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.

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Pw = ½ ρAV3

Where Pw = Power of the wind (W)

ρ = Air density = 1.23 kg/m3

A = Area of a segment of the wind = D x H = 1 x 1 = 1 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

ω = λ . V / R

Where λ= Tip speed ratio.

λ is a characteristic of each specific wind mill and for a savonius rotor λ 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 * ω

P = Output in N-m/s (1 N.m/s = 1W)

M = Torque in N-m

ω = Angular speed / s = 2 π n / 60

n = Rotational speed in rpm = (60 ω) / 2π

M = 60 P / 2 π n

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

P max = 16/27 * 1/2 *ρ * d * h * v3

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

11	11	22	210	482.95	21.95
12	12	24	229	627.00	26.13
13	13	26	248	797.18	30.66
14	14	28	267	995.66	35.56
15	15	30	287	1224.62	40.82

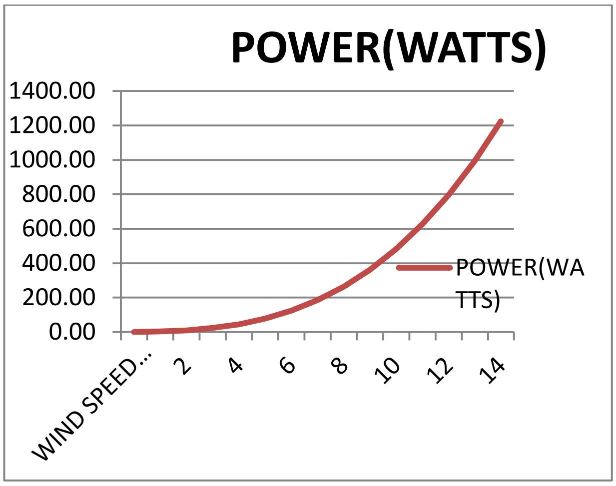
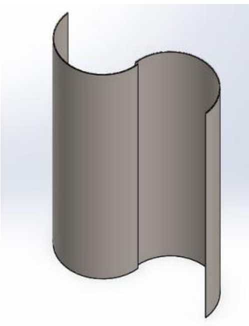
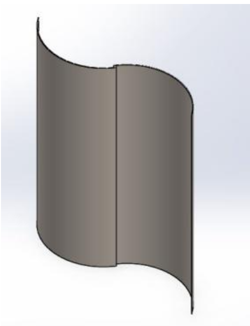


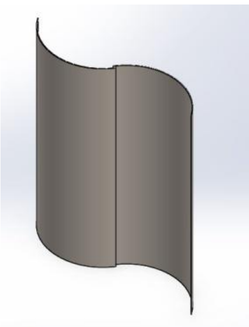
Fig.1 : Wind Speed Vs Wind Power

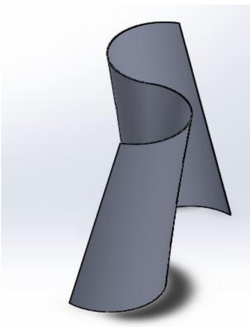
DESIGN OF SAVONIUS BLADE WITH FOUR DIFFERENT SHAPES





R250 mm **R300mm**





R350 mm **Twisted blade**

Fig.2 : Different shapes of Wind blades

Dimension : Height : 1000 mm, Rotor Diameter : 1000 mm, Thickness : 3 mm

Each Blade has same chord length of 500 mm with different arc radius.

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.

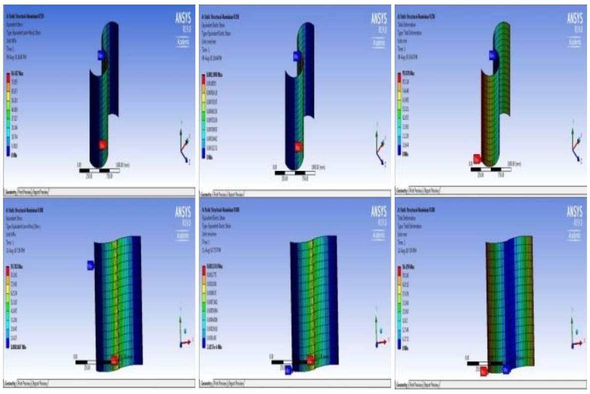


Fig.3 : Stress, Strain and Total Deformation for R250 mm and R300 mm in 500N loads

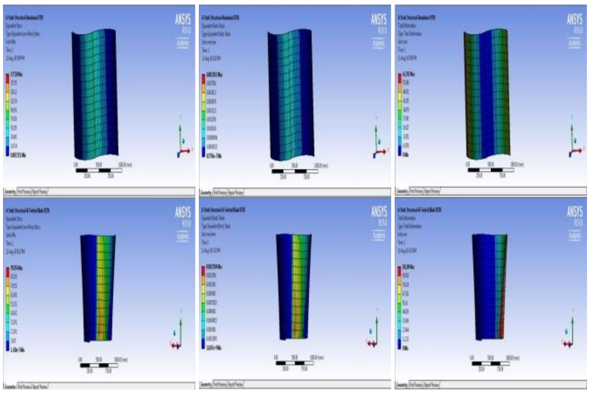


Fig.4 : Stress, Strain and Total Deformation for R350 mm and Twisted with R250 mm in 500N loads

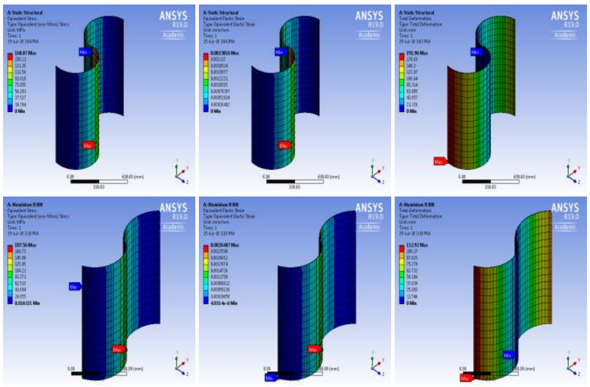


Fig.5 : Stress, Strain and Total Deformation for R250 mm and R300 mm in 1000N loads

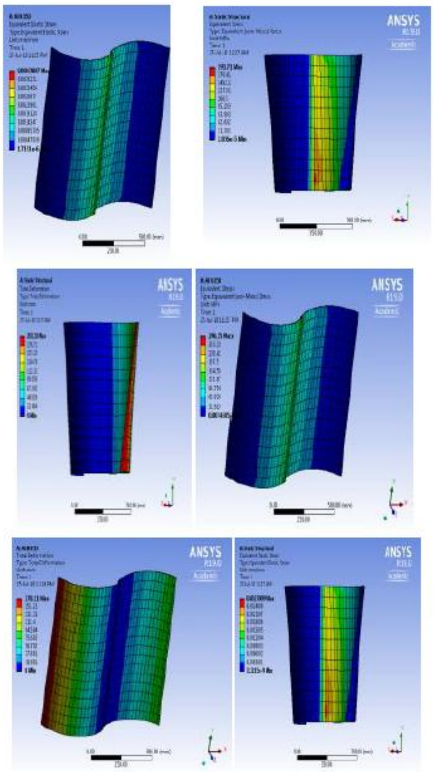


Fig.6 : Stress, Strain and Deformation for R350 mm and Twisted with R250 mm in 1000N

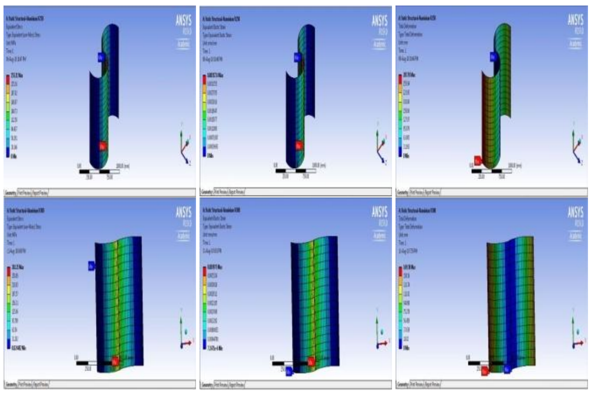


Fig.7 : Stress, Strain and Total Deformation for R250 mm and R300 mm in 1500N loads

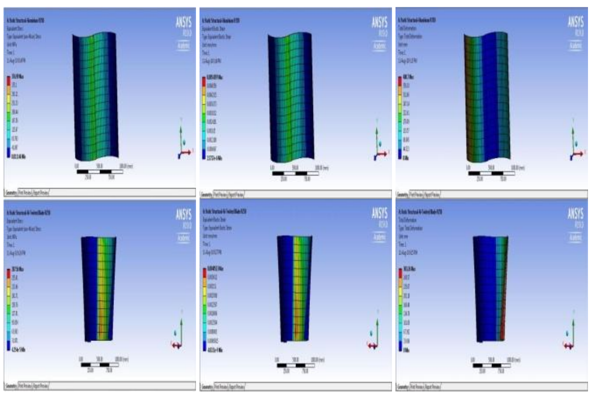


Fig.8 : Stress, Strain and Deformation for R350 mm and Twisted with R250 mm in 1500N

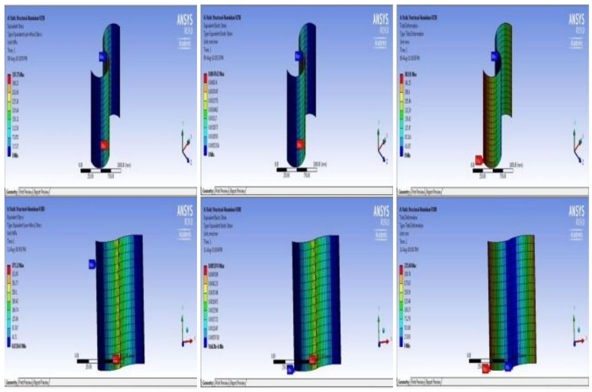


Fig.9 : Stress, Strain and Total Deformation for R250 mm and R300 mm in 2000N loads

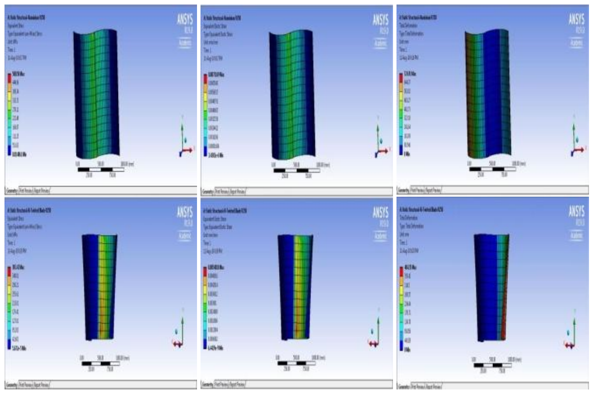


Fig.10 : Stress, Strain and Deformation for R350 mm and Twisted with R250 mm in 2000N

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.

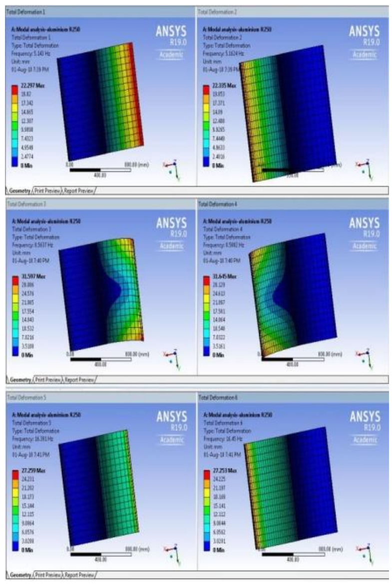


Fig.11 : Natural Frequency and Total Deformation for R250

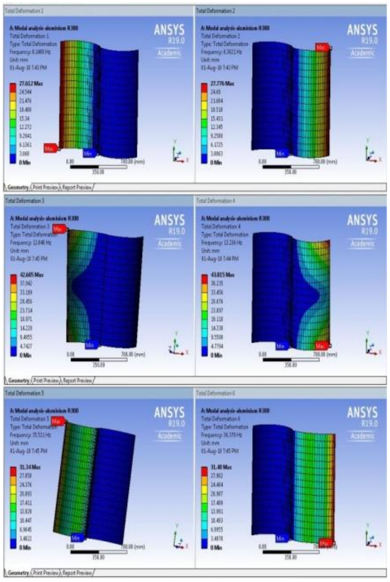


Fig.12 : Natural Frequency and Total Deformation for R300

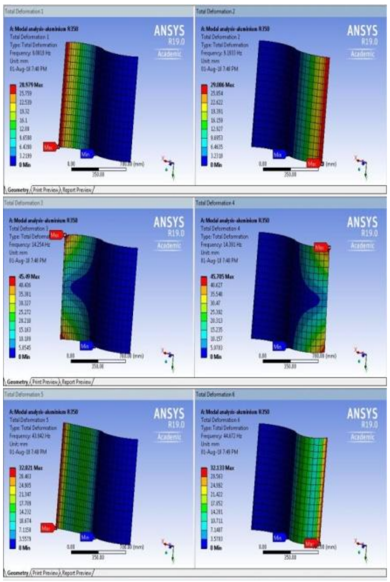


Fig.13 : Natural Frequency and Total Deformation for R350

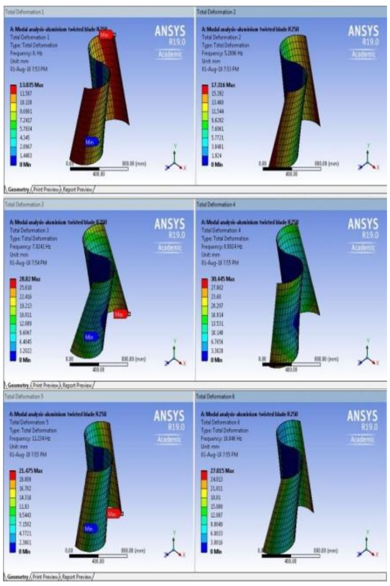


Fig.14 : Natural Frequency and Total Deformation for Twisted blade

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

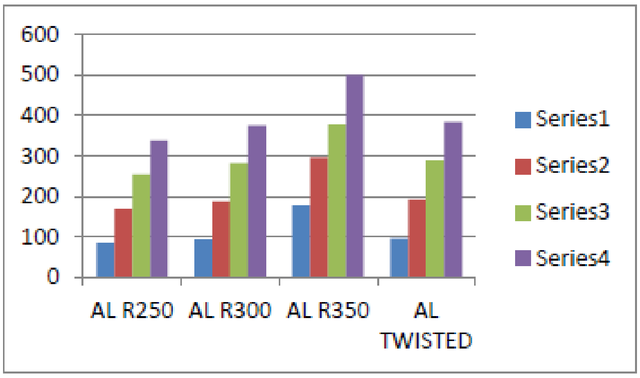


Fig.15 : Load Vs Stress

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

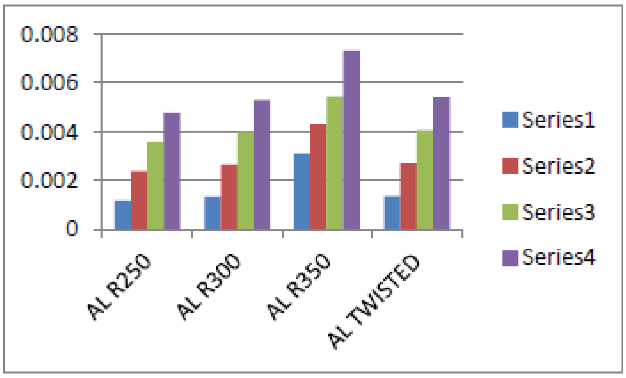


Fig.16 : Load Vs Strain

Table 4 Load and Deformation(mm)

LOAD(N)	AL R250	AL R300	AL R350	AL TWISTED
500	95.978	56.459	62.782	101.09
1000	191.96	112.92	170.11	202.18
1500	287.93	169.38	400.7	303.26
2000	383.91	225.84	724.91	404.35

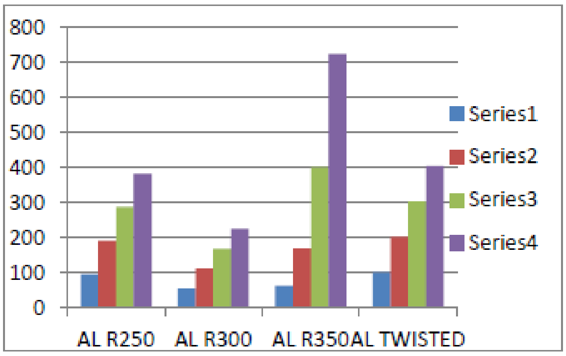


Fig.17 : Load Vs Deformation

Table 5 Natural Frequencies and Deformation

Mode	Aluminum R250		Aluminum R300		Aluminum R350		Aluminum Twisted Blade	
	Freq.(hz)	Defor (mm)	Freq. (hz)	Defor (mm)	Freq. (hz)	Defor (mm)	Freq. (hz)	Defor (mm)
1	5.14	22.29	8.14	27.61	9.08	28.97	0.001	13.03
2	5.16	22.33	8.36	27.77	9.19	29.0	5.289	17.31
3	8.56	31.59	13.04	42.68	14.25	45.49	7.924	28.82
4	8.58	31.64	13.23	43.01	14.39	45.7	8.99	30.44
5	16.3	27.25	35.52	31.34	43.94	32.02	11.23	21.47
6	16.4	27.25	36.37	31.48	44.13	32.13	16.84	27.01

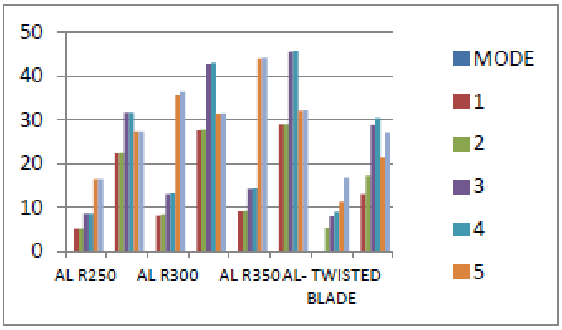


Fig.18 : Natural Frequency and Deformation for Different Mode Shapes

Modal analysis is used to calculate the linear response of structures to dynamic loading. In this analysis, we decompose the response of the structure into several vibration modes. A mode is defined by its frequency and shape and it is the shape of the vibration.

The results taken from static structural analysis to evaluate displacement, stress and strain is good and the maximum stress of 500.58 MPa and stain of 0.00732 is realized in Aluminum R350 blades at 2000N loads.

In modal analysis, the natural frequency of different blades made of aluminum at different wind speed is compared with forcing frequency and no natural frequencies match with forcing frequencies. So failure of structure will not occur.

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.

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.

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