Study the effect of angle of attack on flow characteristics at racing bike helmet using CFD

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Abstract. At a cyclist drag racing champions greatly affect the speed of the bike, especially on the use of racing bike helmets. If the aerodynamic force from the racing bike helmet is getting smaller than the use of helmets on the bike racing will be more optimal and will affect the rate of the racer. In this study, numerical simulations were used to investigate the magnitude of the drag force that occurs around the surface of the helmet. With CFD software, 4 variations of attack angle 0°, 10°, 20° and 30° and variations of Reynold number 7.14x104, 1.00x105, and 1.16x105 are simulated to determine the flow characteristics of each state. The simulation results show that large area vortex is formed at the bottom of the helmet curve and dominates at the attack angle 30°. The result of the drag coefficient generated at the angle of attack 0° to 20° tends to decrease but at the attack angle 200 and 30° the drag coefficient increases.

1 Introduction

The development throughout the world of bicycle sports in the world pretty much favored by many people today, one of which is the Asian road bike championship held in India in 2013 ago. As a personal protective equipment, the helmet is a compulsory equipment for safety or minimizing the possibility of injury, from an accident considering the bike racing speed traveled an average of 30-50 km / hour.

The use of a helmet on cycling is very an impact on the aerodynamic side because it can cause drag for the user. Research on racing bike helmets has been done a lot before, as in research conducted by [1], Which in this study some aerodynamic cycling helmets were tested with variations of yaw angle (0°, 5°, 10° and 15°) and also 3 variations of head angle [1]. The results of the research found that all aerodynamic helmets can reduce the drag force, but each helmet has been varying performance depending upon the yaw angle and the head angle. The effects of visor and frontal ventilation on aerodynamic performance at a time trial helmet have also been analyzed by Vincent Chabroux *et al.* [2]. In the study

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found that the use of visors had a significant effect in reducing drag coefficients in both low and high inclinations, whereas in frontal vents, did not show a significant effect on drag coefficients.

This study aims to investigate the magnitude to the drag force that occurs on around the surface of the helmet with variation of the angle of attack by using computational methods (CFD). With this simulation, hopefully can be used as a reference to improve racing bike helmet to produce a smaller drag force.

2 Research method

In this study to analyses the flow characteristics of racing bike helmets, the model of the time-trial helmet is re-drawn into 2 D by using SolidWorks software as shown in Figure 1,

Fig. 1. Time trial helmet design; a. The real helmet, b. 2D Design

From the image above will be analysed using numerical simulation method CFD, where in this software its numerical method using the finite volume method as the method for its completion [3]. In this simulation, variations of angle of attack helmet are 0° , 10° , 20° and 30° for more detail can be seen in Figure 2. In this study, the fluid used is air with a density of 1.2 kg / m^3 and viscosity $1.81 \times 10^{-5} \text{ Pa.s}$. Reynold numbers are also varied to know the flow characteristic which Reynold numbers used is 7.14×10^4 , 1.00×10^5 , and 1.16×10^5 . With variation of attack angle and Reynold's number the result of simulation is used to analyses drag force and coefficient drag force received by helmet using equation:

$$C_d = \frac{F_d}{\frac{1}{2} \cdot \rho \cdot v^2 \cdot A} \quad (1)$$

where C_d is a coefficient drag, F_d is a drag force, ρ is a density, v is a viscosity, and A is a frontal area [4].

Fig. 2. Angle of attack variation

3 Result & Discussions

3.1 Validation

Verification and validation of the results of numeric simulation are necessary before further investigation in this study. Data obtained from the results of numerical simulations are compared with data from a study conducted by Bradford and Peter (2011) [5]. In Table 1 it can be seen that the result of a drag coefficient ratio (C_d) for this research is 0.001 or smaller compared to the previous researcher at 0.1% turbulence input which the difference is about 1.3%. From the results of this difference shows that the simulation is capable and can be used to know the phenomena that occur.

Table 1. The comparison of C_d from this method with C_d from the results of the researcher before

No.	Study	Model	Turbulence Intensity	Drag coefficient (C_d)
1	Bradford & Peter (2011)	Helmet from top view (2D)		0.590
2	Present Study	Helmet from top view (2D)	0.1%	0.598
			0.2%	0.529
			1%	0.305

3.2 Flow visualization the effect of angle of attack

To determine the effect of angle of attack on this study, the study was conducted using 4 variations of angle of attack as shown in Figure 2 were using Reynold number 1.00×10^5 . The comparison result of angle of attack variation is shown in Figure 3. In the figure it shows that at 0° angle the vortex is formed at the rear end and the bottom of the helmet. This is very common because the Reynold number 1.00×10^5 Oscillating Karman Vortex usually occurs at the back of the helmet. At an angle of 10° the vortex formed at the rear

joins the vortex that is at the bottom of the helmet and forms a large vortex. At an angle of attack 20° Oscillating Karman Vortex disappears and forms a new stream. While at 30° attack angle, Oscillating Karman Vortex re-emerged and formed a vortex with a larger area than the vortex before.

Fig. 3. Flow visualisation using variation angle of attack

3.3. The effect of angle of attack to the drag force

The results of numerical simulations with CFDs on variations of attack angle 0°, 10°, 20° and 30° at Reynold numbers 7.14×10^4 , 1.00×10^5 and 1.16×10^5 to the drag force are shown in Figure 4,

Fig. 4. The relationship between the angle of attack against the drag force

It is generally seen that the largest Reynold number, i.e. Reynolds number 1.16×10^5 has a greater drag force than the other Reynold numbers. Meanwhile with the greater angle of attack, the greater the drag force. For the example at the angle of attack 30 ° with Reynold's

number 1.16×10^5 has a drag force of 0.57569 N which is larger than the angle of 20^0 with Reynold’s number 1.16×10^5 i.e. 0.20948 N. For more details can be seen in Table 2 below,

Table 2. The influence of angle of attack to the drag force

No	Angle of attack	Drag Force (F_d)		
		Re 7.14×10^4	Re 1.00×10^5	Re 1.16×10^5
1	0^0	0.16765	0.28313	0.30311
2	10^0	0.16762	0.17808	0.21535
3	20^0	0.13031	0.17158	0.20948
4	30^0	0.17405	0.33859	0.57569

3.4 Flow visualization of the production helmet looks over

The picture of the flow visualization of the production helmet with the top view can be seen in Figure 5 below,

Fig. 5. Flow visualization from production helmet

The picture above is a visualization of the flow of the production helmet with the view visible above. From the figure shows that the fluid flow across the helmet with the Reynolds number 1.00×10^5 , will generally appear oscillating karman vortex in the wake region. The phenomenon also appears in previous studies by [5]. Bradford and Peter (2011) [5] found that at Reynolds 1.00×10^5 it appears that the stream is fitted when the flow crosses the body of the helmet and then will form an oscillating karman vortex on the back. The alternating pattern of a vortex and the alternate pattern of a large vortex is formed at the end of the helmet. Then this pattern moves down and loosens at the edge then develops again.

4 Conclusions

The results from numerical simulations of the effect of variation angle of attack on the characteristics of the flow on this racing bike helmet, it can be concluded that:

1. Vortex with a large area formed at the bottom of the curve of the helmet and quite dominate, especially at angle of attack 30° .
2. Drag coefficient generated at the angle of attack 0° to 20° tends to decrease, but at angle 20° until 30° the drag coefficient increased.

With this result is expected to be used as a reference to improve design from racing bike helmets to get a smaller drag force to reduce the air resistance that occurs when the rider on the track racing.

References

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