Numerical Study of The Effect of Blade Thickness on The Performance of H-Darrieus Rotor

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***Abstract*- Today's world is fully depended on fossil fuels. The demand and usage of fossil fuels are increasing day by day. For this reason, the day is not very far when the stored fossil fuels will be vanished. Now the space scientists and space organizations are investing their time on searching the fossil fuels in other planets. This process is time consuming and very much expensive. This present situation leads to research more on renewable energies. Wind is the most popular and clean source of renewable energy. Researchers are investing more money in wind turbine research. The growth of wind turbine technology is drastically increasing in recent years. Wind turbine converts mechanical energy to electrical energy by extracting kinetic energy from wind through rotating turbine shaft. Due to limitations in horizontal axis wind turbine, vertical axis wind turbine has become an important topic for researchers in wind turbine research. The present research paper focuses a comparison between two H-darrieus rotors. The blade profile S1046 and S1046 having 19.2% thickness are used for two rotors. From the aerodynamic analysis, it is found that blade profile S1046 having 19.2% thickness shows better performance and gives Cp of 0.36 at 4.0 TSR and wind velocity 8m/s.**

***Keywords: Wind Turbine, Tip Speed Ratio, Blade Profile, CFD*.**

I. INTRODUCTION

In our day-to-day life, energy plays an important role for survival where there is heavy dependence of modern industries on conventional energy such as coal, natural gas, oil, nuclear power etc. The heavy usage of this conventional energy is the main cause of greenhouse effect, ozone layer depletion, global warming. To reduce, we have to utilize the energy that we can generate from the renewable energy sources such as solar energy, wind energy, hydro energy etc. Energy generated from the renewable sources has been considered as an important and safe way to generate electricity.

The population in Nigeria is 170 million but only 6GW electricity is produced. In Brazil, the population is 190 million but 200 GW electricity is generated [1]. In this Scenario, the easiest and comparatively cheapest way to generate electricity is by using wind turbines. For this, research in wind turbines has become very popular. In many countries like Taiwan, US, Japan, South Korea, Brazil, Europe, wind turbine industries are rapidly growing and it is predicted that in the next 30 years, 1400 GW electricity will be produced by the use of wind turbine [1]. Installation of wind power is increased in 2020 by 53% as compared to 2019 [2]. Two types of wind turbine are commonly used to extract energy from wind, vertical axis wind turbine and horizontal axis wind turbine. VAWT has some advantages over HAWT like they are omni-directional, simple in design aspect, low sound emission, etc. [3, 4]. The flow of wind over airfoil blade affects directly to the performance of the VAWT. Dimension of airfoil affects the flow of air over the blade. So, it is necessary to analyze the dimension of blade. A.R Sengupta et al. [5] performed a CFD analysis with two unsymmetrical blade profile S815 and EN0005. They found at TSR of 1.5 and wind velocity of 6 m/s, S815 blade profile gave best performance value of power coefficient 0.20. R. Martinez et al. [6] had performed CFD analysis with NREL S815 profile by increasing the size 12.8%, 19.2%, 32%. At TSR of 1.7125 and wind velocity of 8 m/s, the airfoil having thickness 19.2% showed best power coefficient 0.28. G. Bedon et al. [7] performed CFD analysis between NACA 0018 and NACA 0021 and found that NACA 0018 gave best Cp of 0.4133. M.H. Mohamed [8] carried out an aerodynamic analysis by 2D CFD method, taking twenty different airfoils in order to maximize output torque coefficient and output power coefficient (efficiency). S1046 airfoil shows maximum power coefficient of 0.4051. 2D simulation was performed by M. H Mohamed et al. [9] with 24 new airfoil shapes. At TSR of 4.0, S1046 airfoil shows best power coefficient 0.3463. The purpose of this study is to compare between S1046 blade profile and 19.2% thickness increased S1046 blade profile of H-darrieus Rotor through 2D-CFD analysis. The conclusions are summarized below

II. DESIGN AND COMPUTATIONAL ANALYSIS

For this experiment, the three bladed H-rotor is chosen. The blade profile S1046 and S1046 (19.2% thickness) shown in figure 1 and 2, are taken in two rotors respectively. Here, the chord length of both blades is same as 0.05m. Tip Speed Ratio (TSR) and wind speed are taken as 4.0 & 8 m-s respectively for both the cases.

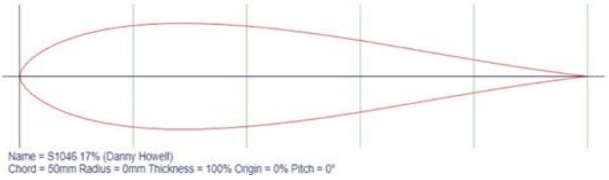

Figure 1: S1046 Blade Profile [10]

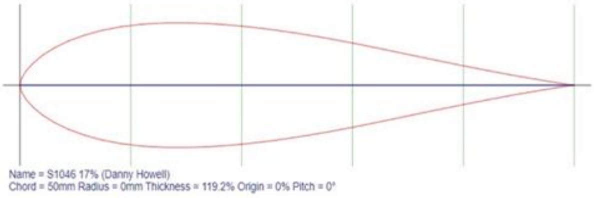

Figure 2: S1046(19.2% thickness) Blade Profile [10]

For the geometry, two domains as rotating domain and computational domain with circular interface are shown in figure 3 and 4. The velocity inlet and pressure outlet are at left and right boundaries respectively taking named selection method in consideration as shown in figure 4. Top and bottom boundaries are considered as fixed wall. The 2D CFD simulations of the two H- rotors of three bladed S1046 and S1046 (19.2% thickness) respectively, are carried out by ANSYS FLUENT 2020-R2 software.

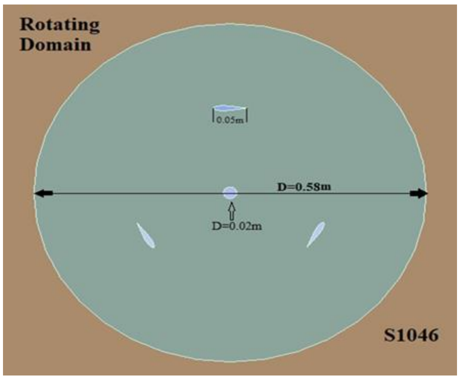

Figure 3: Rotating Domain

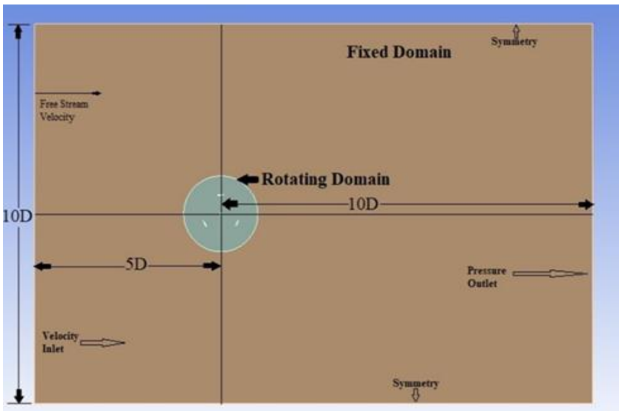

Figure 4: Computational Domain

Various levels of refinements as edge sizing, face sizing, etc. are done for both during the simulation to attain Grid Independent Limit (GIL) mesh. The mesh method shown in figure 5, is taken as quadratic triangular meshing for simulation in both domains respectively. The RNG k-ε turbulence model with standard wall function for no-slip condition at the walls of the airfoils are used for both simulations of the rotors [6]. The values of wind speed, density and temperature of air, etc., are considered same for both cases during simulation. The SIMPLE algorithm is used for pressure and velocity. For contour plotting the velocity, lift and drag are taken for each three blades separately in both rotors [6].

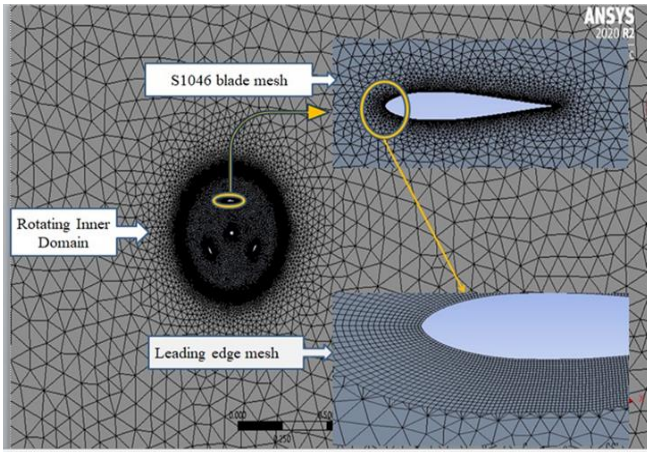

Figure 5: Meshing of Rotational and Computational Domain

III.SIMULATION RESULTS AND DISCUSSIONS

For the understanding of the aerodynamic flow physics of air on rotor, static pressure and velocity contour plots of both rotors are plotted. For the rotor having blade profile S1046, it is found that static pressure decreases from 2.40×10^1 Pa in upstream side to -2.07×10^1 Pa in downstream side across the advancing blade, shown in figure 6. It is also found that velocity decreases from 2.74×10^1 m/s in upstream side to 1.10×10^1 m/s to downstream side, shown in figure 7.

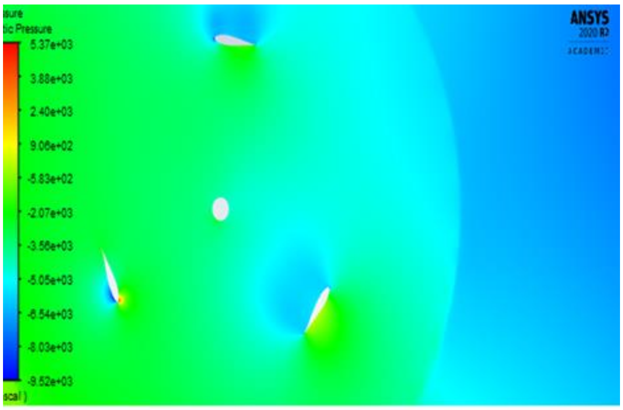

Figure 6: Static Pressure contour plot (S1046)

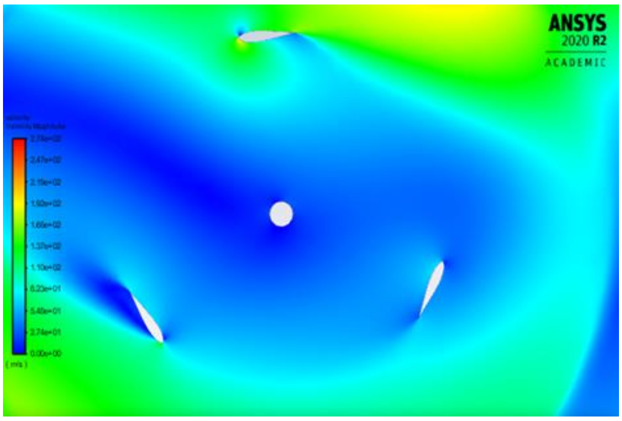

Figure 7: Velocity magnitude contour plot (S1046)

For the rotor having blade profile S1046 with 19.2% thickness, it is found that static pressure decreases from 2.48×10^{1} Pa in upstream side to -2.92×10^{1} Pa in downstream side across the advancing blade, shown in figure 8. It is also found that velocity decreases from 4.16×10^{1} m/s in upstream side to 1.25×10^{1} m/s to downstream side, shown in figure 9.

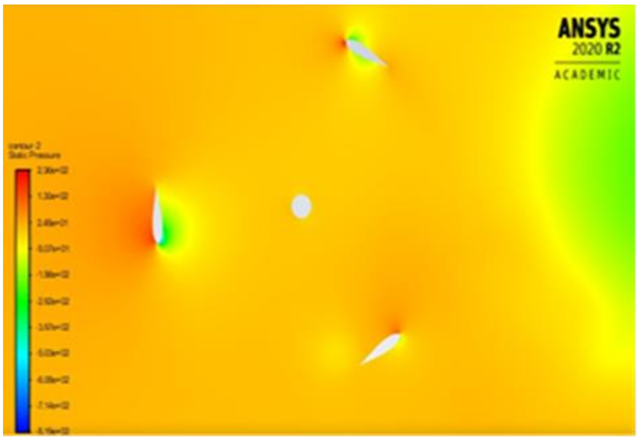

Figure 8: Static Pressure contour plot S1046 (19.2% thickness)

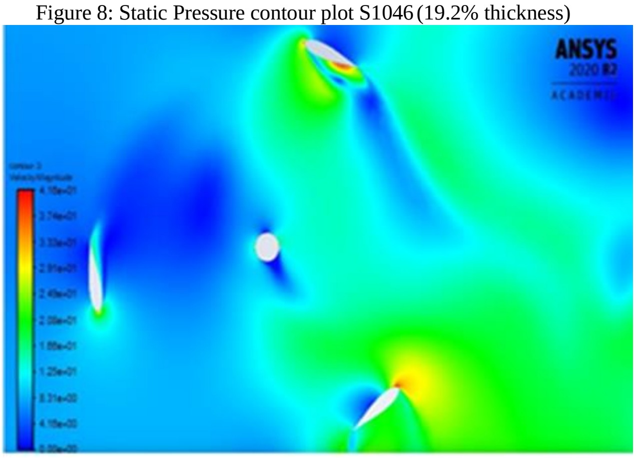

Figure 9: Velocity magnitude contour plot (19.2% thickness)

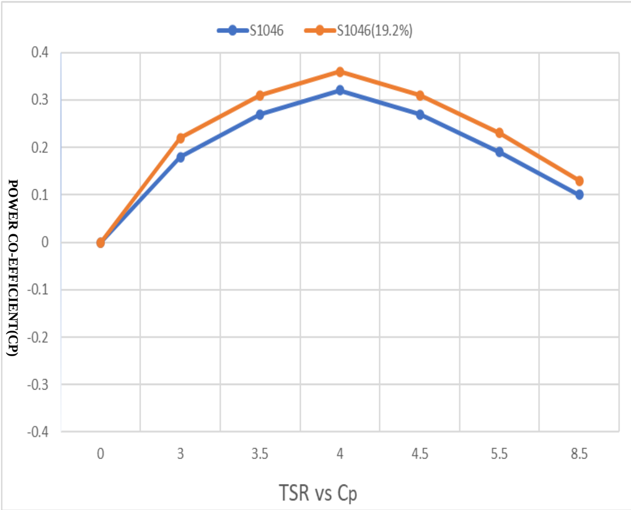

Figure 10: TSR vs Cp Graph

Figure 10 shows the variation of power co-efficient with tip speed ratio between blade profile S1046 and S1046 having 19.2% thickness. It can be seen that H-rotor having blade profile S1046 gave Cp of 0.32 at TSR of 4.0. The H-rotor having blade profile S1046 with 19.2% thickness gave Cp of 0.36 at TSR of 4.0. So, from the analysis of TSR vs Cp graph it can be concluded that H-darrieus rotor having blade profile S1046 with 19.2% thickness shows better performance.

IV. CONCLUSIONS

Dimension and structure of airfoil blade are very important parameters because these two parameters affect the flow over airfoil directly. Two-dimensional numerical simulation is performed for the analysis to find the effect of thickness on airfoil.

- According to physics of aerodynamic analysis, higher static pressure difference between upstream and downstream side means greater lift is generated on airfoil. Hence, performance of rotor is higher.
- By this analysis of present study, the higher static pressure between upstream and downstream side is found for blade profile of S1046 having 19.2% thickness.
- For simulation of three bladed rotor the RNG k-ε turbulence model with standard wall function gives better results.
- The blade profile S1046 having 19.2% thickness shows better performance of power co-efficient 0.36 than S1046 blade profile at TSR of 4.0 and wind speed of 8m/s.

V. FUTURE SCOPES

- Present work research has shown that S1046 having 19.2% thickness blade profile shows better performance.
- Further this work might direct future researchers towards on:
  - The works on comparison by taking different thickness of S1046 blade profile.

- The comparison of the result of present study and practical analysis.
- The works on 3D structure analysis of present experiment.
- To compare the efficiency by changing the blade materials.
- Works on by considering the struts in the design of the rotor for simulation.

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