Available online: www.ijsrmes.com

International Journal for Scientific Research in Modern Engineering and Science

International Journal for Scientific Research in Modern Engineering and Science, 1(6): 10–14 (2020)

Computation Fluid Flow Analysis and Effect of The Performance of Vertical Axis Savonius Wind Turbine

Rohit Pandey[1]*, Abhishek Singh[2]

[1]*M. Tech. Scholar, Department of Mechanical Engineering, SSTC-SSGI, Bhilai (C.G.)*
[2]*Assistant Professor, SSTC-SSGI, Bhilai, Bhilai (C.G.)*

Abstract

The demand for wind energy as a renewable source is rising substantially. A growing interest exists in utilizing potential energy conversion applications in areas with less powerful and less consistent wind conditions. In these areas, vertical-axis wind turbines (VAWTs) possess several advantages over the conventional horizontal-axis type. Savonius turbines are drag-based rotors which operate due to a pressure difference between the advancing and retreating blades. These turbines are simpler in design, less expensive to install, non-dependent of wind direction, and more efficient in lower wind speeds. In the present work, four different number of rotor blade designs with equal swept areas are analyzed with numerical simulations. The models were designed using the CAD software Creo Parametric and for the numerical approach, Ansys Fluent 3D simulations were used for analyzing performance of wind turbine. The main objective of this work was to obtain the effect of power, torque, lift and drag coefficient with different tip speed ratios (TSR) at constant height of blade 0.5m. First, the speed of wind inlet is varied from 5 – 10 m/s and fixed rotor speed 500 rpm; Secondly, wind inlet is fixed at 5 m/s and rotor speed is varied in range from 500 – 700 rpm and achieved the results. Also, to achieve the accuracy of the results, a grid independence test is employed.

Keywords: *CFD Analysis; Savonius Wind Turbine, Torque Coefficient; Power Coefficient.*

** Corresponding author*

1. Introduction

Some countries are flourishing due to the development of wind energy, while in others it is not meeting the capacity that can be inferred from a simple idea of wind resource, are complex. Important factors include financial support mechanisms for wind-produced electricity, by which local planning authorities allow the construction of wind farms, and the perception of the general population, particularly in relation to visual effects. To address the concerns of rural people about the environmental impact of wind farms, there is now increasing interest in developing offshore sites. The windmills in use today are made of galvanized steel. The improved design incorporates a hull, which balances the wheel on an axle to capture wind from any direction and optimize wind force. Windmills are a cheap source of energy and are used to irrigate fields or provide water for animals on grasslands.

The first wind mill to drive an electrical generator was built by P. LaCour of Denmark late in the 19th century. After World War I, sails with air foil cross sections (like the blades of an air plane propeller) were developed for use in windmills the result was what is now called the propeller type wind mill or wind turbine. In 1931, such a windmill was built in the Crimea and produced low voltage electricity that was fed directly into the local grid.

2. Methodology

Computational fluid dynamics is the most common way to construct a simulation on a built-in experiment model that represents real-world flow. This reduces the cost and time for practical setup. The purpose of this simulation is to estimate the pressure and momentum at the edges of concave and convex blade surfaces. Initially, the main objectives of the experiment should be established. Then the flow must be given. The boundary specimen should be built around the test specimen. Flow is controlled within the boundary layer. The pressure flow indicates the distribution of the pressure rate on the surface of the rotating blade.

Table 1. Specification of the Savonius rotor blade wind turbine

Parameters	Unite	Value
Height of the rotor (H)	m	0.5
Diameter of the turbine (D_t)	m	0.9023
Diameter of the blade (d)	m	0.5
Density of the air (ρ)	Kg/m^3	1.225
Reynolds number (Re)	-	4.32×10^5
Inlet velocity (u)	m/s	5, 6, 7, 8, 9, 10
Angular rotor speed (n)	rpm	500, 550, 600, 650, 700
Number of blade (n)	-	2, 3, 4, 5

3. Results and Discussion

In this section, comprehensive discussions about the effect of flow field and performance characteristics of Savonius wind turbine with different velocity in the range from 5 – 10m/s, turbine speed range from 500 – 700 and number of blades 2 – 5 have been presented. For 3-D space, a 3-D model and for viscous models a k-ε (2 equa.), simulation has been required at a steady state with RNG turbulence model with a standard wall function condition has been considered for present models.

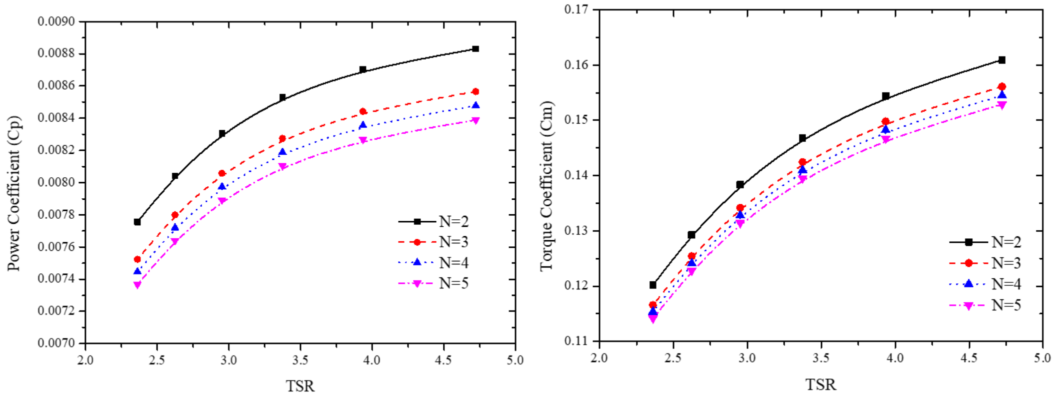

Figure 1. Effect of power and torque coefficient in variation of number of Savonius wind turbine as function of TSR (v= 5 – 10m/s) (at constant N=500rpm and H=0.5m)

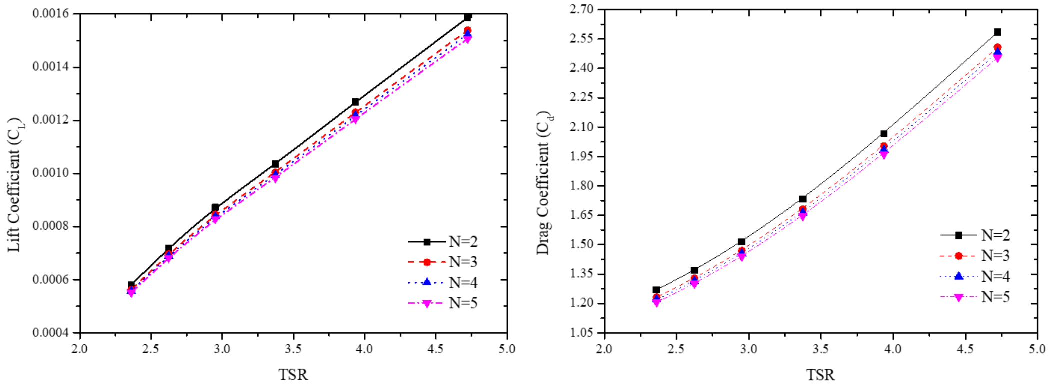

Figure 2. Effect of lift and drag Coefficient in number of Savonius wind turbine as function of TSR (v= 5 – 10m/s) (at constant N=500rpm and H=0.5m)

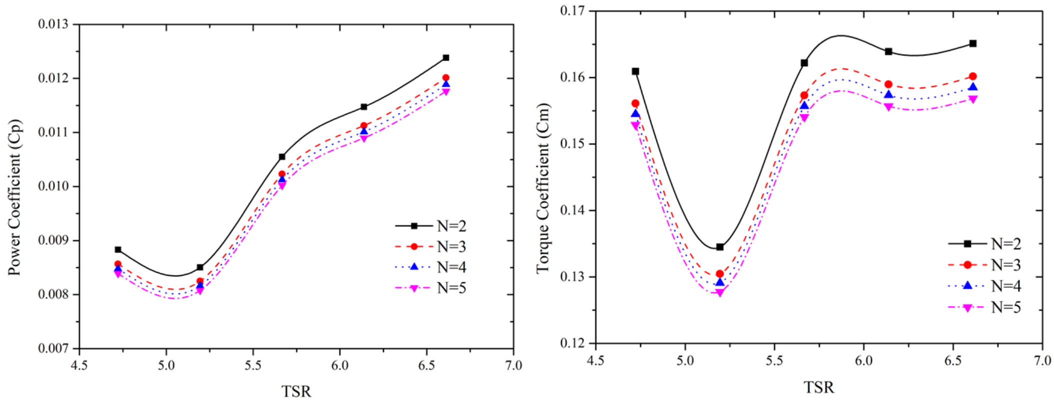

Figure 3. Effect of power and torque coefficient (C_p) in variation of number of Savonius wind turbine as function of TSR (v= 5m/s) (at N=500 – 700 rpm and H=0.5m)

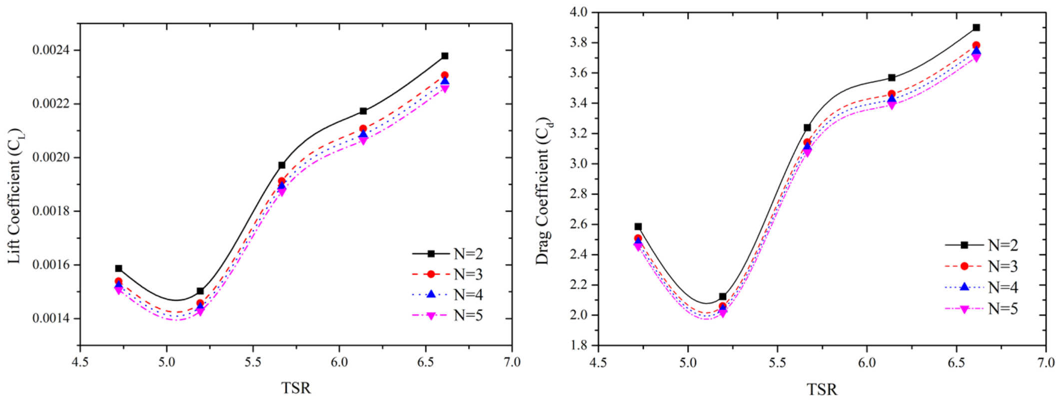

Figure 4. Effect of lift and drag coefficient (C_p) in variation of number of Savonius wind turbine as function of TSR (v= 5m/s) (at N=500 – 700 rpm and H=0.5m)

4. Conclusion

The conclusions obtained from the CFD simulation modeling and analysis are as follows:

- The novel part of the work refers to finite element analysis on the method of determining power coefficient, torque coefficient, lift coefficient and drag coefficient by the generated power, torque, blade speed and initial velocity of wind.
- Effect of power, torque, lift and drag coefficient with different tip speed ratios (TSR) at constant height of blade (H) is 0.5m. First, the speed of wind inlet is varied from 5 – 10 m/s and fixed rotor speed 500 rpm; Secondly, wind inlet is fixed at 5 m/s and rotor speed is varied in range from 500 – 700 rpm and achieved the results.
- Pressure gradient distributes over a higher area of the Savonius 2 and 3 – bladed rotor than in different cases, denoted that these two rotors are chosen to decrease stress on the blade and ensure an operation is stable of turbine
- Turbulence intensity is uniform distribution over blades in the cases of 2, 3 and 4–blade rotors, which is an advantage according to their operational efficiency.
- The 2-blade rotor has the highest values for drag force and torque, meaning that this type of rotor has the highest efficiency compared to others.
- The power coefficient, as the furthermost significant parameter that shows the efficiency of the wind turbine, has a higher value for the Savonius 2-blade rotor; the power coefficient for the 3-blade rotor is approximately half of the 2-blade rotor values. A number greater than 3 for a blade produces a dramatic decrease in the power coefficient. The values of power coefficient are affected, in the similar technique, the value of the power generated.
- The initial wind speed (5 m/sec) and blade speed (550 rpm) has the smallest values for a 2-bladed wind turbine, so accordingly, this turbine is best suited for use in the case of small wind speeds.
- Overall conclusion, it is recommended to use a Savonius 2-blade wind turbine instead of a Savonius wind turbine with a large number of blades

References

[1] Dobrev and F. Massouh, "CFD and PIV investigation of unsteady flow through Savonius wind turbine," Energy Procedia, vol. 6, pp. 711–720, 2011.

[2] S. Roy and U. K. Saha, "Computational study to assess the influence of overlap ratio on static torque characteristics of a vertical axis wind turbine," Procedia Eng., vol. 51, no. NUiCONE 2012, pp. 694–702, 2013.

[3] S. Brusca, R. Lanzafame, and M. Messina, "Design of a vertical-axis wind turbine: how the aspect ratio affects the turbine's performance," Int. J. Energy Environ. Eng., vol. 5, no. 4, pp. 333–340, 2014.

[4] R. D. Maldonado et al., "Design, simulation and construction of a Savonius wind rotor for subsidized houses in Mexico," Energy Procedia, vol. 57, pp. 691–697, 2014.

[5] M. Lates and R. Velicu, "Sustainable Energy in the Built Environment - Steps Towards nZEB," in Sustainable Energy in the Built Environment, 2014, pp. 403–415.

[6] B. S. Patil and H. R. Thakare, "Computational Fluid Dynamics Analysis of Wind Turbine Blade at Various Angles of Attack and Different Reynolds Number," Procedia Eng., vol. 127, pp. 1363–1369, 2015.

[7] Dhote and V. Bankar, "Design, Analysis and Fabrication of Savonius Vertical Axis Wind Turbine," Int. Res. J. Eng. Technol., vol. 02, no. 03, pp. 2048–2054, 2015.

[8] K. Suffer, R. Usubamatov, G. Quadir, and K. Ismail, "Modeling and numerical simulation of a vertical axis wind turbine having cavity vanes," in International Conference on Intelligent Systems, Modelling and Simulation, 2015, vol. 2015, pp. 479–484.

[9] M. Chowdhury, H. Akimoto, and Y. Hara, "Comparative CFD analysis of Vertical Axis Wind Turbine in upright and tilted configuration," Renew. Energy, vol. 85, pp. 327–337, 2016.

[10] S. C. Goh, S. R. Boopathy, C. Krishnaswami, and J. U. Schlüter, "Tow testing of Savonius wind turbine above a bluff body complemented by CFD simulation," Renew. Energy, vol. 87, pp. 332–345, 2016.

[11] K. A. Sunny and N. M. Kumar, "Vertical Axis Wind Turbine: Aerodynamic Modelling and its Testing in Wind Tunnel," Procedia Comput. Sci., vol. 93, pp. 1017–1023, 2016.

[12] Rezaeiha, I. Kalkman, and B. Blocken, "CFD simulation of a vertical axis wind turbine operating at a moderate tip speed ratio: Guidelines for minimum domain size and azimuthal increment," Renew. Energy, vol. 107, pp. 373–385, 2017.

[13] G. Ferrari, D. Federici, P. Schito, F. Inzoli, and R. Mereu, "CFD study of Savonius wind turbine: 3D model validation and parametric analysis," Renew. Energy, vol. 105, pp. 722–734, 2017.