

Effect of Material Blade Types on Performance a Small Wind Turbine

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Abstract - The very growth in wind energy technology in the last 20 years has led to presence of many wind turbines around the world in different shapes and designs and even in the type of materials they are made of Wind energy can offer a promising source of environmentally safe renewable energy and clean without any emissions during operation, this paper highlights many types of materials can used in made the structural of wind turbine blades, to find the best performance and suitable material for wind turbine blade. Designing reliable wind turbine blades materials under various loading and environmental conditions. the four materials are using in this study (wood_yew, E_glassfibers blastic_asa and aluminum 1200) the result after doing simulations for four types of materials using for design blades of small wind turbine noted the better the efficiency and performance of the wind turbine at the higher the Betz number, Light materials, such as glassfibers and aluminum, require less energy resistant to weather conditions such as humidity and corrosion, resulting in lower mechanical losses. Unlike heavier materials, such as wood and plastic, which require a high coefficient exposed to weather conditions, especially humidity, which causes faster turbine damage.

Keywords: Small wind turbines, blade design, Composite materials.

replacing the stiff and strong design of current blades with more compliant structures [2,3]. Many materials commonly used in wind turbines due to their excellent mechanical properties which match them in the design of wind turbine blades [4].

Material performance criteria therefore identify fiber reinforced polymer composites as for rotor blades. The material properties, design and manufacturing process as an integrated. Here the stiff fibers (usually glass, sometimes carbon, usually thermosetting polyester or epoxy) the processing technology for such material [5].

M. Sessarego and D. Wood [6] The optimization aimed to study a range materials of small wind turbine blade design depends on material and density, from traditional fiberglass through sustainable alternatives The materials like traditional E-glass and polyester resin, flax and polyester resin, plastic and timber. All blade materials gave feasible.

O. T. Thomsen et al. [7] are being manufactured designs are mainly based on this study Wind turbine blades on glass fiber-reinforced composites (GFRP), to reduce the weight also for up-scaling of wind turbine blades from the maximum length in excess of 61 m for large wind turbines to of 90 m.

L. C. Bank et al. [8] discusses of wind turbine blades that can be salvaged from the turbine blades growth in the amount of non-biodegradable, thermosetting fiber reinforced polymer large-sized FRP material pieces, when design specific regional locations and architectural model developed by Sandia National Laboratories in Mexico on the Gulf of Mexico To demonstrate the concept 100 m long wind blade.

A. André et al. [9] investigates solutions in re-using wind turbine blades as effective bridges and contribute to a sustainable use of fiber reinforced polymer (FRP). In a larger re-manufacturing end-of-life glass FRP composites highlight the economically profitable potential.

R. E. Murray et al. [10] Reactive non-fusible thermoplastics are useful for wind turbine blades Thermoplastic composites because they are recyclable at the end of their life, can reduce manufacturing costs, and have similar, and in some cases better, structural properties than

List of Acronyms	Nomenclature
FRP: fiber_reinforced polymer	m: mass
GFRP: glass fiber_reinforced polymer	V: volume
TSR: Tip speed ratio	t:time
CFD: Computational fluid dynamics	ρ : Air Density
SWT: Small Wind Turbine	V_t :tip Velocity
BEMT: Betz's Element Momentum Theory	r: radius of blade
HAWT: horizontal axis wind turbine	A: Rotor Area
VAWTs: Vertical axis wind turbines	E_{in} : kinetic energy inlet
P_w : Wind power available	b: betz's number
	C_p : Power Coefficient
	I: moment of inertia
	W: angular velocity

I. INTRODUCTION

Morphing technologies are significant interest from the wind turbine community because of their potential high aerodynamic efficiency [1], low weight and simple construction, the key challenge for morphing structures in

traditional epoxy composites. The heat compound blade has increased damping compared to the epoxy blade, it leads to reduced operational loads.

A. Cooperman et al.[11] Much of the material in those turbines can be recycled, at the United States, turbine blades may be disposed of in landfills, shifts in recycling technologies, blade materials, or move towards a circular economy for wind turbine blades.

1.1 Types of Wind Turbines

Wind turbines fall into two main groups: the first the horizontal-axis wind Turbines (HAWTs) that rotate around a horizontal axis are most common at 95%. It have the main rotor shaft running horizontally [12] And design Vertical axis wind turbines (VAWTs) have the potential to produce more power than the common HAWT based on their structural [13].

1.2 Types of Blades Wind Turbines

In general, there are many different types in terms of shape, such as flat, curved, and round blades, and they have different numbers of blades, such as single, double, triple, or more blades [14]. This difference gives us different values for wind energy.

Rotor blade consists of several profiles blended at an angle of twist terminating at a circular flange like (Fig. 1) used in study include most features such as, chord length and angle of twist optimization of blade design.

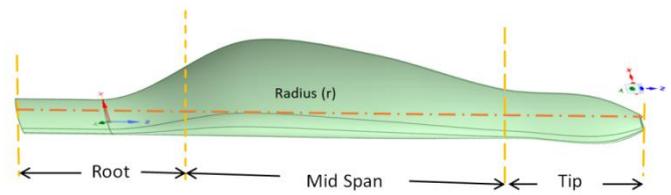


Figure 1: Typical blade shape design used in this study

1.3 Types of Materials Blades

From the previous studies there are advantages of the materials used and which properties should be desired to ensure the best performance. It is light weight to reduce gravitational forces, high toughness and toughness to withstand wind force, high fatigue resistance to withstand changing load [15]. It is made of available materials with low maintenance and costs. The blade in this study is made of containing one or more than one composite materials, each with different structural properties. So through research we used 4 types of materials and compared them, see (fig. 2), which are plastic_asa, plastic_pp_50% glass fibers, aluminum 1200, and wood_yew.

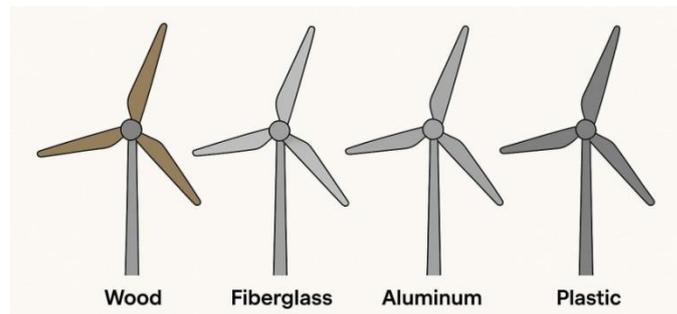


Figure 2: Effect materials on turbine efficiency

Table 1: Investigated Materials Properties

Material	young's modulus [GPa]	electrical conductivity[s/m]	Density [kg/m ³]
plastic_asa	2.0_2.5 3.1547e-12	1055_1100	
E_glass fibers	70_852.0023e_17	2526.8_2600	
aluminum 1200	69_71 3.3925e+07	2709.8	
wood_yew	10_12	9.1227e-07	696.5

1.4 Model description

The SWT used in the simulation were an imported model with horizontal main axis and three blades that equal in dimension and shape see (fig.3). The imported wind turbine uses the profile NREL, constant chord length movement. HAWT are very sensitive to rotate at wind speed changes in blade profile and design. This section briefly discusses the major parameters that influence the performance of HAWT blades.

A focus is now being made on HAWT is very sensitive to changes in blade profile and design the due to its dominance in the wind turbine industry.

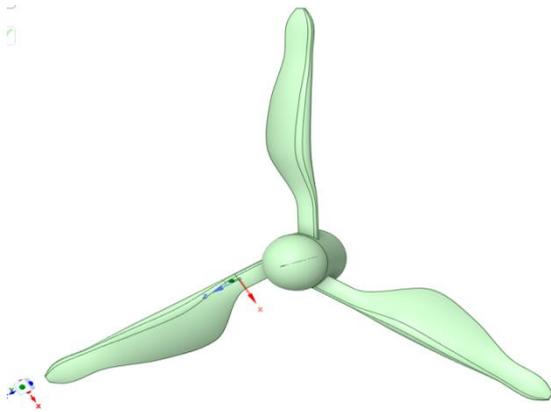


Figure 3: Typical small wind turbine shape design used in this study

Main input parameters:	values
Speed of wind (v)	6-10 m/s
Rotation speed (n)	700 rev/min
Power in(p)	100-300 W
Temperature (T)	5-42 °c
Choose fluid	air
Diameter of rotor (d)	200 mm
Length of blade	600 m
Sweep area (rotor plane)	700 mm
No. of blades	3
High of wind turbine	18m
Angle of degree (α)	10 - 20°
Piton values of air foil	NACA_4412

II. THEORETICAL BACKGROUND

Steady flow Three-dimensional, flow turbulent, flow incompressible, flow viscous and Wind turbine outlet pressure is zero Pa, which means equal to atmospheric pressure, CFD simulation in ANSYS software with stable inlet flow velocity of wind [16], and density for 4 types using in study also doing, mesh was defined according to the rotating frame and 3 blades[17].

2.1 Betz limit axial momentum theory

Meant by betz's low is that no wind turbine can extract more than 59.3% of the wind's because the air cannot be controlled.

$$b = \frac{E_{in}}{E_{out}} * 100 \% \dots\dots\dots (1)$$

$$E_{in} = \frac{1}{2} I W^2 cp \dots\dots\dots (2)$$

$$I = m r^2 \quad w = \frac{vt}{r} \quad 35 \% \leq b \leq 59.3 \%$$

$$Cp = \frac{\text{Expected power output}}{\text{Power available from the wind}} = \frac{p}{pw} Cp=0.45$$

$$E_{in} = \frac{1}{2} m v^2 \frac{vt^2}{2} cp$$

$$E_{in} = \frac{1}{2} (\rho V) vt^2 cp$$

$$E_{in} = \frac{1}{2} (\rho A \frac{L}{t}) vt^2 cp$$

$$E_{in} = \frac{1}{2} (\rho A) vt^3 cp \dots\dots\dots (3)$$

$$A = \pi r^2 \quad A = \pi (0.6)^2 \therefore A = 1.131 m^2$$

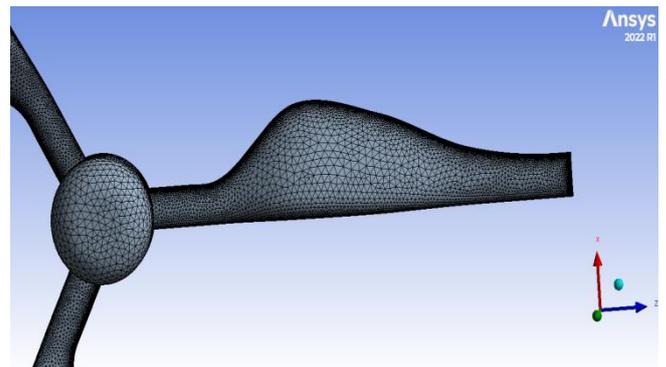


Figure 4: Distribution of mesh to design small wind turbine used in this study

III. NUMERICAL CALCULATION RESULTS

Light materials such as aluminum and fiberglass reduce vibration and sound, thus improving performance and energy efficiency, which leads to an increase in the Betz number, unlike heavy materials such as wood and plastic, which increase noise and vibration, leading to energy loss and Betz number, as shown in the (fig. 5). We also note that the Betz number does not exceed 53 and does not fall below 35 when taking speeds for the four types from (5 to 10) this is considered a good indicator.

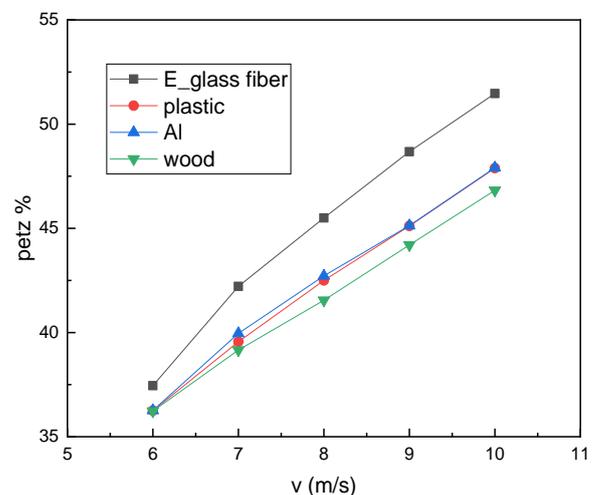


Figure 5: Relationship between wind speed and petz No

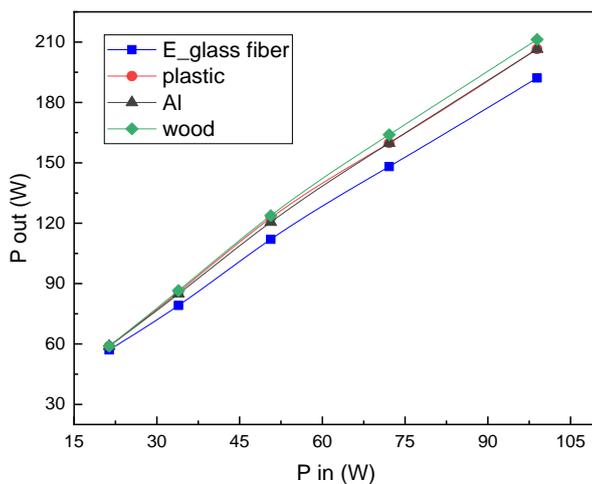


Figure 6: Relationship between power_in and power_out

IV. DISCUSSIONS

- The higher the Betz number, the better the efficiency and performance of the wind turbine, as it utilizes more wind energy.
- Light materials, such as fiberglass and aluminum, require less energy for acceleration and rotation, resulting in lower mechanical losses. Unlike heavier materials, such as wood and plastic, which require a high coefficient of inertia to operate, this causes higher mechanical losses.
- Fiberglass and aluminum are resistant to weather conditions such as humidity and corrosion, unlike wood and plastic, which are exposed to weather conditions, especially humidity, which causes faster turbine damage.

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