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Aerodynamically Efficient Wind Turbine Blade

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ABSTRACT: *This article presents a new design of wind turbine blades which is highly aerodynamically efficient. The underlying concept is the usage of high lift devices flap in the wind turbine blades. In This extensive research study, reveals how the flaps can be efficiently integrated in to the already existing wind turbine blades so that the wind energy harvested can be increased with nearly zero extra manufacturing cost. This research study also discusses the range of operation of these flaps in the real life. In addition to that, this aerodynamically efficient wind turbine blade when deflected negatively it has the tendency to act as brakes which will help us to halt the wind turbines during worst times like hurricanes, strong winds or storms prevailing with high wind speeds.*

I. INTRODUCTION:

What is wind and wind energy? How it is utilized?

Wind is a form of solar energy. Winds are caused by the uneven heating of the atmosphere by the sun, the irregularities of the earth's surface, and rotation of the earth. Wind flow patterns are modified by the earth's terrain, bodies of water, and vegetative cover. Wind power is the conversion of wind energy into a useful form of energy, such as using wind turbines to make electricity. This wind flow, or motion energy, when "harvested" by modern **wind turbines** are used to generate **electricity**. Wind energy is also a source of **clean, non-polluting, electricity**. Unlike conventional power plants, wind plants emit no air pollutants or greenhouse gases. According to the U.S. Department of Energy, in later years, California's wind power plants offset the emission of more than 2.5 billion pounds of carbon dioxide, and 15 million pounds of other pollutants that would have otherwise been produced. It would take a forest of 90 million to 175 million trees to provide the same air quality. Wind energy is energy collected from motion caused by heavy winds. Wind energy is collected in turbines with propellers that spin when the wind blows and turn the motion of the Propeller into energy that can be used in the electrical grid. Wind energy is a clean, renewable energy source that is abundant in windy areas. Large wind farms are often located outside of cities, supplying power for electrical grids within the city.

WIND TURBINE:

When we talk about modern wind turbines, we are looking at two primary designs:
[1] Horizontal-axis and
[2] Vertical-axis.

Vertical-Axis Wind Turbines (VAWTs) are pretty rare. It is generally used in the less height regions. Instead of a tower, it typically uses guy wires for support, so the rotor elevation is lower. Lower elevation means slower wind due to ground interference, so VAWTs are generally less efficient than HAWTs. As implied by the name, the **Horizontal Axis Wind Turbines (**HAWT) shaft is mounted horizontally,

parallel to the ground. HAWTs need to constantly align themselves with the wind using a yaw-adjustment mechanism. The yaw system typically consists of electric motors and gearboxes that move the entire rotor left or right in small increments. The turbine's electronic controller reads the position of a wind vane device (either mechanical or electronic) and adjusts the position of the rotor to capture the most wind energy available. HAWTs [6] use a tower to lift the turbine components to an optimum elevation for wind speed (and so the blades can clear the ground) and take up very little ground space since almost all of the components are up to 260 feet (80 meters) in the air. In this research report, the Horizontal axis wind turbine [6] and its blades have been taken in to consideration to innovatively optimise its design using aerodynamics concept to increase its efficiency and capability to be used in lower heights also. *The major innovation is use of Flaps which in an aircraft is used efficiently to optimise the runway length vs. climb rate.*

AERODYNAMIC FLAPS:

Flaps are hinged surfaces mounted on the trailing edges of the airplane wings to either increase its lift or drag, depending on the selection by the pilot. Extending the flap increases the camber or curvature of the wing, raising the maximum lift coefficient or the lift a wing can generate. This allows the aircraft to generate more lift at a lower speed, reducing the stalling speed of the aircraft, or the minimum speed at which the aircraft will maintain flight. Extending the flap also increases the drag which can be beneficial during approach and landing. But in our innovation, the flap is used as a high lift device that is devised to design a highly efficient blade. The flap is placed at the trailing edge of the blade as the air over the blade speeds up at the tip of the blade as the circulation occurs over the tip [1]. The rotational moment created on the tip is more, even when the force is very much less as the perpendicular distance is more at the tip giving us more lift (i.e. rotation in the case of wind turbine). Hence our design flaps have been used at the tip of the wind turbine blade (Ref fig 1).

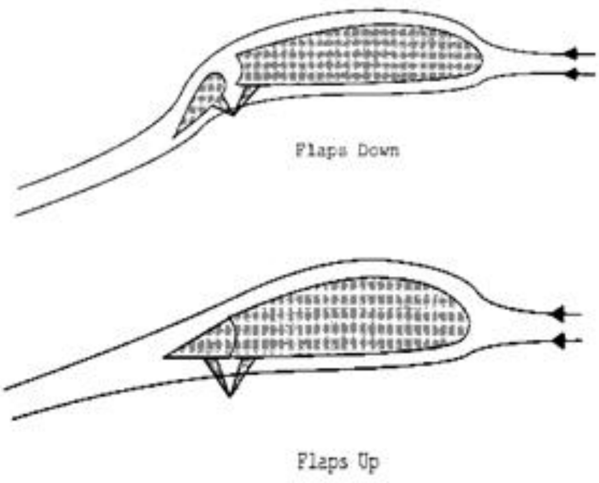

Fig-1 Usage of Flap

The analytical results (The analysis has been done using ANSYS CFD flow solvers) show that with the use of flaps on tip there is:

- Increased positive pressure difference between the upper and lower side of aerofoil increasing the lift coefficient [2]
- Increased camber length which in turn increases the surface area and generates more lift than prior designs [

II. RESULTS AND ANALYSIS OF AEROFOIL WITH AND WITHOUT FLAPS:

PRESSURE CONTOUR ANALYSIS:

The CFD analysis of the aerofoil with and without flaps has been carried out and the results are depicted below:

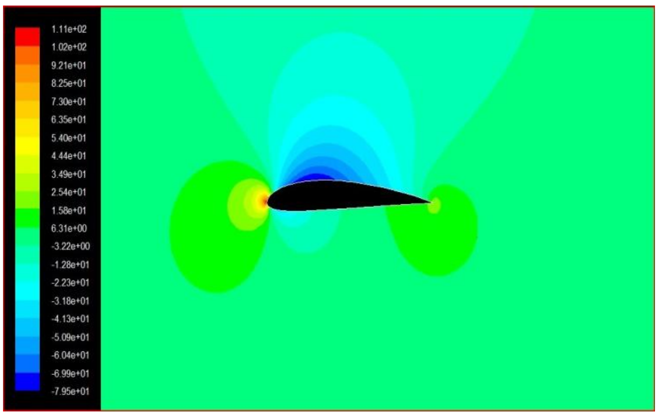

Fig-2 pressure distribution of aerofoil without flaps

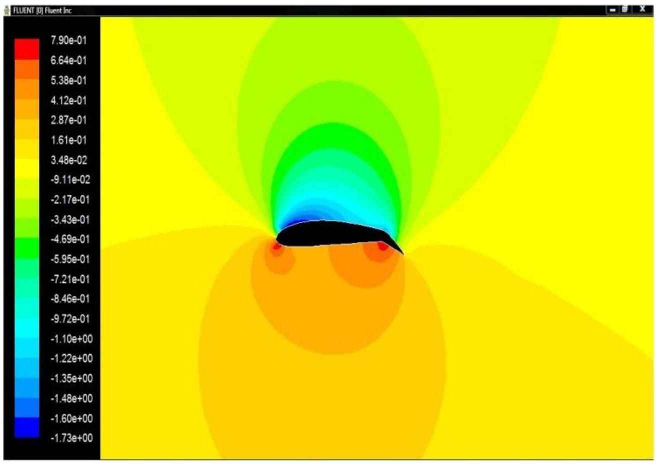

Fig-3 pressure distribution of aerofoil with flaps 20^0 deflected

The pressure contour clearly shows that, the use of flap creates positive pressure difference on the aerofoil shape thereby increasing the lift coefficient. We know that when the air is flowing over the aerofoil the velocity is maximum over the upper surface and the pressure is more on the lower surface of the aerofoil (BERNOULI'S THEOREM) [4] which is defined here as positive pressure difference and which in turn influences the above mentioned lift coefficient. From the below graphs, we can clearly see that aerofoil without flap has the maximum $\mathbf{C_L}$ =1.4 at 12^0 angle of attack whereas we get $\mathbf{C_L}$ =1.7 at zero angle of attack in case of aerofoil with flap.

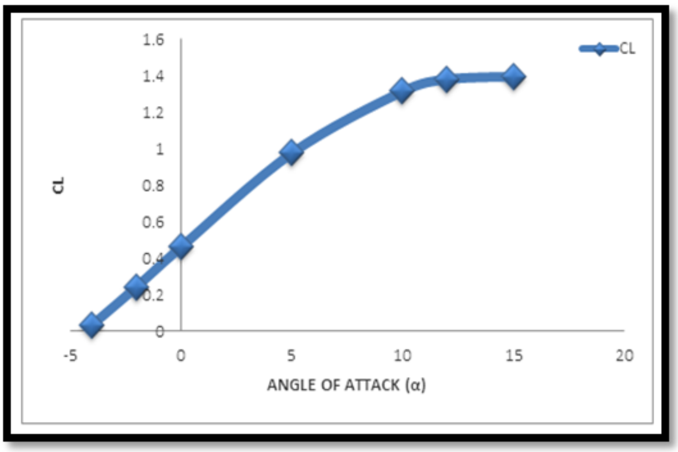

Fig-5 C_l Vs A For Without Flap

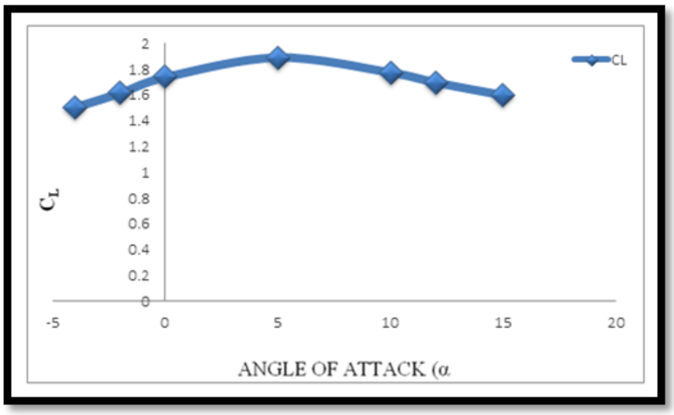

Fig-5 C_l Vs A For With Flap at 30 Degree

As, we have found that the use of flaps increases the lift coefficient and influences the positive pressure difference, we analysed it for the effective limitation, if any, of the flap deflection in case of wind turbine blades. We have done flow analysis over the wide range of flap deflected aerofoil. It was inferred that the use of flaps beyond 25^0 produces more drag than the expected power. So, efficient usage of flaps in wind turbine is limited to 25^0 degree. Refer the figure below where path lines clearly indicate the deduction arrived at

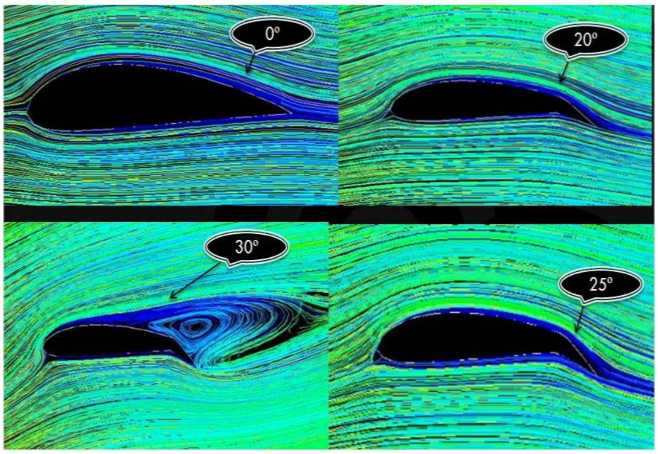

Fig-6 Path Lines of Aerofoil with Flaps Deflections at Different Degrees

We all know that the 2D and 3D analysis has some changes in their calculations due to the some design challenges. So, it's mandatory to go for 3D analysis to check the desired results. In our study, to prove the concept in 3D analysis, we have compared the blade model without flap (existing model) and the blade with flap (redefined model) and analysed it by comparing the pressure distribution graph, lift coefficient curve and the pressure and velocity contour diagrams of flow analysis. The analysis technique used and the various analysis results are given below:

III. ANALYSIS TECHNIQUE:

Initially the blade model is drawn in GAMBIT with and without flap and then the control volume for that surface is defined. The length of the wind turbine blade is taken as 40m length wind turbine blade and as the rotational moment created on the tip is more, we attach the flaps at the tip of the blade from 32m to 40m (considering 8m long flap).Now, the blade model and the control surfaces are meshed and the boundary conditions are set up according to the real simulation. Then the mesh file is exported to GAMBIT and flow analysis is performed in FLUENT. The ASCII files of the blade are then exported to plot the pressure co-efficient and velocity profile over the blades. The velocity distribution over the aerofoil clearly shows that the use of flaps increased the velocity over the aerofoil and the flow is moving further downstream than the flow over the normal aerofoil. Thus the increased velocity over the aerofoil means further low pressure on the top side of the aerofoil. The pressure distribution over the aerofoil with and without flap is shown below. The pressure distribution over the aerofoil clearly shows the high pressure on the bottom surface of the aerofoil on the contour diagram. Higher the pressure exerted on the bottom surface more is the force which bound to rotate the wind turbine blades

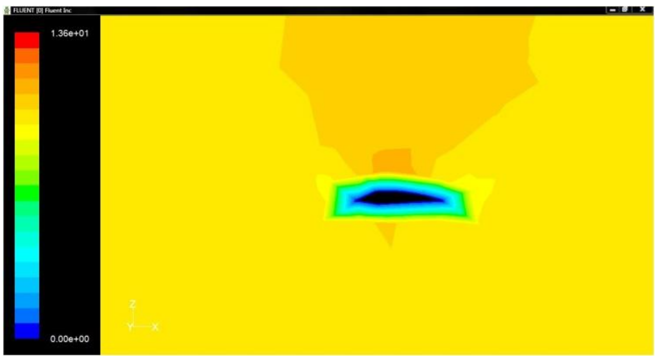

Fig-7 Velocity Distribution of Redefined Blade Model without Flap

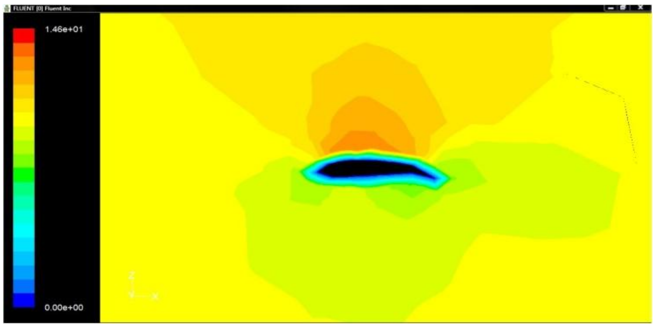

Fig-8 Velocity Distribution of Redefined Blade Model with Flap

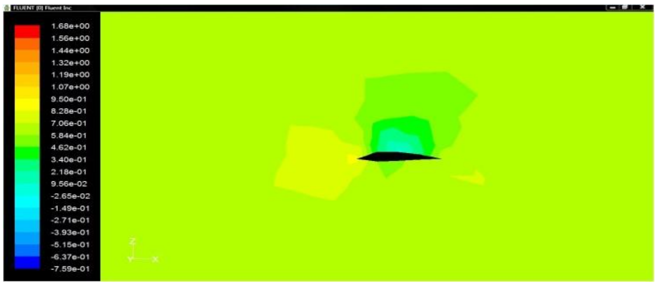

Fig-9 Pressure Distribution of Aerofoil without Flap Deflections at 35m of the Blade

The graphs showing the coefficient of pressure c_p is shown below for both the model of wind turbine blade with and without flap. We know that the pressure is more at the bottom surface and less at the upper surface [5] The pressure difference between the upper and the lower surfaces are less in the case of available wind turbine models (i.e. basic model without flap) and the deviation is quite more in the redefined model (i.e. wind turbine blade model with flap)

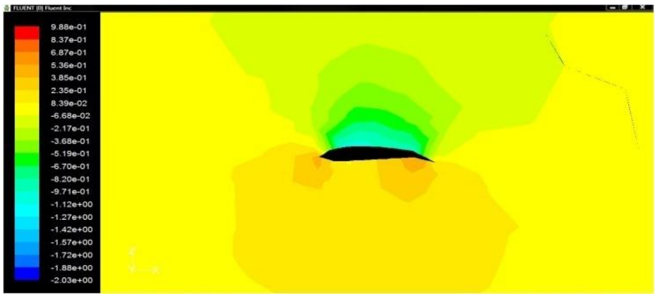

Fig-10 Pressure Distribution of Wind Turbine Blade with Flap Deflection of 20 Degree at 35m Of The Blade

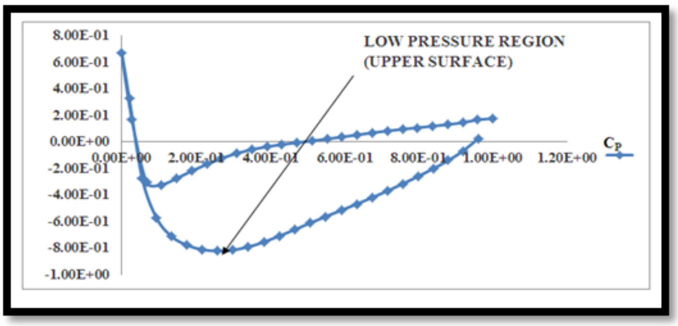

Fig-11 C_p for Aerofoil without Flap

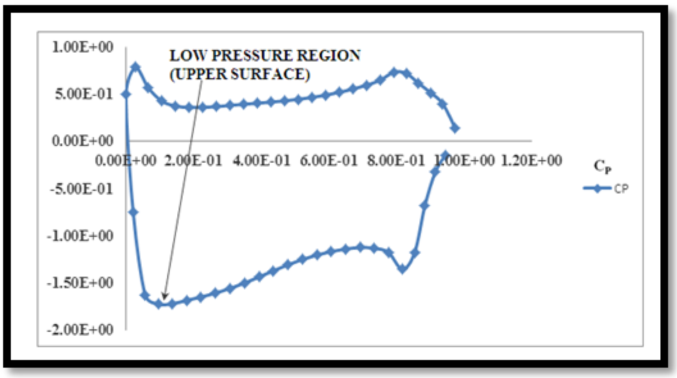

Fig-12 C_p for Aerofoil with Flap at 30 Degree

INFERENCE:

[1] Flap increases the lift coefficient c_L
[2] Flap inserted at tip of the blade maximizes the rotational moment
[3] Flap creates pressure difference which makes the turbine to start rotating at lower speeds
[4] Rotating at low speeds enables building wind farms at low wind regions
[5] Early start of wind turbine enhances the operating time and power generation
[6] Installation of suitable flap increases the surface area(a) (power equation of wind turbine (p)=1/2 $\rho a v^3$)
[7] Tower heights can be reduced which minimizes cost and makes accessibility much easier
[8] Deflected in opposite direction as a brake during high wind conditions to protect from structural damage.

IV. CONCLUSION:

We know that the world is facing energy crisis everywhere and we can solve that by adopting this new technology in wind turbine field. From the power equation if the area swept by the rotor increases then the power increases. As the same if the pressure increases on the bottom surface of the blade then the blade starts to rotate at much earlier time and at very low wind speeds. It is expected to rotate at about 3.5 m/s instead of 5.5 m/s. As it starts earlier there is more energy production. In wind turbine field each and every minute is very important and they pay for that. This innovative technology is going to change the shape of the wind turbine blades soon.As per the American estimation we can produce power for less than 5 cents/kWh. By this technology we can save more than that and the amount of production also increases for sure. *We can solve the energy crisis everywhere by this technology as it works effectively even in low wind speed regions too.*

RFERENCES:

[1] Peter J Schubel ,Richard J Crossley .,"Wind Turbine Blade Design, "Energies 2012, ISSN 1996-1073
[2] Cory S. Jang, James C Ross., "Numerical Investigation of an Aerofoil with a Gurney Flap" NASA Ames Research Centre, USA.
[3] Chapter-4 ," Introduction to Aeronautics – A Design Perspective " ., University of Southampton
[4] Mizrap Bulunuz, Olga S Jarrett., "Properties of Air and Bernoulli's principle, "Asia Pacific Forum on Science Learning and Teaching".
[5] David M. Smiadak ., " Lift Coefficient for an Aerofoil ., " Grand valley State University " July 15 2008
[6] A C Hansen , C P Butterfield ., "Aerodynamics of Horizontal Axis Wind Turbine Blades, "Annual Review of Fluid Mechanics, volume-25 , January-1993