Design and Analysis of Wind Turbine Diffuser Shroud

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Abstract— to fulfill the energy need and face the upcoming energy crisis, there is a need for researching new and innovative systems. Thus to improve the efficiency of wind turbines for the areas having low wind velocities in India, the Shrouding (diffuser augmented) for small wind turbines has been shown to be an effective way to potentially improve the efficiency of small wind turbines for applications in built environments. The degree of the performance improvement depends on several factors including the diffuser shape and geometries, blade airfoils, and the wind condition at the mounting site. The effect of diffuser shape and geometries is reported in this work. Performance of the diffuser investigated with straight diffuser, nozzle-diffuser combination and flanged diffuser. This work aims to investigate the effect of wind velocity on various diffuser shapes and the diffuser geometrical parameters: diffuser lengths (L/D = 0.75 to 1.25) and flange heights (H/D = 0 to 0.25). Various diffuser designs are developed in Creo and simulated in Computational Fluid Dynamics (CFD) for low wind velocity. The diffuser shroud improves the performance by 60% as compared to the turbine without shroud and with the nozzle-diffuser with flange 72.5% which is slightly better than diffuser only.

Keywords: diffuser shroud, CFD fluent, wind speed

I. Introduction

Wind power generation is proportional to the wind speed cubed [1]. If we can increase wind speed in some way by using the fluid dynamic nature around a structure or migration, that is, if we can capture and concentrate wind energy locally, the output energy of the wind turbine can be greatly increased. This facilitates us to utilize power in a more efficient way. One such method is the flanged diffuser concept, which is discussed in this thesis. It is also applied to the turbine being studied, and is seen to aid significantly in the generation of power. The flange causes the creation of vortices behind itself, which gives rise to a low pressure region. This low pressure region is responsible for drawing in more flow and thus increasing the net mass flow into the turbine.

Hence the motivation behind the research conducted is to find a viable way to generate electricity at the site of usage. It is also extremely vital to shepherd the design process towards a turbine that can consistently produce electricity at low wind speeds, with good efficiency.

II. Objective of this Work

A. To implement the flanged diffuser concept and increase the mass flow into the turbine

The ultimate goal of this work is to first optimize a shroud design and then demonstrate through scaled model testing that the shroud design can increase both the duration for which a small wind turbine can be effectively used at peak efficiency and its total operating time.

By making a proper assessment of the geometry of diffuser shroud, the flow in the turbine can be significantly increased. Using this, the power coefficient of the turbine can be improved greatly. Wind turbines have a specified wind speed operating range at which they produce energy at higher efficiencies. A successful diffuser shroud prototype accelerates incoming wind by inserting a nozzle / diffuser shroud mounted on the turbine to improve wind flow circulation. Specifically, the shroud increases wind speeds through the turbine, is structurally sound, and minimizes drag. Feedback from faculty advisors and other qualified professionals was incorporated throughout the process.

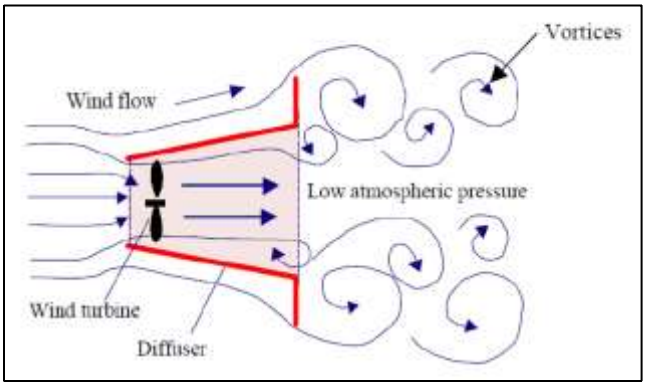
B. To use the CFD tool efficiently

It is necessary to properly understand the various parameters relevant to the analyses that will be conducted. This includes meshing strategy, boundary conditions, type of solver etc. Each of the parameters must be accurate and pertinent to the study being conducted. This must also be validated. The design approach consists of:

1) The development of a 3D CAD (computer aided design) model of the shroud.
2) Testing using CFD (computational fluid dynamic) modeling to provide information about the wind speed through the turbine.

III. Research Methodology

The concept of diffuser is the power output of a wind turbine increases by accelerating the wind velocity approaching the wind turbine. To increase the wind speed, a lower pressure would appear at the back of the wind turbine which acts as a vacuum to suck the wind and accelerate it towards the blades as shown in Fig.4. The region of areas surrounding or near the vortex would have typically lower pressure where the suction force will be formed by the vortex. Therefore, a diffuser acts as an accelerator to accelerate the wind speed approaching the wind turbine. It was stated that the vortex core will collapse the pressure field flow reversal and therefore no augmentation occurs [2]. This statement represents an alternative approach, where Vortex is used to create a low pressure region in the event of a turbine. Vortex should appear at the wake of the diffuser but as little as possible inside the diffuser wall.



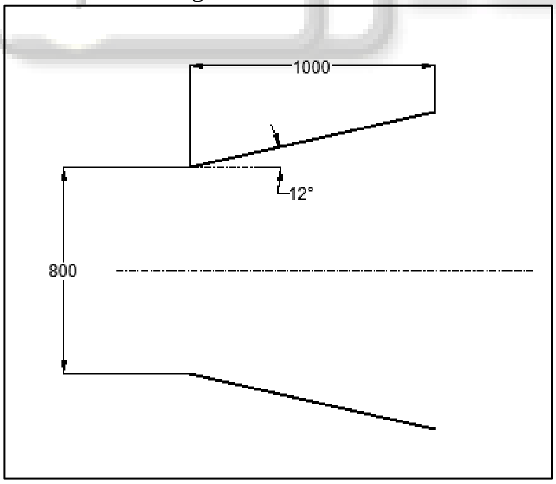
Schematic Cross-Sectional View of a Flanged Diffuser and Wind Speed Increasing Flow Mechanism [3].

If vertices form inside the diffuser, the pressure inside the diffuser may be lower than in the rear of the wind turbine. In this case, the diffuser amplifying wind will slow down the turbine's discharge or wind speed and will result in only a very small energy coefficient. To achieve optimal incremental acceleration at wind speed, the pressure in the wind turbine should not be less than the pressure at the wake of the diffuser. This can be achieved by reducing or avoiding separation of fluid flow on the inner diffuser wall and causing vortices while creating as many vortices as possible at the back [3].

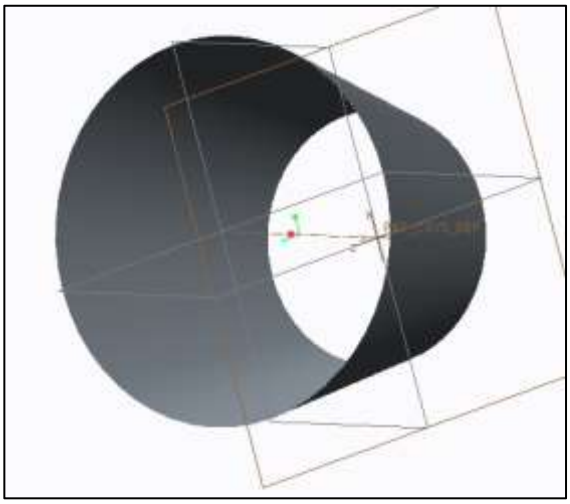
IV. DESIGN AND ANALYSIS

A. CAD Models

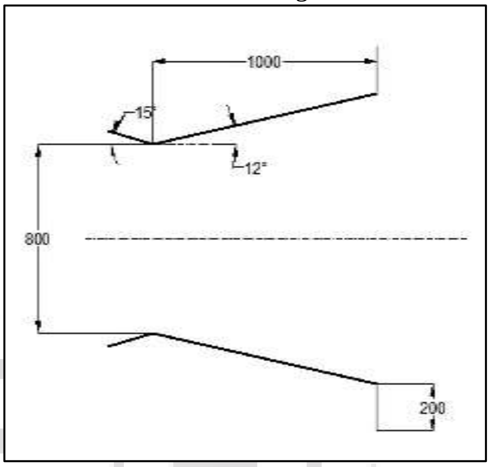
The CREO software is used to develop the basic 3D models of various types of diffuser like, Straight Diffuser, Straight Diffuser with flange and nozzle, and curved nozzle diffuser. These 3D models are created with suitable dimensions as given in schematic diagram.



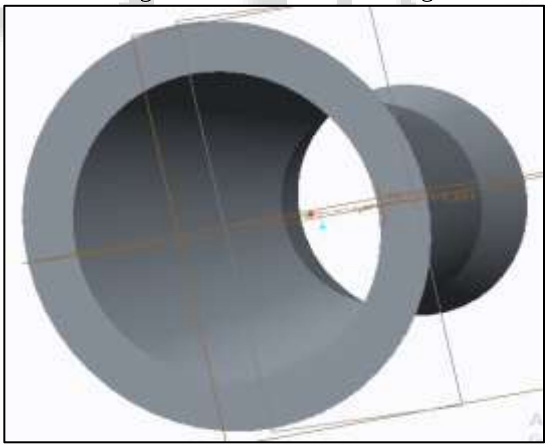
Schematic Diagram of Straight Diffuser



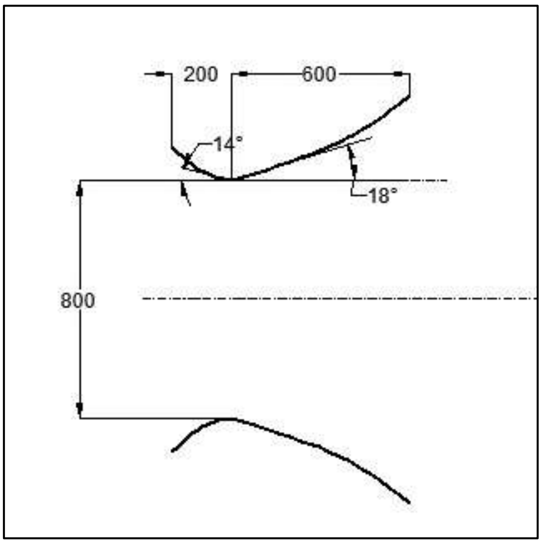
CREO model of Straight Diffuser



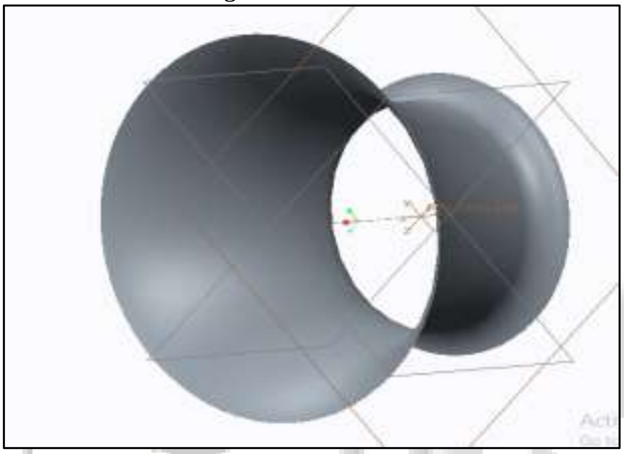
Schematic Diagram of Diffuser with flange and nozzle



CREO model of Diffuser with flange and nozzle



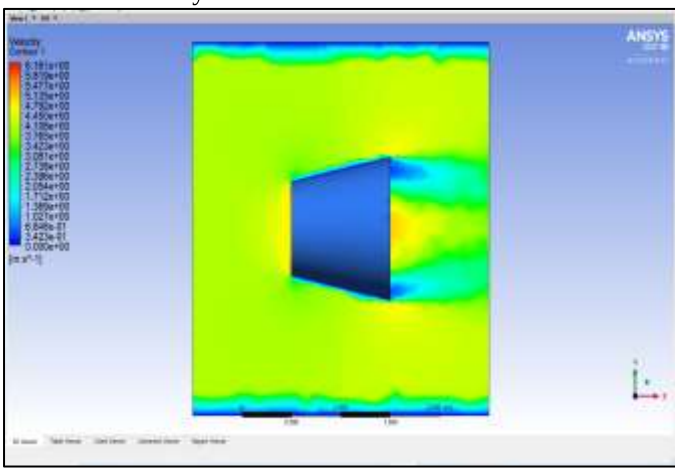
Schematic Diagram of Curved nozzle diffuser



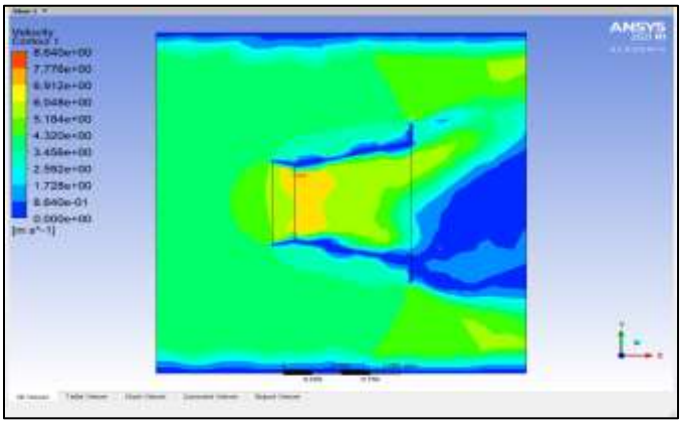
CREO model of Curved nozzle diffuser

B. Computational Fluid Dynamics Analysis

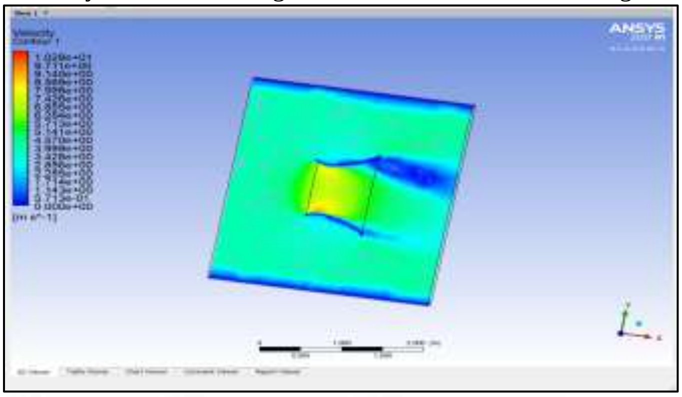
The above CAD models have tested by using CFD Fluent software in uniform wind speed of 4m/s. the following figures shows the Velocity contours of the three diffuser shroud.



Velocity contour of straight diffuser



Velocity contour of Straight diffuser with nozzle and flange



Velocity contour of curved nozzle diffuser

V. Result

Shroud Type	Inlet Velocity(m/s)	Outlet Velocity(m/s)
Straight Diffuser	4	5.13
Straight diffuser with nozzle and flange	4	6.91
curved nozzle, diffuser	4	8.56

VI. Conclusion

From the above result table this is concluded that when we apply the diffuser on a wind turbine, it will produce a lower pressure region behind the wind turbine. Due to this lower pressure region more mass flow rate is occurring. Also it will produce higher power output than a bare wind turbine. If we compare the diffuser without flange & diffuser with flange, it will show that diffuser with flange will produce more vortex. The above study reveals each aspect from each concept developed has perfection in diffuser efficiency and wind outlet velocity. A remarkable 8.56 m/s wind velocity with 2.14augmentations was obtained using a curved nozzle diffuser.

VII. Reference

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