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THE INFLUENCE OF LENGTH CUTS TRAILING EDGE ON FLOW CHARACTERISTICS IN THE RAILWAY HELM USING COMPUTATIONAL FLUID DYNAMICS

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ABSTRACT

There are many important reviews about the flow characteristics in the body of the racing bike helmet caused by the relative motion of the air along the Trailing Edge shape. The lines formed in such a way in the speed field will form a streamline stream so that the lines are in line with the flow at each point in the flow field. Thus, the streamline will form a pattern of airflow around the helmet. This aerodynamic characteristic study was performed on time meter helmet body visualized numerically using Computational Fluid Dynamics (CFD) with Solid Work Flow Simulation software. With variation of Trailing Edge 25 mm, 75 mm, 125 mm. Urgency research about helm time trial is believed to provide information about the flow that occurred. The result shows that the drag coefficient reduction that occurs on the cut variation of 75 mm compared with other variations on the Reynolds number 1.16 x 105 of 0.395.

Keywords: Helm time trial, trailing edge, drag, CFD, SolidWorks Flow Simulation.

INTRODUCTION

Pressure and speed are the fundamental quantities in the concept of aerodynamics, the two parameters being the foundation for the development of concepts and applications of aerodynamics as well as the field of automotive (Fox et al., 2011). Currently, developing countries in the world much to make the technology grow and modern as in the world of cycling. The technology is widely used for research on aerodynamic flow and drag coefficient on racing bike helmets.

Basically the aerodynamic characteristics that occur in the body of the bicycle racing helmet is caused by the relative movement of the air along the shape of the body helmet. The lines formed in such a way in the speed field will form a streamline so that the lines will be in the direction of the flow at each point in the flow field. Thus, the streamline will form a pattern of airflow around the helmet.

Performance for racing bikes is intended to reduce the frontal area when the athlete's head is exposed to flow throughout the body that can significantly improve performance. Aerodynamic improvements apply aerofoil shapes with Trailing Edge modifications to the design of the helmet. One of the goals for knowing performance with cutting variations on Trailing Edge is to reduce the desired aerodynamic drag.

A study conducted by Bradford and Peter (2011) on Trailing Edge cut variations on racing helmets indicates different cutting lengths of 0.5 m and 0.85 m resulting in the lowest drag coefficient. The length of the helmet affects the size and formation of the vortex. The helmet geometry at the intersection of about 0.5 m and 0.85 m forms a small vortex on the Trailing Edge. The optimal length to reduce the drag coefficient is obtained at a 0.5 m intersection. This length has a slightly higher drag coefficient but will present a reduced frontal area if the helmet is rotated 90 degrees into the airflow.

In contrast to Bradford and Peter, the initial research conducted by Nash et al (1966) focused on the low pressure zone formed behind the trailing edge. This modified rear area of the body leads to increased pressure and substrate bottlenecks for splitter plates, wedges, cavities and other methods to reduce basic obstacles. An airfoil with a dull end is observed and produces the most effective characteristic with a rounded versus square trailing edge.

Chabroux et al (2008) also studied the effects of ventilation on the drag force using three similar aerodynamic helmets. One helmet has open ventilation, one having a small vertical slit opening, and the other one has no ventilation. Their data showed no significant difference in the drag force between the three helmets.

Van Dam, Kahn, and Berg (2008) saw the application of cut airfoils to the inboard region of wind turbine blades. The clipped form provides improved lift and better structural characteristics but also shows a significant increase in drag compared to airfoils with sharp trailing edges.

While in this study wanted to show the characteristics of aerodynamics performed on the body helm time trial by numerical visualization using CFD software with cut variations of Trailing Edge 25 mm, 75 mm, 125 mm. Urgency research about helm time trial is believed to provide information about the flow that occurred.

METHODOLOGY

This research was carried out by first describing the design in solidWorks Flow Simulation software. The geometry scheme can be seen in the figure below.

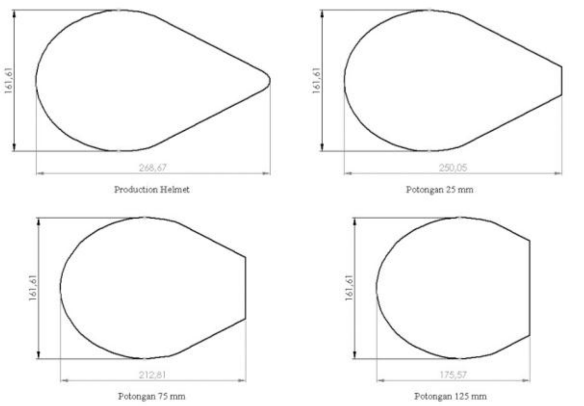

Figure 1. Cut Variations in trailing edge

Computer Specifications

The thing that needs to be considered in conducting CFD simulations is the computer specifications used. The higher and better the computer specifications used so the time needed for the simulation process. In this study using computer specifications as shown in Table 1 below:

Table 1. Laptop specifications

Laptop Brand	LENOVO
Type	Ideapead 310 80 ST
Processor	AMD A-12-9700P RADEON R7, COMPUTE CORES 4C+6G (4CPUs)- 2.5 GHz
Memory (RAM)	8 GB
Memory Hardisk	1 TB
Operating system	Windows 10Pro 64-bit (10.0, Build 14393)
VGA Card	AMD Radeon R7 Graphics

Numerical Simulation with SolidWorks

Pre-Processing

The pre-processing stage is the initial stage to analyze CFD modeling. This stage consists of making geometry using CFD software in pre-processing, among others as follows:

1. Making geometry models in the process of analyzing the flow characteristics, geometry models are made in advance with several stages:
   a. First determine the plane we will use to draw the geometry, here the author uses the top plane to start drawing.
   b. After determining the plane, based on the previous study which discussed the time-trial helmet, by Bradford W Sims, Peter E Jenkins (2011), the geometric shape planning was obtained which would later be used as a reference for taking points of plot coordinates x, y for the next point

are connected to a 2D model build.

The following is a picture of a previous study by Bradford W Sims, Peter E Jenkins (2011) which will be used as a reference for taking points of plot coordinates x, y.

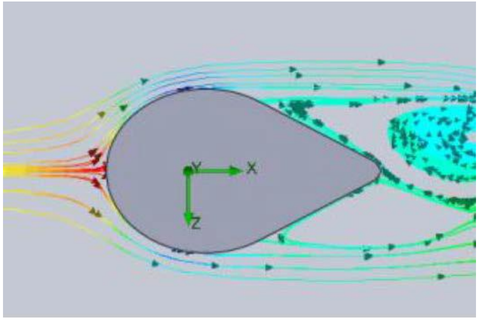

Figure 2. 2D model of time-trial helmet from a previous study by Bradford W Sims, Peter E Jenkins (2011)

Based on the image above will be taken points on the software CFD, so that the geometry of time-trial helmet coordinates for the present study will be formed as shown in Figure 3 below.

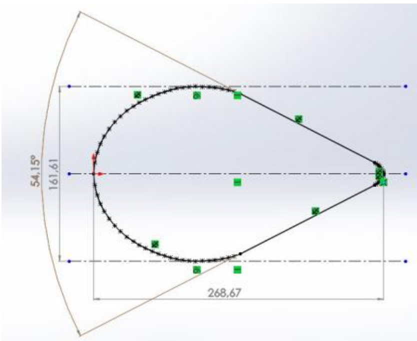

Figure 3. Results of point coordinates in CFD software

Figure 3, it is known the position of each point that has been adapted to the shape and dimensions of the Bradford W Sims study, Peter E Jenkins (2011). After that, the points are connected into one line to form a 2D model that resembles a production time-trial helmet.

a. Then after making sketch drawing, it is changed to a form by clicking the features on the toolbar on the top left corner> form> sketch plane> reverse direction> mid plane> depth, filling in the values that the writer wants and then entering.

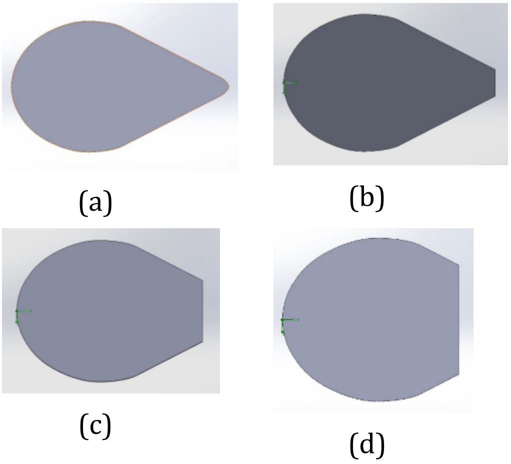

Figure 4. Various variations of trailing edge (a) production helmet models, (b) 25 mm pieces, (c) 75 mm pieces, (d) 125 mm pieces.

For the variation of trailing edge model 1, model 2, and model 3 it is necessary to do sketch editing on the back of the helmet to form a trailing edge variation model as shown in Figure 4.

Processing

CFD simulation starts with opening CFD software. Then proceed with opening the geometry file that was created earlier by

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clicking the open menu on the menu bar of the initial window of SolidWorks and selecting the directory where the file was saved before. After the geometry or model is open in the window, proceed with entering the corresponding solver parameters by creating a new Flow Simulation project.

a. Enable the Flow Simulation add-in
b. Open the project wizard
c. Name the project
d. Determine the unit system
e. Determine the type of analysis
f. Define the type and type of fluid
g. Defines boundary conditions
h. Define the initial and ambient conditions
i. Set computational domain
j. Defining goals
k. Meshing

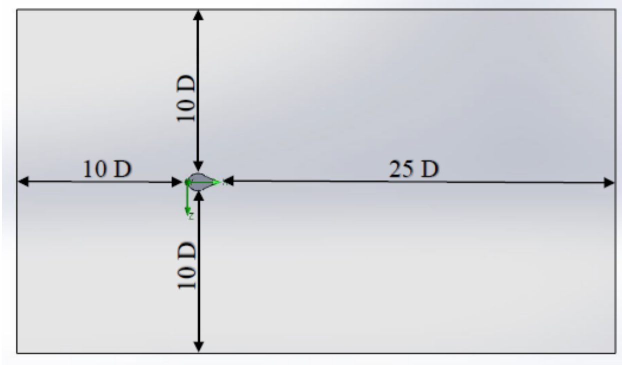


Figure 5. The computational domain results in the body resembles a helmet time-trial

Table 2. Validation of drag coefficient values generated from simulation experiments using SolidWorks

	Identities	Model	Input Turbulence (%)	Cd
1	Bradford and Peter (2011)	Top view helmet 2D		**0.59**
2	Study results now	Top view helmet 2D	**0.1 %**	0.589
			0.2 %	**0.529**
			1 %	**0.305**

RESULTS AND DISCUSSION

Drag Coefficient Validation (Cd)

The first validation test is the drag coefficient (Cd). And for the drag coefficient comparison value from the results of the present and previous studies are shown in Table 2.

Validation of fluid flow characteristics

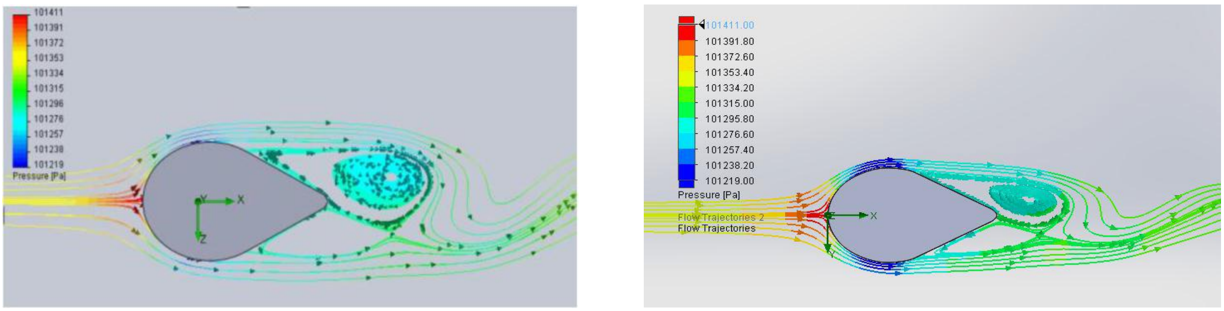
This Oscillating Karman vortex is a phenomenon where fluid flow at the back of the time-trial helmet forms a recurrent vortex pattern caused by unsteady flow around the blunt bodies, so the fluid flow benchmark problem crosses the time-trial helmet with Reynolds number 1.00 x 10^5 generally there will be oscillating Karman vortex in the wake area behind the helmet area. It also proves that the simulation steps performed are correct and correct for the second validation test.

Results of Simulation of Various Model Variations in Reynolds Numbers 1.00 x 10^5

Figure 7 (a) is the flow visualization of the fluid flow across the helmet 2D time trial is shown above at Reynolds number 1.00 x 10^5. In the figure shows the fluid flow trace when crossing the helmet body and it is seen that the flow will follow the body contour. But when the fluid will cross the

Trailing-Edge section, it forms oscillating karman vortex in the wake area behind the helmet body. Oscillating karman vortex is a phenomenon where fluid flow at the back of a time-trial helmet forms a recurrent vortex pattern caused by unsteady flow around blunt bodies.

This phenomenon also appeared in previous researchers by Bradford and Peter (2011). At Reynold number 1.00 x 10^5, there is a parallel flow when crossing the helmet body and will form an oscillating karman vortex. This alternating flow pattern is formed in the area behind the helmet body and then moves down at the edge of the Trailing Edge, causing drag on the helmet body. Wake areas behind the body are formed when fluid flow begins to be aligned. Wake itself is a low pressure area caused by changes in momentum due to flow separation. And in general wake can be found in the area behind the body. From the characteristics of the fluid flow that will affect the size of the drag force received by the body.



(a) **(b)**

Figure 6. Flow visualization figure at Reynolds number 1.00 x 105 (a) Bradford W Sims, Peter E Jenkins (2011) (b) Results of the present study.

Figure 7 (b) for the Reynolds number 1.00 x 10^5 with Trailing Edge cut modifications as long as 25 mm, Flow visualization of the fluid flow across the top 2D time-trial helmet top. The image shows that the fluid flow trace as it passes through the helmet body shows that the flow will follow the contours of the body. After the fluid in which the author uses air, passing the Trailing Edge section forms a vortex that is smaller in size than the vortex that occurs in the Trailing Edge production helmet.

In a pattern with a 25 mm cutoff flow variation shown in Figure 7 (b) it turns around because it forms on the area behind the helmet body and then descends to the edge of the Trailing Edge so that the helmet's body causes drag. For the wake area behind the body is formed when the air flow starts to be refit. The existence of momentum change and flow separation is the occurrence because the low pressure region is called the wake region. When viewed more closely on the Trailing Edge side, the size of the vortex smaller than the production helmet shows a decrease in pressure compared to the production helmet.

Figure 7 (c) for Reynolds number 1.00 x 10^5 with modification of Trailing Edge pieces as long as 75 mm, Flow Visualization of fluid flow across the 2D time-trial helmet appears above. for flow patterns on variations of 75 mm cut that are shown above the image turns away because it forms on the area behind the helmet body then drops to the edge of the Trailing Edge so that the body of the helmet causes drag. For the wake area behind the body is formed when the air flow starts to be refit. This change in momentum and flow separation is because the low pressure region is called the wake region. When viewed more closely on the Trailing Edge side, the size of the vortex smaller than the production helmet shows a decrease in pressure compared to the production helmet.

The image shows that the fluid flow trace as it passes through the helmet body shows that the flow will follow the contours of the body. After the fluid in which the author uses air, passing through the Trailing Edge is formed a vortex that has a larger size than the vortex that occurs in the Trailing Edge production helmet and cut variations of Trailing Edge with a 25-mm platform.

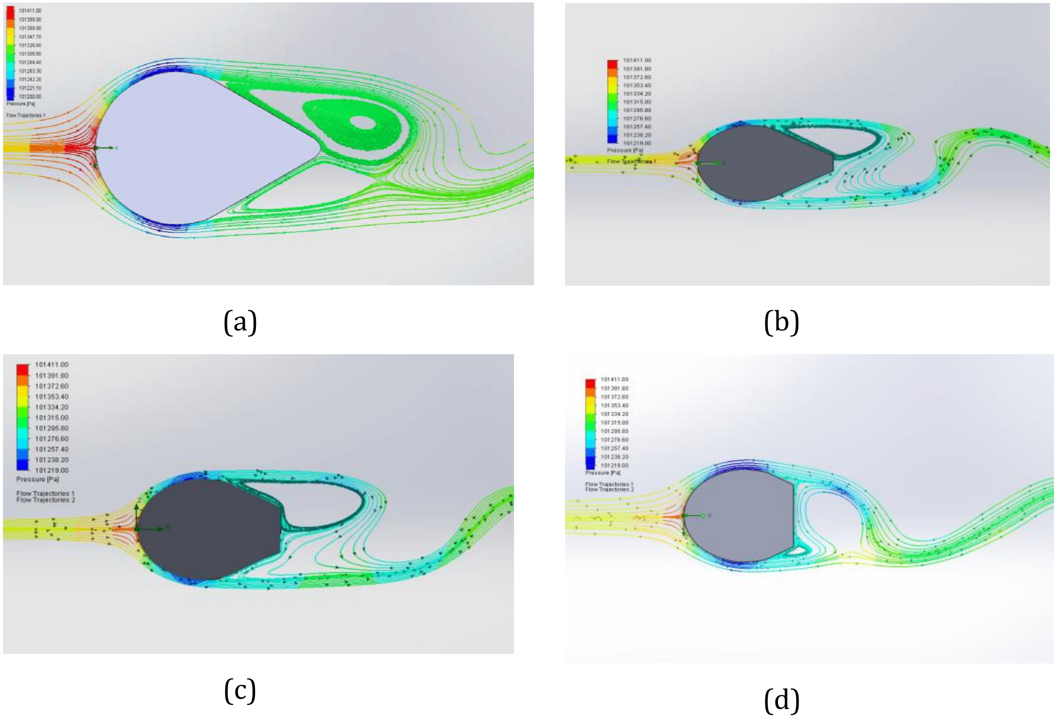


Figure 7. Flow Visualization (a) production helmet, (b) 25 mm (c) pieces of 75 mm pieces and (d) 125 mm pieces at Reynolds number 1.00 x 10^5

Figure 7 (d) for Reynolds number 1.00 x 105 with modification of 125 mm Trailing Edge pieces, Flow Visualization of fluid flow across the 2D time-trial helmet appears above. The figure shows that for stagnation is below, this is because the influence of the flow from above is greater than the flow of fluid below which causes the wake that forms behind the helmet body, after that it experiences a shear layer that goes straight back and presses down. The image also gets maximum and minimum pressure values that are almost the same as previous studies. At maximum pressure = 101411 Pa and minimum = 101219 Pa.

Effect of Variation of Trailing Edge Pieces on Drag Style

The drag force simulation results (Fd) that occur in each model of the production helmet, variations of 25 mm Trailing Edge pieces, variations of 75 mm Trailing Edge pieces, variations of 125 mm Trailing Edge pieces are stored and the data taken. Then we get the drag force value that occurs at each Reynolds number.

Table 3. The drag force table for variations in Trailing Edge pieces

No	Variations of pieces	*Drag Style* (N)		
		Re 7.14 x 10^4	Re 1.00 x 10^5	Re 1.16 x 10^5
1	Production Helmet	0.175	0.299	0.357
2	25 mm piece	0.167	0.282	0.321
3	75 mm piece	0.188	0.289	0.270
4	125 mm piece	0.201	0.290	0.292

In Table 3 the smallest drag force values are generated on Reynolds 7.14 x 104 on variations of Trailing Edge pieces of 25 mm, and for the highest drag force values in Reynolds 1.16 x 105 that is in the variation of production helmet. But for the results obtained from previous studies conducted by Bradford W Sims, Peter E Jenkins (2011) is almost close to the results of the drag coefficient on Reynolds 7.14 x 104 with a difference of 0.01. This proves that the greater the value of Reynolds to eat the greater the value of its drag coefficient.

Effect of variations of Trailing Edge pieces on drag coefficient

Data in the form of drag force (Fd) obtained from the simulation results using SolidWorks Flow Simulation software is then used to calculate the drag coefficient (Cd).

Table 4. Drag coefficient table on Trailing Edge cut variations

No	Variations of pieces	*Drag* Coefficient		
		Re 7.14 x 10^4	Re 1.00 x 10^5	Re 1.16 x 10^5
1	Production Helmet	0.675	0.589	0.521
2	25 mm piece	0.645	0.555	0.469
3	75 mm piece	0.723	0.569	0.395
4	125 mm piece	0.774	0.571	0.427

Table 4 the smallest drag coefficient value is generated at Reynolds 1.16 x 105 on Trailing Edge 75 mm variations, and for the highest drag coefficient value in Reynolds 7.14 x 104 is on the 125 mm cut variation. But for the results obtained by Bradford W Sims's previous research, Peter E Jenkins (2011) came close to the result of the drag coefficient on Reynolds 1.00 x 105 with a difference of 0.01. This proves that the greater the value of Reynolds the smaller the value of the drag coefficient (Munson et al, 2013). Another purpose of entering the data in this table is to make it easier to include the value of the Trailing Edge crop variation comparison with the drag coefficient value into the teapot software and applied to the graph model.

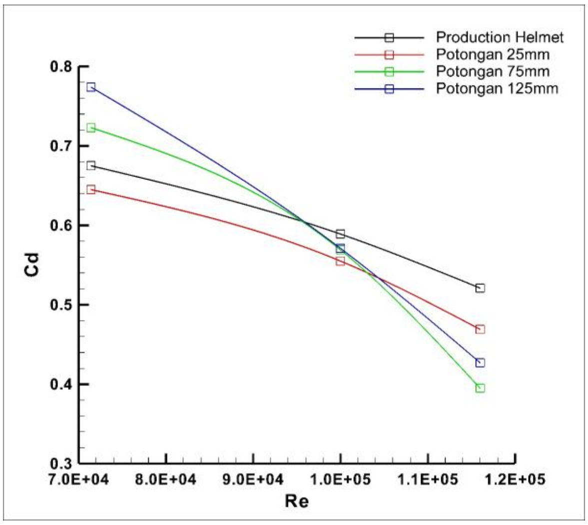


Figure 8. Graphical view of drag coefficient comparison to Reynolds number on various Trailing Edge variations

Figure 8 outlines the larger Reynolds value, the lower the drag coefficient value. The explanation is shown in a variation of 75 mm pieces with red lines, while the second smallest coefficient value is obtained from the variation of 125 mm Trailing Edge pieces with the blue lines shown in the same Reynolds. The results above show the variation of Trailing Edge pieces that are the best for the drag coefficient value is the variation of Trailing Edge 75 mm.

CONCLUSION

Based on the simulation results regarding the effect of the variation of the length of the Trailing Edge pieces on the flow characteristics of the racing bicycle helmets that have been carried out numerically, it can be concluded that:

1. The characteristics of fluid flow across the time-trial helmet with a Reynolds number of 1.00 x 105 will generally result in oscillating karman vortex on wake behind the helmet area. As for the value of the small drag coefficient shown on the variation of Trailing Edge 75 mm on Reynolds number 1.16 x 105 is 0.395.
2. The effect of Trailing Edge variation on aerodynamic forces is obtained by the smallest drag force value shown by Reynolds number 7.14 x 104 with a variation of 25 mm Trailing Edge pieces, namely 0.167.

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