A numerical study of the effect of a single cylinder and plate deflector toward the Savonius wind turbine performance

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Abstract. This study has investigated the effect of the circular cylinder placed at the side of advancing and plate deflector placed in front of returning blade. The CFD approach is done to solve the incompressible URANS. The numerical validation is done by comparing the experimental results using torque coefficient data for Cm=0.185 and TSR=1.078. The turbine using conventional Savonius 1 m of diameter and 1 m of height. A circular cylinder have diameter of 0.7D placed at x/D = 0.5D and y/D = 0.7D. The plate deflector is placed at 1D in front and center of turbine by varying the deflector plate on perpendicular free stream in placed in front of returning at distance variations (y/D) of 0, 0.1, 0.2, 0.3 and 0.4 with deflector angle of 30 degree towards the free stream direction and the Reynolds number of 4.32×10^5. The study indicates that the deflector and circular cylinder can increase the turbine Performance at y/D of 0.3 in about 9.71 %.

1. Introduction

The turbine are clasified become two types, namely vertical axis and horizontal axis. An experiment for Savonius is done in wind tunnel at 7 m/s and 14 m/s with Reynolds of 4.32×10^5 and 8.67×10^5, respectively. The best performance occurred at overlap ratio 0.1 – 0.15 and bucket number 3 [1]. Patel et al also have employed study about overlap ratio by the best results obtained at overlap ratio 0.2 [2]. Freitas et al has been conducted study about uncertainty numerical by changing of the turbulence model [3]. The realizable k-ε turbulence model is used in the simulation [4]. The circular cylinder has been done the previous author [5], [6], [7], [8]. The results show that the best at ds/D=0.7 by placing cylinder at the side of advancing [5]. Various diameter have been done numerically in front of advancing and the best performance at ds/D=0.5 for stagger angle 60^o [6]. The turbine performance is also carried out by using the change of the horizontal distance at the side of advancing and varying x/D of 0, 0.5, 1.0, 1.5, and 2. The best result has obtained at x/D=0.5 [7]. In addition, the turbine performance has investigated by placing cylinder in front of returning with stagger angle variations 0^o, 30^o, 60^o and 90^o. The best performance has been reached at stagger angle 60^o [8].

The investigation of the performance analysis is done to determine the value of coefficient of torque, coefficient of power and improvement of performance. The power coefficient is called the performance of turbine. The numerical has used Gambit 2.2.30 software and ANSYS software. Firstly, the

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verification and validation will be performed by comparing experimental data from Sheldahl et al. [3] with grid variations, and then a circular cylinder is installed at the side of advancing. In addition, deflector will installed in front of returning at y/D of 0, 0.1, 0.2, 0.3 and 0.4. Finally, computational Fluid dynamics (CFD) will get the coefficient of torque, coefficient of performance and improvement of turbine performance.

2. Methodology

2.1. Equations and mathematics

The calculation of TSR, torque coefficient, and power coefficient are based on the equation below for turbine. The rotation of turbine rotor is shown in Figure 1.

$$\mathrm{TSR} = \frac{\omega . \mathrm{D}}{2 . \mathrm{U}} \tag{1}$$

$$\mathrm{C_m} = \frac{\mathrm{T}}{\frac{1}{4}\rho \mathrm{A_s} \mathrm{D} \mathrm{U}^2} \tag{2}$$

$$\mathrm{C_p} = \frac{\mathrm{P}}{\frac{1}{2}\rho \mathrm{A_s} \mathrm{U}^3} \tag{3}$$

$$C_p = TSR \; C_m \tag{4}$$

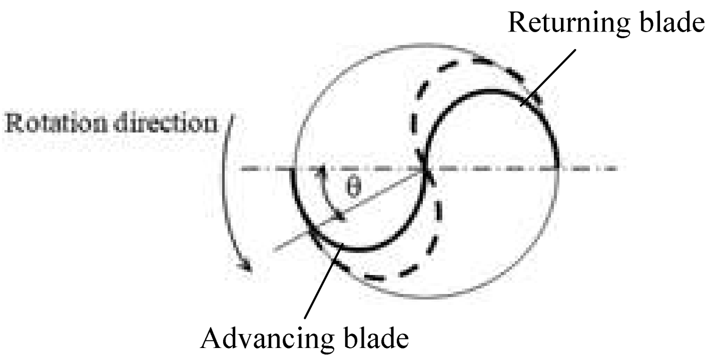


Figure 1. Savonius rotation

2.2. Numerical method

Published data from Sheldahl et al. [1] will be used to verify by taking data of torque coefficient at Reynolds number of 4.32 x10^5. The dimension will follow the experiment of Sheldahl et al. [1] by using the diameter of 1 m. The boundary condition can be displayed in Figure 2.

The boundary conditions can be seen in figure 2. This work uses transient simulation with moving mesh in rotating area. The change of grid size is used to verification in about 17.006, 61.105 and 120.000 nodes. The grid size will be chosen 61.105 nodes for the next simulation. The verification step and validation step can be displayed in Figure 3 (a) and 3 (b), respectively.

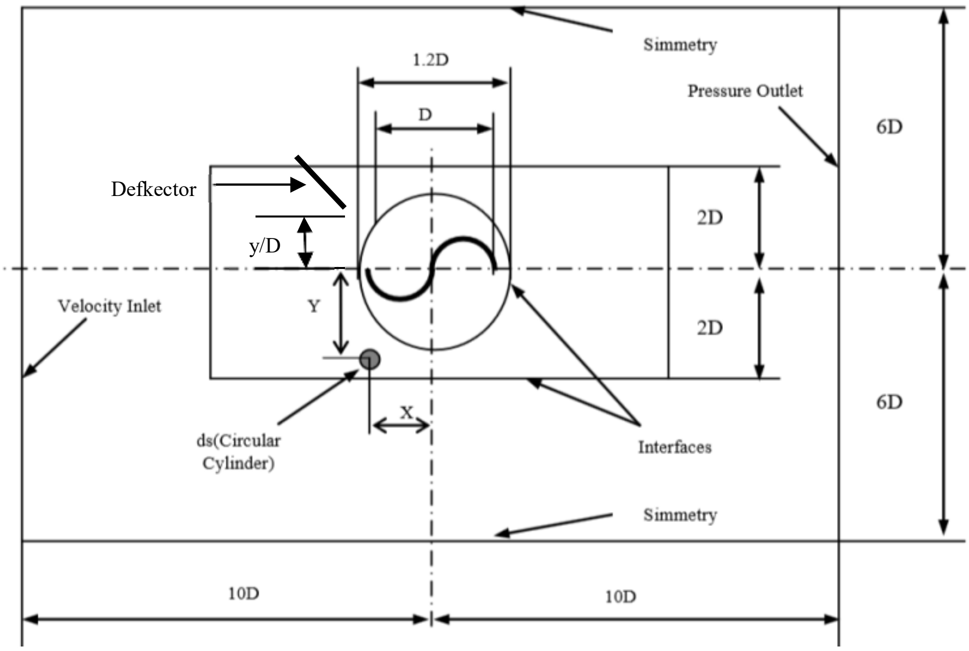


Figure 2. Boundary conditions of Savonius Turbine

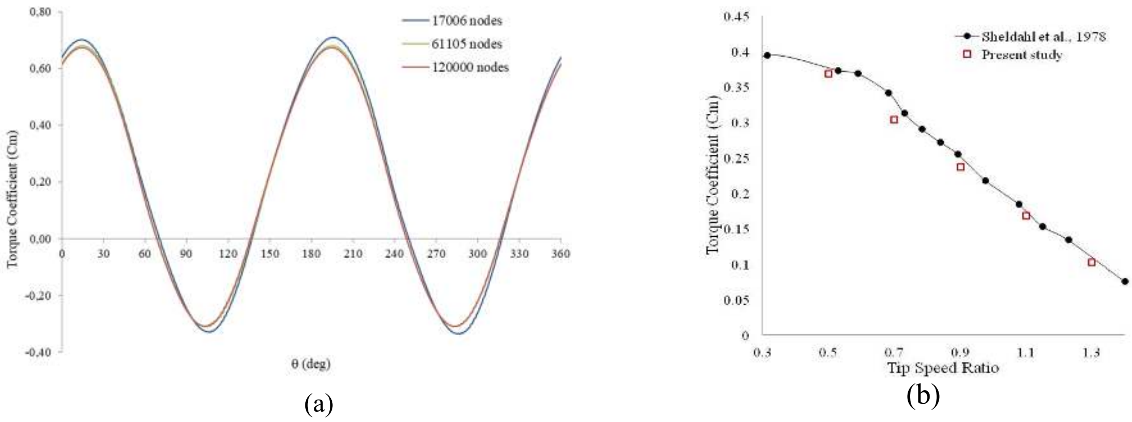
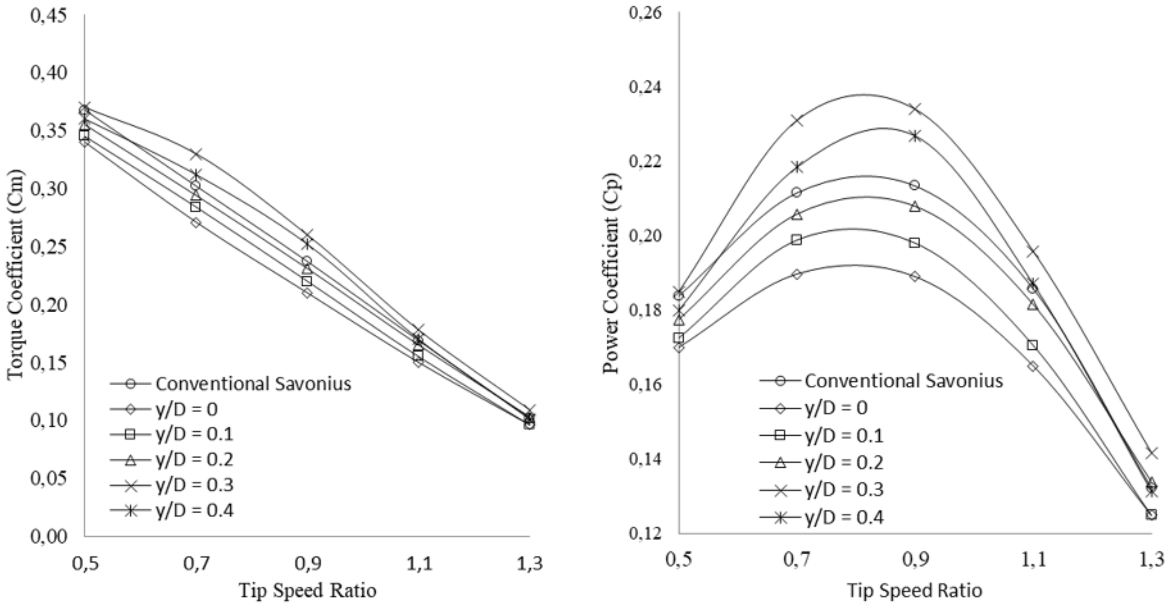


Figure 3. Results for verification (a) and validation (b)

3. Results and Discussion

3.1. Comparison of the different stagger angle

Figure 5(a) represents comparison the coefficient of torque (Cm) with respect to tip speed ratio (TSR). The coefficient of torque decreases with increasing the value of tip speed ratio (TSR) for all variations. Comparison power coefficient (Cp) for the change of y/D and conventional Savonius is represented in Figure 5(a).



(a) (b)

Figure 5. The coefficient of torque (C_m) (a) and the coefficient of power (C_p) (b)

Torque coefficient in Figure 5(a) has shown that the torque coefficient decrease at y/D from 0 to 0.2 and the best at y/D=0.3. The results of torque coefficient decrease by the increase of TSR. This shows that the torque is inversly proportional to TSR. The change of y/D decreases performance from 0 to 0.2 with the Cp value lower than conventional. The best Cp occur at y/D = 0.3, TSR of 0.8 like conventional.

Table 1. Improvement the performance to y/D variations

Variation	Peak Cp	at TSR	The performance Improvement (%)
Savonius conventional	0.2133	0.8	0
Deflector 30^o and y/D=0	0.1890	0.8	-11.39
Deflector 30^o and y/D=0.1	0.1980	0.8	-7.17
Deflector 30^o and y/D=0.2	0.2079	0.8	-2.53
Deflector 30^o and y/D=0.3	0.2340	0.8	9.71
Deflector 30^o and y/D=0.4	0.2268	0.8	6.33

The peak performance with y/D variations are compared by conventional Savonius as represented in Table 1. The peak Cp is 0.2340 obtained for y/D = 0.3 at TSR of 0.8 with improvement in about 9.71% compared conventional. At y/D 0, 0.1 and 0.2, The Cp value is negative. This value shows that the performance value is lower than Conventional Savonius.

4. Conclusion
The analysis of performance shows that the performance increase at y/D of 0.3 in about 9.71%. The y/D of 0., 0.1, 0.2 decrease below the conventional. The deflector will be blockage flow and need analysis about visualization flow over turbine.

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