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Performance of vertical axis Savonius wind turbines related to the fin number on the blade

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Abstract. Model and the number of blades on the wind turbine greatly affect its performance. The purpose of this research is to know the effect of the fin on Savonius turbine U type 4 number blade. Simulation using Solidworks (Flow Simulation) software based on Finite Element Analysis (FEA) Method, will show pressure distribution and velocity distribution of blade rotor savonius wind turbines. The simulations to compare on the variation of the addition of 1 fin, 2 fins, and blade without fin (standard). The wind speed variations applied to each of the blades is 5 m/s, and 7 m/s respectively. The simulation results showed that the performance of pressure distribution and velocity distribution on each blade is higher and more widespread and evenly distributed, occurring on each blade with the addition of two fins compared to a single fin turbine and standard blade (without the addition of fin). The higher wind speed applied to the turbine blades will have a significant effect on the value of pressure distribution and velocity distribution on the blade. The effectiveness of pressure distributions and velocity distributions that occurs on the turbine blades will be significant to effect for the rotation on the turbine shaft, so as to have a significant impact on the performance the turbines.

1. Introduction

Turbines are classified into two categories, namely horizontal axis wind turbines (HAWTs) and vertical axis wind turbines (VAWTs). Where, HAWT has a horizontal rotation axis, while VAWT has a vertical rotation axis. The advantages of VAWT, is able to produce power at relatively low wind speeds compared to HAWTs. In addition, VAWTs are also easy to install [1]. VAWT has a simpler structure and installation than HAWT. VAWT generators are placed at the bottom of the central shaft on the ground so it does not require to be supported by the tower. Turbines are useful in different wind speeds and directions [2]. However, VAWTs have low pressure coefficients, so the scope for research, especially in VAWT rotors is still wide open which is intended to improve its performance. VAWT rotors have different types, such as Savonius, Darriues, and H-Darrieus rotor rotors [4]. Greenpeace predicted that wind power is able to reach nearly 2000 GW by 2030 that supplying 16.7% to 18.8% of global electricity, helping save over 3 billion tons of CO_2 emissions annually [5,6].

As a simplest turbine, Savonius wind turbine works due to the difference of forces exerted on each blade. The concave part to the wind direction caught the air wind and forces the blade to rotate around its central vertical shaft. Otherwise, the convex part hits the air wind and causes the blade to be deflected sideway around the shaft. The blades curvature has less drag force when moving against the wind or *Fconvex* than the blades moving with the wind or *concave* as seen in Fig. 3. Hence, concave blades with more drag force than the other half cylinder will force the rotor to rotate. [3].
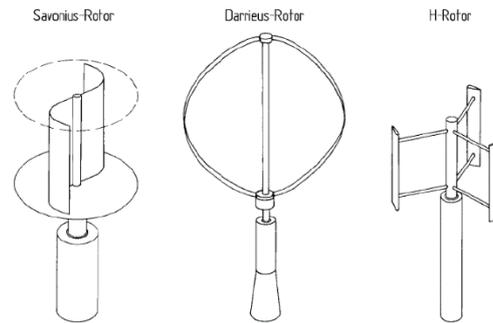
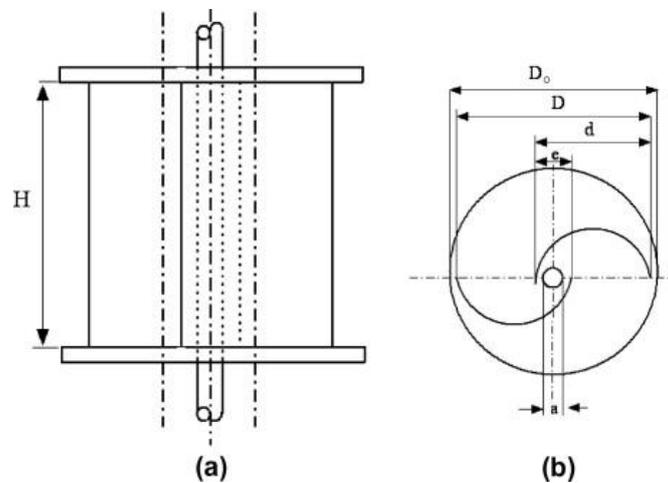**Figure 1.** Types of vertical axis wind turbines [6]

Figure2. Savonius wind rotor[4,7]: (a) Front view ; (b). Top view

As for the characteristics of the type of VAWT wind turbine has a variety of advantages [5]

1. Blade has a basic design that is simpler construction than other types of VAWT
2. Able to leverage the flow of the wind from all directions and thus no yaw mechanism construction as found on HAWT
3. The construction is simple and the manufacturing costs are also more affordable than HAWT
4. The treatment process easier because of the simple construction and the number of components that are above the soil surface
5. Being able to perform self start at relatively low wind velocitys
6. Able to produce higher torque from low wind velocity range to high wind velocitys.

2. Methodology

In this study, a VAWT was developed. Where the model of the wind turbine was built with overlap ratio (e : d) equal to 0.15; aspect ratio (D: h) equal to 1.0 and end plate parameter (D0 : D) equal to 1.1. The model of blades we described in Figure 3. In this figure, the diameter of the blade (d) = 200 mm, rotor height = 370 mm, and thickness of blades and end plates = 2 mm. [3,6]
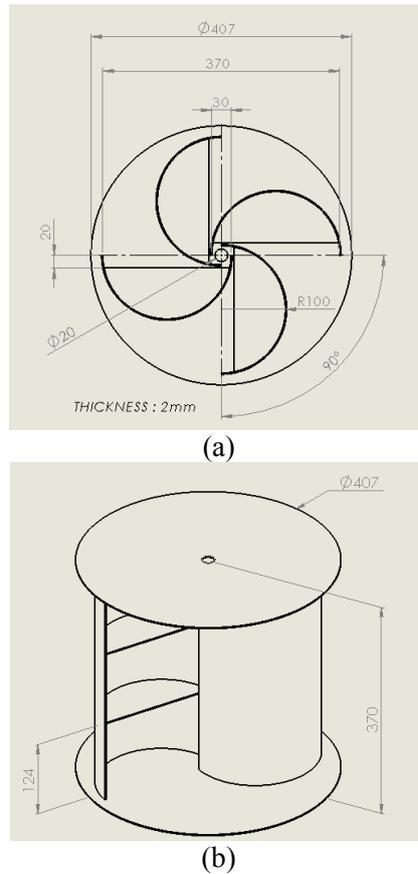
(a)

(b)

Figure 3. , Blade dimentions. (a)Top view, (b) cross section

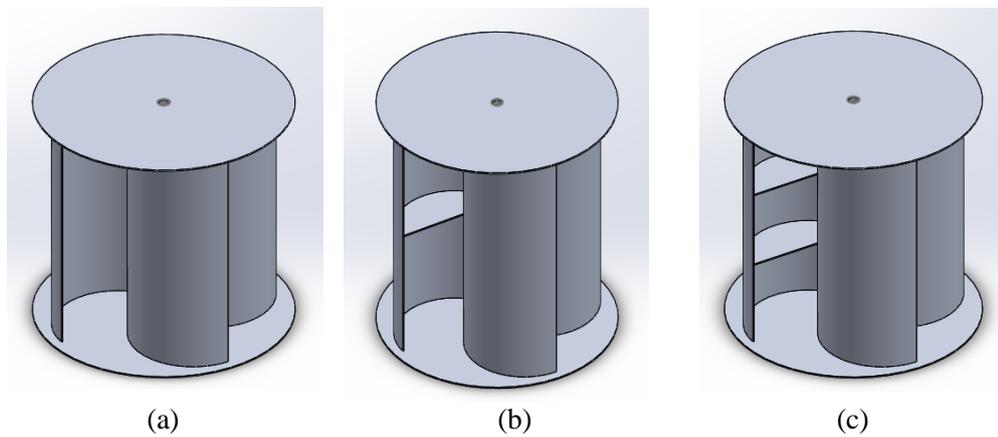(a)   (b)   (c)

Figure 4. Blade rotor U Type. (a) Blade without fin, (b) blade with 1 fin, (c) Blade with 2 fin .

The flowchart for running simulations using Solidworks software, The flow Simulations based on Finite Element Analysis (FEA) Method, as shown in figure 5. [9].
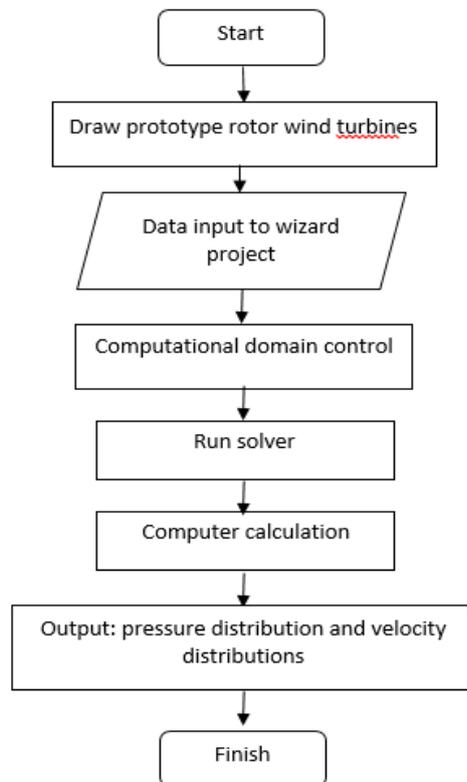
Figure 5. Flowchart Simulation

3. Result and Discussion

Results of simulations indicated the relationships between wind speeds 5 m / s and 7 m / s as well as the number of the fin was added to the blades. Fig.6, to fig.9, show the cut plot pressure distribution and velocity distribution.
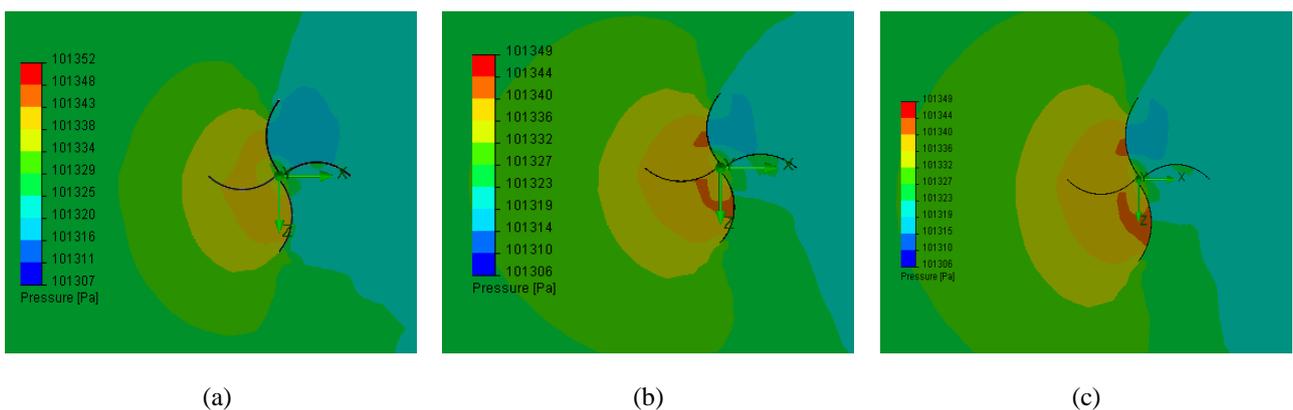

(a)   (b)   (c)

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Figure 6. Cut Plot Pressure at wind speed 5 m/s. (a) 0 Fin (b) 1 Fin (c) 2 Fin.

Figure **6** shows the cut plot pressure of the U-type blade with a wind speed of 5 m/s. In Figure 6 (a), can be seen that the pressure area for the U-blade without the fin, 0 fin where the largest Pressure is 101,343 Pa and the smallest Pressure is 101,311 Pa. Fig.6(b) for the U-type blade with 1 Fin, can be

seen that the largest Pressure is 101,344 Pa and the smallest Pressure is 101,310 Pa. Furthermore, figure 6(c) shows the U-type blade with 2 Fin where the largest Pressure is 101,344 Pa and the smallest Pressure is 101,310 Pa. The area of high pressure increases with the addition of fin, where Figure 6 (c) is the largest area with a Pressure 101,344 Pa.
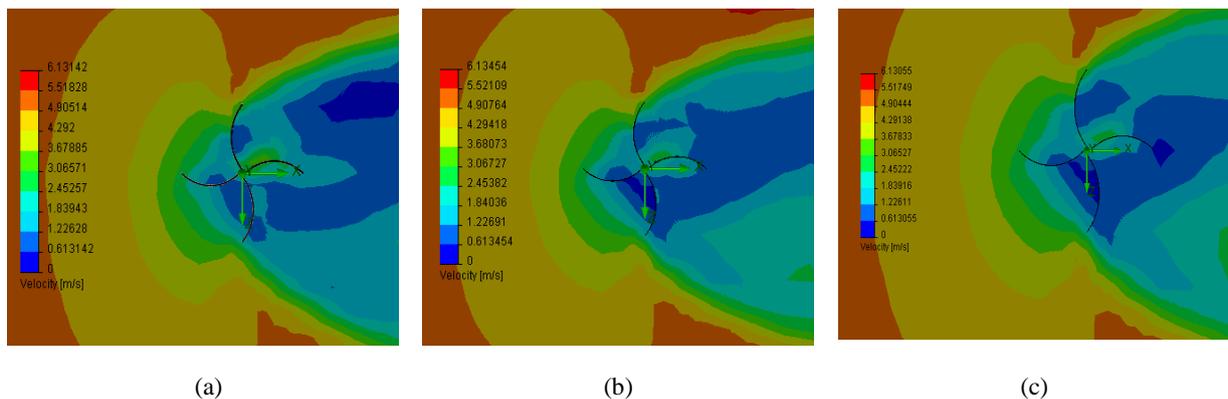

(a) (b) (c)

Figure 7. Cut Plot Velocity at wind speed 5 m/s. (a) 0 Fin (b) 1 Fin (c) 2 Fin.

Figure 7 shows the cut plot velocity of a U-type blade with a wind speed of 5 m/s. In Figure 7 (a), can be seen that the area of wind velocity for U-type blades without fin/ blade standard has the highest velocity of 1.839 m/s and the lowest velocity of 0.613 m/s. In figure 7 (b) which is the U-type blade with 1 fin, has the highest velocity of 1.840 m/s and the lowest velocity of 0 m/s. Furthermore, in figure 7 (c) which is a U-type blade with 2 fins has the highest velocity of 1,839 m/s and the lowest velocity of 0 m / s. The widest area velocity is 1,839 m/s.
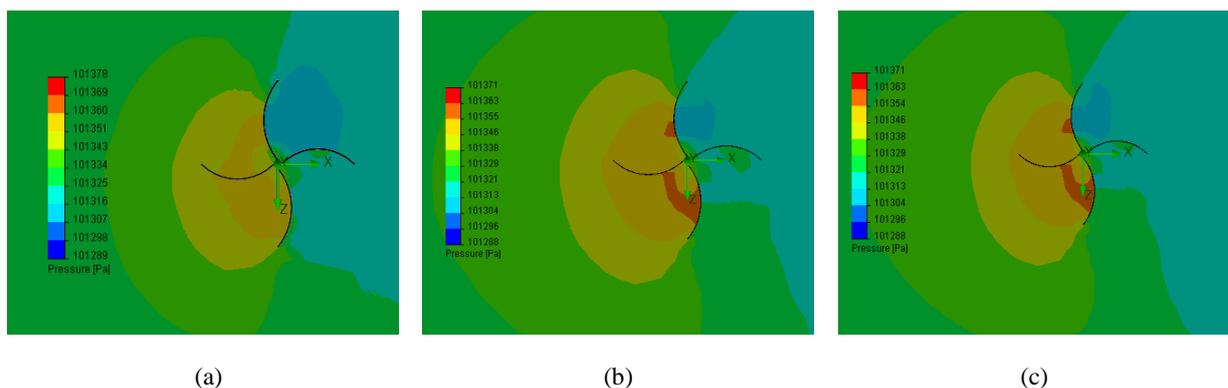

(a) (b) (c)

Figure 8. Cut Plot Pressure at wind speed 7 m/s . (a) 0 (without) Fin (b) 1 Fin (c) 2 Fin.

Figure 8 shows the cut plot pressure of the U-type blade with a wind speed of 7 m/s. In In Figure 8 (a), described the pressure area by a U-type with four of the blade without modification (standard blade) wherein the largest pressure is 101,360 Pa and the smallest Pressure is 101.298 Pa. In Figure. 8 (b), illustrated the pressure of the U-type blade with 1 fin where the largest Pressure is 101.363 Pa and the smallest Pressure is 101.298 Pa. In Figure. 8 (c), for the type U blade with 2 fins, can be seen the plot where the largest Pressure is 101,363 Pa and the smallest pressure is 101.298 Pa. The area of

pressure is increasing with the addition of the fin, in which for both Figure 8 (b) and Figure 8(c) have a pressure area equal to 101,363 Pa.
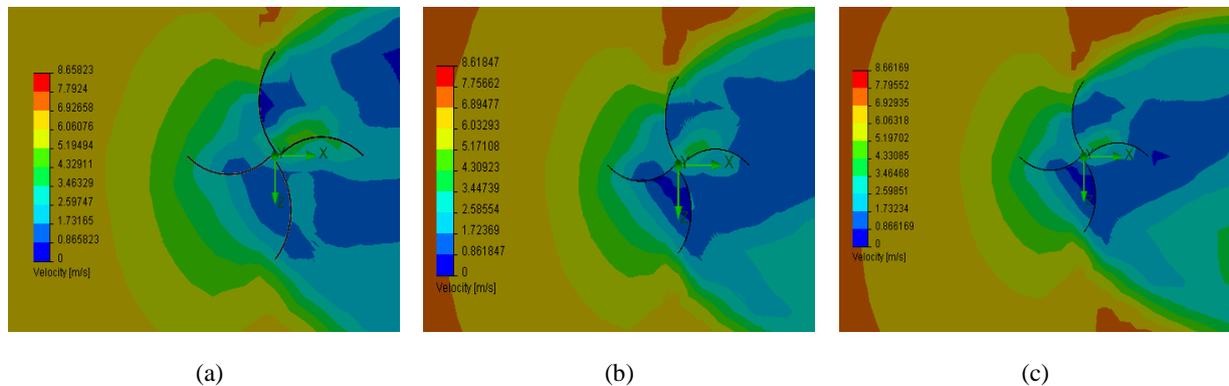

| (a) | (b) | (c) |

Figure 9. Cut Plot Velocity at wind speed 7 m/s . (a) 0 Fin (b) 1 Fin (c) 2 Fin.

Figure 9 shows the cut plot velocity of the U-type blade with a wind speed of 7 m / s. In figure 9 (a), displayed the area of wind velocity for U-type blades without fin where the highest velocity is 2.597 m/s and the lowest velocity is 0 m/s. Figure 9 (b) for the U-type blade with 1 fin produce the highest velocity of 2.585 m / s and the lowest velocity of 0 m / s. Furthermore, In Figure. 9 (c) which is a U-type blade with 2 fins, generate the highest velocity of 2.598 m/s and the lowest velocity of 0 m/s. The largest area with the largest velocity in Figure 9 (c) with the velocity of 2,598 m/s.

Table 1. Drag coefficient/drag force of the blade

Number Fin	F_D (N)	Wind speed (m/s)	C_D
0	2.775592686	5	0.001724402
1	4.138989592	5	0.002571444
2	4.146832679	5	0.002576317
0	5.408223959	7	0.001714278
1	8.122327823	7	0.002574585
2	8.136160157	7	0.002578969

Table 1. shows the value of the drag coefficient/drag force. From the table, can be seen the increase of the both with the addition of the fin. The addition of 2 fins give the higher drag coefficient and drag force compared to1 fin and without fin at the same wind speed. This is clearly visible for the wind speed of 5 m/s and 7 m/s.

4. Conclusion
Some conclusions on the simulations study in savonius type wind turbines are the following:

1. The fin number on the blade will influence the value of the pressure distributions and velocity distribution. Where two fins on the blade produced the higher pressure distribution and velocity distribution.
2. Drag coefficient was increasing with addition of fin. Where two fins produced the higher drag coefficient/drag force compared as blade 0 fin and blade 1 fin.
3. Pressure on the concave blades is higher than the convex blades.

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