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Comparative Study of Damper Effects of Steering Tail Fin Shapes: Part I

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ABSTRACT

The wind is a natural resource that will always exist and will not run out. To convert wind into electrical energy that is useful for humans, it takes a Wind Turbine machine. Renewable Energy Design laboratory Untirta has a wind turbine called the Sultan Wind Turbine. This turbine requires a guiding tail fin to help the turbine always face the direction of the wind. The purpose of this study was to determine the best shape of the guiding tail fin based on its damping effect. The method used in this research is experimental. The guiding tail fin to be studied must be scaled by the dimensions of the wind tunnel used. The manufacture of steering tail fin using 3D printing. The experimental results in the wind tunnel in the form of video are converted into a sinusoidal graph. Each graph is compared and searched for the best in terms of time, amplitude, and waveform. From the data analysis, the best graph is obtained, namely the graph of the design of the right triangle fin with the number of waves as much as 1.5 waves, the highest wave peak of 0.0201 m and the attenuation time of 13.4 seconds.

Keywords: *Wind Turbine, Steering Tail, Fin Shapes, Wind Direction*

1. INTRODUCTION

A wind turbine is a mechanical device that converts the wind's kinetic energy into electrical energy[1]. In general, a wind turbine consists of four main components such as the blades, the axis of rotation, the generator, and the steering tail fin. The function of the blades on the wind turbine are to receive the wind's kinetic energy and then convert it into rotary kinetic energy and forward it to the axis of rotation. This axis of rotation is a connecting bridge between the blades of the wind turbine, which is in charge of receiving the wind's kinetic energy to the generator, which functions to convert the rotational kinetic energy into electrical energy[2].

Wind turbines are classified into two according to their rotational axis orientation, namely Vertical Axis Wind Turbine (VAWT) and Horizontal Axis Wind Turbine (HAWT). VAWT is a wind turbine whose axis of rotation is mounted vertically[3]. The movement of the shaft and rotor on the VAWT is parallel to the direction of the wind, so in general, this turbine can rotate in all wind directions. HAWT is the opposite of VAWT, where the shaft on the HAWT is mounted horizontally, which causes the shaft and rotor movement of the HAWT not to be parallel to the direction of the wind which causes the turbine to have a section called the guiding tail fin[4].

Renewable Energy Design Laboratory Untirta has a wind turbine, called Sultan Wind Turbine. It is a vertical axis double pillar wind turbine, where this wind turbine combines Darius and Savonius type wind turbines on each axis. The choice to build a vertical wind turbine makes it easy for turbine maintenance to be carried out regularly or when a breakdown occurs. Based on previous research, the design of the wind turbine, which has a double shaft causes the disappearance of omni-directional nature that vertical wind turbines should have. This causes the Sultan Wind The steering tail fin on the wind turbine has the role of helping the turbine to always point in the direction of the wind. The wind turbine must always face the direction of the wind so that the wind power that can be converted into electrical energy can be maximized. One thing that can maximize the absorbed wind power is the minimum yaw motion that occurs in the steering tail fin[6], or in other words, if the movement of the steering tail fin is used as a sinusoidal graph, and it just has a few waves, then it will be the good steering tail fin.

In the previous research, the damped response of the directional tail fin has not been tested[5]. Adequate information on the tail shape and its effect on wind turbine yawing performance are also not widely available. Therefore, further research is needed to determine which caudal fin shape is better at providing a damped response.

2. METHODS

This research focuses on finding the best directional tail fin design based on the damper effect that occurs. The test method used in this study is an experimental method using a wind tunnel, and data collection is using a camera [7, 8]. The camera is used to record the movement of the rudder tail fin from the initial position of the rudder tail fin exposed to the wind until the rudder tail fin is no longer moving and is in a stable state.

Video data taken using the camera is then processed using software called Tracker. Data processing in this Tracker software uses the auto-tracking method. The Tracker software converts the video data into a sinusoidal graph, with the X-axis being the time and the Y-axis being the displacement distance of the tail fin[9].

3. RESULTS AND DISCUSSION

3.1 The Design Of Tail Fins

Based on previous research, the caudal fin guiding the Sultan Wind Turbine has an area of 0.126 m2 while the ratio of the length and the width is 1.4. From the limitation of the problem, the size of the guiding tail fin can be calculated, which will be tested in the wind tunnel [5].

The first step that must be done first is to scale the original size of the tail fin of Sultan Wind Turbine so it can be installed in the test section of the wind tunnel, the test section's dimention is 50×50 cm. The scale that used in this experiment for the tail fin in wind tunnel from the it real dimention is 1: 3, so the area used for the guiding tail fin used for this test is 0.042 m^2.

3.2 Isosceles Triangle Tail Fin

Based on the area and ratio obtained from previous study[5], the dimensions of the tail fin in the form of an isosceles triangle can be calculated. The calculations are as follows:

$$L = \frac{1}{2} \times a \text{ x } t \quad (1)$$

$42000\ mm^2 = \frac{1}{2} \times 1.4t \times t$

$42000\ mm^2 = 0.7t^2$

$t = 244.95$ mm

$$a = 1.4t \quad (2)$$

$a = 1.4 \times 244.95$

$a = 342.93$ mm

L = Area (mm^2)

a = Base (mm)

t = Height (mm)

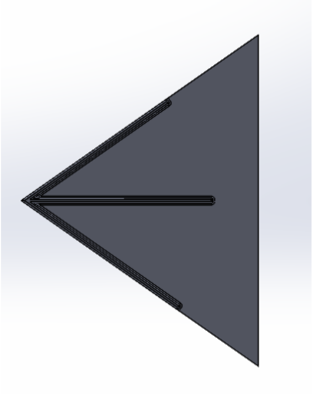


Figure 2 Isosceles triangle tail fin

3.3 Right Triangle Tail Fin

Based on the area and ratio obtained from previous studies[5], the dimensions of the tail fin in the form of a right triangle can be calculated. The calculations are as follows:

$$L = \frac{1}{2} \text{ x} \times a \times t \quad (3)$$

$42000\ mm^2 = \frac{1}{2} \times a \times 1.4a$

$42000\ mm^2 = 0.7a^2$

$a = 244.95$ mm

$$t = 1.4a \quad (4)$$

$a = 1.4 \times 244.95$

$a = 342.93$ mm

L = Area (mm^2)

a = Base (mm)

t = Height (mm)

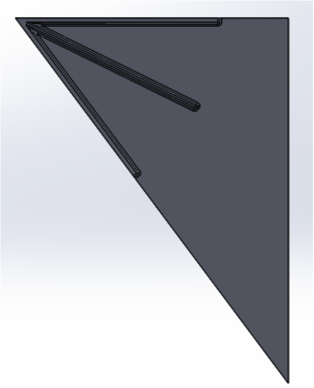


Figure 3 Right triangle tail fin

3.4 Trapezium Tail Fin

Based on the area and ratio obtained from previous studies[5], the dimensions of the trapezoidal tail fin can be calculated. The calculations are as follows:

$L = p \times l$ (5)
$L = 150 \times 200$
$L = 30000\ mm^2$
Trapesium area= square area – triangle area (6)
$42000\ mm^2 = 30000\ mm2$ – triangle area
Triangle area = $12000\ mm^2$

$L = \frac{1}{2} \times a \times t$ (7)
$12000\ mm^2 = \frac{1}{2} \times a \times 200$
$12000\ mm^2 = 100 \times a$
$a = 120\ mm$
L = Area (mm^2)
p = Length (mm)
l = Width (mm)
a = Base (mm)
t = Height (mm)

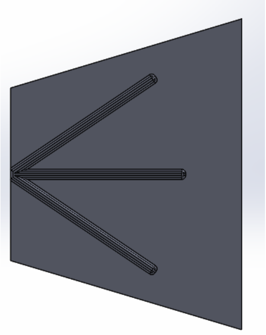


Figure 4 Trapezium tail fin

3.5 Rectangular Tail Fin

Based on the area and ratio obtained from previous studies[5], the dimensions of the rectangular tail fin can be calculated. The calculations are as follows:

$L = p \times l$ (8)
$42000\ mm2 = p \times 1.4p$
$42000\ mm2 = 1.4p^2$
$p^2 = 30000$
$p = 173.2\ mm$

$l = 1.4p$ (9)
$l = 1.4 \times 173.2$
$L = 242.48\ mm$
L = Area (mm^2)
p = Length (mm)
l = Width (mm)

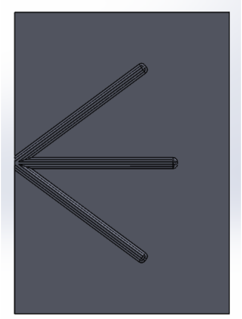
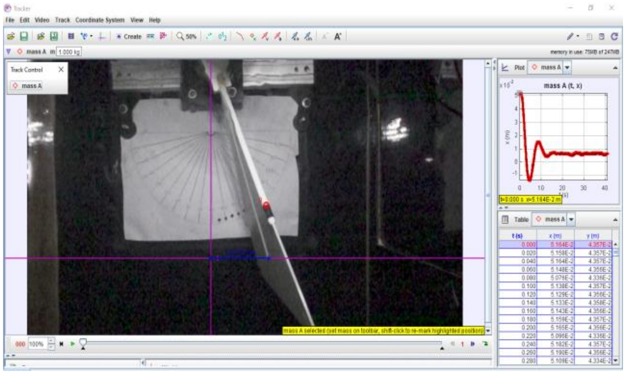


Figure 5 Rectangular tail fin

The Data Collection Procedure Carried Out is as Follows:

1. Place the guiding tail fin on the test section.
2. Place the camera at the top of the test section and parallel to the position of the guiding tail fin.
3. Close the test section door, adjust the angle of the tail fin to the direction of the wind, and turn on the wind tunnel at the desired speed.
4. Recording the movement process of the tail fin at the time of the initial exposure to the wind until the fin does not move anymore.
5. Analyze data using tracker software.

The experiment and test result’s data can be seen in the Figure 6.



t=0.000 s x=5.164E-2 m

t (s)	x (m)	y (m)
0.000	5.164E-2	4.357E-2
0.020	5.158E-2	4.357E-2
0.040	5.164E-2	4.357E-2
0.060	5.148E-2	4.356E-2
0.080	5.076E-2	4.336E-2
0.100	5.138E-2	4.357E-2
0.120	5.129E-2	4.356E-2
0.140	5.133E-2	4.358E-2
0.160	5.143E-2	4.356E-2
0.180	5.159E-2	4.357E-2
0.200	5.165E-2	4.356E-2
0.220	5.096E-2	4.336E-2
0.240	5.182E-2	4.357E-2
0.260	5.190E-2	4.356E-2
0.280	5.109E-2	4.334E-2

Figure 6 Video analysis of tail fin

The test results of various guiding tail fins at an angle of 30º and a speed of 5 m/s are as follows:

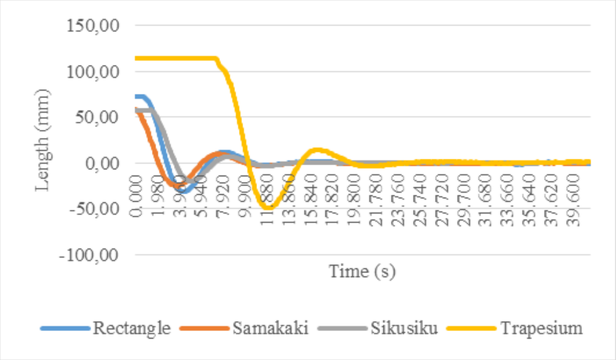


Figure 7. Test Results Graph

The following data are obtained from the Figure 7, which is used to facilitate the shape of the guiding tail fin, which is the best for the damping response of the Sultan Wind Tunnel.

Table 1. Data From The Result Graph

Fin	Wave number	altitude (m)	length (m)	time (s)
Rectangle	1.5	0.0309	0.005165	14.6
Isosceles triangle	2	0.0247	0.00413	18.32
Right triangle	1.5	0.0201	0.003905	13.4
Trapezium	1.5	0.0488	0.008205	18.64

Based on the research of Kwan et al with the title A Catalog of Tail Fin Shapes for Small Wind Turbines[10], there are two factors that determine the best fin shape. The two factors are the least number of waves and the most minor wave crest. This study adapts this but with a few additions, namely, the shortest fin attenuation time is also one of the determining factors for the best fin.

4. CONCLUSION

From each fin design made with an area of 0.042 m^2 and a ratio of 1.4, the final data is a sinusoidal graph. A good chart has a few wave counts, low wave crests and fast equilibrium time. From the data processing and analysis results, the best graph is obtained, namely the graph of a right triangle fin design with the number of waves as much as 1.5 waves, the highest wave peak of 0.0201 m and the attenuation time 13.4 seconds.

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