Design and Analysis of Adaptable Flexed-cup Vertical Axis Wind Turbine

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***Abstract*— The renewable source of energy is the future. The sustainability of the fossil fuels while considering its rate of consumption has paved way for rediscovering the possible ways of converting and conserving one form of energy into another. This paper focuses on similar aspect. Wind energy as a renewable source has great potential to fulfill the ever increasing energy demand worldwide. Newer and improvised design of the wind turbine blade caters for extraction of kinetic energy of the wind to its fullest extent. This paper shows a unique design that recovers kinetic energy of the wind by allowing itself to appropriately align with the direction of the wind. The paper also considers various possible design of blades and optimizes it to obtain the most suitable one using Computation Fluid Dynamic Analysis.**

***Index Terms*— Renewable Energy, Helical-Cup, Adaptable Blade, Power Output, Efficiency**

I. INTRODUCTION

Wind turbines have become an economically competitive form of clean and renewable power generation. Wind energy is a low density source of power [1]. At present, Costs have declined, making wind more competitive clean energy source with other power generation options. Designers apply optimization tools for improving performance and operational efficiency of wind turbines, especially in early stages of product development. Wind turbines are more powerful than early versions and employ sophisticated materials, electronics and aerodynamics [2].

Many meteorological and topological regions in the world are conductive to level of wind velocities suitable for power generation. The kinetic energy of the wind varies with factors like latitude, altitude, seasons and geographical locations. The world is on the verge of scarcity of energy resources and most of the resources used are basically non-renewable sources of energy. Reduced availability of fossil fuels and limited capacity of the world to cope with the pollution caused by fossil fuel are the two major considerations that have forced the world to seek an alternative energy system. Power generation through wind is one of the most attractive solutions for safe and clean renewable energy resources. In recent years, the focus on wind energy has increased significantly for the shortage of resource and climate change [3]. European Union had set a biding target of a 20 percent renewable energy contribution by 2020, and it was estimated that wind energy could contribute one-third of this production [4]. However, wind power occupied less than 0.7 % of the 16% renewable energy resource in 2009 [5], indicating that there was a broad prospect for wind power. There are some rural areas having abundance of wind energy but are still facing the problem of electricity. Therefore, the wind energy can be a proper solution for these types of areas, rather than fossil fuels [4]. Wind power is now the world’s fastest growing energy resource [6]. According to an estimate there is a worldwide annual potential, with power of 10 KWH or 3.6 GJ. The available wind power possesses a huge potential that can contribute 5 times the world energy demand and contribute 0.4% of the huge sum of total energy.

A wind turbine is a type of turbomachine that transfers fluid energy to mechanical energy through the use of blades and a shaft and converts that form of energy to electricity through the use of a generator. Depending on whether the flow is parallel to the axis of rotation (axial flow) or perpendicular (radial flow) determines the classification of the wind turbine. Two major types of wind turbines exist based on their blade configuration and operation. The first type is the horizontal-axis wind turbine (HAWT) and another type is Vertical axis wind turbine (VAWT). VAWTs are small, quiet, easy to install, can take wind from any direction, and operate efficiently in turbulent wind conditions, a new area in wind turbine research has opened up to meet the demands of individuals willing to take control and invest in small wind energy technology. This system enables the low wind speed countries especially in urban areas to harness wind energy from exhaust air resource which are consistent and predictable. The electricity generated from this system can be used for commercial purposes or can be fed into electricity grid [7-8].

However, this paper presents designing of an Adaptable Omni directional Vertical Axis wind turbine blade. Theoretical calculation and optimization is done for obtaining maximum output power.

II. PARAMETERS

The Below parameters represents working at real time operating condition taking into account adverse scenario, However the invented device is Scalable

Height of Turbine = 0.4 m
Width of Turbine = 0.3 m
Operating Temperature = 10° C to 60° C

Blade Type = Unique (Dual i.e. Helical shape with Cup)

A. Theoretical Design Calculations for Wing

Nomenclature in SI units
h = Height of wing
w =Width of wing
A =Frontal Area of wing
r =Radius of wing
v =Velocity of fluid
ω =Angular velocity of wing
δ =Density of fluid
C_d = Coefficient of drag
P = Power produced by device
τ = Torque produced
λ = Tip speed

1) Frontal Area of Wing (A)

$$A = h \times w \times 2 \qquad \text{............. (1)}$$

Substituting value of height and width in equation (1)

A = 0.4*0.3* 2

A = 0.24 m^2

Frontal Area of Wing is 0.24 m^2

2) Overall Radius of Wing

$$r = r_1 + r_2 \qquad \text{............. (2)}$$
= 0.3 + 0.075
r = 0.375 m

Radius of Wing is 0.375 m

3) Torque produced by Wing

$$\tau = 0.5 \times \delta \times v^2 \times A \times r \qquad \text{............. (3)}$$
τ = 0.5*1.225*3.13^2*0.24*0.375
τ = 0.540 N-m
Torque produced by wing is 0.540 N-m

4) Theoretical Power output

$$P = 0.5 \times \delta \times A \times v^3 \times C_d \qquad \text{............. (4)}$$

Here δ= 1.225 ($^{Kg}/_{m^3}$)
Assuming C_d = 1.28 & v = 4 (m/s)
Substituting in equation (2)
P = 0.5*1.225*0.24*4^3*1.28

P = 12.04 W

Theoretical Power Produced by Wing is **12.04 W= Power delivered to wing**

5) Analytical Power Produced by wing according to CFD analysis

$$P = F * V \qquad \text{………… (5)}$$

Where V= Velocity on wing
F= Force on wing

P= 1.95*3.13
= 6.1035 W

Analytical **Power achieved is 6.1035 W**

6) Efficiency of Wing Turbine

$$\eta = \frac{Power\ achieved}{Power\ delivered} \qquad \text{………… (6)}$$

$$\eta = \frac{6.1035}{12.04}$$

$$\eta = 0.5069$$

Percentage **Efficiency of Wing turbine = 50.69 %**

7) Angular Velocity

$$\omega = {}^{P}/_{\tau} \qquad \text{………… (7)}$$

$$\omega = \frac{6.1035}{0.540}$$

ω = 13.65 rad/sec

Angular velocity of turbine is **13.65 rad/sec**

III. CAD MODEL

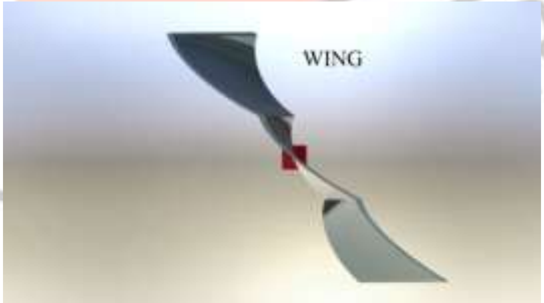

Fig. 1 Side view of the Flexed cup wind turbine blade

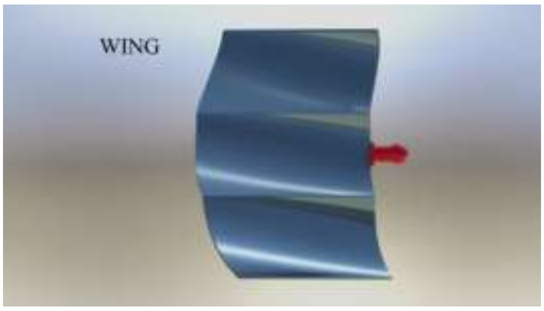

Fig. 2. Front view of the Flexed cup wind turbine blade

IV. ANALYSIS

A. Assumptions

- The surrounding is stationary and the wing is moving
- Geometry is completely closed;
- Any surface geometry that is completely enclosed is considered solid
- Fluid for analysis is Air at 25ºC.
- The surrounding is modelled using an enclosure
- Various modelling operations such as chamfer, fillet etc. are neglected to simply the geometry and reduce the time for analysis

B. Initial Boundary Condition:

- Inlet- velocity = 10kmph
- Outlet- Pressure = 1 atm
- Wing body = Wall (No slip condition)
- Equation used: k-epsilon (2 equation viscous model)

C. Material used: ABS-PC

TABLE I : Material Selection Criteria

Properties	**Fibreglass**	**Carbon fibre**	**Abs-pc**
Density (kg/m^3)	2400-2700	1750-2000	1130
Flexural strength	Moderate	High	Moderate
Cost	Moderate	High	Low
Machining	Moderate	Moderate	Very easy

CFD ANALYSIS OF DESIGN

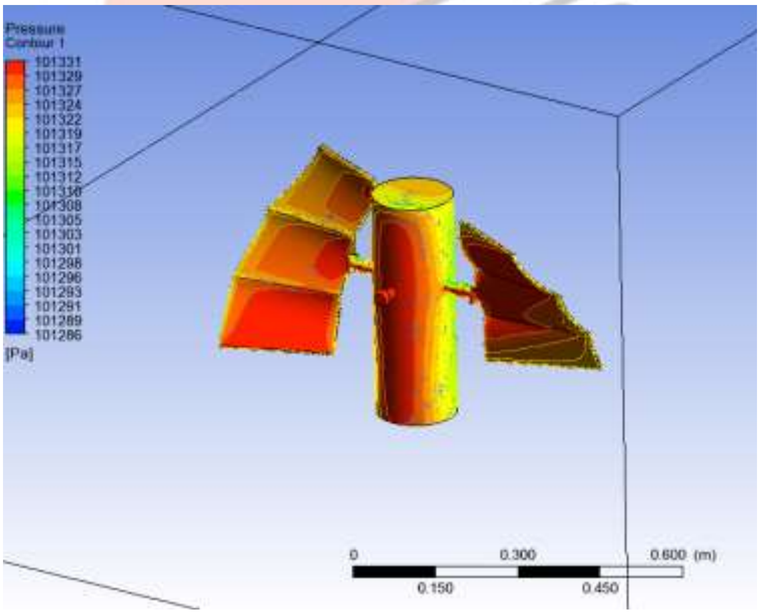

Fig.3. It shows the Pressure distribution over the surface of the wing when velocity of the wind is 10 kmph.

Result:

Force acting on the wing is 1.42 N at 10kmph. The pressure distribution is large on the rear side of the blade which helps in pushing of the blade forward.

V. RESULT

The plot of the value of forces acting on different profiles of wing at different values of velocity,

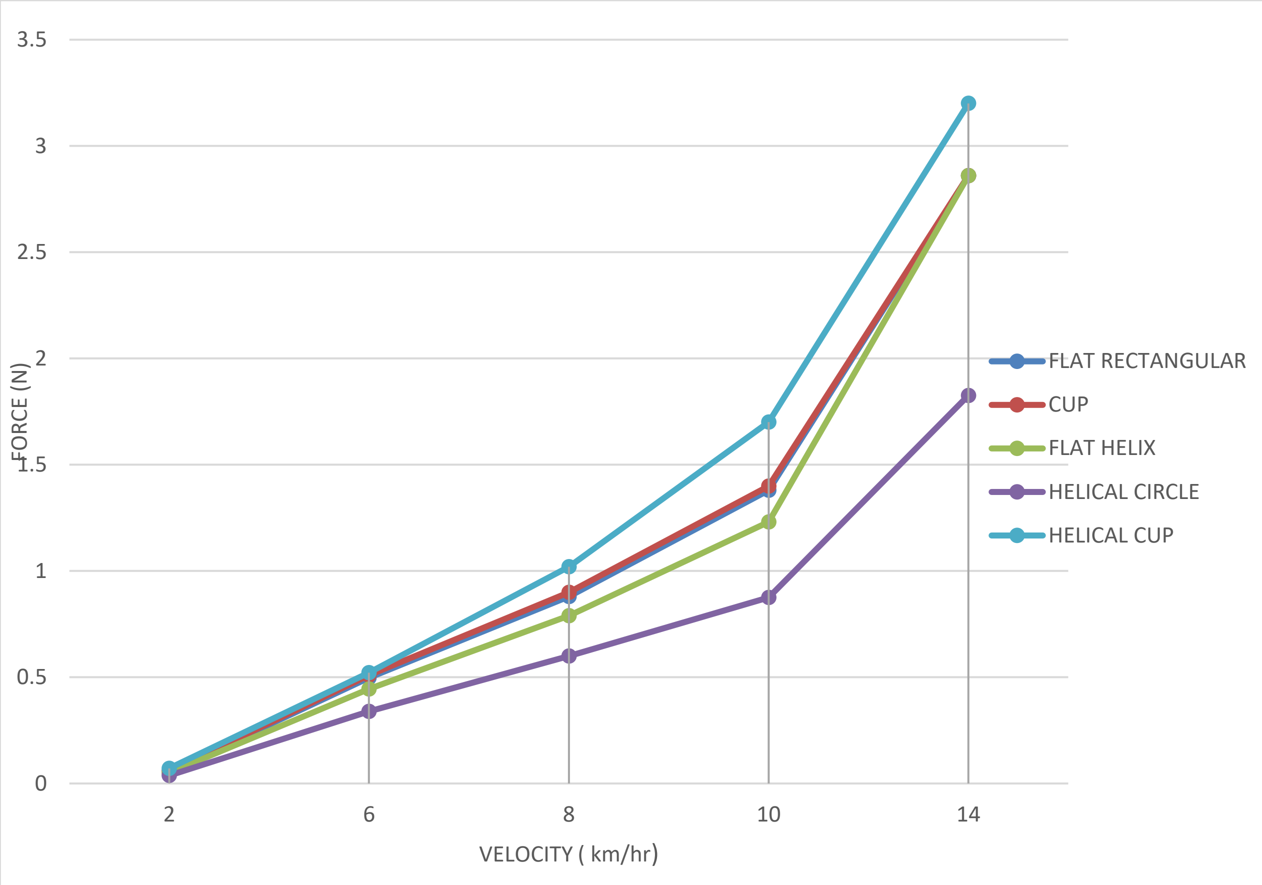

Fig.4 Graph generated using the values obtained from the CFD analysis

From the above analysis, it can be seen that the output of flat rectangular plate remains constant at 2 and 6 km/hr. (nearly zero) which is very undesirable. Also the value of the force obtained is not high. In case of the Cup, the performance of the affected by highly symmetric design. The output of the cup is also low. The Helical circle shows the least value of the force. Thus, it not selected.

VI. CONCLUSION

This paper shows that the Helical Cup, which is proposed for the current design, utilizes the most of the kinetic energy available out of all the various designs. The proposed design is scalable according to application. The Computational analysis shows that force acting on Helical-cup shaped design is maximum. The designed turbine produces power output up to 6.1035 Watt for given parameters, theoretical efficiency calculated comes out to be 50.69 % . The presence of the Ball and Socket joint makes the blades of the turbine adaptable according to the wind direction. The material chosen, ABS-PC, is cheap and easily available.

The disclosure of this unique design opens up new potential outcomes of investigating the worldwide power shortage issues

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