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# Design and Analysis of Horizontal Axis Wind Turbine (HAWT) Blades Using CFD

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***Abstract: Within the current years wind power is extensively taken into consideration and applied as one of the most promising renewable electricity assets. In the recent studies have a look at, aerodynamic analysis of horizontal axis turbine is achieved with the aid of using cfd. Blades which can be often possible for industrial grade wind turbines embody a directly span-wise profile in conjunction with airfoil fashioned go sections. Wind tunnel test is applied in order to check aerodynamic efficiency wind turbine blade. The goal of this study is to design a wind turbine. The layout manner includes the choice of the sun machine for max efficiency and wind turbine kind and the determination of the blade airfoil, pitch attitude distribution along the radius, and chord duration distribution along the radius. The pitch angle and chord period distributions are optimized primarily based on conservation of angular momentum and principle of aerodynamic forces on an airfoil. Blade element momentum (BEM) principle is first derived then used to conduct a parametric observe to be able to determine if the optimized values of blade pitch and chord period create the maximum green blade geometry. This work includes a discussion of the most important parameters in wind turbine blade layout to maximize efficiency.***
***Keywords: Wind Turbine, HAWT, BEM Theory, Parametric Study, Maximization of efficiency etc.***

## I. INTRODUCTION

In the recent studies have a look at, aerodynamic analysis of horizontal axis turbine is executed via the use of CFD. Blades which can be more often than not possible for industrial grade wind turbines encompass a immediately span-wise profile together with airfoil shaped move sections. Wind tunnel test is implemented in order to check aerodynamic efficiency wind turbine blade. In this task, the researchers' choice is NACA 4421 airfoil for evaluation. CFD analysis of HAWT blade is carried out at numerous blade angles with the aid of ANSYS CFX and additionally by means of correlating that result with experimental outcomes. HAWT performance remarkably depends upon the blade profile and its orientation. The researchers are capable of become aware of the most useful angle at which HAWT gives constant output. Wind turbine technology is one of the powerful manners to put in force this renewable aid that allows you to produce environmentally pleasant electric electricity. As it is an intricate gadget it depends upon the is unification of more than one engineering disciplines, which accommodates of structures, aerodynamics, controls and electrical engineering. The principle goal of the wind generators is to capture most strength from the wind power. Quality design parameters must be decided on for every and each constituent of the wind turbine. It leads to increase in performance and lifestyles cycle. The 2 ranges of a wind turbine blade design manner are aerodynamic layout and structural layout.

## II. LITERATURE REVIEW

*A.* A wind turbine is a system which converts the electricity inside the wind into strength. This is contrast to a windmill, that's a gadget that converts the wind's strength into mechanical power. Wind electricity, as an alternative to fossil fuels, is abundant, renewable, and drastically circulated, clean, produces no greenhouse fuel emissions at some point of operation and uses little land (Fthenakis *et al.*, 2002).

*B.* If the efficiency of a wind turbine is accelerated, then more power may be generated for that reason lowering the need for steeply-priced electricity era that causes pollution. Ever since the seventh century, people had been utilizing wind to make their lives less complicated (Satish *et al.*, 2011).

*C.* Renewable energy assets are those electricity assets, which are not spoiled when their power is harnessed. Human use of renewable power calls for technologies that harness herbal phenomena along with sunlight, wind, waves, water go with the flow, and biological procedures including biological hydrogen production and geothermal warmness. Among the above referred to assets of power there has been a variety of development inside the technology for harnessing energy from the wind (Patnaik *et al.*, 2009).

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## III. OBJECTIVE

The targets of the studies are to set up dimensional and three dimensional CFD design of wind turbine blade and rotor, in order

*A.* To investigate the aerodynamic overall performance of various aero foils.
*B.* To predict wind turbine electricity output at one-of-a-kind wind speeds.
*C.* Maximum aerodynamic efficiency at particular wind velocity.
*D.* To optimize blade geometry to present the most strength for a given wind pace.

## IV. DESIGNING OF HAWT

*1)* Determine the rotor diameter from power equation.

Power generated due to wind speed is given by following equation.

Power in the Wind $P = C_p \eta \frac{1}{2} \rho \pi R^2 V^3$

$C_p$ --- Coefficient of performance (0.4 for a modern three bladed wind turbine)

$\eta$ --- Expected Mechanical (or) Electrical efficiency (0.9 would be a suitable value)

$\rho$ --- Effect of air density

R --- Tip Radius

V --- Wind velocity

*2)* Choose Tip Speed Ratio ($\lambda$): For

a) Electrical power Generation Pick $4<\lambda<10$

*3)* Choose Number of Blades (B=3)
*4)* Select an Aero foil.
*5)* Attain and study thoroughly the lift and drag coefficient Curves (CL & Cd) by using CFD Software.
*6)* Determination of chord length:

$C = 8 \pi R \cos\beta / 3B\lambda_r$

Here $\tan\beta = \lambda_r(1+a')/(1-a)$ $\lambda_r = \Omega r/v$

B - Relative flow angle

$\lambda_r$ - Local tip speed ratio

a - Axial induction factor

a' – Angular induction factor

$\Omega$ – Blade rotational speed

*7)* Divide the blade into N elements and moreover 10 to 20 elements are typically used.
*8)* Relative flow angle

$\beta = 90^0 - (2/3)\tan^{-1}(1/\lambda_r)$

$a = \{1 + (4\cos^2\beta/\sigma' C_L \sin\beta)\}^{-1}$

$a' = 1-3a/4a-1$ here $\sigma'$ –local solidity

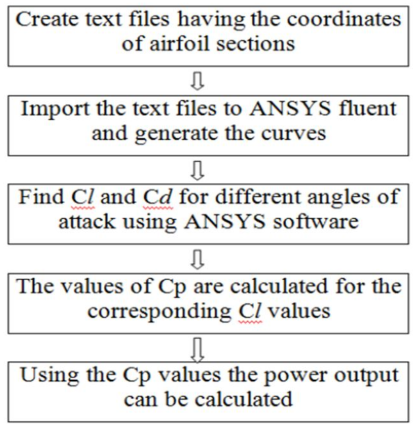
$\sigma' = Bc/2\pi r$

*9)* Calculate the rotor performance and then modify the design procedure.

$$C_p = \frac{8}{\lambda^2} \int_{\lambda_h}^{\lambda} Q \lambda^3 \; a'(1-a)\{1 - \frac{Cd}{CL} \tan\beta\} d\lambda_r$$

## V. METHOD OF ANALYSIS

The aerofoil NACA 4421 is chosen for blade modeling as shown in fig.3. NACA 4421 profiles are obtained from Ansys fluent. The blade is modeled for the specification given in Table1.




| NACA 4421 Profile | |
|---|---|
| Root chord length | 1635mm |
| Tip chord length | 620 mm |
| Length of blade | 10640mm |
| Hub diameter | 318.5mm |
| Hub length | 1446 mm |
| Hub to blade (neck) | 1460 mm |

Table 1. Blade specification

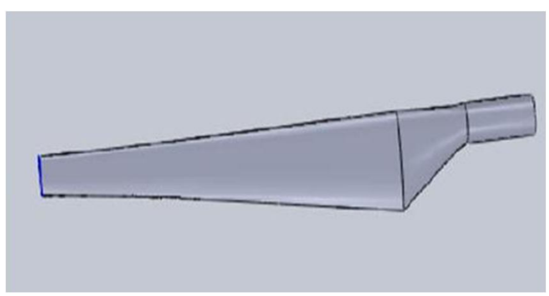


Fig 1. Wind Turbine Blade

## VI. CFD ANALYSIS PROCEDURE

*1)* Cavity model of horizontal axis wind turbine blade is created.

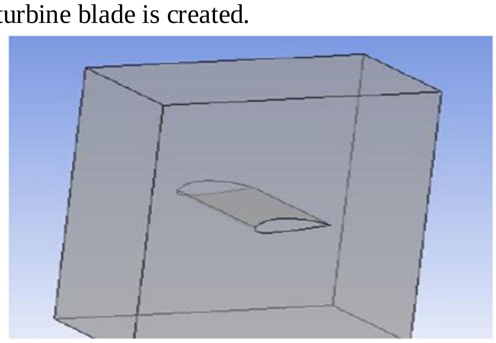


Fig 2. Cavity model of NACA 4421 airfoil

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2) Save the above the cavity model in IGES files Format and import this IGES file Into ANSYS CFX.
3) Geometry in ANSYS CFX is generated.
4) Meshing geometry.
5) ANSYS CFX for Pre- processing.
6) Air domain is created.

| Domain Type | Fluid Domain |
|---|---|
| Fluid | Air Ideal Gas |
| Domain Motion | Stationary |
| Heat Transfer Model | Total energy |
| Turbulence Model | K-Model |

Table 2 Dimensions of Domain

7) Define inlet
8) Define outlet
9) Define solver control criteria.

## VII. RESULT AND DISCUSSION

Inlet speed for the experiments and simulations is sixteen m/sec and turbulence viscosity ratio is 10. In ANSYS CFX, turbulent go with the flow answer was absolutely used. A simple solver has been employed and it becomes set 0 for working the stress. For the "linear" vicinity, calculation must be done earnestly. The airfoil profile and boundary conditions are all created. In cavity domain one inlet, outlets different are symmetry boundary.

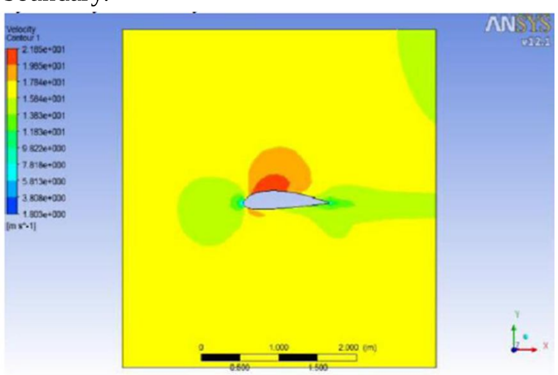


Fig 3. Velocity plot -00 blade angle

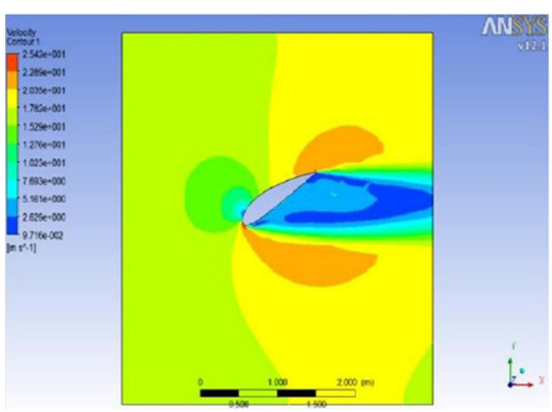


Fig 4. Velocity plot -300 blade angle

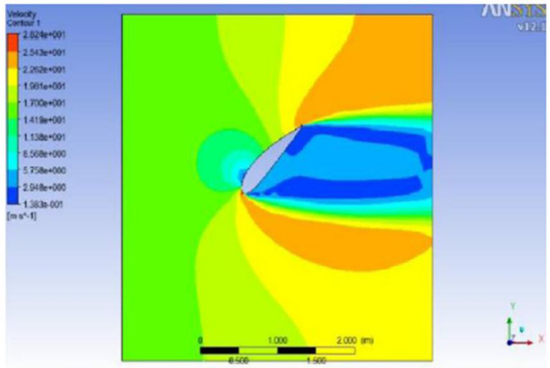


Fig .5. Velocity plot -450 blade angle

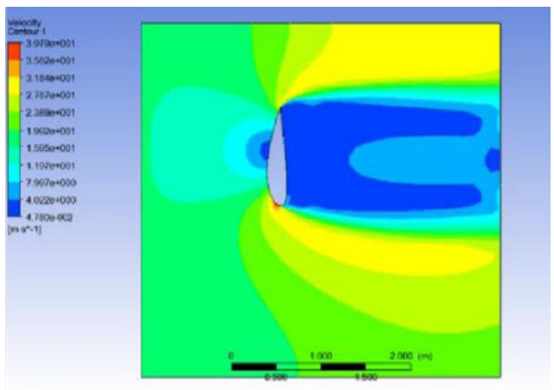


Fig 6. Velocity plot -900 blade angle

| S.No | Blade angle | Velocity(m/s) | Density(kg/m) | Power(W) |
|---|---|---|---|---|
| 1 | 0 | 15.5 | 1.225 | 1457710.87 |
| 2 | 22.5 | 16 | 1.225 | 1603379.2 |
| 3 | 37.5 | 16.05 | 1.225 | 1618457.90 |
| 4 | 45 | 16.10 | 1.225 | 1633630.84 |
| 5 | 60 | 16.17 | 1.225 | 1655031.85 |
| 6 | 75 | 16.94 | 1.225 | 1902902.40 |
| 7 | 90 | 17.8 | 1.225 | 2207680.92 |

Table 3.Effect of power in various angle of blade

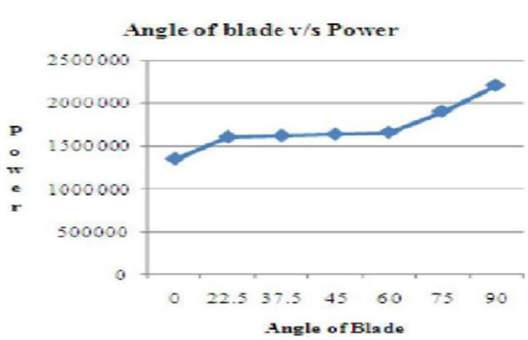


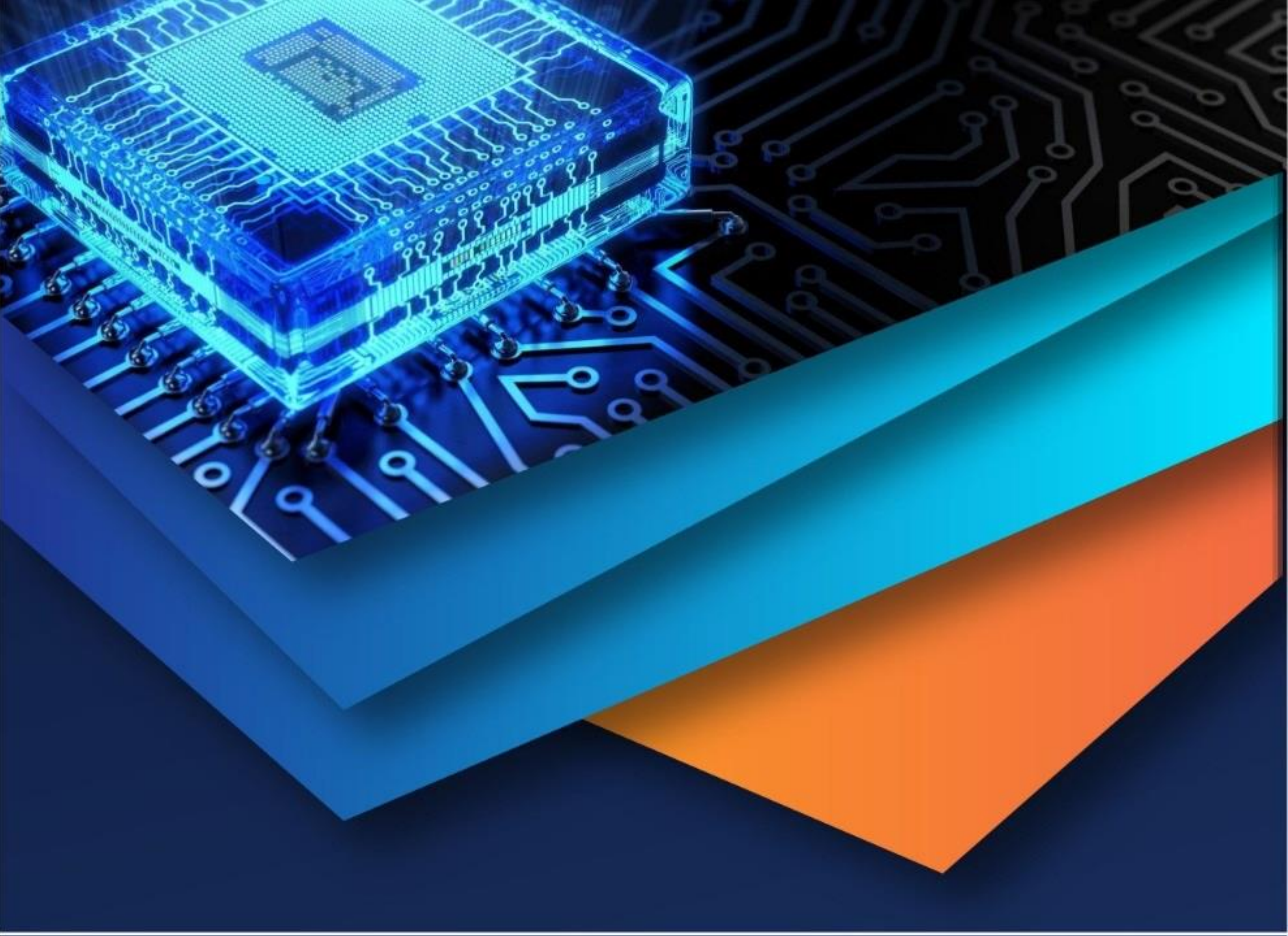

Fig 7.Effect of power in various angle of blade

## VIII. CONCLUSION

The researchers, in this paper, pick out a horizontal axis wind turbine blade with NACA 4421 which is designed and analyzed for one-of-a-kind blade perspective and wind pace. The CFD analysis is accomplished with the aid of the usage of ANSYS CFX software program. Inside the given parent, the rate distribution at numerous blade angles is simply shown. The top floor on the airfoil reports a better pace whilst compared to the lower surface that's without problems determined through this.

## REFERENCES

[1] S. Roy and U. K. Saha, “Review on the numerical investigations into the design and development of savonius wind rotors,” Renewable and Sustainable Energy Reviews, vol. 24, no. 0, pp. 73 – 83, 2013.
[2] I. Al-Bahadly, “Building a wind turbine for rural home,” Energy for Sustainable Development, vol. 13, no. 3, pp. 159 – 165, 2009.
[3] S. Khan, A. Khan, M. Irfan, and S. Hussain, “Aerodynamic analysis and dynamic modeling of small horizontal axis wind turbine,” in Robotics and Artificial Intelligence (ICRAI), 2012 International Conference on, Oct 2012, pp. 117–124.
[4] U. A. Llona, J. P. Rambla, and G. A. Zamalloa, “Spreadsheet assisted overall design of a wind turbine blade,” 2014.
[5] F. Song, Y. Ni, and Z. Tan, “Optimization design, modeling and dynamic analysis for composite wind turbine blade,” Procedia Engineering, vol. 16, no. 0, pp. 369 – 375, 2011, international Workshop on Automobile, Power and Energy Engineering.
[6] R. K. Singh and M. R. Ahmed, “Blade design and performance testing of a small wind turbine rotor for low wind speed applications,” Renewable Energy, vol. 50, no. 0, pp. 812 – 819, 2013.
[7] O. Ozgener and L. Ozgener, “Exergy and reliability analysis of wind turbine systems: A case study,” Renewable and Sustainable Energy Reviews, vol. 11, no. 8, pp. 1811 – 1826, 2007.
[8] N. K. Tony Burton, David Sharpe and E. Bossanyi, Wind Energy Handbook. Chichester: John Wiley & Sons. Ltd, 2011.
[9] “Uiuc airfoil coordinate database.”
[10] A. L. R. James F. Manwell, Jon G. McGowan, Wind Energy Explained: Theory, Design and Application. John Wiley & Sons, 2010.



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