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Design of Wind Speed Measurement System in Wind Tunnel Based on Pitot Tube

Perancangan Sistem Pengukur Kecepatan Angin pada Terowongan Angin Berbasis Tabung Pitot

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Abstract

In the current era, the development of science in all aspects continues to change. The use of wind at this time is necessary for the efficiency of the energy used. The wind speed research method for this study utilizes experimental laboratory methods, specifically employing a Pitot tube measuring instrument to collect wind speed data. From the wind speed data obtained using a frequency of 25–50 Hz, there is only a slight difference between readings from a testometer with a pitot tube and only at frequencies of 39 Hz and 43 Hz, which have a visible difference. The graph indicates that the research was successful by comparing the readings on the testometer.

Keywords: pitot tube, wind speed, wind tunnel.

***SDGs*:**

Abstrak

Di era saat ini, perkembangan ilmu pengetahuan dari segala aspek terus mengalami perubahan. Penggunaan terowongan angin pada saat ini sangat diperlukan untuk efisiensi energi yang digunakan. Metode penelitian pengukuran kecepatan angin pada terowongan angin ini menggunakan metode laboratorium eksperimental dengan menggunakan alat ukur tabung pitot untuk mengambil data kecepatan angin. Dari data kecepatan angin yang diperoleh dengan menggunakan frekuensi 25-50 Hz, hanya terdapat sedikit perbedaan antara pembacaan dari testometer dengan pitot tube dan hanya pada frekuensi sebesar 39 Hz dan 43 Hz yang memiliki perbedaan yang terlihat. Dari grafik tersebut dapat disimpulkan bahwa hasil penelitian yang dilakukan berhasil dengan melakukan perbandingan dengan pembacaan pada alat testometer.

Kata Kunci: kecepatan angin, tabung pitot, terowongan angin.

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1. INTRODUCTION

In the current era, the development of science from all aspects continues to change. In the design of the wind tunnel building, measuring the airflow velocity is a very important part (Iqbal and Faisal, 2018). Because determining the fan rotation speed allows the determination of the total airflow velocity, speed can be obtained by measuring the time it takes to move a certain distance. Therefore, it is necessary to know the wind tunnel's air flow speed. The use of wind tunnels at this time is very necessary for the efficiency of the energy used (Yuniarsih and Rossbandrio, 2015).

Wind tunnels were invented in the early days of aeronautical research. Wind tunnels are used in the aerodynamic testing of an object to study the characteristics of the airflow passing through the object. wind tunnels are used to complete calculation tests by simulating real conditions under the influence of aerodynamic forces (Risnawan *et al.*, 2018). Aerodynamics is taken from the word Aero, which means air, and dynamics, which means change. in movement. It can also be called a change in the movement of an object due to air resistance when the object moves at high speed (Erwin, Hidayat and Wiyono, 2022). In addition, wind tunnels are used to test objects in various conditions and analyze them. performance of flight mechanics and see the movement of fluid flow (Roberts, 1980). Fluid flow can be divided into laminar flow, where the fluid moves in layers, or laminar, where one-layer slides smoothly. Turbulent flow, where the flow of movement of fluid particles is very uncertain due to the mixing and rotation of particles between layers, resulting in the exchange of momentum together (Mukhlisin, Erwin and Wiyono, 2022).

Wind speed in a wind tunnel can be measured using a pitot tube placed in the test section (Plit and Partner, 1982). To determine the velocity of the air flowing in the test section, a reference is needed to the readings from the pitot tube. Calibration of the pitot tube in the wind tunnel is required so that the airflow velocity data obtained is in accordance with the actual conditions. Also, calibration is useful to know and determine the RPM on the motor you want to use.

In a pitot tube, it has a relationship with Bernoulli's equation, where if the pressure increases, it is replaced by Bernoulli's equation, it becomes:

$$V= \sqrt{\frac{2(P_d)}{\rho}} \qquad (1)$$

where:

Pd = dynamic pressure (N/m^2)

V= fluid flow velocity (m/s)

ρ= air density (kg/m^3)

If the pitot tube has a deviation angle of 5°, then there is the biggest error when measuring stagnation pressure and static pressure (Walujodjati, 2005). pitot tube is used to measure stagnation pressure, also called total pressure. The total pressure is divided into two parts along the length of the flowing fluid column.

Arduino is an open-source electronic circuit board that contains various components. The main component of the Arduino is an AVR-sized microcontroller chip from the Atmel company. Arduino has digital pins on the Arduino board, which can be used for input or output. Arduino has its own software that is used to write or create programs to be uploaded to the Arduino (Rohmanu and Widiyanto, 2018).

A fluid is a substance (liquid or gas) that can flow. Fluid flow is divided into two categories. A flow in which the fluid movement of each particle follows the same direction as the previous particle. Fluid moves in parallel layers, without interference from each layer. A flow in which the fluid movement of each particle is irregular. Fluid in turbulent flow does not move in parallel layers. This turbulent flow has a Reynolds number above 4000.

2. METHODOLOGY

The research method to measure wind speed in this wind tunnel uses experimental laboratory methods using a pitot tube measuring device to collect wind speed data. Here is the flow chart along with the stages in Figure 1.

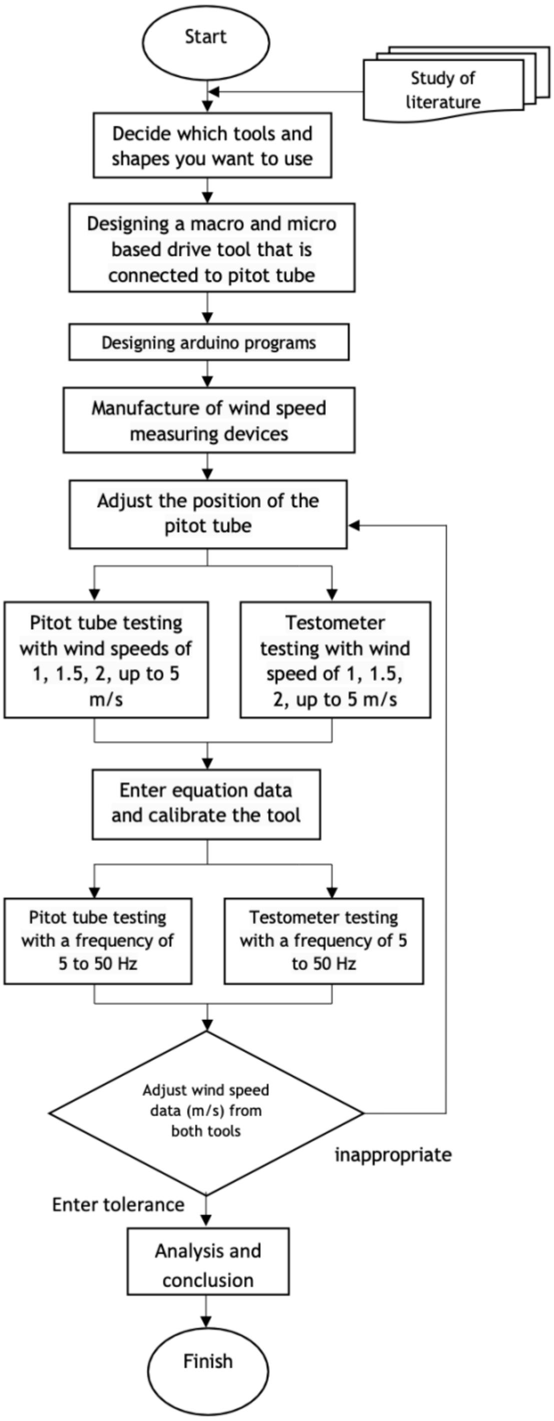


Figure 1. Flow chart.

The flow of research activities that will be carried out is starting the research from determining the tools and shapes that will be made based on research that has been carried out previously, then manufacturing the tools, then preparing the tools and materials to carry out the degree direction of the pitot tube. Testing is carried out using a testometer with a pitot tube to obtain data so that it can be entered into the equation for calibration. After obtaining the data, then carry out tests on the pitot tube measuring instrument with a wind speed of 3 to 5.5 m/s. then compare the data obtained with the results from the testometer. If the data obtained is far from the tolerance, do the test again. However, when the data obtained is suitable, proceed to the data analysis stage.

2.1. Set Up Experiment

Figure 2 explains the experimental setup for this test, where the pitot tube is placed in the test section of the wind tunnel. then the Arduino is placed outside the wind tunnel.

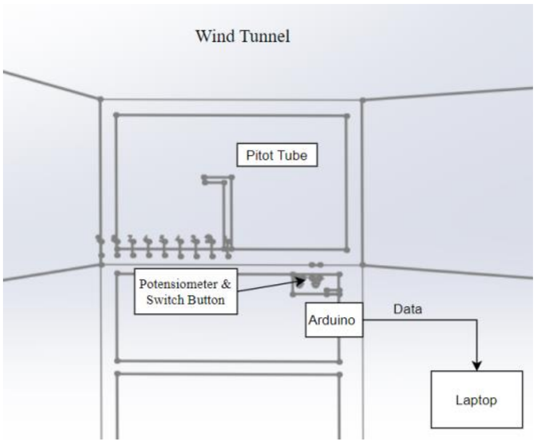


Figure 2. Set up experiment.

Wind tunnels are used to distribute airflow at varying speeds according to the motor frequency that has been set on the inverter. The airflow velocity in the wind tunnel will go through a pitot tube-based wind speed measuring device in the test section. The pitot tube is placed at the end of the test section in a central position so that there is no obstruction from the wall of the test section room. After the airflow is read by the pitot tube, the pitot tube will send the data to the Arduino, and then the Arduino will read and convert the data from the pitot tube into wind speed data that will be fed into the connected device.

Figure 3 shown the experimental setup for the circuit design connected to the Arduino that will be used. An MPXV7002DP sensor connected directly from the pitot tube has three streams connected to Analog In A2, 5V power, and GND power on the Arduino. There is a servo to move up and down the pitot tube, which has three streams connected to the Digital 10, 5V, and GND power parts on the Arduino. There is a servo to move right and left on the pitot tube with three streams connected to the Digital 11 part, 5V power, and GND power on the Arduino. There is a potentiometer to move the servo up and down macro-wise, which has three streams connected to Analog In A1, 5V power, and GND power on the Arduino. There is a potentiometer to move the right and left servo macros, which has three streams connected to Analog In A0, 5V power, and GND power on the Arduino. There are 2 Switch buttons to move the servo up and down the microwise, each of which has two streams connected to GND power, Digital 4 and 1 connected to GND power, Digital 5.

There are 2 Switch buttons to move the servo right and left microwise, each with two streams connected to GND power, Digital 6, and 1 connected to GND power, Digital 7.

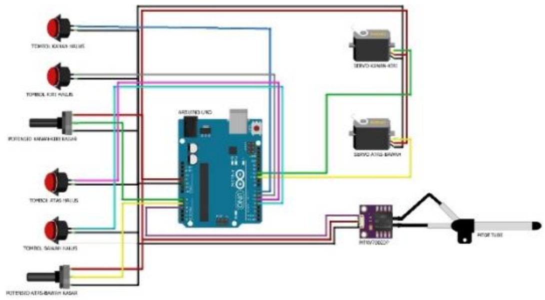


Figure 3. Circuit diagram.

2.2. Tools Used

Figure 4 shown are the tools and materials used in this research.

a. Pitot tube

b. Arduino

c. Acrylic glass

d. Breadboard

e. Servo

f. Switch button

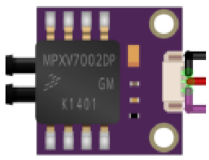
g. Cable male to female

h. Cable male to male

i. Testometer

j. Dexton's glue

k. Potensiometer



l. MPXV7002DP

m. Iron plate

Figure 4. Tools and materials.

2.3. Test Procedure

2.3.1. Calibration

The first step that must be taken is to calibrate the tool, so that the tool can read the wind speed in the wind tunnel specifically, here are the steps (Pope, 1961; Sulistya, 2018):

1) Prepare a series of tools used and set up measuring instruments in the wind tunnel.
2) Set the direction of the pitot tube using a potentiometer and a switch button connected to the servo.
3) Turn on the drive motor in the wind tunnel and adjust the frequency to get a data reading of 0.25 m/s on the measuring instrument.
4) Record the readings obtained from the Arduino.
5) Repeat from step 3 by increasing the wind speed by 0.25 m/s until it reaches 5 m/s.
6) After the data is completely obtained, the data is entered into the equation in the Arduino program to obtain the wind speed data.

2.3.2. Test

After calibrating the tool, then carry out testing to find out whether the test tool is functioning properly or there are errors, as follows:

1) Prepare a series of test tools.
2) Turn on the motor in the wind tunnel by setting the motor frequency to 25 Hz.
3) Retrieve the data obtained from the Arduino reading.
4) Repeat the test in stage 2 by only increasing the motor frequency by 1 Hz to 50 Hz.
5) Turn off the motor in the wind tunnel and replace the test tool with the testometer.
6) Restart the motor and set the motor frequency to 25 Hz.
7) Retrieving the data obtained from the testometer reading.
8) Repeat the test in step 6 by only increasing the motor frequency by 1 Hz to 50 Hz.
9) Comparing the data results from the two tools.

3. RESULTS AND DISCUSSION

A pitot tube is used to measure the wind speed in the wind tunnel in the test section. The pitot tube is connected to 2 servos, where the lower servo moves the pitot tube to the right and left. Also, the top servo to move the pitot tube up and down. Both servos are intended to steer the pitot tube in the same direction as the wind speed in the wind tunnel. two servos have two drive systems, which are macro and micro. The purpose of having two propulsion systems is to determine the pitot tube's direction so that it can be in the same direction as the wind speed. Then, the use of steel plates as poles, so that there is no obstacle to the wind speed in use steel plates as poles, so the wind tunnel.

The design has a height of 25 cm from the center hole point of the pitot tube to the bottom of the support column. The height is obtained from the following calculations if height of the test section = 50 cm:

$$\text{Tool height} = \frac{\text{height of the test section}}{2} \qquad (2)$$

$$\text{Tool height} = \frac{50\text{ cm}}{2} = 25\text{ cm}$$

The determination of the height of this measuring device is based on the placement of the trial model at the center point of the test section. Therefore, the height of this gauge is half of the test section, so the data obtained is the same as the wind speed that hits the experimental model.

3.1. Calibration Data

The data from pitot tube testing results with a wind tunnel measuring tool to calibrate the tool are as shown in Table 1. From Table 1 data tests were carried out by determining the wind speed in the wind tunnel. A testometer is used to determine wind speed from 0; 0.25; up to 6.5 m/s. From determining the wind speed, ADC (Analog to Digital Converter) data is obtained from the Arduino, from this data the curving method can be used to obtain equations that will be used in pitot tube programming.

Table 1. Calibration result data.

No.	Pitot Tube (mV)	Testometer (m/s)
1	529	0
2	530	0.25
3	531	0.5
4	532	0.75
5	533	1
6	534	1.25
7	535	1.5
8	536	1.75
9	537	2
10	538	2.25
11	539	2.5
12	540	2.75
13	541	3
14	542	3.2
15	543	3.5
16	544	3.75
17	545	4
18	546	4.25
19	547	4.5
20	548	4.75
21	549	5
22	550	5.25
23	551	5.5
24	552	5.75
25	553	6
26	554	6.25
27	555	6.5

3.2. Test Result Data

After calibrating the instrument, run a test by comparing the data results, between the pitot tube and the testometer. Tests were conducted in a wind tunnel at the test section. From Table 2, explains the tests carried out by determining the frequency value of the tunnel fan motor, with a value of 25 to 50 Hz.

Data was obtained from reading wind speed measuring instruments using pitot tubes and calibrated test instruments. The test is carried out by determining the frequency of the wind tunnel motor. The test was carried out 26 times, with frequencies ranging from 25 Hz to 50 Hz. The data obtained shows a slight difference in the reading between the pitot tube and the test tool. There is also reading data that has the same speed value from the pitot tube as the gauge. There is a possibility of influence from the difference in reading results when measuring the wind speed in the wind tunnel.

Table 2. Test result data.

No.	Frequency (Hz)	Testometer (m/s)	Pitot Tube (m/s)
1	25	3.07	3.05
2	26	3.16	3.13
3	27	3.28	3.27
4	28	3.42	3.42
5	29	3.53	3.52
6	30	3.67	3.69
7	31	3.73	3.74
8	32	3.8	3.8
9	33	4	4
10	34	4.1	4.11
11	35	4.16	4.15
12	36	4.27	4.29
13	37	4.37	4.37
14	38	4.47	4.48
15	39	4.62	4.62
16	40	4.73	4.7
17	41	4.76	4.76
18	42	4.88	4.86
19	43	4.98	4.98
20	44	5.07	5.1
21	45	5.19	5.19
22	46	5.25	5.25
23	47	5.37	5.36
24	48	5.45	5.45
25	49	5.52	5.52
26	50	5.55	5.55

3.3. Pitot Tube Calibration

The Curving method is a method that uses a curve to process previously obtained data, to obtain x and y values. The following Figure 5, is the result of the calibration curve.

This calibration graph is obtained from testometer readings with pitot tubes placed side by side in a wind tunnel. This calibration aims to match the displayed data with the original. From this calibration, the formula for the Arduino program is derived which is:

$$y = 0{,}25x - 132{,}25 \quad (4)$$

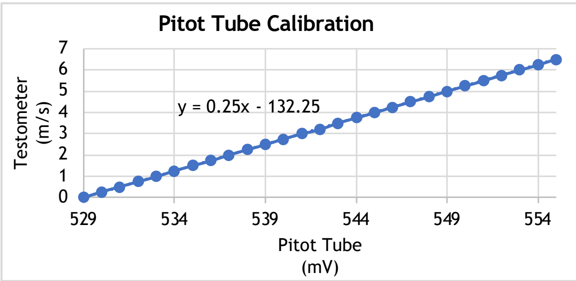


Figure 5. Pitot tube calibration.

This equation can be entered into an Arduino program to calibrate the readings from the pitot tube. Where the y value (velocity) will be obtained by multiplying the x value (ADC on the pitot tube) by 0.25 then subtracting 132.25. The result of this equation is wind speed data. the above results are obtained from a simple regression equation, along with equation (5):

$$Y = a + bX \quad (5)$$

3.4. Comparison Chart

Figure 6 shown the comparison diagram of the readings of a wind speed measuring device using a pitot tube and a testometer. The comparison is seen from the results of wind speed readings which are determined by the frequency on the wind tunnel motor. Frequency is used to regulate the speed of the wind tunnel motor.

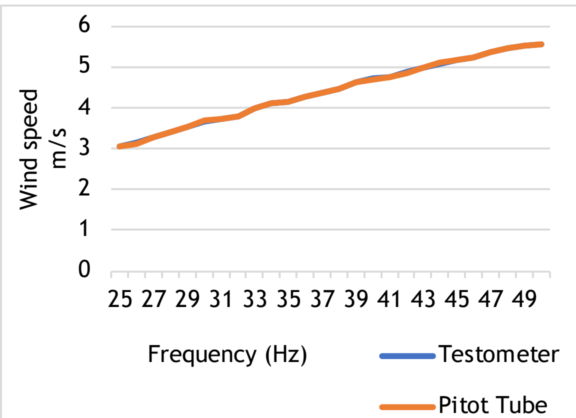


Figure 6. Results diagram comparison pitot tube with testometer.

The data obtained from the graph above is a comparison taken by determining the frequency used. From the wind speed data obtained using the frequency of 25-50 Hz, overall, in the Results Diagram Comparison pitot tube with testometer there is only a slight difference, and only at the frequency of 35 and 37 Hz is there a visible difference. From the graph (Figure 6), it can be concluded that the study results are appropriate because there is only a slight difference with the reading on the reference tool (testometer).

In research by Kurniayanto et al. tests were carried out in a low subsonic wind tunnel with speed limits from 5 m/s to 50 m/s (Kurniyanto *et al.*, 2022). The test of this research is by comparing the reading results from calibrated anemometers. From the results of this comparison, there were no deviations in the wind speed measurement readings. While in research tests were carried out in a low subsonic wind tunnel. The test of this research is by comparing the reading results from calibrated anemometers. From the data obtained, there are differences ranging from 0 to 0,71 m/s compared to the anemometer.

4. CONCLUSION

The conclusion obtained from this research is that the data on the comparison graph shows that the pitot tube that measures wind speed already has readings that are almost close to the readings from the reference measurement (testometer). In this study the level of difference ranged from 0 to 0,03 m/s. This means that this measuring instrument can be used to measure wind speed in a wind tunnel.

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