonius, Aluminum, Modal analysis, ANSYS Workbench.

I. INTRODUCTION

Savonius wind turbine is one type of vertical axis wind turbine used for converting the wind force into electric power. The turbine consists of minimum two blades vertically mounted on a rotating shaft. It is reliable and low cost, but efficiency is poor. This turbine is self starting and no pointing mechanism is necessary to allow for shifting wind direction. Sigurd Johannes Savonius invented this turbine in the year 1922. It was not widely used for many years. Its popularity is now increasing recently due to increase of urbanized areas.

II. DESIGN CALCULATION

Wind power is proportional to area of the segment of wind being considered, air density and the natural wind speed. The relationships between the above variables are given in equation below.

\[ P_w = \frac{1}{2} \rho A V^3 \]

Where \( P_w \) = Power of the wind (W)
\( \rho \) = Air density = 1.23 kg/m³
\( A \) = Area of a segment of the wind = \( D \times H = 1 \times 1 = 1 \text{ m}^2 \)
\( D \) = Diameter of the turbine in meter
\( H \) = Height of the Turbine in meter
\( V \) = Wind speed in m/s

The angular velocity of a rotor is given by
\[ \omega = \lambda \times \frac{V}{R} \]

Where \( \lambda \) = Tip speed ratio.
\( \lambda \) is a characteristic of each specific windmill and for a savonius rotor \( \lambda \) is typically around unity
\( R \) = Radius of the rotor

The output of a rotating body is obtained from the product of torque and angular speed.

\[ P = M \times \omega \]

\[ P = \text{Output in N-m/s} (1 \text{ N.m/s} = 1 \text{W}) \]

\[ M = \text{Torque in N-m} \]

\[ n = \text{Rotational speed in rpm} = \left( \frac{60 \omega}{2 \pi} \right) \text{/} 60 \]

According to Betz’s law, the maximum power that is possible to extract from a rotor is

\[ P_{max} = 16/27 * \frac{1}{2} * \rho * d^2 * h * v^3 \]

The power of wind depends on the swept area of wind turbine and velocity of wind.

Table 1 Power and Torque of the proposed wind turbine for various wind speeds

| S. No | Wind Speed (m/s) | Angular Speed rad/sec | Rotational Speed (rpm) | \( P_{max} \) Watts | Torque (N-M) |
|-------|-----------------|-----------------------|------------------------|---------------------|-------------|
| 1     | 1               | 2                     | 19                     | 0.36                | 0.18        |
| 2     | 2               | 4                     | 38                     | 2.90                | 0.73        |
| 3     | 3               | 6                     | 57                     | 9.80                | 1.63        |
| 4     | 4               | 8                     | 76                     | 23.22               | 2.90        |
| 5     | 5               | 10                    | 96                     | 45.36               | 4.54        |
| 6     | 6               | 12                    | 115                    | 78.38               | 6.53        |
| 7     | 7               | 14                    | 134                    | 124.46              | 8.89        |
| 8     | 8               | 16                    | 153                    | 185.78              | 11.61       |
| 9     | 9               | 18                    | 172                    | 264.52              | 14.70       |
| 10    | 10              | 20                    | 191                    | 362.85              | 18.14       |

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III. STATIC STRUCTURAL ANALYSIS OF WIND BLADE

All the four different shapes of Aluminum blades are analyzed with different loads of 500N, 1000N, 1500N and 2000N. The results are tabulated and the comparisons of the results are plotted.

| Load (N) | R250 mm | R300 mm | R350 mm | Twisted blade |
|---------|---------|---------|---------|--------------|
| 500     |         |         |         |              |
| 1000    |         |         |         |              |
| 1500    |         |         |         |              |
| 2000    |         |         |         |              |
FIGURES

Fig. 6: Stress, Strain and Deformation for R350 mm and Twisted with R250 mm in 1000N

Fig. 7: Stress, Strain and Total Deformation for R250 mm and R300 mm in 1500N loads

Fig. 8: Stress, Strain and Deformation for R350 mm and Twisted with R250 mm in 1500N

Fig. 9: Stress, Strain and Total Deformation for R250 mm and R300 mm in 2000N loads

Fig. 10: Stress, Strain and Deformation for R350 mm and Twisted with R250 mm in 2000N

IV. MODAL ANALYSIS OF WIND BLADE

All the four different shapes of aluminum material blades are analyzed. The results are tabulated and the comparisons of the results are plotted.

Fig. 11: Natural Frequency and Total Deformation for R250
V. RESULT AND DISCUSSION

Table 2 Load and Stress (Mpa)

| LOAD(N) | AL R250 | AL R300 | AL R350 | AL TWISTED |
|---------|---------|---------|---------|------------|
| 500     | 84.437  | 93.782  | 177.58  | 95.854     |
| 1000    | 168.87  | 187.56  | 296.25  | 191.71     |
| 1500    | 253.31  | 281.35  | 376.99  | 287.56     |
| 2000    | 337.75  | 375.13  | 500.58  | 383.42     |

Fig.15: Load Vs Stress

Table 3 Load and Strain

| Load (N) | AL R250 | AL R300 | AL R350 | AL TWISTED |
|----------|---------|---------|---------|------------|
| 500      | 0.00119 | 0.00132 | 0.003101| 0.0013504  |
| 1000     | 0.00238 | 0.00264 | 0.004300| 0.0027009  |
| 1500     | 0.00357 | 0.00397 | 0.005439| 0.0040513  |
| 2000     | 0.00476 | 0.00529 | 0.007316| 0.0054018  |

Fig.16: Load Vs Strain
It is suitable for houses in urban areas to produce electric power with available wind energy. The proposed wind turbine can produce electric power of 363 Watts at wind speed of 10 m/s and 1225 Watts at wind speed of 15 m/s.

VI. CONCLUSION

From both the structural and modal analysis results, it is found that aluminum is suitable for fabrication of wind blades with less weight and low cost without affecting its performance and stability. By comparing all the four different shapes of the blades, it is decided that Aluminum R350 mm is better choice for the fabrication of the wind blade.

REFERENCES

1. Selvam, M., Ramesh, R., Palanisamy, R., Mohan, A. and Muthumanokar, A. “Design and Analysis of Vertical Axis Wind Turbine”, IJDR, 2014.

2. N.H.Mahmoud, A.A.El-Haroun, E.Wahba, M.H.Nasef, “An experimental study on improvement of Savonius rotor performance”, Alexandria Engineering Journal(2012).

3. K. A. Brown and R.Brooks, “Design And Analysis Of Vertical Axis Thermoplastic Composite Wind Turbine Blade”, 2013

4. Ashwin Dhote, Vaibhav Bankar, “Design, Analysis and Fabrication of Savonius Vertical Axis Wind Turbine”, IRJET, 2015.

5. M.Saravanan, K.G.Muthurajan, “Design And Analysis Of Vertical Axis Wind Turbine Blades Made Of Aluminum Using Ansys Workbench”, Journal of Applied Science and Computations, ISSN: 1076-5131, Volume 6, Issue 1, January 2019, pp. 77-84.

6. M.Saravanan, Dr.K.G.Muthurajan, “Modal Analysis Of Savonius Vertical Axis Wind Turbine Blade Made Of Aluminum Using Ansys”, International Journal of Research And Analytical Reviews, E ISSN 2348-1269, Print ISSN 2349-5138, Volume 5, Issue 4, Oct. – Dec. 2018, pp.1787-1790

7. B.Bittumon, Amith Raju, Harish Abraham Mammen, Abhy Thamby, Aby K Abraham, “Design and Analysis of Maglev Vertical Axis Wind Turbine”, IJETAE, 2014.

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