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Numerical study on the effect of width of single curtain on the performance of Savonius wind turbine

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Abstract. This is a preliminary results of the flow around the Savonius wind turbine with installing curtain plate in front of the returning blade turbine. It was investigated numerically in a uniform flow at Reynolds number of 30,000 and 90,000. The velocity vector and pressure distribution around the turbine were simulate by varying the width of curtain plate relative to the diameter of rotor blade (S/D) of = 1.00, 1.02, 1.03, 1.15, 1.41, and 2.00, using STAR CCM++ Software. The k-ε realizable as turbulence model was used to visualize the flow phenomena occurred around the turbine, and where in this simulation, the rotor turbine was set static. The results show that it seems the width of the curtain installed in front of the returning blade of the turbine plays an important role in the performance of the turbine. In general, the installing of the curtain in front of the returning blade of the turbine is more effective to improve the turbine performance. This is not necessarily, but depends on the width of the curtain and the number of Reynolds (Re). For the width of the large curtain of S/D = 2 at Re = 90,000, the performance of the turbine is estimated lower than when the turbine without the curtain.

1 Introduction

Wind energy is a freely available natural resource that is abundant and available over the years. But unfortunately the wind speed in Indonesia is relatively low, which is about 4-7 m/s. The appropriate turbine for the low wind speed is the Savonius turbine. This turbine is a vertical pivot turbine type, Vertical Axis wind Turbine (VAWT). The Savonius turbine is one example of a drag type turbine. The phenomenon of flow across the Savonius turbine is the use of drag force to improve the performance of the turbine. The flow will cross the 2 (two) side of the advancing blade and the returning blade of the tubine. The difference of drag force between the returning blade and the advancing blade will result in a total drag to rotate the Savonius turbine, and finally to generate power to drive the generator producing an electrical energy. The advantages of this type of drag turbine are the self-starting ability with a small fluid velocity, so there is no need for external push support; it is very suitable for the region of Indonesia which has a relatively the low average speed.

However, this type of the wind turbine has the lowest performance compared to others types of the wind turbine. That is why various studies have been done to improve the performance of the turbine Savonius. Among others, by varying the number of bucket, the authors [1] concluded that the two-bucket configurations have better aerodynamic performance than the three-bucket configurations. The Authors [2] has conducted research on optimizing the design of Vertical Axis Wind Turbine (VAWT) Darrius-Savonius type. One is done to get a VAWT design that has a strong structure is by varying the length of the shaft top-side and bottom-side support. The authors [3] conducted a study on the Savonius turbine, by varying the overlapping ratio of 0, 0.1 and 0.2. They have observed that for varied wind speed the maximum torque has obtained at the overlap ratio of 0.2. The authors [4] studied experimentally on improvement of a Savonius rotor performance with curtaining. They used two curtain blades, composed of flat sheet plates, to directing the wind toward the advancing blade where one curtain placed in front of returning blade and one others positioned beside of advancing blade. They have proved that the arrangement of Savonius wind rotor with three different curtains have the power coefficient higher than one without curtain. The authors [5] conducted a study on the use Savonius turbine deflector on the front side of the advancing blade sideways, where the configuration can improve turbine performance. The phenomenon of flow across the advancing blade in the form of drag force will be increased by using two deflectors.

Based on the previous study, there is no research about the size of curtain plate, concerning its influence on the performance of Savonius turbine. So, it is interesting to study numerically the effect of width of single curtain, where the curtain in varied width is installed in the front of the returning blade, to improve the performance of Savonius turbine.

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2 Numerical Study

2.1 Simulation Method

STAR CCM++ Software has used to simulate the flow characteristics around the Savonius turbine. The k-ε realizable as turbulence model was used to visualize the flow phenomena occurred around the rotor turbine. In this simulation, the rotor turbine was set static or not moving. This simulations is performed at Reynolds number (Re) of 30,000 and 90,000 based on the characteristic length of d = 2D-b and free stream velocity (U). There are 7 sizes of curtain plate were tested in this simulation, such as for the width of curtain plate relative to the diameter of rotor blade (S/D) of = 1.00, 1.02, 1.03, 1.15, 1.41, and 2.00. Figure 1 shows the scheme of modeling domain of the present study. As boundary conditions of the problem, it has been set at the inlet of the domain is velocity inlet of U = 2,48 m/s for Re = 30,000 and U = 7.45 m/s for Re = 90,000, at the outlet is pressure outlet, and the symmetry plane (walls) at the upper and lower side of the domain.

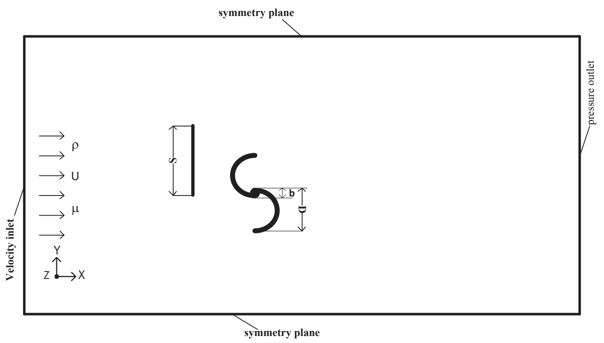
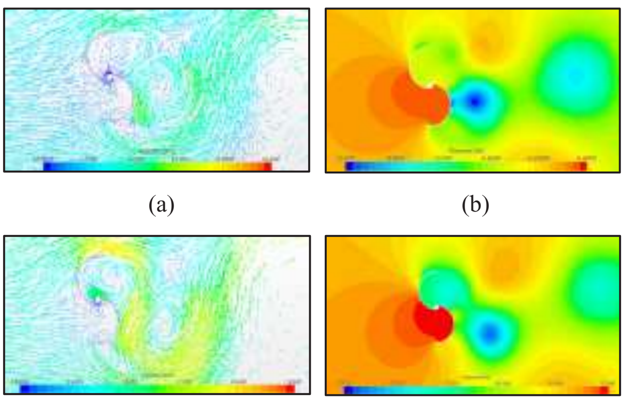


Fig 1. Scheme of the modeling domain.

2.2 Results and Discussions

Figure 2 shows the results of the simulation for flow arround the Savonius rotor turbine without curtain, for Re = 30,000 (figure 2a and 2b) and Re = 90,000 (figure 2c and 2d), where in this simulation the rotor turbine was set static or not moving.



(a) (b)

(c) (d)

Fig 2. Flow around the Savonius rotor turbine without curtain, for Re = 30,000: (a) velocity vector, (b) pressure countur, and for Re = 90,000: (c) velocity vector and (d) pressure countur

Figure 2 shows that there is generally a different pressure between the pressure in front of the returning blade and the rear, where the pressure in the front of the returning blade higher than the rear, and this is also the same case for the flow around advancing blade. It causes the pressure drag in the front side is higher than the rear side. It seems clearly enough that the pressure drag acting on the advancing blade is higher than on the returning blade. It results a positive static torque and will cause the rotor turbine turning in counter clockwise. When compared between the flow with Re = 30,000 and 90,000, it seems that the rotor turbine being flowed with Re = 90,000 will have a static torque higher than with Re = 30,000. It is clearly indicated by the pressure in the rear of the advancing blade for Re = 30,000 (blue colour, figure 2d) lower than for Re = 90,000 (green colour, figure 2b). So, the negative torque on the returning blade for Re = 30,000 higher than the one for Re = 90,000.

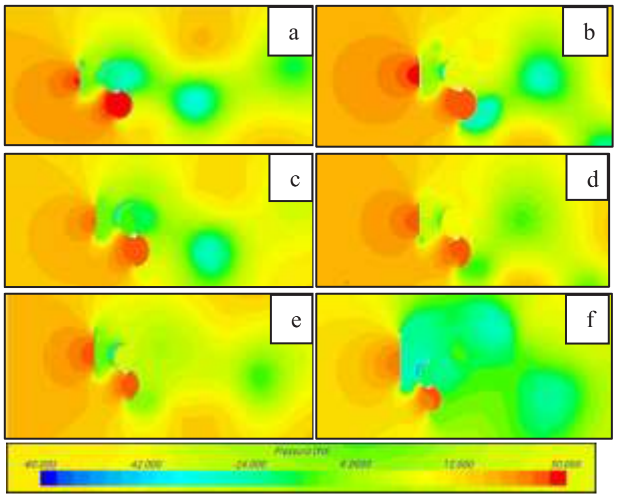


Fig 3. Pressure countur flow around the Savonius rotor turbine with curtain, for Re = 30,000: (a) S/D = 1,00, (b) S/D = 1.02, (c) S/D = 1.03, (d) S/D = 1.15, (e). 1.41 and (f) S/D = 2.00

Figure 3 shows the results of the simulation for flow arround the Savonius rotor turbine with curtain varied of S/D = 1,00; 1.02, 1.03, 1.15, 1.41 and 2.00, for Re = 30,000. As seen in the figure that due to the installing of curtain plate in front of returning blade rotor, the pressure in the rear of curtain plate or in front of returning blade area is decrease, meanwhile the pressure in the front of advacing blade is relatively not changing compared to the Savonius rotor turbine without curtain (see figure 2b). It causes the pressure drag acting on the returning blade decreased and as result the positive static torque increased. So, the installation of curtain plate in front of returning blade of the Savonius turbine can be expected to increase the performance of turbine.

Figure 4 shows the results of the simulation for flow arround the Savonius rotor turbine with curtain varied of S/D = 1,00; 1.02, 1.03, 1.15, 1.41 and 2.00, for Re = 90,000. Except for S/D = 2, for Re = 90,000 the phenomenon of the flow around the turbine rotor is almost exactly as for Re = 30,000.

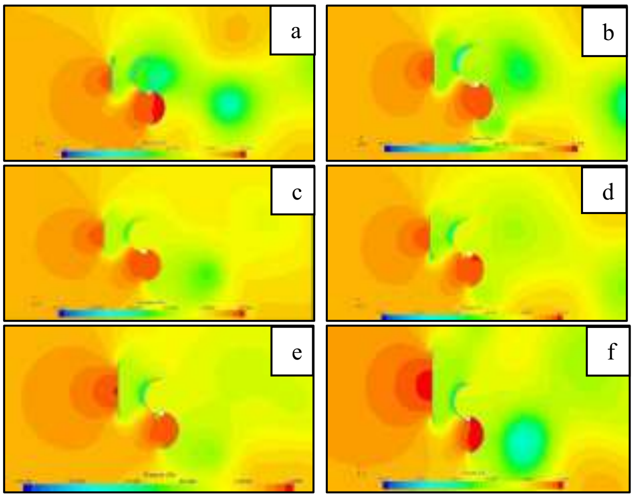


Fig 4. Pressure countur flow around the Savonius rotor turbine with curtain, for Re = 90,000: (a) S/D = 1,00, (b) S/D = 1.02, (c) S/D = 1.03, (d) S/D = 1.15, (e). 1.41 and (f) S/D = 2.00

For SD = 2, the curtain plate installing in front of the returning blade is predicted to decrease turbine performance. It is seemly due to the region with lower pressure in front of returning blade is larger than the one for S/D < 2, it causes the flow tends to pass in this region instead of push the advancing blade to produce the positive torque. As a result a decrease in turbine peformance was obtained. It is clearly indicated by the velocity vector around the turbine with the curtain (figure 5), when compared to the velocity vector around the turbine without the curtain (figure 1c). So, the installing of curtain plate which the size of S/D = 2 in front of returning blade of the Savonius turbine for Re = 90,000 is not efective to increase turbine performance. It is as well as ensures that the size of the curtain width, placing in front of the blades, has an important role in affecting the performance of the turbine. But this is required a justification, either through simulation with the turbine rotor in a rotating state, or by an experimental study.

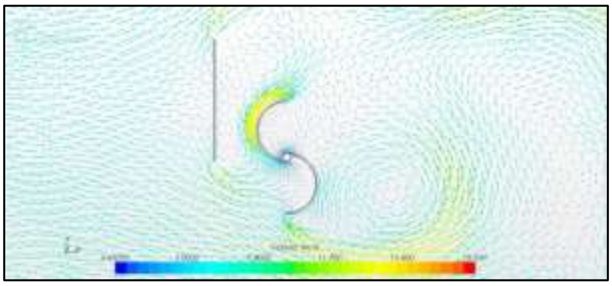


Fig 5. Velocity vector around the Savonius rotor turbine with the curtain of S/D = 2.0 for Re = 90,000.

2.3 Conclusions

The size of a single curtain installed in front of the returning blade of the Savonius wind turbine plays an important role in the performance of the turbine rotor. In general, the installing of the curtain in front of the returning blade of the Savonius wind turbine is more effective for improving turbine performance. This is not necessarily, but depends on the width of the curtain and the number of Reynolds (Re). For the width of the large curtain (S/D = 2) at Re = 90,000, the performance of the Savonius turbine is estimated lower than when the turbine is without the curtain. This is required a justification, either through a simulation with the turbine rotor in a rotating state, or an experimental study.

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