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Numerical and Experimental investigation of Multi blade Vertical Axis Wind Turbine

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Abstract:* *Now a days small straight blade Darrius vertical axis wind turbine are receive more attention compared to horizontal wind turbines due to their advantage in urban use because they generate less noise, overall formation simple and less cost. First an efficient design methodology built on the design parameters like number of blade(four,five,six), Blade profile ,Tip to speed ratio influencing a straight bladed-VAWT (SBVAWT) aerodynamic performance and determine the optimal range of above parameters for prototype construction. Wind tunnel performance results are presented for cases of different wind velocity, tip-speed ratio and solidity. The main purpose numerical study described here is to investigate effect of camber in blade profile of NACA0022 SB-VAWT on its Self-Starting capability using CFD simulation. It is found that asymmetric blade profile NACA 2422 and NACA 4422 with camber instead of symmetric blade profile improves self-starting capability of SB-VAWT. Results indicated wind turbine with blades of asymmetric and thick blade-section was generally more suitable for applying to SB-VAWT. All results of above this study can be used the optimization design parameters of VAWT blades in further. Comparison of the overall multi blade vertical axis wind turbine performance parameters has been studied through numerical simulations and experimental measurements.

Keywords— Darrieus Turbine, NACA 0022, CFD, Self-Starting.

I. INTRODUCTION

There are many different types of wind turbines and they can be divided into two groups of turbines depending on the orientation of their axis of rotation, namely horizontal axis wind turbines (HAWTs) and vertical axis wind turbines (VAWTs). There are a number of substantial advantages [1] over HAWTs, such as:

- The VAWT has no need to constantly yaw into the local wind direction.
- Due to the relatively lower rotational speed, VAWTs are typically less noise than HAWTs.
- The VAWT height from ground small as compare to HAWT.

There are some parameters which affect the performance of vertical axis wind turbines. Some of the most significant variables are Turbine solidity, Number of blades, Airfoil selection, Blade chord, Blade pitch angle, Turbine aspect ratio (H/D), Tip speed ratio and Initial angle of attack.
Robert Howell et al. [2] experiment carried out small model research VAWT turbine has been manufactured and tested over a range of operating conditions. Computational predictions of the performance coefficient of this turbine were carried out considering errors and uncertainties in both the CFD simulations and the wind tunnel measurements. The 2D simulations showed a significantly increased performance compared to the 3D simulations.

Liang Cao et al. [3] has been calculate and analysis with the help of CFD is an important means for understanding the aerodynamic performance of vertical axis wind turbine in design. The higher part of wind turbines rotation region has large turbulent kinetic energy and the lower part has little turbulent kinetic energy. The value of turbulent kinetic energy in calculation domain increase with the increase of the wind turbine rotational speed.

Samaraweera K.K.M.N.P et al. [4] presented Development of Darrieus-type vertical axis wind turbine for standalone applications. In this paper a theoretical model for the design and performance simulation of Darrieus-type vertical axis standalone wind turbine for energy applications was developed. Results were used to analyse the effects of blade profile, rotor solidity and aspect ratio on the maximum power and torque coefficients, optimum tip speed ratio and ability to self-start which lead to design of optimum rotor configurations. It is found that when the number of blades of the vertical axis wind turbine is increased, it can be seen an apparent improvement of self -starting.

Joseph P. Tillman [5] works on improvement to vertical axis wind turbine blades for benefit in self-starting. In this study the authors have investigated, improvements in airfoil blade design to aid in the starting of an H-rotor vertical axis wind turbine (VAWT) and how these changes would affect the performance of an H-rotor VAWT. The authors concluded that the asymmetric airfoils can enable H-rotor VAWT to self-start though airfoil blades with a greater cord and thicker cross section work better in the lower wind speeds.

VAWT having good capability of generate more power from low wind than HAWT. It can be used for domestic purpose like on office, multi-storey buildings. For CFD analysis 2D and K-€ SST model is best suited for simulation of VAWT. For working model of VAWT suitable material is wood like devdar, balsa. It is found that when the number of blades of the vertical axis wind turbine is increased, it can be seen an apparent improvement of self-starting.VAWT having effect of parameters like Number of blade, Pitch angle, Solidity, blade profile and TSR. For more power generation thick blade is suitable than thin blade.

II. OVERALL DESIGN

The model of Multi bladed Darrieus rotor was designed and fabricated in the workshop of the department. Based on design model of Darrieus type vertical axis wind turbine is developed and made-up using following components. The hollow stainless steel shaft with outer diameter 25 mm is used. Hollow shaft with length of 580mm is selected for weight reduction purpose. At the both side of shaft used rod of 300mm for free moment of turbine. Straight blades of NACA 0022 airfoil are prepared from Deodar wood. Chord length for blades is 22 mm and span is 600 mm. For good surface finish coating of wooden varnish is used. Both the end of blade fit with stud and nut for assemble in links. Mild Steel strip of 2mm thick, 20mm width and length of 300 mm are used as main links. In main links 2 hole on disk side and one hole in blade side for strong fitting of blade with disk. Main links holes drill in lathe machine of diameter 5mm. The main links transfer lift blade to disk and to shaft. Two wooden – 10 mm thick and 200mm diameter disks are used to transmit the power from the main links to central shaft. Centre hole of 5mm drill in drilling machine. Disk surface make smooth with the help of lathe machine. Steady galvanize material used for frame. Length of frame 800mm and height of 850mm and width of 450mm. For batter stability and fix angle plate we used two other rod welding at length of 320mm. Bearing: Two stainless steel bearings with inner diameter of 5mm are used for reduce friction between fixed frame and shaft. Bearings mounting on frame and fit with welding. angle plate use to fix the DC generator. Length of angle plate 450mm and fix at distance from frame 320mm. one pulley of diameter 300mm used for power transmission. For light weight wooden material used. At centre of pulley 5mm diameter hole drill with drilling machine. Sewing machine string used for power transmission pulley to DC generator shaft. DC generator is connecting Pulley to angle plate. An electric motor is an electric machine that converts electrical energy into mechanical energy. The reverse conversion of mechanical energy into electrical energy is done by an electric generator.24V DC Motor used for the project the gear motor is mounted on the Angle plate and connects with pulley.

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Figure 1.1 Four blade model

Figure 1.2 five blade model

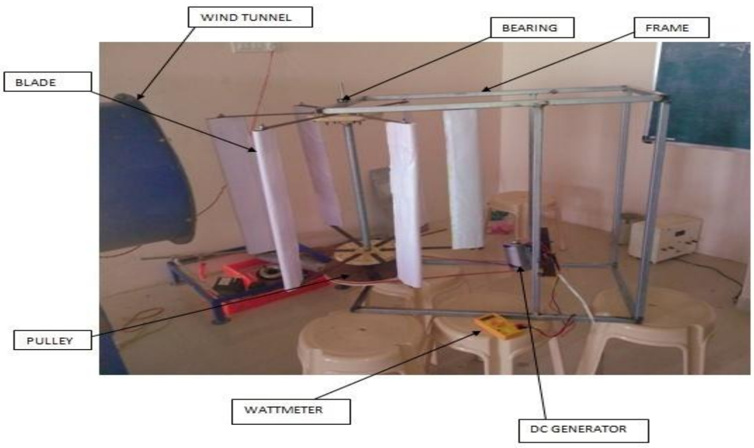


Figure 1.3 six blade model

III. EXPERIMENTAL ANALYSIS OF MULTI BLADE VERTICAL AXIS WIND TURBINE

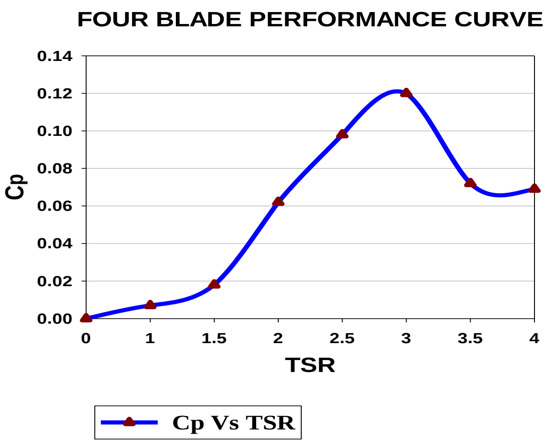
3.1 Experimental procedure :

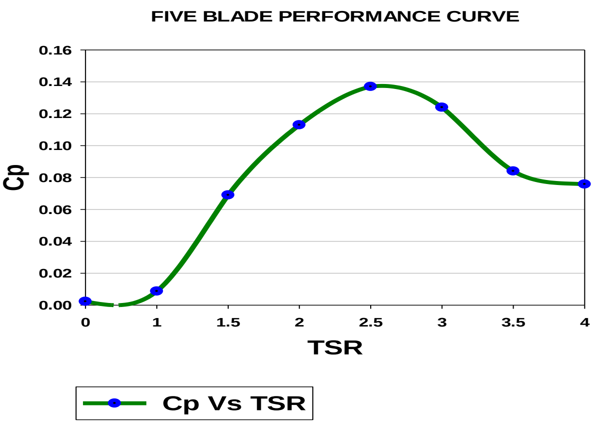
Wind tunnel is started and wind velocity is adjusted to 8 m/s with the help of butterfly regulator on wind tunnel and anemometer. Due to wind as wind turbine starts rotating speed of turbine is continuously measured with the help of tachometer and as speed reaches determined value power output reading at wattmeter is noted down. First measure reading of four blade turbine, five blade turbine and six blade turbine respectively. Different required RPM of all model wind turbine power output is noted with help of wattmeter connect to DC generator. Repeat procedure for all three different number blade turbines 3 times to eliminate possible error in experimental results. At last load connect to wind turbine and the bulb started to blink.

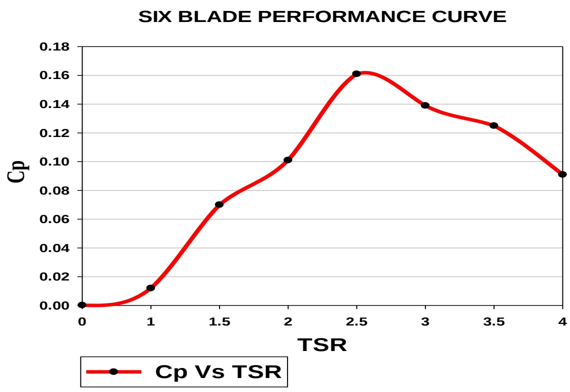
Table 3.1 Experiment Result and Performance

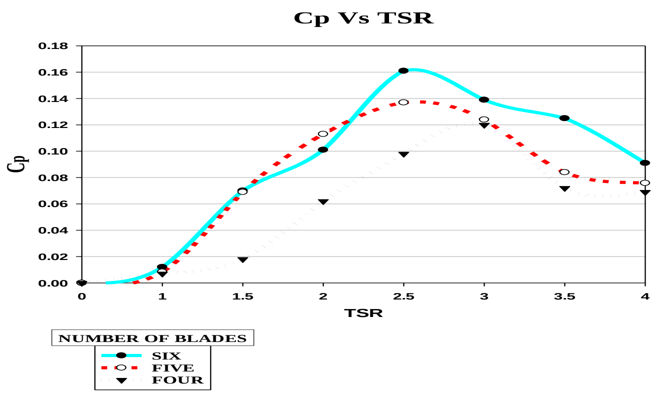
TSR	Speed related to given TSR	SIX BLADE		FIVE BLADE		FOUR BLADE	
		POWER	Cp	POWER	Cp	POWER	Cp
1	30	1.23	0.012	0.91	0.0084	0.72	0.007
1.5	45	7.2	0.070	7.14	0.069	1.85	0.018
2	60	10.49	0.101	11.71	0.113	6.37	0.062
2.5	75	**16.46**	**0.161**	**14.16**	**0.137**	10.08	0.098
3	90	14.3	0.139	12.77	0.124	**12.34**	**0.120**
3.5	105	12.85	0.125	8.7	0.084	7.4	0.072
4	120	9.36	0.091	7.71	0.076	7.09	0.069

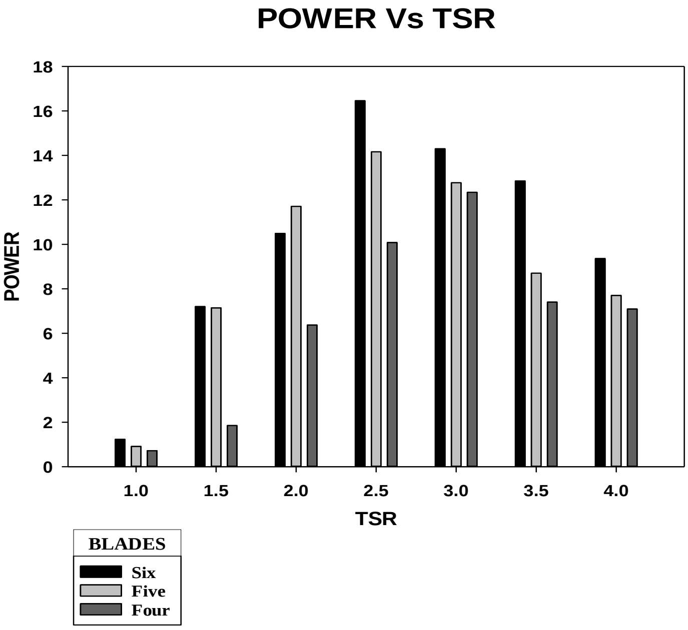
3.2 Performance analysis of various models:

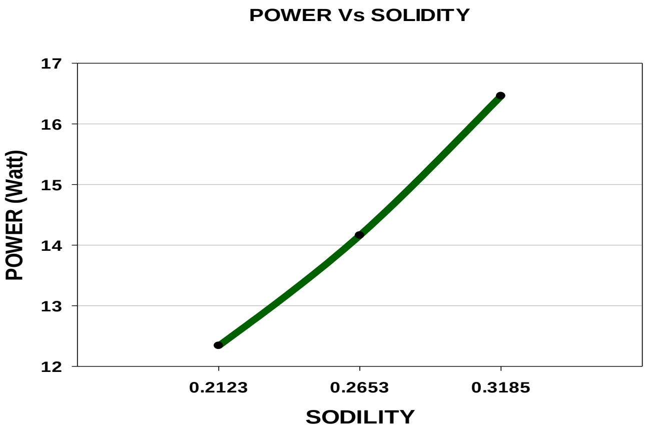












IV. NUMERICAL ANALYSIS OF MULTI BLADE VERTICAL AXIS WIND TURBINE

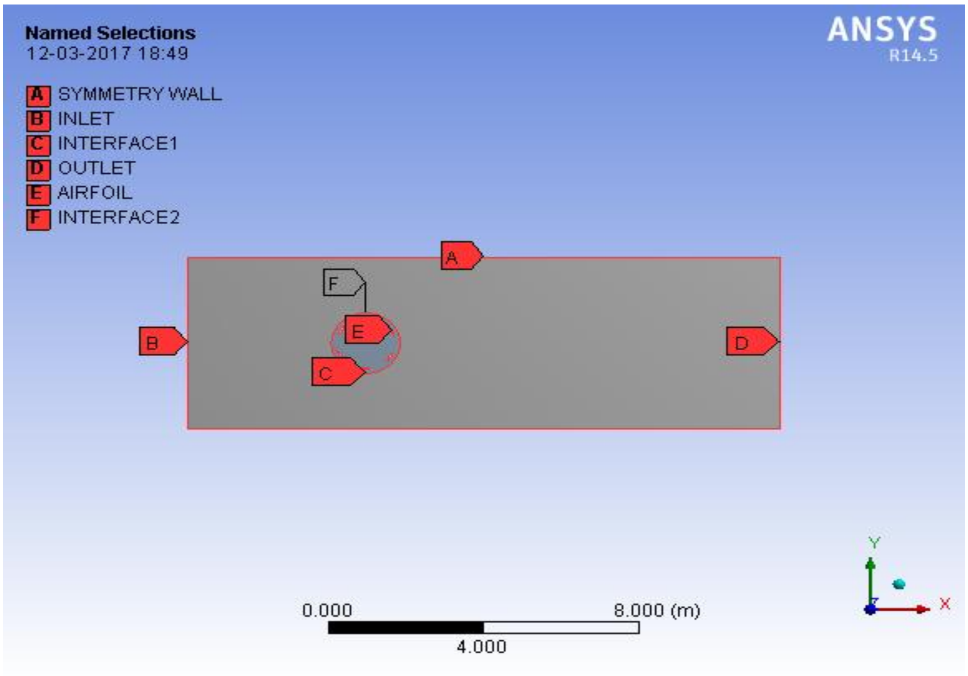


Fig 4.1 Domain for vertical axis wind turbine

INLET: This region is used for giving inlet boundary condition which is wind speed. In our concern wind velocity is taken as 9 m/s which generally good speed for VAWT.

OUTLET: This region is used to define outlet condition of wind. Which is taken as zero gauge pressure means atmospheric pressure.

INTERFACE 1: This region is defined to generate moving mesh between stationary domain and rotating circular domain. Interface 1 is outer edge of circular domain.

INTERFACE 2: This region is defined to generate moving mesh between stationary domain and rotating circular domain. Interface 2 is inner edge of rectangular stationary domain.

AIRFOIL: This region is used to define airfoil as solid wall. This rotates with rotating domain and gives wall condition.

SYMMETRY WALL: This is wall upward and downside edge of rectangular stationary domain and defined as wall.

4.1Calculation of coefficient of performance for vertical axis wind turbine

$T = 0.5*Ct*\rho*V^2*l*s$

$T = 0.5*0.098*1.225*9^2*0.60*1$

T = 2.923 N m

Power Calculation P,

$$P= \frac{2*\pi*N*T}{60}$$

$$P=\frac{2*3.14*75*2.923}{60}$$

P = 22.98Watt

Coefficient of Performance, Cp:
Cp= Pm / (0.5*ρ*A*V3)
Cp = 22.98/(0.5*1.225*0.36*93)
Cp= 0.144

Table 4.1 Comparison Experimental and CFD result

TSR	Experiment result	CFD result	Error %
2.5	0.161	0.144	10.55%

Now, From above result approximate 10.55% error between Experimental and CFD results. Today Computational Fluid Dynamics (CFD) is used for simulating flow VAWT analysis. The quality of the results depends on various factors like grid quality, boundary conditions and computational model of the fluid. For all this reason, it is important to validate the performed computation result with experimental results.

Fig 4.2 various contours of NACA asymmetrical blades

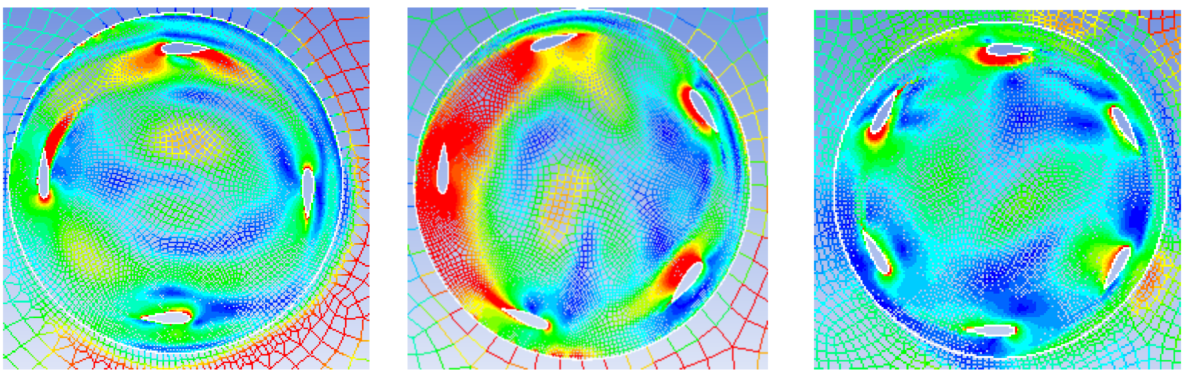


Table 4.2 Result of NACA 0022, 2422, 4422 blades

SR NO	**TSR**	**NO OF BLADE**	**TORQUE CO-EFFICIENT**		
			NACA 0022	**NACA 2422**	**NACA 4422**
1	3	4	0.042	0.048	0.053
2	2.5	5	0.064	0.069	0.072
3	2.5	6	0.098	0.106	0.119

V. APPLICATION OF MULTI BLADE VERTICAL AXIS WIND TURBINE

Vertical Axis Wind Turbine six blade model rotate at nominal speed 2-6 m/s and give best result. Continues rotation of VAWT at different position. We are performing this experiment model at seashore from continues research of 15 days and take reading of battery charge. **Start 1 April, 2017 to 15 April, 2017** measure for different number of blades take time to charge 3 Voltage of LIPO battery.

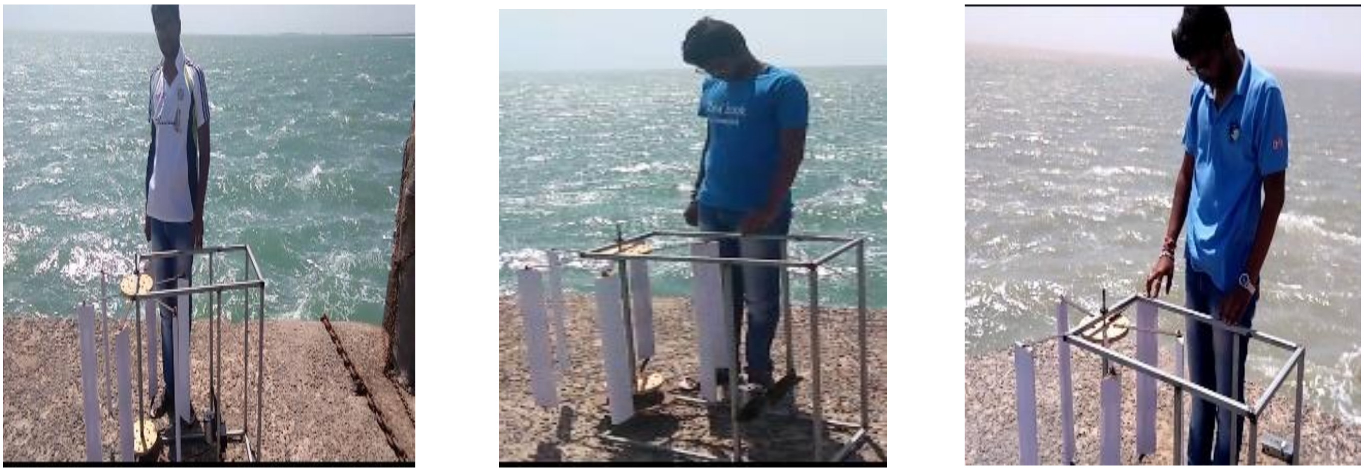


Fig 5.1 Battery charge at seashore

Table 5.1 Time taking to battery charge for different number of blade

DAY	1	2	**3**	4	5	6	7	8	9	10	**11**	12	13	14	15
Four blade(min)	38	34	**32**	34	33	32	34	35	36	34	**40**	38	34	35	38
Five blade(min)	24	25	**23**	26	25	24	23	26	24	24	**28**	**28**	25	25	24
Six blade(min)	20	22	**18**	21	21	22	19	20	20	21	23	**24**	21	20	21

VI. CONCLUSTION

1) The power coefficient is a function of three main parameters namely tip speed ratio, Rotor Solidity and Number of blade.
2) From Experiment of Four blade wind turbine gives maximum **Cp 0.120** at TSR 3, Five blade wind turbine gives maximum **Cp 0.137** at TSR 2.5and six blade turbine gives maximum value of **Cp 0.161** at TSR 3.
3) In this research model, NACA0022 airfoil (thick airfoil) for present small-scale VAWT system. Moreover, **Six blade model** is more appropriate than **Five blade** and **Four blade model** for the application in VAWT.
4) The higher the wind speed the higher the maximum average power coefficient.
5) The symmetrical airfoil (NACA 0022) show good aerodynamic performance for solidity of more than 0.3 and 0.4. For solidity of 0.2, the highest power output is at a tip speed ratio of 3, while for solidity of 0.4, the highest power output is at a tip speed ratio of 2.5.

6) CFD simulation is effective and more feasible tool for various analyses for improvement of Wind Turbine performance. Sliding mesh method is effective for CFD simulation of rotating VAWT simulation. It gives result equivalent to experimental result with maximum 11 % variation.

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