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Design and Calculation of Coefficient of Lift and Drag for Helix Wind Turbine using Solidworks and Ansys Fluent

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***Abstract**: This paper is about the Helix Wind Turbine which focusses on its design and calculation of its coefficient of lift and drag. The Helix Wind Turbine is designed in the Solidworks 2014 with NACA airfoil. The aerodynamics characteristics like coefficient of lift and drag is calculated in Ansys Fluent 15.0. The overall objective of this paper is to select the best NACA airfoil out of the airfoils over which analysis is performed. The paper also discusses about the certain design parameters.*

***Keywords:** Helix Wind Turbine, NACA, Coefficient of lift (C_l), Coefficient of drag (C_d).*

1. Introduction

The generation of electricity is done by either renewable resources or non-renewable resources. The electricity generation by non-renewable resources led to the emissions of SO_x, CO_x and NOx. This era need to be eco-friendly and follow that path which lead to sustainable development. Therefore, electricity generation by renewable source is a topic of more concern.

In INDIA we have the total installed capacity of 263.66 GW out of which renewable energy is 34.35 GW. This contributes to 13% of installed capacity and approximately 7% of electricity produced (as on March, 2015). [1] INDIA have total wind potential of 400 GW i.e. 300 GW + 100 GW (off-shore). The installed wind energy base is over 25000 MW spread across 8 states. [2]

The moving air is known as wind. The wind blow from the high pressure region to the low pressure region. Wind energy is the indirect form of solar energy. Wind blows due to pressure difference which is created due to the uneven heating of air. The energy from wind can be harnessed by converting the kinetic energy of the moving air into the rotational energy from wind turbines. There after converting this rotational energy of wind turbine to electrical energy from generator. The wind turbines are classified into two on the basis of axis of rotation i.e. Horizontal Axis Wind Turbines and Vertical Axis Wind Turbines. The Horizontal Axis Wind Turbine means axis is parallel to the air flow, whereas the Vertical Axis Wind Turbine means the axis is perpendicular to the air flow. Helix Wind Turbine is the type of Vertical Axis Turbine. They have helical airfoils usually having three blades with helical twist. The power generation equipment's are placed on the ground which makes it easier for maintenance. They are omni-directional which means they need not to be positioned in the wind direction for power generation. The gravitational stresses on helical wind turbine are even allowing lighter and larger construction in contrast to Horizontal Axis Wind Turbines. Force is applied to the airfoil blades by the wind both entering and leaving the turbine, allowing maximum extraction of energy from wind.

2. Helix Wind Turbine Design

To understand the design of helix wind turbine, we should have knowledge about airfoil. The shape of the wing and blade is known as airfoil. When the fluid moves over the airfoil, aerodynamics forces are produced. The component of force parallel to the wind direction is called drag and the perpendicular to wind direction is called lift. The airfoils used in the wind turbines comes under the NACA series. NACA (National Advisory Committee for Aeronautics) specifies the characteristics of the airfoils by numbers. For example in four digit specifications, the first number specifies the maximum camber in percentage of chord (airfoil length). The second indicates the position of maximum camber in tenths of chord. And the last two numbers provides the maximum thickness of the airfoil in percentage of chord. So, NACA 2415 airfoil has maximum thickness of 15% with 2% camber located 40% back from the airfoil leading edge. [3]

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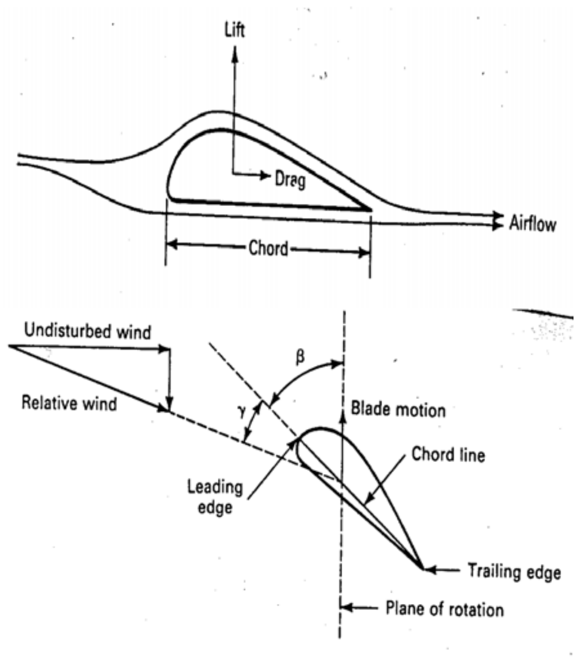

Figure 1. Wind Turbine Blade Profile [4]

2.1 Design Parameters

- **Free Stream Velocity:** The magnitude of incoming flow velocity. For complex stream flows, mean average value of flow speed through the frontal area can be assumed.[5]
- **Blade Profile:** The 2-D cross sectional area of the airfoil which makes up the geometry of each section of blade.
- **Chord Length:** The length of the airfoil profile. (Refer Fig. 1)[5]
- **Solidity:** The percentage of the frontal area of the turbine which is taken by the turbine blades.
- **Sweep Angle:** The angle around circumference that each blade sweeps.[5]
- **Twist Rate:** The rate at which blade twists about the center axis of the turbine with respect to height of turbine.[5]
- **Fluid Density:** The density of the fluid that flows around the blades.
- **Turbine Height:** The central axis length of turbine.
- **Turbine Diameter:** The diameter of circumference of the turbine.
- **Tip Speed Ratio**: The ratio of the tangential blade tip speed to the actual wind flow speed.

3. Modelling and Simulation

First task is to prepare the geometry. We have prepared four geometry. To prepare the geometry first find out the airfoil co-ordinates to draw the airfoil shape. The airfoil co-ordinates can be easily found out on internet. Here NACA 0018 and NACA 0020 airfoils are used. NACA 0018 means maximum thickness of the airfoil in the percentage of the cord is18%. Similarly, 20% maximum thickness of airfoil in percentage of chord for NACA 0020. These two profiles are drawn in the Solidworks 2014. These airfoils points are imported to Solidworks and then taking circular reference number of blades are given. After which rate of twist in given and these airfoils are extruded about the vertical line. For each NACA airfoils two cases are taken one for three blades and other for two blades.
The parameters for the NACA airfoil are as follows:

Table 1. NACA 0018

	NACA 0018 (3 Blades)	NACA 0018 (2 Blades)
Chord Length	1m	0.8m
Blade Length	4m	3.7m
Rotor Diameter	3m	3m
Inner Shaft Diameter	0.25m	0.25m
Plate Thickness	0.15m	0.15m
Turbine Height	4.3m	3.9m
Solidity	56.58%	41.87%
Twist Rate	120°	120°

Table 2. NACA 0020

	NACA 0018 (3 Blades)	NACA 0018 (2 Blades)
Chord Length	0.8m	1m
Blade Length	3.7m	4m
Rotor Diameter	3m	3m
Inner Shaft Diameter	0.25m	0.25m
Plate Thickness	0.15m	0.15m
Turbine Height	3.9m	4.3m
Solidity	41.87%	56.58%
Twist Rate	120°	120°

The design of the helix wind turbine in the Solidworks 2014 is as follows:

Figure 2. NACA 0018 (3 Blades)

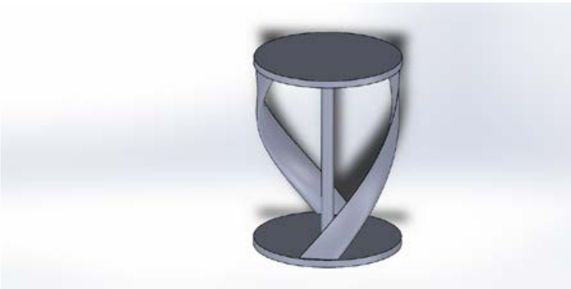

Figure 3. NACA 0018 (2 Blades)

Figure 4. NACA 0020 (3 Blades)

Figure 5. NACA 0020 (2 Blades)

These design are imported to the Ansys Fluent. The domain is defined for the Helix Wind Turbine. The domain used is cuboidal with 11.5D, 7.5D, 7.5D as X, Y, Z axes respectively. The boundary conditions are given like inlet, outlet, fixed and stationary walls. The turbine is meshed with the following nodes and elements:

Table 3. Helix Wind Turbine Meshing

	Nodes	Elements
NACA 0018 (3 Blades)	413665	2243781
NACA 0018 (2 Blades)	383015	2069016
NACA 0020 (3 Blades)	502989	2733861
NACA 0020 (2 Blades)	399724	1885892

The meshing of the helix wind turbine in the Ansys Fluent 15.0 is shown below:

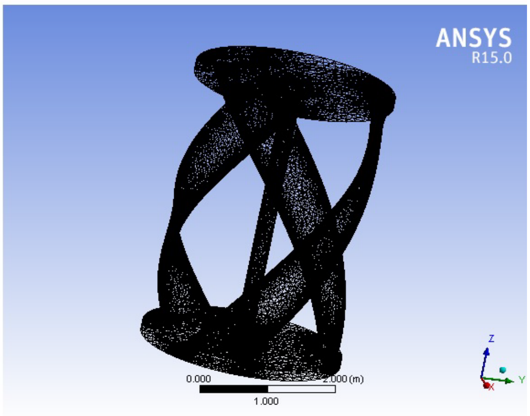

Figure 6. NACA 0018 (3 Blades) Meshing

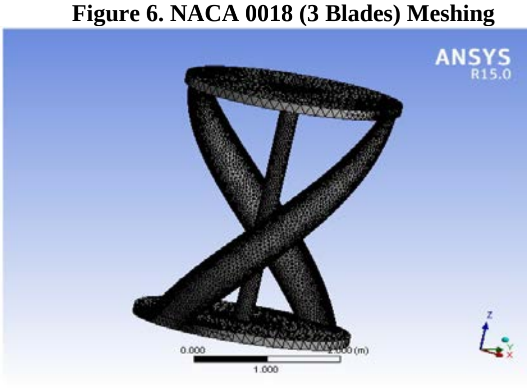

Figure 7. NACA 0018 (2 Blades) Meshing

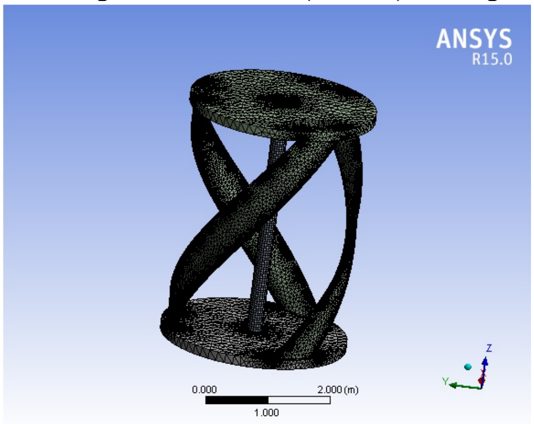

Figure 8. NACA 0020 (3 Blades) Meshing

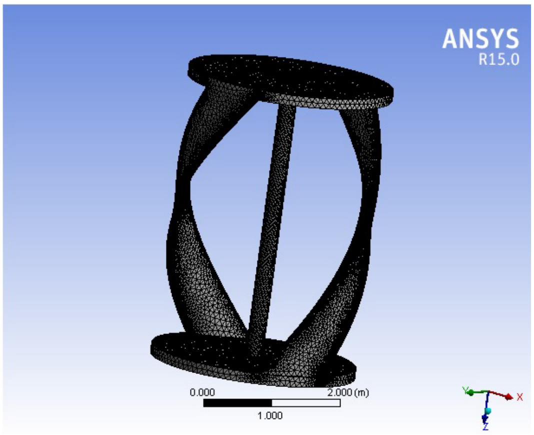

Figure 9. NACA 0020 (2 Blades) Meshing

After getting the helix wind turbine meshed, there is a requirement to set up the problem. The following computational conditions were set up in Ansys Fluent:

Table 4. Computational Conditions

Simulation Type	Steady State
Fluid Material	Air
Temperature	288 K
Kinematic Viscosity	$1.4*10^{-5}$ m^2/s
Density	1.225 kg/m^3
Pressure	101325 Pa
Wind Speed	3 m/s
CFD Algorithm	Simple
Type of Model	Shear Stress Transport (SST) k- ω
Boundary Conditions	Velocity Inlet and Pressure Outlet

4. Lift and Drag Estimation

The coefficient of lift and drag are computed by giving the computational conditions. The number of iterations used to get the solution is 100. Here are the values of C_l and C_d for the airfoils.

Table 5. C_l and C_d Values

	C_l	C_d
NACA 0018 (3 Blades)	0.9	0.45
NACA 0018 (2 Blades)	0.75	0.15
NACA 0020 (3 Blades)	0.9	0.4
NACA 0020 (2 Blades)	0.55	0.15

The graphs for the values of C_l and C_d with respect to number of iterations are shown below:

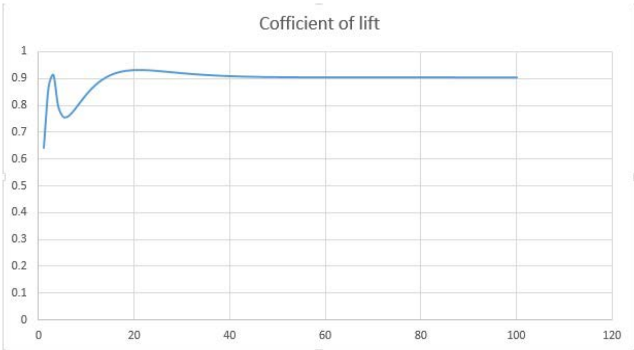

Figure 10. C_l for NACA 0018 (3 Blades)

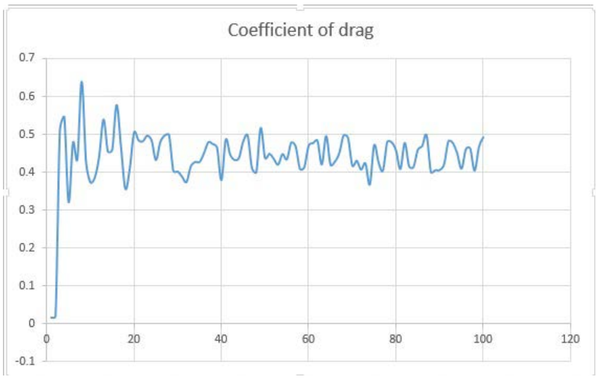

Figure 11. C_d for NACA 0018 (3 Blades)

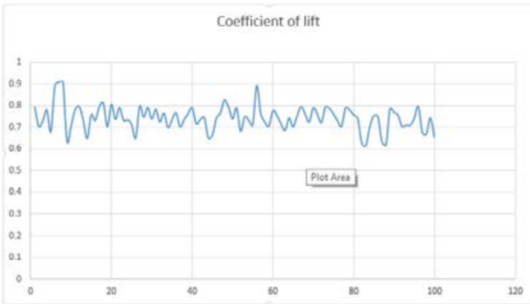

Figure 12. C_l for NACA 0018 (2 Blades)

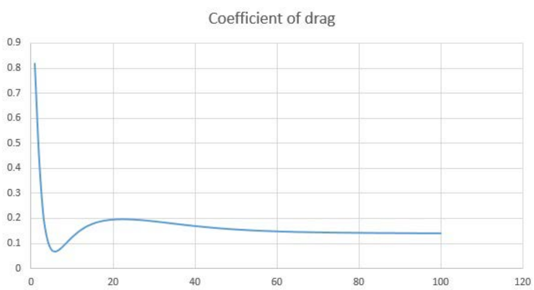

Figure 13. C_d for NACA 0018 (2 Blades)

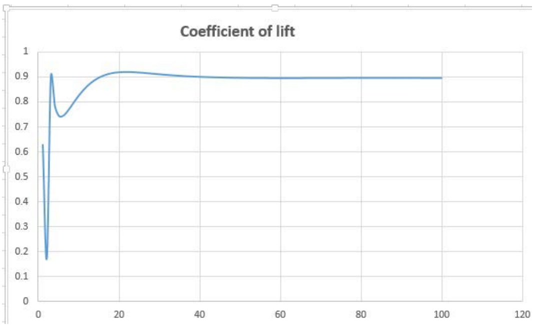

Figure 14. C_l for NACA 0020 (3 Blades)

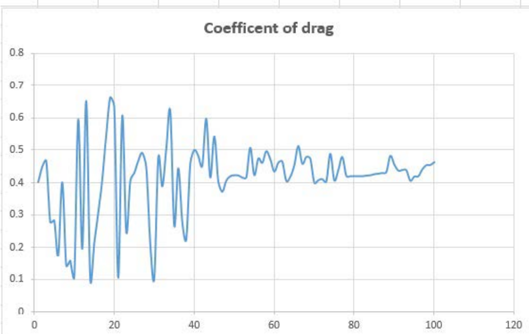

Figure 15. C_d for NACA 0020 (3 Blades)

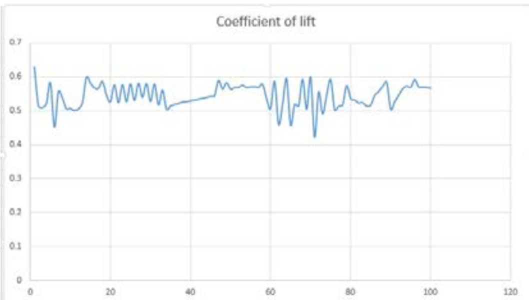

Figure 16. C_l for NACA 0020 (2 Blades)

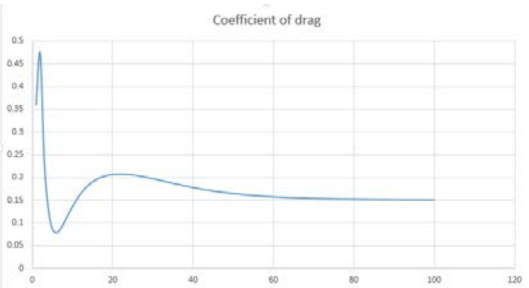

Figure 17. C_d for NACA 0020 (2 Blades)

As, it can be observed in some graphs the values are not getting converged. The reason may be less number of iterations, insufficient boundary conditions or may be anything.

5. Calculation

With the help of the value of C_l the lift force is calculated. The power harvested, available and efficiency is also calculated. The formulae used are given below:

Swept area of blade A= D×L
Average wind speed available V= 3 m/s
Mass of air per second striking on the blade (m) = $\rho \times A \times V$
Power available = $\frac{1}{2}(m \times v^2)$
= $\frac{1}{2}(\rho \times A \times V^3)$
Lift force = $\frac{1}{2}(Cl \times \rho \times A \times V^2)$
Power harvested = lift force × relative velocity of blade
Efficiency = Power harvested/Power available
$\acute{\eta} = P_h / P_a$

Table 6. Result

	NACA 0018		**NACA 0020**	
	3 Blades	**2 Blades**	**3 Blades**	**2 Blades**
Solidity (%)	56.58	41.87	41.87	56.58
Power available (watt)	66.15	48.95	48.95	66.15
Lift force (N)	19.845	12.237	14.685	12.127
Power harvested (watt)	12.899	7.954	9.545	7.882
Efficiency (%)	19.5	16.25	19.5	11.91

6. Conclusion

Following conclusions can be made from this work:

- The efficiency of NACA 0018 (3 Blades) and NACA 0020 (3 Blades) are same. But the lift force of NACA 0018 (3 Blades) is greater than that of NACA 0020 (3 Blades).
- The efficiency of 3 blades helix wind turbine is more than the 2 blades helix wind turbine.
- The lift force depends on the frontal area of the turbine.
- Larger the turbine diameter more power can be harvested for same speed and turbine configurations.
- The power harvested is proportional to the diameter of the turbine. But there is a limit to how much diameter can be increased so

as to prevent structural damages due to centrifugal forces.

- Increasing the number of iteration converges the coefficient of lift and drag. But the number of iterations depends on the system configurations.
- They are less efficient than horizontal wind turbines but they can be used to decrease the small loads judiciously like street lightings, hoardings, mobile towers, shopping malls and etc.

7. Acknowledgement

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8. References

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