# Simulation of Wind Turbines with Variation of Number of Blades and Blades Angle on Turbine Performance

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Abstract: Crossflow wind turbines are known because of the advantages of producing maximum torque in a low tip speed ratio also as a self-starting wind turbine. Therefore, it is an ideal wind turbine type for application as a power generator in rural areas that have low wind speed between 2-5 m/s. The design parameter of cross-flow wind turbines is required in order to improve turbine performance. This work investigates the influence of blades number and blades angle on the performance of cross-flow wind turbines. Furthermore, to investigate the effect of blades number and blades angle on crossflow wind turbine performance. Crossflow wind turbines designed using 18 and 20 blades on 45˚, 60˚, and 75˚ blades angle on 0.68 aspect ratio diameter. Based on the results obtained, cross-flow wind turbines with 18 number of blades and 45˚ blades angle showed the best result.

## 1 INTRODUCTION

Crossflow type wind turbines are ideal turbines for remote areas because crossflow type turbines can produce large torque when a small tip speed ratio. Crossflow wind turbines can effectively capture wind when the wind conditions are in poor condition.

If considering the limits of the type of classic wind turbines, crossflow type wind turbines should be a solution for areas that have poor wind conditions and low speeds of 2-5 m / s [1].

At present, there is a lot of follow-up research on crossflow type wind turbines. The efficiency produced by crossflow wind turbines is high because energy is produced from two sides of the turbine; first, when the wind enters and pushes the front turbine, the two come out of the turbine and push back the backside of the wind turbine [2].

The purpose of the study was to measure the performance of a crossflow type wind turbine with variations in the number of blades and blade angle. So that it can be seen the turbine design with the best performing variation of research.

Turbine performance analysis is done with Computational Fluid Dynamics (CFD). The design made is 1 x 1 m2 outer diameter and 0.68 x 0.68 m2 in diameter with a ratio of aspect ratios of 0.68 with two variations in the number of blades as much as 18 blades and 20 blades and also three variations of blade angle 45 sudut, 60˚, and 75˚. Based on the results of the study, the design of a crossflow type wind turbine with 18 blades and a slope angle of 45˚ produced the highest Cp value of 0.45.

## 2 LITERATURE REVIEW

Computational Fluid Dynamics (CFD) is used to help calculate the output value, CFD uses the continuity equation as follows:

$$(\partial \rho u)/\partial x + (\partial \rho v)/\partial y \qquad (1)$$

Taking into account the conditions are ideal conditions, the incompressible Navier-Stokes calculation formula is used as follows:

$$\rho Dv/Dt = -\nabla p + \nabla.\mathrm{T} + \mathrm{f}. \qquad (2)$$

Kinetic energy is transferred to the rotor, and the wind leaves the turbine. The actual power of the turbine is efficiency or known as Cp. Thus, the Cp value can be searched by comparing the actual power and wind power available by:



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$$Cp=\frac{2\,Pt}{\rho\,At\,V^3} \quad (1)$$

Where Pt is the turbine output power, the Cp value can depend on the type of blade, a number of blades, blade settings, and others.

$$Ct=\frac{2\,Tt}{\rho\,At\,V^2R} \quad (2)$$

Where Tt is motor torque. Tip Speed Ratio (TSR) can be defined between turbine speed and wind speed.

$$\lambda=\frac{Cp}{Ct} \quad (3)$$

The maximum Tip Speed Ratio (TSR) value is directly proportional to the value of turbine efficiency [1].

## 3 METHODOLOGY

In this study, cross-flow wind turbines were carried out using the 2D method. Cross-flow wind turbines with D1 = 1 m and D2 = 0.68 m are placed in modeling with a length of 15 m with a width of 7.5 m, and the distance between inlets to wind turbines is 2.5 m. The domain of modeling can be seen in Figure 1.

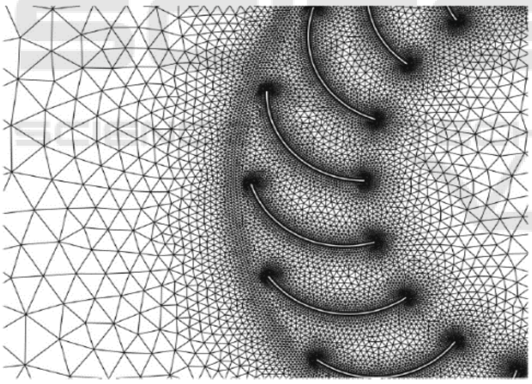

Figure 1 Meshing Quality

The computational domain is divided into two subdomains, namely fixed domain and rotating domain. The inlet is where the wind enters and is modeled with a wind speed of 2 m / s. Meanwhile, the right side is modeled as a pressure outlet with a relatively static pressure of 0 Pa. The upper and lower sides of the turbine are boundary walls as the upper and lower limits of the wind turbine.

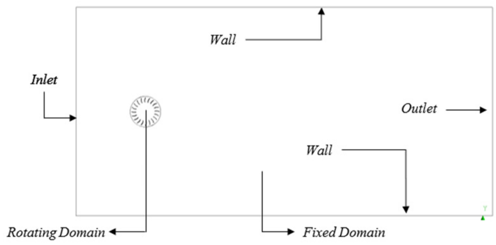


Figure 2 Computational Domain

Value Tip Speed Ratio (TSR) for the simulation in Computational Fluid Dynamics (CFD) can be defined by the equation as follows:

$$\lambda=\frac{\omega\,R}{V} \quad (4)$$

Where $\omega$ is the angular speed of the cross-flow wind turbine and R = D1 / 2, which is the outer diameter, and v is the air velocity modeled in the simulation.

Table 1 Tip Speed Ratio (TSR)

| $\lambda$ | $\omega$ (rad/s) |
|---|---|
| 0 | 0 |
| 0.1 | 0.4 |
| 0.2 | 0.8 |
| 0.3 | 1.2 |
| 0.4 | 1.6 |

The meshing used is the Triangular Meshing model used in all parts of the cross-flow wind turbine domain. The quality of the meshing results in the study shows that 0.78, where the meshing results belong to the category of good meshing, which makes meshing can be used to continue the research (Wikantyoso, 2017). The following are the results of meshing.

Meshing results will affect the accuracy of the research conducted. Therefore, triangle meshing is used because it has a sufficient level of accuracy.

## 4 RESULTS

The turbulence modeling k-□ is widely used to carry out crossflow type wind turbine simulations because the application is complex and is very suitable for rotation so that the resulting results can approach the results of experimental studies.

It can be seen that the trend of the torque coefficient value (ct) decreases as the value of the Tip Speed Ratio (TSR) increases because this value of Ct is not directly proportional to the TSR value. The highest Ct value is found when the TSR is 0.1, and the lowest TSR value is at TSR 0.4

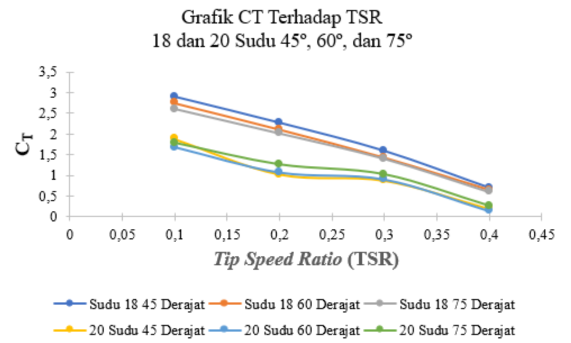


Figure 3 CT

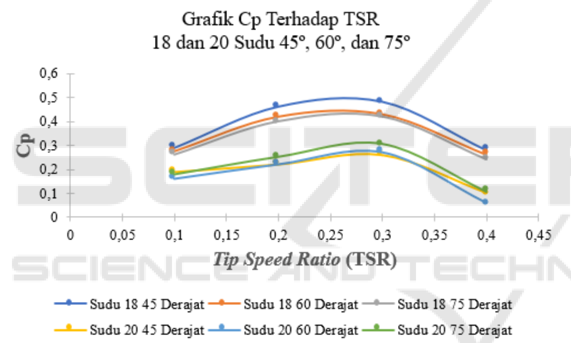


Figure 4 Grafik Cp

The highest Cp value is found in blade 18 with a blade angle of 45˚ on TSR 0.3. This proves that there are differences in performance with blades 18 and blade 20. Power Coefficient (Cp) generated from wind turbines is directly proportional to the actual power value produced by the turbine. Cp value forms a parabolic pattern where when the value reaches the maximum value, the value of Cp will decrease after reaching the maximum point. This is caused by when the value of Cp reaching the maximum value will decrease directly proportional to the value of TSR.

Based on Albert Betz's theory that the maximum CP value that can be owned by a crossflow type wind turbine is 0.59 because the air that hits the turbine will pass the distance between one turbine to another. Inner vortex increases at TSR 0.4 and TSR 0.5, causing a decrease in crossflow wind turbine performance. Where the higher TSR values given to variations will affect the performance of crossflow type wind turbines. The performance of the wind turbine reaches a peak at the point of TSR 0.2 and TSR 0.3, which has a maximum CP value of 0.45.

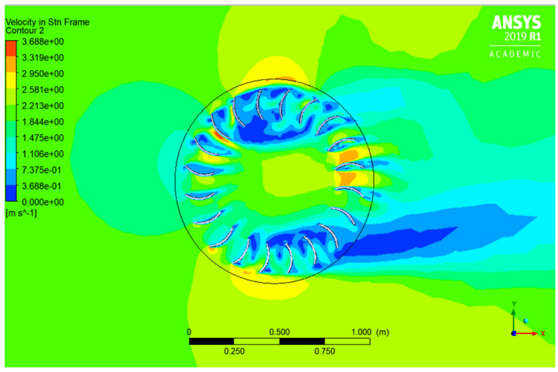


Figure 5 Contour Velocity 18 Blades 45˚ Blades Angle

The velocity contour of blade 18 and 45 blade angles show that there is an inner vortex that occurs around the turbine blades. Inner vortex is backflow from the wind that passes through the turbine so that it disturbs the flow of air that passes through the turbine blade. Inner vortex has an effect on the Cp value generated by the turbine, the more there is an inner vortex, the more resistance to airflow in the turbine so that the turbine does not function optimally.

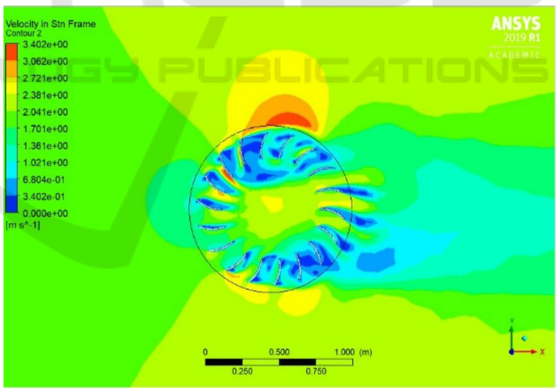


Figure 6 Velocity Contour 20 blades

If we compare inner vortex in the number of blades 18 and the number of blades 20, it can be seen that the number of blades 20 has inner vortex which is more because the number of blades 20 has too many blades in the crossflow wind turbine resulting in broken wind through the blade which causes a lot of inner vortex occurred in the crossflow wind turbine caused the flow of the wind can't reach its optimum level, so based on figure 5 the value of Cp blade 20 is not optimal compared to the value of Cp blade 18.

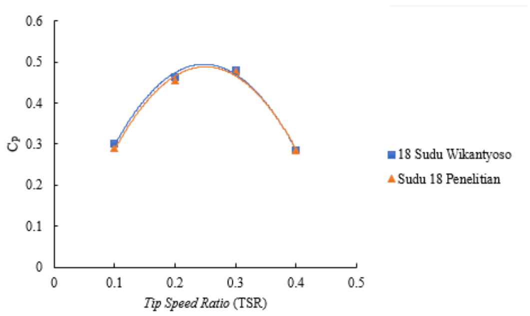


Figure 7 Results Comparation

The highest CP performance occurs at a TSR blade 0.3. The highest CP value is due to the variation of blade thickness of 10 mm, which has an influence on the CP research results. The thickness of the blade of 10 mm influences the speed of the incoming winds, which hit the first level wind turbine so that the speed of the incoming wind and the speed of the outgoing wind. Blades can affect the incoming wind, in research conducted the number of recommended blades for wind turbines is blade 18 to blade 22 if it exceeds the wind will split and cannot enter the maximum

Based on figure 7, the value of the power coefficient will increase maximally at Tip Speed Ratio (TSR) 0.3 and decrease at TSR 0.4. This is caused after the turbine reaches a maximum point at TSR 0.3 after which the turbine will decrease after reaching the maximum point. The maximum point of a crossflow wind turbine is at a low Tip Speed Ratio (TSR) of 0.3, and this makes a crossflow wind turbine an excellent turbine for low wind speeds. If using a TSR value of 0.5 to TSR of 0.6, the results of the performance of a cross-flow wind turbine will experience a decrease so that the value of the power coefficient can experience a minus. The comparison of CP values can reach 0.5 very high when compared with the Beltz momentum theory.

## 5 CONCLUSIONS

Based on the results of the analysis after conducting research, it is suggested that the turbine can only operate with a maximum Tip Speed Ratio (TSR) at 0.4, the higher the TSR value, the maximum turbine drop will occur after reaching the maximum value on TSR 0.3. And a comparison with experimental research is needed to ensure the simulation results with experimental research in the real world.

Furthermore, based on the results of the contour speed analysis it is recommended to use symmetrical casing to make the wind direction more regular and can change the direction of the wind so that it can make the wind direction more convergent which causes a little backflow which makes the Cp value of the turbine more leverage. For 1 x 1 m turbine size, it is recommended to use blade 18 because, based on the results of the study, it produces a value that is more optimal when compared to blade 20.

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