CFD Analysis for computing Drag force on various types of blades for Vertical Axis Wind Turbine

Shubham Karhadkar[1], Sarvesh Kanetkar[2], Neel Pawar[3], Hardik Mistry[4]

[1,2,3,4] *Department of Mechanical Engineering, Dwarkadas J. Sanghvi College of Engineering, Mumbai, India*

Abstract – *The energy crisis is the concern that the world's demands on the limited natural resources, which are essential for power generation, are running down as the demands are on a raise. Wind as a source of energy is luring due to the fact that furl is free in this case. This paper focuses on aerodynamic design of Vertical Axis Wind turbine (VAWT) using geometrical models and simulation techniques for small scale turbines which can be used for domestic purposes. One of the critical factors of vertical axis wind turbines is low starting wind speed. Drag is the primary driving force in its working. Thus, it is necessary to have a maximum possible coefficient of drag, from an incoming stream of wind. The primary purpose was to select a blade design fulfilling this criterion. A conventional airfoil blade (EPPLER863 profile) was cut and one-fourth of the trailing edge was removed, and the airfoil was subjected to CFD fluent analysis. A higher drag force was achieved. Further analysis was done on a Lenz2 type turbine blade profile and the coefficient of drag and drag force was obtained.*

Key Words: CFD, Renewable Energy, VAWT, Airfoil

1. INTRODUCTION

VAWT has undoubtedly many advantages over Horizontal Axis Wind Turbine(HAWT) which makes it more convenient for installation in urban areas since it works efficiently in turbulent winds even when placed on low heights. They can harness power coming from any direction, owing to the fact that pitch and yawing are not much of a problem. However, this type of wind turbine is susceptible to high wind speeds. The main difference between VAWT and HAWT is driving force. The prior type is driven by horizontal drag component of wind force and the latter is driven by lift component of wind force. Here, this research is concentrated on vertical axis wind turbine, hence drag force, drag coefficient and pressure on various types of blades of wind turbine will be scrutinized.

Performance analysis to calculate drag force was conducted numerically on ANSYS Workbench version 16.0 for three aerodynamic blade profiles (EPPLER863, EPPLER863 with one fourth trailing edge removed, Lenz2) where the focal point of research was to study the drag force pertaining to the blades to obtain maximum at low wind speed. In this paper ingenious turbine blades were modelled using SolidWorks 3D modelling software. The material in use was aluminium and the analysis was done using k-epsilon model to obtain best possible results. The incoming velocity of air was assumed to be moderate to high and it was taken as 10 m/s for this analysis.

2. NUMERICAL MODELLING

ANSYS fluent has been used for complete analysis of airfoil blades. Using CFD simulation drag force and coefficient of drag for blades are predicted. The 3D geometry of blades has been created using preprocessor Design Modular. The control volume was created for all three blade profiles with specific boundary conditions of inlet velocity and outlet pressure. The control volume enclosure of 100mm box shape and uniform cushion was used for all the three cases. The inlet velocity was fixed on the one face of enclosure to the value of V= 10 m/s and the static outlet pressure was set to 0 gauge on the opposite face of the enclosure. Abiding by these boundary conditions, further the analysis was carried out. To generate more accurate results, 'fine' quality of meshing with high degree of smoothing was used.

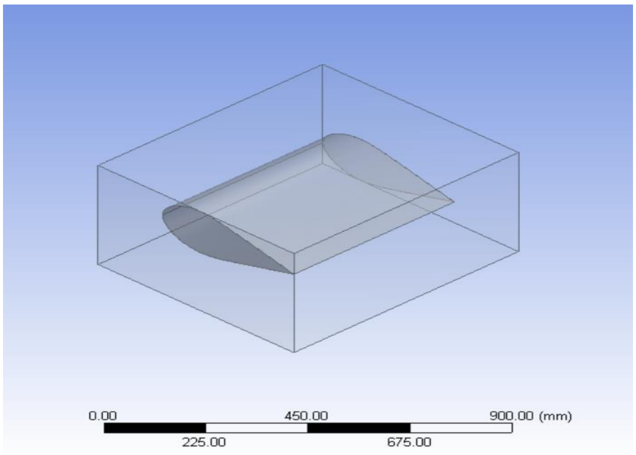


Figure 1. Airfoil blade placed in an Enclosure

3. AERODYNAMICS OF BLADE

As the blade of VAWT rotates it is acted upon by two components of wind force namely lift component which is vertical component and drag component which is horizontal component of wind force. Both the components of incident wind force are mutually perpendicular. While lift is the major component driving HAWT, drag does the needful in this case of VAWT. Drag force is the main driving force for Vertical Axis Wind Turbines, which depends on the shape of the object and it increases with the area facing the wind. The drag force also depends on the density of air and increases with the square of velocity of incoming air.

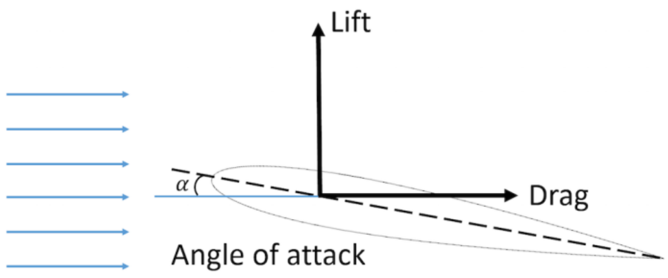


Figure 2. lift and drag components of airfoil

3.1 Lift Force

The lift force is given by the formula,

$$F_L = \frac{1}{2} \varrho A V^2 C_L$$

Where,
C_L = Coefficient of lift
ϱ = Density of air taken as 1.22 kg/m^2
A = Area of blade facing the wind
V = velocity of air taken as 10 m/s in this case

3.2 Drag Force

The lift force is given by the formula,

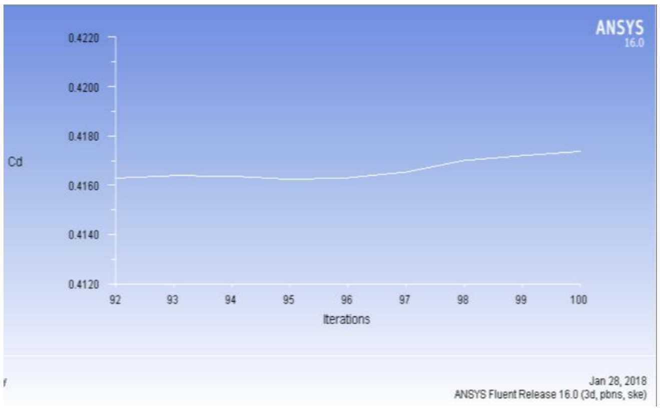
$$F_D = \frac{1}{2} \varrho A V^2 C_D$$

Where,
C_D= Coefficient of drag
ϱ = Density of air taken as 1.22 kg/m^2
A = Area of blade facing the wind
V = velocity of air taken as 10 m/s in this case

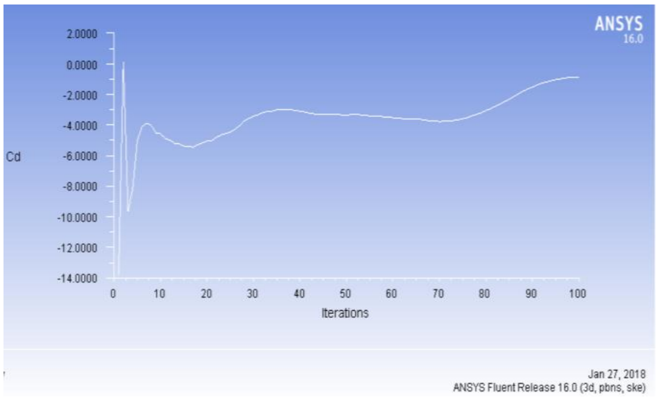
Referring to the above equations, it can be inferred that the only values subject to significant manipulation are coefficients of lift and drag as density of air and surface area of aerodynamic blades are constants and velocity of incoming air will not vary significantly under normal conditions. That is why, to increase drag force significantly, we must increase the value of drag coefficient(C_D).

Since VAWT runs on drag component of the wind force, which in turn depends on the drag coefficient. Usually, the values of coefficient of drag(C_D) for airfoils lie between 0.2-0.5. But for the urban areas, where average wind speeds are in the range of 6m/s to 10 m/s, we need larger values of C_D. During this research to achieve those values, first EPPLER863 airfoil profile was modified and then standard profile of Lenz turbine was tested. Coefficients of drag for all three profiles were iterated several times to make sure that results obtained were accurate.

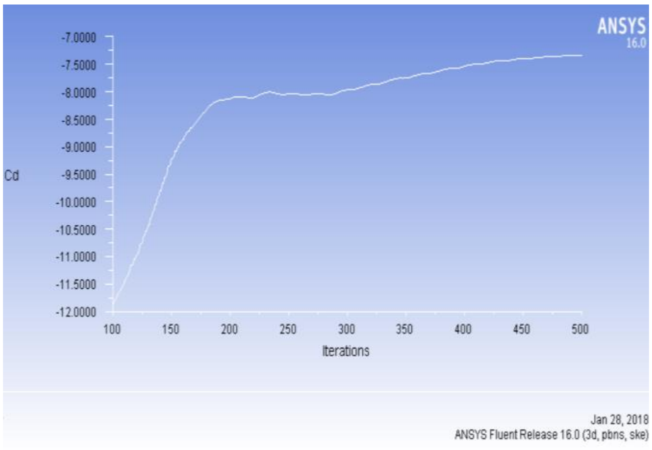
Following are the graphs obtained on ANSYS fluent for three above mentioned profiles. Horizontal X-axis represents number of iterations and vertical Y-axis represents coefficient of drag (C_D) in all graphs.



Graph 1. Iterations of drag coefficient for profile EPPLER863



Graph 2. Iterations of drag coefficient for profile EPPLER863 with one fourth trailing edge removed

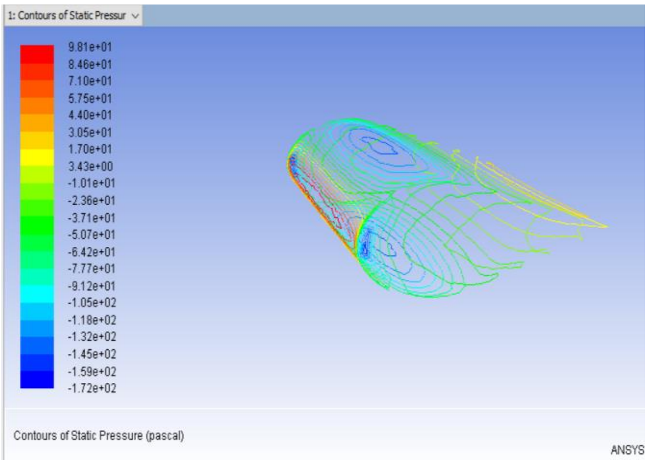


Graph 3. Iterations of drag coefficient for profile Lenz2

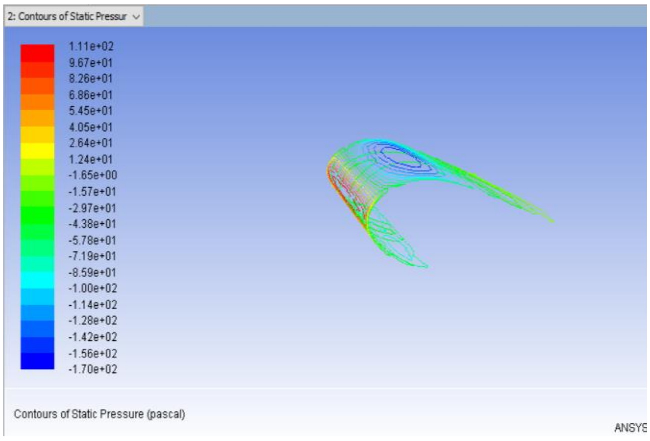
The above graphs demonstrate iterations of C_D which clearly show that coefficient of drag is positive first case, while it is negative for other two cases. In Lenz2 profile negative coefficient of drag was maximum.

3.3 Static Pressure Contours

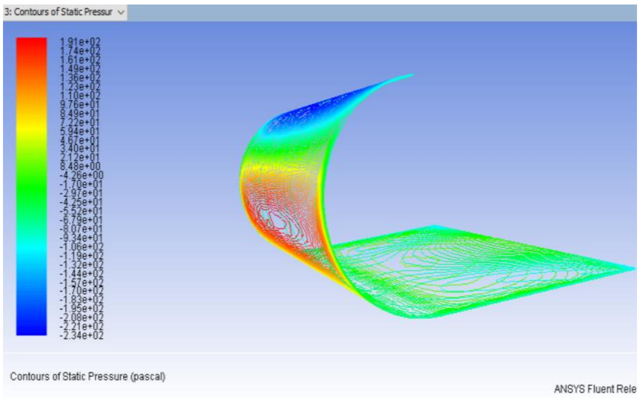
The pressure variations along the profiles of blades are given in the graphics below.



Contour 1. Static pressure variation for profile EPPLER863



Contour 2. Static pressure variation for profile EPPLER863 with one fourth trailing edge removed



Contour 3. Static pressure variation for profile Lenz2

In above contours unit of pressure was pascal. As illustrated by above contours, the leading edge bears the maximum pressure and least pressure was observed on trailing edge in all three cases. Due to the pressure difference on the leading and trailing edge of an airfoil, lift is generated which helps in the motion of turbine.

4. RESULTS AND DISCUSSIONS

After all boundary conditions are applied and the solution is complete, findings of the research suggest that the drag force was maximum for Lenz2 Turbine Blade, thus making it the most suitable option for VAWT installations in urban areas having low to moderate wind speed in the range of 6 m/s to 10 m/s.

PROFILE	EPPLER863	EPPLER863 with one fourth trailing edge removed	LENZ2
DRAG FORCE (N)	1.2	3.557	11.21
DRAG COEFFICIENT (C_D)	0.41	-1.5	-7.5

It is evident that the modifications done to the original EPPLER863 profile were successful, but the profile used in Lenz2 turbine is proven to the best profile among the three to be used when low starting speeds are necessary.

From the C_D graphs, it is evident that while designing VAWT for urban areas, it is desirable to have a negative coefficient of drag as it helps the wind turbine to accelerate.

3. CONCLUSIONS

Three profiles of innovative Vertical Axis Wind Turbine blades have been modelled in SolidWorks and computational fluid dynamics analysis has been done in ANSYS fluent.

The values of drag coefficients, drag forces have been calculated and contours of pressure distribution for each profile has been shown. It is concluded that:

1) Pressure is maximum on the leading edge and it is minimum on the trailing edge for all profiles.

2) Lenz2 profile generated maximum drag force (11.2 newtons) amongst all three tested profiles. Thus, for installations in urban areas, Vertical Axis Wind Turbine with the blade profile of Lenz2 is the best option.

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