Analysis of near wake recovery scale model vawt hybrid wind turbine in wind tunnel

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Abstract. CFD simulations of full scale wind turbine have been carried out to predict recovery of wake that occur behind the hybrid VAWT turbine double, which states that recovery starts to occur in plane x/d = 4, verification of this result needs to be done. This study tested and measured the wind speed behind the scale model turbine in the wind tunnel. The purpose of this study was to create a prototype scale model of the VAWT hybrid, test it in the wind tunnel. Statistical methods will be used in this study to process data and determine the recovery position of wake from the VAWT double hybrid. The results show that wake recovery in wind tunnel experiment, in field x/d = 3 with 99%, compare with wake recovery occurs in simulation, shown a show the same trend, but need further investigation with similarity and Reynold number.

1. Introduction

CFD simulation testing has been conducted to predict recovery wake that occurs behind the hybrid VAWT turbine which states that near wake recovery occurs in the x / d = 4 plane [1]. Many studies aimed at increasing the efficiency of wind turbines both individuals and arrays. The placement pattern and distance of the turbines on the farm array are important in improving the farm array performance. Some studies use methods such as genetic algorithm optimization [2], wind farm layouts with biography-based optimization [3]; grid-like layouts [4] can significantly improve farm array performance. In this study, the investigation the closest distance of the turbines that have been done with CFD simulation, and verification of CFD simulation results from the near wake recovery with experiments using a scale model in wind tunnel.

Full scale wind turbine has been analysis in wind tunnel with turbulen flow condition [5], this wind turbine is intended as a hybrid in a renewable energy generating system for an economic cluster [6]. In this study, the wake distance recovery zone will be a reference in determining the distance and arrangement of the turbines in the farm array. There have been no studies discussing the effects of

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wake produced by hybrid VAWT especially hybrid savonius-darrieus and its effect on power density and its comparison with HAWT.

2. Research methodology
In this study the scale model 1/8 size of the hybrid wind turbine was made to be tested in wind tunnels, to make a scale model, there are several important things that must be done so that the scale model can represent a full-scale prototype. First, adjust the dimensions of the wind turbine, then follow the rules in similitude in determining the Reynold number to be used [6, 7]. Because of specification of wind tunnel did not meet similarity requirement and scale model turbine will not be able to withstand wind speed loads as required by similarity and Reynold number. hence in this study will only evaluate wake recovery on scale models in wind tunnels.

the use of scale models with sizes above 5% cross section of wind tunnel test sections will cause blockage effects. this blockage effect is calculated as below [8, 9].

- **Sweep area of the blade**: $0.048 \text{ m}^2$
- **Test section**: $0.509 \text{ m}^3$

\[
Blockage = \frac{0.048}{0.509} \times 100 = 9.4\%
\]

Where

- $V_f$ = Wind speed behind wind tunnel
- $V_c$ = Wind speed in wind tunnel

![Figure 1. Wind Turbine Scale Model and wind turbine digital model.](image)
The wind turbine sultan prototype is a turbine scale model of savonius and darrieus with a scale ratio of 1: 8. The Wind Tunnel used in this experiment is the wind tunnel at the Pancasila University [10], following the wind tunnel used:

![Wind Tunnel Image](image)

**Figure 2.** Wind Tunnel

Data analysis will use the same method as in CFD simulation testing, using descriptive analysis, The Kruskal–Wallis test, Test Kolmogorov-Smirnov Z for non parametric test, One Way ANOVA Test on the parametric test [1]

\[
\bar{X} = \frac{\sum_{i=1}^{n} X_i}{n} \quad \text{.......... (1)}
\]

\[
K = (N - 1) \frac{\sum_{i=1}^{g} n_i (\bar{r}_i - \bar{r})^2}{\sum_{i=1}^{g} \sum_{j=1}^{n_i} (r_{ij} - \bar{r})^2} \quad \text{.......... (2)}
\]

\[
U_1 = n_1 n_2 + \frac{n_1 (n_1 + 1)}{2} - R_1 \quad \text{.......... (3)}
\]

3. **Data Collecting Procedure**

The experiment following this procedure

1. point of data retrieval is at the upper line for the middle position of Savonius and the bottom line for the middle position of Darrieus, speed data is measured using wireless hot wire a digital multimeter Testo_ model 435, duration of data retrieval for each point is 2 minutes and every 2 seconds data is taken, at one wind speed 5 fields and each field there are 10 points. Of the 5 fields namely x / D = 3, x / D = 4, x / D = 5 fields, x / D = 6 fields, and x / d = 7 fields.

![Cross Section Image](image)

**Figure 3.** cross section of point data retrieval
2. At each data point will be taken for 1 minute, with a data retrieval range per 2 seconds, so for one point in one field there will be 30 wind speed data. Wind speed data is taken using wireless hot wire testo 405.

![Testo 405](image)

**Figure 4.** Testo 405

3. Data retrieval is done starting from the field \(x / D = 3\) to \(x / D = 8\) with variations in wind speed from 3 m/s to 8 m/s.

4. **Result**

   In the results section, wake recovery results from simulation and wake recovery will be displayed from the experimental results.

   For example the results of the wind speed contour in plane 3 in a position with a wind speed of 5 m/s.
Figure 6. perbandingan profil kecepatan angin pada bidang x/D=3

In figure 6, it shows that the center of the wake wind turbine still occurs and the wake due to the turbine darrieus is slightly larger than savonius. This is because the savonius placement at the top of the turbine, and wake Savonius that arises moves upward, see figure 7, so that in the wake test field it is no longer readable in sensor. Some research found the same fenomena, one experimen put savonius under darriues turbine [11] and get a result that wake recovery is more far than this research result.

Figure 7. Side view of simulation
Figure 8. Wake recovery at a speed of 3-8 m/s in the simulation [1]

The wind speed that falls behind the shaft recovers and rises to the initial velocity such as before the shaft, or the affected zone of the wake only occurs up to \( x/D = 3 \), wake recovery has begun to occur in fields 4 to 7 with a percentage of 95%.

Figure 9. Graph recovery at a speed of 3-8 m/s wind tunnel testing
The wind speed that falls behind the shaft recovers and rises to the initial velocity such as before the shaft, or the affected zone of the wake only occurs before the \( x / d = 3 \) field, \( x / d = 2 \), wake recovery has begun in fields 3 through 7 with percentage of 99%.

5. Discussion
As stated in the methodology that this experiment is not intended as a validation of the simulation results. Both results will be displayed; this experiment also uses the same statistical method to generate wake recovery fields. Wind tunnel experiment can validate simulation full scale prototype if it can produce wind speed up to 64 m/s in order to have the same full scale Reynolds number [12], also model scale must withstand the force. Another way to validate is validate some part of simulation that in wind tunnel range, its mean that simulation result around 0.5 m/s to 1 m/s. The technique that is often used in testing physical scale models when you cannot reach the intended parameters is to vary the speed to see the trend of the intended parameters such as the drag coefficient. Another option is to simulate a CFD model and compare it with the experimental results of a wind tunnel scale model to get information about a full-scale CFD model.

6. Conclusion
From the experimental results the scale model for wake recovery began to occur in the \( x / d = 3 \) field with a percentage of wake recovery of 99%. The simulation results of CFD for wake recovery occur at \( x / d = 4 \). From these data it can be concluded that CFD have the similar result with wind tunnel result it show that wind tunnel scale model have the ability to validate CFD simulations if it fulfill similarity requirement. full scale CFD simulation and scale experiment models wind tunnel have similarities in trend of wake that is in the middle of the turbine, and wake from savonius is slightly smaller than wake darrieus.

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