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EXPERIMENTAL STUDY OF A NOVEL MANTLE NOZZLE SYSTEM TO STEP UP THE WIND VELOCITY REACHING A HORIZONTAL AXIS WIND TURBINE

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ABSTRACT

Increasing the efficiency of a wind turbine is certainly a superior area of research. There is a great need of increasing the velocity of wind that is reaching a wind turbine particularly a horizontal axis wind turbine which in turn helps increasing the efficiency of the wind turbine. In getting a best solution for the problem that is to increase the wind velocity reaching a wind turbine in any direction, we need to fabricate a nozzle particularly a convergent nozzle to step-up the velocity of wind (ambient air that is about to reach the rotor). The wind velocity reaching the wind turbine is studied with and without the nozzle (novel mantle nozzle) for a laboratory model wind turbine as part of study.

INTRODUCTION

Experiment is carried to increase the wind velocity that is about to reach wind turbine using nozzle system. Design is developed under 'Ducted Wind Turbine', 'Mantle Wind Turbine', 'Vertical Axis Wind Turbine with Convergent Nozzle', 'Diffuser Augmented Wind Turbine' and 'Swift Wind Turbine etc. First ever, the duct type wind turbine is introduced by Lilley et al. [1]. The efficiency can be increased by at least 65% from conventional wind turbine. An experiment using mantle nozzle to increase the efficiency of wind turbine is conducted by Frankovi et al. [2]. The profit due to mantle wind turbine is equal to five times to the conventional wind turbine. Few investigations are conducted by Touryan et al. [3], Macpherson et al. [4] and New man [5] on vertical axis wind turbine to increase the power coefficient using nozzle system. Under the guidance of Dave Anderson Renewable Devices Company, Edinburg produced on novel design of 'Swift Wind Turbine' using Cascade engineering. Such swift turbine supplies energy suitable to produce 1.5 kW of electric power with the cut in speed, in the range of 8.33 m/sec. The design of a solar stack to be used in rural areas of developing countries is presented by Grant et al. [6]. For a solar chimney, 36 meters high and 4 meters diameter, the air velocity of 3.53 m/s, the maximum theoretical power output was founded to be 49.24 watts. According to Kogan et al. [7], power output is a function of the, diffuser inlet and exit pressure. In their analysis, the diffuser was characterized by the exit to the entrance area ratio of 3.5. The investigation concludes that the power output of DAWT is 2.9 times more than the power produced by conventional wind turbine.

NACA Airfoils

National Advisory Committee for Aeronautics (NACA) has developed airfoils under 4 digit series and 5 digit series. For 4 digit series, the camber as a percentage of the chord is represented by the first digit. The second digit represents the maximum camber from the end of leading edge of airfoil in ten's of percentage of the chord. The last two digits represent maximum thickness of airfoil as a percentage of the chord. The airfoils used in the present study resemble NACA 0012. Wind power generator, as long as the tower can with stand the drag, only lift force is paramount. According to the investigations of Sheldal [8] and Tangler [9] lift coefficient is high at 45^0 of attack for flat airfoils. The lift coefficient is determined from 0^0 to 180^0 of angles of attack.

RESEARCH METHODOLOGY

1. Convergent nozzle system fabrication in such a way that wind velocity can be increased in any direction.
2. Studying the wind velocity variation on laboratory model horizontal axis wind turbine. This can be done in two different modules, They are (i) without nozzle system (Module M_0) (ii) with nozzle system (Module M_1)

Instrumentation and Experimental Set Up

Rotating disc type anemometer is used to determine air velocity. A Non-contacting type tachometer is used to measure speed of driver and driven pulleys. All instruments used in the study are calibrated. Experimental setup consists wind tunnel, lab model wind turbine and nozzle system. Wind tunnel produces wind at speed of 8.5 m/sec. In the present investigation, a three bladed laboratory model horizontal axis wind turbine is used. The wind turbine has length 0.24 m, height 1.45 m and mass of 500 gm for each rotor blade.

Nozzle System

As a part of manufacture of nozzle system, the convergent nozzle is fabricated. It is fabricated with its outlet diameter equal to the wind turbines rotor.

Line Diagrams of Experiment Modules M_0 and M_1

Line diagram of module M_0 is illustrated in figure 1. The direction of wind from wind tunnel to wind turbine is shown. No nozzle system is used at this stage of the experiment. Line diagram of module M_1 is shown in figure 2. The convergent nozzle is assembled separately. Air from wind tunnel is allowed to pass through the outer convergent nozzle from wind tunnel. Wind turbine may suffer severe stresses if the nozzle system is assembled to it.

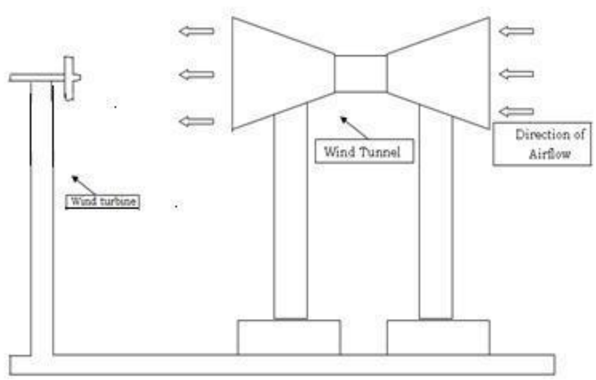

Figure 1 Line Diagram of Module M_0

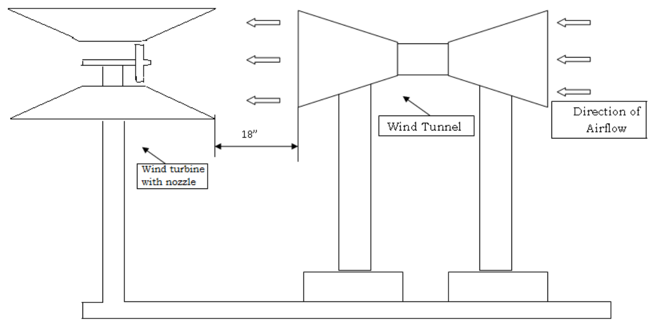

Figure 2 Line Diagram of Module M_1

Experimental Procedure

In various modules of experiments stated above, the wind velocity reaching wind turbine is determined at various blade orientations. In each module, of investigation the chord of all blades is oriented at 0^0, 45^0 and 90^0. The air at high speed from wind tunnel is focused on to rotor of the turbine. In these modules, the efficiency of lab model wind turbine is determined using with and without nozzle system at different positions of blade. Laboratory model wind turbine is placed at a distance of one and half foot from wind tunnel. Air from the wind tunnel causes turbine to rotate. If wind turbine is located close to wind tunnel, air may not focus on to the rotor with enough momentum. But, if it is placed far from the wind tunnel, the air domain between wind tunnel and wind turbine may absorb a portion of the velocity. On the trial and error, it is founded that the turbine rotates at more speed if it is at a distance of one and half foot from tunnel.

Where, V_i and V_e indicate velocity of air at entry and exit of wind turbine. The density of air determined used gas equation treating the air at atmospheric pressure.

RESULTS AND DISCUSSION

Experiment is conducted at 0^0, 45^0 and 90^0 of blade positions in the quarter segment of a circle. In the modules, it is founded that wind velocity is high after installing nozzle to the wind mill. Here, 45 degrees of attack is taken for comparison.

Module M_0 and M_1

Table 1 Investigation for Module M_0 (without Nozzle System)

A	T_i (^{0}C)	(V_i) m/sec	(V_e) m/sec
0	26.8^0	8.2	8.2
45	27.0^0	8.5	6.4
90	26.8^0	8.5	7.3

Table 2 Investigation for Module M_1 (With Nozzle System)

A	T_i (^{0}C)	(V_i) m/sec	(V_e) m/sec
0	26.8^0	10.6	10.6
45	26.9^0	11.2	7.2
90	26.9^0	11.1	8.8

Graphical Representation

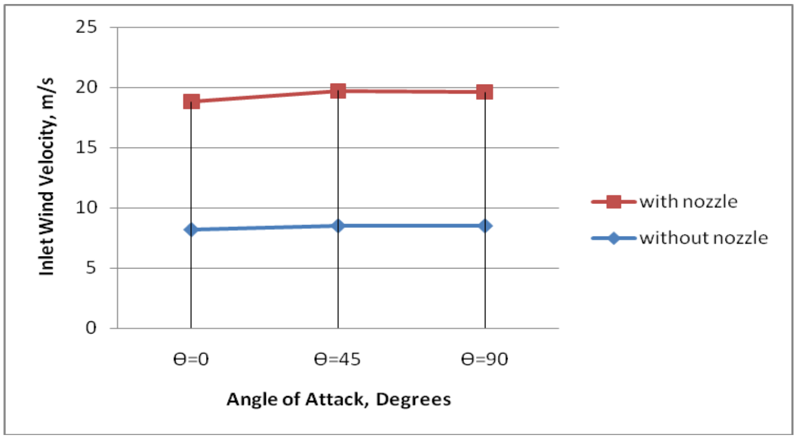

Fig 3. Angle Of Attack Vs Inlet Wind Velocity

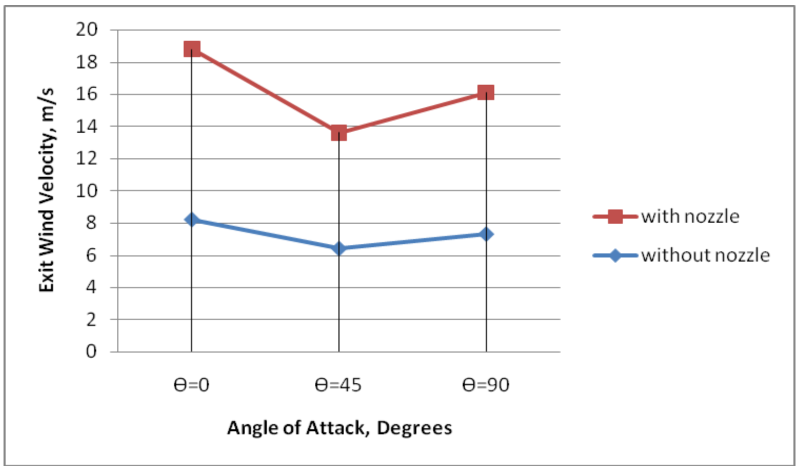

Fig 4. Angle Of Attack Vs Exit Wind Velocity

DISCUSSION

Graphical representation in figures 3 and 4 illustrates the rise in wind velocity with nozzle system. The effective utilization of kinetic energy of air is occurred at 45^0 of attack.

CONCLUSION

From the investigation, it was found that at 45^0 angle of attack wind velocity at entry has increased up to 11.2 m/s from 8.5 m/s after installing a novel mantle nozzle system, eventually the efficiency of the wind turbine also increases.

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journals and books from where the literature of this article has been reviewed and discussed.

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