The Effect of Orifice Diameter Variations of Conical Cavity Synthetic Jet Actuator on the Drag Reduction of the Reversed Ahmed Body Model

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ABSTRACT

The decreasing number of non-renewable fuel supply due to the very high use of private transportation leads many of researcher to make some innovation in order to improve the fuel consumption efficiency. The fuel consumption is related to the amount of air and drags force that passes through the body shape transportation. Based on the theory that we have been learned, the higher drag force on transportation body the higher fuel consumption, since the higher amount of drag force causing the transportation need more energy to form some speed power. One of the technologies which can reduce the aerodynamic drag force is the application of synthetic jet actuator of flow active control as a modification of simple transportation model in order to reduce the aerodynamic drag on transportation model. The focus of this research is the experimental analysis of the effect orifice diameter variations of the conical shape cavities synthetic jet application on reversed Ahmed Body model. The independent variables that applied in this experiment are the variation of the square, triangle, sine wave frequencies that range from 90 Hz to 130 Hz with the frequency interval is 10 Hz, and the wind airflow velocities which ranging from 40 km/hour to 60 km/hour. The free variable is the orifice diameter of cavity variations, there are 3 mm, 5 mm and 8 mm. This research is focused on experimental method, and based on the recent experiment, the square wave type with a frequency 110 Hz has the highest drag coefficient reduction percentage for the orifice diameter 3 mm and 8 mm, the value coefficient drag reduction percentage is 9.93% for 3 mm orifice diameter and 8.37% for 8 mm orifice diameter. For 5 mm orifice diameter has the optimum percentage coefficient drag reduction and its value is 5.58%.

CCS Concepts

Computing methodologies→ Modeling and simulation→ Model development and analysis → Modeling methodologies

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Keywords

Active Control, Ahmed Body, CFD, Sine, Square, Synthetic Jet, Triangle

1. INTRODUCTION

One of the human activities that contribute to gas pollution production is the increasing of private transportation for doing their daily activities [1]. The higher demand for private transportation in Indonesia is due to the public transportation are not well-managed. For example, in Indonesia where the public transportation facilities are not very well-maintained, it makes Indonesian citizen prefer to use their own private transportation to do their daily activities. The dependency of using private transportation, the amount of transportation (car) supply demand becomes higher. For example, the car types that have high demand in Indonesia are Multi purpose vehicle (MPV) or sports utility vehicle (SUV), this car type has high load capacity and usually Indonesian use this type cars for bringing their family or friends in one car. Absolutely, this car types that can bring high load capacity consumes more of fuels. Based on the problem that has been explained above, this is an obligation for automotive industry to make some innovation in transportation that has feature low-fuel consumption and environmental-friendly. The variables that affect to fuel consumption is aerodynamic drag force, this variable is dependent to air flow separation which passing through transportation shape. Generally, to reduce the drag force we can use three methods:

a) Local airflow modification
b) Postpone airflow separation
c) Reducing the growth of circulation zone on a rare area of separated swirling structure.

Those methods can be done by controlling the airflow by using active or passive control of airflow separation. The difference between active control and passive control system is the active control involving the additional energy, and in opposites, the passive control is not involving the additional energy. Many of experiments about airflow passive control by using transportation prototype and wind tunnel is done by the researcher [2]. However, passive control of airflow separation has so many limitations in controlling technique of airflow separation to reduce the higher amount of drag force [3]. Based on this research limitation problem we should learn the other system besides airflow passive control. Besides learning airflow active control system in general, we should learn to optimize the utilization of synthetic jet actuator movement. Therefore, we need to do the research about *The Effect of Orifice Diameter of Conical Cavity Synthetic Jet Actuator on The Drag Reduction of The Reversed Ahmed Body Model*.

2. METHODS

In this research, the author used the model which size is 70% from the original Ahmed Body Model with slant angle 35° on the rear area surface for taking the data [4,6]. This research is analyzing the coefficient drag reduction on the conical cavity of the synthetic jet which orifice diameter is 3 mm, 5 mm and 8 mm with the actuator mount diameter is 48 mm. The distance between each actuator mounting center is 50 mm.

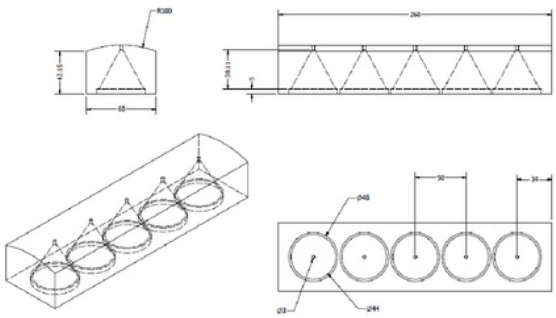

Figure 1 Synthetic Jet Cavity Orifice Diameter 3 mm

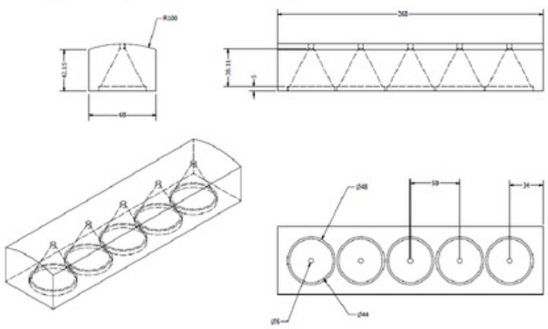

Figure 2 Synthetic Jet Cavity Orifice Diameter 5 mm

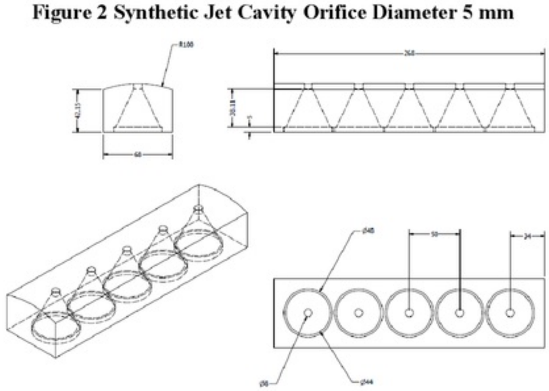

Figure 3 Synthetic Jet Cavity Orifice Diameter 8 mm

The actuator type used in this experiment is a speaker which brand is Synthetic Jet speaker and it is produced by Nuventix. The picture below is membrane actuator used in this research.

Figure 4 Synthetic Jet Membrane Actuator

This membrane actuator has 48 mm of the outer diameter and it will be placed on the base of conical shape synthetic jet cavity.

2.1 Experimental Process

The experimental research is conducted at Aerodynamic and Acoustic Laboratory which located in PUSPIPTEK research center, Serpong. The experiment process is using LSWT (Low-Speed Wind Tunnel) to give the external airflow through the reversed Ahmed body model. The dimension of the test section of this wind tunnel is 0.5 m x 0.5 m and the maximum wind speed is 45 m/s. During the experiment, the researcher using two types of Reversed Ahmed body, there is the model which applied the synthetic jet and the model without a synthetic jet actuator. A number of synthetic jet actuators are five and it applied on the rural area of Ahmed Body Model where the airflow separation happens.

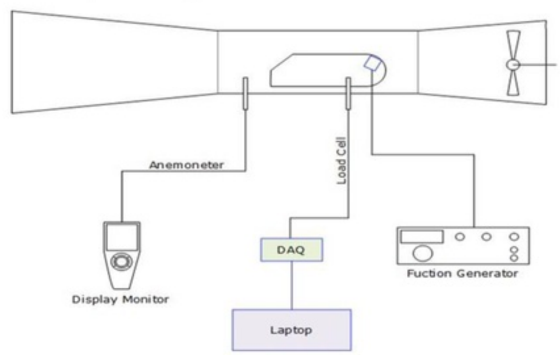

Figure 5 Schematic Experimental Set Up

Before placing the reversed Ahmed body model into the test section, it needs the load cell installation, the load cell was placed on the bottom side of the model. The load cell role was as the sensor to detect the amount of load which caused by the wind. Then the load cell was connected to the acquisition data recorder. The method to take data is similar to the simulation method, and the variations of the signal wave are square, sine, and triangle. This signal wave and the variations of frequency is produced by the function generator. The amount of data taken on LabView software data recorder is set 1000 data for every type of wind tunnel speed and the signal wave variations.

Here are the details of tools and equipment which used through the experimental process:

2.2 Low-Speed Wind Tunnel

Based on Figure 7, the boundary layer size of model placement location must be more than 1.5 cm. To set the wind velocity inside the test section we need to set the frequencies input of the panel control. Then, to measure the wind velocity, the researcher uses the anemometer Hotwire which installed inside the wind tunnel. In this project, the researcher analyzes the effects of the orifice diameter variations of conical cavity synthetic jet from the experimental results. The researcher will focus the analysis on the percentage coefficient drag reduction before using the synthetic jet and after the application of the synthetic jet. The parameter which will be applied during the experiment and simulation process in purpose to get the drag coefficient are, sine, triangle, and square wave types. The frequency variations of the wave are from 90 Hz into 130 Hz with the interval 10 Hz, and the variations of the wind tunnel speed are 11.1 m/s, 13.9 m/s, and 16.7 m/s

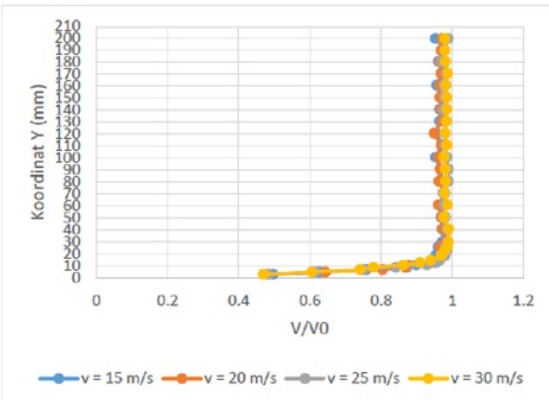

Figure 6 Wind Tunnel Velocity Distribution Graph

2.3 Uncertainty

Before calculating the recorded data from the NI DAQ, we need to ensure that the experimental data are valid. The method for checking the validity of data population is by calculating the value of the uncertainty. The amount of the uncertainty is based on the amount of the data population. The amount of data population that will be checked are 50, 100, 200, 300, 400, 500, 600 700, 800 and 1000. The amount of the uncertainty in each data population can be explained in the graph below.

Figure 7 Uncertainty of Experimental Data

As it can be seen from the Figure 8, the amount of data population is 1000 and the value of the uncertainty in coefficient drag reduction percentage at square 110 Hz when the wind tunnel speed is 16.7 m/s is 1.07 %. This value of the uncertainty of NI DAQ data recorded can be classified as the valid data.

2.4 Aerodynamic Drag Coefficient Reduction on Experimental

The method to put the data on the experimental is by using load cell which installed under the reversed Ahmed Body model to get the amount of coefficient drag reduction percentage in each wind tunnel speed variations, the researcher used the formula [5].

$$\%Cd\ reduction = (Cd\ Non\ Synjet - Cd\ Synjet)/Cd\ Non\ Synjet\ x\ 100\%$$

2.5 SIGVIEW Results

By using FFT analysis tools on SIGVIEW software, we can monitor which data is fluctuating during taking the experimental data. The data that is taken to be analyzed by using FFT analysis tool is the experimental data of conical cavity synthetic jet which orifice diameter is 8 mm.

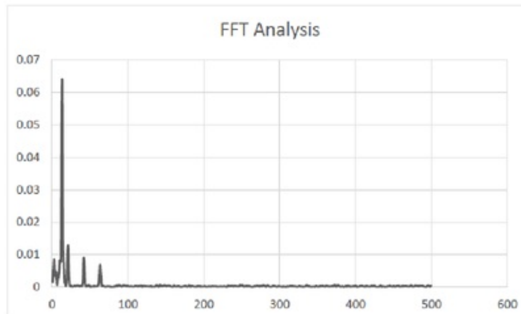

Figure 8 FFT Analysis of Experimental Data

3. RESULTS AND DISCUSSIONS

Figure 9 Cd Reduction Percentage in Each Orifice Diameter (11.1 m/s Sinus)

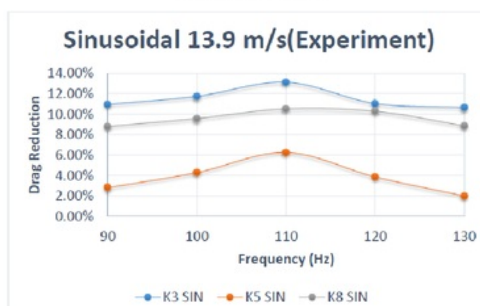

Figure 10 Cd Reduction Percentage in Each Orifice Diameter (13.9 m/s Sinus)

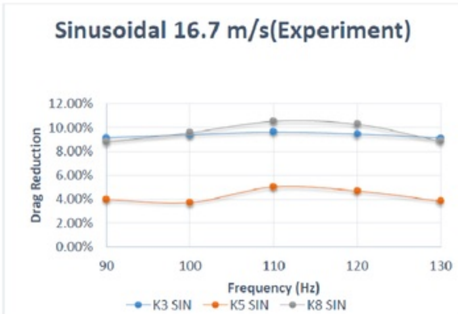

Figure 11 Cd Reduction Percentage in Each Orifice Diameter (16.7 m/s Sinus)

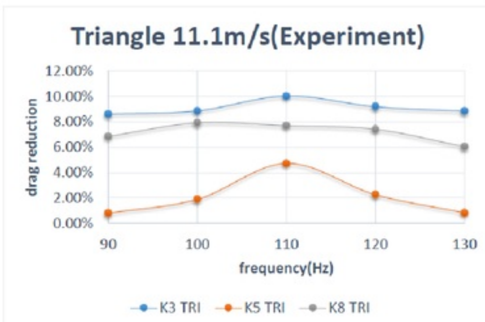

Figure 12 Cd Reduction Percentage in Each Orifice Diameter (11.1 m/s Triangle)

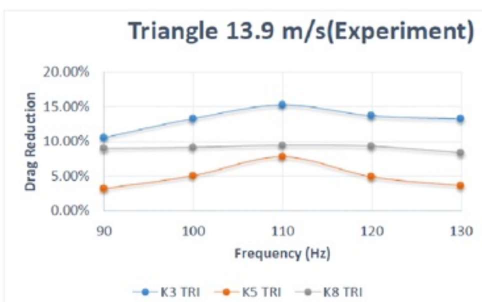

Figure 13 Cd Reduction Percentage in Each Orifice Diameter (13.9 m/s Triangle)

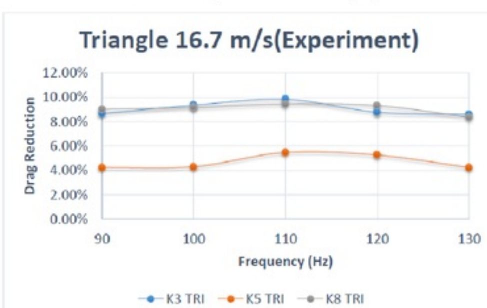

Figure 14 Cd Reduction Percentage in Each Orifice Diameter (16.7 m/s Triangle)

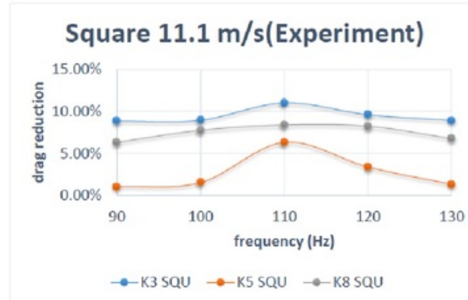

Figure 15 Cd Reduction Percentage in Each Orifice Diameter (11.1 m/s Square)

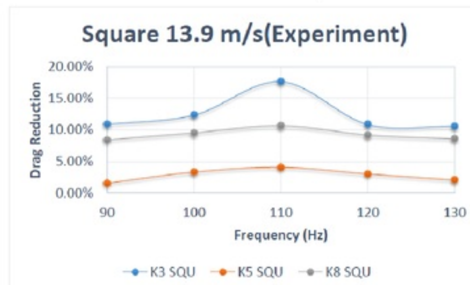

Figure 16 Cd Reduction Percentage in Each Orifice Diameter (13.9 m/s Square)

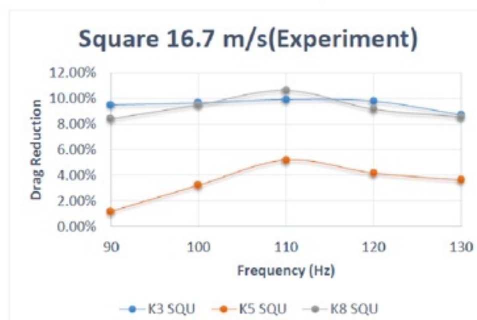

Figure 17 Cd Reduction Percentage in Each Orifice Diameter (16.7 m/s Square)

All the graphs above show the value of the Cd reduction percentage of Ahmed Body model in every wave type and frequency of 3 mm, 5 mm, and 8 mm orifice diameter of synthetic jet. By analyzing the experimental results, this project can explain the effects of synthetic jet orifice diameter variations to the value of coefficient drag reduction percentage. The synthetic jet which orifice diameter is [illegible] mm has the highest coefficient drag reduction percentage when the wind tunnel speed is 16.7 m/s and the signal wave is square 110 Hz. The value of the drag reduction percentage is 9.93 %, and when the other condition of wind tunnel speeds, for example, 11.1 m/s and 13.9 m/s also had the maximum coefficient drag reduction percentage when the signal wave type and frequency is [illegible]uare 110 Hz, the amount of drag reduction i[illegible].69% for 11.1 m/s of wind tunnel speed and 7.97% for 13.9 m/s of the wind tunnel speed. From this condition, the 3 mm orifice diameter of synthetic jet coefficient drag reduction percentage remains incline as the wind tunnel speed is faster. For the 5 mm orifice diameter of the synthetic jet conical cavity, it has the highest drag coefficient reduction percentage during the application of 110 Hz sine wave types of synthetic jet and when the wind tunnel speed is 11 m/s, the value of Cd reduction percentage in this condition is 5.58%.For the other condition of the wind, tunnel speed shows that the application of 110 Hz sine wave gives the highest Cd reduction percentage, there are 4.06% when the wind tunnel speed is 13.9 m/s and 2.4% when the wind tunnel speed is 16.7 m/s. This 5 mm orifice of the synthetic jet cavity is applicable to reduce drag coefficient when the wind tunnel speed is low. The 8 mm orifice diameter of the synthetic jet conical cavity has the maximum coefficient drag reduction percentage when the 110 Hz square wave signal and when the wind tunnel speed is 11.1 m/s. The amount of drag reduction in this condition is 8.37 %. With the same wave signal and frequency, as the wind tunnel speed, higher the value of the drag reductions are declining lucratively, for example when the wind tunnel speed is 13.9 m/as the drag reduction percentage is 2.5 % and as the wind tunnel speed is 16.7 m/s the drag reduction percentage is gaining to the 3.01%. Even though the signal wave and wind tunnel speed variations are the same, it can be proven that the orifice diameter of synthetic jet cavity gives the effects on the coefficient drag reduction. The 3 mm orifice diameter of synthetic jet is applicable for the higher speed of wind tunnel, and this type of orifice has the higher performance than the other type of synthetic jet orifice even though they applied the same boundary condition of the signal frequency, because this type of synthetic jet give the 9.93 % of coefficient drag reduction percentage when the wind tunnel speed is 16.7 m/s Then, the 5 mm and 8 mm of synthetic jet conical cavity orifice diameter is more applicable when the low speed is applied to the Ahmed body model, but based on the experimental result, when both of the 5 mm and the 8 mm orifice diameter is applied to the 11.1 m/s of wind tunnel speed, both of them have the maximum coefficient drag reduction percentage in the different wave signal type condition. The 5 mm has the maximum Cd reduction percentage when it applied with the sine 110 Hz signal and the 8 mm orifice diameter give the highest Cd reduction percentage when it applied square 110 Hz signal. Actually, this experimental process is quite far from the perfection, many of factor that affects on this experimental results, for example, load cell allocation is under the reversed Ahmed body model and it has a gap between the reversed Ahmed Body model and the load cell, this gap causing any additional wind pulse. The other factor is the wind tunnel wall friction also affects with the experimental results, because the pulse between the wind airflow with the wind tunnel wall also affected to the airflow line which will pass through the reversed Ahmed body model.

4. CONCLUSIONS

The focus of this research is knowing the effects of orifice diameter variations of conical cavity synthetic jet into the coefficient drag reduction percentage.From the experimental analysis, it can be concluded that:

a) The optimum coefficient drag reduction which formed by each conical cavity orifice diameter when it applied a signal wave types:

- Orifice Diameter 3 mm : Square 110 Hz
- Orifice Diameter 5 mm : Sine 110 Hz
- Orifice Diameter 8 mm : Square 110 Hz

b) The hypothesis of the variation of orifice diameter will affect to the coefficient drag reduction is proven. The 3 mm orifice diameter of the synthetic jet has the highest Cd reduction percentage when the 16.7 m/s of wind speed is applied on the reversed Ahmed body model, the amount of Cd reduction percentage is 9.93%. On the other hand, the 5 mm and 8 mm of orifice diameter has the maximum Cd reduction percentage when the wind tunnel speed is 11.1 m/s, the value of Cd reductions for both 5 mm and 8 mm of the synthetic jet are 5.58 % and 8.37 %.

5. ACKNOWLEDGEMENTS

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