

# Development of Carbon Fiber Composite Material Blades for Vertical Axis Wind Turbines as an Alternative Energy Source for Street Lights for a Speed Range of 2-8 m/s

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## Abstract

Global warming causes weather anomalies in urban areas in Indonesia, causing wind speeds of 6-7 m/s, far above the normal average speed of 2-4 m/s, causing damage to the vertical axis wind turbine (VAWT) blades made from duralumin material, which is used to drive street lights in rural Bandung, West Java- Indonesia. So, it is necessary to use stronger blade material to anticipate the forces generated due to wind speed anomalies, besides that it must also be able to function at low wind speeds: and the composite material used in this research is carbon fiber material. This paper discusses the development of vertical axis wind turbine blades with blades made from carbon fiber composite materials and compares their durability duralumin blades. The research began with making carbon fiber composite material specimens to then be tested for impact strength and bending strength respectively according to ASTM D790-03 and ASTM D6110-08 standards. The VAWT models for both blade material variants were made at a scale of 1:3 and the durability performance were tested in the wind tunnel. The result is that the VAWT with carbon fiber blade material is able to withstand vibrations up to 50% compared to the duralumin blade VAWT at a wind speed of 8 m/s. The tensile strength of carbon fiber is 8.86% greater than the tensile strength of duralumin, and the impact strength of carbon fiber is 13.36% greater than duralumin, so that the use of carbon fiber composite material as a VAWT blade can be used for wind speed anomalies up to 8 m/s.

## 1. Introduction

Global warming causes extreme weather in Indonesia and results in tropical cyclones which have wind speeds of 63 km/h to 75 km/h so they are very dangerous storms [1]. The impact of climate change has even resulted in an increase in temperatures of up to 11°C [2]. In Indonesia, climate change not only has implications for the country's environment, it also immensely affects people and development [3]. Even though the Indonesian economy has grown rapidly during the last two decades, with GDP growth averaging over 7 percent annually [4], if climate

change is not adequately addressed it will have severe consequences on economic development and the reduction of poverty.

In facing the challenges of climate change and striving for sustainable national growth, through the National Energy Policy (KEN), the Indonesian government has set a target of increasing the share of primary renewable energy to 23% by 2025 [5], and the electricity sector as having the most significant potential to support the achievement of renewable energy targets. Indonesia has developed wind power plants, such as in Sidrap [6], Selayar and Janeponto Islands in South Sulawesi [7], and Serang-Banten [8], but until 2022 only reached 12.3% of the target or around 135 MW from the target of 255 MW [9], [10], and heretofore, The National Energy Council (DEN) is being discussed with the DPR on updating the NRE mix target in 2025 down from the previous 23 percent to 17-19 percent. Meanwhile, the NRE target in 2050 increases from 30 percent to 58-61 percent and at 70-72 percent in 2060 [11].

The scarcity of electrical energy as energy for street lights by utilizing wind turbines has been widely designed to adapt to the wind speed of residential areas in Indonesia which are classified in the low wind speed category, 2 – 4 m/s, based on the distribution map of onshore and offshore wind speeds [12], as seen in Fig. 1. From Fig. 1, it can be seen that the wind speed on Indonesia's offshore is dominated by green color, with a rate of  $V = 1-2$  m/s and green light color, with a rate of  $V = 3-4$  m/s. However, with the occurrence of weather anomalies due to global warming, it results in wind storms that impact wind speeds reaching 6 - 8 m/s [13], which is expressed through the blue colors and light blue colors, as seen in Fig. 2. Therefore, the development of turbine blade materials is urgently needed to accommodate wind speeds of up to 8 m/s.

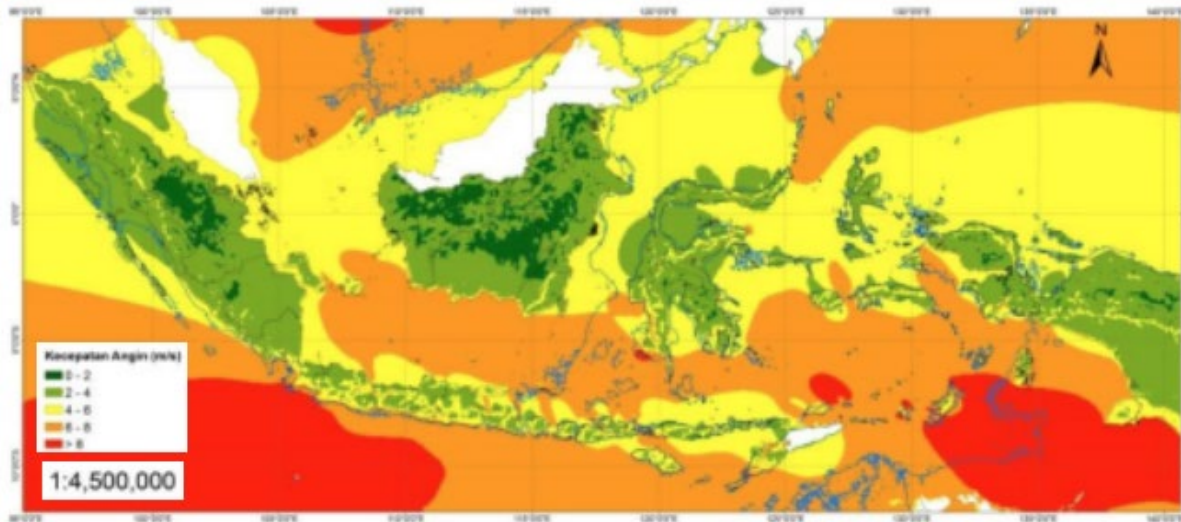


Fig. 1 Map of Indonesia's wind speed by the Indonesian Center for Maritime and Geological Development Research [12]

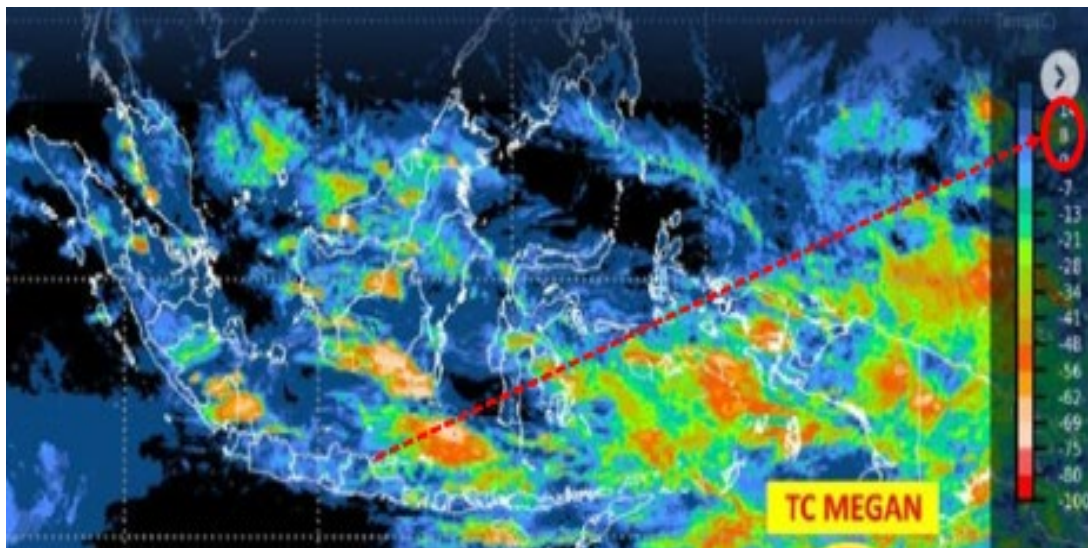


Fig. 2 Map of Indonesia's wind speed under weather anomalies [13]

In this paper, a three-bladed Vertical Axis Wind Turbine (VAWT), Savonius type, was developed using carbon fiber composite material as the turbine blade, adapted from the aluminium blade VAWT produced by [14] and has been used as a driving energy for street lighting adapted to wind speed condition on most of Indonesia's off shore islands, as seen in Fig. 3. Due to their simplicity and ease of manufacturing, Savonius-rotor type vertical axis wind turbines (VAWT) are still considered one of the most attractive solutions [15], [16], [17]. Besides, Savonius VAWTs are well suited to such environments due to their inherent axisymmetric design, which can reduce loads on the turbine tower to reduce material costs and enable urban areas with low wind potential to be supplied with clean electric power. These benefits are necessary for the installation and continued operation of cheap small-scale wind turbines [18], [19], [20].



**Fig. 3** The damage of turbine blades due to wind speeds far exceeding normal wind speed limits [14]

The aim of this paper is to obtain a VAWT blade material that is not only capable of converting wind energy to rotate the turbine shaft to produce power at low wind speeds, 2 m/s, but is also strong enough to withstand storms with a wind speed of 8 m/s. In this research, carbon fiber was chosen to be used as a VAWT blade material to replace aluminium blades, because Carbon fiber composites are unrivalled in strength and stiffness for their weight [21]. Composites are widely used due to their high strength-to-weight and hardness-to-weight ratios [22], and the use of composites in Building materials technology allows for high processing and material properties, as well as the formation of completely new materials with predetermined properties [23]. The carbon fiber-reinforced polymer matrix composite (PMC) has thereby become forefront material in aerospace, automobile, sporting goods, and other applications which demand high strength and high modulus [24].

This research was carried out experimentally into two stages: The first stage is experimental testing of the bending strength and impact strength of the carbon fiber material that will be used as the VAWT blade material, by making bending test specimens and impact test specimens in accordance with ASTM standard requirements, respectively: ASTM D6110 -18 for impact testing, and ASTM D790 for bending testing by using three-point flexure metode. The purposes of the activities at first stage are: to determine tensile properties in the material carbon fiber using, to obtain the material strength along with the specimen deflection and bending elastic modulus, and to determine the toughness of material by calculating the amount of energy absorbed during fracture.

The second stage is experimental testing of VAWT models in wind tunnel. As a first step, the manufacture of 2 VAWT models was carried out by applying the principle of dynamic similitude, with a model scale of 1:3 to the prototype, where one of the VAWT models used 3 blades made from aluminium, and the other VAWT model used 3 turbine blades made from carbon fiber. Next, the process of assembling the three blades of each turbine with its mechanical components, such as shaft, bearing, bearing housing; and the last step, is testing of each VAWT model in a wind tunnel to obtain the durability parameter of the turbine blade to high wind speeds, which is expressed through the Tip Speed Ratio (TSR) parameter, which is the ratio between the tangential speed of the tip of a blade and the actual speed of the wind, especially for TSR which is greater than the normal TSR range value, i.e: TSR 0.1 – TSR1.3, as shown by the curve in light blue in Fig. 4, and the vibration value it produces.

Vibration testing, as the ability parameter of the two VAWT models to withstand high shaft rotation, was carried out by providing 4 variations of wind tunnel motor RPM from 150 rpm to 450 rpm. The resulting wind speed is measured with an anemometer, and the rotation of the turbine shaft is measured by using a tachometer, and turbine vibration is measured using a vibrometer.

This paper discusses the bending strength and impact strength of carbon fiber which will be used as blade material, compared with the bending strength and impact strength of duralumin from previous research; manufacture of two wind turbine models, each of which uses duralumin blades and carbon fiber composite blades, as well as the results of their tests in the wind tunnel. This article also discusses the durability performance of each wind turbine model as a function of TSR, wind speed and RPM, as well as the vibration value that occurs.

## 2. Literature Review

From previous studies it was stated that composite materials, especially carbon/ epoxy has the best tensile strength, so it can used as a turbine blade material. The following are some reviews of previous studies related to this paper: Composite materials, known for their strength, versatility, and resilience, have seen substantial advances, especially with the incorporation of nanotechnologies and hybrid fiber reinforcements. The transition from traditional composites to advanced metal matrix nanocomposites (MMNCS) and fiber reinforced polymers (FRPS) is highlighted by Hussain, et al [26], which addresses its impact on the environment and specializes in sustainable options such as natural fiber reinforcement.

A novel bamboo fiber and recycled plastics composite developed by Andoh, et al [27] for wind turbine blade application and provide results that as the percentage of bamboo fiber in the specimen increased, the tensile strength and impact energy also increased, and the specimen with 25% bamboo fiber and 75% HDPE matrix possesses the quality that qualifies it to be used as a material for wind turbine blade fabrication. The use of composite materials in the world of aviation has been widely implemented, as done by Adamy, et al [28] by using composite carbon/epoxy T300/N5208, Aluminium dan Titanium, and obtain stress values at uniform thickness for each material: 75,8 MPa for composite, 59,2 MPa for aluminium, and 59,2 MPa for Titanium.

Many previous researchers have also conducted research on carbon fiber, such as: Dedhe, et al [29] prove that variations in volume fraction and length of carbon fiber can affect the mechanical properties of carbon fiber reinforced polyester composites. Composite strength increases with increasing volume fraction and fiber length. The highest tensile strength of a polyester composite with carbon fiber reinforcement = 135 MPA, is found at a fiber volume fraction of 40% with a fiber length of 33.41mm, and the maximum impact strength = 208.25 MPa , is found in a composite with a fiber volume fraction of 56.82% and a fiber length of 25mm. Dewo, et al [30] carried out a comparison of the specific characteristics of tensile tests of composite materials with an epoxy lycal resin matrix reinforced with Kevlar carbon fiber, using the vacuum infusion method versus vacuum bagging; and concluded that the material using the vacuum bagging method was better than the vacuum infusion method.

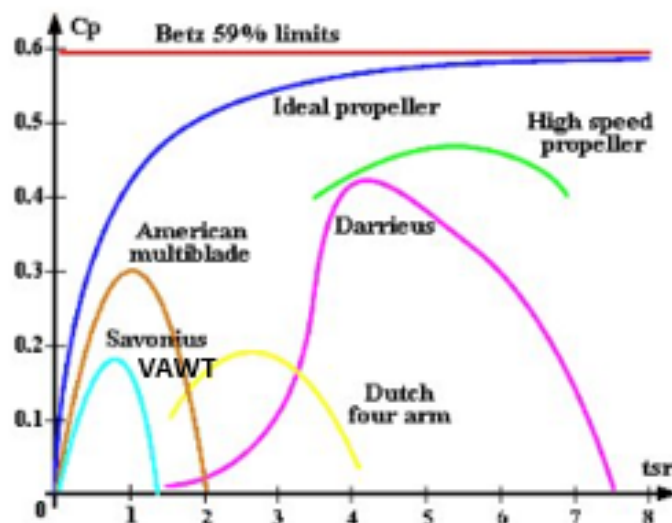


Fig. 4 Diagram of  $C_p$  - TSR for several types of wind turbine [25]

Experimental research, which is conducted by Bere, et al [31], aimed at determining the tensile stress characteristics of composite plates. Epoxy resin, type Epiphen RE 4020/DE 4020 was used for the matrix. The reinforcement material used was a biaxial carbon fiber fabric by 0-90o plain, twill and unidirectional weave fabric

3K, 200 g/m<sup>2</sup>. Result: The mechanical characteristics of plates made of composite materials reinforced presented indicates closed value like metal materials.

Previous research conducted by Astasari, et al [32] regarding Carbon Fiber and Balsa Wood Sandwich Composite sandwiches, gave results: focus on deformation, the best material is sandwich composite with 0° of fiber orientation, but focus on the stiffness, the best material is sandwich composite with 45° of fiber orientation.

Banowati, et al [33] analyzed the Tensile Strength of Carbon/Epoxy Vs E-Glass/Epoxy and the Bending Strength of Sandwich Composites to find out which composite is lighter, stronger and also has good thermal properties for making Aero0-73K aircraft ribs. As a result, the tensile strength of the E-glass/Epoxy fiber composite was 147,493 MPa and Carbon/Epoxy 452,949 MPa.

From previous studies it was found that carbon fiber has the best tensile strength compared to other composites, which will be adopted in this research as a turbine blade material. Previous research also concluded that the direction of the fibers, the number of layers, and the method used influence the strength of the material, so in the current research, test specimens were also made according to ASTM standards [34], [35].

### 3. Methodology

#### 3.1 Bending Testing ASTM D 790 Description

The decision of whether to use carbon fiber composites can be considered from 2 parameters, i.e: flexure strength and flexural modulus of the material. These two parameters are measures of a material to resist cracking or breaking under bending stress. The value of high flexural strength means the more ability to resist deformation when force is applied in tension or compression, and withstand bending, stretching, and twisting stress. ASTM 790 is used to measure how strong or stiff a material is, in this case, carbon fiber.

The bending modulus or flexural modulus, as the ratio of stress to strain in flexural deformation, is determine from the slope of a stress-strain curve produced by the ASTM D790. In this paper, the flexural modulus defined using the 2-point (cantilever) and 3-point bend tests, assumes a linear stress strain response (D790-03. 2023).



Fig. 5 Three point bending

The equations of bending stress and modulus elasticity [36] are:

Bending Stress:

$$S = \frac{3FL}{2bd} \quad (1)$$

Modulus Elasticity:

$$E = \frac{FL^3}{48I\delta} \quad (2)$$

Where: F = load, L= pendulum's length, I = second moment of area, and  $\delta$  = deflection due to the load F.

#### 3.2 Impact Testing ASTM D6110-18

The method used in this test is charpy method by using ASTM D6110-18 standard, as depicted in Fig. 6. Impact testing is a type of material testing by absorbing potential energy from a pendulum load that swings from a certain height and then hits the specimen, so that the specimen experiences deformation. In the impact test, the toughness of the specimen can be seen from the amount of energy absorbed. Fig. 7 explains the test calculation sketch.

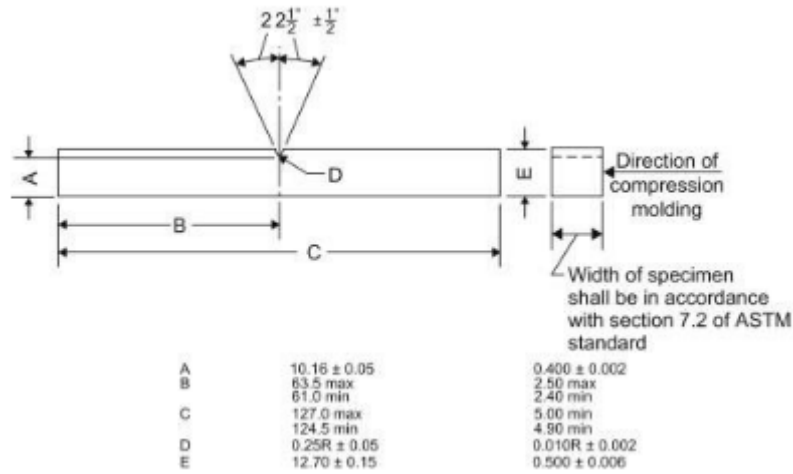


Fig. 6 Specimen ASTM D6110-18 dimension [34]

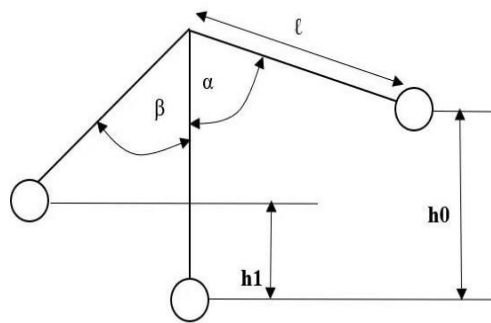


Fig. 7 Impact testing method

The pendulum impact test indicates the energy to break standard test specimens of specified size under stipulated conditions of specimen mounting, notching (stress concentration), and pendulum velocity at impact. Equation used in the impact testing were:

$$E = W \times h \tag{3}$$

$$h_1 = l - l \cos \beta$$

$$h_0 = l - l \cos \alpha$$

Energy absorbed by the specimen:

$$\Delta E = W(h_0 - h_1) \tag{4}$$

With  $W$  is pendulum weight,  $h_1$  is the distance between pendulum and specimen after breakage the specimen. The energy difference value will be negative because the energy is absorbed. If the energy absorbed has a high negative value, then the specimen has a high toughness value and has ductile mechanical properties, while if it has a low negative value then the specimen has a low toughness value and has brittle mechanical properties.

### 3.3 Model VAWT and Experimental Testing

Next, two VAWT models were made with a scale of 1:3 according to the wind turbine design in previous research, including mechanical and electrical components which were also adjusted to the previous design as shown in Fig. 8. In this research, one of the VAWT models used 3 blades made from aluminium, and the other VAWT model used 3 turbine blades made from carbon fiber. In the aluminium blade VAWT model, the turbine blade processing process starts from cutting the plate to rolling using a roller machine. All machining work on the mechanical components of the VAWT model is carried out in the fabrication laboratory and aerodynamic laboratory. the aluminium blade VAWT model, the turbine blade processing process starts from cutting the plate to rolling using a roller machine. Welding work such as on support beam structures is carried out in the welding lab, mechanical engineering department, Bandung State Polytechnic. The assembly of the three aluminium turbine blades is then fastened using strout at 3 points of each turbine blade and connected to the turbine shaft using welds.

The process of making a 3 blade VAWT model using carbon fiber, starting from making a carbon fiber composite mold of 3 VAWT blades. The molds are made in pairs, which are formed from 2 molds, namely an outer

mold with a semi-circular concave profile paired with an inner mold in the form of a cylinder, as seen in Fig. 9. The method used is a combination of hand lay-up and vacuum bag. The assembly of the three carbon fiber turbine blades is then fastened using strout at 3 points of each turbine blade and connected to the turbine shaft using welds.



**Fig. 8** Design model VAWT according to previous research [14]



**Fig. 9** Mold pairing to make carbon fiber composite blades

Next, the process of assembling the three blades of each turbine with its mechanical components, such as shaft, bearing, bearing housing; and the last step, is testing of each VAWT model in a wind tunnel to obtain the resistance parameter of the turbine blade to high wind speeds, which is expressed through the Tip Speed Ratio (TSR) parameter, which is the ratio between the tangential speed of the tip of a blade and the actual speed of the wind, and strength value against vibration. The wind speed testing conditions were up to 8 m/s, carried out by giving 3 variations to the wind tunnel motor rotation: 117 rpm, 217 rpm and 317 rpm and the wind speed was measured 5 times using an anemometer, for each motor rpm.

Turbine rotation is measured using a tachometer and stroboscope. Vibrations arising from high wind speeds are measured using a vibrometer. The whole process can be seen in Fig. 10. The definition of success in impact testing with ASTM D6110-08 specimens and bending tests with ASTM D790-03 specimens is determined by the success of the test specimen in fulfilling the test process on each testing machine. If the test specimen cracks during handling, the test specimen must be remade.

Meanwhile, the decision of success in testing the wind turbine model in the wind tunnel is seen from the assembly resistance of the turbine blades and the mechanical components of the test model at high wind speeds. Before starting testing in the wind tunnel, standard testing procedures have been carried out, including the conditions for placing the turbine model so that the vibrations generated are the influence of wind speed parameters and turbine rotation.

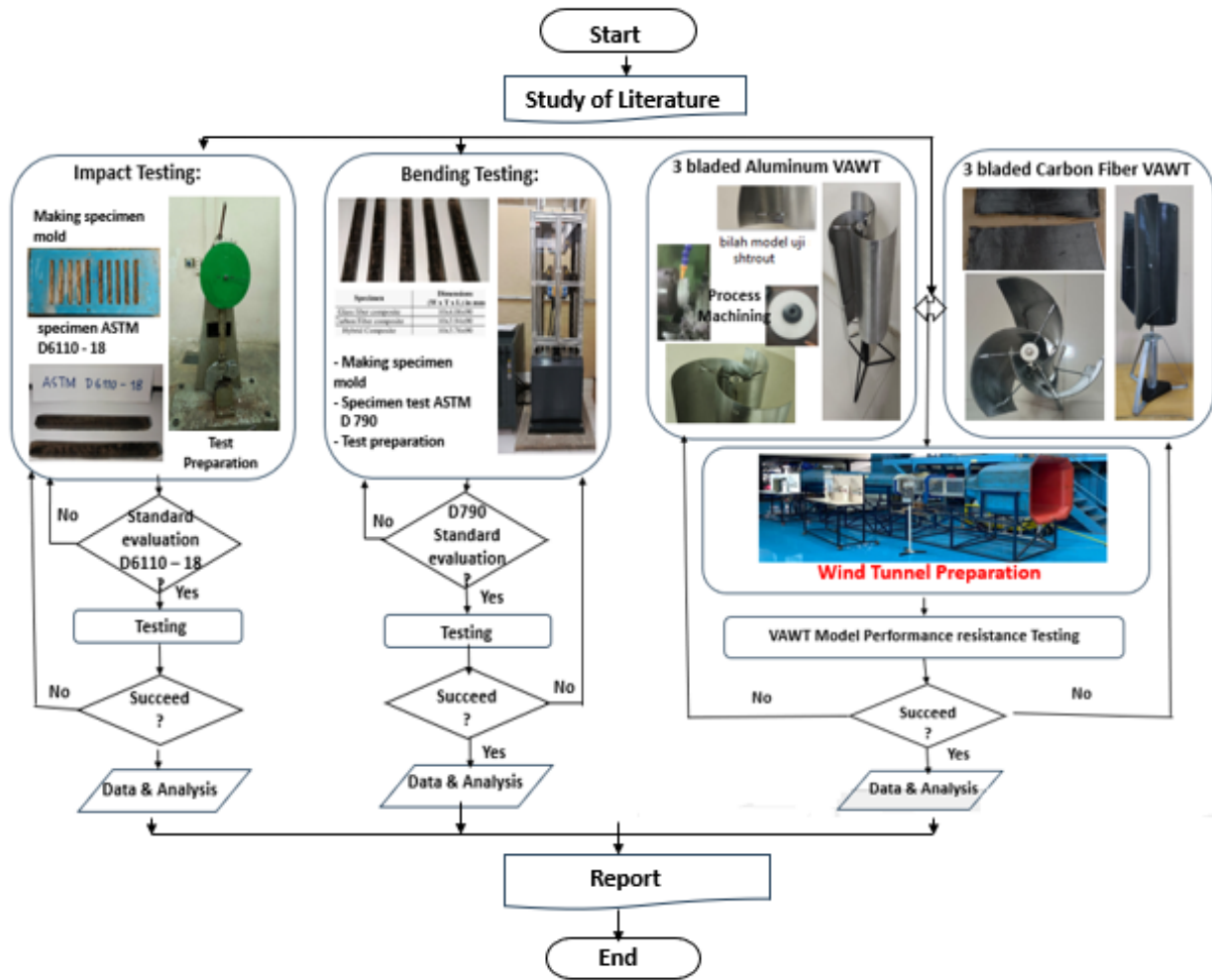


Fig. 10 Working process flowchart

## 4. Results & Discussions

### 4.1 Bending Specimen Testing

The fracture results of the bending test of specimen ASTM D790 carbon fiber can be seen in Fig. 11. The value sought in bending tests is bending strength specimen and the bending modulus elasticity of the specimen, shown in Table 1, and Fig. 12 shows the increase in specimen length due to the increase in load given during the testing process until it breaks. From Table 1, the maximum bending strength of carbon fiber is 70,122 MPa, while the dural bending strength as a result of research by Wahyono, et al, is 66.8 MPa [37]. It means that the ability of fiber carbon composite to resist deformation under load is greater than dural.

### 4.2 Impact Specimen Testing

The fracture results of the bending test of specimen ASTM D6110-18 carbon fiber can be seen in Fig. 13. Impact testing is a type of material testing by absorbing potential energy from a pendulum load swinging from a certain height and then striking the specimen, so that the specimen experiences a change in shape (deformation). The data obtained from this impact test is in the form of the angle of the pendulum hitting the specimen. Following are the data results after testing in Table 2. The value sought in impact tests is Impact Value (IV) and Potential Energy (EP), where IV is the ratio of the difference in potential energy before and after the impact to the surface area of the specimen. The Impact Value and Potential Energy before and after testing of the specimen, shown in Table 3.

Impact Value (IV) determines the ability of a material to resist sudden impact or shock load. Potential Energy (EP) determines how much impact energy can be absorbed by the material specimen. The higher the IV determines that the material tends to have ductile mechanical properties, while the low IV indicates that the material tends to be in the brittle category.

From Tabel 3, the average IV is 0.3860 Joule/ mm<sup>2</sup>, compared with the results of research conducted by Vicky [38] regarding the strength of duralumin undergoing stage 1 of heat treatment process which has an average

impact value of 0.0745 Joule/ mm<sup>2</sup>, that means carbon fiber composite materials have a better ability to absorb excess energy, such as when excessive wind speeds occur during weather anomalies, compared to duralumin blades. So the carbon fiber composite materials are suitable for use as wind turbine blades as a replacement for duralumin blades to anticipate high wind speed anomalies.



Fig. 11 Specimen ASTM D790 after testing

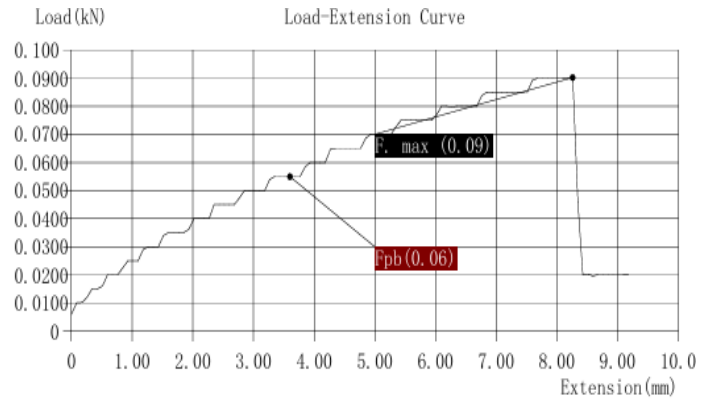


Fig. 12 Load-length chart of carbon fiber specimens

Table 1 Bending test result for carbon fiber

No. of Specimen	Load (N)	Deflection (m)	Bending Strength (MPa)	Modulus elasticity (MPa)
1	90	0.00826	54.878048	0.2214074
2	86	0.01059	52.439024	0.1650116
3	115	0.00568	70.121951	0.4115138
4	106	0.00459	64.634146	0.4685671
5	100	0.00591	60.975609	0.3436214
Mean	99.4	0.00701	60.609756	0.3220243



Fig. 13 Specimen ASTM D6610-18 after testing

Table 2 Specimen pendulum angle measurement

Specimen	Initial Angle of Pendulum	Final Angle of Pendulum
1	130	75
2	130	68
3	130	59
4	130	48
5	130	80

**Table 3** Calculation of IV carbon fiber

Material	No.	h1 (m)	EP1 (J)	h2 (m)	EP2 (J)	IV (J/mm <sup>2</sup> )
Carbon Fiber	1	0.985	77.355	0.445	34.900	0.3343
	2	0.985	77.355	0.375	29.448	0.3772
	3	0.985	77.355	0.291	22.836	0.4293
	4	0.985	77.355	0.199	15.580	0.4864
	5	0.985	77.356	0.496	38.911	0.3027
Mean IV					28.335	0.3860

### 4.3 VAWT Model

Two types of three-blade VAWT models were used in this study using different blade materials. The first VAWT model uses duralumin material as the blade material, while the second VAWT model uses carbon fiber composite material. Fig. 14 shows both types of VAWT models that have been made and assembled, with a top view of 3 turbine blades. Fig. 15 shows the wind tunnel used to simulate wind speed according to real conditions. The wind tunnel used in this research is an open-loop wind tunnel type. Before the test is carried out, preparations must be made, the point is to ensure that the wind tunnel conditions are safe when used, apart from that, all the equipment needed is also prepared so that the test runs well. Both models have been confirmed to be attached well to the test table using clamps. This is to ensure that the vibrations received by the vibrometer are vibrations caused by the rotation of the turbine at high speed. Fig. 16 shows the condition of the VAWT model with three blades made of duralumin material during testing, and Fig. 17 shows the VAWT model with three blades made of carbon fiber composite material during testing.



**Fig. 14** Two types of VAWT used in this research



**Fig. 15** Open loop wind tunnel



**Fig. 16** Testing of the aluminum blade VAWT model in wind tunnel: measuring turbine's rotation, wind speed correspondence, and measuring vibration



**Fig. 17** Testing of the carbon fiber blade VAWT model in wind tunnel

#### 4.4 Experimental Testing Results

From testing the VAWT model, turbine characteristic parameters were obtained: wind speed, turbine rotation, tip speed ratio, and vibrations caused by three variations of wind tunnel motor rpm are shown in Table 5 for the VAWT model with carbon fiber composite blades. From Table 5 the VAWT model works in the TSR range, which is outside the VAWT domain, which means that the VAWT blade can withstand higher wind speeds. Vibration Test Results of Dural blade of TASV Model and Carbon Fiber blades from variations wind tunnel motor of rotation from 150 rpm to 450 rpm (equivalent to maximum wind speed = 8.5 m/s) are presented in Table 6. It can be seen from Table 6 that the average wind speed produced in the tests of the two VAWT models shows that a difference in wind speed of 6.87% can result in a difference in turbine rotational speed of 3.59%; and from the results of vibration measurements it is known that under the same wind speed conditions, the effects received by the two VAWT models are not the same, for the duralumin blade the VAWT model is categorized as strong wind, while for the VAWT model the carbon fiber blade is classified as not yet strong, as shown in Table 7. This confirms that turbine blades with composite materials can absorb excess energy because they have a greater impact value than duralumin materials.

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In vibration measurements, physical vibrations caused by the rotation of the turbine blades for each VAWT model are converted into analog signals via vibration sensors and obtained in the form of vibration signals. This vibration signal is then channelled to a dynamic signal analyzer to finally obtain a digital value which shows the vibration strength value of each VAWT model. In this speed range, the results were 2.9 and 2, for the Aluminum blade model VAWT and the carbon fiber blade model VAWT respectively.

Fig. 18 displays the two VAWT models used in this study according to the TSR obtained during testing, and compares them with the TSR range of the VAWT under normal conditions. Both VAWT models can be assumed to be capable of rotating at high wind speeds, and the turbine model with carbon fiber composite material blades has better vibration resistance compared to the duralumin bladed VAWT model.

**Table 5** Carbon fiber composite of three bladed VAWT model data results

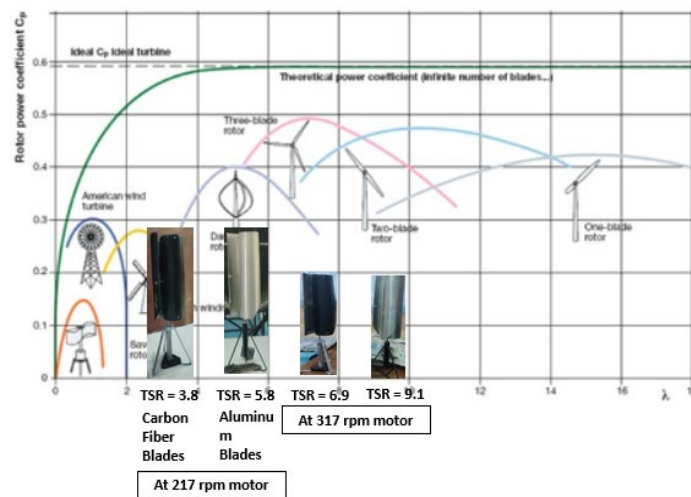
RPM motor	No. of Test	V mean (m/s)	rpm VAWT	$\omega$ (rad/s)	TSR
117	1	1.68	125.6	13.15	1.97
	2	1.51	376.5	39.41	1.96
	3	1.59	422.2	44.19	2.09
	4	1.49	427	44.69	2.25
	5	1.72	456.1	47.74	2.08
217	1	2.51	315	32.97	0.98
	2	3.30	804	84.15	1.91
	3	3.19	870	91.06	2.14
	4	2.25	765	80.07	2.67
	5	2.80	925	96.82	2.59
317	1	4.06	763	79.86	1.49
	2	3.06	1450.7	151.84	3.73
	3	3.10	1452.1	151.99	3.68
	4	5.11	1445	151.24	2.22
	5	3.56	1580	165.37	3.49

**Table 6** Classification of wind speed

Material	Mean Wind Speed	RPM	Mean Vibration	Classification
Alum	5.96	1445	5.4	V1: Strong
Carbon Fiber	5.55	1393	4.0	V: Rather Strong

**Table 7** Vibration data results

Data Testing of VAWT Model at the same Rotation of Motor of Wind Tunnel				
at 217 rpm (V = 2 - 6 m/s)				
	TSR (max)	Rotation of Turbine (RPM)	Rotation ( $\Omega$ ) (rad/s)	Vibration
Aluminium	2.78	361.5	37.845	2.2
Carbon Fiber	2.67	321.76	33.673	1.8
At 317 rpm (V = 6 - 8 m/s)				
Aluminium	4.08	1585.16	165.87	2.9
Carbon Fiber	3.73	1450.7	151.8	2.0



**Fig. 18** The two VAWT models used in this study according to the TSR obtained during testing, and compares them with the TSR range of the VAWT under normal conditions [25]

### 5. Conclusions

From the results of the TSR data which shows the two VAWT models of this research which are outside the work domain of the Savonius type VAWT, it can be concluded that the real conditions of storm winds faced by wind turbines as a result of global warming can be represented through the rotation of the wind tunnel motor. From the results of testing the bending and impact strength of carbon fiber composite materials which are greater than the bending strength and impact strength of dural materials, as well as the vibrations produced at high wind speeds, it proves that carbon fiber composite materials are very suitable for use as wind turbine blades to replace duralumin material blades for drives the turbine shaft to drive environmentally friendly and sustainable street light energy.

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### Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

## Author Contribution

The authors confirm contribution to the paper as follows: Maria study **conception and design**, and **supervised the finding of the results**: Citra **fabricated the specimens ASTM D790 and ASTM D6110-18 standard**, supervised by Maria, Syarif, Maria and Lenny, **data collection, analysis and interpretation of results**: Budi and Adri, **fabricated the model of wind turbine**, Maria, Budi, and Adri **carried out the experiment model in wind tunnel**. Maria took the lead in **writing the article manuscript**. All authors reviewed the results and provided critical feedback and helped shape the research, analysis and manuscript.

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