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TESTING OF VERTICAL AXIS WIND TURBINE IN SUBSONIC WIND TUNNEL

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ABSTRACT : A wind turbine is a rotary device that extracts energy from the wind. Any wind turbine comprises of three main components, namely: rotor, generator and structural support. Based on the alignment of their shafts of rotation, two types of turbines are designed – Horizontal Axis Wind Turbines (HAWT) and Vertical Axis Wind Turbines (VAWT). Although the VAWTs have been in use right from 200 BC, only in the recent times the availability of material and construction techniques has made the design attractive again. One such development is the inception of VAWTs with a helical twist. Helical turbines provide steadiness of aerodynamic force and torque, giving a smooth power distribution. In this paper the vertical axis wind turbine with V-type has higher efficiency compared with savonius wind turbine is developed and performances are measured.
KEYWORDS –sub-sonic, wind, vertical.

I. INTRIDUCTION

Wind power has been used for a long time historically by many civilizations in order to produce mechanical energy for the processing of food or for navigation. Although the advent of coal and oil reduced their importance, wind energy continued to evolve over the years. The first known use of wind power was said to be located, according to various sources, in the area between today's Iran and Afghanistan during the 7th to 10th century. These windmills were mainly used to pump water or to grind wheat. They had vertical axis and used the *drag* component of wind power resulting in low efficiency. In 1931, French aeronautical engineer Georges Jean Marie Darrieus patented a "Turbine having its shaft transverse to the flow of the current", and his previous patent (1927) covered practically any possible arrangement using vertical airfoils. Then came the era of lift-based vertical axis turbines. It is one of the most common VAWT, and there was also an attempt to implement the Darrieus wind turbine on a large scale in California by the FloWind Corporation, The Darrieus design to date is a starting point of any studies in present day VAWT.

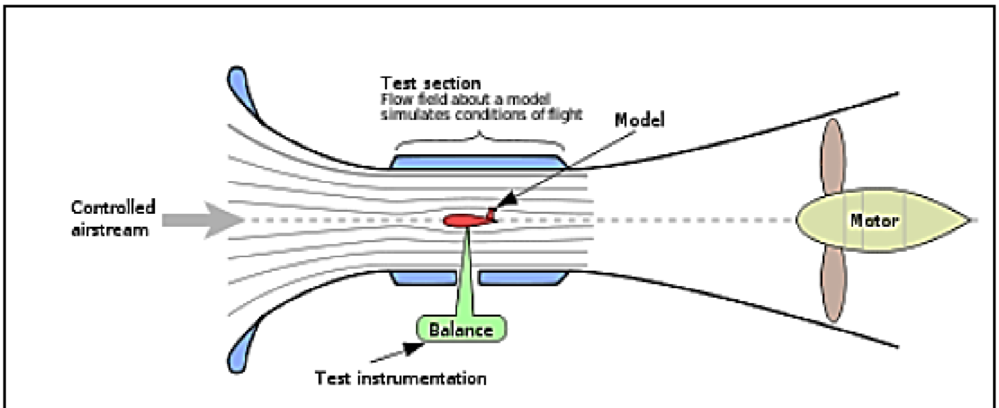

Fig. 1.0 Wind tunnel schematic diagram

From the study of VAWT aerodynamics, it is clear that the unsteady flow domain around the VAWT and the resulting wake patterns are crucial in the turbine design. However, due to insufficient data about the wake in the transient regime, only steady flow conditions were used. Consequently, the blade element momentum (BEM) theory was used to compute the lift and drag. This two blade position type of wind turbine, using v-type vertical axis rotating. This type of wind turbine can increase the output of power with less wind kinetic energy required. The new design has simple construction, small size, simple technology, and economical material usage. It forms a cavity on one side of the turbine while letting the other side of turbine open to let go the wind, hence high drag can occur. This ensures higher efficiency and low starting wind velocity.

II. LITERATURE REVIEW

Feng-Zhu Tai et al (2013): This paper review on Recent interest in Darrieus wind turbines has led to a need for proper performance prediction models. In this proposed paper, an algorithm LDWT, which applied local blade Re instead of one representative Re, was developed and researched. In the calculation, 2-dimensional experimental data for aerofoil characteristics were applied because their 3-dimensional data for different Re could not be accessible. This study shows that results for high TSR from LDWT match test data better than previous research instead of underestimation in other regions. Therefore, it is expected to be useful in the proper design and optimisation of rotors at high tip-speed ratios when their test data is not available or incomplete. Abdulkadir Ali et al (2012): This paper investigates the design of a Savonius type vertical axis wind turbine and its potential to generate power. To enhance the performance of the turbine, a flow restricting cowl is incorporated into the turbine. The airflow behavior of the turbine was investigated both experimentally and computationally. Three different configurations were studied (open position, centered position and a closed position). It is found that a partially cowled turbine in a centered and closed position resulted in a better performance of the turbine than a fully cowled turbine with the same configuration. .T. Chong et al (2013): A shrouded wind turbine system has a number of potential advantages over the conventional wind turbine. A novel power-augmentation-guide-vane (PAGV) that surrounds a Sistan wind turbine was designed to improve the wind rotor performance by increasing the on-coming wind speed and guiding it to an optimum flow angle before it interacts with the rotor blades. Besides, the design of the PAGV that blends into the building architecture can be aesthetic as well. From the wind tunnel testing measurements where the wind turbine is under free-running condition was increased by 75.16%. N.A. Ahmed et al (2013): A 'proof of concept' study of a novel wind turbine that overcomes some of the deficiencies and combines the advantages of the conventional horizontal and vertical axis wind turbines is presented in this paper. The study conducted using computational fluid dynamics and wind tunnel tests clearly demonstrate that such a proposition is feasible and a low cost, low noise, safe and easy to operate, but enhanced performance wind turbine for small scale power generation in low wind speed is viable.

III. EXPERIMENTAL SETUP

V-type shape vertical axis wind turbine, has been designing the frame depending on calculation, the higher values of the drag factor. The blade of wind turbine testing used the three models fabricated by metal with same dimensions, [d= 0.34 m, h = 0.19 m, t=0.9 mm]. The analyses considered a drag force test, and drag force coefficient varies with wind velocity. The typical wind tunnel used stationary turbofan engines that sucked air through a duct equipped with a viewing port and instrumentation where models on the shaft are mounted in order to study. The shaft is connected to a digital scale was used to measure the drag force.

The entire assembly rests on a disk of diameter 10 mm, which in turn is used to anchor to the wind tunnel. It is screwed on four sides and inserted through the bottom of the tunnel test section. The turbine is mounted on a shaft of diameter 12 mm, whose sole function is to transmit the rotational motion of the turbine to the bearing. The material used as the shaft is stainless steel, the reason for this being its less cost and high strength. The shaft is held fixed to the disk by a cylindrical housing with a wide base, which is screwed to the based disk. The function of the housing is to reduce vibration and provide overall support to the turbine.

Minimizing the start-up torque is essential for the smooth operation of VAWT. This requires the smoothest of bearings. With regard to market availability, the chosen bearings were UBC6202 Z. One ball bearing thus eased the rotation of the shaft, at the top and bottom of the housing. The coupler made of aluminium is used to couple the shaft to the motor shaft, so that the axis of rotation doesn't incur an eccentricity. The shafts are kept locked in place with the help of crub screws.

IV. PROCEDURE

The set-up is installed in the wind tunnel and is sealed properly without allowing air to escape. The Wind Tunnel is turned on and set to a low RPM. The fluctuations in the flow are allowed to minimize and no readings are taken in the first few minutes. The wind tunnel velocity is increased-with the help of an inbuilt digital speed regulator- until the turbine starts to rotate on its own. The wind velocity is measured using both an anemometer and an inclined u tube manometer. The startup speed is noted. The RPM of the turbine is measured using a digital noncontact type tachometer. Since VAWTs are generally non-self starting, an external initial torque is provided in some cases. As soon as the drag and lift force are to be measured. The wind tunnel velocity is gradually increased in steps and the speed of the turbine is measured with the help of a digital tachometer.

Fig.2.0 VAWT schematic diagram (Blade Position 1)

Fig. 3.0 VAWT schematic diagram (Blade Position 2)

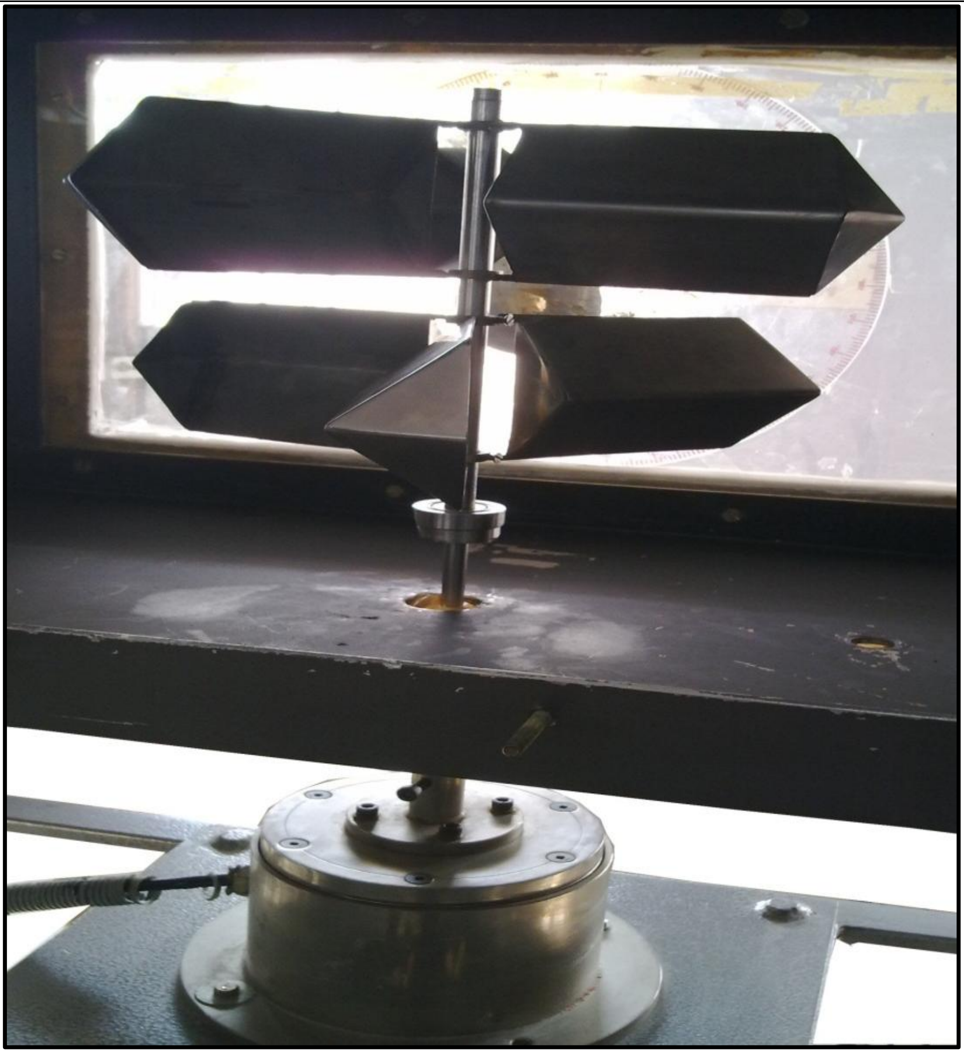

Fig. 3.0 Test Section for Blade

V. DESIGN PARAMETERS

Due to limitations in availability of literature regarding the design of a vertical axis wind turbine, the commercial model, savonius turbine was set as the base for the design so as to understand and characterize the essential design features. The amount of power produced by a VAWT primarily depends on the wind velocity and swept area. In six bladed turbines, the cyclic variations in both the torque and magnitude and direction of the net force on the rotor due to the combined effects of drag increase and lift are reduced. This is caused because the aerodynamic forces on a VAWT peak twice during a revolution. In a six bladed turbine, the forces would peak in the same direction causing resonant vibrations. Since the VAWT in consideration involves a constant chord throughout the blade span, literature was insufficient in deciding the optimum chord. The designer's discretion was exercised and the chord was fixed at 8.5 cm. The whole setup was made from aluminium due to high impact strength.

VI. RESULTS AND DISCUSSION

Results obtained from the wind tunnel tests are depicted in Figure 6.1, show that the blade position 1 with the v-type shape has higher drag coefficients than the blade position 2. When blade position 1. The analyses considered a power output test, and the number of revolutions per min (RPM) of the rotating shaft.

Experimental observations for blade position 1

SL NO	VELOCITY m/s	P_W Watts	DRAG FORCE N	LIFT FORCE N	SPEED RPM	C_D	C_L	P_T Watts	C_P
1	5	4.9661	1.2	0	64	2.8694	0	1.3665	0.2751
2	5.5	6.6099	1.4	0	76	2.7667	0	1.8932	0.2864
3	6	8.5814	1.6	0	94	2.6569	0	2.6761	0.3118
4	6.5	10.9105	1.8	0.1	110	2.5468	0.1414	3.5230	0.3229
5	7	13.6270	1.9	0.1	126	2.318	0.122	4.2597	0.3125
6	7.5	16.7606	2.1	0.1	140	2.2318	0.1062	5.2312	0.3121
7	8	20.3412	2.3	0.1	151	2.1483	0.0934	6.1796	0.3038
8	8.5	24.3985	2.5	0.1	166	2.0685	0.0827	7.3842	0.3026
9	9	28.9624	2.6	0.1	183	1.9189	0.0738	8.4660	0.2923
10	9.5	34.0626	2.8	0.1	198	1.8547	0.0662	9.8646	0.2896
11	10	39.729	3	0.1	214	1.7934	0.0597	11.4233	0.2875

Experimental observations for blade position 2

SL NO	VELOCITY m/s	P_W Watts	DRAG FORCE N	LIFT FORCE N	SPEED RPM	C_D	C_L	P_T Watts	C_P
1	5	4.9661	1.1	0	60	2.6303	0	1.1744	0.2365
2	5.5	6.6099	1.3	0.1	73	2.5691	0.1976	1.6886	0.2555
3	6	8.5814	1.5	0.1	89	2.4908	0.1660	2.3754	0.2768
4	6.5	10.9105	1.7	0.1	106	2.4053	0.1414	3.2064	0.2939
5	7	13.6270	1.9	0.1	122	2.318	0.122	4.1245	0.3027
6	7.5	16.7606	2.1	0.1	138	2.2318	0.1062	5.1565	0.3077
7	8	20.3412	2.3	0.1	153	2.1483	0.0934	6.2615	0.3078
8	8.5	24.3985	2.5	0.1	161	2.0685	0.0827	7.1618	0.2935
9	9	28.9624	2.7	0.1	175	1.9927	0.0738	8.4074	0.2903
10	9.5	34.0626	2.8	0.1	194	1.8547	0.0662	9.6653	0.2838
11	10	39.729	3.1	0.1	203	1.8532	0.0597	11.197	0.2818

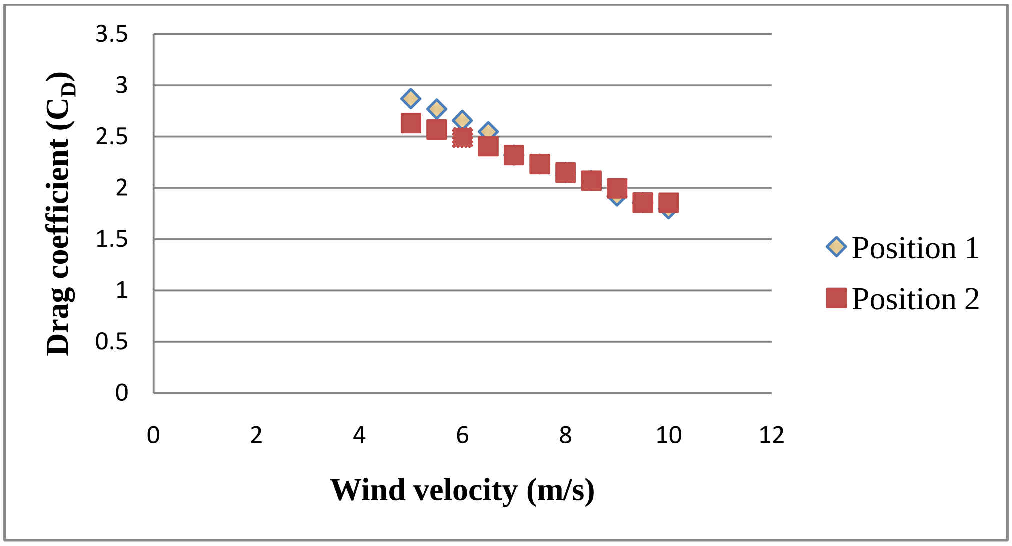

Fig. 4.0 Drag coefficients for two blade positions versus wind velocity.

The typical wind tunnel used stationary turbofan engines that sucked air through a duct equipped with a viewing port and instrumentation where models on the ball bearing shaft are mounted in order to study. The testing area of the wind tunnel length is the cube with dimensions 400 x 400 mm^3. The model of the v-type wind turbine is located in the middle of the wind tunnel testing area and connected to a generator. The range of the wind speed used is between 5 m/s and 10 m/s. The tachometer model Compact Instrument Advent Tachopole was used to measure the rotation speed of the wind turbine shaft with the piece of white paper

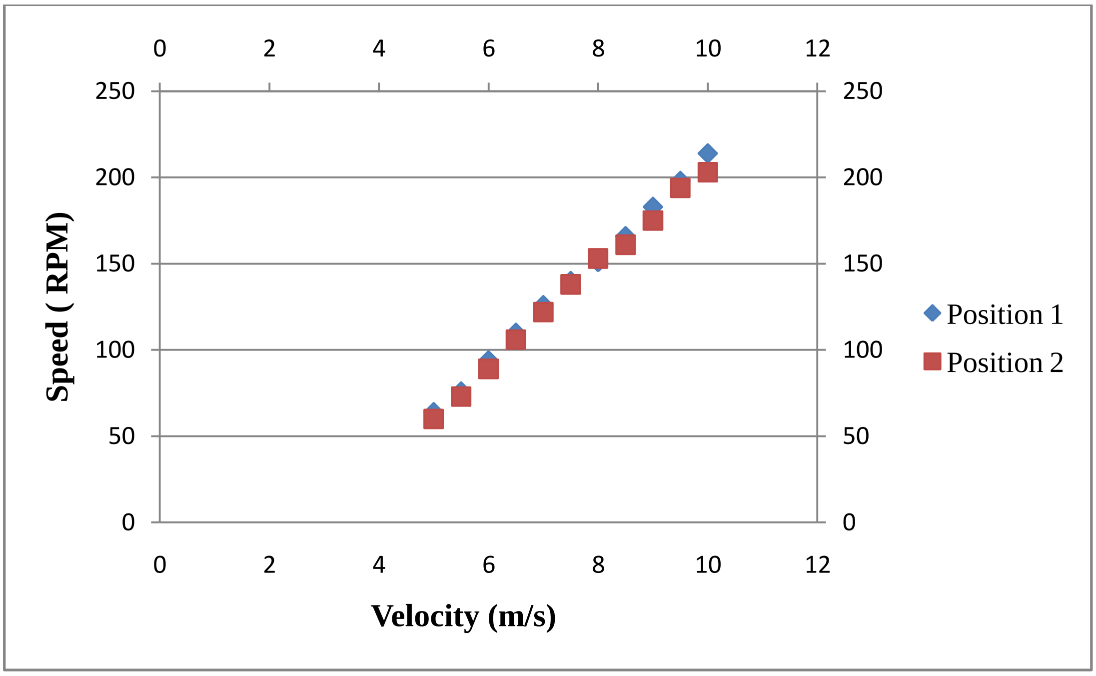

Fig. 5.0 Speed in RPM for two blade positions versus wind velocity.

attached, which reflects light. In the analysis data experiments showed the blade position 1 is a higher than blade position 2 (Figure 6.2). The power curve for different wind speed is reported in Figure 6.4. As torque on the blade position 1 is higher than blade position 2.

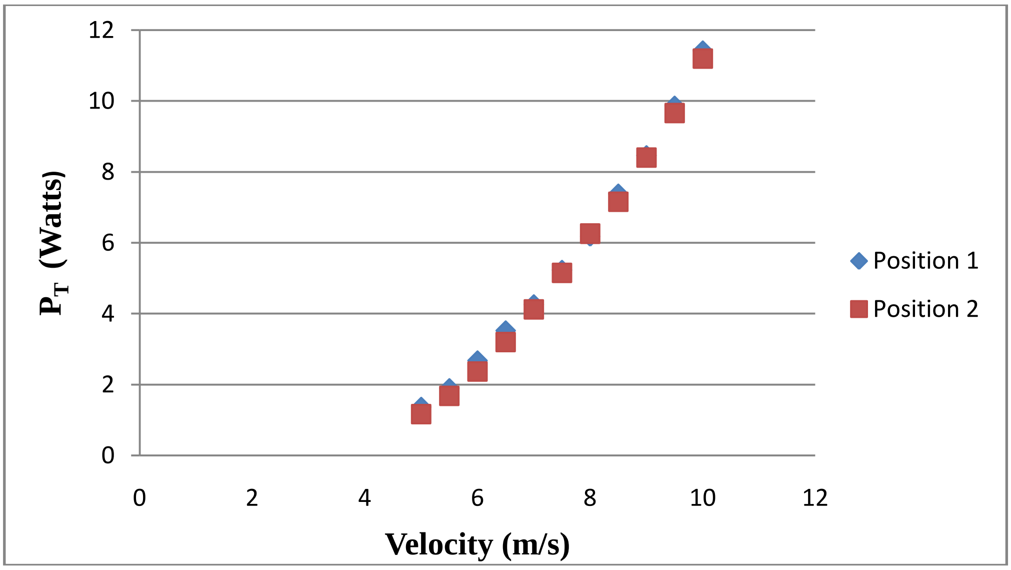

Fig. 6.0 Power output from wind turbine for two blade positions versus wind velocity.

The power coefficient of wind turbine *Cp* is defined as a mechanical power delivered by that turbine divided by the total power available in the cross sectional area of the wind stream. The result shown that C_P was increased to a maximum value.

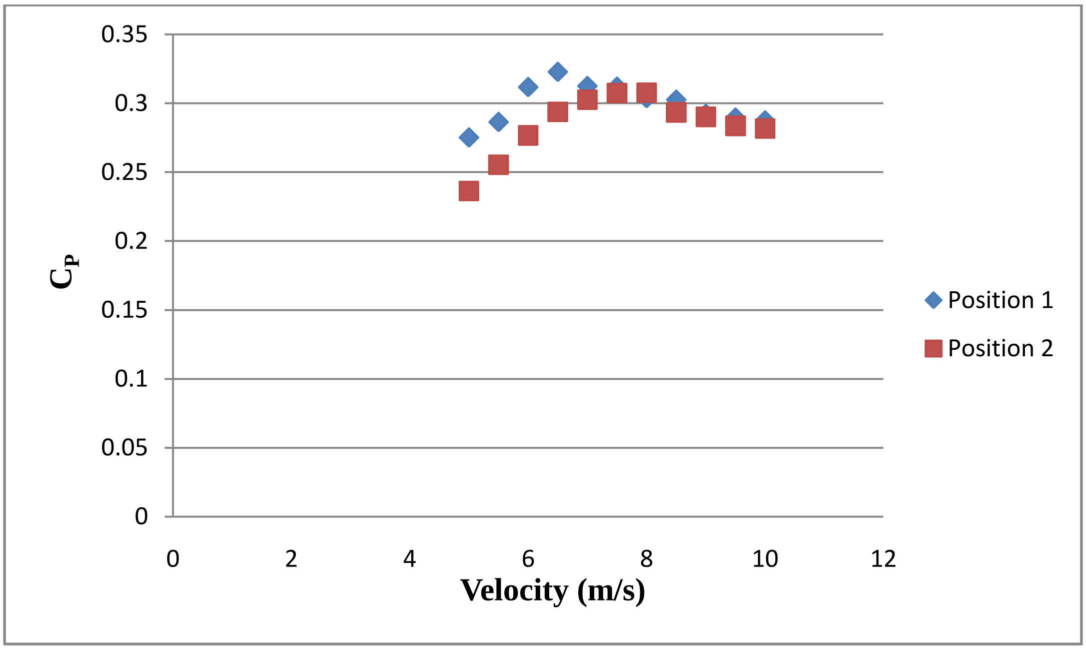

Fig. 7.0 Coefficient of power for two blade positions versus wind velocity.

Also, the Figure 6.5 shows that the overall trend of $C_P$increase with wind speed. The maximum value of *Cp* for any wind speed was 0.32. Blade position 2 shows the gradual increase in *Cp* and provide consistent performance.

VII. EXPERIMENTAL ANALYSIS

The tests were conducted in an in-house subsonic wind tunnel. The suction section of the tunnel had an axial flow fan with variable pitch blades placed in a cylindrical casing, which was driven by a three-phase motor. The cross-sectional area of the test section was 400×400 mm. The operating range of speed in the wind tunnel was 0–35 m/s. The schematic layout of the wind tunnel is shown in Fig 1.0. The convergence ratio is 6:1. The turbulence intensity of the wind tunnel was less than 0.1%

VIII. CONCLUSION

The vertical axis wind turbine with V-type has higher efficiency compared with a savonius wind turbine. When we change the blade position with respect to blade position 1 the coefficient of drag increase than blade position 2. This is causing the wind turbine to develop a high drag factor enables to capture wind energy. This type wind turbine has good technical properties and can be used for generating a power more efficiency for the low speed of the wind turbine. Increase drag factor can increase the output power, and the v-type wind turbine can be high efficiency. The power coefficients are measured experimentally to be equal to 0.32 and 0.31 to position 1 and position 2, respectively. Figure 6.1 shows the position 1 increase the drag coefficients of 2.87, when the drag coefficient for position 2 is 2.63.

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