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Analysis of Variations in Tub Cover Tarpaulin Shape against Airflow Patterns and Pressure Distribution Characteristics on Pickup Trucks with the Addition of Roof Deflector

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A B S T R A C T

This study aimed to analyze the airflow pattern and pressure distribution characteristics of a pickup truck with a roof deflector added. with an angle of curvature of 20° and is accompanied by the installation of a tarpaulin cover on the body of the pickup truck. The method used in this study is an experimental method by testing 6 specimens, namely a pickup truck added with a roof deflector without using a tarp or baseline, a pickup truck added with a roof deflector fitted with a tonneau cover tarp (type A), aerocap tarpaulin with an angle of 0° (type B). and 12° (type C), and cincing type tarpaulin with a foot angle of 15° (type D) and 30° (type E) in a wind tunnel with a speed of 5.47 m/s. The more aerodynamic the use of tarpaulin, the more the blockage mass will be reduced so that it can produce a streamlined flow pattern. The results showed that the pickup truck added with a roof deflector with a 15° cincing tarp had a stable Cp value fluctuation at the rear of the pickup truck, while the pickup truck added a roof deflector with a 12° aerocap tarp. as well as produce aerodynamic flow thereby reducing the occurrence of blockage mass and obstacles.

1. Introduction

Along with the public's interest in pickup trucks, many people change the shape without knowing the feasibility of a pickup truck, such as changing the bumper, roof, the body cover. This can affect the aerodynamics of the pickup truck. A study states that controlling aerodynamic forces on a pickup vehicle can also improve the performance of the vehicle. The installation of a tarpaulin on the body of a pickup truck has a major effect on the aerodynamic style of the vehicle. The effect is caused by the mechanics of the airflow that occurs and flows around the pickup truck body.[1]

The vehicle body design is designed by considering various aerodynamic aspects, such as drag and lift forces that affect the pressure, speed, and coefficient of drag generated by the vehicle body. The aerodynamic aspect of a vehicle is one of the most important parameters in automotive design because it relates to the emergence of drag on the vehicle and will affect the amount of electricity or fuel consumption used, the stability of the vehicle direction, and free flow dynamic pressure. and vehicle surface area. When viewed from a two-dimensional flow, a flow that flows horizontally will cause a drag force or drag force because the direction of this force is opposite to the direction of the flow, while a flow that flows vertically creates a lift or lift force.[2-4]

The aerodynamic effects acting on the vehicle include air resistance (drag), lift and side forces, as well as pitching, dive, and rolling moments. It is necessary to modify or redesign the geometry. By modifying or redesigning the geometry, it is expected to be able to produce a smaller drag force so that the vehicle can drive stably and the use of fuel can be reduced. Therefore, many studies have been carried out to obtain an optimal design. The result of this research is the development of construction that is increasingly paying attention to fluid flow patterns.[5,6]

The body shape is engineered in such a way as to produce optimal aerodynamic characteristics. The method that can be used to analyze vehicle aerodynamics is by using a wind tunnel, and it can be done by using the computational fluid dynamic (CFD) method.[6] The tunnel method is the main way to find the aerodynamic coefficients of a vehicle because this method can measure the three aerodynamic forces at a certain wind speed (Va) and a certain angle of attack (βa) in scale form wind tunnel testing has advantages, namely the influence of research variables is measured more precisely, planning systematically, it is easier to obtain important data, and the results obtained are not much different from the original physical phenomena. Meanwhile, if you use the computational fluid dynamic method, it requires more settings to match the original event, so it will not be as accurate as the experimental method.[7-9] This study aimed to analyze the airflow pattern and the characteristics of the pressure distribution on a pickup truck with a roof deflector with an angle of curvature of 20°, attached to the body of the pickup truck.

2. Methods

This research is experimental research. This study will examine variations in the use of tarpaulins on pickup trucks with the addition of a roof deflector on airflow patterns and pressure distribution characteristics. Analysis was carried out on the effect of installing tarpaulin on the body of a pickup truck added with a roof deflector with a large angle of curvature of 20° to several variations of tarpaulin, namely tonneau cover, aerocap tarpaulin with an angle of 0°, aerocap tarpaulin with an inclined angle of 12°, cincing tarpaulin with a foot angle of 15° and cincing tarpaulin with a foot angle of 30° to the airflow pattern and static pressure distribution carried out experimentally using one wind tunnel unit.

The independent variable used in this study is a pickup truck test vehicle model with an additional 20° angle roof deflector, without the use of a tarp, a pickup truck with an additional 20° angle roof deflector with the use of variations in the shape of the tub cover including tonneau cover tarpaulin or flat tarpaulin with the tub (type A), aerocap tarpaulin with an angle of 0° (type B), aerocap tarpaulin with an inclined angle of 12° (type C), cincing tarpaulin with a foot angle of 15° (type D), and cincing tarpaulin with a foot angle of 30° (type E). The dependent variables in this study are freestream static pressure, freestream dynamic pressure, static pressure on the contours of the vehicle model, pressure coefficient and airflow pattern. The control variables used in this study were the airflow velocity in the test section which was constant at 5.47 m/s and temperature air was kept constant in the test section.

The equipment used in this research is a wind tunnel, hot wire anemometer, inclined tube manometer, smoke machine, and camera. The test specimen in this study was a model of a Mitsubishi L300 pickup truck which was printed using 3D printing using polylactic acid (PLA) material with a roof deflector at an angle of 20° with a variation of the tarpaulin in between.

This study uses 41 test points which are divided into two parts, namely the upper side, as many as 30 points and the under side as much as 11 points, with the distance between each point that is ± 17 mm on the upper side and ± 30 mm which is located on the upper side. underside. The pickup truck model was tested in a wind tunnel with a constant speed of ± 5.47 m/s. Data analysis was carried out with the following process; taking pictures from video visualization of airflow patterns and processing into images of analysis of airflow phenomena. Then calculate the Reynolds number and the dynamic pressure of the airflow. Next, processing the "L" data on the inclined tube manometer into a freestream and static pressure system arrangement of static pressure on the body contours of the test pickup truck. Next, the pressure coefficient is calculated.

3. Results and Discussion

Visualization of flow patterns on vehicle models

This study uses smoke to assist the process of visualizing airflow patterns across the body of a pickup truck model vehicle. The following is a visualization image of the airflow pattern on each vehicle model. The research obtained 6 visualizations of airflow patterns on a pickup truck model with a deflector. Variations in the use of tarpaulins are without tarpaulin (baseline), tonneau cover tarpaulin (type A), 0° aerocap tarpaulin (type B), 12° aerocap tarpaulin (type C), 30° cincing tarpaulin (type D), and 15° cincing tarpaulin. (type E) (Figure 1).

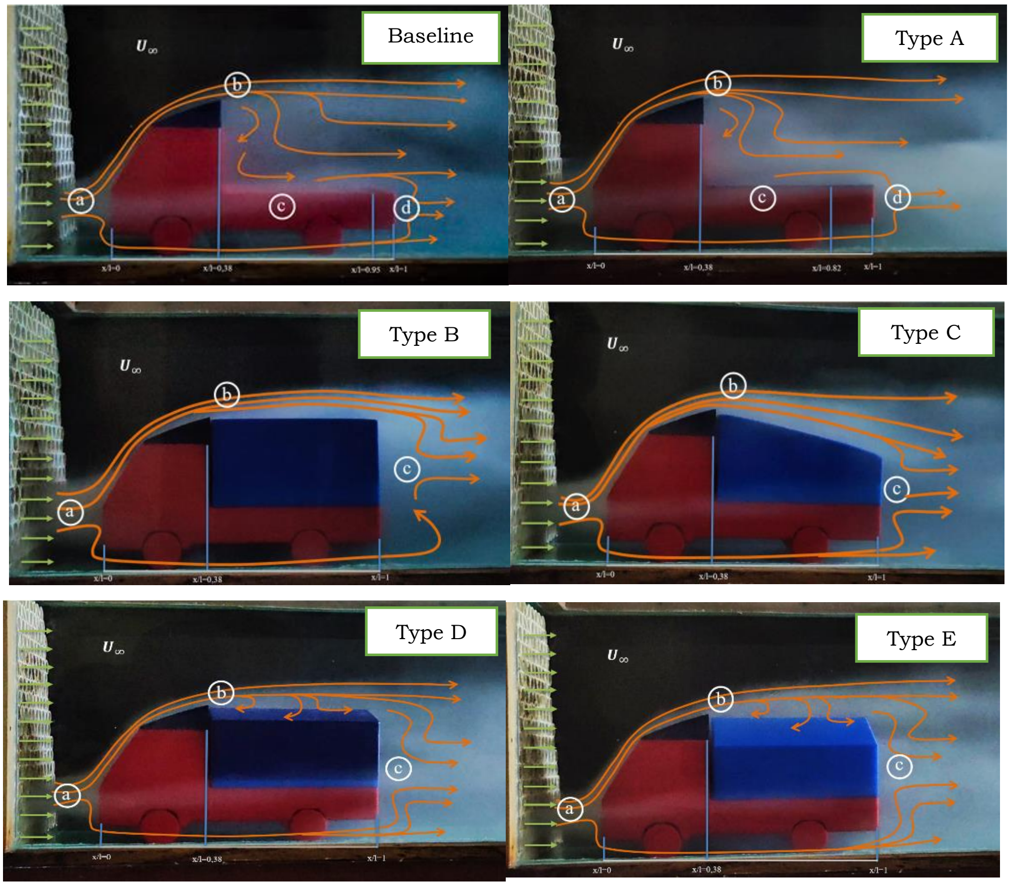

Figure 1. Visual analysis of the experimental airflow pattern on a pickup truck with a deflector added. Notes: Baseline: truck model without tarpaulin; type A (tonneau cover tarpaulin pickup truck); type B (aerocap tarpaulin model pickup truck 0°); type C (aerocap tarpaulin model pickup truck 12°); type D (cincing tarpaulin model pickup truck 30°); type E (cincing tarpaulin model pickup truck 15°).

The airflow moves from the leading edge to the trailing edge of the test vehicle. Point (a) is the stagnation point, at that point the airflow velocity is v = 0 m/s. The stagnation point occurs at a ratio of x/l = 0 i.e. from measurement point 1 to measurement point 3. Not all pressure measurement points in the vehicle front area or the x/l ratio = 0 vehicles have a Cp value = 1. This is due to the occurrence of the forward bound vortex on the front area vehicle. Point (b) in the baseline vehicle model is the separation point that occurs at a ratio of x/l=0.38 which causes an adverse pressure gradient that is characterized by backflow. The separation phenomenon occurs because the flow line is no longer able to adhere to the shape of the vehicle body surface, namely the deflector, and is pushed away towards free flow. At point (c), at a ratio of x/l = 0.38 to a ratio of x/l = 0.95, the flow that flows in the tub section produces blockage mass which causes a large and thick circulation as indicated by thick white smoke that accumulates at the bottom. pickup truck. This circulation is caused by the pressure difference in the empty body of the pickup truck with the surrounding air. Point (d) is an area of low pressure (wake) that occurs at a ratio of x/l=0.38. At the bottom of the vehicle at measurement points 31 and 32 there is a stagnation point but not all of the Cp values are 1, this happens because of the forward bound vortex on the underside. The flow that flows below is slightly separated due to the shape of the body at the bottom of the pickup truck and the friction from the road.

Point (c) on the type A vehicle model at a ratio of x/l = 0.38 to a ratio of x/l = 0.82, the flow that flows in the body produces blockage mass but is less than that of a pickup truck without tarpaulin and causes a significant reduction inflow. accumulate in the tub because the airflow through the tarpaulin is indicated by white smoke. Point (d) is an area of low pressure (wake) that occurs at a ratio of x/l = 1 but is more regular than without the use of tarpaulin.

Point (c) on the type B vehicle model is a low-pressure area (wake) that occurs at a ratio of x/l = 1, on this type of tarpaulin wakes that occur due to the height of the tarpaulin or the wide rear area of the tarpaulin causes a large wake distance. At the bottom of the vehicle at measurement points 31 and 32 there is a stagnation point but not all of the Cp values are 1, this happens because of the forward bound vortex on the underside. The flow that flows below is slightly separated due to the shape of the body at the bottom of the pickup truck and the friction from the road.

Point (c) on the type C vehicle model is an area of low pressure (wake) that occurs at a ratio of x/l = 1, on this type of tarp, the wake is smaller due to the height of the tarpaulin or the area behind the tarpaulin which shrinks following the airflow pattern causing reduced wake distance. At the bottom of the vehicle at measurement points 31 and 32 there is a stagnation point but not all of the Cp values are 1, this happens because of the forward bound vortex on the underside. Furthermore, point (c) on the type D vehicle model is a low-pressure area (wake) that occurs at a ratio of x/l = 1, on this type of tarpaulin wake that occurs due to the height of the tarp or the area behind the tarpaulin that forms a triangle so that it divides the airflow from the tarpaulin. front causes the wake area to decrease. Meanwhile, point (c) on the type E vehicle model is a low-pressure area (wake) that occurs at a ratio of x/l = 1. On this type of tarpaulin, wake occurs due to the height of the tarp or the area behind the tarpaulin that forms a triangle so that it divides the flow. air from the front but causes a larger wake area than the 15° cincing.

Calculation of Reynolds number freestream

Based on the measurements, the fluid properties are obtained as follows; fluid velocity (V) = 5,47 m/s, fluid temperature (T) = 30.8°C, and characteristic length (L) = 0.35 m. By knowing the fluid temperature, the fluid density (ρ) = 1,161 kg/m^3, dynamic viscosity (μ) = 0,000018756 N.s/m^2, and kinematic viscosity (v) = 0,000016155 m^2/s Then the Reynolds number can be calculated by the following equation;

$$Re = \frac{\rho \text{ v D}}{\mu} = \frac{1{,}161 \text{ kg/m}^3 \text{ . } 5{,}47 \text{ m/s . } 0{,}35 \text{ m}}{0{,}000018756 \text{ N.s/m}^2} = 118.507$$

In this study, each specimen was tested with the same Re freestream. the air velocity in the test section in the wind tunnel is 5.47 m/s and the fluid density is 1.161 kg/m3 dynamic pressure freestream in the wind tunnel can be calculated by the following equation;

$$P_{d\infty} = {}^{1}/_{2}\, \rho\, U_{\infty}{}^{2} = {}^{1}/_{2}\ 1{,}161\ \mathrm{kg}/m^{3}\ .\ (5{,}47\ \mathrm{m/s})^{2}\ = 17{,}369\ \mathrm{N}/m^{2} \text{ (relative pressure)}$$

Static pressure on the wind tunnel test section is determined by obtaining the maximum pressure value on the body contour surface. Based on the data obtained, the maximum pressure on each vehicle model is the fluid displacement distance (ΔL = 13.5 mm) so the maximum static pressure on the contours of each vehicle model is 26.530 N/m2.

After obtaining the maximum pressure value on the contour, the static pressure of the *test section* can be calculated as follows

$$P_0 = P_{S\infty} + \frac{1}{2}\,\rho\, U_{\infty}{}^{2}$$

$$P_{S\infty} = P_0 - \frac{1}{2}\,\rho\, U_{\infty}{}^{2}$$

$$P_{S\infty} = 26{,}530\ \mathrm{N/m^2} - 17{,}369\ \mathrm{N/m^2}$$

$$P_{S\infty} = 9{,}161\ \mathrm{N/m^2}$$

The value of the wall static pressure of the test section is used to determine the value of Cp (pressure coefficient) at all other measurement points in each pickup truck model.

Analysis of the pressure coefficient (Cp) on the combination of all vehicle models

Below is a graph of the distribution of the pressure coefficient on each combined vehicle model.

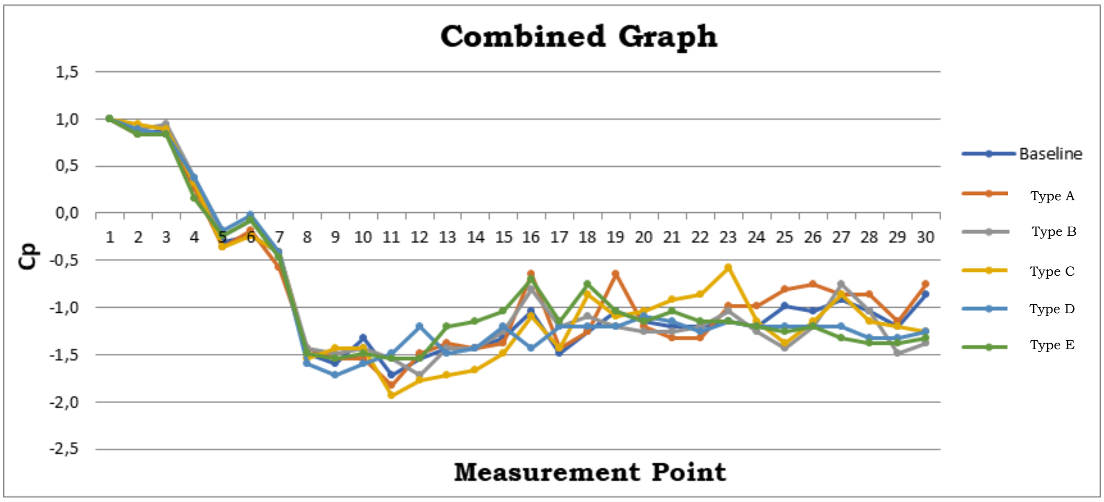

Figure 2. Graph of combined Cp on the upper side of the pickup truck.

Based on Figure 2, the distribution of the pressure coefficient on the upper side of the vehicle body as a whole becomes 1 graph, it can be seen that on the front of the vehicle the ratio x/1 = 0, the maximum Cp value is Cp = 1 which indicates the occurrence of a stagnation point, where the maximum airflow pressure and air velocity v = 0 m/s. However, not all Cp values at the ratio x/l=0 are worth 1, this is because there is a forward-bound vortex phenomenon in the front of the pickup truck.

The use of a roof deflector resulted in a decrease in the value of Cp which was not too large. The significantly increased Cp value was produced by the pickup truck with the use of 12° aerocap tarpaulin so that the flow pattern was more aerodynamic or streamlined and the blockage mass that occurred was smaller. The use of 12° aerocap tarpaulin also resulted in a smaller wake area at the rear of the pickup truck, as evidenced by the value of Cp= -1.150.

Stable Cp values are produced in 15° cincing pickup trucks, which indicate the occurrence of low blockage mass. Thanks to the addition of a roof deflector, the flow of a pickup truck with a 15° cincing tarp has a stable Cp value in the body area. While unstable flow and Cp values are shown in pickup trucks without tarpaulins, using tonneau cover tarps, 30° cincing tarps produce a more complex flow where bound vortex and blockage mass occur on the body as well as airflow patterns that are not streamlined and irregular. The largest wake area occurred in the use of 30° cincing tarpaulin, as evidenced by the smallest value of Cp= -1.376 due to the non-aerodynamic shape of the tall and large tarpaulin.

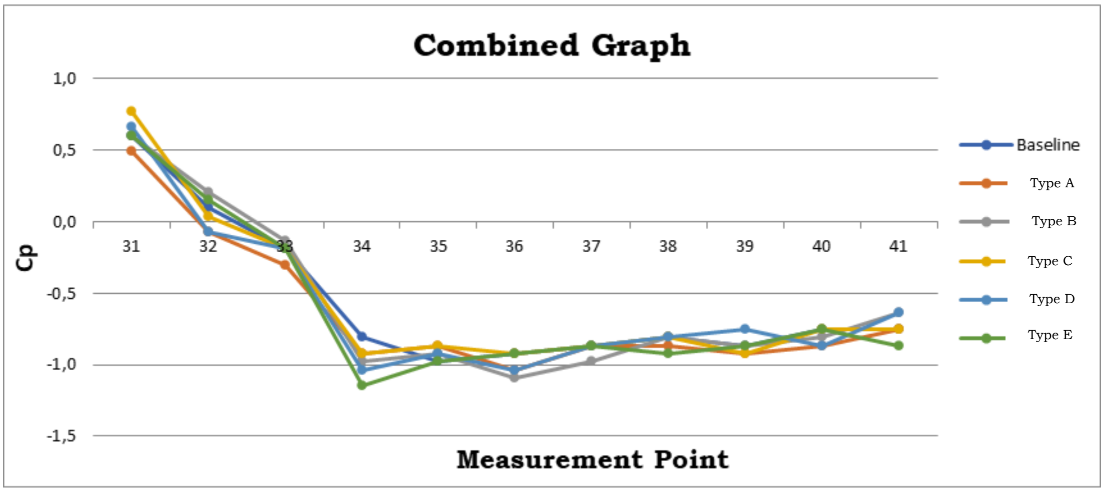

Figure 3. Graph of combined Cp on the underside of the pickup truck.

Based on Figure 3, the distribution of the pressure coefficient on the underside of the vehicle body as a whole becomes 1 graph, it can be seen that on the front of the vehicle, there is a significant decrease in the Cp value from the measurement point 31 to point measurement 34 after the measurement point 34 until the measurement point 41 is not too significant a change in the Cp value, the largest Cp value that occurs at the bottom is a pickup truck added with a deflector with aerocap tarpaulin 12° because the airflow approaches the contour of the lower body, while the smallest Cp value is produced by a 30° cincing pickup truck where the airflow is away from the contour of the lower body. From the graph above, it can be seen that Cp measurements at the bottom of the vehicle tend to get relatively the same results in all tests. This is because there is no change in body shape at the bottom of the vehicle.

4. Conclusion

The pickup truck model with 12° aerocap tarpaulin has more aerodynamic flow than other pickup trucks. The pickup truck added with the deflector affects the value of the static pressure distribution along the body of the pickup truck because of the blockage mass followed by fluctuations in the Cp value. The results showed that the pickup truck added with a roof deflector with a 15° cincing tarp had a stable Cp value fluctuation at the rear of the pickup truck, while the pickup truck added a roof deflector with a 12° aerocap tarp.

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