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Effect of Blade Thickness of Vertical Axis Wind Turbine on Power Generation

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Abstract: **Wind is one of the renewable energy sources among all the energy sources being used for many years. It has lots of importance in the present age of energy crisis, with recent flow in remnant fuel prices and for pollution free renewable energy sources; wind turbines are another choice to generate power. To overcome the problem of power generation in turbulent winds, vertical axis wind turbines (VAWT) were developed. In which blade is the main element, it regulates the performance of wind turbine. The present paper describes the analysis of symmetric airfoils naca 0012, naca 0015, naca 0018 and naca 0025 to choose better airfoil by considering the high lift to drag ratio for VAWT using commercial software ANSYS FLUENT. The correlation between the lift and drag coefficients are very important for the selection of airfoil for vertical axis wind turbines. Power output obtained analytically for naca 0025.**

Key words: **VAWT, ANSYS FLUENT 14.0, Airfoil.**

I. Nomenclature

C_p [-]	Coefficient of power
ρ [kg/m^3]	Density
A [m^2]	Swept area
V[m/s]	Wind velocity
P_t[w]	Turbine power
P_w[w]	wind power

II. INTRODUCTION

Energy is a fundamental thing to grow economically and socially. On beginning of 21st era we will face challenging problems to supply energy, energy utilization increasing day to day, we are depending on fossil fuels heavily these are giving pollution threat to climate and also an economic threat [1]. To solve this problem so many developed countries are investing largely in renewable energy resources, as part of the international co_2 emission decreasing policy Australia was established strategies to produce power from renewable energy of at least 20 % by the year 2020 [2] .

Wind energy is an effective resource to generate power, it is readily available and it is clean, safe. Particularly in Europe it has a share of 70 % of the international wind energy industry [1]. The efforts have been put to analyze the aerodynamic models employed for the performance of vertical axis wind turbine. The main advantages of Vertical axis wind turbines are quiet, omnidirectional, and create less stress on support structure, self-starting. They require less wind to produce power, the large blades of vertical axis wind turbines with high aspect ratio's exposed to a very large value of bending moments due to centrifugal forces, these causes the failure of blades [kragten 2004]. Even small blades of vertical axis wind turbines are dangerous because of the blades spins or rotate very quickly and give acceleration due to lack of stall. The high rotational speeds causes the high centrifugal forces and torque, which normally supports the blades but have a probability of increasing structural failures at that time [Jain 2011].

The objective of this paper describes that design, analysis of symmetric airfoils of a vertical axis wind turbine using analytical and numerical techniques and validated naca0012 airfoil with experimental data

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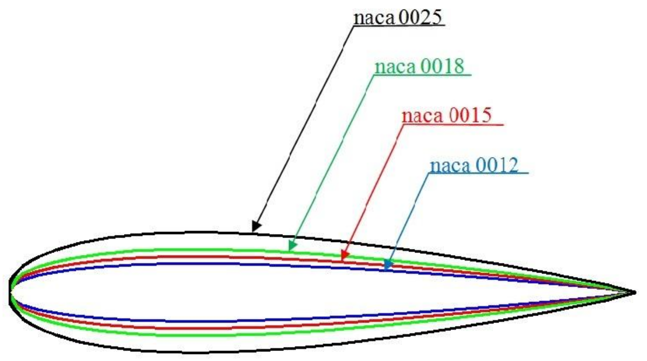
III. DESCRIPTION OF AIRFOILS

The airfoils were developed by the national advisory committee for aeronautics. In the naca airfoils four digits describe that

1. The first digit represents max camber as percentage of the chord.
2. The second digit represents a distance of max camber from the airfoil leading edge.
3. The last two digits represent the thickness of the airfoil.

In the present paper, we will discuss about four naca symmetric airfoils, naca 0012, 0015, 0018, 0025. These are most commonly using airfoils. The actual profiles of above mentioned airfoils shown below.



IV. SELECTION OF AIRFOIL

Symmetrical airfoils are used for a small scale VAWT, these have similar characteristics of lift and drag on upper and lower surfaces .The advantage is that symmetrical airfoils provide lift from both side of the airfoil, so these will give a lift during 360^o rotation and we are not having a problem to adjust the blades relative to wind direction. For vertical axis wind turbines commonly used symmetrical airfoils are naca 0012, 0015, 0018, and naca 0025. Therefore chosen airfoils were simulated analytically and numerically, naca 0025 gives high lift to drag ratio.

V. NUMERICAL SIMULATION

For numerical simulations, the above mentioned airfoils are selected. The co-ordinates for all airfoils are obtained from NASA website for simulations. The chord length (C) of airfoils are 1m. The dimensions of flow domain is based on chord length, that is x_{max} = 20C, x_{min} = 12.5C, y_{min} =12.5C, y_{max} =12.5C. The creation of domain and mesh generation accomplished by the commercial software Gambit. The 2D computational mesh designed in C-type rectangular domain, it consists of 12240 cells shown in figure. And simulations are done by use of ANSYS FLUENT 14.0. In CFD calculations, it uses a finite volume method [5]. The k-ω turbulence model chosen for analysis and for momentum equations second order upwind discretization, for pressure velocity coupling COUPLED algorithm is chosen for naca 0012. For analysis, the solver is density based solver, the viscous model is used is inviscid. The spatial descretization for pressre used is PRESTO and SECOND ORDER UPWIND descretization is used for momentum equation. Fig 1 and 2 shows the mesh for the analytical domain.

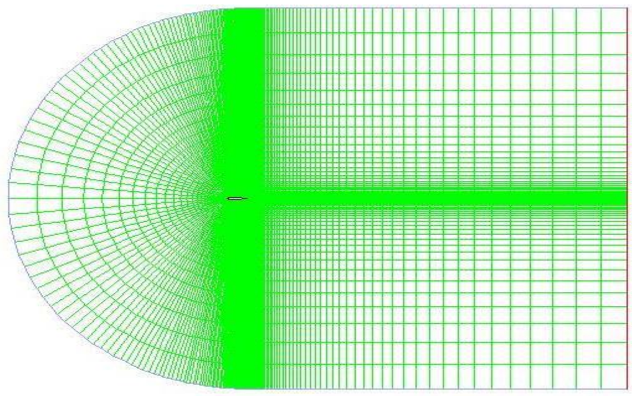


Figure1: Model diagram of airfoil mesh

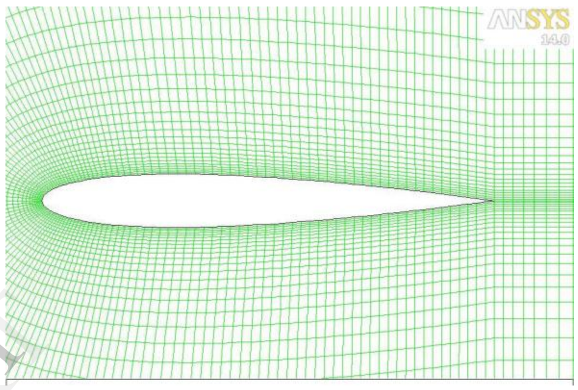


Figure2: Mesh close to airfoil wall

VI. VALIDATION

The Experimental data used for validation of NACA 0012 airfoil, data obtained from the Langley Research Center. The flow properties are considered here are M=0.15, R_e = 6 million validation [Abbott. 1959], [7]. The variation of coefficient of lift (C_L) with angle of attack (α) is compared with the experimental results as shown in fig3. The numerical results are good agreement with experimental results as shown in figure3.

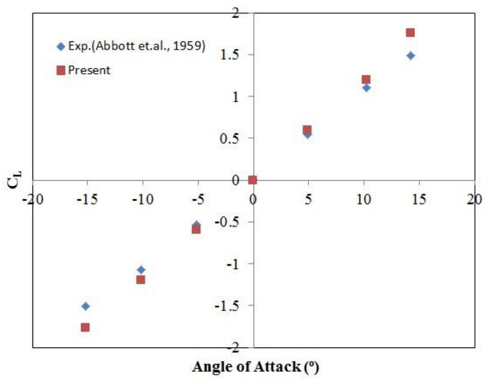


Figure3: Angle of attack V_S Coefficient of lift

VII. ANALYTICAL CALCULATIONS

Power coefficient: It is the ratio of power absorbed by the turbine to the power available in the wind.

Power coefficient (C_P) = $\frac{P_T}{P_W}$

Power available in the wind (P_w) = $0.5C_p\rho AV^3$
Where $C_p = 0.593$(Betz, 1926), [6].

VIII. RESULTS AND DISCUSSIONS

Two dimensional numerical simulations are performed at R_e = 6 million. The maximum lift to drag ratios were calculated which is very important parameter for starting up the wind turbine. Based on the results, the correlation between the lift coefficient and drag coefficient is higher, that is when the drag increases with lift irrespective of the angle of attack for naca 0012, naca 0015 and naca 0018, where as for naca 0025 the drag is less even when the lift is higher as shown in Fig6, due to this reason, the maximum lift to drag ratio is higher for naca 0025. All the results which are discussed in the following are for naca0025. Fig 4 and Fig 5 shows the variation in lift and drag coefficients with angle of attack for all airfoils. The static pressure contours and velocity vectors have been plotted for 0^o and 10^o angle of attack for naca 0025 in Fig 7 and 8. The static pressure distributions are unsymmetric when the angle of attack increases and this causes the major variations in lift and drag forces. For an angle of attack at 10^o, the stagnation point is observed under the leading edge and hence generates lift as there is a low pressure region on the upper surface of airfoil, as shown in Fig7. At this angle of attack (10^o), the lift force is higher and corresponding drag force shows relatively lower values for remaining angles of attack. The power generation for various wind velocities is tabulated in Table 1. The wind velocities are considered here are from 2 to 53 m/s. Fig 9 shows power generation for various wind speeds. The power generation is very low at lower wind velocities, that is below 20 m/sec and it is varying very rapidly to higher levels as the wind velocity increases.

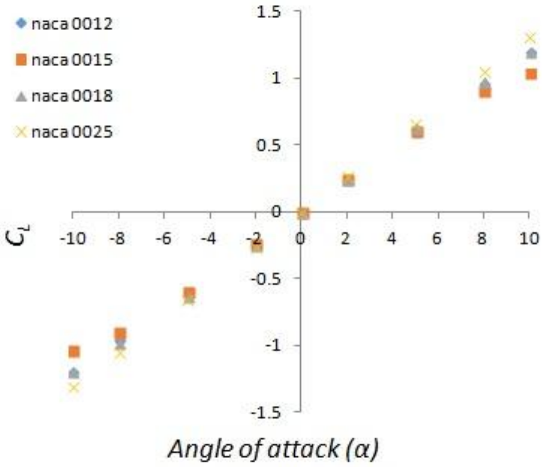


Figure4: Angle of attack V_S Coefficient of Lift

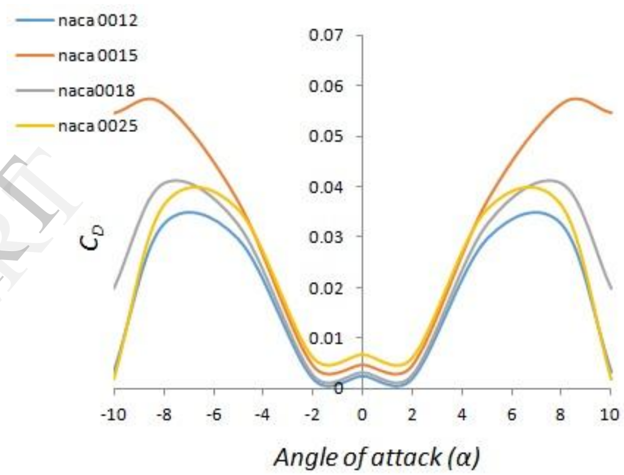


Figure5: Angle of attack V_S Coefficient of Drag

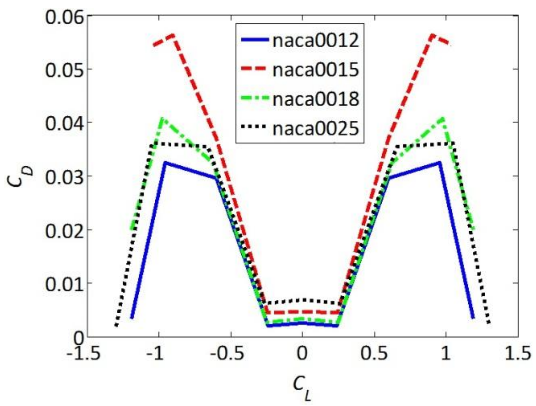


Figure6: Coefficient of lift (C_L) V_S Coefficient of drag (C_D)

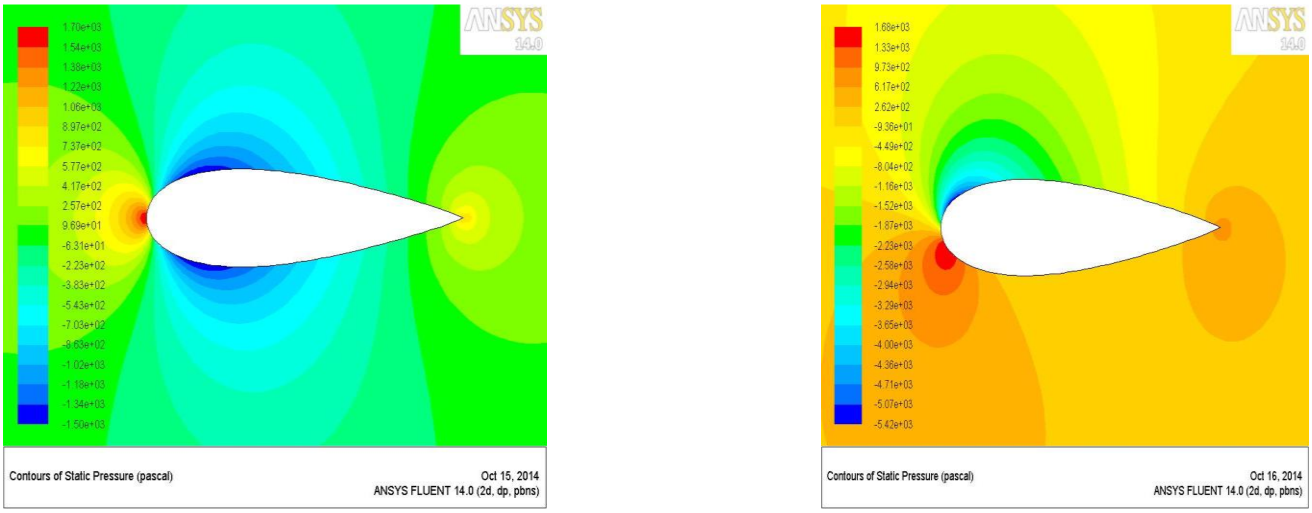


Figure7: Static Pressures at 0^o, 10^o Angle of attack

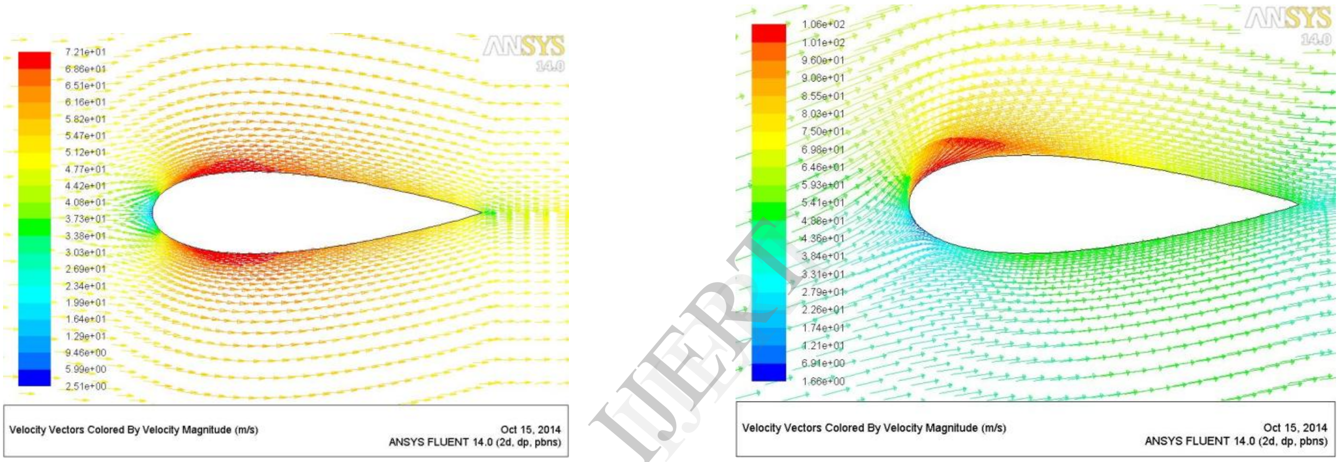


Figure8: Velocity Vectors at 0^o, 10^o Angle of attack

Table1: Calculation of Power at different Wind Velocities

S.NO	Wind velocity(m/s)	Wind Power (w) P_W	Turbine Power (w) P_T
1	2	3.1	1.8
2	4	24.7	14.6
3	6	83.2	49.4
4	8	197.3	116.9
5	10	385.3	228.5
6	20	3082.65	1828.01
7	30	10403.96	6169.54
8	40	24661.25	14624.12
9	53	57367.09	34018.68

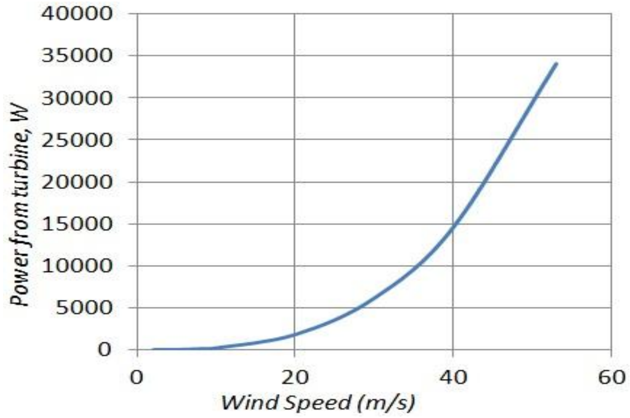


Figure9: Wind speed V_S Power from turbine

IX. CONCLUSIONS

1. The correlation between the lift and drag coefficients are considered for all airfoils. The lowest drag coefficient was found even at higher lift coefficients for naca 0025, that is higher lift to drag ratios occurred for naca 0025. Hence naca 0025 will be the optimum blade profile for maximum power generation.
2. The optimum wind power will be available at velocities more than 20 m/sec. Also found very less power generation at velocities below 20 m/sec.

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