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An Investigation to Estimate the Maximum Yielding Capability of Power for Mini Venturi Wind Turbine

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ABSTRACT

The present research work deals with the design and fabrication of windmill using venturi effect. The venturi effect is achieved such a way that the propeller rotation is increased about four times for the wind velocity in the surroundings. For any direction of wind flow, the propeller is rotated. The wind velocity required for power production in our research area is very less when compared with the existing systems. There are no effects on the birds and also there is reduction in noise level when compared with existing conventional wind mills. The wind enters the nozzle where its velocity is increased slightly. Hence the proposed idea is to overcome the difficulties in exisisting wind mills. From this experimental analysis it was understood that the maximum yield of power was increased by 12% nearly (800 to 1000 W) compared to conventional windmills, which can be used essentially for domestic applications. The design in terms of cost and life was to be increased by 6% as compared to VAWT and HAWT. By the utilization of venturi wind turbines; the possibilities of facing real time problems such as resonance and sound intensity was decresed by 10% as compared to conventional wind turbines.

Keywords: Venturi effect wind mill, Nozzle design windmill, economic windmill, efficient windmill

INTRODUCTION

When the wind blows from the atmosphere and it enters into the main nozzle. The function of main nozzle is to collect the air from any direction with very high pressure and reduces the pressure where as desired velocity is achieved .Although the direction of wind changes, the main nozzle collects it and sends it to the collector tank. After passing through the main nozzle, the velocity of air is slightly increased and it flows to the throat part through convergent nozzle. The cross section of the nozzle varies and the pressure and velocity parameters may changed according to the wind requirement, Though this design is very simple and the maintenance cost were effectively low and manufacturing costs were comparatively low while compared to other significant wind mills, The study also found that having each VAWT spin in the opposite direction of its neighbour blade allowed to rotate and pin very faster motion, because the opposing spins reduced the drag on force on each turbine, which will increases the efficiency more and more and the main advantage of this system is no frictional losses, since there is no rotational parts involved in this system and hence the absence of gear box tends to neglect the more complicated term noise and vibration. (Kumar et al. 2016) experimented analysis on gearbox in windmill tends to more and adverse effect on environment which will produce huge resonant frequency up to 105 dB. This phenomena can purely avoided in venturi wind turbines and maintanence costs are negliable and also proved maximum efficiency can be achieved using venturi effect and minimal losses are possible by achieving maximum mass flow rates and maximum pressure drops across the turbine using venturi effect (Gohar et al. 2019). Elliott and Infield (2012) investigated power performance curves of a 15 kW wind turbine to predict energy yield and he concluded that the yield energy required can be seen from to maximum power curve, he recommended in 1min average errors at 1 kg in 10 min data with some possible errors. The numerical simulation analysis was performed to measure the performance of mini wind turbine using Ansys, and from him study it was observed that the materials composed of stainless with composites posses best performance in terms of power and life (Kumar et al. 2017). The selection of materials is an important critical factor while designing the wind turbine blade, gearbox and associated parts. The endurance strength of the material decides the maximum possible energy to be yield (Rashedi and Sridhar 2012).

MATERIAL AND METHODOLOGY

Material selection is very important factor that taken into consideration while fabrication of windmill part. The light material is choose such a way that it should achieve the propulsion velocity four times more than the existing velocity. Pehlivan et al. (2021) proved by selection of materials for wind turbine applications must the parameter based on durability and endurance strength. Here we choosed sheet metal as the material selection for the components venturi, Main nozzle, diffuser. The sheet metal has very more advantages while comparing other materials, Since sheet metal has very light in weight and it is very extremely strong and life span of the sheet metal is extremely durable and it posses very good mechanical properties like good endurance Strength. Zhu et al. (2008) mentioned definite knowledge must require for the development of design support to meet its life time adaptions. Trzepieciński (2020) has analysed sheet metals and him investigation properties were useful to carry out some thermal properties at very high temperatures. The Table 1 illustrates the material properties involved in this project and tends to improve the better durability, Hence in this research the materials was choosen as sheet metal as the material for the components involved in this system (Bagudanch et al. 2017). Some temperature measuring sensors are required to overcome the temperature that generated during the process of power generation due to high velocities (Kumar et al. 2022).

Table 1. Material properties

No.	Components	Materials
1	Main Nozzle	Sheet metal
2	Convergent Nozzle	Sheet metal
3	Throat part	Sheet metal
4	Diffuser	Sheet metal
5	Propeller	Sheet metal

WORKING PRINCIPLE AND DESIGN MODEL

Pro-E is the tool that develops the 2d line diagrams into real time 3D computer aided drafting models. It is can be used as surface drawn or solid drawn according to the requirements of design (Manzoor Hussain et al. 2008). Figure 2 shows the working principle behind the venturi effect. The term venturi effect takes place at throat section where considerably fluid velocity must increase and the pressure of the fluid is reduced and hence the velocity required to spin the propeller is achieved with the help of venture effect and hence throat section in venturi plays a main role in significant in design to achieve higher velocity parameters for appropriate parameters (Chidambaram et al. 2021).

From the Figure 3 Pro-e model of the economic model and its dimensions were tabulated in Table 2. Figure 4 shows pro-E model of convergant part and its dimensions were shown in Table 3. Figure 5 shows the throat part and Figure 6 represents outlet part of the model and corresponding dimensions as shown in corresponding Tables 3 and 4 respectively. The dimensions are drawn by the references of ANSI codes that effectively utilised for wind turbine applications.

RESULTS AND DISCUSSION

The velocity and pressure is the indication to measure the performance of wind turbine. The maximum power that extracted from wind turbine depends upon the average velocities of 12 m/s (Sayed et al. 2020). Figure 7 shows the significance of inlet pressure that entering into the nozzle. The three different inlet pressure values were accounted by venturi design to estimate

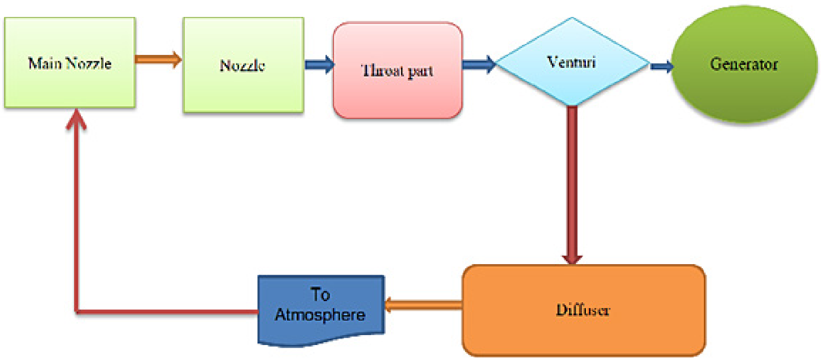

Fig. 1. Methodology

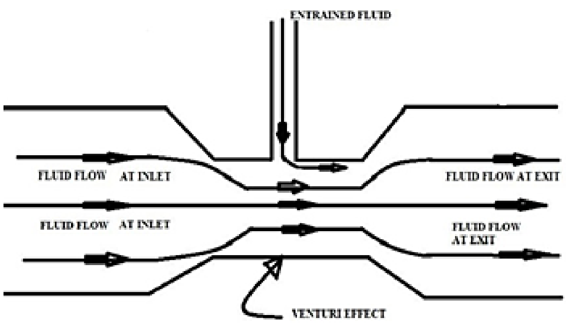

Fig. 2. Working principle of venturi

maximum power. First sample inlet pressure say 1.05 bar with corresponding velocity 2 m/s, Second sample pressure subjected to 2.5 bar the corresponding velocity is 4 m/s. Similarly third sample inlet pressure subjected to 2.8 bar the corresponding inlet velocity is 4.3 m/s. Hence from the above graphs it is clearly understood that the pressures entering into the nozzle will be abruptly decrease at throat, but the velocity at the throat and exit is higher when compared to velocity at entry, This will cause higher increase in power (Manzano et al. 2016).

The velocity of venturi depends upon the conical height and its design parameters. The velocity is gradually increased from 5 m/s to 12 m/s depending upon the wind flow (Chore and Navale 2018). Figure 8 shows the graphical representation of throat pressure distributional values. From the results it can proved that that the pressure at throat is gradually decreased for three different experimental values. At the entry of the nozzle the initial pressure 1.05 bar. This is due to the impingement of air at the throat will cause decrese in pressure up to 0.4 bar. Similarly for other two experimental values the pressure at throat will decreased. The experimental results show that there was an 5% in improvement of venturi turbine compared with conventional wind turbines (Nardecchia et al. 2020).

Exit pressure and velocities is an indication to measure the rated torque and power of the wind turbine. Figure 9 illustrates that the velocities at inlet, throat and exit velocities for three different experimental values. The results proven that pressure at entry is gradually decreased from convergent section to throat and throat to exit. This is due to the behaviour of the increase in average velocities from inlet to throat, and throat to exit for three different experimental values (Nardecchia et al. 2021). It is clearly understood that the maximum power can be achieved when increasing the velocity by reducing the pressure, Here the divergent angle should be maintained 5 to 10 degree to achieve maximum velocity of 1st 2nd and 3rd iterations and it was found that the velocities was observed by 4 to 8 m/s, 8 to 9.5 m/s, 8.1 to 9 m/s (Boyer 1996; Ragheb 2014).

$$P_1 > P_t > P_2 \quad (1)$$

$$V_1 < V_t < V_2 \quad (2)$$

Table 2. Dimensions of main Nozzle in mm

No.	Top Nozzle	Dimensions
1	Top length	355
2	Bottom length	235
3	Radius of arc	325
4	Side length	200
5	Height	300

Table 3. Dimensions of convergant and divergent Nozzle in mm

No.	Type	Diameter	Height
1	Convergent	200	150
2	Divergant	200	100

Fig. 3. Pro-E Model of venturi wind mill

Fig. 4. Convergent part

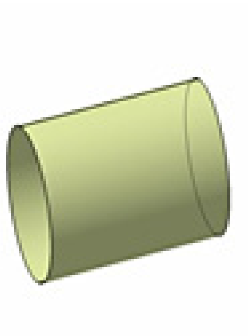

Fig. 5.Throat part

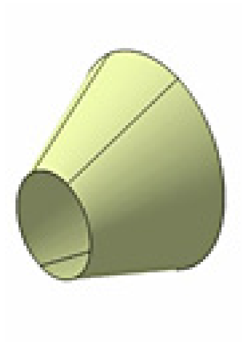

Fig. 6. Divergant part

where: P_1 – inlet pressure in bar,
P_t – throat pressure in bar,
P_2 – exit pressure in bar,
V_1 – inlet velocity in m/s,
V_t – throat velocity in m/s,
V_2 – exit velocity in m/s.

PERFORMANCE CALCULATION IN TERMS OF POWER

As mentioned in Table 5, the experimental results for three different pressure values is decresed from throat to exit as followed by 0.4 to 0.3 bar, 1 to 0.5 bar and 1.1 to 0.6 bar and corresponding achieved powers is tabulated in Table 5. From Figure 7, 8 and 9 it is due to the effect of pressures at high inlet pressures, gradual increment in velocities (Chong et al. 2013). Meanwhile bases on venturi experimental analysis it was understood that the velocity at throat section is considerably increased to achieve maximum mass flow, maximum pressure at exit. This is due to the impact of average velocities (5 to 13 m/s) section 1, section 2, throat and section 3 (Hanna, 2019). From this analysis it was identified as velocity at exit is gradually increased in all these three cases to achieve maximum mass flow rate and maximum power. The perfomance of the venturi wind type depends upon the design of throat, maximum flow capability, Venturi conical diameters and mass flow rate of the air (Elshazly et al. 2019). The maximum amount of deformations can be predicted by the simulation before the product was manufactured, hence it can saves the time and costs (Karthickeyan et al. 2017).

VELOCITY VS POWER

The measurement of velocity with respect to power denotes the performance of the wind turbine with respect to power. The velocity was gradually increased due to inherent increase in cross sectional area of wind turbine (Solanki et al. 2017). Figure 10 represents the mass flow rate, velocity distribution of air with respect to generation of active power. The power generated from venturi turbine was gradually increased due to increase in mass flow rate; a substantial output of 0.08 kW was developed during the maximum mass flow rate of 8 kg/s. This is due to the phenomenon of maximum extraction of energy (59.3%) due to betz limit (Meratizaman and Nateqi 2021).

Table 4. Dimensions of Venturi part in degree

No.	Convergant angle	Divergant angle	Area ratio
1	20–30 deg	5–10	0.05–0.65

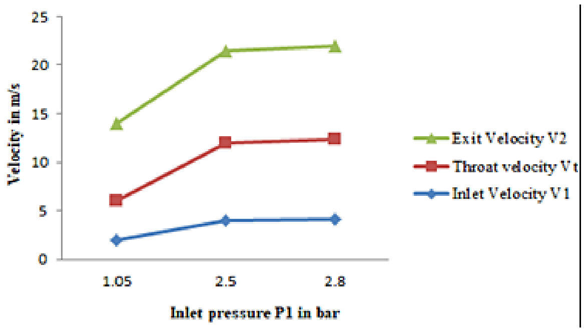

Fig.7. Pressure distribution vs velocities

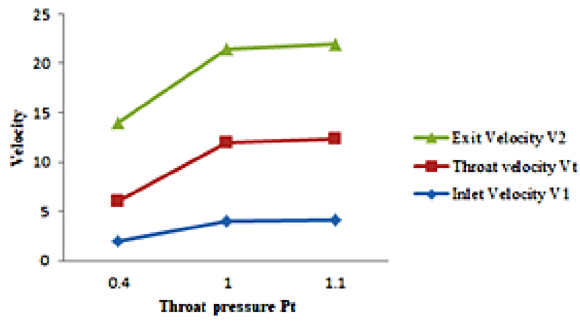

Fig. 8. Throat pressure vs velocities

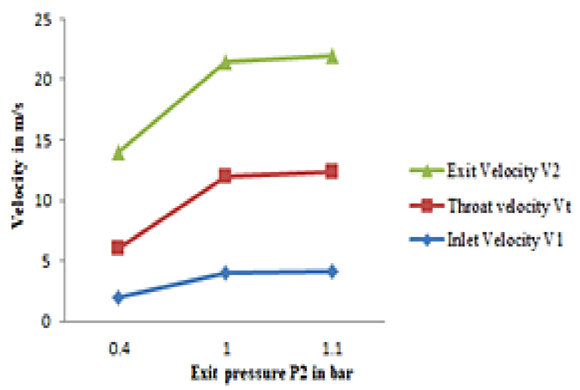

Fig. 9. Exit pressure vs velocity

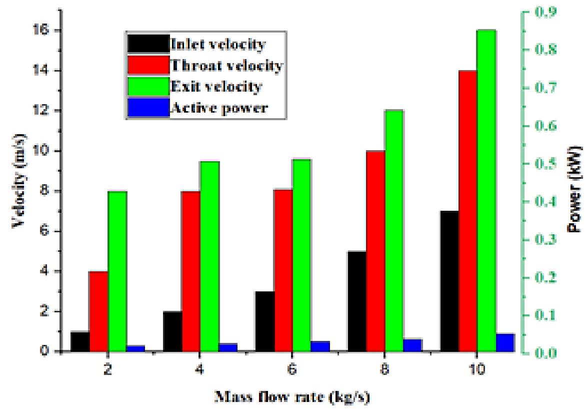

Fig. 10. Distribution of wind velocity over the venturi wind turbine

Table 5. Actual Measured values from economic wind turbine

No.	Mass flow rate at diff attitudes, kg/s	Maximum mass flow rate, kg/s	Measured pressure values, bar			Measures velocity values, m/s			Actual power, W
			P1	Pt	P2	V1	Vt	V2	
1	0.0769	1.894	1.05	0.4	0.3	2	4	8	436.96
2	0.08	1.894	2.5	1	0.5	4	8	9.5	758.45
3	1	1.894	2.8	1.1	0.6	4.3	8.1	9.6	761.33

CONCLUSIONS

From the results it was able to conclude that actual power will be increased even at smaller attitudes from 5 m/s to achieve rated actual power and also there is no frictional losses occurred in this type of wind turbine using venturi effect. Hence it is suitable for wind speeds at lower speeds also this proposed project study hence deals with rotation of propeller by four times for the wind velocity in the surroundings. So, there is adverse effect on the humans and since the absence of rotational parts tends to absence of meshing frequency ranges and hence no noise prediction in this system. So this system can overcome the existing HAWT and VAWT Turbines in future. From the mass flow rate calculations; due to venturi effect will increases, thereby increase in velocity tends to rotate the impeller more and more four times than the normal VAWT turbines So this method is effectively utilized and proposed future research work is going on for higher attitudes and CFD Simulation works were present in future for higher altitudes.

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