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Experimentation of helical flow path in an augmented wind turbine

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***Abstract*---**The design of wind turbine blade for low wind speed area is historically experimented by many researchers and gives us different results with nearly same parameters. Also, augmentation of wind turbine improves power generation capacity in magnified manner. This paper deals with the fabrication and investigation of augmented wind turbine specially prepared with helical flow path. The experimentation done with combination of different parameters such as wind speed, pitch distance and angle of attack of wind flow.

***Keywords*---**Fabrication, helical flow, windspeed.

Introduction

A wind turbine is a device that converts the wind's kinetic energy into electrical energy. Wind turbines vary vastly in size, shape, and orientation. Small turbines are used for a variety of rudimentary applications, while larger turbines are often found in wind farms and provide power to the electric grid. Wind was shown to have the "lowest relative greenhouse gas emissions, the least water consumption demands and cause far less environmental damage than other current energy providers, such as fossilfuels.many other energy sources are developing to produce electricity. Next to Solar Energy, Wind Energy plays an important role in production of electricity. Over the past decades many new approaches were made in developing wind energy and succeeded as well from generating 6.1 GW in Dec 1996 to 432.4 GW in Dec 2015 (GWEC) globally. But still in Urban areas wind energy were not used efficiently and an ordinary wind turbine will not be able to generate enough power in low wind speed. To overcome this ducted wind turbine has been introduced. Dr.Niel Campbell et al., identified three possible strategies to

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generate wind power in urban areas, 1) simply siting free-standing wind turbines in urban environment, 2) Retro-fitting wind turbines onto the existing buildings, 3) integration of wind turbines into the buildings which are specially designed for the purpose. Andrew Grant et al., experienced that ducted turbines are reliable alternative than keeping a conventional wind turbine on rooftops.. Djordje Romanic et al., have found that the houses of mid- section in Urban Area can be able to produce one third of the maximum extractable or potential wind energy. S. Martens et al., found average wind speed at roof top is large compared to undisturbed wind at built environment and large energy yield can be obtained in Vertical Axis Wind Turbine (VAWT) than Horizontal Axis Wind Turbine (HAWT) in small upwind roughness. By conducting experiment for wind condition over the building with 1 breadth, 1 width, 2 height, TakaakiKono et al., stated that the Wind Power Density over the region of windward corner ofthebuildingis very large and the effect at the upwind region is negligible. Gerard J.W. van Bussel et al., concluded from a mathematical model that optimum situation in both HAWT and DAWT is same and diffuser efficiency in DAWT can be increased with increase in back pressure. Deborah Alineet al., made a different approach and extend the blade element theory for diffuser augmented wind turbine. Though some values have to be obtain experimentally, in some cases the mathematical blade element model justifies the use of diffuser by increasing the performance, as the power coefficient increase. Philippe Giguereet al., mentioned about the difficulties of using conventional airfoil. Low speed wind turbine blades will operate under low Reynolds number along the entire span. If the selected airfoils are not suitable for low Reynolds number operation, then there will be degradation in performance of HAWT. This is because, the conventional airfoils usually operates at high Reynolds Number, where the boundary layer transition takes place before the laminar separation, thereby reducing the peculiarities of low Reynolds number aerodynamics. At low Reynolds number, these airfoils exhibit poor performance because of laminar separation effects which is predominant. Thus to get a better performance on HAWT, a small wind turbine blade is designed to operate at subcritical flow regime or low Reynolds number. Though there is no fixed Reynolds number regime for this condition, usually it is taken as the chord Reynolds number is below 500,000. At low Reynolds number, turbulent reattachment usually follows laminar separation, thereby forming the so-called laminar separation bubble. At low Reynolds Number, most of the unusual aerodynamic characteristics can be traced by the presence and behaviour of a laminar separation bubble on the airfoil. The length and behaviour of laminar separation bubble is depend on airfoil, Reynolds Number, and angle of attack, At chord Reynolds number below 200,000 the effects are very severe that the bubble will burst prematurely and hence the drag will increase rapidly along with discontinuity in lift-curve slope. In order to reduce these effects, two methodscan beused i) to provide early transition on airfoil through use of mechanical turbulator or trip and ii) designing the airfoil with very gradual upper surface pressure recovery. For Small Scale HAWT, most of the works were focused on effect of various parameters such as TSR, rotor speed, and pitch angle for specific airfoil. Not Much work has been done on the effect of airfoil on performance of small scale HAWT, effect of wind gust, wind direction and effect of turbulence intensity. Also the airfoil design has to be optimized taking consideration, ease of manufacturing and operation [9].

The total diameter of the blade can be assumed to be 50 cm for a prototype, which can be easily evaluated using a local wind tunnel. The wind turbine setup can be placed in front of a fan or propeller which will be large enough to cover a length of 1m. Depend on hub size, the total diameter can be increased by a maximum of 15 cm. The design of the Blade can be optimized numerically by Blade Element Momentum method. Initially some assumptions must be made such as Tip speed ratio (TSR), Number of Blades '*B*', Airfoil, etc. The tip speed ratio is one of an important parameter to be considered in designing a wind turbine. In order to extract as much as possible power from the wind turbine, it must be designed at their optimum tip speed ratio. Tip speed ratio is the ratio between the speed of the tip of wind turbine blade and the actual oncoming velocity of the wind.

Consider a wind turbine of '*B*' blades, Wind velocity '*V*', Angular Velocity '*ω*', and in operation, the time period of the blade to move to its predecessor '*tw*' is given by tw=sV [s] and the time period of the wind to return to normal after disturbed both upstream and downstream '*ts*' is given by ts=2π/(Bω) [s]. If ts>tw, then some wind is unaffected and if tw>tsthen some wind is blocked. I.e., If the blade rotates slowly, then most of the energy from the wind will be unutilized and if the blade rotates too fast then the fast moving blade will rotates like a solid walland block the oncoming wind, thus reduce the power extraction. Thus, to get maximum power extraction, these two values must be nearly equal,ts=tw. Equating these two equations, we get ωopt=2πV/(Bs) &λopt=2πr/(Bs). Empirically, the value of '*s*', i.e., Length of the strongly disturbed wind speed is approximated to half the rotor radius.

The selection of TSR itself has several factors to be depend on. Some are acoustic noises, vibration, starting difficulties, consideration of rotor efficiency due to drag and tip losses, turbine runaway from excessive rotor speed, etc,. The optimal TSR will be more than 25 to 30 percent if the airfoil designed with care. Poorly designed blade with low TSR, will tend the rotor to slow and to stall. We can logically assume that, putting more blade to a wind turbine, will extract more power. But in real case, increasing number of blades will increase power extraction very slightly as adding more blades will put resistance to air. Also it will increase the rotor weight which eventually drops the rotation where the peak power delivered. A one bladed rotor may seems light but it will experience aerodynamic instabilities. On compare with one bladed rotor, a two bladed rotor will give 10 percent increase in power production, but will eventually fail due to cyclic loads. Stresses will pile upon many parts of the structure. Realising peak efficiency, a two bladed rotor is less efficient than a three bladed rotor. Two bladed rotor requires higher rotational speed to generate more power that a three bladed rotor gives. It will rotate at a tip speed of 9-10. This will generate higher level noise. A three bladed rotor will add 3-4 percent increase in power on compare to two bladed. A rotor with odd number blades will act similar to a disc when calculate its dynamic properties. Increasing the blade numbers beyond this will not be cost effective. Adding one more blade will increase power production from one to two percent only. Thus a three bladed rotor can be finalized. Swirl loss, tip loss anddraglossarethreefactorsthatinfluenceoverallperformanceofaturbine.

Methodology

1 Airfoil Selection:

The total diameter of the blade is assumed to be 1m. Depend on hub size, the total diameter can be increased by a maximum of 20 cm. The design of the Blade can be optimized Numerically by Blade Element Momentum method. Initially some assumptions such as Tip speed ratio, Number of Blades, Airfoil, etc. SG604X series airfoil has beenselected.

2 Blade Designing:

These optimizations were done using QBlade, an open source wind turbine design software. The turbine was divided into 5 sections. The first two sections used a circular airfoil for structural reasons. The next four sections use SG6040, the four after that use SG6041and the sections at the end useSG6043.

Table 3.1

Station	Pos(m)	Chord(m)	Twist(deg)	Airfoil
1	0	0.065	9	SG6040
2	0.125	0.055	6.75	SG6041
3	0.220	0.045	5.04	SG6042
4	0.475	0.027	0.45	SG6042
5	0.500	0.025	0.00	SG6043

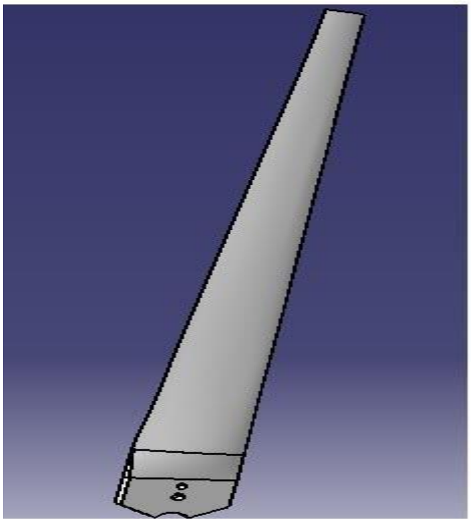


Fig 3.1 Blade Design In Catia V5 And Model

3.1 Hubdesign

The hub diameter is selected based on size of BLADE (10 CM). The blade is connected to the hub through ball bearing to avoid structural loss. The diameter of the hub is assumed to be 58.2cm. The blade of the turbine is attached to the hub varying the 120^0 angle of attack.

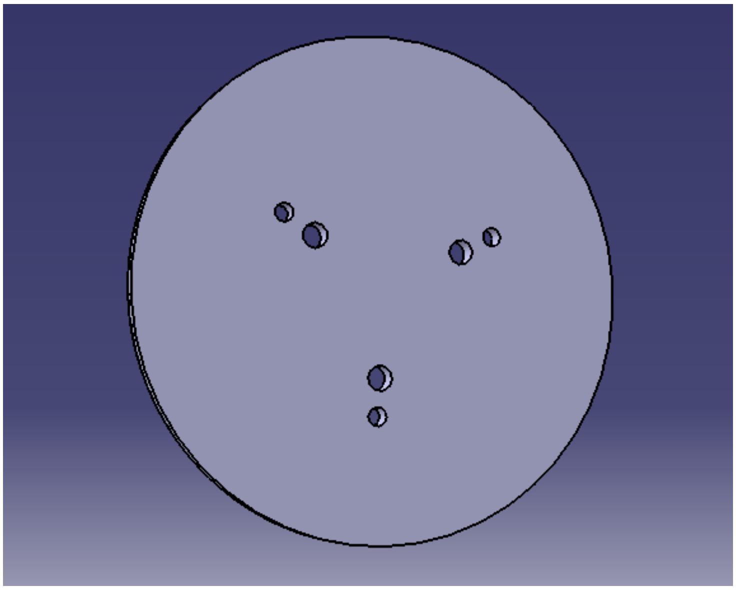


Fig 3.2 Hub Design In Catia V5

The blades and Hub are then manufactured using 3D printing technology from DIVVELA 3D.

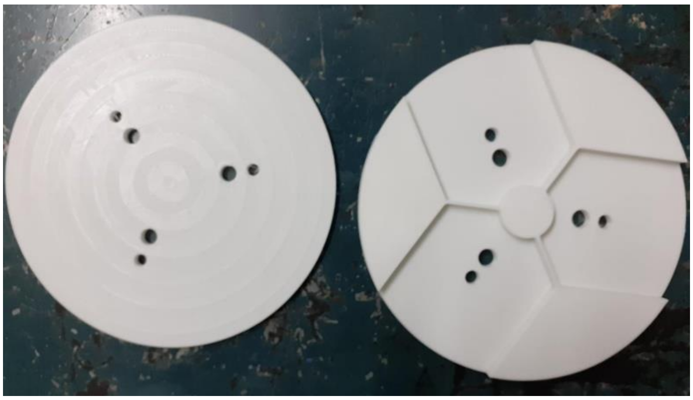


Fig 3.3 Hub Design In Catia V5

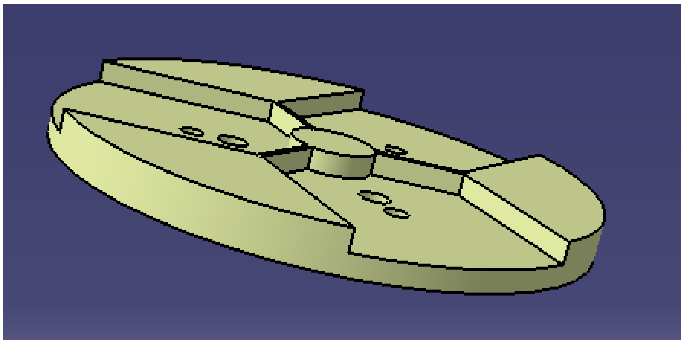


Fig 3.4 Hub Model

3.2* Wind Turbine Generator Specifications*:

RPM : 300 – 3000.
AMP : 4amp. VOLTAGE : 24V POWER : 140 Watts .
TORQUE : Low Torque.

Fig 3.4 Wind Turbine Generator

3.3 Wind turbine duct model &parameters:

The design is then manufactured using making the converging duct, a duct has been designed using wooden materials. A glass fibre and resin is then over laided after the application of wax and made it dry for two days. **Glass fiber** (or**glass fibre**) is a material consisting of numerous extremely fine fibersof glass.Glass fiber has roughly comparable mechanical properties to other fibers such as polymers and carbon fiber.Although not as strong or as rigid as carbon fiber, it is much cheaper and significantly less brittle when used in composites. Glass fibers are therefore used as a reinforcing agent for many polymerproducts; to form a very strong and relatively lightweight fiber-reinforcedpolymer(FRP) composite materialcalled glass-reinforced plastic(GRP), also popularly known as "fiberglass". This material contains little or no air or gas, is more dense, and is a much poorer thermal insulator than is glasswool.

Epoxy resins—because of their reactivity that enables them to bond well to fibers and their toughness—are the thermoset resins that, combined with glass, carbon, or aramid fibers, produce composite materials with the best properties of most thermosets. There are several processes for the manufacture of composite materials but the most important, in the case of epoxy resins . The processes are divided between “wet resin” and “prepreg.” Wet resin processes involve direct combination, by the fabricator of epoxy resin and reinforcing fibers. This can be accomplished by hand, by the simple application of resin and reinforcement to a suitably treated mold.As mentioned, many epoxy resin precursors require to be heated to allow a sufficiently low level of viscosity to bereached. It is then taken out and frame made of MS plate is fixed over that. To get a proper curve, and for smooth flow, a sandwich of glass fibre and resin, foam board and then cardboard covered with smooth chart is applied allover.

3.4 Wind Turbine Duct Preparationsteps:

Step 1: Moluding made by wooden materials.

Fig 3.5 Duct Mould

Step 2 :composite separated from the mould and fixed in the stand

Fig 3.6 Duct Prepared With Composite Material

Step 3: foam board used for the smoothing the surface of the composite

Fig 3.7 Preparation Of Duct

Step 4: final model of the duct after the giving the necessary finishing works

Fig 3.8 Duct Preparation

3.5 Instrumentsused

Anemometer : This instruments is used to measure the upcoming velocity.
Multimeter : This instruments is used to measure the current and voltage to calculate the exact power.
Tachometer : This instruments is used to measure the rotational speed of the rotor in terms of rpm.

Result and Discussion

The purpose of the discussion is to explain the implications of findings and suggested future work. This contains a result for the testing in the wind tunnel. The testing is done by placing the experimental setup on the suction side of the blower. Asthe blower sucks the air through different velocities, this sucked flow of air passes through the blades tends the rotor to rotate. Voltage and current is calculated by multimeter and the velocity at which the blade rotates is calculated by tachometer in terms of rpm, and the flow of air is calculated by anemometer. By these instruments different parameters were taken and calculated as described below:

Fig 3.9 Actual Setup

Voltage

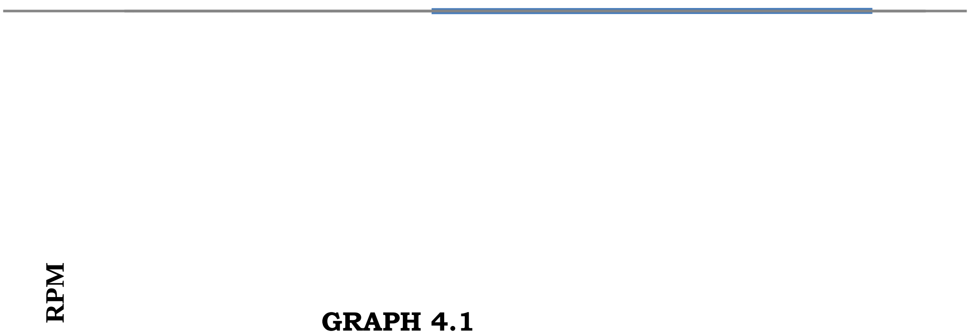
Voltage is the electric potential energy per unit charge. Mathematically, this is expressed as the line integral of the electric field and the time rate of change of magnetic field along the path. Instruments used for the measuring voltage are voltmeter and potentiometer.

RPM VS Velocity

Table 4.1 RPM Vs Velocity

RPM	VELOCITY
3	26
3.9	150
5.2	280
5.8	360
6.3	420
6.7	480
7.5	560

GRAPH:



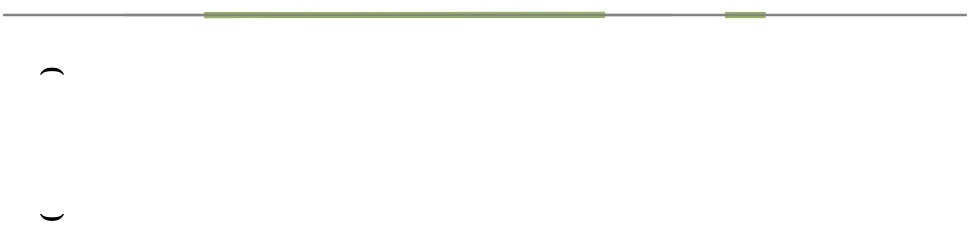
GRAPH 4.1

The above graph 4.1 shows that the rpm of the rotor increases when the velocity of the air increases.

Table 4.2
Velocity vs voltage without pitch and with one pitch:

VELOCITY (m/s)	VOLTAGE (VOLT)	
	WITHOUT PITCH	WITH ONE PITCH
7	1.2	1.3
9	1.55	1.6
11	1.73	1.8
14	2.11	2.3
15	2.2	2.4
17	2.56	2.8

GRAPH:



Graph 4.2

The above graph shows that the voltage has been increased by introducing the pitch.

TABLE 4.3

Table 4.3
Velocity vs voltage without pitch and with three pitch:

VELOCITY (m/s)	VOLTAGE (VOLT)	
	WITHOUT PITCH	WITH THREE PITCHES
7	1.2	1.6
9	1.55	1.9
11	1.73	2.25
14	2.11	2.45
15	2.2	2.59
17	2.56	2.93

Graph

Graph 4.3

The above graph shows that the voltage has been increased by increasing the number of pitches.

Table 4.4
Velocity vs voltage without pitch and with five pitches:

VELOCITY (m/s)	VOLTAGE (VOLT)	
	WITHOUT PITCH	WITH FIVE PITCHES
7	1.2	1.52
9	1.55	1.78
11	1.73	2.03
14	2.11	2.30
15	2.2	2.45
17	2.56	2.75

Graph:

Graph 4.4

The above graph shows that the voltage has been increased by increasing the number of pitches to five.

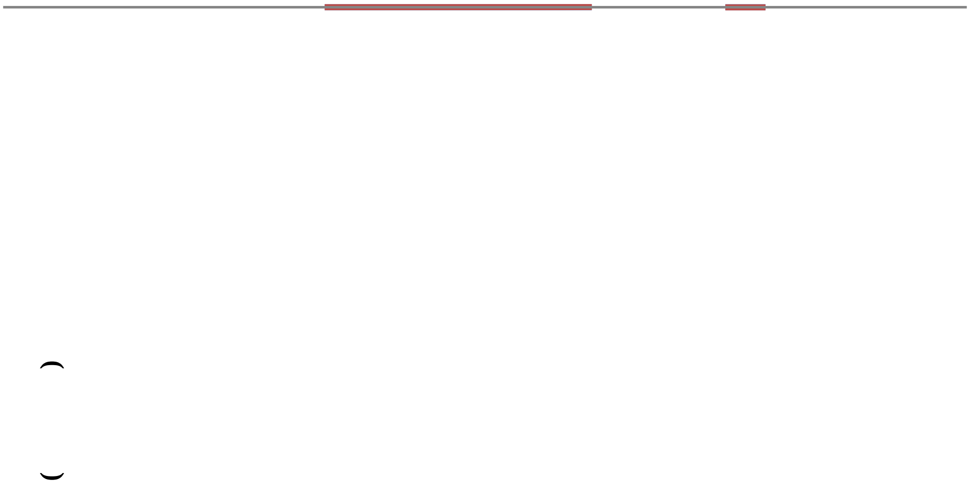
Current

An electric current is a flow of electric charge. In an electric circuit this change is often carried by moving electrons in a wire. The SI unit for measuring an electric current is Ampere, Which is the flow of electric charges through a surface at the rate of one Coulomb per second. It can be measured in Ammeter.

Table .4.5
Velocity vs current without pitch and with one pitch:

VELOCITY (m/s)	CURRENT (AMP)	
	WITHOUT PITCH	WITH ONE PITCH
7	0.4	0.45
9	0.5	0.55
11	0.57	0.63
14	0.7	0.76
15	0.73	0.80
17	0.85	0.96

Graph:



Graph 4.5

The above graph shows that the current has been increased by introducing the pitch.

Table 4.6

Velocity vs current without pitch and with three pitches:

VELOCITY (m/s)	CURRENT (AMP)	
	WITHOUT PITCH	WITH THRE PITCHES
7	0.4	0.53
9	0.5	0.63
11	0.57	0.70
14	0.7	0.80
15	0.73	0.85
17	0.85	0.97

Graph:

Graph 4.6

The above graph shows that the current has been increased by increasing the pitches to number of three.

Table 4.7
Velocity vs current without pitch and with five pitches:

VELOCITY (m/s)	CURRENT (AMP)	
	WITHOUT PITCH	WITH FIVE PITCHES
7	0.4	0.5
9	0.5	0.59
11	0.57	0.69
14	0.7	0.79
15	0.73	0.85
17	0.85	0.95

Graph**:**

Graph 4.7

The above graph shows that the current has been increased by increasing the pitches to number of five.

Fig 4.1 Setup with one pitch

Fig 4.2 Setup with three pitches

Conclusion

From the experimentation data and the result, we can conclude that the ducted wind turbine with 3 helical pitch can provide better result over bare wind turbine and simple ducted wind turbine. Thus this type of wind turbine can be mounted over rooftop to get better self-sustained power supply in even low wind speed with more powerful generator in action.

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