NUMERICAL STUDY OF SAVONIUS WATER TURBINE PERFORMANCE BY ADDING DEFLECTOR TO ADVANCING BLADE SIDE

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ABSTRACT

As one of the best renewable energy sources, hydropower becomes more predictable source compared to wind energy and Savonius which its performance does not contingent to fluid flow direction. In this present, computational Fluid Dynamics acomplished by Finite Volume Method and unsteady RANS equation were applied to analyze the numerical simulation. The present study investigated the performance of Savonius Turbine by adding deflector plate installed to advancing blade side at 5, 10, 15, 30 and 45 of deflector angles in the direction of the fluid flow. The viscous turbulence model used realizable k-epsilon (RKE) and its descritization used second order upwind. The type of mesh was made from coarse to fine meshing with 8 (eight) types of meshing and the grid independency of the numerical simulation had been validated by the publish experimental data at TSR of 1,078. Grid independency occured at meshing G with the error lower than 5 % compared to published experimental data. The result of this study shows that the performance of Savonius turbine increased by adding deflector in advancing blade side with the maximum torque and power coefficient at 30 of deflector angle.

Keywords: Computational Fluid Dynamics, Savonius turbine, Deflector angle, RKE

INTRODUCTION

Types of turbine are generally divided into two, vertical axis turbines (VATs) and horizontal axis turbines (HATs), based on the alignment of shaft between their axis of rotation and water direction. VATs are used to generate small scale power because the turbine performance does not depend on the fluid flow direction (Yang B et al, 2011). Type of VATs generates torque through combining drag effects and side forces. Energy of hydro from river, sea current, waves are the best renewable energy sources and very predictable compared to wind energy or the other. The application of vertical axis turbine is generally Savonius turbine, helical turbine and Darrieus turbine (Golecha et al, 2012).

An experimental investigation on the performance of the improvement of the modified Savonius rotor by providing a deflector plate on returning blade side ~~is~~ was carried out by Golecha et al. in 2011. Position of the deflector plate was identified in their study for giving the maximum coefficient of power. The result~~s~~ showed that the deflector plate could increase the power coefficient by 50% for a single stage modified Savonius rotor at optimal position. Maximum power coefficient improved by 42%, 31%, and 17% with deflector plate for two stages 0 phase shift, 90 phase shift, and three stage modified Savonius rotor. The next experimental research from Golecha et al (2012) ~~is~~ was carried out to investigate the performance of Savonius water turbine using two deflectors placed on advancing blade side and in front of the returning blade.

The method used was experimentally on single stage by modifying Savonius rotor in an open water channel at a Reynolds number of 1.32 x 10^5, based on the diameter of the rotor. The maximum power coefficient of single stage of modified Savonius rotor was 0.14 at a tip speed ratio of 0.7 without adding deflector plate. Placing the deflector plate on the returning blade side could improve the power coefficient of the modified Savonius rotor to 0.21 at a tip speed ratio of 0.82. The two deflectors placed at two positions could increase the performance of Savonius turbine. Flow phenomenon through the advancing blade, increased the drag force, using two deflectors. The flow on returning blade was decreased by deflector placed in front of the returning blade. However the difference drag between advancing blade and returning blade produced maximum torque at Savonius rotor. (Golecha et al, 2012).

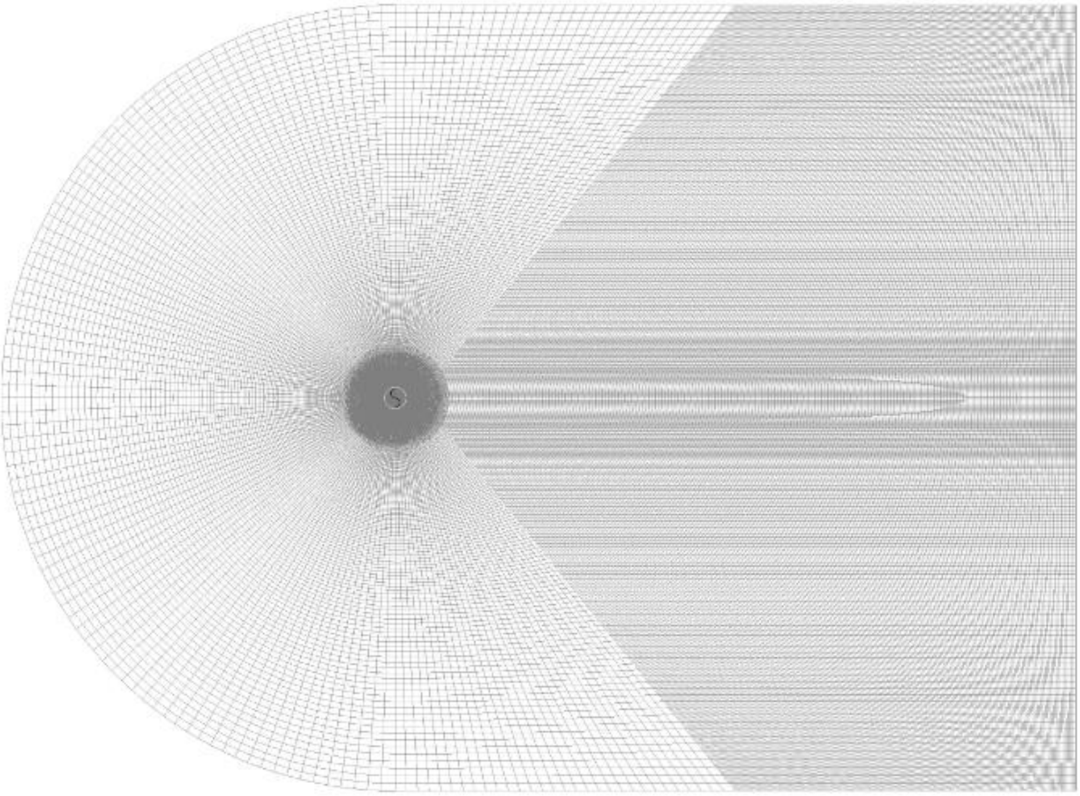
Savonius turbine performance was observed by changing the velocity which obtained maximum torque coefficient at overlap ratio (e) 0.2 (Patel et al, 2013). The same research was done towards Savonius turbine using deflector in front of turbine of returning blade and beside of advancing blade. Developing of Vertical Axis Marine Current Turbine (VAMCT) had been carried out by investigation on low current condition. The experimental method had been carried out at range of overlap ratio 0.2-0.25 and the result of best performance occured at overlap ratio 0.21 (Yaakob et al, 2013).

This numerical simulation has been conducted to avoid uncertainty, however it produced some numerical simulation policies. The policy is very important to improve the result of numerical as discretization second order upwind and compare the numerical towards experimental data (Freitas et al, 1999). The comparison of 2-D simulation and 3-D simulation has shown great approach of experiment's result. The result of 2-D simulation has coefficient power which was closer to experiment than 3-D simulation (Hyun et al, 2012). The Spalart-Allmaras (SA) turbulence viscosity model is a one-equation turbulence model which is near with wall gradients of the transported variable, is much smaller than the turbulent kinetic energy equation based k-ε models (Spallart et al, 1992). The standard k-ε model (Launder Spalding et al, 1972) is more suitable when flow is fully turbulent and has given better result~~s~~ than SA model for turbine analysis (Pope, 2010). Previous studies for Savonius turbine have shown that two dimensional simulations gave acceptable results. (Yang et al, 2011 , Tian et al, 2014 and Mc. Tavish et al, 2012).

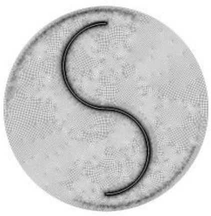
In this present study, The deflector directed the fluids flow to increase flow velocity over Savonius turbine and applied the deflector to Savonius turbine with the function to add positive torque to advancing blade side. The deflector plate affected on the turbine performance and it obtained the performance of Savonius turbine as function of torque coefficient and power coefficient. The numerical simulation in this study analyzed the unsteady flow around the Savonius turbine by changing deflector angle placed in advancing blade side.

NUMERICAL SIMULATION

The present study used numerical simulation with Savonius turbine as model. Savonius model has two blades with 1 (one) meter of the diametre Savonius turbine. Unsteady incompressible Reynolds-Averaged Navier-Stokes (RANS) equation was used based on the cell-centered finite volume method and ~~has~~ implemented the rotation by using the sliding mesh technique to rotate the space of turbine area. The structured grid was employed to all the grid system of rotor and the computational domain reached to 5D in the inlet direction, 10D in the outlet direction and 10D in the vertical direction, where D denoted the diametre of Savonius turbine. The calculations were made based on the 2-dimensional unsteady flow assumption for its relative simplicity. The mesh characteristics of numerical simulation is shown in Figure 1.



a)



b)

Figure 1. Mesh characteristics of the (a) fixed domain, (b) rotating domain

Grid Independency investigated the changing size grid from coarse to fine. The objective of grid independency was to determine the meshing of simulation that the numerical simulation did not influence the result of simulation. The grid independency was obtained by using Blackwell experimental data without deflector or conventional Savonius rotor. It was installed in front of the returning blade without overlap ratio. The value of torque coefficient (Cm) referred to Blackwell experimental data at a tip speed ratio (TSR) of 1.078 with value of Torque Coefficient (Cm) was 0.185, 7 m/s of free stream velocity, and diameter of Savonius turbine was 1 (one) m with angular velocity of 144.087 rpm. The grid independency was carried out 8 (eight) times from coarse meshing to fine meshing. The result of grid independency is shown in Figure.2. Grid independency occured at Meshing type of G, which the simulation did not influence numerical simulation result.

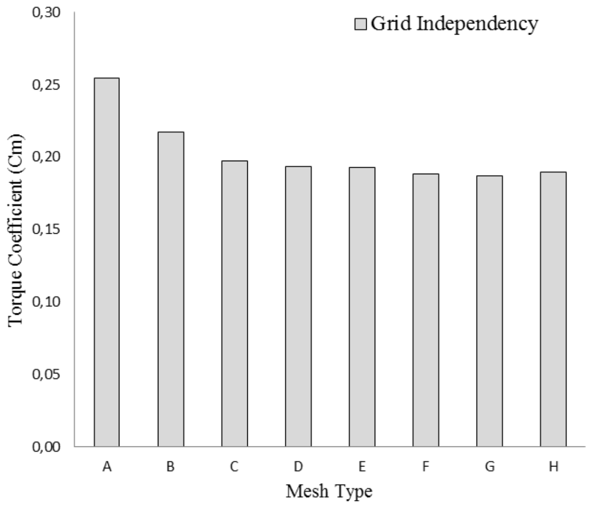


Figure 2. Study of grid-independency for the torque coefficient

The validation of Numerical Simulation was carried out by comparing publish experimental results with the air fluid for one stage conventional Savonius turbine by Blackwell as shown in Figure 3. The numerical taken from experimental data at free stream velocity kept constant in about 7 m/s, 1 m rotor of diameter, and 0.3, 0.5, 0.7, 0.9, 1.1 and 1.3 of varying TSR. In this present study, graphics of numerical simulation are similar to graphic of Blackwell experimental data, without overlap ratio for all tip speed ratio (TSR) which was employed to analyze the configuration of Savonius turbine. Figure.3 shows that the numerical simulation result is in very good agreement with the publishing experimental data when the turbulence model used Realizable k-epsilon. TSR equals to U/V, where U is defined as tip peripheral velocity of the rotor equal to ω R. ω is defined as the velocity angular of blade, R is defined as the radius of rotor, and V is defined as the free stream velocity that kept constant in about 7 m/s. The maximum error occured at a tip speed ratio (TSR) of 0.55 to 0.65, where the numerical simulation result was about 5% lower than Blackwell experimental data.

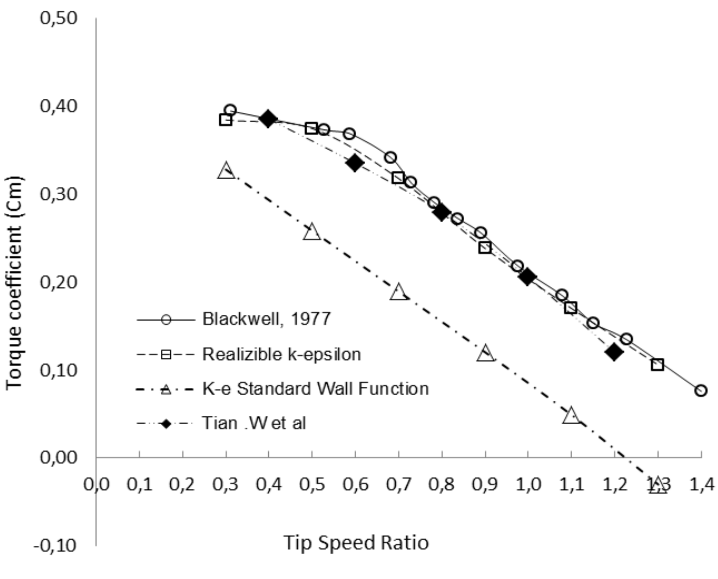


Figure 3. Tip speed ratio (TSR) as the function of Torque Coefficient (Cm)

RESULTS AND DISCUSSION

In this present study, The result of grid independency was obtained by changing properties of fluids from air to water fluids at free stream velocity kept constant in about 0.22 m/s, 0.4 m rotor of diameter, 1 of X/D, 1 of Y/D and 0.3, 0.5, 0.7, 0.9, 1.1 and 1.3 of varying TSR. The geometry of this study used deflector to advancing blade side as shown in figure 4.

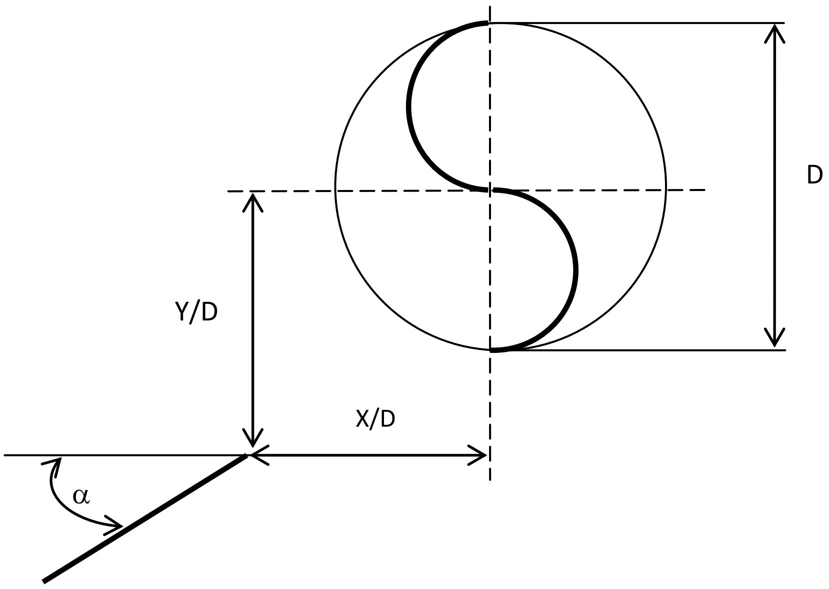


Figure 4. The geometry of Savonius turbine with deflector

The result of numerical simulation was the Tip speed ratio (TSR) as function of torque coefficient as shown in figure 5. The value of torque coefficient increased with the increasing of deflector angle at 30 degree. Meanwhile, the value of torque coefficient decreased with the increasing of deflector angle at 45 degree.

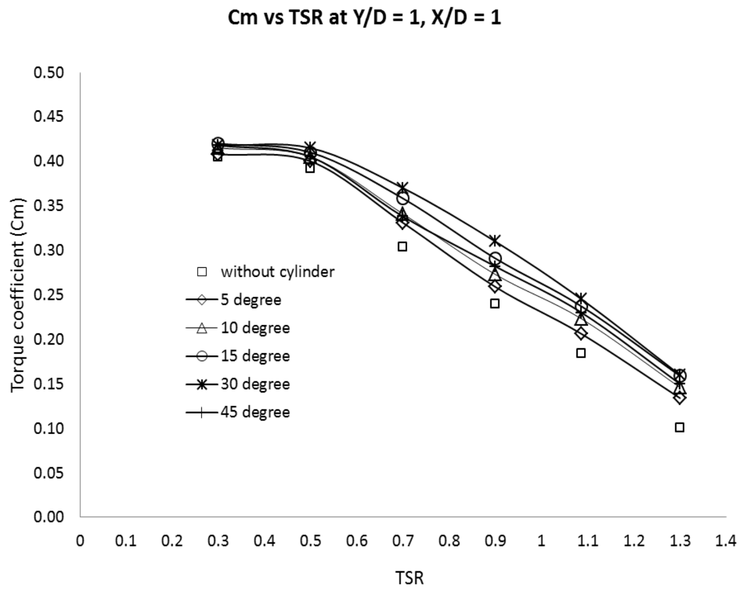


Figure 5. Tip speed ratio (TSR) as the function of Torque Coefficient(Cm)

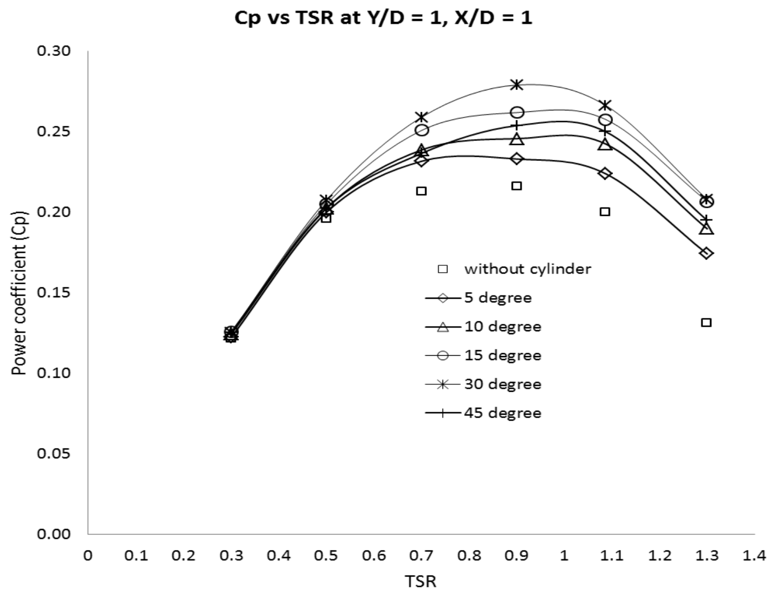


Figure 6. Tip speed ratio (TSR) as the function of Power Coefficient (Cm)

The result of numerical simulation as shown in figure 6 is Tip speed ratio (TSR) as function of power coefficient (Cp). The value of power coefficient increased with the increasing of deflector angle at 30 degree. On the other hand, the value of power coefficient decreased with the increasing of deflector angle at 45 degree. The maximum power occurred at 30 of deflector angle.

CONCLUSION

Adding deflector to advancing blade side contributed great effect to the performance of Savonius turbine. From the result of above discussion, it shows that Savonius rotor which was modified by adding deflector to advancing blade side at X/D = 1 and Y/D = 1 influenced the torque coefficient and the power coefficient. A numerical investigation was conducted on a single stage Savonius rotor using sliding mesh at free stream velocity 0.22 m/s. The result indicated that there were changes to the flow characteristic. Obviously, by adding deflector in advancing blade side would influence the flow characteristic over the Savonius turbine and improved the torque coefficient and power coefficient at 30 of deflector angle. The present study also shows that the use of plate deflector to advancing blade side could increase the performance of Savonius turbine. Deflector angle increased the torque coefficient and maximum torque coefficient occurred at 30 of deflector angle.

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