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A Study on Novel Ducted Blade VAWT Using Subsonic Wind Tunnel

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Abstract

In this study, a novel ducted blade with varying width is proposed for wind energy application. The proposed wind blade is designed, fabricated, and used to develop a vertical axis wind turbine (VAWT). Here, VAWT with 2,3 and 4 blade configurations are modeled, fabricated and tested experimentally in subsonic wind tunnel. Based on the experiments conducted, the performance of three VAWT models for varying wind speed is analyzed. It is revealed that the ducted VAWT with a 3-blade configuration outperforms the other two configurations.

Keywords: varying blade width, ducted blade, VAWT, subsonic wind tunnel testing, VAWT performance

1 Introduction

Access to affordable, reliable, and modern energy services are becoming the primary goal of enabling energy to residential electricity users, and in this context, small scale wind turbines for power generation are being used widely. Among the commercially available wind turbines, for small scale power generation, vertical axis wind turbines (VAWT) are generally preferred [1,2]. The main reason for this is, yaw control mechanism is eliminated in VAWTs and have ability to work in lower wind speed conditions. Even the manufacturing of VAWT is easy and installation cost is less [3,4].

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The use of VAWT is limited in spite of having several benefits as they experience challenges with performance and design, and the same is stressed in the literature. There are many works published related to blade design research and they mostly stress on the performance issues of blades [4][5][6]. Most conducted studies are available on experimental basis and numerical basis, and simulation.

In this paper, work has been carried on the design aspects of VAWT, and the main objectives are as follows:

- To design and fabricate new ducted type wind blades for VAWT;
- To carry out the experimental investigations on scaled models of VAWT with 2,3 and 4 blade configurations in subsonic wind tunnel.
- To study the performance of VAWT with different blade configurations at different wind velocities;
- The performance results are compared to select the best VAWT wind blade configuration.

The article is structured as: Section 2 explains the methodology to frame the article, Section 3 discuss the performance parameters and their variations for different technologies and Section 4 concludes the article.

2 Methodology

The designed ducted type VAWT wind turbine is shown in Figure 1. The blade with varying width is shown in Fig. 1a).

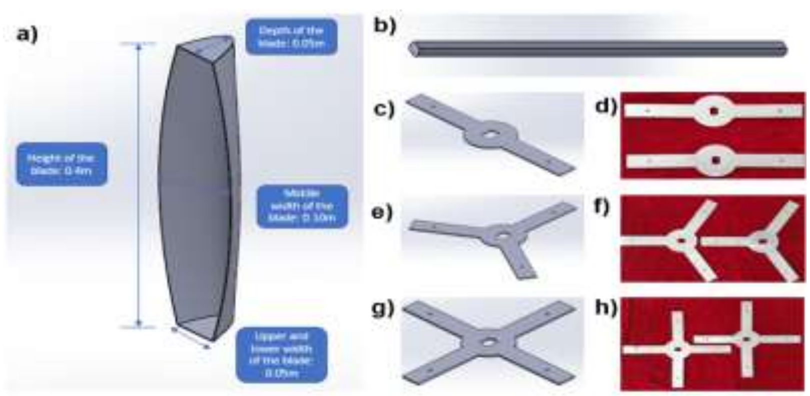

Figure 1 a). Ducted type wind blade; b). supporting shaft for VAWT; c). solid works model of supporting frame for VAWT with 2 blade configuration; d). fabricated model of supporting frame for VAWT with 2 blade configuration; e). solid works model of supporting frame for VAWT with 3 blade configuration; f). fabricated model of supporting frame for VAWT with 3 blade configuration; g). solid works model of supporting frame for VAWT with 4 blade configuration; h). fabricated model of supporting frame for VAWT with 4 blade configuration.

Based on the design, modeling of ducted VAWT blade and supporting systems are carried out using solid works. The supporting frames and shaft of VAWT with 2, 3, 4-blade are fabricated by CNC machining process. The material used here is Aluminum 7020 alloy, see in Figs. 1(b-h).

At the same time, the three VAWT models are also fabricated and then fabricated, and the material used here is the Aluminum 7020 alloy. The basic lighting loads are connected with the VAWT. The electrical indicators are monitored using electronic devices. The subsonic wind is chosen for testing purpose, see in Fig. 2a). As shown in in Fig. b), c), and d), the VAWT systems are kept inside the wind tunnel and the experiment was conducted. While conducting the experiment, the reading were noted and by using Eq 1. wind speed is estimated .

$$W_s = \sqrt{\frac{\rho_{fluid}}{\rho_{air}} \times 2 \times g \times (h_2 - h_1)} \qquad (1)$$

where, W_s is the wind speed in m/s; ρ_{fluid} is the density of the fluid used in manometer; ρ_{air} is the air density; g is the gravitational force; h_1 and h_2 are the manometers height difference

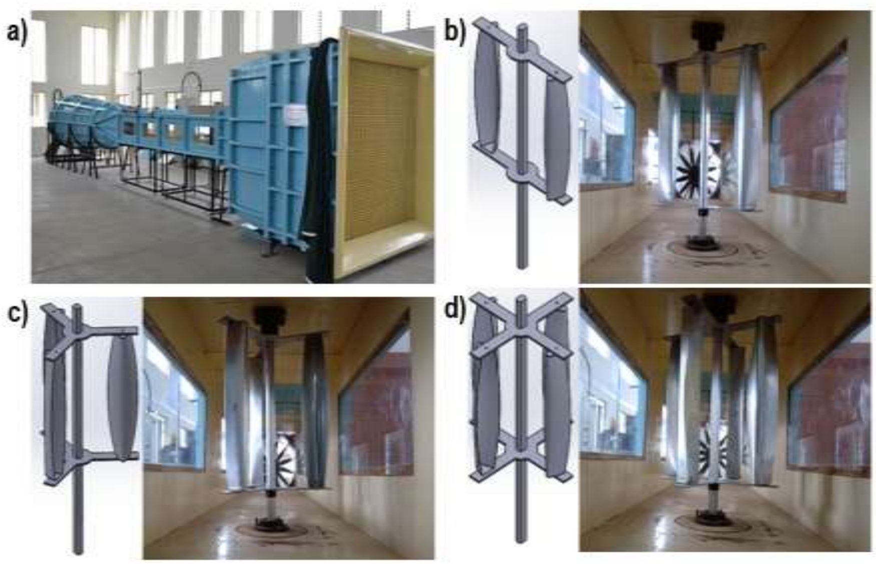

Figure 2a). Subsonic wind tunnel with bell mouthed inlet; b). Ducted VAWT with 2 blade configuration; c). Ducted VAWT with 3 blade configuration; d). Ducted VAWT with 4 blade configuration;

3 Results

The results obtained from the experiments conducted on ducted VAWT with 2, 3 and 4 blade configurations are presented in this section. The theoretical power available in the wind for varying wind speeds is shown in Figs. 3.a). The tip-speed ratios with varying wind speeds are presented in Fig. 3 b). The variation of TSR for 2, 3, and 4 blade combination wind turbines is almost linear in nature with a variation of wind velocity. The TSR of the 2-blade based VAWT is observed quite high when compared to 3 and 4-blade based model. For the VAWTs, the electrical indicators for varying wind speeds are shown in Figs. 3.c) and d). The variation in observed output currents is shown in Fig. 3.c). 4- bladed VAWT is producing more current than 2 and 3-bladed VAWT for varying wind speeds. The voltage variation with respect to varying wind speeds is shown in Fig. 3 d). 2- bladed VAWT is producing more voltage than 3 and 4-bladed VAWT for varying wind speeds.

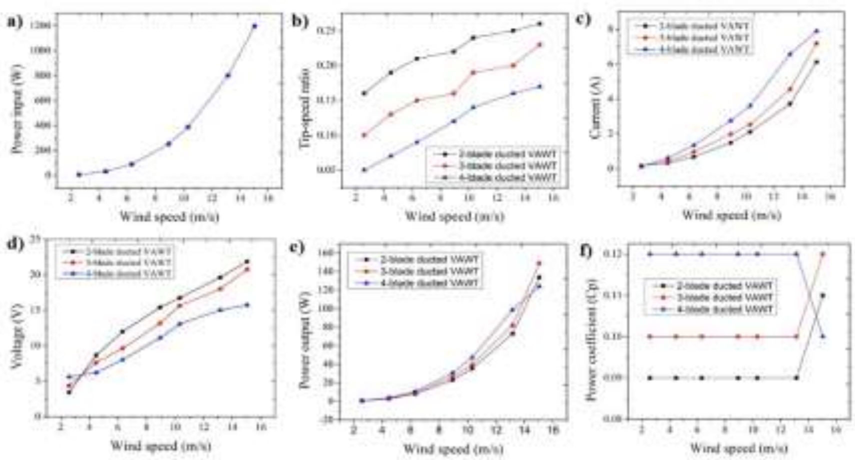

Figure 3 a). Power available in the wind; b). Tip-speed ratio; c). Current output; d). Voltage output; e). Power outputs of different VAWTs; f). power coefficient of different VAWTs.

In Fig. 3. e), variation observed in the power outputs from the three different VAWTs are presented. 4-blade combination is producing more power than 2-blade and 3-blade combination wind turbines. 2-blade combination is producing less power than 3-blade and 4-blade combination wind turbines. The variation of power for 2, 3, and 4-blade combination wind turbine is parabolic in nature with the variation of wind velocity. The power coefficient for the VAWTs is calculated and presented in Fig. 3. f). 4-blade combination co-efficient of performance is more than 2 and 3 blade combinations up to 13.16 m/s; after 13.16 m/s, the performance of the turbine is falling below that of 2 and 3 blade combinations. 2-blade combination co-efficient of performance is less than 3 and 4 blade combination up to 13.16 m/s, after 13.16 m/s 3 blades are performing better than 2 and 4 blade combination wind turbines.

4 Conclusion

A scaled models of the ducted VAWT with different blade configurations are designed, modeled, fabricated. The experimental test were conducted in the subsonic wind tunnel. While experimentation, varying wind speeds are considered. Following conclusions were made from preliminary research; as the number of blades increased there is rise in the net power output up to certain wind speeds and later reduced. With wind speeds greater than 13.16 m/s the 3-blade based ducted type VAWT performs and resulted as an optimum configuration. Based on the investigations carried out in this study, it can be concluded that, the ducted type VAWT, with 3-blades can be used for power generation.

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Biographies

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Gadudasu Babu Rao has more than 18 years of teaching and research experience in Mechanical Engineering in Automation and Manufacturing. He has carried out research sponsored projects like Harvard Medical School, Boston, USA and published several research papers through reputed journals and international conferences. His research interest areas are medical devices, mechatronics, energy and material engineering.