Horizontal Axis Wind Turbine with Polyester Fibre Blades for Power Generation

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Abstract: *In wind turbines, sharp edges are the principle vital part, its execution reliance on the material, machinability and outline of edge. Beforehand numerous investigation have been made on Horizontal Axis Wind Turbine (HAWT) sharp edges are Aluminum (7020 Alloy), Mild Steel (grade 55), Stainless Steel (A580) and Polycarbonate sheet. Lightweight metals (aluminum) have discovered a few applications yet now late patterns has accompanied, high quality, firmness and the capacity to tailor the material to the heaps has prompted its broad use as a cutting edge by composite material as a decision.*

The blades with composite materials of polyester epoxy fiber blades are carried out. Comparing to many materials like stainless steel, mild steel, aluminum etc, the composite is where we have high durability with great strength. The comparison of torque coefficient, power coefficient and TSR of both the materials i.e., aluminum blades and polyester blades performance are calculated. The design of blades polyester epoxy fiber blades and aluminum blades performance is calculated.

Keywords- horizontal axis wind turbine; polyester fiber blades; aluminum blades; power coefficient; torque coefficient; flow velocity;

I. INTRODUCTION

The principal wind turbine for electric force era was developed by the organization S.Morgan-Smith st Grandpa's Knob in Vermont, USA, in 1941. The turbine (53.3m rotor, 2 cutting edges, power rating 1.25MW) was outfitted with monstrous steel sharp edges. One of the cutting edges fizzled after just a couple of hundred hours of discontinuous operation. In this manner, the significance of the best possible decision of material and natural constraints of metal as a wind cutting edge material was exhibited exactly toward the start of the historical backdrop of wind vitality improvement. The following, entirely effective case of wind turbine for vitality era is alleged gedser coast in 1956-57.the turbine was delivered as of now with composite sharp edges, worked from steel saves, with aluminum shell upheld by wooden ribs. The turbine (three sharp edges, 24m rotor, and 200kW) war the principal example of overcoming adversity of wind vitality: it has keep running for a long time without upkeep. After 1970's, a large portion of wind turbines were delivered with composite sharp edges (Manwell et al, 2002, Brondsted et al, 2005)

Along these lines, the association between the accomplishment of wind vitality era innovation and the advancement and utilization of composite materials for turbine parts got to be apparent from the initial step of wind vitality use: while the principal turbine, worked with steel edges, fizzled, the second one with composite cutting edges worked for a long time.

By definition, composite are materials, which comprise of two or all the more synthetically disparate constituents with various properties. Because of their prevalent mechanical properties, higher quality and lower weight, when contrasted with numerous metals and compounds, and in addition the likelihood of fitting the microstructures, composites found a wide applications in auxiliary, common and mechanical building, car industry and also vitality applications.

Why does composite material assume the key part in the wind vitality advancement? The objective of fossil fuel independency in closest decades implies that the renewable vitality segment must be radically expanded.EU set an objective to get 20% of its vitality requirements for renewable by 2020. Keeping in mind the end goal to supply 20% of power for renewable sources to 2020, the EU seaward wind vitality limit ought to be extended by two requests of extent. The high volumes of wind vitality era, important to accomplish this objective, required the establishment and utilization of change extensive wind turbines (8-10MW and higher) remaining in wind homesteads of a few hundred MW. For this situation, the potential expense of repair and substitution of harmed wind turbine may be colossal.

In perspective of this necessity, just material with the high quality, weariness resistance and solidness i.e., composites, - can be utilized as a part of wind turbine edges. No different materials, - neither metals, nor combinations, nor wood, - can fulfill this rundown of prerequisites completely

II. COMPOSITE FIBERS

In industry, the bit of the pie of composites is not withstanding growing much speedier, and composites are right now comprehensively used as a piece of flying business, auto industry, marine industry, Composites or composite materials are a mix of two or more materials, in a way that you can even now perceive the diverse material stages consequent to amassing. The system can basically be any kind of plastic: epoxy, polyester, vinyl ester, polypropylene (PP), There is a noteworthy refinement amongst thermosetting and thermoplastic gums for composites.

Thermoset polymers are the network of choice for most assistant composite materials. The single most prominent purpose of enthusiasm of thermoset polymers is that they have a low thickness and can thusly be brought into fibers at low weights. Impregnation of the strands is trailed by substance curing to give a solid structure, which should usually be possible isothermally.

Table 1: Resins Types

Thermosetting resins	*Thermoplastic resins*
Epoxy	Polypropylene (PP)
Unsaturated polyester (UP)	Thermoplastic polyesters (PET, PBT)
Vinyl ester	Polyether sulphide (PES)
Polyurethane (PUR)	Polyphenylene sulphide (PPS)
Phenolic resin	Polyether imide (PEI)
Acrylic resin	Polyether ether ketone (PEEK)

Thermoplastic polymers tend to have melt viscosities some place around 500 and 1000 times that of thermosets, which requires higher weights, causes planning challenges and incorporates cost. On the other hand, ideal position of thermoplastics is that the trim should be possible non-isothermally, i.e. a hot melt into a cold mold, in order to fulfill snappy procedure lengths. Thermoplastic composite polymers can in like manner be speedily reused.

Dense, more than 90% of polymers used as a piece of composites are thermo sets, with thermoplastic composites still a claim to fame market, principally in view of the difficulties in get ready.

The fibers are typically glass, carbon (graphite) or aramid (trade name Kevlar). The fiber stronghold can take any structure: a mat of short cut fibers, a woven fabric, a unidirectional course of action of strands, a turn, a weave.

III. FIBER BLADES

3.1 Polyester Resins ;

Polyester tars are the most extensively used gum systems, particularly in the marine business. By far the bigger piece of dinghies, yachts and workboats worked in composites make usage of this sap system.

Polyester saps, for instance, these are of the "unsaturated" sort. Unsaturated polyester gum is a thermo set, prepared for being cured from a liquid or solid state when subject to the right conditions. It is consistent to insinuate unsaturated polyester saps as 'polyester gums', or basically as 'polyesters'. There are two guideline sorts of polyester tar used as standard overlaying systems as a part of the composites business. Orthophthalic polyester gum is the standard money related sap used by various people. Isophthalic polyester sap is in the blink of an eye transforming into the favored material in business wanders, for instance, marine where its unrivaled water resistance is appealing.

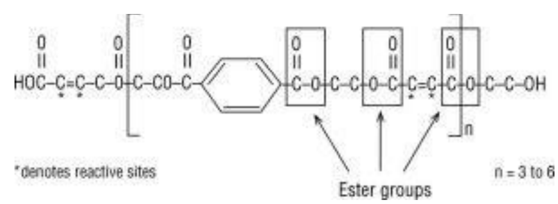


Figure 1. Structure Of Polyester Resin

The figure exhibits the appreciated compound structure of normal polyester. Note the positions of the ester bundles (CO - O - C) and the responsive destinations (C* = C*) inside the nuclear chain.

A maker may supply the tar in its key structure or with any of the above included substances viably included. Tars can be characterized to the breaks down requirements arranged only for the development of the force going before frivolity. As has been determined, adequately given time an unsaturated polyester sap will set without any other person's information. This rate of polymerization is excessively direct for down, making it impossible to earth purposes and along these lines impulses and reviving operators are used to fulfill the polymerization of the gum inside a useful day and age. Driving forces are added to the gum structure right away before use to begin the polymerization reaction. The impulse does not participate in the substance reaction yet rather just starts the technique. An animating operator is added to the catalyzed pitch to engage the reaction to proceed at workshop temperature and/or at a more critical rate. Since animating operators have little effect on the tar without a catalyst they are as a less than dependable rule added to the tar by the polyester producer to make a 'pre-enlivened' sap.

3.2 Epoxy;

Epoxies address without a doubt the most versatile tars available to the composite creator. Generally, in all characterizations of work, the engineer/repairer will comprehend the best level of bond quality, waterproofing and solidness with particularly arranged epoxies. New period epoxies are VOC free and have curing structures which are sans phenol (addressing a secured stride forward for all tar customers). Whether an area or repair is made of wood, carbon, Kevlar, fiberglass, focus material or half and parts of the above, epoxies will wet and for record-breaking stick to the composite.

3.3 CASTING:

Process of Casting:

1. Rough Engineering drawing
2. Pre-form matching
3. Mould making
4. Component casting
5. Final finished assembly

Rough Engineering Drawing:

Firstly we designed an engineering drawing with certain dimensions as per the design parameters of NACA

Table-2: Blade parameters

Blade parameters as per NACA
Chord length = 70mm
Tip of blade chord = 30mm
Length of blades = 200mm
No of blades =3 blades
Fiber Thickness = 3mm
Nacelle height = 600mm
Blades of Hallow fiber blades

Pre-form Making;

Build up a pre-structure in wood or POP on any of alternate metals by cutting the profile in CNC machines

By making this pre-structure design we can undoubtedly make an example which is of reproduction of a completed item this aides in making the work simple and basic yet ought to be done with gifted work. Once in the wake of finishing the pre-structure item we can facilitate continue to Mold making here we can proceed for the further procedure.

Mould making:

Once a wooden example is made we continue to shape making. In mold making we need to finish the wax on the wooden example where we coat a wax finish for simple evacuation of examples

Next we need to do cotton rubbing for clearing dust stockpiling on the wooden example. Apply PVA (Poly vinyl Alcohol) which is a fluid shape this fills in as a discharging operator.

There after we have to apply gel coat 2 times with Resin (cobalt). This further continues by applying glass fabric with tar (cosmetics methyl, ethyl, cornerstone, peroxide) completing with water paper.

Component Casting:

Rehashing mold making by the required measurements and apply the same procedure like need to finish the wax on the wooden example where we coat a wax finish for simple expulsion of examples

Next we need to do cotton rubbing for clearing dust stockpiling on the wooden example. Apply PVA (Poly vinyl Alcohol) which is a fluid frame this fills in as a discharging specialist.

Develop an pre-form in wood or POP on any of the other metals by cutting the profile in CNC machines

By making this pre-form pattern we can easily make a pattern which is of replica of an finished product this helps in making the work easy and simple but should be carried out with skilled labor. Once after completing the pre-form product we can further proceed to Mould making here we can go ahead for the further process.

Fig 4 fiber pattern **Fig 5** Patterns made for fiber Blades

There after we need to apply gel coat 2 times with Resin (cobalt). This further proceeds by applying glass cloth with resin (makeup methyl, ethylene, keystone, peroxide) finishing with water paper

A finished product is ready and an pattern is used for multiple design blades.

Final Finished Assembly:

Finished blades are casted with placing an threaded bolts which are of 5mm diameter here this bolts are arranged with looking system with a nut where we can change the angles to a desired angle of blade.

Fig 6 Polyester blades **Fig 7** Polyester fiber blades with bolt in bottom

3.4 HUB Coupled With Motor:

A HUB is planned with aluminum material and its composed as a screw framework to string the screw inside the center point for changing the edge of cutting edges, this threading is orchestrated in the center point at a focal point of center point length and we put a brilliant coupling toward the end of the aluminum hub and coupled it with yelanky keys and organized contact to the engine shaft this engine is associated with and positive and negative terminals which would me be able to used to interface the globule and check the multi-meter readings and the voltage is seen as appeared in figure the engine and the aluminum center are associated.

A test by utilizing iron center point is done yet because of less weight of sharp edges the cutting edges doesn't get appropriate speed to turn the iron center so we changed the iron center point to an aluminum center point which is of less weight so here we got the best results, every one of the readings in aluminum center we didn't consider the readings of iron center since it didn't began the revolution by utilizing iron center

Additionally we outlined aluminum cutting edges which is of less weight. Here we are contrasting aluminum sharp edges and fiber cutting edges

Fig 8 motor with aluminum hub **Fig 9** Iron hub

3.5 Wind Supply:

We used wind tunnel to give the wind its an forced wind, as we known this wind tunnel can be helpful in giving the wind supply

The blower consist of an fan of diameter = 400mm

The nozzle of the wind tunnel is = 300mm

The motor is of = 3hp

The rpm of motor is = 1500rpm

Fig 11 wind tunnel with wind turbine made of aluminum blades

IV. CALCULATIONS

Power Developed By Wind

$(P_W) = \frac{1}{2}\rho A V_I^3$

ρ = Density of air(1.23 Kg/m^3)

A = swept area (πr^2 m^2)

V = Velocity at inlet of blade(m/sec)

Power Developed By Turbine

$(P_T) = \frac{1}{4}(V_I + V_O)(V_I^2 - V_O^2)\rho A$

V_I = Velocity at inlet of blade (m/sec)

V_O = Velocity at outlet of blade (m/sec)

ρ = Density of air(1.23 kg/m^3)

A = swept area (πr^2 m^2)

Power Coefficient

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

P_T = Power developedby Turbine(watts)

P_W = Power developed by wind (watts)

Torque

$(\tau) = \frac{60 \times P_T}{2\pi N}$

P_T = Power developed by turbine (watts)

N = speed (rpm)

Max Torque

$(\tau_{Max}) = \frac{1}{2}\rho A V_I R$

ρ = Density of air(1.23 kg/m^3)

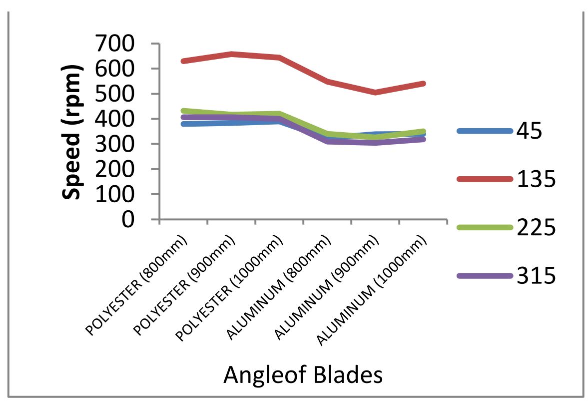
A = swept area (πr^2 m^2)

R = radius of wind turbine

V. EXPERIMENTAL RESULTS

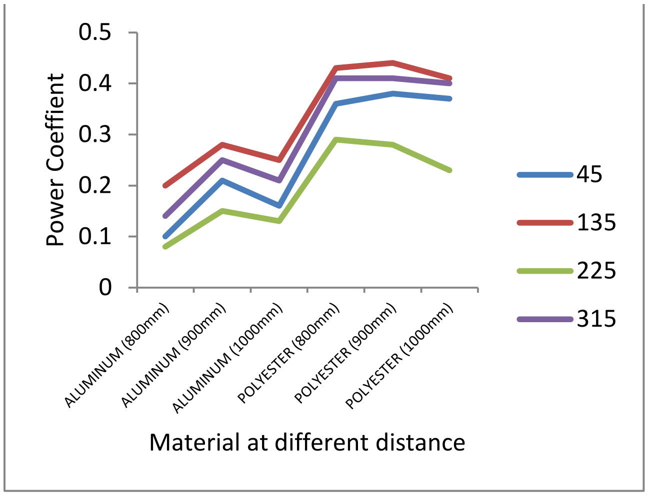
Table 3: Experimental Readings

S.NO	BLADE ANGLE degrees	BLADE INLET VELOCITY (V1) m/sec	BLADE OUTLET VELOCITY (V2) m/sec	SPEED (RPM)	MULTI-METER VOLTAGE (V)
At 800mm Distance from the Wind Tunnel with Polyester fiber Blades					
1	45	15.3	11.8	380	1
2	135	14.5	9.1	630	2.3
3	225	14.9	12.3	332	1
4	315	13.9	10.1	406	1.1
At 800mm Distance from the Wind Tunnel with Aluminum Blades					
13	45	12	11.4	323	0.7
14	135	12.8	10.5	548	1.7
15	225	10.2	9.8	284	0.5
16	315	10.2	9.4	344	0.7



Graph 1: Overall Speed Comparison of polyester blades and Aluminum blades

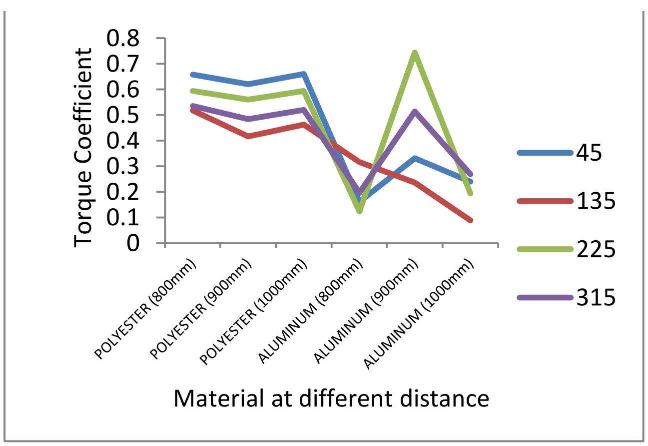
SPEED comparison at different angles with Aluminum and Polyester at different distance from blower. The maximum speed is obtained at 135 degrees here exist the high power this can be called as efficient angle here the next efficient angle comes as 225 degrees but coming to the comparison the aluminum speed is lesser then the polyester. So now we absorb that polyester is efficient.



Graph 2: Overall Power Coefficient Comparison of polyester blades and Aluminum blades

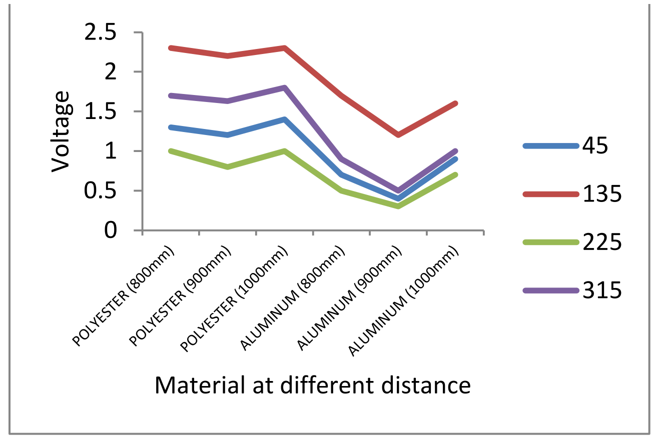
POWER COEFFICIENT comparision at different angles with Aluminum and Polyester at different distance from blower

135° degrees 1st place of, 315°degrees 2nd place, 45° degrees 3rd place, 225°degrees 4th place here we can absorb the angle of blades at which more power coefficient is obtained. Coming to comparison the polyester have good power coefficient then the aluminum blades.



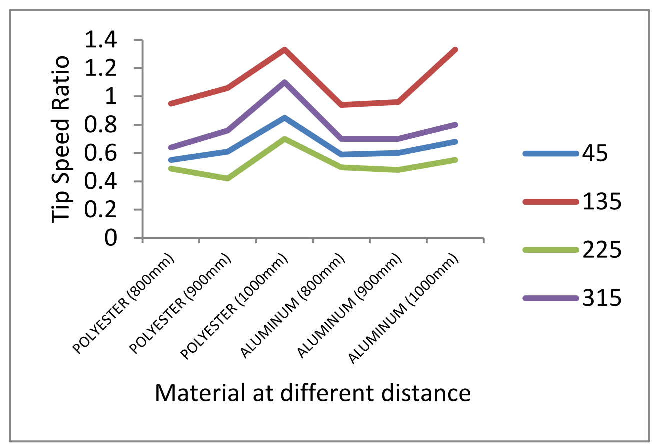
Graph 3: Overall Torque Comparison of polyester blades and Aluminum blades

TORQUE COEFFICIENT * comparison different angles with Aluminum and Polyester at different distance from blower, Here we see that the aluminum at 900mm distance the torque is more where as polyester has maximum at all distance. In aluminum the torque coefficient keeps on varying but in polyester it shows as minor variations.



Graph 4: Overall Voltage Comparison of polyester blades and Aluminum blades

VOLTAGE comparison at different angles with Aluminum and Polyester at different distance from blower, here voltage at 135° angle produce more voltage then we can see that 315° angle produce 2nd maximum voltage comparing to aluminum polyester produce more voltage.



Graph 5: Tip Speed Ratio Comparison of polyester blades and Aluminum blades

TIP SPEED RATIO* comparison different angles with Aluminum and Polyester at different distance from blower, Here there is no much change in polyester and aluminum always there is minor change in aluminum and polyester, the variation in angle of blades can be absorbed.

VI. RESULTS AND CONCLUSION

- Aluminium verses fibre- at 135° the maximum voltage is recorded as 2.3 volts, in distance of 800mm &1000mm from the wind tunnel with fibre blades, and @ 135° the maximum voltage is recorded as 1.8 volts, in distance of 800mm from the wind tunnel with aluminium blades and in-between 135° & 225° the voltage keep on increasing here the turbine in Polyester fibre works more effectively then Aluminium
- Polyester fibre blades speed- At 135° the rpm is more, here the highest rpm keeps effective in 135° & 225° as rpm is proportional to voltage there we always absorb that voltage is also effective in fibre we see maximum rpm as 640rpm, but in aluminium we see 470 as highest rpm
- Aluminium blades speed- at 135° the rpm is more, here the highest rpm keeps effective in 135° & 225° as rpm is proportional to voltage there we always absorb that voltage is also effective in aluminium we see maximum rpm as 470rpm, but in fibre we see 640rpm as highest rpm.
- So fibre is most efficient then aluminium blades, the power generated in aluminium blades is less than the power generated in fibre blades. The mechanism of fibre composites is worked out very effectively.
- Since the fibre is costly we have heavy design expenses where as this fibres are in composite material which involves chemical engineering designs.
- In fibres the material has good strength and durability as well low thermal conductivity, where as in aluminium the thermal conductivity is more than the fibres and strength is sustainable to wind velocity

VII. REFERENCES

1. Jechoutek, Karl, R ural Energy and Development- An Action Plan, World Bank Renewable Energy Roundtable, March 25, 1997.
2. Serageldin, Ismail, Village Power, Environmentally Sustainable Development, the World Bank; presentation to the Solar Energy Forum, April 28, 1993.
3. Sesto, E., Village Power, Environmentally Sustainable Development, the World Bank; presentation to the Solar Energy Forum, April 28, 1993.
4. Jechoutek, Karl, R ural Energy and Development- An Action Plan, World Bank Renewable EnergyRoundtable March 25, 1997.
5. http://www.netcomposites.com/guide-tools/guide
6. Askland, Donald R. & P.Phule , Pradeep. (fourth edition). (2003). Composites, In: The Science and Engineering of Materials, (721-765), Thomson Learning, ISBN 0-534-95373-5, USA
7. Black, T. & Kosher, R. (tenth edition). (2008). Non Metallic Materials: Plastic, Elastomers, Ceramics and Composites, In : Materials and Processing in Manufacturing, (162-194), John Wiley & Sons, Inc, ISBN 978-0470-05512-0, USA
8. Mathews, F. & Rawlings, R. (1994). Polymer Matrix Composite, In: Composite Materials: Engineering and sciences, (168-200), The Alden Press, Oxford, ISBN 0-412-55960-9, UK
9. Tuttle, M. (2004), Introduction. In: Structural analysis of Polymeric Composite Materials, (1- 40), University of Washington, ISBN 0-8247-4717-8 USA

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