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# *Design and Testing of Drag and Lift Measurement Tools for Low Wind Speed Wind Tunnels*

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## *ABSTRACT*

*Science and technology are constantly advancing in every era, much like aerodynamics. At Sultan Ageng Tirtayasa University, there is one Renewable Energy Engineering Lab that has a wind tunnel but lacks equipment to measure drag and lift forces. Therefore, researchers have developed a measurement tool for these forces. There are a few steps that need to be taken in order to finish this research project. These include a literature review, design work, and experimental studies, which include calibration testing to determine the gauge R&R values and direct performance testing with the NACA S1046 airfoil. The calibration results showed the highest standard deviation for drag force to be 0.25 and for lift force to be 0.8. For drag force testing, the gauge R&R value was found to be 0.678%, and for lift force testing, it was 1.828%. These values are below 10%, indicating that this measurement tool is acceptable based on the Gauge R&R variance study criteria. This measurement tool can be considered acceptable. During testing with the NACA S1046 airfoil, the measurement tool performed well at speeds ranging from 1 to 5 m/s because the standard deviation was not too large, whereas at a speed of 6 m/s there was a tendency for a high standard deviation in lift force. This measurement tool can be used with a maximum test object weight of 0.7 kg.*

**Keywords:** *Airfoil, Drag and Lift Force Measurement, Drag Force, Lift Force, Naca S1046, Wind Tunnel.*

## 1. INTRODUCTION

Science and technology are constantly evolving in every era, from technology in industry to automotive, construction, and so on. A lot of such technology requires aerodynamics, for example, aerodinamics testing on car bodies, high buildings, bridges, airplanes, and others that must be subjected to the style due to the flow of wind passing through the so-called Aerodynamic style
Several methods can be used to study the aerodynamic styles that occur in an object, including the theoretical method, the experimental method, and the simulation method.

When objects are tested in the wind tunnel, they come in two types drag and lift force. These styles can be obtained by using the drag and lift measurement tools. Based on the conditions of the wind tunnel instruments available in the REBT Laboratory, this unit does not currently have the capability to measure drag and lift force, which limits the students' ability to perform these tasks. Therefore, tools are needed to measure the strength of the drag and lift to develop the existing facilities in the wind tunnel.

A wind tunnel is a device used in aerodynamic research to study the effects of air moving through solid objects. The wind tunnel is also used to simulate the actual condition of an object that is under the influence of aerodynamic styles. [1].

Aerodynamics is a science that studies the properties of objects that are influenced by air flow. Aerodynamic forces are generated due to the pressure distribution and shear stress distribution on the surface of an object, which can produce drag force, lift force, side force, and force due to air vortices (turbulence force).[2].

Drag Force in aerodynamics is a condition in which there is a push backwards due to a wind disturbance, or in another sense, drag force is the amount of external pressure in a fluid flow that is opposed to the direction of movement of an object and caused by a turbulent air flow so as to counter the motion forward around an object. [2].

Lift force is a type that occurs as a result of a difference in the distribution of pressure on the upper and lower surfaces of an object, and the pressure distribution on this surface follows the Bernoulli equation that in a location with a high flow speed the pressure will be low, whereas on a low speed side the pressure produced will be high.[3].

Measurement System Analysis or MSA is a set of experiments of measurements, procedures, and standards used to evaluate measurement systems such as capabilities, and performance. [4]. This MSA is applied to detect inaccuracies in a measurement system. [5]. A method that can be used to obtain repeated measurements with the same operator as well as measurement results with different operators by using the method of gauge repeatability and reproducibility, abbreviated to gauge R&R.

Gauge R&R method is used to evaluate and also ensure the reliability of measuring instruments in the measuring system. Repeatability is a variation of a measurement obtained using the same measuring instrument to measure the same object repeatedly, performed by the same operator.[6]. Variation studies are used to evaluate variations related to the measurement system, as well as provide an overview of how variable the measuring system is, so with variation studies can ensure that measuring instruments can provide consistent and reliable measuring results..

In the decision-making of acceptable or not a measurement instrument there is a cirteria based on the percentage of study variance which is as follows:.

1. If the percentage value of the study variance total R&R gauge is less than equal to ≤ 10% then the measurement system can be said acceptable If the percentage value of the study variance total R&R gauge is less than equal to ≤ 10% then the measurement system can be said acceptable [5].
2. If the percentage value of the study variance total R&R gauge is in the range of 10% to 30% then the measurement system can be said to have been acceptable under certain conditions [5]
3. If the percentage value of the study variance total of the R&R gauge is greater than >30%, then the measurement system is unacceptable and requires improvements to the measuring system. [5].

## 2. RESEARCH METHODS

The research methodology in this study contains several parts such as flow diagrams, phases of the research, component schemes, experiment setups, tools and materials, and data retrieval. The flow diagram in this study is shown in Figure 1 below.

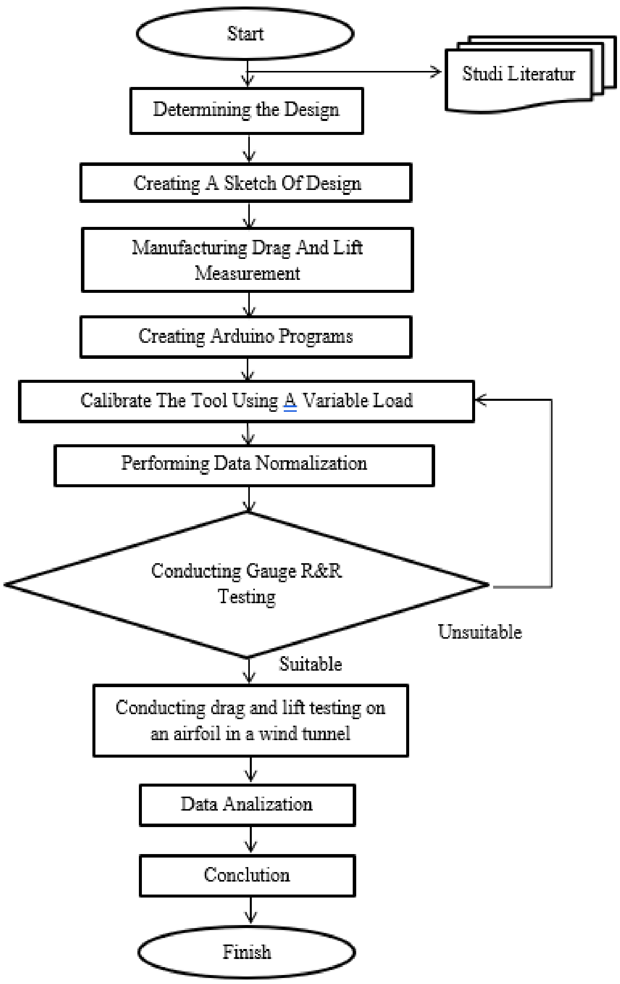

**Figure 1** Flow Diagram

The activity in this research is initiated by determining the design of the desired form by searching for references from several available research sources. Then create a sketch of the design of the device measuring the drag and lift force. Then do the process of manufacturing the device according to the plan. Once the tool mechanism is done, then make the arduino program read the drag force and lift force. The next step is to calibrate the tool by testing the tool using a variable load, then entering the value that appears in MS Excel. After everything's done, make the equation to normalize the data. Then test the gauge R&R readings using the airfoil test object, if it does not meet the variation study criteria, then re-fix the calibration, if the criteria are met, then proceed with the performance test of the device using airfoils in the wind tunnel, then analyze the data obtained and conclude the results of this study.

2.1. Stage of Research

As for the stage of research used in this study, it is as follows.

1. Library Study

   This library study is done by looking for references from several sources of research that have been conducted on the study of the drag and lift force on an aeordinamic test of a test object..

2. Design Study

   This design study was carried out by designing the mechanisms of the drag and lift measurements so that it can read the force of drag and lift.

3. Experimental Study

   The experimental study was carried out using calibration using variable loads in the direction of drag and lift, after which the read value was adjusted to the given load. Then test the performance of this device using the airfoil on the wintunnel.

2.2. Component Scheme

In the design of this measuring instrument, there is a scheme of measuring instruments that can be seen in Figure 2 below.

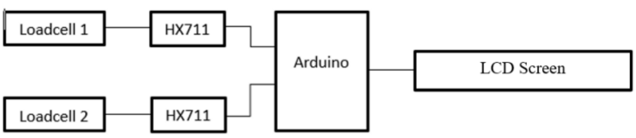


**Figure 2** Component Scheme

On this drag and force measurement tool there are several electronic components such as loadcell, HX711 module, arduino, and LCD screen. The design scheme of the components can be seen in Figure 2, on the image there are 2 loadcells connected to each HX71 module and then the two HX7211 modules are connected with the arduinos as input signals to be processed by the Arduino..

2.3. Eksperiment Setup

There are two kinds of experimental setups: the calibration setup and the testing setup. That is as follows:

1. Calibration Setup

   The calibration set-up scheme can be seen in Figure 3 below, which is the calibrating process by giving the load in the direction of the drag and lift, where the load has a variable mass. The load is used to simulate the condition at the time the test object is experiencing a drag and lift during the test..

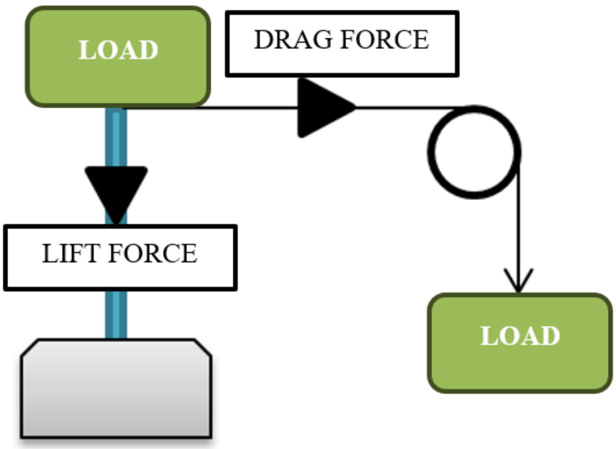


**Figure 3** Calibration Setup Scheme

In the lift force calibration process, the load is placed parallel to the measuring tool bar, whereas for drag force calibrating, the mechanism is required as in Figure 3, i.e. using a rope connected between the ends of the bar and the load, so that the weight of the load will be the same as the given drag force.

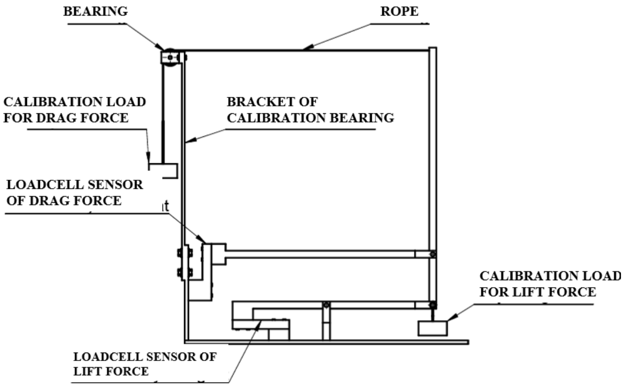


**Figure 4** Design of Setup Calibration

The design of setup calibration is in Figure 4, which requires a special mechanism to obtain the drag force, whereas for the load of the lift force it is placed at the bottom of the rod in order to a more stable style.

2. Test Setup

To set up the test, it is done directly in the wind tunnel, exactly in the test section, as shown in figure 5 below..

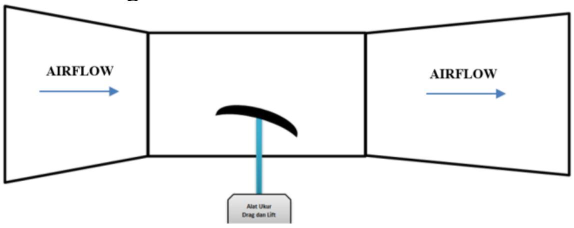


**Figure 5** Test Setup Scheme

For the test setup plan, see figure 6 below.

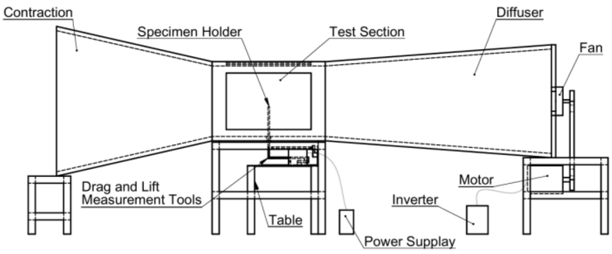


**Figure 6** Test Setup Plan

In figure 6, place the drag force and lift force measurment instruments on the test section, while the other parts of the mechanism are outside the testing section, this is intended to reduce the negative influence if the measuring instrument is in the Test section. The measuring instruments are placed on a table separated by the wind tunnel, with the aim of reducing the influence of vibration during wind tunnel operation.

The measuring instrument has parts like those in figure 7 below..

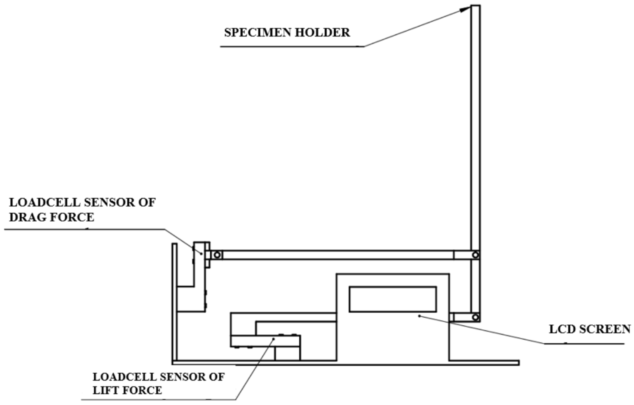


**Figure 7** The parts of the drag force and lift force measurement

2.4. Tools and Materials

The tools and materials used in this study are as follows:.:

1. *Wind tunnel*
2. Drag and lift measurement
3. Testometer
4. Airfoil Naca S104
5. Variable load
6. Loadcell
7. Modul HX711
8. Arduino
9. LCD

2.2 Data Acquisition

In this study, there are two types of data acquisition that are performed, namely, as follows:

1. Calibration Data Acquisition

   The calibration process is performed to compare the given load with the value read by the device. Data collection at the time of this calibrating is done using weight variations of 10 gram, 20 gram, 30 gram, 40 gram, 50 gram, 60 gram, 70 gram, 80 gram, 90 gram, and 100 gram and data is obtained as much as 30 data on each lift and drag force..

2. Test Data Acquisition

   Data acquisition at the time of this test was performed to test the stability of the repetition in the measurement. This data was collected using an airfoil on a wind tunnel with variations in wind speed of 1 m/s, 2 m/s, 3 m/s, 4 m/c, 5 m/s, and 6 m/s. The data obtained from this measurement is the drag and lift force.

2.3 Research Procedure

In this study, there are two types of data Acquisition: the calibration process and the testing process. Therefore, the research procedure for this study is as follows:.

A. Calibration Procedure

At the calibration stage of this measurement system, can be done with the following steps.

1. Set up drag and lift measurement and the calibration support equipment.
2. Set up drag and lift measurment with a set of calibrations set up as shown in Figure 3
3. Turn on the drag and lift measurment and wait until the LCD display shows a 0 for the drag and lift values.
4. Perform the calibration acquisition of the drag force data by placing a 10 grams split load on the part of the drag force.
5. Record the values of the drag force that come out on the LCD screen on the excel microsft.
6. Repeat steps 4 and 5 by adding a load variation of 10 grams up to a load of 100 grams, then repeat the load data of 0 grams to 100 grammes 30 times.
7. Perform the calibration acquisition of the lift force data by placing a 10 grams split load on the part of the drag force.
8. Record the values of the lift force that come out on the LCD screen on the excel microsft.
9. Repeat steps 7 and 8 by adding a load variation of 10 grams up to a load of 100 grams, then repeat the load data of 0 grams to 100 grammes 30 times.
10. Do data normalization in microsoft excel.
11. Do data analysis of calibration results.

B. Test Procedure

At the testing procedure of this drag and lift measurement, it can be done with the following steps:

1. Prepare the drag and lift measurement instruments, as well as their supporting instruments.
2. Assemble the measurment instrument in accordance with the test setup in Figure 7.
3. Place the test object (airfoil) in the desired position on the laying part of the test objects on the drag and lift measurement.
4. Turn on the measuring device and wait until the LCD display shows a zero on drag and lift force value.
5. Set the initial lifti load using a 200-gram split load.
6. Record the drag and lift value that appears on the LCD screen as data at a speed of 0 m/s.
7. Turn on a wind tunnel at a rate of 1 m / s.
8. They recorded the values that appeared on the LCD for 6 minutes.
9. Repeat steps 6 and 7 by increasing the speed variation by 1 m/s to a speed of 6m/s.
10. When you're done recording, tap the drag and lift measurements, and tap the wind tunnel
11. Recorded drag and lift force values based on recordings from the second to the six minutes every 10 seconds ranging from 0 m/s to 6m/s in microsoft excel.
12. Analysis of the data obtained from the tests.

## 3. RESULT AND DISCUSSION

### 3.1 Scheme Design

The scheme design on the study of the drag and lift measurement instrument includes a number of things, namely the following::

1. Design Drag And Lift Force Measurement.

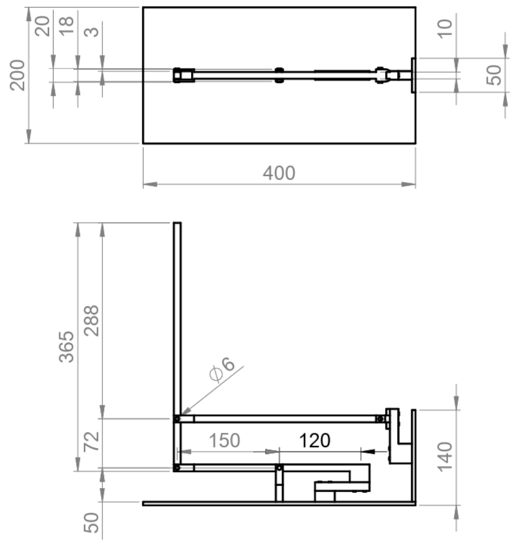


**Figure 1** Desain Drag And Lift Force Measurement

From the design of the measuring instrument in figure 4.1 above, there is a mechanism for reading the drag force and lift fotce which can be described as follows:

a) Mechanisms of Lift Force

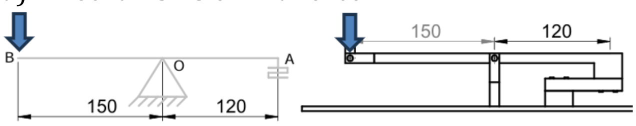


**Figure 2** Mechanisms of Lift Force

From figure 2 above, it's a mechanism for reading the lift force and its dimensions. Point a is the loadcell sensor reading point, and point b is the test load point. This measuring device uses a loadcell with a maximum load specification of 1 kg or 10 N. So the initial load of the object that can be tested with this measuring instrument can be calculated using a comparison of the length of the ao bar and the ob bar as in figure 2 with the following calculations.

Known :
$F_B$ (loadcell) = 10 N
$L_{OB}$ = 150 mm
$L_{AO}$ = 120 mm

Answer :

$$\boldsymbol{F_A . L_{AO} = b . L_{AB}}$$
$$\boldsymbol{10 . 120 = F_B . 150}$$
$$\boldsymbol{F_B = 8N.}$$

The maximum load at point b is 8 N, because there is an additional load if the lift force is experienced, then 1 N is reduced. So the initial load of the object to be tested is 8 – 1 = 7 N or 0.7 kg.

b) Mechanisms of Drag Force

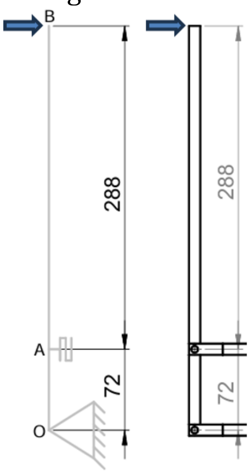


**Figure 3** Mechanisms of Drag Force

From figure 3 above, it's a mechanism for reading the drag force, point A is the point of the loadcell sensor reading, and point b is the test load point. This measurement also uses A loadcell with a maximum load specification of 1 kg or 10 N. So the maximum drag force that can be measured with this measuring instrument can be calculated using a comparison of the length of the ao bar and the ob bar as in figure 3 with the following calculation.

Diketahui :
$F_B$ (loadcell) = 10 N
$L_{OB}$ = 72 mm
$L_{BO}$ = 350 mm

Maka :

$$\boldsymbol{F_A . L_{AO} = b . L_{AB}}$$
$$\boldsymbol{10 . 72 = F_B . 350}$$
$$\boldsymbol{F_B = 2,05N.}$$

So the drag force that can be measured is 2.05 N. From the above drawing, the manufacturing process to make the device, and the result can be seen in Figure 4.4 below.

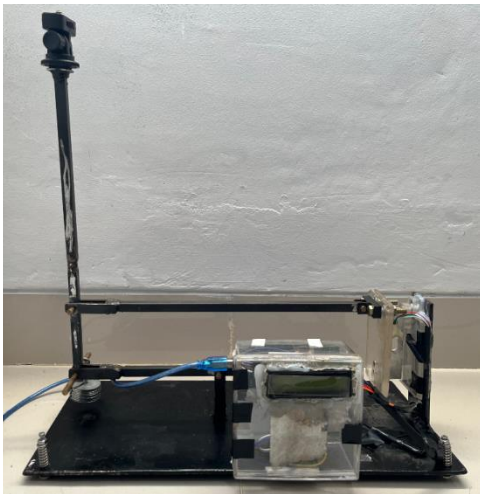

**Figure 4** Manufacturing Result of Drag and Lift Force Measurement

2. Design Calibration Drag and Lift Force Measurement

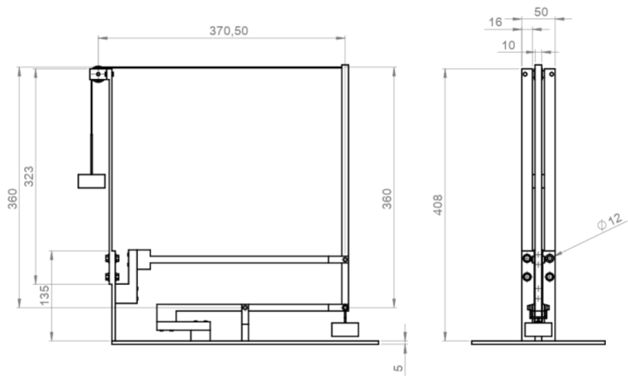


**Figure 5** Design of Calibration Setup

The design of the calibration setup as shown in Figure 5. This calibrating setup requires an additional bracket as a bearing or cylinder with an adjustable bracket height so that the rope used for calibrations can be upright with the bracket of the test object, this is done to give a load on the part of the drag force to be calibrated. The results of the manufacture of this measuring instrument on the calibration setup can be seen in figure 6 below.

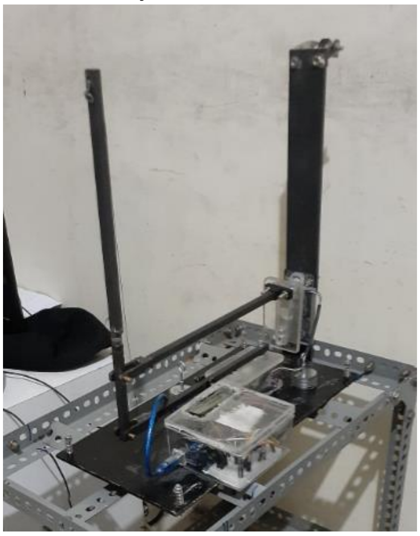

**Figure 6** Manufacturing Result of Calibration Setup

The manufacture set up calibration as in figure 4.6 contains additional auxiliary components in the calibrating process, i.e. there are loads, threads, bearings, bearing, as well as bars of the test object specially made to tie the rope in calibrations.

3. Table Design of drag and lift force measurement

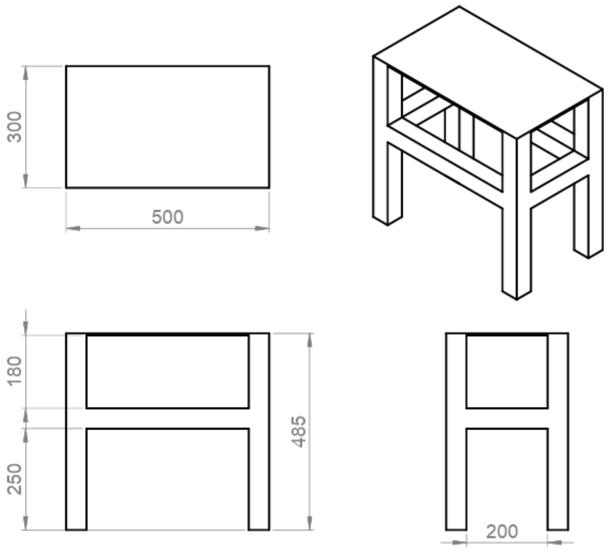


**Figure 7** Table Design

The design of the table as a place for the measuring instrument can be seen in figure 7. The size of this table has been adjusted to the height and dimension of the measurement instrument. Manufacture of the table of these measuring instruments can be seen in figure 8 below.

**Figure 8** Manufacturing Result of Table Drag and Lift Force

This table uses a hollow elbow plate that is easy to make a table with a size that can be customized and uses a bond type connection.

3.2 Bill of Material

In the research design construction of this measuring instrument there is a bill of material that can be seen in the following table

.

**Tabel 1** Bill of Material

| BILL OF MATERIAL | | | | |
|---|---|---|---|---|
| No. | Items | Unit | Price | Total |
| 1 | As Bulat Kuningan 6 mm | 2 | Rp10.500 | Rp21.000 |
| 2 | Loadcell 10 kg + HX711 | 2 | Rp46.000 | Rp92.000 |
| 3 | As Segi Empat 10 mm | 1 | Rp20.000 | Rp20.000 |
| 4 | Besi Plat 5×250×50 mm | 1 | Rp15.000 | Rp15.000 |
| 5 | Besi Plat 5×400×200 mm | 1 | Rp70.000 | Rp70.000 |
| 6 | Snap Ring E4 | 8 | Rp500 | Rp4.000 |
| 7 | Snap Ring E5 | 8 | Rp500 | Rp4.000 |
| 8 | Lcd 12×2 + I2c | 1 | Rp30.000 | Rp30.000 |
| 9 | Lem Dextone | 1 | Rp20.000 | Rp20.000 |
| 10 | Akrilik 8 mm 20×5 cm | 100 | Rp100 | Rp10.000 |
| 11 | Akrilik 5 mm 20×5 cm | 100 | Rp60 | Rp6.000 |
| 12 | Arduino | 1 | Rp200.000 | Rp200.000 |
| 13 | Breadboard | 1 | Rp10.000 | Rp10.000 |
| 14 | Kabel jumper male to male 40 pcs | 1 | Rp13.500 | Rp13.500 |
| 15 | kabel jumper male to female 20 pcs | 1 | Rp10.000 | Rp10.000 |
| 16 | Mata Bor 6 mm | 1 | Rp25.000 | Rp25.000 |
| 17 | Besi Siku Bolong 3 meter 1,3 mm | 6 | Rp95.000 | Rp570.000 |
| 18 | Plat Ambalan | 1 | Rp35.000 | Rp35.000 |
| 19 | Mounting action cam bicycle | 1 | Rp35.000 | Rp35.000 |
| 20 | Kaki meja adjuster | 4 | Rp5.000 | Rp20.000 |
| 21 | Baut dan Mur | 10 | Rp2.000 | Rp20.000 |
| 22 | Lem Tembak | 1 | Rp65.000 | Rp65.000 |
| 23 | isi lem tembak | 3 | 3000 | Rp9.000 |
| 24 | beban bercelah | 2 | 85000 | Rp170.000 |
| Amount | | | | Rp1.474.500 |

From table 1 above, you can see 24 items, and the total price is Rp. 1.474.500.

3.3 Analysis Data Calibration

Calibration data drag force and lift force using weight variations range from 10 grams to 100 grams, which we repeat up to 30 times. The data is divided into two parts, one for the results of the drag force calibration and the other for the results of the lift force calibration. At the bottom of the table, there is an average of 30 data taken, and there is a concentrate value obtained from the calculation of the average value divided by the given load value. The formula is as follows.

$$constant = \frac{Average}{Load}$$

For data drag force calibration and lift force calibrating as follows.

A. Drag Force Calibration Data Result

Data calibration of drag force can be seen in table 2 below

**Tabel 2** Drag Force Calibration Data (Without Normalizatioi)

| DRAG FORCE CALIBRATION DATA (WITHOUT NORMALIZATION) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 10 Gram | 20 Gram | 30 Gram | 40 Gram | 50 Gram | 60 Gram | 70 Gram | 80 Gram | 90 Gram | 100 Gram |
| AVERAGE | 59,43 | 119,33 | 179,20 | 239,10 | 298,60 | 359,30 | 420,47 | 480,37 | 539,97 | 599,90 |
| CONSTANT | 5,94 | 5,97 | 5,97 | 5,98 | 5,97 | 5,99 | 6,01 | 6,00 | 6,00 | 6,00 |

Table 2 shows the calibration data of drag force with weights from 10 grams to 100 grams. After obtaining 6 constant values for the calibration value, then it is necessary to look again for the average of the constant, the calculation is as follows.

$$Average\ constant = \frac{5{,}94 + 5{,}97 + 5{,}97 + 5{,}98 + 5{,}97 + 5{,}99 + 6{,}01 + 6{,}00 + 6{,}00 + 6{,}00}{10}$$

$$Average\ Constant = \frac{59{,}83}{10} = 5{,}98$$

Then get a constant of 5.98. This constant number is used to normalize the data in ms. excel after taking the data of drag force test with this measurement. From table 2 above, if the value of the constant is entered, then the data with the units of newton can be seen in table 3 below.

**Tabel 3** Drag Force Calibration Data (With Normalizatioi)

| DRAG FORCE CALIBRATION DATA (WITH NORMALIZATION) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 10 Gram | 20 Gram | 30 Gram | 40 Gram | 50 Gram | 60 Gram | 70 Gram | 80 Gram | 90 Gram | 100 Gram |
| AVERAGE | 9,94 | 19,96 | 29,97 | 39,98 | 49,93 | 60,08 | 70,31 | 80,33 | 90,30 | 100,32 |
| STD. DEVIATION | 0,19 | 0,17 | 0,13 | 0,18 | 0,15 | 0,17 | 0,20 | 0,21 | 0,21 | 0,25 |

From the data in table 3 above there are some graphs of the average value and the standard deviation. For the graph, you can see on figure 9 as follows.

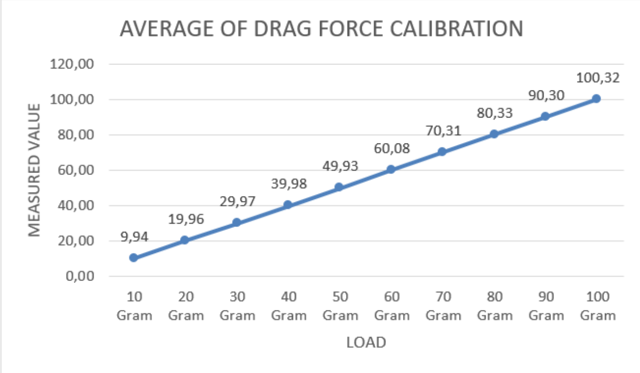


**Figure 9** Diagram Average of Drag Force Calibration

From the above diagram figure, it can be seen that the readings of the load value with the given load relative straight between the two, so this measurement can be specified good measurent. From the same data is also obtained the standard deviation diagram on figure 10 below.

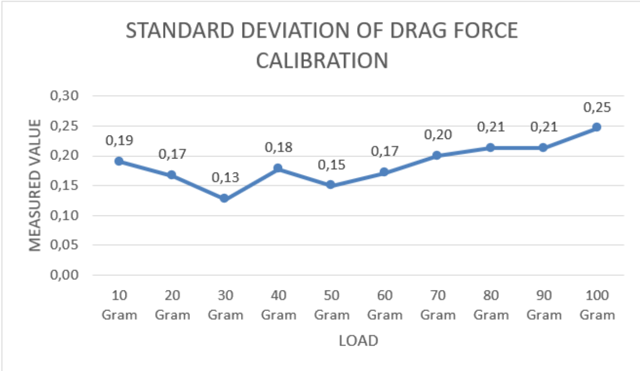


**Figure 10** Diagram Standard Deviation of Drag Force Calibration

From the diagram figure above is the standard calibration deviation of the drag force with the weighting of 10 grams to 100 grams. It can be seen that the minimum standard deviation is at 30 grams, and the highest is at 100 grams. While on 10 to 70 grams of weighing there is a standard deviation below 0.20, then of that drag force test with perfect value there is on 10 grams to 70 gram of weights.

Based on table 3, which is the result of normalized drag force testing data, then can be performed Gauge R&R test by finding percentage value of study variance of the data that can be seen in the following table.

**Tabel 4** Gauge R&R of Draf Force

| % Proses Variasi | Study Var | % Study Var |
|---|---|---|
| Repeatability | 0,992171 | 0,678% |
| Reproducibility | 0,001581 | 0,001% |
| R&R | 0,992172 | 0,678% |

From the data in table 4 above it can be seen that the percentage value of the study variance in the drag force test is 0,678% and according to the criterion of the percent study variation values are below 10%, so measurements in this drag force type is acceptable.

B. Lift Force Calibration Data Result

Data calibration of drag force can be seen in table 5 below.

**Tabel 5** Lift Force Calibration Data (Without Normalizatioi)

| LIFT FORCE CALIBRATION DATA (WITHOUT NORMALIZATION) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 10 Gram | 20 Gram | 30 Gram | 40 Gram | 50 Gram | 60 Gram | 70 Gram | 80 Gram | 90 Gram | 100 Gram |
| AVERAGE | 30,63 | 60,53 | 90,43 | 120,90 | 150,70 | 181,10 | 211,67 | 242,00 | 272,37 | 303,17 |
| CONSTANT | 3,06 | 3,03 | 3,01 | 3,02 | 3,01 | 3,02 | 3,02 | 3,03 | 3,03 | 3,03 |

Table 5 shows the calibration data of lift force with weights from 10 grams to 100 grams. After obtaining 6 constant values for the calibration value, then it is necessary to look again for the average of the constant, the calculation is as follows

$$Average\ Constant = \frac{3{,}06 + 3{,}03 + 3{,}01 + 3{,}02 + 3{,}01 + 3{,}02 + 3{,}02 + 3{,}03 + 3{,}03 + 3{,}03}{10}$$

$$Average\ Constant = \frac{30{,}26}{10} = 3{,}02$$

Then get a constant of 3,02. This constant number is used to normalize the data in ms. excel after taking the data of lift force test with this measurement. From table 5 above, if the value of the constant is entered, then the data with the units of newton can be seen in table 6 below

**Tabel 6** Lift Force Calibration Data (With Normalization)

| LIFT FORCE CALIBRATION DATA (WITH NORMALIZATION) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 10 Gram | 20 Gram | 30 Gram | 40 Gram | 50 Gram | 60 Gram | 70 Gram | 80 Gram | 90 Gram | 100 Gram |
| AVERAGE | 10,14 | 20,04 | 29,94 | 40,03 | 49,90 | 59,97 | 70,09 | 80,13 | 90,19 | 100,39 |
| STD. DEVIATION | 0,52 | 0,43 | 0,50 | 0,73 | 0,69 | 0,68 | 0,45 | 0,61 | 0,53 | 0,80 |

From the data in table 6 above there are some graphs of the average value and the standard deviation. For the graph, you can see on figure 11 as follows..

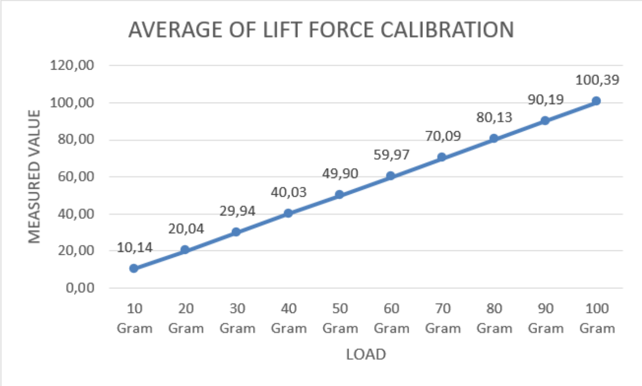


**Figure 11** Diagram Average of Lift Force Calibration

From figure 11 above, it's a average of the calibration on the lift force. It can be seen that the measurement of the value of the load with the given load is relative to the straight between the two, so this measurement can be specified good measurent. From the same data above is also obtained the standard deviation diagram on figure 12 below

.

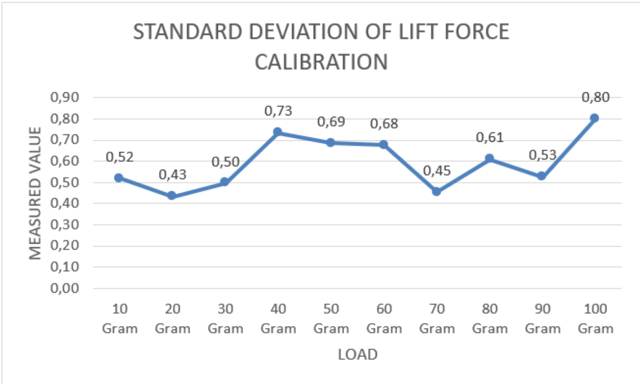


**Figure 12** Diagram Standard Deviation of Lift Force Calibration

From the diagram figure above is the standard calibration deviation of the lift force with the weighting of 10 grams to 100 grams. It can be seen that the minimum standard deviation is at 20 grams, and the highest standard deviation data is at 100 grams. While on weighing 10 to 30 grams as well as 70 grams and 90 grams have the standard deviation below 1.5, then of that lift force with perfect meaurement is on weights 10 grams to 30 gram, as well 70 gram, and 90 gram.

Based on table 6, which is the result of normalized lift force test data, then can be performed Gauge R&R testing by finding percentage value of study variance of the data that can be seen in the following table.

**Tabel 7** Gauge R&R of Lift Force

| % Proses Variasi | Study Var | % Study Var |
|---|---|---|
| Repeatability | 2,971501 | 1,827% |
| Reproducibility | 0,054015 | 0,033% |
| R&R | 2,971992 | 1,828% |

From the data in table 7 above it can be seen that the percentage value of the study variance in the lift force test is 1,828% and according to the criterion of the percent study variation values are below 10%, so measurements in this lift force type is acceptable.

C. Analyze Test Data Result

Acquisition of test data using a NACA S1046 airfoil object with a 7 degree attack angle and 30 data. Average diagram of the test data results is as follows:.

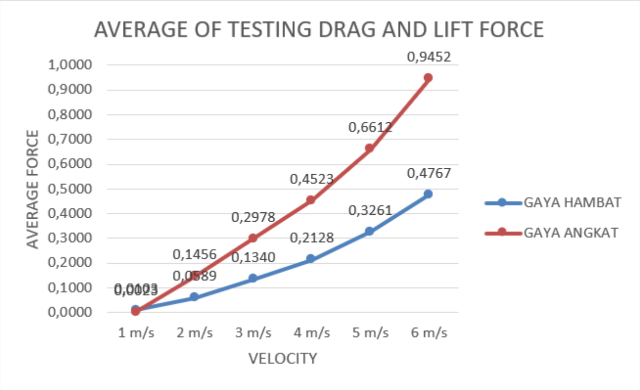


**Figure 13** Average of Testing Data with Airfoil Naca S1046

From figure 13 above is a diagram of the drag and lift force test. It can be seen that the curves on the drag force and lift force diagram have the same shape as the elevation of the style value by the great speed. At a speed of 1 m/s the drag and lift tend to be the same, but the higher the wind speed, the higher force value is the lift force. Therefore, this S1046 naca airfoil, which is set at an angle of 7 degrees, has a higher lift force value than drag force from speeds of 2 m/s to 6m/s. Then the standard deviation diagram can be seen in figure 14 below.

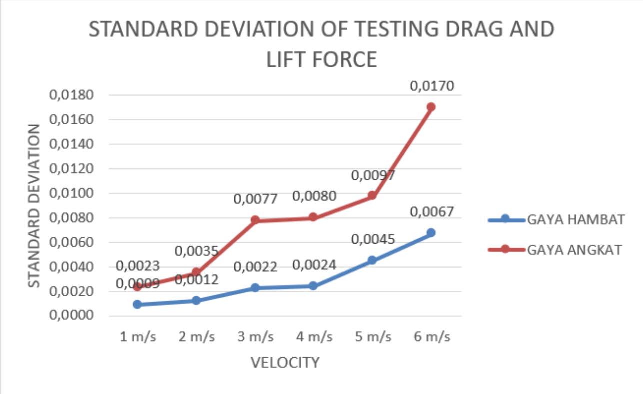


**Figure 14** Diagram of Standard Deviation Testing with Airfoil Naca S1046

From figure 14 above is the standard deviation of the drag force and lift force test results of the airfoil naca S1046. Based on the drag force curve, the standard deviation appears to be low, maximum standard deviation value of drag force is at a speed of 6 m/s, which is 0.0067, whereas the maximum standard deviation value of lift force is at 6m/s that is 0.0170.

So the conclusion of the analysis test data reasult of the drag and lift force by airfoil type naca S1046 is the best measurement at speeds 1 to 5 m/s because at such speeds the standard deviation is not too big, while at a speed of 6 m/s already has a standard deviations on the lift force that tends to be high, so that it has a large spread of measuring data against the average values of the measuring results.

## 4. CONCLUSION

Based on the results of the research, the conclusions and advice are obtained.

The conclusions of this research are as follows:.

1. The drag and lift force measurement device uses a loadcell sensor with a capacity of 10 kg and uses arduino as a sensor reader. This measurment system has a maximum load capacity for the test object of 0.7 kg or 7 N and a maximum drag force of 2.05 N according to the reading mechanism calculation.
2. The performance of drag and lift force measurement in the calibration process has a small standard deviation of less than 0.25 at the drag force and below 0.8 at the lift force. Then in the test of the Gauge R&R where the percentage value of gauge R&R in the drag force is 0.678% and the percentual gauge R&R value in the lift force is 1.828%, According to the variation study criteria it still below 10% so that this measurement system can be said acceptable.. Then in testing using

the airfoil S1046, the measurment system has the best measurements at speeds 1 to 5 m/s because the standard deviations are not too high, whereas at the speed of 6 m/s it already has the standard deviation in the lift force that to be high, so that it has a large spread of measuring data against the average value of the measured output.
3. SOP or standard operational procedures are guidelines in the operation of this drag and lift force measurement which can be attached to the SOP appendix.

Based on the findings of the study, here are some recommendations for future action:
1. Using a program that can be directly connected to show the measurement results to the computer to make it easier in deposition
2. On the axle part of the mechanism this tool can be modified by using a minimally frictional axle such as bearing or other.
3. This measurement system can be combined with other supporting tools to facilitate the acquisition data in research in wind tunnels, such as wind speed meters and smoke generator.
4. Using a more accurate loadcell sensor.

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