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Fabrication and Performance Analysis of Natural Fiber Turbine Blades

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Abstract:
In past few decades wind turbines are manufactured mainly by using standard components. Later, turbines were fabricated by using special components only. The best way to solve this is by using composite materials in wind turbine blades. Many of the composites are comprises of two materials. One material i.e., which binds together a bunch of fibres matrix (epoxy resin) and the second material (the reinforcement) adjacent these fibres. These days few researchers have aspired in utilizing the diversified applications of composite materials as the materials of the future.
In this perspective wind turbine with three blades (Flax fibre) are designed and fabricated using hand-layup fabrication method and this process considers fiber in weight percentage of 5%, 10%, 15%, 20% and 25%. Moulds are prepared by using these combinations and undergone different tests like flexural, tensile and impact and the best suited combination of weight is used in turbine blade manufacturing. These turbine blade samples are used for understanding of different air velocities and different specifications of wind turbine such as power developed by wind turbine, power developed by wind, power co-efficient, speed of wind turbine are calculated and compared with existing aluminium material blades used in wind turbine.

Keywords-Flax fiber; Hand-layup fabrication method; Power developed by turbine; Power co-efficient; Speed of wind turbine; Power developed by wind.

I. INTRODUCTION

Today many studies in wind turbine industries are put through in order to increase the efficiency of wind turbine. The above studies results in use of advanced material system in new unusual wind turbine blade design for the development of ensuing wind turbine blade structure. The investigation is going on for the use of alternative material system with better qualities such as low density, long life, better performance, capability of processing, ease of recycling, less cost than the present thermoset technology. The best reinforcement for FRP's (Fiber Reinforced plastics) is natural fiber, because of its brilliant qualities such as less cost, excellent mechanical properties, more delicate, more definite strength, perishable, and environmental friendly characteristics. From plants, animals and minerals many types of natural fibres can be extracted [1, 2].
The materials which consist of two or all the artificial constituents with different properties are the composites. These composites which has excellent mechanical properties such as better quality and lesser weight as they found a large applications in automobile industry, mechanical buildings and also live applications[3].
Some up and downs are created by the fast improvement of material technology in the wind turbine structure. These fluctuations have primarily given excellent impacts which reduced the wind turbines prices. A wide range of materials are used in wind turbine blade structures which are well known to us. Many factors such as mechanical material, corrosive resistance, tough to break, fatigue resistance, rigidity, and weight have more effect on wind turbine materials. This has recently caused composite materials to be more often used in wind turbine structures [4].
In this paper we have extracted the flax fiber and square moulds are made with epoxy and flax fibre, then these are cut in to required dimensions and different tests are conducted like tensile, flexural and impact. With the help of these results the required weight quantity is chosen and wind turbine blades are fabricated using hand lay-up method and performance tests are done by using the wind tunnel equipment. The main aim is to reduce the weight of turbine blades and cost and increase the performance

II. MATETRIAL AND METHODOLOGY

Flax Fiber
Among the natural cellulosic fibres flax fiber is the most strongest. From the stem of flax plant flax fiber is extracted. It is made into linen yarn to extract threads or fabrics. So this is also named as linen. It is used before 30000 years so it is also called as one of the oldest fibres. In the early Egyptian tombs this linen cloth which is made from flax is used to wrap mummies.

Epoxy
The composite creator has epoxies as the most adaptable dope. The engineer will understand the good level of bond quality, solidness and waterproofing with specifically arranged epoxies in all departments of works [3].

Fabrication
By using hand layup method, we make square moulds with flax fibre and epoxy by taking fibre of 5%,10%,15%,20%,25% weights and these moulds are removed and the tests for tensile strength, flexural strength and

impact strength are conducted. By considering these results the percentage weight of fibre to be used in turbine blade making is selected.

Rough Engineering drawing

Firstly we design an engineering drawing with dimensions as per the design parameters of NACA-National Advisory committee for Aeronautics

TABLE 1-Dimensions as per the design parameters of NACA

Chord length	**700mm**
Tip of blade chord	30mm
Length of blades	200mm
Number. Of blades	3
Fiber thickness	3mm
Nacelle height	600mm

Pre-Form Making

By cutting an outline in CNC machine we construct a pre-structure in wood or any other metals. Once the pre-structure is completed we can move on to mould making process.

Mould making and component casting

We move on to shape making after the wooden sample is made. In this process for the wooden sample we have to apply wax. In the next step for clearing dust stockpiling on wooden sample we need to do is rubbing with cotton. Next we need to apply PVA (Poly Vinyl Alcohol) which fills in as a discharging operator because this is in fluid form. Next with resin apply gel coat 2 times. Next step is by applying glass fabric with dope and finishing with water paper. Component casting is same as the mould making process. Here the required fiber blades mould is made by applying same process of mould making [3].

FIGURE.1 Patterns made for fiber Blades

FIGURE.2 fiber pattern [3]

Final Finished Assembly

By placing threaded bolts which are of 5mm diameter final finished blades are made which is arranged with a nut with locking system where we can change to different angles which are desired.

FIGURE.3 Flax fiber with epoxy blades with bolt in bottom

Wind Supply

Here we used a wind tunnel to give the wind. It's a forced wind, as we know this wind tunnel can be helpful in giving the wind supply.
The blower consist of a fan of diameter = 400mm
The nozzle of the wind tunnel is 300mm
The motor is of 3hp
The rpm of motor is 1500rpm.

FIGURE.4 wind tunnel with wind turbine made of flax fiber blades

Experimental Procedure of Fiber Blades with Wind Tunnel

- Aerofoil blades of laboratory model wind mill are set at various angles of attack namely 0^0, 45^0, 90^0, 135^0, 180^0.
- Power supply should be given to run blower to suck air into suction zone of wind tunnel
- Using rotating disc type of anemometer, at inlet and outlet of wind mill the velocity of air is to be measured.
- The distance of wind mill should be kept constant while doing the experiment.
- Temperature of air is taken into account to evaluate wind energy associated with it at inlet.
- The procedure should be repeated for the 60cm, 90cm, and 120cm distances.
-

Calculations

Power Developed By Wind (PW) = $\frac{1}{2}\rho A V_I^3$

$\rho = \text{Density of air} \frac{P}{RT}$ (P) atmospheric air $= 1.01325 * 10\forall 5\ N/m^2$

(R) Gas constant 287 J/Kg-K

(T) Temperature= 300K

$A = \text{ area of rotor } (\frac{\pi}{4} * (2(l + r))^2\ m^2)$

$V = \text{Velocity at inlet of blade(m/sec)}$

Power Developed By Turbine (PT) $=\frac{1}{4}(V_I + V_O)(V_I^2 - V_O^2)\rho A$

$V_I = \text{Velocity at inlet of blade (m/sec)}$

$V_O = \text{Velocity at outlet of blade (m/sec)}$

Power Coefficient $(C_P) = \frac{P_T}{P_W}$

$P_T = \text{Power developedby Turbine(watts)}$

$P_W = \text{Power developed by wind (watts)}$

Length (l) =0.23m
Radius(r) =0.0505m
Area of rotor (A) = 0.2472 m^2
Density of air (ρ) =1.1768

III. EXPERIMENTAL RESULTS

The flax fibre with epoxy specimens are cut according to standard lengths and are undergone the tests like flexural and tensile in the conventional UTM machine and the digital readings are taken, in the same way specimens are undergone Impact test in the Charpy Impact testing machine and the readings are noted. The results obtained are used to draw graphs as show below.

TABLE.2 Results of Flexural, Tensile and Impact tests

Weight (%)	Flex modulus (MPa)	Max stress (MPa)	Tensile stress at max load(Mpa)	Tensile strain at break (mm/mm)	Young's modulus(Mpa)	Impact strength (J)
5	2460.72	25.12	28.88	0.01466	2271.51	0.8
10	4344.33	25	37.37	0.01434	3181.03	1.4
15	5856.1	44.38	34.71	0.01233	3202.23	1.8
20	7080.52	74.19	64.35	0.02283	4547.8	3.6
25	6560.67	52.86	57.84	0.02017	3743.77	3.2

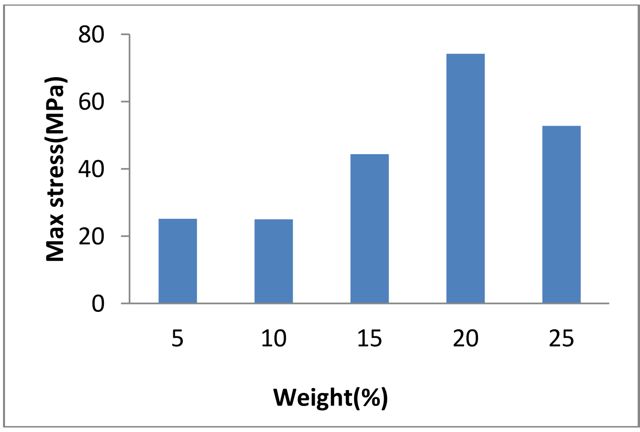


FIGURE.4 Weight vs. Max stress in flexural test

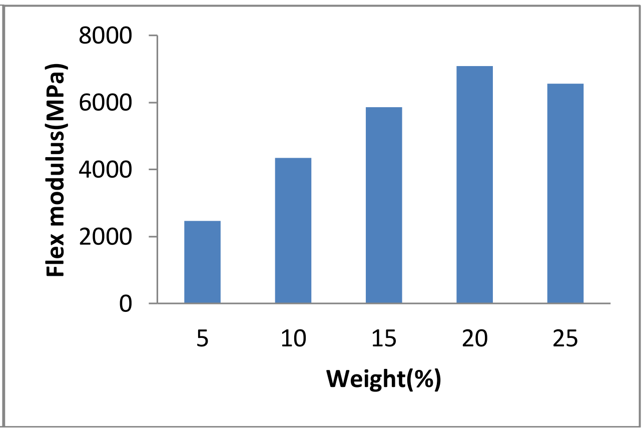


FIGURE.5 Weight vs. Flexural modulus

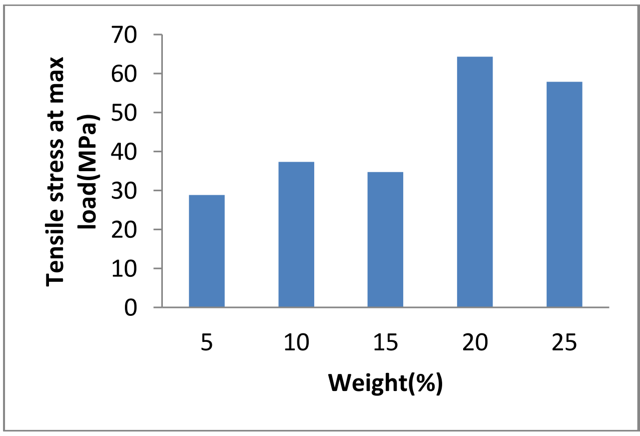


FIGURE.6 Weight vs. Tensile stress at max load

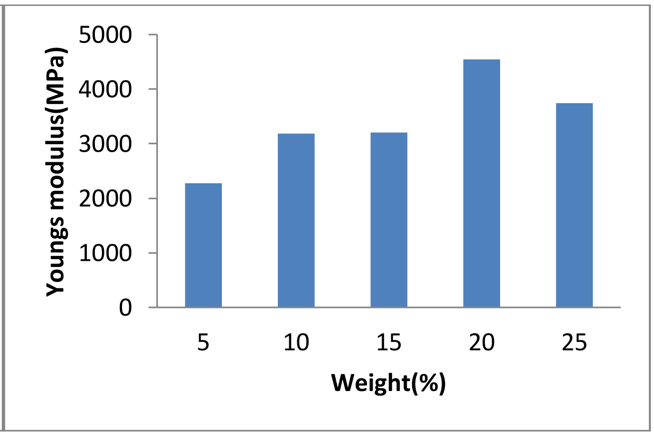


FIGURE.7 Weight vs. Young's modulus

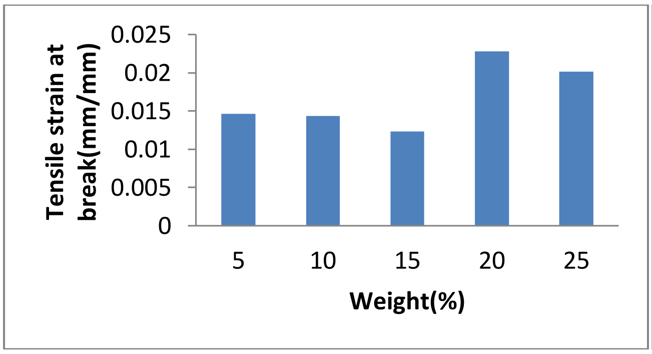


FIGURE.8 Weight vs. Tensile strain at break

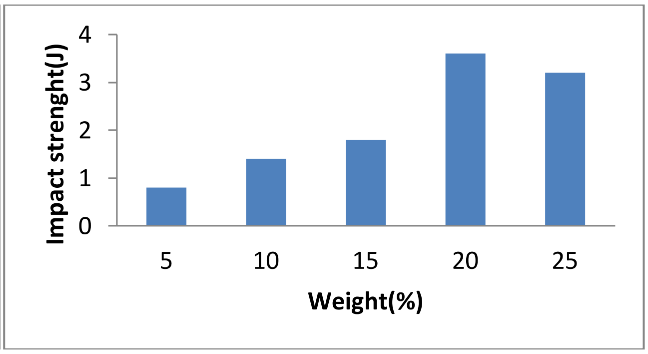


FIGURE.9 Weight vs. Impact strength

From the above tables and graphs it is evident that the graph increases up to 20% weight and then decreases, this is due to the increase in fibre content after 20% results in decrease in bond strength. So it is concluded that 20% weight of flax fibre is to be used in wind turbine blade making.

TABLE.3 With flax fiber body at a distance of 60cm from wind tunnel

Angle (Degrees)	Speed (Rpm)	Atm Temp (K)	Inlet velocity (m/sec)	Outlet velocity (m/sec)	Power input (kW)	Power output (kW)	Power Co-efficient
0	90	300	16.2	13.5	$6.2*10^{-3}$	$1.73*10^{-3}$	0.27
45	370	300	16.2	12.6	$6.2*10^{-3}$	$2.17*10^{-3}$	0.35
90	310	300	16.2	12.0	$6.2*10^{-3}$	$2.28*10^{-3}$	0.37
135	730	300	16.2	13.8	$6.2*10^{-3}$	$1.42*10^{-3}$	0.23
180	210	300	16.2	14.1	$6.2*10^{-3}$	$1.25*10^{-3}$	0.2

TABLE.4 With alluminium body at a distance of 60cm from wind tunnel

Angle (Degrees)	Speed (Rpm)	Atm Temp (K)	Inlet velocity (m/sec)	Outlet velocity (m/sec)	Power input (kW)	Power output (kW)	Power Co-efficient
0	190	300	16.2	15.2	$6.2*10^{-3}$	$0.71*10^{-3}$	0.11
45	300	300	16.2	14.2	$6.2*10^{-3}$	$1.34*10^{-3}$	0.22
90	90	300	16.2	12	$6.2*10^{-3}$	$2.42*10^{-3}$	0.39
135	720	300	16.2	13.2	$6.2*10^{-3}$	$1.88*10^{-3}$	0.30
180	110	300	16.2	14.2	$6.2*10^{-3}$	$1.34*10^{-3}$	0.22

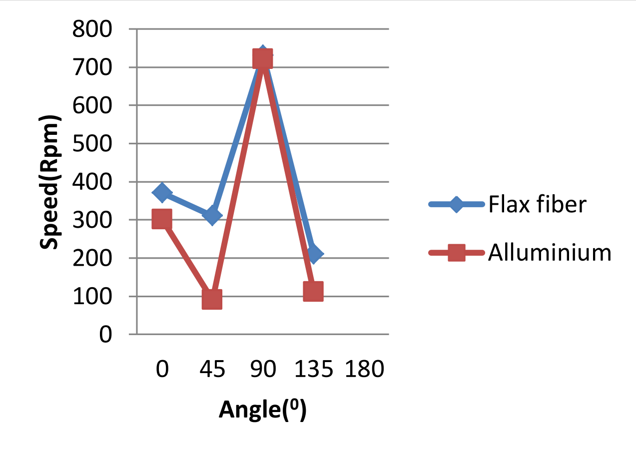


FIGURE.10 Angle vs. speed graph at 60cm

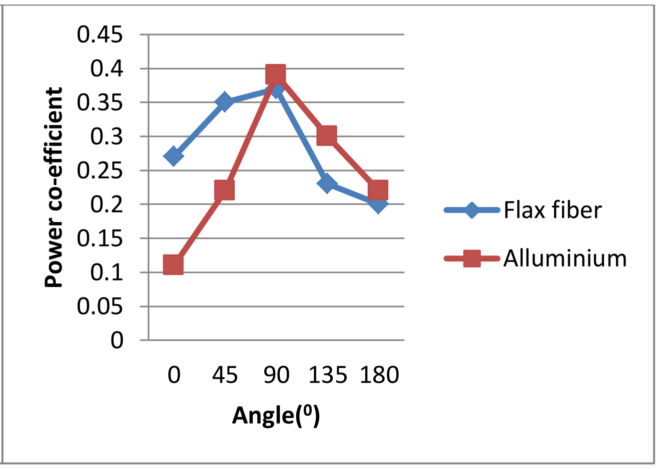


FIGURE.11 Angle vs. power co-efficient graph at 60cm

TABLE.5 With flax fiber body at a distance of 90cm from wind tunnel

Angle (Degrees)	Speed (Rpm)	Atm Temp (K)	Inlet velocity (m/sec)	Outlet velocity (m/sec)	Power input (kW)	Power output (kW)	Power Co-efficient
0	130	300	15.2	12.2	$5.1*10^{-3}$	$1.63*10^{-3}$	0.32
45	380	300	15.2	11.6	$5.1*10^{-3}$	$1.88*10^{-3}$	0.37
90	460	300	15.2	6.5	$5.1*10^{-3}$	$2.97*10^{-3}$	0.58
135	650	300	15.2	10.9	$5.1*10^{-3}$	$2.13*10^{-3}$	0.42
180	190	300	15.2	11.7	$5.1*10^{-3}$	$1.84*10^{-3}$	0.36

TABLE.6 With alluminium body at a distance of 90cm from wind tunnel

Angle (Degrees)	Speed (Rpm)	Atm Temp (K)	Inlet velocity (m/sec)	Outlet velocity (m/sec)	Power input (kW)	Power output (kW)	Power Co-efficient
0	140	300	15.2	14	$5.1*10^{-3}$	$0.74*10^{-3}$	0.14
45	270	300	15.2	12.6	$5.1*10^{-3}$	$1.46*10^{-3}$	0.29
90	580	300	15.2	10.2	$5.1*10^{-3}$	$2.34*10^{-3}$	0.46
135	640	300	15.2	11.5	$5.1*10^{-3}$	$1.91*10^{-3}$	0.37
180	120	300	15.2	12.3	$5.1*10^{-3}$	$1.59*10^{-3}$	0.31

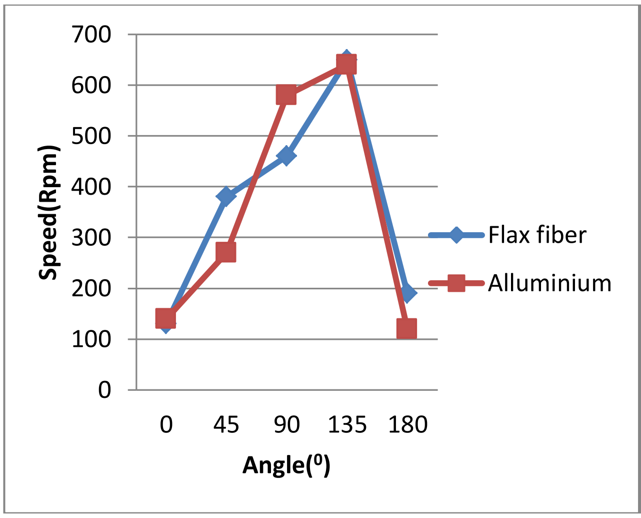


FIGURE.12 Angle vs. speed graph at 90 cm

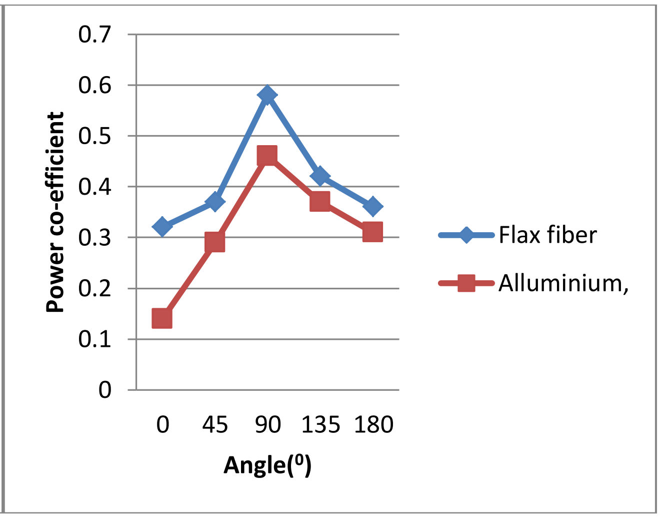


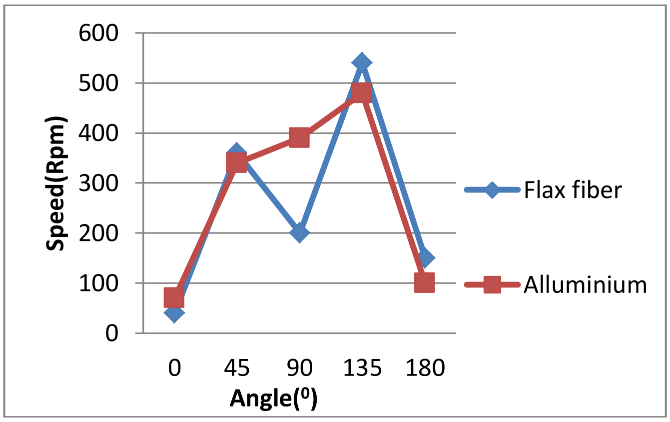
FIGURE.13 Angle vs. power co-efficient graph at 90cm

TABLE.7 With flax fiber body at a distance of 120cm from wind tunnel

Angle (Degrees)	Speed (Rpm)	Atm Temp (K)	Inlet velocity (m/sec)	Outlet velocity (m/sec)	Power input (kW)	Power output (kW)	Power Co-efficient
0	40	300	14.0	9.3	$3.9*10^{-3}$	$1.85*10^{-3}$	0.47
45	360	300	14.0	8.4	$3.9*10^{-3}$	$2.04*10^{-3}$	0.52
90	200	300	14.0	7.0	$3.9*10^{-3}$	$2.24*10^{-3}$	0.57
135	540	300	14.0	8.4	$3.9*10^{-3}$	$2.04*10^{-3}$	0.52
180	150	300	14.0	10.1	$3.9*10^{-3}$	$1.64*10^{-3}$	0.42

TABLE.8 With alluminium body at a distance of 120cm from wind tunnel

Angle (Degrees)	Speed (Rpm)	Atm Temp (K)	Inlet velocity (m/sec)	Outlet velocity (m/sec)	Power input (kW)	Power output (kW)	Power Co-efficient
0	70	300	14.0	10.2	$3.9*10^{-3}$	$1.61*10^{-3}$	0.41
45	340	300	14.0	9.8	$3.9*10^{-3}$	$1.73*10^{-3}$	0.44
90	390	300	14.0	9.3	$3.9*10^{-3}$	$1.85*10^{-3}$	0.47
135	480	300	14.0	9.9	$3.9*10^{-3}$	$1.70*10^{-3}$	0.43
180	100	300	14.0	10.5	$3.9*10^{-3}$	$1.52*10^{-3}$	0.39



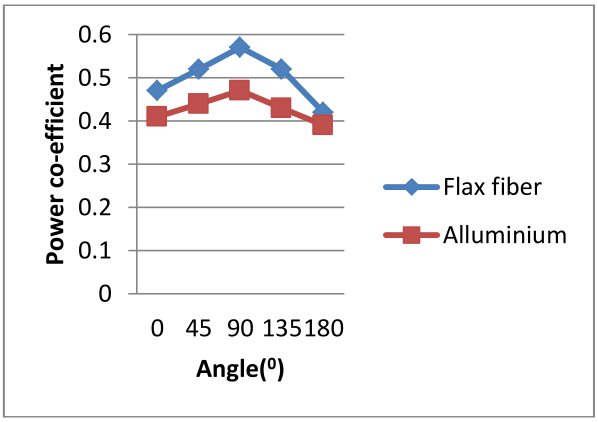


FIGURE.14 Angle vs. speed graph at 120cm

FIGURE.15 Angle vs. power co-efficient graph at 120cm

IV. RESULTS AND CONCUSION

- From the above graphs and tables it is evident that at 90^0 the maximum power co-efficient is 0.58 for flax fiber blades at a distance of 90cm from wind tunnel and at 135^0 the maximum power co-efficient is noted as 0.52 at a distance of 120cm from the wind tunnel and here the turbine blades with flax fiber and epoxy works more prolifically as power co-efficient keep on increasing in between 90^0 and 135^0.
- In flax fiber blades the highest speed is 730 rpm which is at 135^0 and as the speed is proportional to power co-efficient we can see that power co-efficient is also maximum for flax fiber blades. In aluminium blades we see the maximum speed as 720 rpm which is less than flax fiber blades.
- So in many cases the aluminium blades are less efficient than flax fiber blades, the power generated in flax fiber blades is more than aluminium blades. Here our work of fiber composites worked out more effectively.
- In aluminium the thermal conductivity is greater than fibres and strength is imperishable to wind velocity but in contrast fibres have low thermal conductivity, better strength and more durable.

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