Verification Test of High Flap Macrofluidic Air Flow Sensor in Wind Tunnel

Mohamad Dzulhelmy bin Amari, Sukarnur Che Abdullah and Muhammad Imran Hafiz bin Ahmad Kamil

Abstract—This air sensor functioning to detect the speed of air surrounding while in motionor a sudden changes in its environment. The effect of fast detection of a security sensor through the high sensitivity of the airflow sensor has enabled the system to identify and analyze the critical condition in higher accuracy compared to the conventional of any security system. Previous studies have developed the macrofluidic air flow sensor that observed the air flow in higher accuracy while the sensor in motion will be verified by detection of high sensitivity in the relative velocity of the airflow sensor compared to a conventional sensor. An experimental investigation was conducted to verify macrofluidic air flow sensor in wind tunnel by control velocity of range (30 to 110 km/h). The result shows the characterization of the changes in voltage reading with respect to the airflow speed in the wind tunnel. Sensor 1 to 4 have been placed at 0 to 360 degree of orientation with respective of 90 degree space interval.

Keywords**: Air Sensor, Deflection, High Sensitivity, Speed Of Air.**

I. INTRODUCTION

Automated reaction from the system is most important in fulfilling the requirement of the intelligent control system. Hence, many related studies regarding developing the hardware of the system such as high sensitivity of the airflow sensor in detecting the changes either in user or the environment [1]. The effect of the fast detection of the sensor through the high sensitivity of the airflow sensor has enabled the system to identify and analyze the behavior of the user in higher accuracy compared to a conventional system.

This project focused in developing a standard procedure on how to verify the macrofluidic air flow sensor and verify the sensor data reading by the bending of the flap sensor in a controlled environment using wind tunnel. The primary concern of this studies is to make sure the improvement design as in the progress will not bad affecting the result for the future references. The current technologies shows there is no standard configuration of the airflow sensor, such due to the weather, environment, and even the material itself [2]. The design of the procedure must be specified because it will affect the result while conducting the verification of the macrofluidic air flow sensor.

Furthermore, by utilizing the Microelectromechanical System technology (MEMS) principal, a miniaturized and electro-mechanical element such as microsensor, able to convert measured mechanical signal into an electrical signal [3]. Providing it can be characterized into two categories which are thermal and non-thermal. The thermal concept, use hot wire or hot film to measure the direct air mass. However, the heat loss rate of the hot wire sensor depends on the velocity of the flow while the heating wire temperature is determined by the thermal equilibrium between heating and heat loss in the flow [4]. Thus, thermal concept resulted in inconsistent and inaccurate result. In contrast, using the non-thermal approach has a more favorable approach and lower power consumption. Using a mechanical working principle where the airflow can be directly measured by the drag force will produce a fixed result.

Hence, the sensitivity of the macrofluidic air flow sensor in detecting the changes in user or environment through real actual testing in a controlled environment needs to be done in proper procedure and correct parameters. This is related to the Malaysian speed limit between 30 to 110 km/h that has been set as one of the parameters [5]. More details concern is focusing more to the velocity of airflow used in order to increase the performance of airflow sensor, so that, the test of the macrofluidic air flow sensor must be done rapidly to make sure that the accuracy of sensitivity the sensor itself [6]. There are also a few major factors that need to be considered in doing the testing such as humidity, lighting and space to make sure the result is satisfying.

In order to achieve a high potential result which is consistent and accurate, our lab has designed an airflow sensor 3D printed using Polylactide, PLA material. Fabricated flex sensor used in the airflow sensor is to measure the amount of bending or deflection. The flex sensor has been attached to the flap sensor to get a reading of the voltage output of the bending deflection of the flap sensor [7]. The procedure and the verification of the macrofluidic air flow sensor will be made to archive this objective. Hence, this type of airflow sensor can give a huge impact in the future.

Fig. 1 to 3 shows the developed high sensitive airflow sensor consists of two region which is high and low velocity [8]. The region is covered with two types of flap structure to detect the airflow changes from the deflection. The airflow model also can cover 360 degree of incoming air in order to achieve better coverage of airflow changes.

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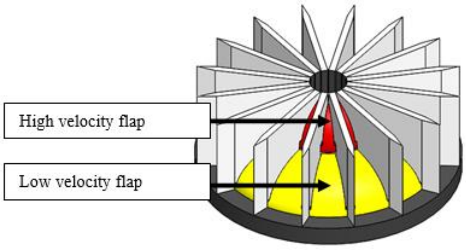

Fig. 1 Design casing of airflow sensor

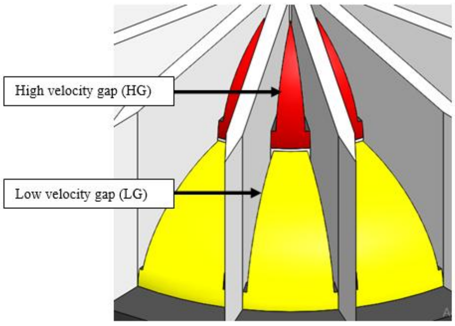

Fig. 2 Close up design of high velocity gap and low velocity gap

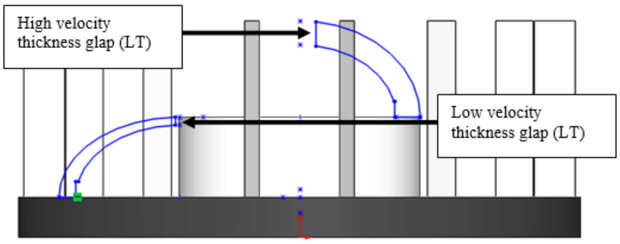

Fig. 3 Sketch of high and low velocity thickness flap

II. METHODOLOGY

A. Experimental Set Up

The table below shows that the speed, km/h was converted the speed of fan control for the wind tunnel which is used the dynamic pressure reading at manometer $\Delta P_1, mmH_2O$. A calculation will be made for the dynamic pressure reading parameter for the manometer to control the fan speed. The equation that will be used as follow:

$$V = \sqrt{\frac{2\times\Delta P_1\times 9.81}{\rho_a}} \text{ and } \rho_a = \frac{P_a\times 100}{RT_a} \qquad (1)$$

Where:

ΔP_1 = Dynamic pressure (mmH_2O)
V = Velocity ($m.s^{-1}$)
ρ_a = Local air density (kg/m^3)
T_a = Ambient air temperature (K)
P_a = Ambient atmospheric pressure (millibar)
R = Gas constant = 287 m^2/s^2K

Table- I: Proposed Data Collection Table In The Wind Tunnel Testing Stage

Speed, (km/h)	Velocity, V (m/s)	$\Delta P_1, mmH_2O$	Voltage Output, Vo (V)
0	0.0	0.0	
10	2.8	0.5	
20	5.6	1.9	
30	8.3	4.2	
40	11.1	7.5	
50	13.9	11.7	
60	16.7	16.9	
70	19.4	23.0	
80	22.2	30.0	
90	25.0	38.0	
100	27.8	46.9	
110	30.6	56.8	

B. Voltage Reader

This study indicates that the program writing based on the set up of high flap sensor with microcontroller programmed. The layout shown in Fig. 4 is set up with the high flap sensor connected to the microcontroller. Each of the flap sensors has a different resistance value that requires the different value of resistor of each own. The set-up has shown each of the high flap sensors connect in series with the resistor. To connect with the microcontroller, some other part is needed such as microcontroller, breadboard, high flap sensor and resistor.

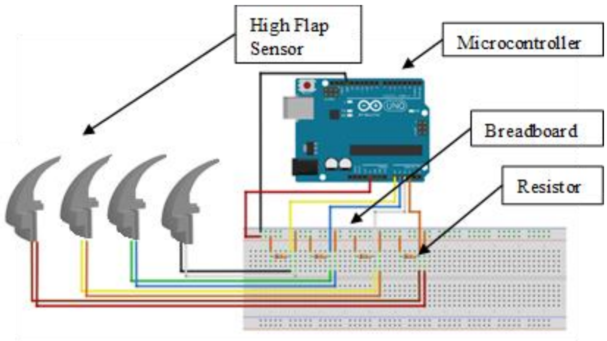

Fig. 4 Set up of Microcontroller Layout

Four units of high flap sensor connect to the microcontroller. By doing so, enable to collect data from the resistance of the flex of a flap when pushed by the air pressure. The data collected will show the speed of the wind recorded the sensor. By simply followed the circuit board, every data collected during the testing from the computer can be observed [9].

C. The Design Experimental Set Up to Verify Macrofluidic Air Flow Sensor in Wind Tunnel

The prototype of the air sensor will be tested in the AF100 Subsonic Wind Tunnel. This wind tunnel capable to match the air velocity from 0-36 m/s equivalent to 129.6 km/h. For design a procedure the study needs to be done in this process about the characteristics of the wind tunnel. The design of the procedure also needs to design how the air sensor can be placed on the working section on the wind tunnel.

Before the design of the attachment for the air sensor done, the working section on the wind tunnel have to be measured because the location of the air sensor in the working section is the main of study. The location of the sensor that will test in the wind tunnel will affect the result of the test because the flap sensor has a high sensitivity approach.

D. Verification of Sensor Voltage of Macrofluidic Air Flow Sensor in Controlled Environment

Based on the improvement of the macrofluidic air flow sensor and microcontroller programming of the sensor, the testing of the macrofluidic air flow sensor can be run to verify the voltage output. This experimental study will be evaluated to meet the second objective which is to verify the speed in a controlled environment versus sensor voltage value. Thoroughly procedure and proper method will be the product from this study for the use of future preferences.

III. RESULT AND DISCUSSION

A. Sensor Characterization

The optimization for the flap structure is very important in order to obtain more accurate result [10]. For this sensor characterization, Fig. 5 the high flap sensor has been indicated the airflow that covers the four entrance when one direction of air velocity applied.

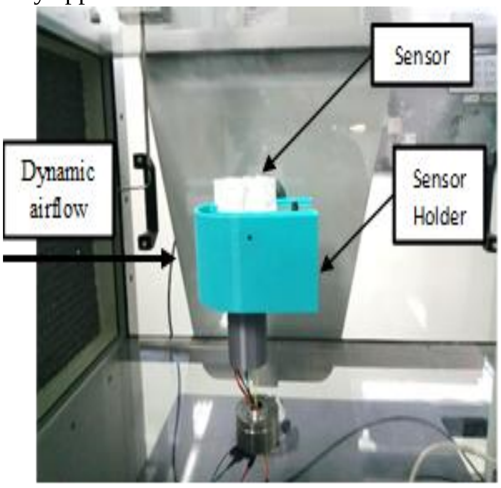

Fig. 5 Enclosure Area in Wind Tunnel

In other hand, the verification test of high flap sensor in Fig. 6 show that there are four locations of the high flap sensor that will test in wind tunnel which shows that the location A at angle 0°, location B at 90°, location C at 180° and location D at the 270°. For this case, the verification test has been changed into four locations for each high flap sensors to find voltage output of dynamic airflow in a wind tunnel. The verification test 1 will start with the high flap sensor 1 at the location A, high flap sensor 2 at location B, high flap sensor 3 at location C and high flap sensor 4 at the location D. The location of the flap sensor will rotate clockwise as the 90° for the next test as the high flap sensor 1 at the location B, high flap sensor 2 at the location C, high flap sensor 3 at the location D and the high flap sensor 4 at the location A. This verification test shows that when the sensor at the location A, high flap sensor will detect high sensitivity of the dynamic airflow in wind tunnel based on the laminar flow in the wind tunnel. [7]

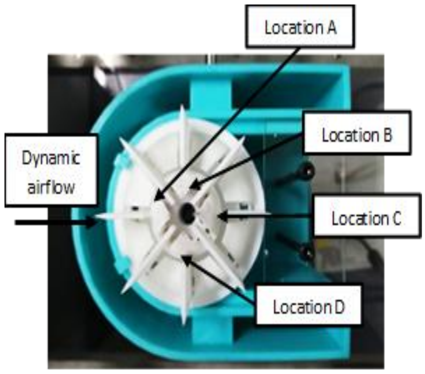

Fig. 6 Location of The High Flap Sensor

B. Verification of Sensor Voltage of Macrofluidic Air Flow Sensor in Controlled Environment

This project was used four flap sensors to undergo the verification stage in a controlled environment. Each sensor was tested for every location that state as Fig. 5.

Table- II: Sample Data For High Flap Sensor 1 At Angle 0°

	Voltage, V			
	Sensor 1	**Sensor 2**	**Sensor 3**	**Sensor 4**
Speed, km/h	**0 °**	**90 °**	**180 °**	**270 °**
0	**-13.2**	-13.1	-12.6	-13.3
10	**-13.6**	-13.1	-13.9	-13.0
20	**-13.3**	-12.8	-13.6	-13.0
30	**-12.2**	-13.7	-13.7	-13.6
40	**-11.9**	-13.9	-13.6	-13.8
50	**-11.8**	-13.1	-13.7	-12.7
60	**-11.2**	-14.1	-13.7	-13.6
70	**-10.8**	-14.0	-14.1	-13.9
80	**-10.2**	-14.2	-14.0	-13.9
90	**-9.8**	-14.3	-13.7	-14.0
100	**-9.2**	-14.6	-14.0	-14.2
110	**-8.4**	-14.3	-14.1	-14.0

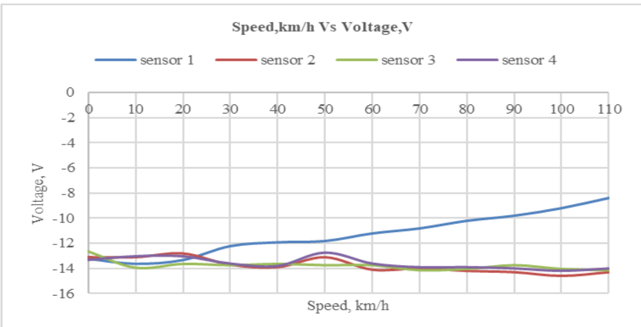

Fig. 7 High Flap Sensor 1 At the Angle 0°

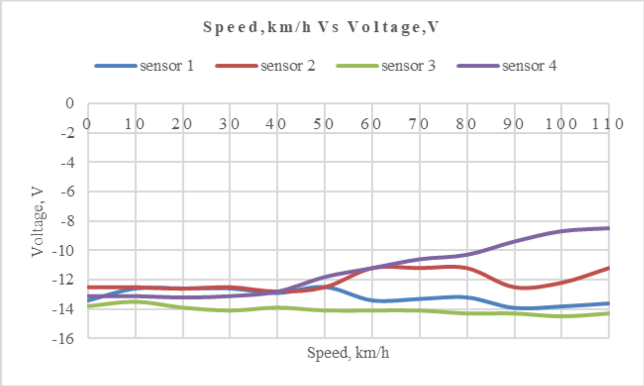

Fig. 8 High Flap Sensor 2 At the Angle 90°

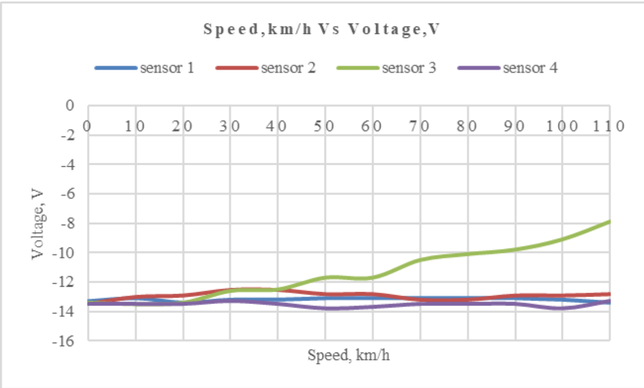

Fig. 9 High Flap Sensor 3 At the Angle 180°

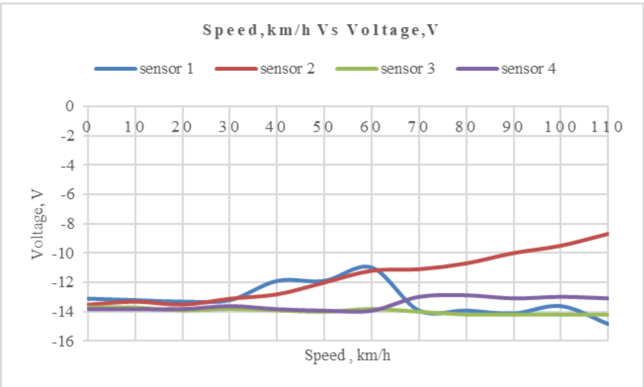

Fig. 10 High Flap Sensor 4 At the Angle 180°

All the four-flex sensor voltage output show that the voltage output was increasing in term of negative value refer to the serial monitor value display by the microcontroller programme. The voltage output recorded starting from the 30 km/h with interval 10km/h until the speed reach 110km/h. The results also show that Fig. 3, the high flap sensor 1 at angle 0° detect the dynamic airflow movement in wind tunnel when at this position. It was found that all the high flap sensor shows the increasing value of voltage output when at the Location A at angle 0°. This is because of the laminar condition of the dynamic airflow from the wind tunnel. Data from the Fig. 4 and Fig. 6 show that the inconsistent value for the high flap sensor at the location C because the laminar flow in the wind tunnel will take 30 seconds to achieve the laminar condition. This is because the constraint from the wind tunnel occurs the inconsistent speed when increasing the speed fan control by using the reading of manometer.

Table- III: Comparison of data for High Flap Sensors At The Angle 0°

	Voltage, V			
	Sensor 1	**Sensor 2**	**Sensor 3**	**Sensor 4**
Speed, km/h	**0 °**	**0 °**	**0 °**	**0 °**
0	-13.2	-13.5	-13.4	-13.1
10	-13.6	-13.3	-13.5	-13.1
20	-13.3	-13.5	-13.4	-13.2
30	-12.2	-13.1	-12.6	-13.1
40	-11.9	-12.8	-12.5	-12.8
50	-11.8	-12.0	-11.7	-11.8
60	**-11.2**	**-11.2**	**-11.7**	**-11.2**
70	**-10.8**	**-11.1**	**-10.5**	**-10.6**
80	**-10.2**	**-10.7**	**-10.1**	**-10.3**
90	**-9.8**	**-10.0**	**-9.8**	**-9.4**
100	**-9.2**	**-9.5**	**-9.1**	**-8.7**
110	**-8.4**	**-8.7**	**-7.9**	**-8.5**

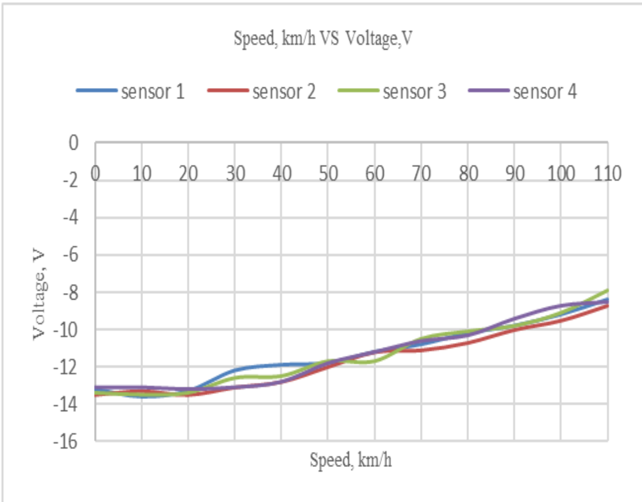

Fig. 11 High Flap Sensors At the Angle 0°

Based on the results, Fig. 11 show that the consistency of voltage output for each of high flap sensor has been tested and placed at angle of 0°. Hence, this can proved the reliability of the sensors when different sensors are used in a single location. The percentage difference between the 4 sensors are less than 8%. Since the test was done for high velocity region, the sensitivity were higher from 60 km/h to 110 km/h. The high velocity flap structure was designed to be sensitive and able to capture the velocity above 60 km/h. Nevertheless, the structure is still under elastic region throughout the deflection process in the airflow testing phase.

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IV. CONCLUSION

In this paper, the airflow in single direction was assessed to evaluate in wind tunnel as the controlled environment by control the fan speed and characterize the small change of air flow that acting on the model structure of the flap sensor. This characterized that is the need to be fulfilled to observe the behavior of the airflow movement around the structure body. This paper also describes the best approach or method in sensing an element of the airflow sensor is a non-thermal principle in order to archive high sensitivity aspect. This is because, the performance and accuracy of the non-thermal airflow sensor are not disrupted due to environmental condition. Moreover, one of the more significant goal to emerge from this study is finding the dynamic motion parameter of the airflow sensor. The result then had been compared to the different sensor that is used in the macrofluidic air flow sensor. This study has found that there are few small different values in the voltage output of the four high flap sensors because the wind speed in the wind tunnel is laminar.

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