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Prototype Design Analysis of Digital-Based Wind Tunnel Aerodynamic Testing Equipment

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ABSTRACT

The design of the prototype uses an electric motor / fan that can be adjusted to produce wind gusts in the wind tunnel. Measurement of dynamic pressure, static pressure and (for compressed flow only) temperature rise in the air stream. The direction of airflow around the model can be determined from the tufts of threads attached to the aerodynamic surface. An important Wind Tunnel design is the geometrical similarity of all dimensions of the object must be proportionally scaled, Mach number the ratio between the speed of air and the speed of sound must be identical for the scaled model and the actual object. the method used in the completion of the wind tunnel machine using the design concept of data collection techniques using solidwork. Making a wind tunnel model by determining the length of the test section of 0.50m, the length of the diffuser being 0.8m, the calculation of the contraction length of the contraction being 0.54m and the height of the contraction being 0.60m calculating the length The only gain is 0.096m Energy losses in the Wind tunnel of 0.02373, Energy Losses on the screen of 0.02373, Energy Losses in Contraction of 0.01728, Energy Losses in the test section of 0.05, Energy Losses on the diffuser of 0.04518 The result of the research that the wind using an anemometer is 2.9 m/s with a temperature of 32.4 °C. The style of getting the results of the airfoil test is that the first form has a drag force of 11.61 grams and a left force of 2.61 grams, while for the second form a drag force is obtained. of 11.50 grams and the left force of 2.50 grams. In this wind tunnel the maximum wind speed is 2.9 m/s, the average wind speed in Indonesia is 2.5 – 3 m/s. In the honeycomb, the wind is controlled so that the wind entering the tunnel becomes unidirectional or focused, and then enters the intake contraction, the wind is increased in pressure by reducing the size of the test section, the goal is to maximize the friction between the test object and the wind.

INTRODUCTION

Wind tunnel or wind tunnel is equipment used to perform aerodynamic testing of a model, such as an airplane or car. Wind tunnels are usually used to simulate an airflow condition against a model. The existence of this wind tunnel is intended to support the field of aerodynamics and facilitate wind turbine research

The instrument/measuring instrument or the value represented by the measuring material is the calibration (which relates to the range being measured). In wind tunnel flow testing, the flow test point used to measure the flow in the wind tunnel is an exhaust wind tunnel. If it is operated it will produce vibration, to dampen the vibration, a strong position frame is needed so that the machine does not slide easily and vibrates. The frame will receive the load from the wind tunnel body (reinforcement), sensor box, and also the test object. The frame is the holder of a tool, so that the frame is safe to use and a calculation is made of the load that will support the frame, the wrong material becomes the frame that is not strong or unable to withstand the load. The frame design has the main function to accommodate all engine components installed in the frame. In essence, the basic form of the machine that functions as a buffer or reinforcement position, it is very important to design in terms of layout and pedestal

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so as not to interfere with the performance of the machine itself.

Based on research conducted by Ahmad Marabdi Siregar, Mechanical Engineering Study Program, Faculty of Engineering, University of Muhammadiyah North Sumatra in 2016, a simple Wind Tunnel design for supporting experimental studies whose research resulted in a prototype test plan for a wind turbine whose rotor is 350 mm in diameter and 540 mm in height. the test section of the wind tunnel was constrained due to the absence of an adequate wind tunnel. With the dimensions of the prototype requires adequate wind tunnel specifications. If the procurement is through an equipment provider agent, of course it will really require a fairly large capital. Meanwhile, the facilities and workshop facilities in the vicinity are very possible to carry out the design and construction of wind tunnels. The components of the Wind tunnel equipment, namely the compressor, test section, and diffuser which are aligned or in direct contact with the drive section will not vibrate unless the blower is turned on and the test is carried out. The blower rotation will cause a vibration effect during the test. In testing as much as possible the vibrations that arise can be minimized or eliminated, for this reason the design of this low speed wind tunnel in which the diffuser section and the drive section will be connected with cloth and built in the work shop of the mechanical engineering department of the University of North Sumatra.

Wind tunnel design on the determination and shape of the wind tunnel, especially the diffuser. There are two types of wind tunnels, open and closed, namely open wind tunnels (**Figure 1**).

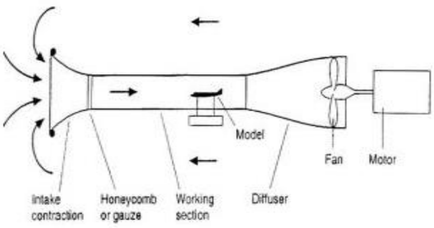

Figure 1. Open wind tunnel

The construction is simpler, cheaper, saves space and is not affected by fluctuations in room temperature, it is relatively more stable. And the closed wind tunnel (**Figure 2**) air is circulated along the wind tunnel so that the size is larger. The diffuser is a static pressure recovery to increase efficiency in the wind tunnel, it is very important to keep the flow together. If there is a separation then there is pressure that will be channeled into the test section (testing), which occurs non-uniformity of pressure and wind speed.

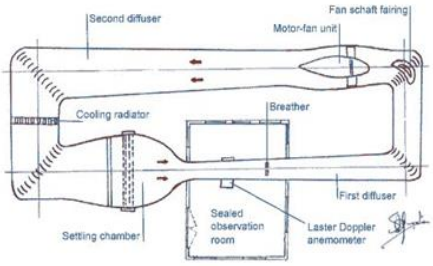

Figure 2. Closed wind tunnel

Formulation of the problem
The research problems that exist above can be identified as follows:

1. Required a relevant test equipment to determine the lift and thrust caused by wind speed.
2. It is necessary to have complete test equipment in a study related to wind speed.
3. It is necessary to have test equipment to determine the resistance of the material to wind speed.

Benefits of Wind Tunnel Aerodynamic Test Equipment

Wind tunnel design research in this study is expected to be an experimental study tool. In addition, it is also a form of contribution to the development of science, especially the use of wind energy.

EXPERIMENTAL METHOD

The method used in the completion of this Wind Tunnel machine uses a design concept, then it is designed , and system testing is carried out to find out whether the system has worked well or not. The test is carried out by measuring the wind speed in the Wind Tunnel test section

Wind tunnel construction to be made:

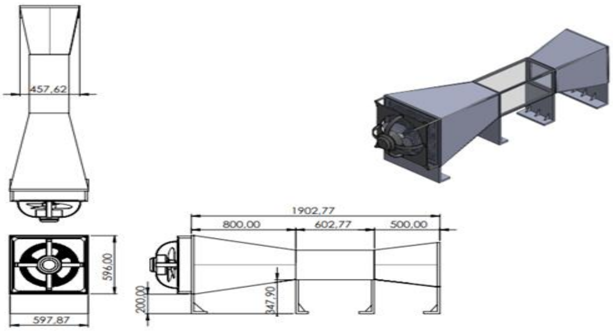

Figure 3. Wind tunnel construction

Wind Tunnel Design

The components in the wind tunnel include settling chamber, screen, honeycombs, contraction section, test section, test section, diffuser, fan.

Contraction section (Construction section)

It is the flow in the settling chamber towards the test section. Located between the setting chamber and the test section, to increase the average speed at the entrance of the test section, reduce fluctuations (changes) Genre. Comparison of large and long construction in smaller parts of the building can prevent the formation of separation or separators.

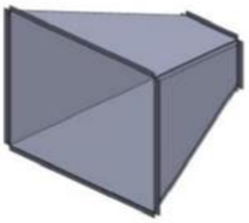

Figure 4. Contraction Section

Energy Losses on Contraction

The energy of contraction is mainly due to friction losses. For Contraction, namely almini.

Contraction loss values are:

$$K_2 = 0{,}32 \times \lambda \times \left(\frac{Lc}{Do}\right)$$

Where:
λ = friction coefficient of aluminum = 0.03
Lc = Length of contraction
Do = diameter contraction

Test Section

The place where the objects to be tested are placed, therefore the desired speed and quality of air flow must be considered.

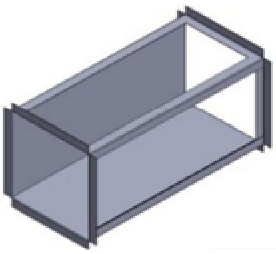

Figure 5. Test Section

The length of the Test Section can be found with the following formula:

Formula

$$Ls = 2.Dh$$

Where

Dh=Hydraulic diameter

$$Dh = \sqrt[2]{\frac{A}{\pi}}$$

Where:
Dh = Hydraulic diameter
A = Area of test section

The hydraulic diameter can be found by the formula:

$$A = \pi\frac{Dh^2}{2}$$

Where:

A = Area of test section
Dh = Hydraulic diameter

Calculation of Energy Losses in the Test Section

The material used in the test section is clear acrylic (transparent). Calculate the energy loss in the test section as follows:

$$K_2 = \lambda\left(\frac{Lts}{D}\right)\left(\frac{Do}{D}\right)^4 \qquad \ldots(5)$$

Where :
λ = friction coefficient of aluminum = 0.03
Lts = Test Section Length
D = Outlet diameter
Do = Diameter of inlet

Diffuser

The diffuser is pressure recovery to increase efficiency in the wind tunnel and it is very important to keep the flow together. If there is a separation the pressure will be channeled into the test section or the testing section which will result in non-uniform pressure and speed.

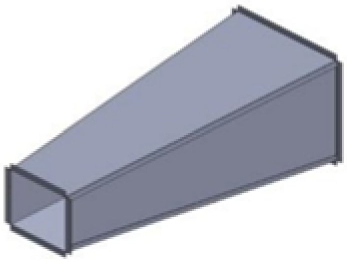

Figure 6. Diffuser

To find the length of the diffuser, it is necessary to know the diameter of the fan. Fan area 2 to 3 times the test section, with the following formula:

$$FA = \frac{\pi}{2} Dh^2$$

If the above calculation results do not exist with the diameter of the fan sold on the market then it is rounded up, and then the fan diameter is used as a parameter to determine the length of the diffuser with the following formula:

$$Ar \frac{Far}{A} 3{,}24$$

Calculation of Energy Losses in Diffuser

In the diffuser, the energy loss that occurs is caused by the coefficient of friction, it is necessary to calculate the cross-sectional enlargement of the diffuser from the inlet to the diffuser outlet. Then the energy loss in the diffuser is:

$$K_4 = \left(\frac{\lambda}{2\tan(7^\circ)} + 0.6 \text{ ton}\left(\frac{\alpha}{2}\right)\right)\left(1 - \frac{D_1^4}{D_2^4}\right)\left(\frac{D_0^4}{D_1^4}\right) \ldots..(8)$$

Where:
λ= Divergence angle 7°
Do = Outlet Diameter
D1 = Diameter inlet
D2 = Diameterfan

Honeycombs

A hexagon, rectangular or triangular structure located in the setting chamber serves to uniform the flow, in Honeycombs it eliminates eddies, reduces velocity variations in the lateral direction and reduces flow turbulence.

The length of the hanycome can be found by the formula

Lh = D.Fc

RESULTS AND DISCUSSION

Wind Tunnel Test

In testing the Wind Tunnel engine, first measure the total wind speed using an anemometer. The total wind results using an anemometer are 2.9 m/s with a temperature of 32.4 ° C. Below are the test results obtained:

Table 1. Wind Tunel Test Results

No	Bentuk Air Foil	Kecepatan Angin	Gaya Drag	Gaya Left
1		2.9 m/s	11,61 Gram	2,61 Gram
2		2.8 m/s	11,50 Gram	2,50 Gram
3		2.8 m/s	7,54 Gram	2,54 Gram
4		2.8 m/s	6,94 Gram	2,93 Gram

From the test results above, it can be concluded from the two forms of airfoil specimens that the first form has a drag force of 11.61 grams and a left force of 2.61 grams, while for the second form a drag force of 11.50 grams and a left force of 2.50 grams are obtained. . The shape of the airfoil greatly affects the drag and lift forces. Each of the above airfoils has the following criteria or sizes:

The first Airfoil form has the following sizes:

Figure 7. First Form of Air Foil

Length = 8 cm
Flow Angle = 15.47
The shape of the second Airfoil has a size of

Figure 8. Shape of the 2nd Air Foil

Width = 2.4 cm
Length = 8 cm
Flow Angle = 12.62
The Third Airfoil Form has a size of

Figure 9. Shape of the Third Air Foil

Width = 0.55 cm
Length = 8 cm
Flow Angle = 15.47
The Fourth Airfoil Form has a size of

Figure 10. Shapes of Air Foil Four

Width = 1.2 cm
Length = 8 cm
Flow Angle= 12.62

The test results concluded that the greater the value of the flow angle, the greater the drag and lift forces produced. Basically a system that uses aerodynamics must pay attention to the force generated from the planned shape and criteria or size, so that the friction between objects and the wind is small and is able to maximize the performance of the system.

Computational Fluid Dynamics (CFD) Analysis Parameters Used in Analysis

To perform an analysis on the wind tunnel, the thing that needs to be considered is to know in advance the parameters that will be used in testing the wind tunnel analysis. The parameters used are as follows:

1. Setting the Mesh or Nets
   The basic dimensions of the mesh used are as follows:
   a. Number of cells in X : 6
   b. Number of cells in Y : 6
   c. Number of cells in Z : 22
2. Mesh Analysis
   a. Total number of cells : 2989 cells
   b. Fluid cells : 2989 cells
   c. Solid cells : 2808 cells
   d. Partial cell : 1902 cell
   e. Trimmed cells : 0

Additional Physical Calculation Options

The analysis is carried out on the wind tunnel to determine the heat conduction heat transfer in each part contained in the wind tunnel. The type of flow used is turbulence, and the materials used in this analysis are liquids and gases.

3. Initial Condition Parameters
   a. Thermodynamic parameters
      1. Approximate Static Pressure : 101325.00 Pa
      2. Temperature : 20.05 °C
   b. Vector speed parameters
      1. Speed in X direction : 0 m/s
      2. Speed in Y direction : 0 m/s
      3. Speed in Z direction : 0 m/s

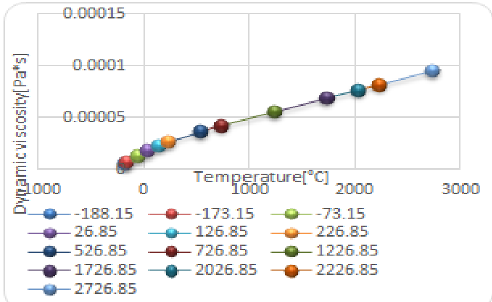

Figure 11. Dynamic Viscosity Graph

Molecular mass : 0.0290 kg/mo

From graph 11 above it can be explained that the greater the air temperature in the *wind tunnel* , the greater the dynamic viscosity value, this means that the ratio of shear stress to changes resulting from friction between the wind and the test object is shown in the light blue graph with dynamic viscosity value of 0.0001 Pa causes the temperature to be 2726.85 C.

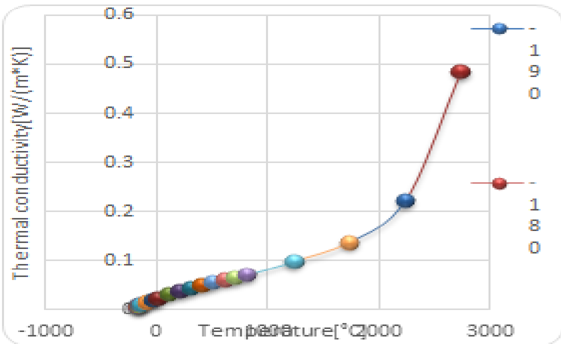

Figure 12. Graph of Specific Heat (Cp)

From Figure 12 above, it can be explained that the greater the specific heat temperature of the air in the wind tunnel , the greater the thermal conductivity value, this means a comparison of the shear stress to changes resulting from friction between the wind and the test object, this is shown in the colored graph. Orange the thermal conductivity value is 0.48 W/(mxk) with a specific heat temperature of 2726.85 C.

Airflow Wind Tunnel

Wind Tunnel (Wind Tunnel) is designed as an aerodynamic testing tool in the form of objects that rub against the wind and generate heat, basically the flow rate in this wind tunnel uses a fan or exos so that the wind is sucked into the wind tunnel room through various forms of components or parts, namely including screen, honeycomb, setting chamber, intake contraction, test section, output diffuser.

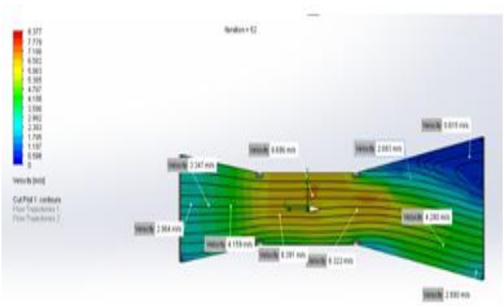

Figure 13. Air Flow

CONCLUSION

Based on the results of the design and calculation of losses that occur in the *wind tunnel* and testing of test objects, the following conclusions are obtained:

1. The results of the design obtained wind tunnel specification data with the following sizes:

Length of test section Ls	= 0.50 m
Diffuser Length Ld	= 0.793 m = 0.80 m
Fan diameter	= 0.3385 m = 13 inch
Contraction length	= 0.54 m = 0.60 m
Honeycomb length	= 0.096 m

2. The results of the calculation of energy losses that occur in the wind tunnel are as follows:
   - Losses on honeycomb Ko = 0.02373
   - Losses on Screen K_1 = 0.02373
   - Losses on Contraction K_2 = 0.01728
   - Losses in Test Section K_3 = 0.05
   - Losses on diffuser K_4 = 0.04518
   - Total loss Ktotal = 0.1191904
   - Total power required = 152.2 kg.m ^{2}/s ^{3} = 200 Watt

   The air volume capacity in the test section is = 553,059 m3 $^/$ hour
3. The test results of the two forms of airfoil are as follows:
   - The first airfoil form produces a drag force of 11.61 grams and a lift force of 2.61 grams.
   - The shape of the second airfoil produces a drag force of 11.50 grams and a lift force of 2.50 grams.
4. Wind tunnel is feasible to calculate Air Foil aerodynamics.

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