MODAL ANALYSIS OF SAVONIUS VERTICAL AXIS WIND TURBINE BLADE MADE OF STAINLESS STEEL MATERIAL USING ANSYS

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Abstract: **Vertical Axis Wind Turbine(VAWT) is used to generating electric power. This paper studies modal analysis of savonius vertical axis wind turbine systems. The efficiency of the wind turbine depends on the material, shape and angle of the blade. So material plays important role in the design of wind turbine. In this paper, Stainless Steel material has been used to design wind blades of 1000 mm height and 500 mm chord length with 4 different arc radius.**

For this purpose, CAD modeling software Solid Works is used to model wind blade and modal analysis of the Stainless Steel blade was done by using ANSYS. Modal analysis is used to determine the response of structure for dynamic loading. It is used to determine the natural frequency and mode shape of vibration of any structure.

Keywords: **VAWT, Savonius, STAINLESS STEEL, Modal Analysis, Ansys.**

1. DESIGN CALCULATION

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

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

where P_w = Power of the wind (W)

ρ = Air density = 1.23 kg/m^3

A = Area of a segment of the wind being considered (m^2)

= 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

$\omega = \lambda \cdot V / R$

Where λ = Dimensionless factor called the 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 * v^3

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

Table.1: Power and Forcing Frequency for various wind speeds

SL. NO	WIND SPEED (m/s)	ANGULAR SPEED (rad/sec)	ROTATIONAL SPEED (RPM)	FORCING FREQUECY OF ROTOR(Hz)= (RPM/60)	P_{max} (Watts)	Torque (N-M)
1	1	2	19	0.32	0.36	0.18
2	2	4	38	0.64	2.90	0.73
3	3	6	57	0.96	9.80	1.63
4	4	8	76	1.27	23.22	2.90
5	5	10	96	1.59	45.36	4.54
6	6	12	115	1.91	78.38	6.53
7	7	14	134	2.23	124.46	8.89
8	8	16	153	2.55	185.78	11.61
9	9	18	172	2.87	264.52	14.70
10	10	20	191	3.18	362.85	18.14
11	11	22	210	3.50	482.95	21.95
12	12	24	229	3.82	627.00	26.13
13	13	26	248	4.14	797.18	30.66
14	14	28	267	4.46	995.66	35.56
15	15	30	287	4.78	1224.62	40.82

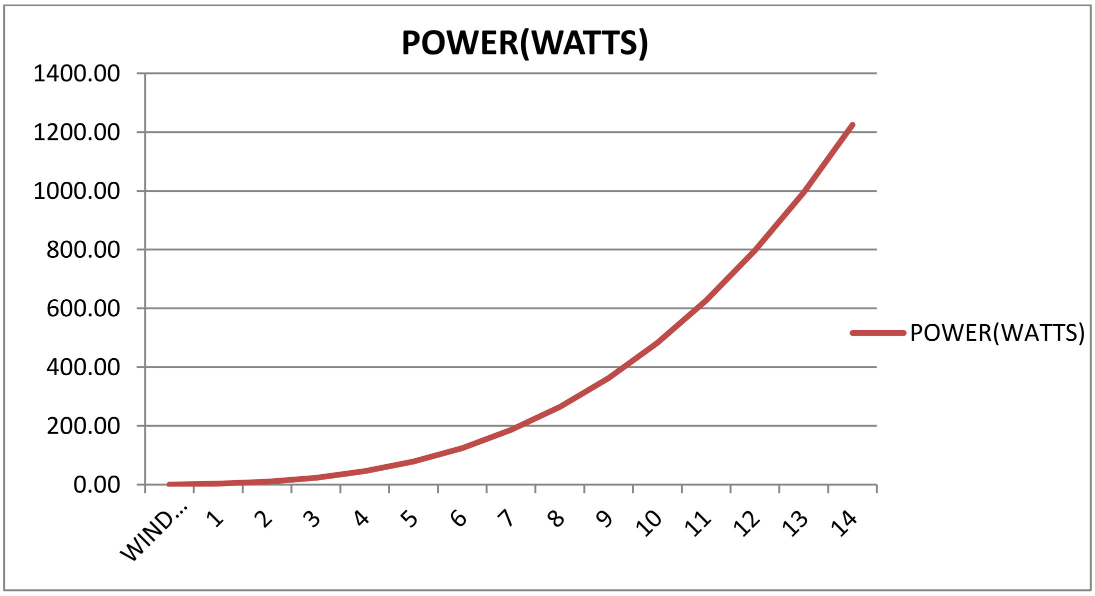
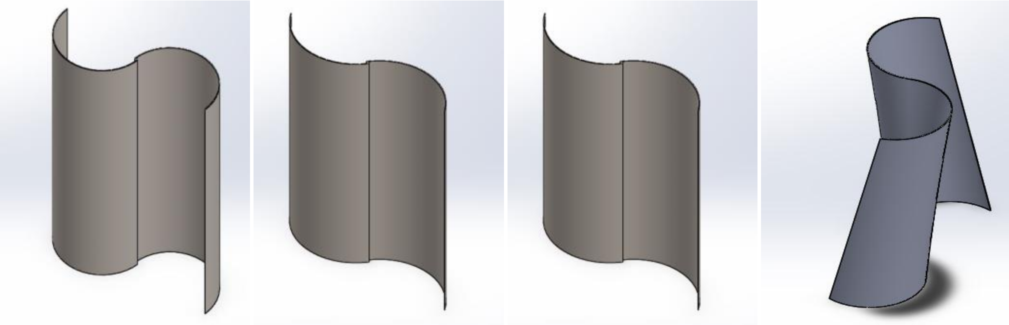


Fig.1 : Wind Speed Vs Power

2. 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.

3. MODAL ANALYSIS OF WIND BLADE

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

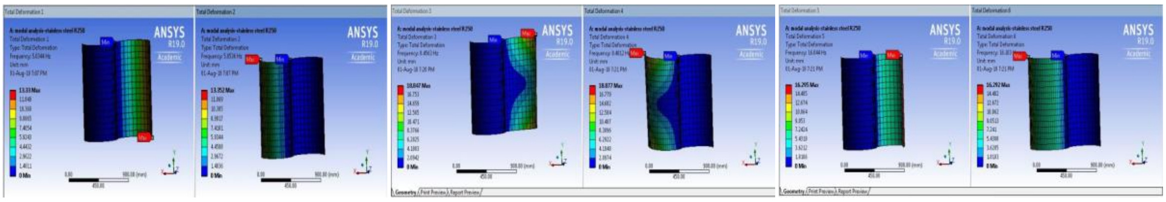


Fig.3 : Natural Frequency and Total Deformation for R250

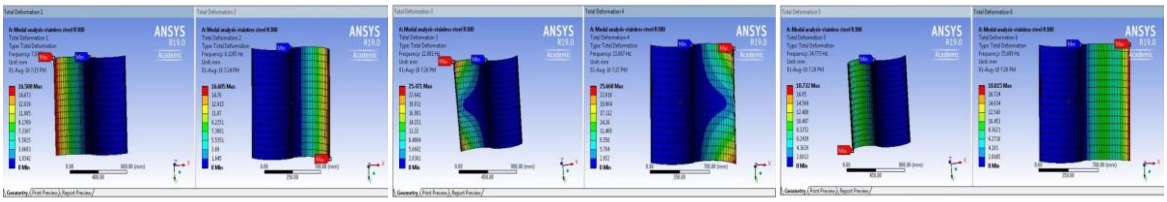


Fig.4 : Natural Frequency and Total Deformation for R300

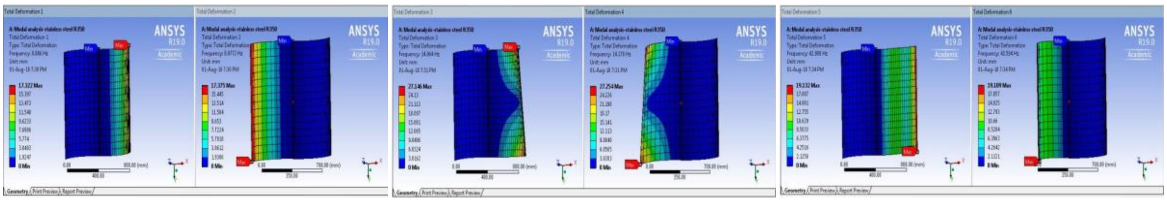


Fig.5 : Natural Frequency and Total Deformation for R350

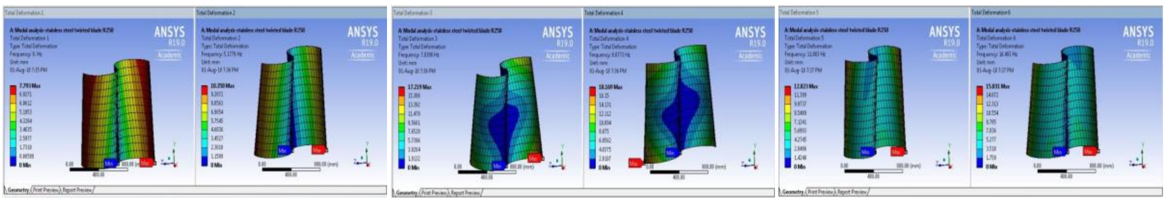


Fig.6 : Natural Frequency and Total Deformation for Twisted blade

TABLE. 2: NATURAL FREQUENCY AND DEFORMATION

	SS R250		SS R300		SS R350		SS- TWISTED BLADE	
MODE	FREQ.(Hz)	DEFOR(mm)	FREQ. (Hz)	DEFOR (mm)	FREQ. (Hz)	DEFOR (mm)	FREQ. (Hz)	DEFOR (mm)
1	5.0344	13.33	7.933	16.508	8.886	17.322	0	7.793
2	5.0536	13.352	8.1265	16.605	8.9772	17.375	5.1779	10.358
3	8.4563	18.847	12.88	25.471	14.064	27.146	7.8308	17.219
4	8.4812	18.877	13.067	25.668	14.178	27.254	8.8773	18.169
5	16.044	16.295	34.773	18.732	42.989	19.132	11.003	12.823
6	16.103	16.292	35.609	18.815	43.594	19.189	16.493	15.831

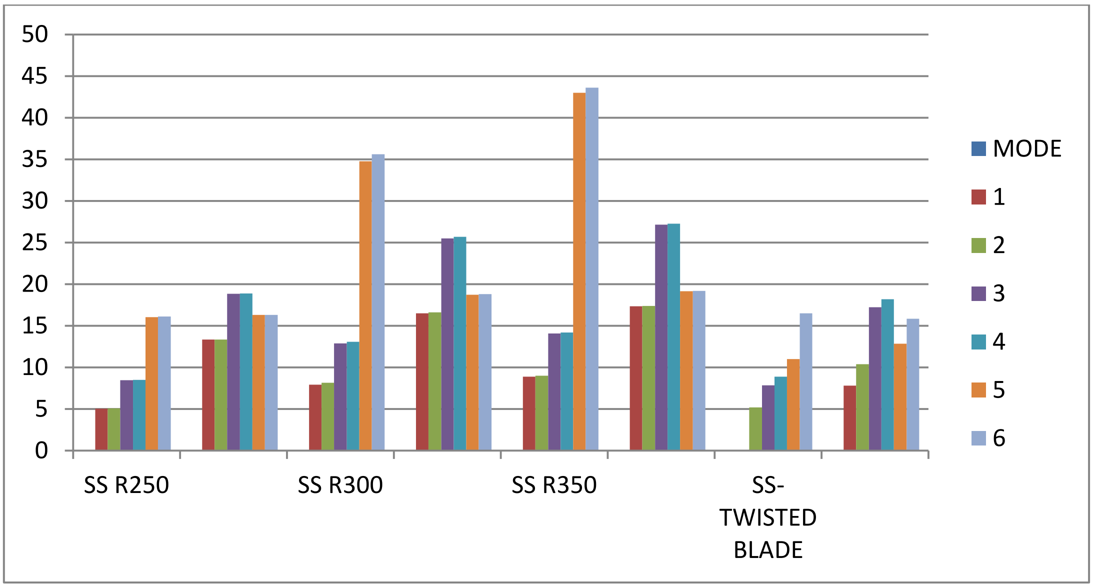


Fig.7 : NATURAL FREQUENCY AND DEFORMATION FOR DIFFERENT MODE SHAPES

MODAL ANALYSIS

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

NATURAL FREQUENCIES AND MODE SHAPES

Natural frequency is the frequency of the structure at which it tends to vibrate when it is disturbed. Mode shape is specific pattern of vibration of a structure to a specific frequency. Due to various rotational speed (RPM) of the rotor, we obtain various forcing frequency which has been tabulated.

Forcing Frequency (Hz) = Rotational Speed in Revolution/Second

The natural frequency of the rotor should not be equal to forcing frequency. If both the frequency match, the structure of rotor is going to be resonate. This resonance will cause the increased amplitude of vibration and this increased amplitude may lead to the failure of structure.

RESONANCE

Resonance is the tendency of a system to oscillate with high amplitude when excited by energy at a certain frequency. This frequency is known as the system's natural frequency of vibration or resonant frequency. For a wind turbine, this means that the rotational speed during normal operations should never be the same as the natural frequency of its component

4. CONCLUSION

Here the natural frequencies of different blades made of stainless steel at different wind speed were compared with forcing frequency and no natural frequencies match with forcing frequencies. So failure of structure will not occur. So the material is suitable for fabrication of wind blades of that dimensions.

It is suitable for houses in urban areas to produce green energy. It can produce electric power of 363 Watts and 1225 Watts at wind speed of 10m/s and 15 m/s respectively.

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