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Design of Wind Nozzle for Nozzle Augmented Wind Turbine

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ABSTRACT

In some countries, wind turbines are designed to operate at relatively high speeds to be appropriately efficient, limiting the use of wind turbines in urban areas with low wind speeds. Thus, innovation is needed to enhance the possibility of wind energy use within the range of low speeds. In order to increase the electrical power of the wind turbines, the velocity of the wind blowing on the wind turbine, is the most important factor that has to increase. In this paper it has been recommended that contraction nozzles could be applied between Wind Turbines and wind-way to provide the wind through themselves with more velocity. The main objective of this research is to optimize the nozzle design for vertical axis wind turbine (VAWT). Specifically, this study investigates the effect of wind velocity on different shapes of nozzle to develop the suitable nozzle for the wind turbine. For that purpose, the ideologies of contraction nozzle have been studied. Different nozzle design concepts were developed and the wind speed for each design is simulated.

1. Introduction

The development and application of renewable, clean energy have become an important issue in recent years due to the serious effects of global warming and rapid depletion of fossil fuels. In order to address the current energy crisis various means of alternative energy are being evaluated [1]. Wind energy technologies have become one of the fastest growing energy sources in the world and it symbolizes a feasible alternative, as it is a virtually endless resource. However, in comparison with the overall demand for energy, the scale of wind power usage is still very meager. As for the reasons various causes are possible including cost [2]. Therefore, the introduction of a new wind power system that can produce higher power output even in areas where lower wind speeds are expected would be cost effective. Also in conventional wind turbine the air flow is slowed down and widened. This effect causes a loss in the efficiency of the turbine. By creating a field of low pressure behind the turbine, that effect reduced and the corresponding loss in efficiency can be avoided [3].

The power from wind can be augmented by different innovative concepts have been proposed to augment wind turbine power output including the counter-rotation technique [4, 5]. Performance

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of wind turbines can be improved by various ways such as modification of blades design, the augmentation attempts by application of tip vanes on the rotor blades, vortex type augmentation devices and ducted wind turbine by shrouds, concentrators or diffusers. Most of the research show that the Diffuser Augmented Wind Turbine (DAWT) exhibits advantages compared to other augmentation solutions [6], where the concept of DAWT is introduced to increase the power by enclosing the turbine with a duct (shroud). Hence, one of the most promising concepts in the wind energy field is the development of wind power nozzle systems. Wind power generation in wind turbine is directly proportional to the wind speed served. Therefore, a large increase in output is brought about if it is possible to create even a slight increase in the velocity of the impending wind to a wind turbine [7, 8]. If we can increase the wind speed by exploiting the fluid dynamic nature around a structure or topography, the power output of a wind turbine can be increased substantially. In conventional wind turbine the wind speed served from the location is directly used to generate power. In nozzle system, the available wind speed is increased by the nozzle to generate high power output. Currently very few studies have been reported the effect of nozzle shape in wind speed using computational simulations.

Therefore, the development of a wind power system with high output and low cost aims at determining how to collect the wind energy and wind velocity efficiently and what kind of nozzle design can generate energy effectively from the wind speed. The aim of this work is to develop and design a new wind contraction nozzle that can collect and accelerate the wind approaching better.

2. Wind Nozzle Design

The proposed method of improving turbine efficiency is to put a duct around the turbine, often termed as Nozzle Augmented Wind Turbine (NAWT), an improvement to the conventional Vertical Axis Wind Turbine (VAWT). NAWTs employ a duct around the VAWT that decreases in the area as it extends after. The purpose is to increase the mass flow through the blades and hence increase the power extracted for a given rotor size [9, 10]. The wind nozzle concept is a ducted rotor design. The current configuration utilizes a nozzle to increase the power produced by an open rotor turbine. This concept combines several concepts into a functionally attractive design to eliminate the need for higher wind velocity and larger height. This design improves efficiency by accelerating the wind through turbine blades and carries more dynamic energy. One such method of improving turbine efficiency is a nozzle augmented wind turbine (NAWT) as an improvement to the conventional vertical axis wind turbine (VAWT). A nozzle augmented wind turbine (NAWT) has a bucket-shaped duct that surrounds the wind turbine blades and this enhances the turbine to run more efficiently than traditional open-bladed systems by extracting more energy from the wind. In nozzle type arrangement the inlet diameter is larger than the outlet diameter; due to this the air velocity at the inlet is low. When it comes to the outlet, the velocity gets increased due to a reduction of area, at the same time air starts to flow in all directions. In order to bring the air in the horizontal direction cylinder is connected at the outlet side of the nozzle. So, the air is concentrated to the narrow path of the cylinder with increased velocity [11, 12].

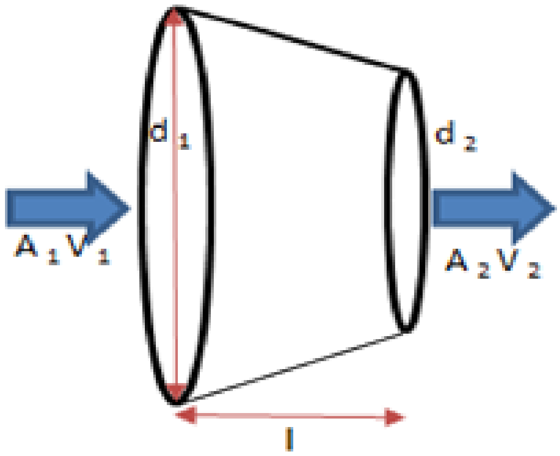

Fig. 1. Schematic diagram of a contraction nozzle

In nozzle type wind turbines this principle is used to increase the wind velocity. From Figure 1, the velocity of air at the inlet is V1. This wind is concentrated to the cylinder with a velocity of V2. Due to the Bernoulli's principle velocity of air at the cylinder is greater than the inlet velocity (V1) by using nozzle type wind turbines. The diameter of the nozzle of its inlet is D1; Diameter of the cylinder at its outlet is D2. Length of the nozzle and is l. In case of conventional wind mills, blades are directly driven by wind. When wind velocity decreases the blade speed also decreases. This decrease in the blade speed is insufficient to produce power but in nozzle type wind mills the velocity of the air is increased by the nozzle and it operates at low wind velocity also. So we can generate power even at low wind speed. Studies on NAWT showed that a sucking effect can be produced according to the Bernoulli's principle and this significantly increases the wind speed inside the duct and also substantially enhances the efficiency of the wind turbine. NAWT equipped with an aerodynamically designed nozzle demonstrated power augmentation for a given turbine diameter and wind speed by a factor of about 5–6 is compared to standard micro wind turbine. This NAWT design is also safer due to the shroud with no lunar or solar flicker, blade/ice throw and is avoidable to birds and bats. Even more attractive is the potential for operational flexibility afforded by the nozzle, enabling the useful power generation at lower and higher wind velocities, and simpler control features.

Through this study three different concepts for nozzle design have been developed as shown in Figure 2, Figure 3 and Figure 4 and flow simulations were performed to find wind velocity for different nozzle. The material used for the design is composite. Discontinuous reinforcements in the form of whiskers, platelets and ceramic particles are used in the aluminium matrix composites, which are very familiar materials and are mostly used in the case of aerospace and structural applications. These are very useful with their increased mechanical and surface properties, compared to non-reinforced metallic matrices. This improvement obtained without increasing in weight and having higher strength to weight ratio [13].

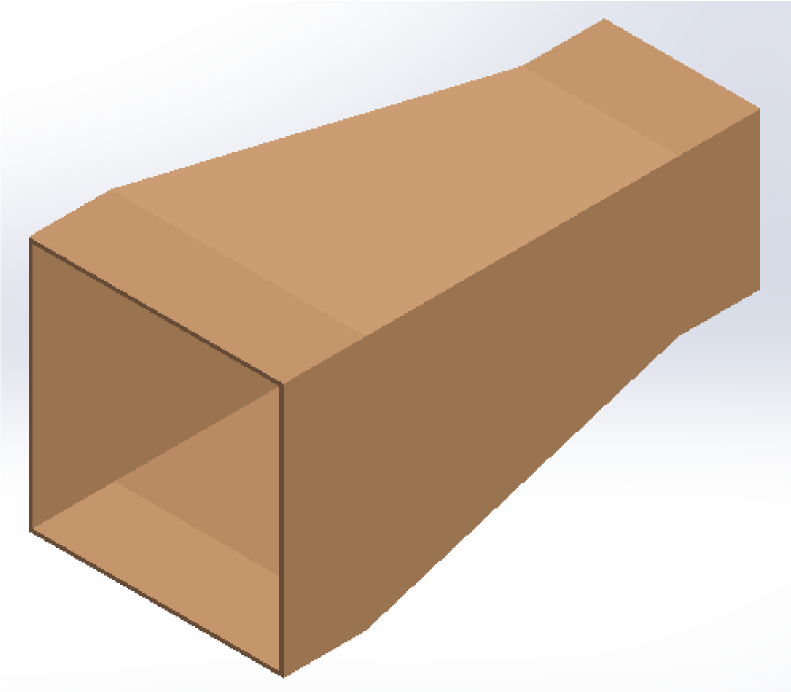

Fig. 2. Design of nozzle 1

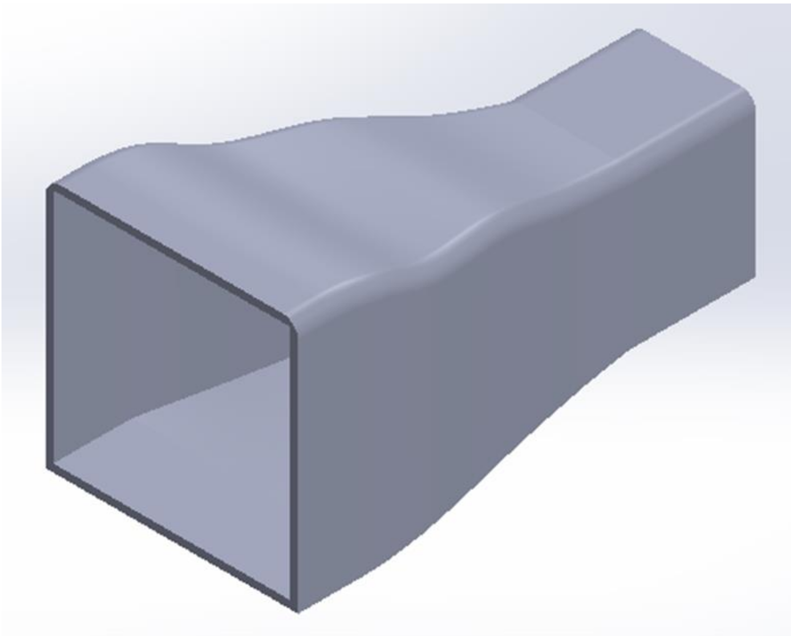

Fig. 3. Design of nozzle 2

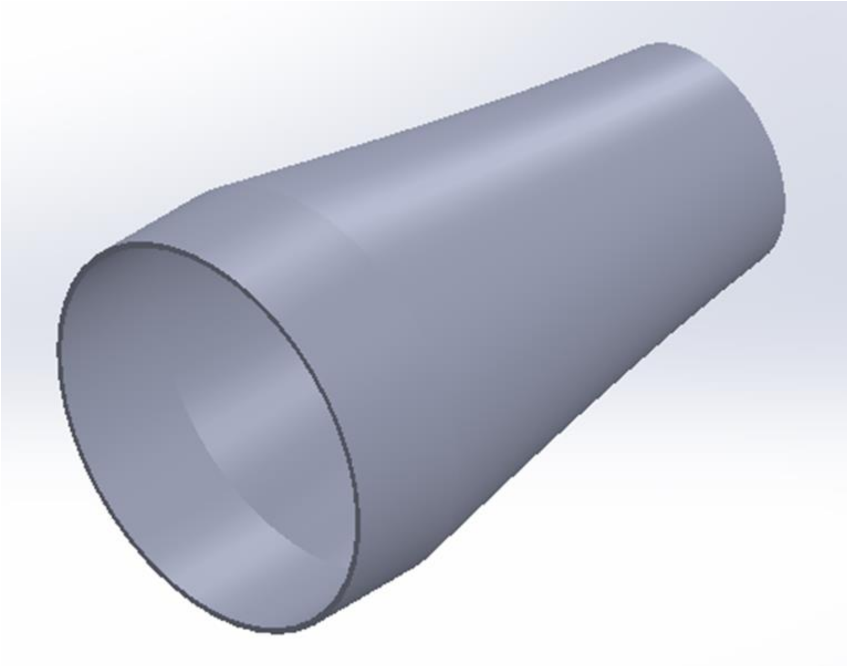

Fig. 4. Design of nozzle 3

3. Flow Analysis of Nozzle Design

The flow analysis was simulated to observe the outlet wind velocity for three nozzle design. To achieve very authentic results by the simulation, the mesh type of mesh considered was a structured one which has identical elements and nodes. Also, for the excellent results, the mesh must be refined manually using the size of the element by applying some element division. To develop a complete grid structured the converging length, throat location, diverging part, and the enlarged duct sections of the nozzle are divided in a different part, and every part meshes separately [14]. Aerodynamic optimization has provided a suitable tool for all aerodynamic designs used in the design of aircraft, cars, trains, bridges, wind turbines, flow inside pipes, cavities, etc. Due to the issues of reducing fuel consumption and controlling the harmful effects on the environment, it is necessary to choose the best aerodynamic shape for. CFD methods provide tools for the optimization of such configurations [15].

Figure 5, Figure 6 and Figure 7 showed the streamline velocity across the nozzle. It was observed that similar trend was shown in the analysis of the nozzle designs. Nozzle 1 showed that the wind velocity was increased to 0.4 m/s while nozzle 2 and 3 were increased to 1.2 m/s and 0.7 m/s respectively. In all the three cases which are nozzle 1, nozzle 2 and nozzle 3, it is observed that the velocity at the nozzle exit is always higher than the inlet.

As the inlet velocity of the wind increases, the outlet velocity is also increased proportionately. Design of nozzle 2 has higher outlet wind velocity compared to design of nozzle 1 and nozzle 3. The pressure at the inlet is higher, and it gradually decrease at the exit. By the conservation of energy, this loss in pressure is converted into kinetic energy, where the speed of the air is increased at the exit.

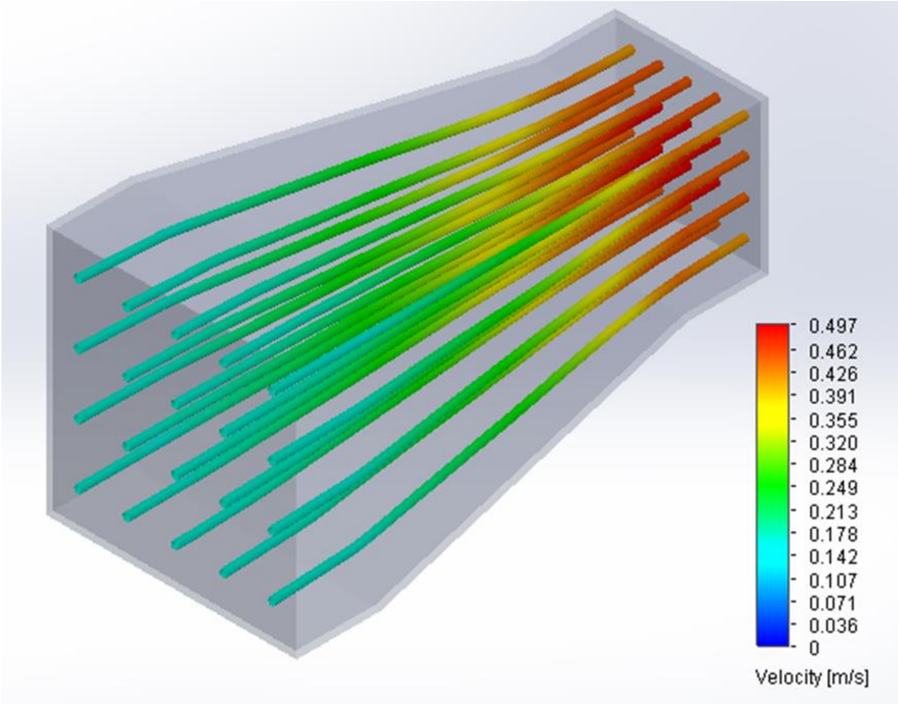

Fig. 5. Flow analysis for nozzle 1

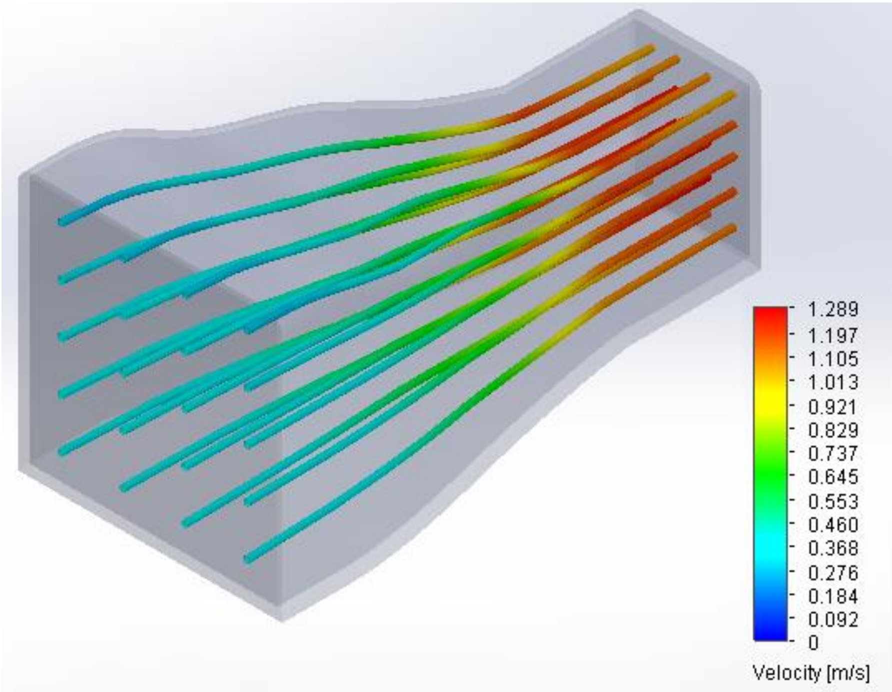

Fig. 6. Flow analysis for nozzle 2

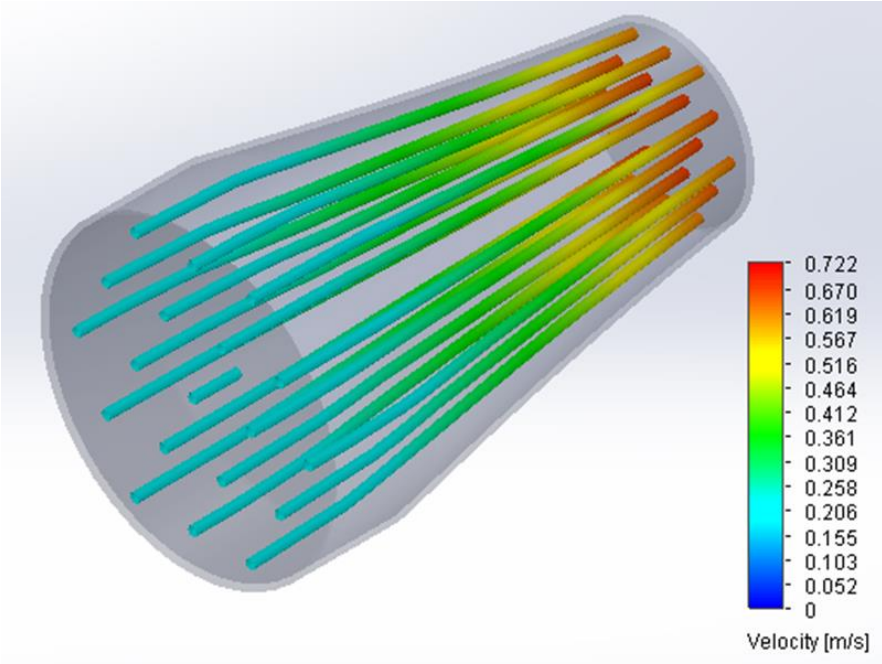

Fig. 7. Flow analysis for nozzle 3

4. Conclusions

The Nozzle Augmented system has been reported to have a greater efficiency than the VAWTs based on the structural design. The above results show the performance of the nozzle augmented wind turbine for wind velocity. Thus, it is clear from the results and discussion that the proposed system can generate more power at the lower wind velocity than the conventional vertical axis wind turbine. In nozzle augmented system, the output power depends upon the design of the nozzle and the wind flow at the inlet. Hence, if the nozzle is designed for a larger diameter, it is possible to generate more power. The nozzle augmented system works effectively where the wind velocity is even. In future with the help of large nozzle and standard ratings of alternator the nozzle augmented system can be mounted to generate more power than the conventional systems.

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