Windmill Blade Design & Analysis

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Abstract— The world vision for the renewable energy resources and its utilization is increasing day-by-day. As a result, researchers in the area of renewable energy resources also in increased especially in the area of wind energy. By 2030 every major country of the world is on a vision to utilize wind energy by 35% for their electrical needs. Many types of challenges are faced in the construction of wind power units such as topology, geography, engineering challenges, etc. In order to achieve the world vision for wind energy and to provide electricity even for remote areas, this paper aims at developing the windmill blade which can be installed in the remote areas of the world including inhabitable islands, places and in remote areas with less population density. The design of wind mill blade is carried out in Solidworks Part Design and the fluid flow analysis is carried out in Solidworks Flow Simulation.

Key words: Airfoil, Blade, CFD, Drag Coefficient, Lift Coefficient, FEA, Simulation, Wind Mill

I. INTRODUCTION

In recent years there is a drastic rise in the need for the development of renewable energy technologies due to the exhausting non-renewable energies. As a result, every country has its own contributions to the development of renewable energy technologies. In the area of windmills, many types of research are taking place in the methods to increase the efficiency and for the optimized designs to install in almost every part of the world. The major complexities faced in the windmill manufacturing are the complexities in the design of geometry of the blade, the size of the windmill and section of right topology in which they must be installed. So the development and the research for the better windmill blade plays a vital role in the development of safe and better windmill. A new design of windmill blade is provided in this paper.

In this paper the procedure for the design of windmill blade and analysis it's in the real working conditions of the are detailed. The new design of windmill blade is done by using three standard Airfoil profiles in a single windmill blade design. NACA 4424, NACA 4421 and NACA 4418 are the standard profiles used in the design of windmill blade in this paper.

The windmill blade workings are similar to the wings of an aircraft. The lift of the windmill blade is caused due to the pressure difference on two sides of the blade. This lift force makes the windmill blade to rotate. A horizontal axis windmill blade is designed in this paper.

II. AIRFOIL DETAILS & CHARACTERISTICS

The details and performance characteristics of the NACA 4424, NACA 4421 and NACA 4418 airfoils are shown in Table 1.

Details	NACA 4424	NACA 4421	NACA 4418
Thickness	24.0%	21.0%	18.0%
Camber	4.0%	4.0%	4.0%
Trailing edge angle	27.0°	31.3°	27.0°
Lower flatness	3.2%	4.6%	5.9%
Leading edge radius	5.6%	4.8%	4.0%
Efficiency	36.1	34.9	33.2
Max C_L	2.255	1.285	1.187
Max C_L angle	15.0	15.0	14.0
Max L/D	95.628	86.297	79.747
Max L/D angle	-0.5	-0.5	-0.5
Max L/D C_L	0.521	0.504	0.488
Stall angle	-0.5	-0.5	-0.5
Zero-lift angle	-5.0	-4.5	-4.0

Table 1:

III. GEOMETRY OF WINDMILL BLADE

The isometric view of the windmill blade designed in Solidworks Part Design is shown in Figure 1 and the wireframe model is shown in Figure 2.

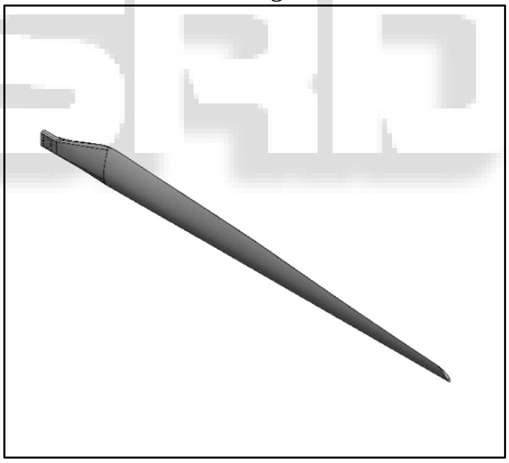


Fig. 1: Isometric view of Windmill Blade

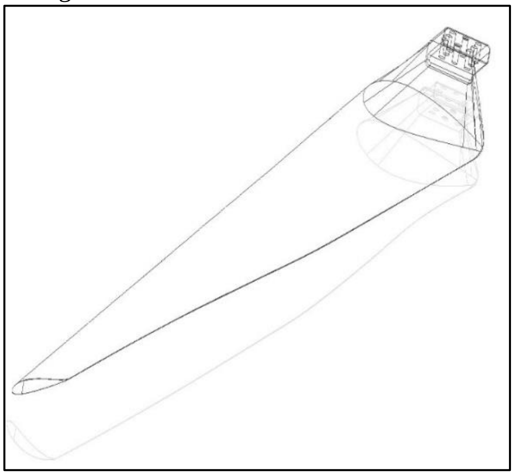


Fig. 2: Wireframe model of Windmill Blade

IV. METHODOLOGY

The model which is created in Solidworks Part Design is analyzed in Solidworks Flow Simulation. The CFD analysis procedure follows the following steps:

A. Grid generation:

Structured cartesian immersed – body mesh which consists of solid cells, fluid cells, and partial cells are used in the generation of grids for the model. The solid cells and fluid cells contain solid and fluid respectively. The partial cells contain both solid and fluid. Cuboid shaped cells are used in the meshing. The respective cells count of windmill blade is shown in Table 2.

Model	Fluid cells	Solid cells	Partial cells	Total cells
Windmill Blade	349307	4603	3475	357385

Table 2:

B. Flow conditions:

The different initial flow conditions and boundary flow conditions for windmill blade is shown in Table 3.

Parameters	Windmill Blade
Solver	Eulerian Finite Difference (EFD)
Turbulence model	$k-\varepsilon$
Velocity (m/s)	20
Humidity	50%
Angle of attack (degree)	15°
Initial pressure (Pa)	101325
Initial temperature(K)	293.20

Table 3:

C. The meshing of the model:

The model is meshed along with the global domain in the Grid generation step only. Finite element meshing is used in the meshing of the windmill blade. The mesh generated on the model is shown in Figure 3.

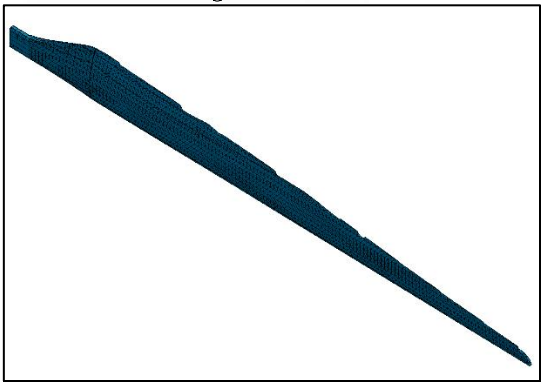


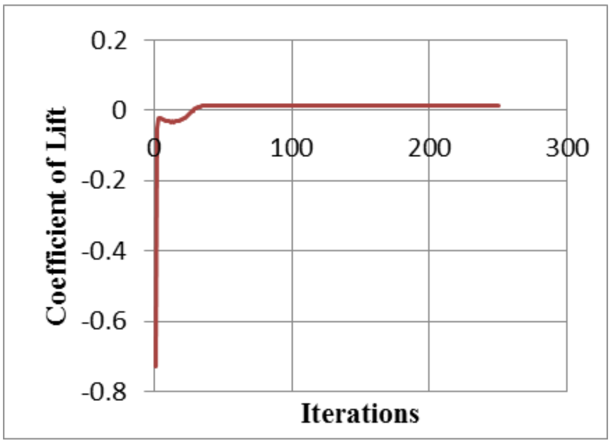
Fig. 3: Windmill blade mesh

V. RESULTS

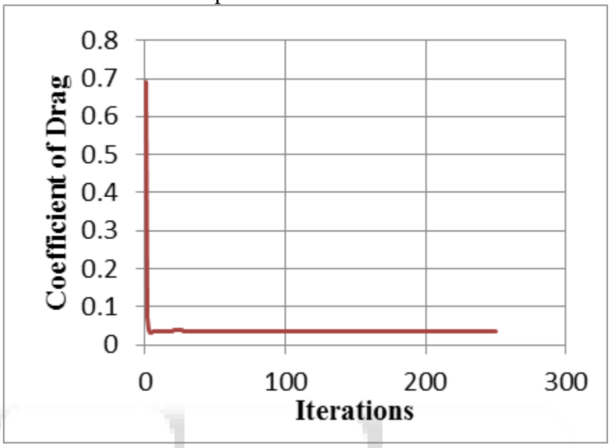
The CFD analysis on the windmill blade gives the results such as drag coefficient, lift coefficient, drag forces and lift forces. The values of different results are plotted against iterations and are shown in graphs as follows:

A. Windmill Blade:

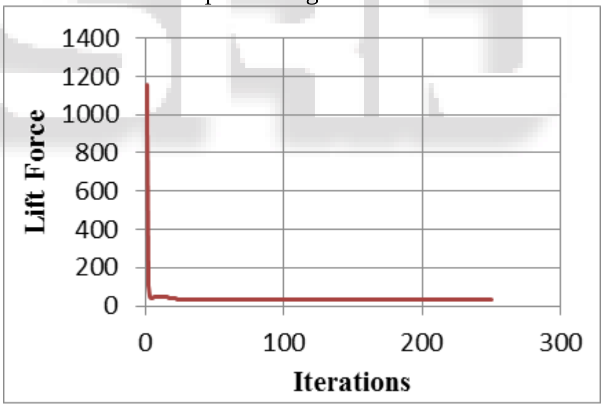
The windmill blade designed operates only at subsonic speeds. The vector plots are given below for different iterations.



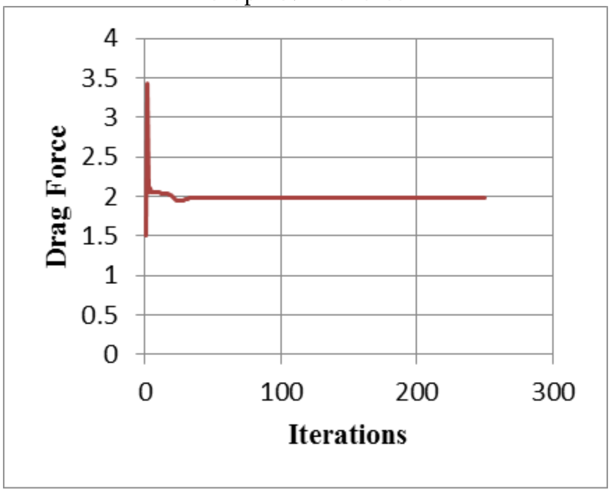
Graph 1: Lift coefficient



Graph 2: Drag coefficient



Graph 3: Lift force



Graph 4: Drag force

Table 4 gives the average values for all iterations.

Name	Unit	Value
Lift coefficient (C_L)	No units	0.0131363
Drag coefficient (C_D)	No units	0.0356459
C_L/C_D	No units	0.3685233
Lift Force	N	31.430
Drag Force	N	1.980

Table 4:

In the Figure 4 surface pressure distribution is shown and initial velocity contours at 7th iteration and final velocity contours at 250th iteration are shown in Figure 5 and Figure 6.

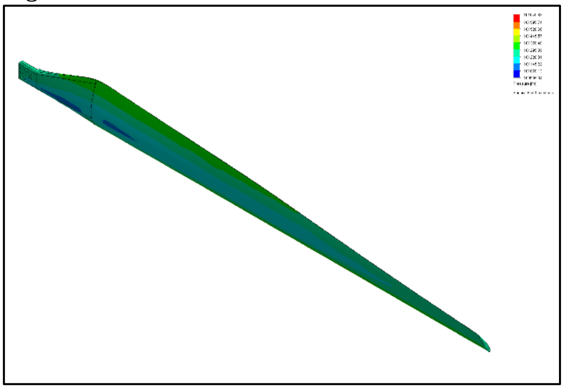


Fig. 4: Surface Pressure Distribution

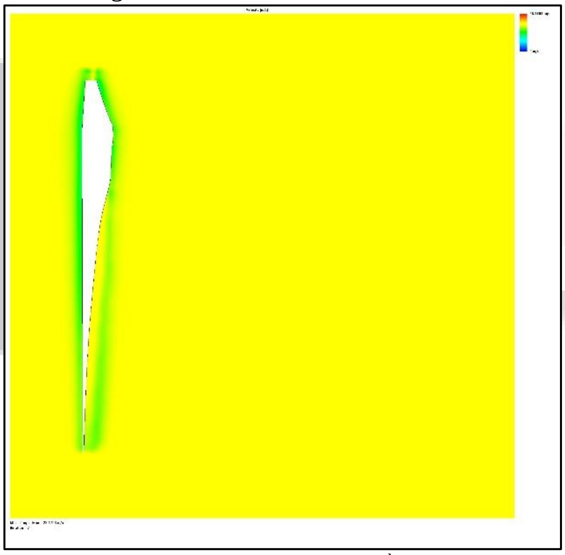


Fig. 5: Velocity Contour at 7th iteration

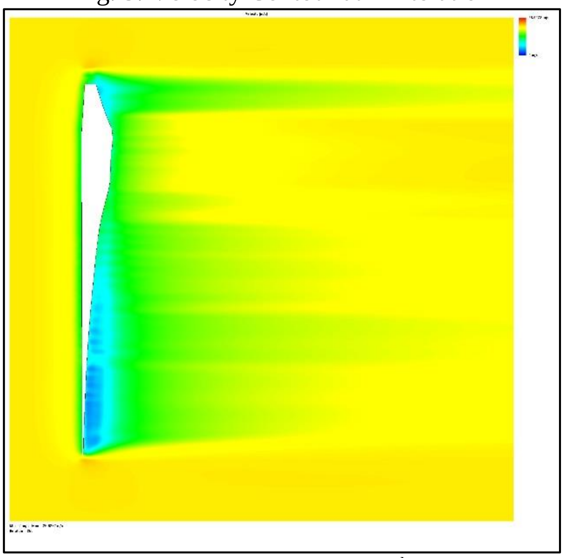


Fig. 6: Velocity Contour at 250th iteration

The cut plots show the variation of pressure and velocity along profile curves of the windmill blade.

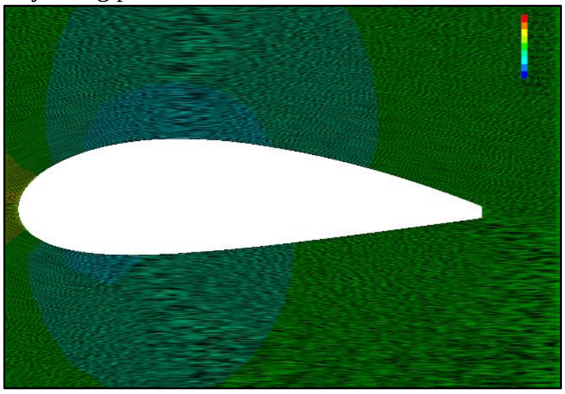


Fig. 7: Pressure cut plot

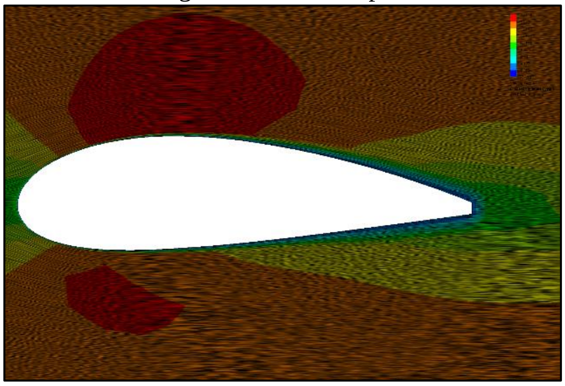


Fig. 8: Velocity cut plot

Figure 7 shows the pressure variation and Figure 8 shows the velocity variation along the profile curves of the windmill blade.

Figure 8 shows the trajectories of the fluid particles along the profile curves of the windmill blade. These fluid particles trajectories are called Streamlines.

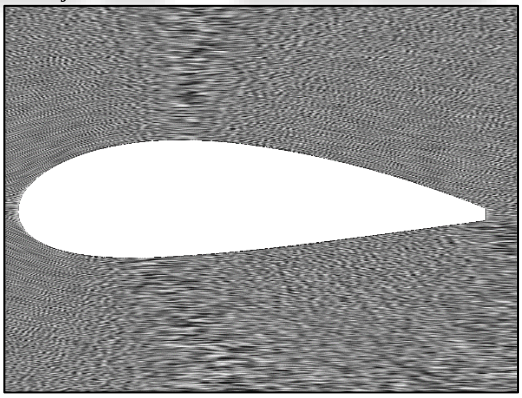


Fig. 9: Streamlines

B. Interpretation of Results:

It can be seen from Table 4 that the values of Lift coefficient (C_L), Drag coefficient (C_D), and the ratio of lift coefficient to the drag coefficient (C_L/C_D) have positive values. From this, we can interpret that the design is successful and can be coupled with the windmills or the wind turbine.

VI. CONCLUSION

With the help of Solidworks Flow Simulation solver, the model is tested under real working conditions with air as working fluid and the aerodynamic coefficients are calculated. From the study we can observe that:

The values of Lift coefficient (C_L), Drag coefficient (C_D), and the ratio of lift coefficient to the drag coefficient (C_L/C_D) are positive values. This shows that model is successful and ready to use in real conditions.

The values of Lift coefficient, C_L = 0.0131363 which is positive. This implies that a lift force is acting on the blade which causes the blade to translate its position. Therefore, if it is coupled to the shaft of the hub of the windmill it causes rotation which is responsible for the rotation of the coupled generator.

Since the model is analyzed 293 K, 20 m/s and Humidity ratio 50%, it can also be used in regions where low temperatures exist and can also be used at sea shores or ocean shores where the humidity is high. The model can withstand high wind velocities.

From the above observations, we conclude that the objectives of the project to design a windmill blade which can operate and can be installed in various topological and geological conditions are fulfilled. The model designed using three standard airfoils NACA 4424, NACA 4421 and NACA 4418 in a single windmill blade is successfully working under real operating conditions.

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