Numerical Analysis of the Influence of Vertical Fin Addition to the Performance of Modified Bach type Vertical Axis Wind Turbine

Dominicus Danardono Dwi Prija Tjahjana, Satrio Tri Jayanto, Sukmaji Indro Cahyono, Bambang Pramujati

***Abstract*— The Savonius wind turbine is a vertical axis wind turbine that works well in relatively low wind speed. Unfortunately, the Savonius wind turbine has relatively low coefficient of power (C_p). Modified designs have been done and studied to increase the performance of the turbine. The purpose of this research is to study the influence of vertical fins addition to performance of the modified Bach type wind turbine. The research was done by 2 dimensional of computational fluid dynamics (CFD) modeling and Ansys Fluent commercial software was used to solve model. Original modified Bach type wind turbine was compared to the modified ones with the addition of one and two fins. The models were simulated on various tip speed ratio, to find out the C_p profile of the wind turbine. The result shows that the best C_p was obtained by adding a single fin to the turbine and compared to the original turbine it increases by 8.81%.**

***Index Terms*— Wind turbine, vertical axis, CFD, vertical fin.**

I. INTRODUCTION

Most of the wind energy generators in the world use horizontal axis wind turbines (HAWTs) type. The HAWTs have the ability of harvesting large amounts of wind energy and have high efficiency [1]. However, HAWT also have disadvantages, such as very noisy, difficult to design and build and need yaw mechanism to keep the rotor always facing the direction of the wind. On the contrary, vertical axis wind turbines (VAWTs) is able to operate omni directionally, means they do not need any yaw mechanism to operate. The design of most VAWTs are simple and easy to produce, that makes them ideal for small-scale application such as a standalone system in remote or urban areas.

Savonius wind turbine has very simple design. Aerodynamically, Savonius is drag type wind turbine that usually has two or three blades. Savonius wind turbine is suitable for small range to medium range of power generation [2]. The benefits of using Savonius wind turbines are, the starting torque is high; the range of operating wind speed is wide; easy to be manufactured and low production cost [3,4]. However, Savonius turbines have limitation because of its relatively low efficiency. Therefore, various efforts in previous study have been done to improve the design of Savonius turbines, which will enhance the turbines performance. From the previous studies there are suggestions of many different modification to obtain the optimal Savonius turbine [4].

The Savonius performance is influenced by geometry and number of the blades, blade spacing, blade overlap, guide vanes and other accessories. Therefore, many design modifications were done to increase the Savonius wind turbine performance. Such as, using obstacle to optimize the blade [5], changing slot position [6], using deflector [7], and using guide plates [8].

Studies also have been done on the blade geometry or shape to increase the performance [5,10,11]. A numerical study shows that a modified Bach type wind turbine with blade arc angle of 135° can obtain maximum coefficient of performance about 36% [9]. The same design also tested experimentally, and it could obtain maximum coefficient of performance about 30% [10]. Meanwhile, a new rotor configuration of Savonius also has been developed. The new rotor incorporates multiple quarter blades added to usual blade configuration [9]. As a result, there is an increase of performance coefficient from 8.89% to 13.69% for the new rotor over the conventional.

In this paper, a numerical study has been done to investigate the effect of vertical fin addition to the modified Bach type blade. An original modified Bach type wind turbine is compared to two type of modifications by adding vertical fins to two bladed modified Bach type. The performance of the turbines is predicted by carrying out dynamic simulations.

II. METHODOLOGY

To save the computational cost, 2-dimension (2D) dynamic simulations is carried out. The 2D models are able to yield the flow properties close to 3-dimensional, as long as the aspect ratio (H/D) of turbine is greater than or equal to unity [11]. In this study Ansys Fluent is used for the whole computation models.

The simulation models are made base on the numerical model in the previous study [12]. The velocity of inlet is set to 6.31 m/s for all models. The tip speed ratios set on the

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Dominicus Danardono Dwi Prija Tjahjana, Universitas Sebelas Maret, Indonesia. (danar1405@gmail.com)

Satrio Tri Jayanto, Universitas Sebelas Maret, Indonesia. (satriotrijayanto@gmail.com)

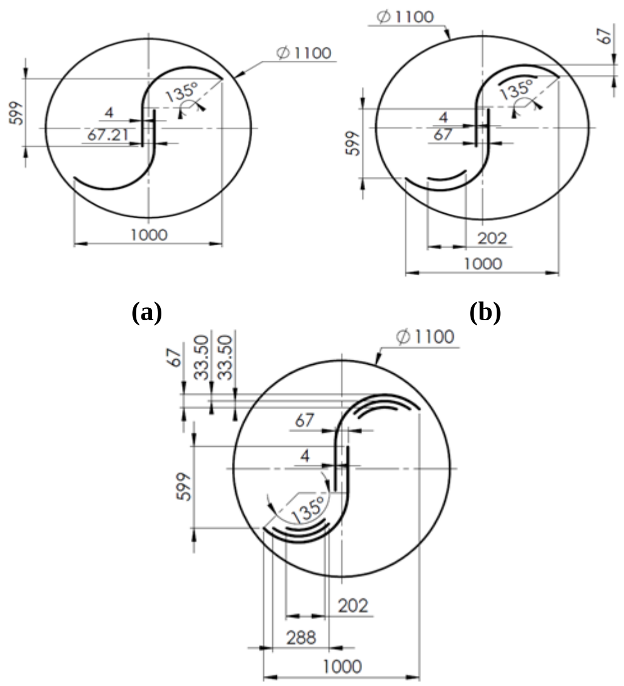
Sukmaji Indro Cahyono, Universitas Sebelas Maret, Indonesia. (sukmaji@ft.uns.ac.id)

Bambang Pramujati, Institut Teknologi Sepuluh Nopember, Indonesia. (pramujati@me.its.ac.id)

models are 0.4, 0.6, 0.8, 1.0 and 1.2. Due the low velocity, the density and temperature on the flow were considered constant and friction on the rotor shaft was negligible.

Turbine Description

There are 3 types of turbine that modeled. The turbine dimensions and configurations are shown in Fig. 1.



(c)

Figure 1. Dimensions and Configurations of the wind turbine (unit in mm), (a) Original modified Bach type, (b) A fin addition and (c) Two fins addition.

The computational domain is shown in Fig. 2 [12]. There are fixed region and rotating region that representing wind turbine, in the computational domain. The velocity inlet is taken for inlet boundary, and pressure outlet is taken for outlet boundary. Sliding mesh method is taken to run the dynamic simulation. The realizable k-ε turbulence model is selected for the simulations. The k-ε turbulence model is chosen because it shows very good result for flows that involve rotation, separation and recirculation. It also superior in capturing mean flow of the complex structures.

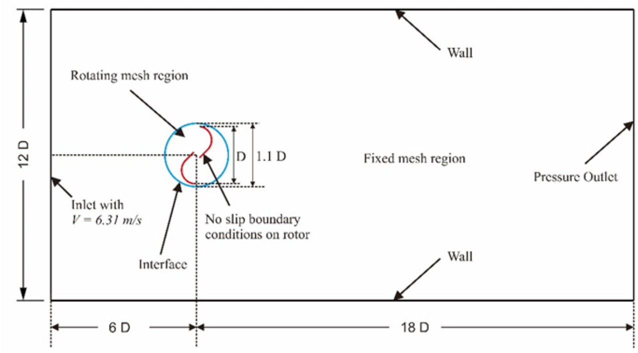


Figure 2. Computational domain and boundary conditions of the model.

Coefficient of Performance

The ratio of rotor tip speed and incoming wind speed is expressed as tip speed ratio (TSR). The TSR is defined as follows:

$$TSR = \lambda = \frac{\text{rotor blade tip speed}}{\text{incoming wind speed}} = \frac{\omega D}{2v} \quad (1)$$

The Savonius wind turbines performance are described by using two indicators, torque coefficient (C_m) and coefficient of power (C_p). C_p is useful for evaluating the performance of Savonius turbines. Therefore, the modifications of wind turbine aim to increase C_p of the turbine. The C_m and C_p of wind turbine can be obtained as follows:

$$C_m = \frac{M}{0{,}25\rho\, v^2\, D^2\, H} \quad (2)$$

$$C_p = \frac{P}{0{,}5\rho\, v^3\, DH} = \frac{M\omega}{0{,}5\rho\, v^3\, DH} = C_m.\lambda \quad (3)$$

Where torque acting on wind turbine is M, turbine power output is P, ρ is the air density and D is the turbine diameter. The height H is equal to 1, because only 2-dimensional simulation were performed.

Validation

In this study, the computation models are validated by modeling result in the previous study [12]. The modeling torque coefficient (C_m) of the modified Bach type without fin addition is compared with the reference, on TSR of 0.4, 0.6, 0.8, 1.0, and 1.2. The results is depicted in Fig. 3. The present study result shows a good agreement with the result of the previous study.

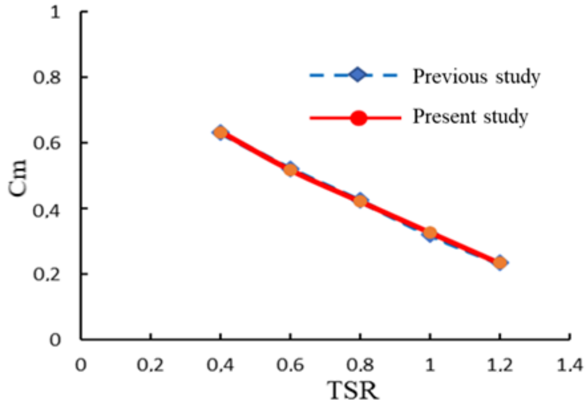


Figure 3. Comparison of C_m between previous and present study.

III. RESULTS AND DISCUSSION

The modeling results of the wind turbine with various rotor model are shown in Fig. 4 and Fig. 5. The results show that at low TSR (below 0.6), all turbines have the same C_m and C_p. However, at TSR above 0.6, the modified Bach turbines with fin addition show higher C_m and C_p. At TSR 1.2, the three turbines show, again, similar performance.

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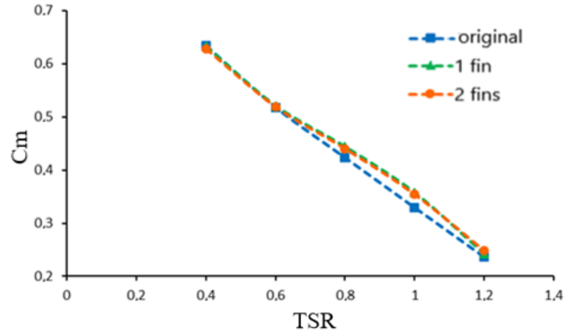

Figure 4. The Cm vs TSR of the turbines with various rotor model

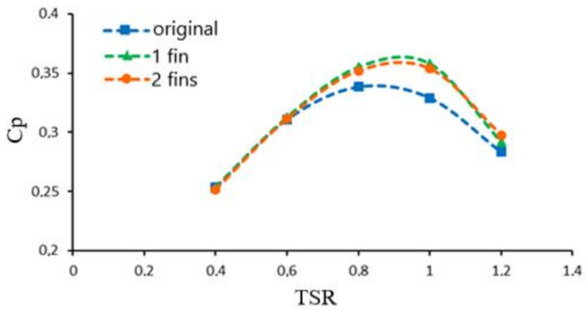

Figure 5. The Cp vs TSR of the turbines with various rotor model

The highest performance is achieved by the 1 fin addition turbine. The maximum C_p achieved by 1 fin addition turbine is about 0.358. Comparing to the original modified Bach type, C_p increases by 8.81%. Similar results have been achieved by previous study of the multiple quarter blades addition on the semicircular type of Savonius wind turbine [9].

Visualization of the velocity contour on the wind turbines is depicted in Fig. 6. The turbines with fin addition show that the air velocity near the blade (red circled) is higher than turbine without fin addition. Higher air velocity increases the flow kinetic energy and then converted into mechanical energy by the returning blade.

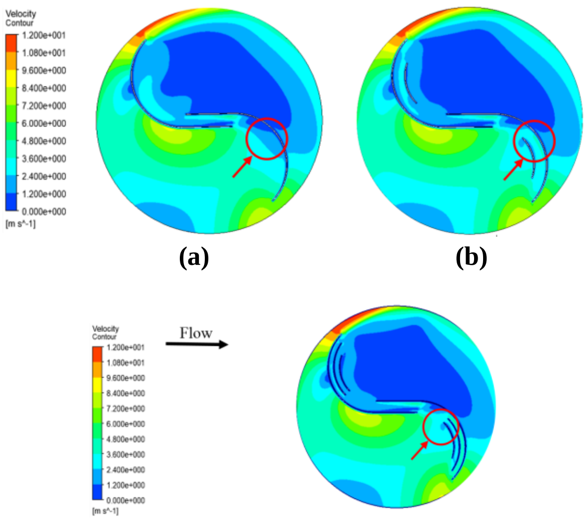

Figure 6. Velocity contour of the wind turbine, (a) without fin, (b) 1 fin and (c) 2 fins.

CONCLUSION

A 2D computational study has been done out to investigate the effects of fin addition to the performance of modified Bach type VAWT. Three types or turbine, without fin addition, 1 fin addition and 2 fins addition, have been compared. The result shows that turbines with fin addition have better performance than without fin addition in the TSR range of 0.6 to 1.2. The highest performance is achieved by 1 fin addition wind turbine, with maximum Cp of 0.358 at TSR of 1.0. Compared to the original turbine it increases by 8.81%.

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