DESIGN AND ANALYSIS OF ADDITIVELY MANUFACTURED CURVED AND CONVENTIONAL BLADE FOR WIND TURBINE

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ABSTRACT

Nowadays, wind turbine became one of the largest energy suppliers of energy in world. The focus point in the wind turbine system is where the wind is harvested and converted into useable energy by the wind turbine blade. This study emphasized on determining the efficiency of curved wind turbine blades for low wind speed in Malaysia. 3D printing technology was used as to develop the designed three-dimensional model of GOE 630 air foil blades and evaluation of aerodynamic characteristics by experimental testing. To achieve the highest extraction of the wind energy, a high efficiency of the wind turbine is needed. In this paper an attempt is made to compare the curved and conventional wind turbine, and which one is more efficient based on the ampere, voltage and rotation per minute (RPM).

Keywords: Blade design, Vertical axis wind turbine, Wind energy, Power coefficient, Additive manufacturing

1. INTRODUCTION

At present, In the world, alternative energy is exceptionally needed to sustain the need of the world. The resources have turned out more necessary as natural resources for example petroleum fuels have harder to discover now days. It is also as a polluted the environment. One of the alternative power resources is wind. Wind power capacity has been about 4% globally which is equivalent to 487 GW by 2017 [1]. This marked the wind power to be one of the fastest emerging technologies for renewable energy and electricity generation. That they are many advantages of wind energy. Wind power is fueled by the wind, thus the wind energy is a clean and renewable energy source. That are no pollution created such as power plant that produce on combustion of fuels. Wind energy is produced from wind power. It also one of the most minimal cost sustainable power sources today. However, to make wind an alternative source of electrical energy is tricky. More detailed and careful design of wind-catching machines is necessary.

Wind turbine generally is a device that change wind kinetic dynamic energy to electrical power. In indicated by World Wind Energy Association (WWEA) 2013 report, wind power has achieved an exceptionally high demand offer in power supply in certain country such as like Denmark (38%) and Spain (21%), wind energy is become the biggest sources of an electricity power wind energy is become the biggest sources of an electricity power for accompanying country such as Portugal

(more than 20%), and Ireland (more than 16%). From the report, the advancement of wind turbine is growing rapidly stage by stage [2].

Wind energy is become higher demand resources in Malaysia but the product design should be suit atmospheric climatic condition in Malaysia. It additionally gives advantage to all user to reduce the cost and also produce electrical power. In general, climatic condition in Malaysia. It additionally gives advantage to all user to reduce the cost and also produce electrical power. In generally, the cost and weight of the blade are in manufacture wind power energy competitive with others power generation.

The decreasing of the weight blades force is very important issue deserving of research. Another factor that assume a very important role is operation life for wind turbine, but the main important part that consider is the blades. As the requirement for improve fatigue life, reliability, and efficiencies increase, so must do the challenge of developing innovative design.

However, if change the plan of design for the blade can be produced at the specific abnormal stage and certainly in Malaysia can possibly create wind energy. In fact, by using curved blade design and upgrade design of blade can improve the energy, save minimal cost and long-term user demand in Malaysia.

Nowadays, wind energy, wave energy, biomass and biogas energy and solar energy related of the example for renewable energy sources which is all the energy will reduce cost also has been produce electricity energy. One of the popular renewable energy is wind energy other than other resources. Wind energy already has been used in Europe because the wind speed ration is much better than others country. It generates energy for their nations. Based on the low wind speed in Malaysia, this country unsuitable use wind turbine for large scale turbine design that potential to create small scale turbine blade with their improvement. One of the improvements that been affected of the effective blade design on their thickness of the chord width and curved at chord section of the blade design wind turbine. Even thought, wind turbine also in the new development technology in Malaysia. Wind turbine is an alternative energy sources because is more save, free from any pollution and also renewable.

In Malaysia, to achieve the highest extraction of the wind energy, a high efficiency of the wind turbine is needed. A turbine would convert more 35 percent of wind passing through the blade into power. In fact, the power efficiency rating for wind turbine such as at Pulau Perhentian in between 30% to 35% of rating power output [3]. Power wind turbine demand at the country are higher compared to 5 years ago. With the use of wind turbine technology, efficiency rating has been increased. Factor that affecting in low efficiency in their low tip speed ratio. Harnessing power from the wind is one cleanest and most sustainable way to create power as it delivers no toxic pollution or global warming emission [4]. Wind also affordable which it a suitable and extensive scale option in contrast to fuel product. Wind power is a clean energy source that had been relied on for the long-term future. A wind turbine creates reliable, cost-effective, pollution free energy. It is affordable, clean and sustainable. Wind turbine can be sufficient to generate energy.

Process planning is eliminated in the fabrication of three-dimensional (3D) models using additive manufacturing (AM) also known as 3D printing. In AM, layers of model are constructed by adhesion with various output sizes available from microns to hundreds of feet. The technology allows for manufacturing of complex geometrical parts, prototype production for single-use products, materials variation, fast construction, and accurate production [5]. It is expected that AM wind turbines can be very cost effective and enhance the quality of the yielded parts.

The main objective of the project is followed were to design of curved blades wind turbine and conventional blades wind turbine and analyze the current, voltage and rotation per minute (RPM) between curved blades wind turbine and conventional blade wind turbine.

2. METHODOLOGY

There has two structure design of blades used for this project. The first one is curved blades. The curved blades have different chord angle length. While for the conventional blades only has same chord angle length. Table 1 show curved blades specific dimension. The design blade used for the analysis are GOE 630 airfoils and there is the chosen blade for this modelling. GOE 630 profile are utilized from Design Foil Workshop for any chord type. This model is done sketching by using Solid Work. An airfoil is the foundation of wind turbine blade design, and accordingly, optimizing its design plays a key role in improving aerodynamic performance, noise control, and structural robustness of a rotor blade [6]. The measurement value is followed from AirFoil Investigation Database and the value for the coefficient of Drag and Lift. Figure 1 shows the type of blade use in the design.

The critical part of the wind turbine system is the blade. If the blade design is not functional to make the rotor generator turns, the blade can be considered failed and for sure it not able to generate electric. Figure 2 shows the curved blade design as be defining higher tip speed, it higher the efficiency of the turbine. The higher tip speed makes decrease the chord width leading to blade profile. This concept has been increasing the force when to make a rotation increase. However, there will be increase in aerodynamics force. The curved blade the total length for both designs is 20 millimetre and the maximum width chord of the blade is 39.92 mm radius. The curved are determined for the angle of curve at 15⁰ degree.

Table 1: Curved blades specific dimension

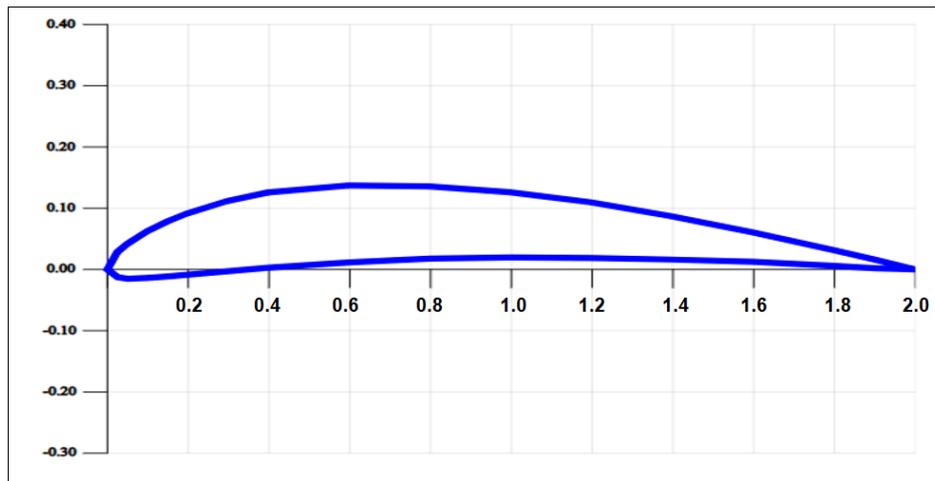| Chord length (mm)	Twist angle (⁰)	Radius (mm)
2.92	15	31.71
8.97	14.4	31.71
17.78	13.63	63.09
21.64	12.92	91.04
27.75	11.07	115.59
30.83	9.97	137.18
33.96	7.83	151.22
37.06	5.95	166.12
39.37	4.76	177.37
39.79	3.83	182.33
39.92	2.29	183.68
7.26	0	114

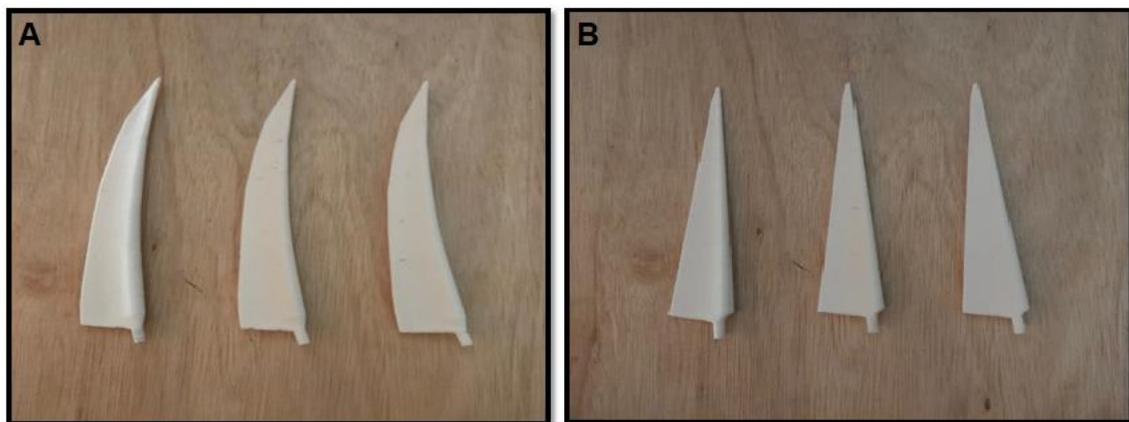Figure 1: Measurement of blade GOE 630 (unit in cm)

Figure 2: Prototype of (A) curved Blade (B) conventional blade design printed using additive manufacturing

The fundamental of this program such as solid work is to create, edit and the main purpose is for visualize 3D project design to users. For final design of the vertical axis wind turbine were simulated to get the drag force and Tip Speed Ratio (TSR) in minimize output power for the efficiency of wind turbine. Simulation analysis also construct by the SolidWork software for calculate the result for force, torque, velocity. In this software also have a flow simulation to construct the flow to analyze the best efficiency for the design. This development shows all the important machine and part need to use for development of experiment. The most of importance part is the build-up the prototype design by 3d printing machine (Cube Pro 3D printer machine, USA) because its accurate in actual analyzing and rendering output compare to the other modeling software.

In this project, the generator used was direct current (DC) motor that function as a generator. In this project, the generator used was 12-volt DC motor that function as a generator. A DC motor is a very simple electric motor and it operate in direct current. It used electric coil and magnets of opposite polarity, as generator turn due to the movement of the wind turbine, the magnet attracts and repel with each other, thus current and voltage are produced.

Table 2: Generator specification

Voltage	12 V
Power	15 W
Ampere	2.083 A
Size shaft	3 mm x 13 mm
Body size	35 mm x 58 mm
Main Colour	Silver
Weight	139 g

Anemometer is used to calculate the wind velocity to affecting the both of design. The equipment consist attachment with small fan inside the device, when the wind is stronger the faster blade spin. The device will measure the speed of air velocity to affecting the blade, and the unit can be converted to meter per second (m/s). The velocity of wind speed was recorded. The velocity wind speed was recorded in table and data was analyzed to reach the objective of the project.

The equipment used to calculate the rotation per minute (RPM) for the both of design. The device provides wide RPM and linier surface speed measurement. For measure the data should be added the reflector sticker at one of the blades to contact laser sensor to make on display reverse direction rotations reading. Reading button hold last reading for 5 minute and recall min/max reading.

For this formula power equation of the wind is relative to air density, drag coefficient and area of the segment of wind being considered, and the natural wind speed. The power in the wind was determined in order to find the efficiency of power.

$$P_{wind} = 1/2 \ [AV]^3$$

(Equation 1)

ρ: Air Density (units in kg/m³)
A: Swept Area (units in m²)
V: wind speed @ velocity (units in m/s)

RPM shown as a tip speed of blade equal RPM and radius divide from actual wind speed. From designing the tip speed ratio, power coefficient has been defined by using the Schmitz power coefficient table into same wind design that are used. RPM data get by the tip speed of blade from the previous experiment of design blade (Curtis Riley, 2011).

$$TSR = (RPM)(r) \ / \ v$$

(Equation 2)

where TSR decide as a tip speed ratio, *RPM* is rotation per minute (rad/s), *r* is radius and *V* is wind speed.

3. RESULTS AND DISCUSSION

The results of this project are when the curved design blade is more effective compare with conventional blade design. That have two design of wind turbine blade with GOE 630 air foils. The wind speed for this experiment has 3 different speed with 3.84 m/s, 4.54 m/s, and 5.52 m/s. Based on structure force, volt, current and RPM the efficiency of the wind turbine will be compared with both designs.

Basically, the result based on voltage output from curve and conventional blade design. The blade attached with 12v Dc motor to generate electricity. The wind velocity had already been assigned, using the speed of portable fan because the wind speed in Malaysia were very low and inconsistent. The velocity of the portable fan generates in minimum, medium and maximum. The data was collected when wind speed setup at 3.89 m/s, 4.54 m/s, 5.53 m/s. The table show the data collected by experiment on the both design wind turbine blade. The setting of the multimeter to measure voltage was set to 2V.
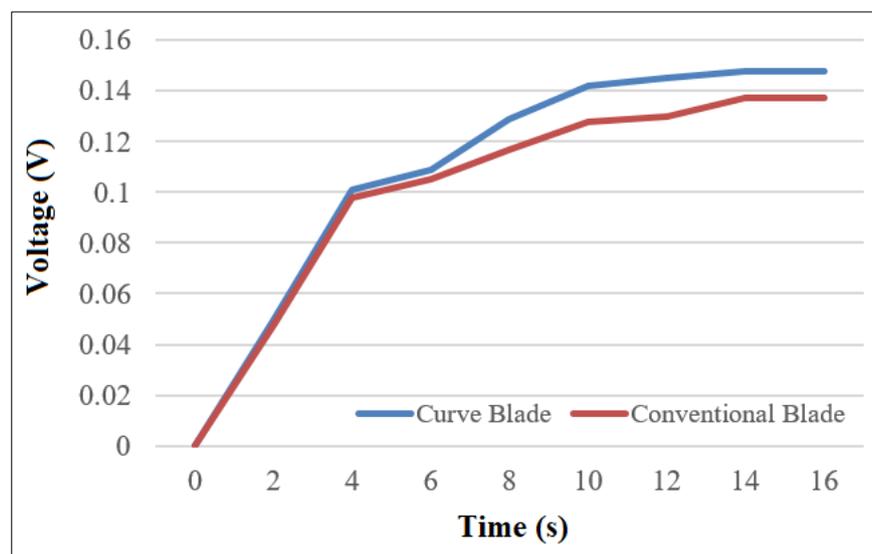
Figure 3: Voltage of curved versus conventional blade at 3.89 meter per second wind velocity

The voltage produces by current generated DC motor when wind speed affected the curve blade. When the wind speed is less than 3.89 m/s, the blade will not rotate enough to generate current. The data was taken every 2 second in a period of 16 seconds, therefore data taken during number one actual data after 2 second of testing, while number two was after 4 second of testing and so on. The voltage output generated can be seen fluctuated during the testing, this may be due to uneven wind captured by the wind velocity.
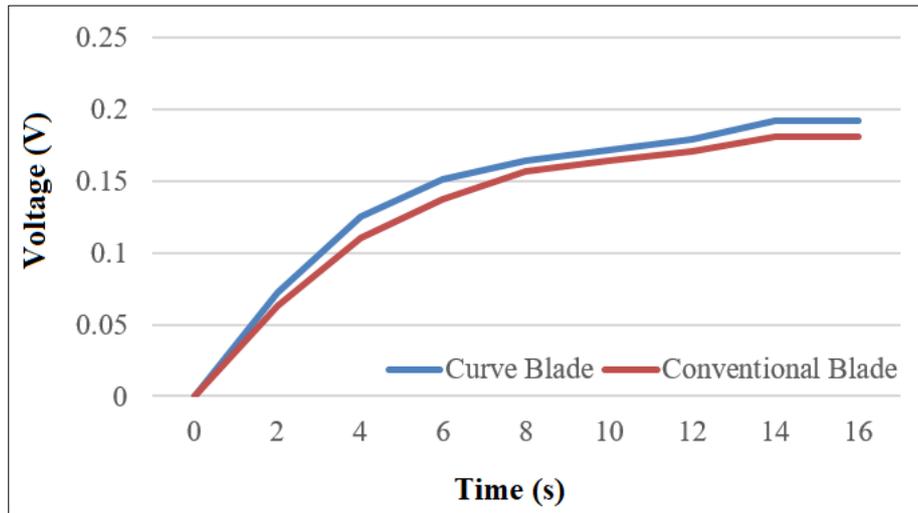
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Figure 4: Voltage of curved versus conventional blade at 4.54 meter per second wind velocity
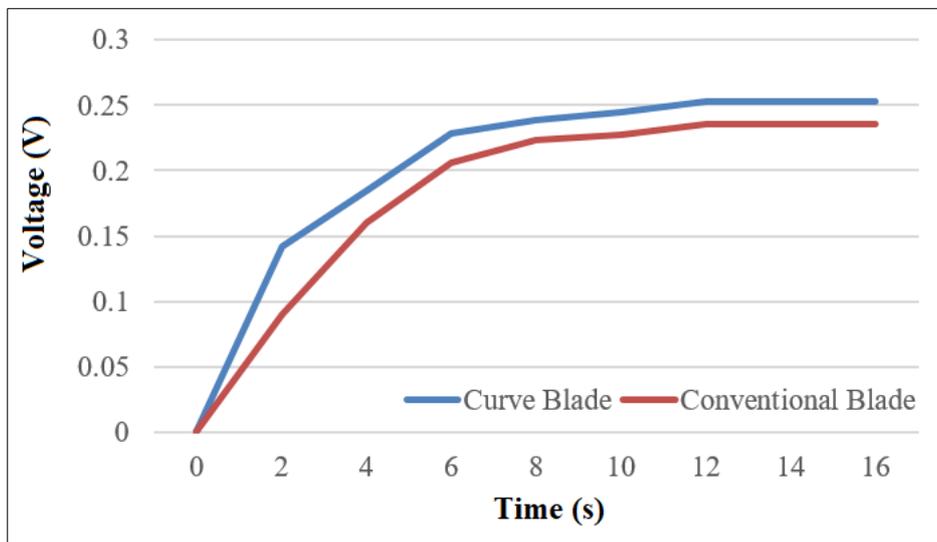

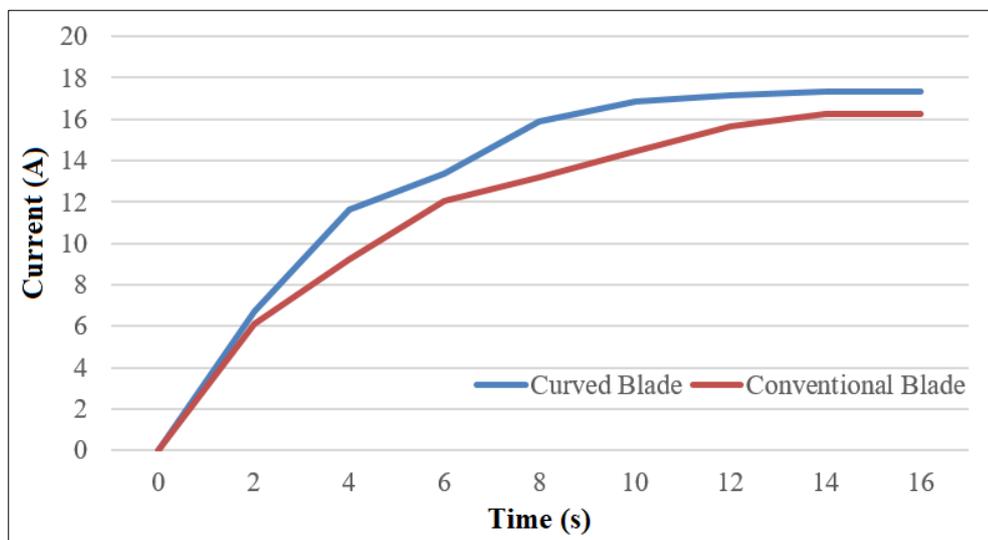Figure 5: Voltage of curved versus conventional blade at 5.53 meter per second wind velocity

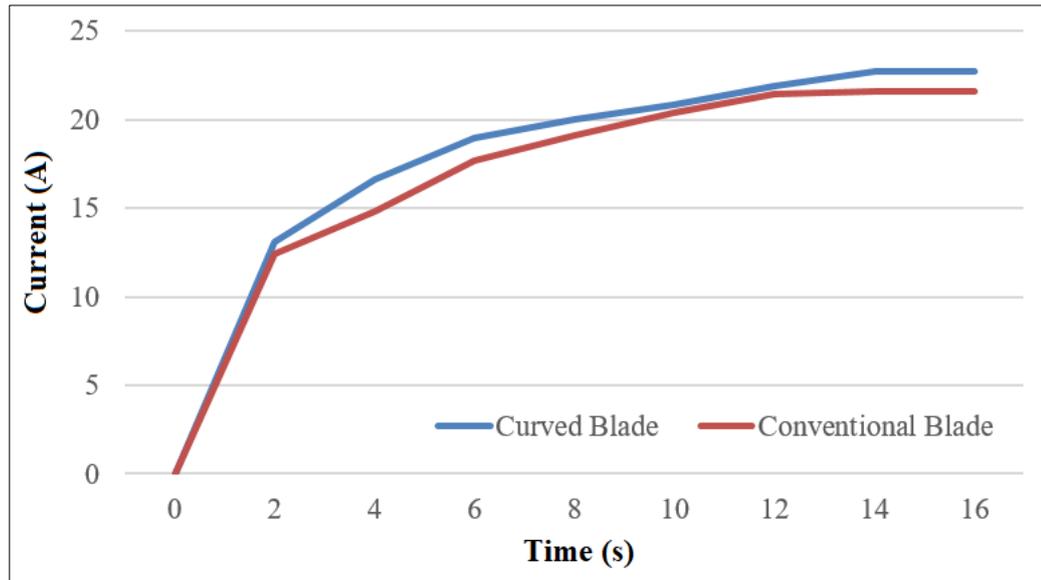Figure 6: Current of curved versus conventional blade at 3.89 meter per second wind velocity

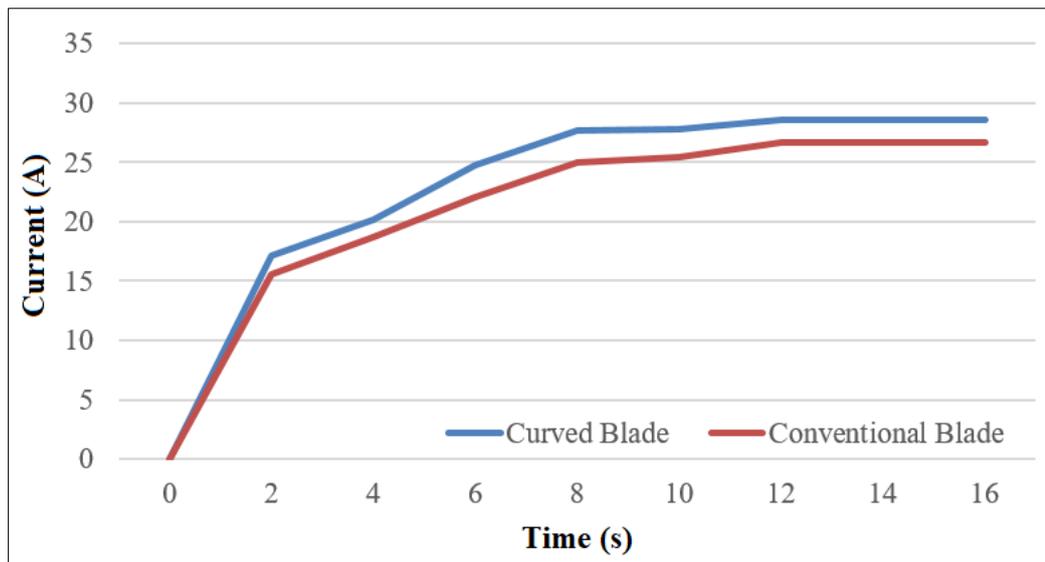Figure 7: Current of curved versus conventional blade at 4.54 meter per second wind velocity

Figure 8: Current of curved versus conventional blade at 5.53 meter per second wind velocity

For the result on curved blade and conventional blade at same wind speed. By velocity speed, the overall wind turbine speed obtained from curved blade and conventional blade from 10 second. Table below are show the graph of wind speed against time at 3.84 m/s, 4.54 m/s and 5.53 m/s wind velocity speed. Both design blade are analyses by experiment using tachometer device at different wind speed. Below are the data table and graph of wind turbine speed against time at three different wind speed.

By experimental to get the data from design for the curve and conventional wind turbine blade, the result shows the comparison between both of design. The curve blade design is better higher the power output by current and voltage produce. It is because the lift coefficient for the blade is higher better than conventional design. The force impact on the curve blade is extremely higher to rotate the turbine generator, and the RPM for curve blade is better faster from conventional design. The table below show the comparison power output from both of design.

This data represents the power contained in an air stream moving through a certain area. The data show the result output below than 0.01 watt when the wind speed are 3.89 m/s, 4.54 m/s, and 5.53 m/s. The result can explain two important point:

1. Power produced is related to the wind velocity (V^3). Therefore, when the wind speed increase in velocity, the power would increase.

2. Power is also related to the area of the wind turbine (A). Thus, an increase in the blade length and diameter will significantly produce more power to the turbine.
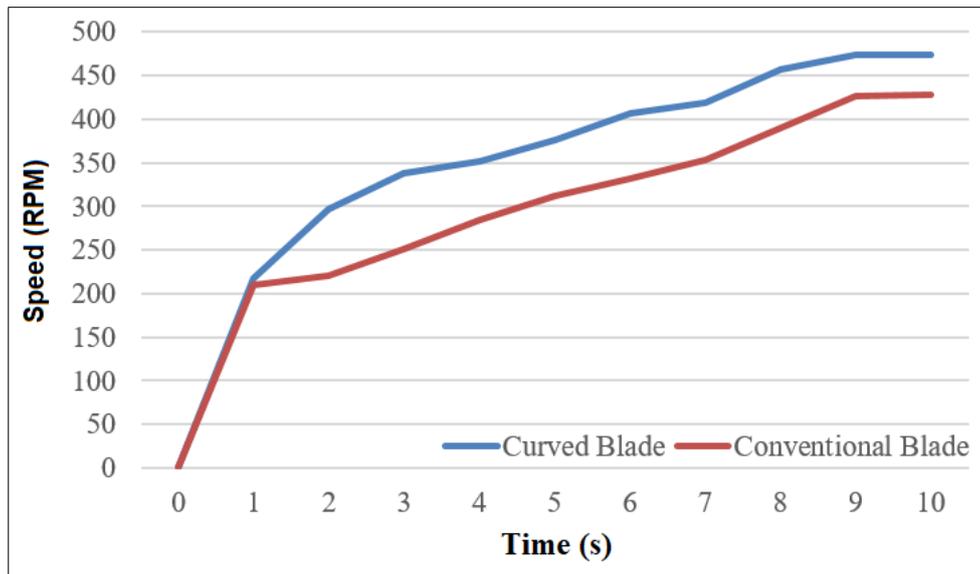

Figure 9: Generator speed of curved vs conventional at 3.89 meter per second of wind velocity
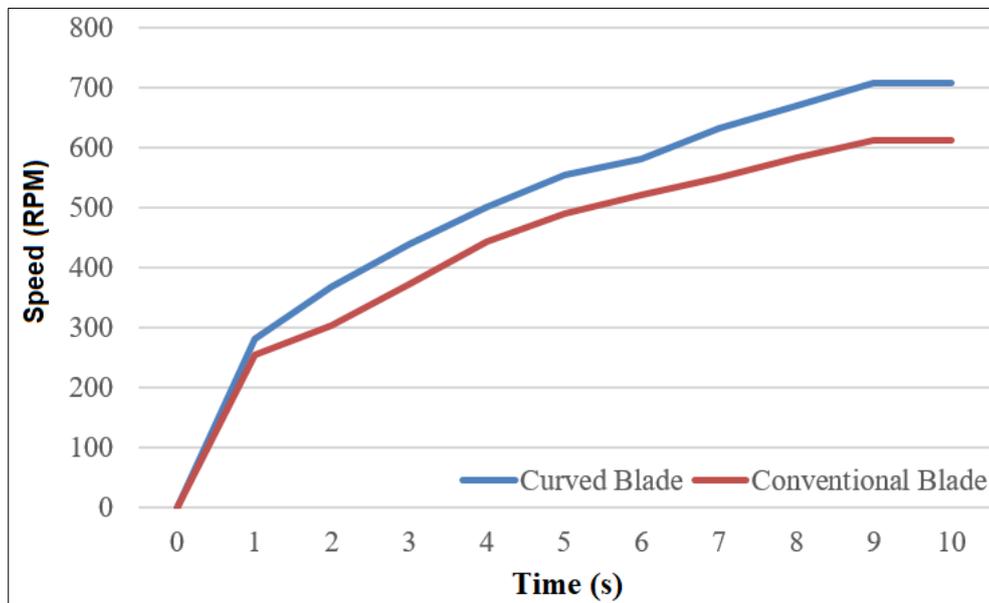

Figure 10: Generator speed of curved vs conventional at 4.54 meter per second of wind velocity
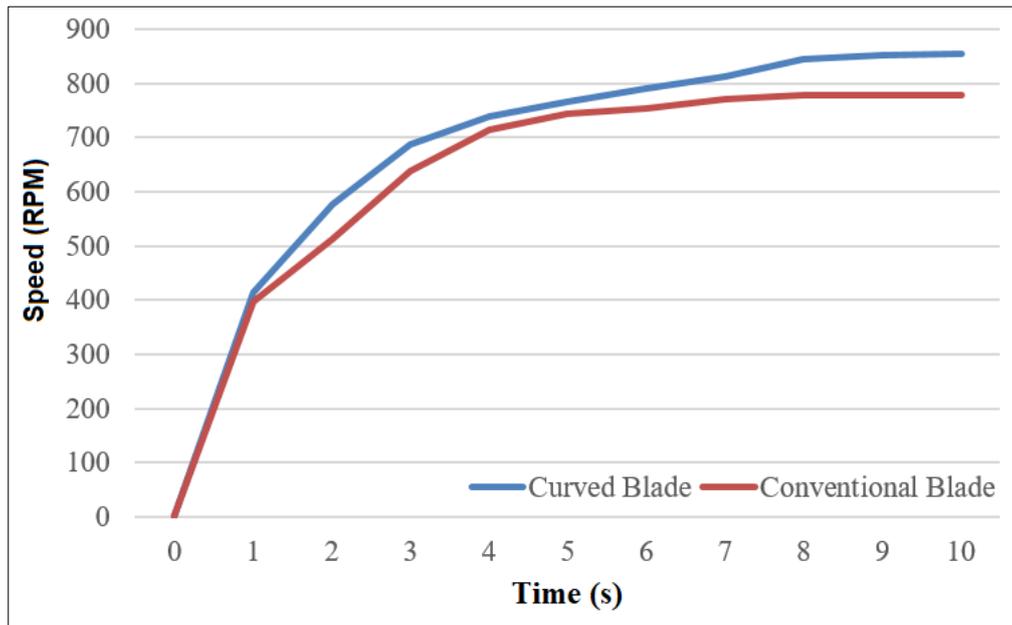
Figure 11: Generator speed of curved vs conventional at 5.53 meter per second of wind velocity
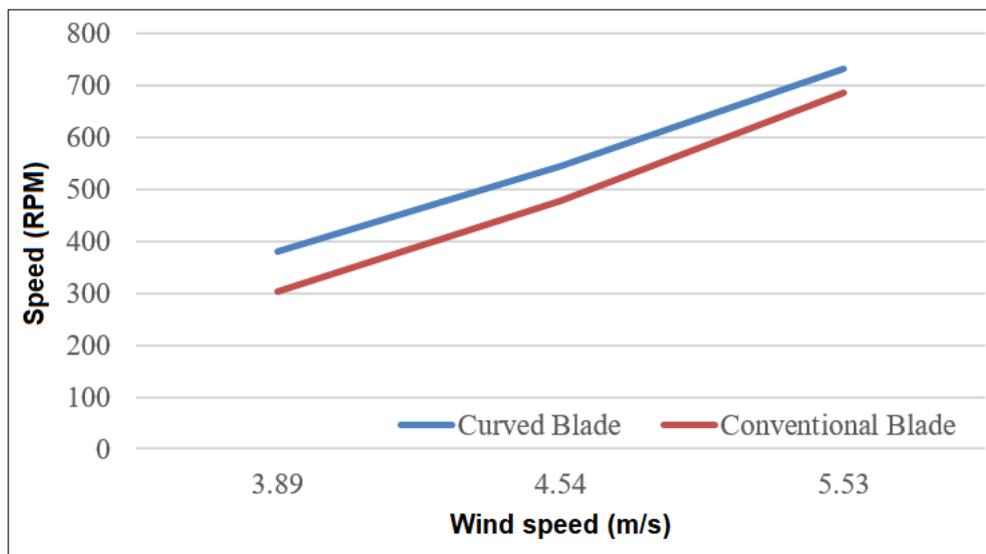

Figure 12: Wind speed effect on average blade rotational speed of curved vs conventional blade design

The average for the curved blades is better higher than conventional blade. That show the curved blade is much higher output better than conventional blade to produce electricity. Figure shows the comparison between curved blades and conventional blades. By experimental to get the data from design for the curve and conventional wind turbine blade, the result shows the comparison between both of design. The curve blade design is better higher the power output by current and voltage produce. It is because the lift coefficient for the blade is higher better than conventional design. The force impact on the curve blade is extremely higher to rotate the turbine generator, and the RPM for curve blade is better faster from conventional design. The table below show the comparison power output from both of design.
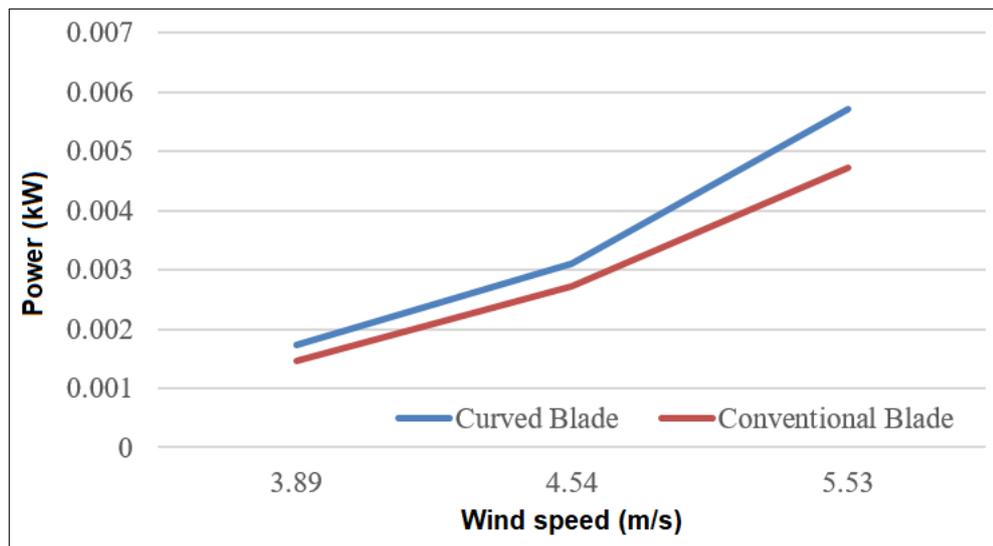
Figure 13: Wind speed effect on average blade rotational speed of curved vs conventional blade design

4. CONCLUSION

The curved and conventional blades prototype is done with an effective cost suitable with all selected materials and design needs. The data was collected and analysed from the power output of both design in curved and conventional wind turbine blade design. The power produce from both designs below than 0.01 kW. The power generated were small reading due to small parameter designs of the both blade design and due to the generator used. This mean that the bigger parameter design blade can be increase electricity generated. The data analysed show the curved blade are better higher than conventional blade due to the higher impact of lift coefficient affected on the curved design. This mean that the result analysis about the data from RPM. The RPM for curved blade is increase when the wind speed increase and same for conventional blade design but is much better than curved blade. Aerodynamic performance, noise and the structural robustness of the wind turbine blades can be improved by applying the airfoil concavity. Therefore, optimization of the small horizontal-axis wind turbine blades overall performance can be achieved.

On this recommendation section provide to improve the problem occurred during this research is done. First, the design parameter needs to be increased the dimension due to real application. This means that this blade needs to capture more wind speed to make higher a rotation speed when to generate more power electricity. Next, the wind speed should be used in compressed air to make higher speed to generate higher electricity power. Other than that, the surface of the blade need to be more clear when the wind affected the blade when to make higher lift coefficient and give high impact to make a rotation of the blade.

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