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CFD Analysis of Winglets for Horizontal Axis Wind Turbine

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ABSTRACT:

This paper is to discussthe optimization of wind turbine blade by adding winglets at the tip of the blade, and to improve the aerodynamic performance of the turbine with the modified blades for decrease the total drag force, decrease the generation pressure and decrease the vortex created at the tip of the blade.The existing turbine blade compared with the modified blade having winglets for different angles for aerodynamic performance.Creo Parametric2,Ansys fluent 14.5 software have been used to design blades. NACA 4415 airfoil profile is considered for analysis of wind turbine blade.

Keywords: Windturbine, Horizontal Axis Wind Turbine (HAWT), Turbine blades, Wingletangles, Drag force.

I.INTRODUCTION:

The exist wind turbine blades are modified by attaching winglets at the tip of the blade to improve the aerodynamic performance of turbine rotors and to make them less sensitive to wind gusts by reduce the pressure on the tip of bladeand decreases the induced drag of the blade by changing the downwash distribution. The idea is to add a winglet which is able to carry aerodynamic loads so that the vortex caused by the winglet spreads out the effect of the tip vortex which results in decreasing the downwash and reducing the induced drag.

II. METHODOLOGY:

The geometry is developed with help of Creo Parametric considering NACA 4415 airfoil profile and CFD fluent 14.5 is used for analysis of the wind turbine blade without winglets (Zero angle) and with winglets for different angles(45,60,75,90) and compared with different models of the wind turbine for same inlet conditions.

A-modeling of wind turbine:

The geometry of a winglet is defined by six parameters

- Height
- Sweep angle
- Cant angle
- Curvature radius
- Toe angle
- Twist angle

The geometry of winglets has been extensively investigated for the aeronautical industry and specifically for high performance sailplanes. Since it has been shown that winglets decrease drag and improve aerodynamic performance of wind turbine rotor blades, it is important to understand and analyze the design and performance improvement process for wind turbine applications. This provides with an idea on how to manage the design process for the wind turbine application.

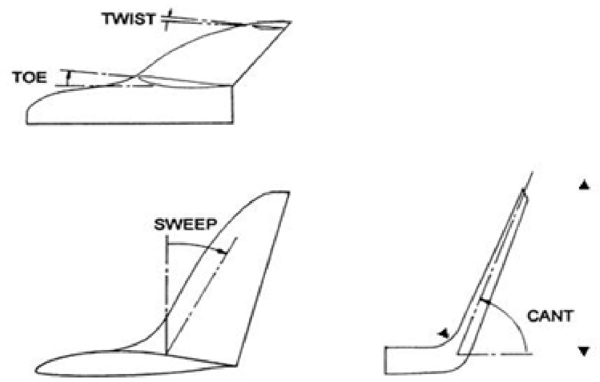

Fig.1Geometric quantities used to define winglet

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These geometric parameters can serve as the variables for input to the optimization algorithm in order to find the optimal shape given the aerodynamic constraints and goals.

Fig. 2(a)

Fig. 2 (b)

Fig. 2(c)

Fig. 2(d)

Fig. 2 (e)

Fig.2 Blade wind turbine with variation winglet angels

The Fig 2 show five types of bladesFig.2(a) without winglet and otherswith difference winglet angles(45,60,75,90)Stations and ordinates of NACA 4415 are given in Table 1.Of airfoil chord length. Aerofoil station distribution for the blade designHAWT blades use airfoils to develop mechanical power. The cross-sections of HAWT blades have the shape of airfoils. The width and length of the blade are functions of the desired aerodynamic performance the maximum desired rotor power, the assumed airfoil parameters and strength calculations. Hence designing HAWT blade depends on knowledge of the data and properties of airfoils.

Table1. Stations and ordinates of NACA 4415

Radius (r) (m)	Radial location r/R	Pitch angle(β) (deg)	Chord length (c) (m)
0.9	0.18	28.1	1.3754
1.24	0.248	19.9	1.1057
1.58	0.316	14.7	0.9113
1.92	0.384	10.9	0.7689
2.26	0.452	8.3	0.6681
2.6	0.52	6.4	0.5865
2.94	0.588	4.9	0.5301
3.28	0.656	3.7	0.4737
3.62	0.724	2.7	0.4409
3.96	0.792	1.9	0.4401
4.3	0.86	1.2	0.3758
4.64	0.928	0.6	0.3489
5	1	0	0.3267

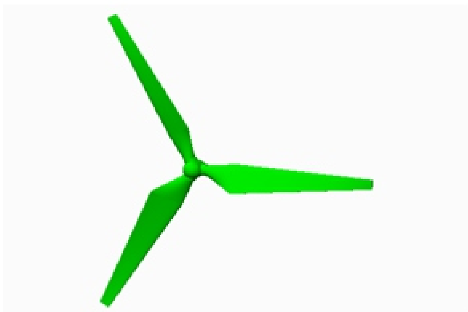

Fig.3Wind Turbine (Without Winglet)

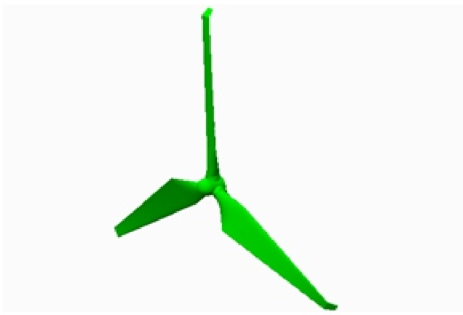

Fig.4 Wind Turbine (With Winglet 45°)

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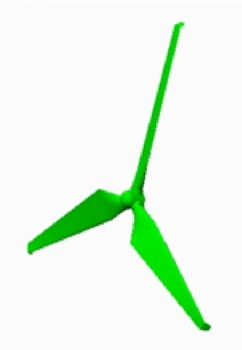

Fig.5 Wind Turbine (With Winglet 60°)

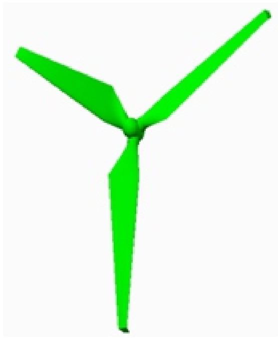

Fig.6 Wind Turbine (With Winglet 75°)

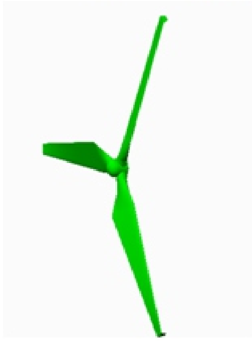

Fig.7 Wind Turbine (With Winglet 90°)

B-Meshing:

The model is meshed with help of ICEMCFDfor HAWT rotor and ANSYS-Fluent 14.5 is used for the analysis of the geometry of the flow field and making the mesh. The HAWT rotor was imported from Creo –parametric 2 program then placed in a cylindrical domain of radius (2R) and length (5R) (R= rotor radius). The upstream boundary was positioned (2R) from the rotor.

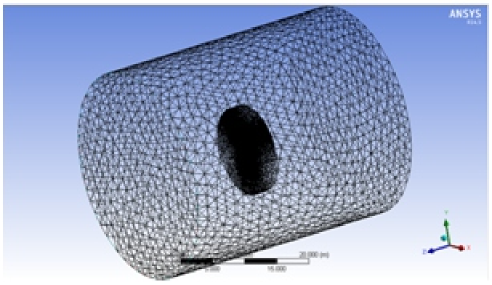

Fig.8 Mesh construction of cylindrical domain

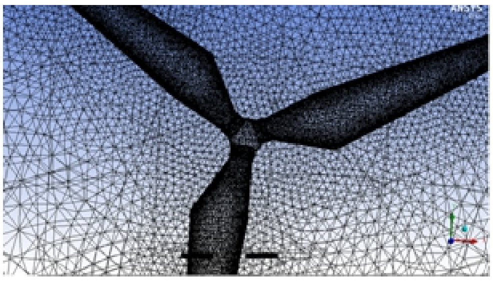

Fig.9Mesh size of local disk

The cylindrical domain was constructed that consist of background (outer fluid) (all cylindrical domain except local disk) with a big size unstructured mesh and local disk (rotating fluid) with fine unstructured mesh as shown in fig.8 and Fig..9The background mesh contained 466826, 456354, 476387, 466487 and 457837 nodes for winglet angle (0, 45, 60, 75, 90) respectively.

In the figures above the meshing is shown like a surface mesh but the truth is it is volume mesh (tetrahedral) because of the figures that are shown as the wireframe simple displayed.

III.Boundary conditions :

After completing the geometry and meshing in ICEM CFD, The model does not only involve the air flow conditions, but also periodicity and rotational machinery capabilities in order to correctly replicate the real-world situation for wind turbines. The inlet boundary conditions for the wind speed were set as

- Entrance velocity of 5 m/s
- Air temperature 25 c
- Density 1.185 kg/m^3.
- The reference pressure is 1atm
- The background of cylindrical model is considered as fixed walls around the rotor ,
- The rotor is assumed to be rotating with angular velocity 8 rad/sec.
- Re = 3x10^6

IVRESULTS AND ANALYSIS :

After the simulation of the 3d wind turbine was successfully completed, the results were compared in terms of velocity eforcand tourpresure con our andtcon contour are primary indicators of aerodynamic performance,A comparison was made between the different types of blades configurations (0,45,60,75,90) angels , The simulation was carried out at an inlet velocity of 5 m/s which corresponded to 3*10^6 Reynolds Number. The different blades configurations were simulated 12 angle of attack.

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A-Pressure contour:

The figures show the pressure contour plot around the aerofoil when the winglet (0, 45, 60, 75, 90) respectively with air velocity 5 m/s it can be observed the low pressure on the leading edge of the aerofoil and high pressure on the trailing edge of the aerofoil where most of the lift is produced. the maximum pressure is (7509, 5519, 7122,6972, 6462)Pa

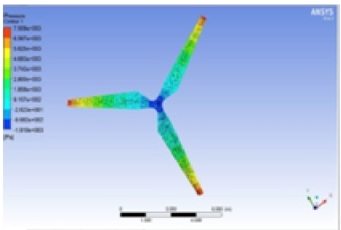

Fig10 Pressure contour (without winglet)

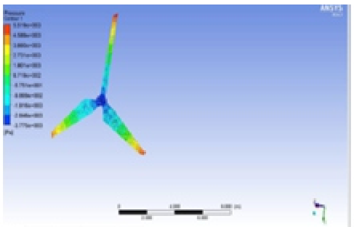

Fig.11 Pressure contour (winglet 45°)

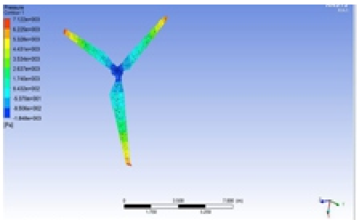

Fig.12 Pressure contour (winglet 60°)

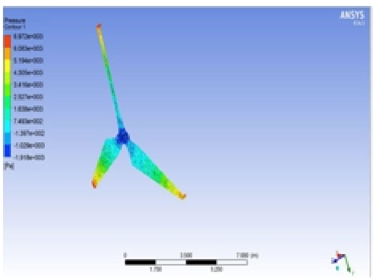

Fig.13Pressure contour (winglet 75°)

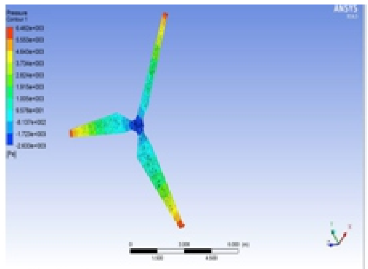

Fig.14 Pressure contour (winglet 90°)

B-Velocitycontour:The figures shows the velocity contour on rotor for 5 m/s of inlet air velocity. Where the velocity on the blades is increasing from root to tip of the blade because of many reasons like reducing of chord length and difference of the radius from root to tip. There is little difference of velocity between the types of the rotors at the tip blade and the maximum Velocity for various winglets (0, 45, 60, 75, 90) is (26.59, 26.79, 26.60, 26.63, 26.86) m/s respectively.

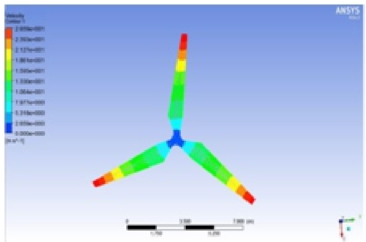

Fig 15Velocity contour (without winglet)

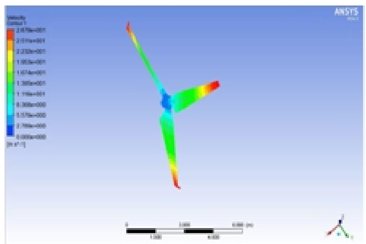

Fig.16Velocity contour (winglet45°)

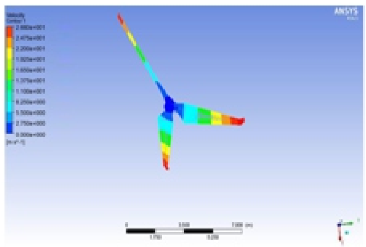

Fig.17 Velocity contour (winglet 60°)

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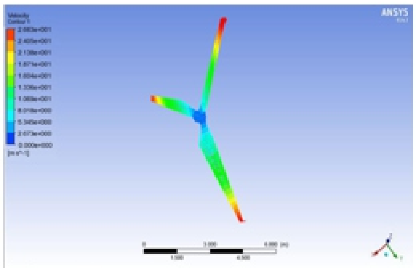

Fig.18Velocity contour (winglet 75°)

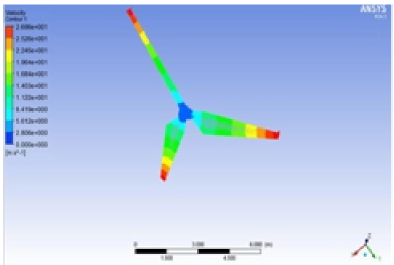

fig.19 Velocity contour (winglet 90°)

C-Force contour:

The figures show the force contour in front of rotor without winglet and for rotor with winglet (45°,60°,75°,90°) respectively. It is observed that the area average of force for rotor without winglet is more than rotor with winglets because the pressure at the winglets is less than without winglets. And the maximum force for each case are (36.93, 27.07, 28.39, 29.25, 28.06) N.

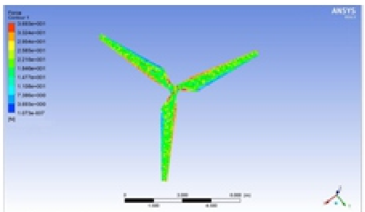

Fig.20 Force contour (without winglet)

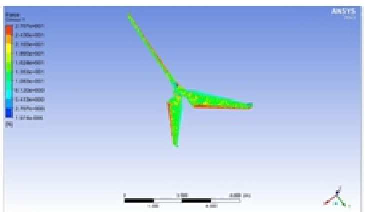

Fig.21 Force contour (winglet 45°)

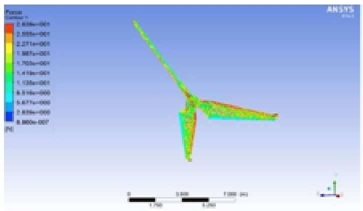

Fig.22Force contour (winglet 45°)

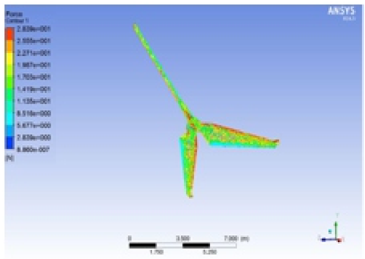

Fig.23Force contour (winglet 75°)

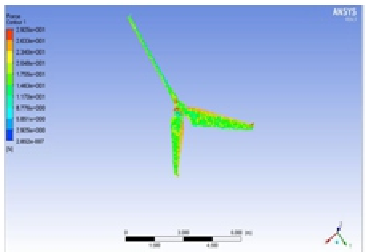

Fig.24 Force contour (winglet 90°)

VI.CONCLUSION:

• The calculation shows When using blades with and withoutwinglet at air velocity 5m/s it was observed that, the maximum pressure are (7509, 5519, 7122,6972, 6462)Pa and velocity counter are(26.59, 26.79, 26.60, 26.63, 26.86) m/s respectively and force on the tip of the blades are (36.93, 27.07, 28.39, 29.25, 28.06) N respectively.

• According to the results obtained from the analysis program, the best winglet angle is (45°). Was found less than the amount of force and pressure with the survival of speed approximately the same rate.

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