AERODYNAMIC CHARACTERIZATION OF ADD-ON COVERS ON THE REAR WHEEL OF THE MOTORCYCLE

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Abstract - High fuel consumption and green greenhouse emissions are the major concerns that drive engineers and researchers to introduce more efficient aerodynamics designs of motorcycles. This study aimed to reduce the aerodynamic resistance and the drag coefficient of the motorcycle by introducing mounted covers on the rear wheel. Experimental and numerical tests were performed on the production wheel, Half cover on a rear wheel and full cover on a rear wheel. A reduction in drag coefficient was found with half cover wheel and full cover wheel compared with no cover by 19% and 33%, respectively.

Key words - Aerodynamics, Drag Coefficient, Wind Tunnel, Wheel Design.

I. INTRODUCTION

Majority of the fuel consumption in the vehicle is consumed by the aerodynamic drag. Modifying the design of the vehicle or attaching add-on parts, is a way to reduce the aerodynamic resistance of the vehicle. The rim coverage area of the wheel has a major influence on the drag coefficient [1]-[2]. Concli et al. [3] noticed that 50% reduction in the drag force can be achieved by a solid disc on a wheel. Haag et al. [4] investigated the effect of different rim designs on aerodynamic properties. Brandt et al. [5] observed that increasing the coverage area at the rear wheel than the front wheel provides a lower drag coefficient.

The effect of wheel design on drag properties is still largely unexplored. To the extent of the author's knowledge, there are few studies reported on the effect of add-on covers on the rear wheel. While there is no prior literature quantified the drag properties using different curved covers on the rear wheel of the motorcycle. Hence, numerical and experimental investigations were conducted on the effect of different designs of add-on covers on the wheel on the overall aerodynamic performance of the motorcycle.

II. MATERIALS AND METHODS

A. Experimental test

An open return wind tunnel system (HM 170, Gunt Hamburg, Barsbüttel, Germany) was used to conduct experimental tests (see Figure 1). The rear wheel of the Ducati 1199 Panigale S model supplied by Tamiya America Inc. (California, USA) was used, with a scale of 1:12. The tire outer and inner diameter were 54 mm and 39 mm, respectively. The wheel outer and inner diameter were 39 mm and 32 mm, respectively. Tests were conducted on three different wheel configurations, no cover (i.e., production wheel), half curved cover and full curved cover on wheel. Cover models were designed in SoildWorks and 3D printed using 3D printer (3DWOX DP200, Sindoh, Seoul, Korea). Tests were conducted at a velocity range from 5 m/s to 25 m/s per tester limit. The drag force was determined using a force balance, and the drag coefficient was computed by the following equation [6]:

$$C_D = \frac{F_D}{0.5\rho v^2 A} \quad (1)$$

Where C_D is the drag coefficient, F_D is the drag force, ρ is the density of fluid medium (i.e., air density 1.225 kg/m³), v is the velocity of fluid and A is the area of the front body.



Figure 1 Wind tunnel experimental test setup

B. Computational test

3D models of the wheel were designed and simulated in SolidWorks (Solidworks Corp. 2021 SP5.1, Dassualt Systems, Concord, MA, USA), at the 1:12 scale size of the Ducati Panigale 1199 S model. Numerical tests were performed on the same wheel configurations and dimensions as mentioned in section A (Figure 2). The size of the computational domain is 0.66 m × 0.52m × 0.48 m ($L \times w \times h$), under velocity range 5 – 83.33 m/s, turbulence intensity TI=5% at a length scale of 0.003 m, and mass flow rate of 0.0001 kg/s.



Figure 2 Half cover wheel (left), and full cover wheel (right)

III. RESULTS

Experimental and computational results of all configurations are shown in Figure 3 and Figure 4. Computational results showed reasonably good agreement with experimental findings from 5 m/s to 25 m/s. Hence, numerical simulations were carried out for higher velocities up to 83.33 m/s (i.e., 300 km/h). The determined drag coefficients of no cover, half cover and full cover on wheel were 0.42, 0.34 and 0.28, respectively.

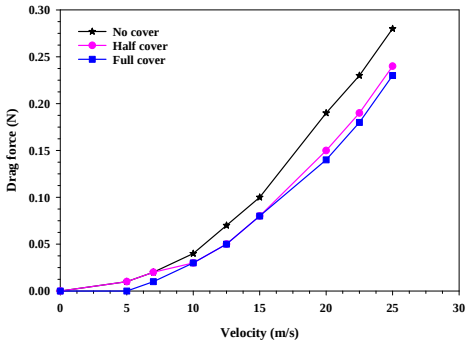


Figure 3 Experimental results of all configurations (5 - 25 m/s)

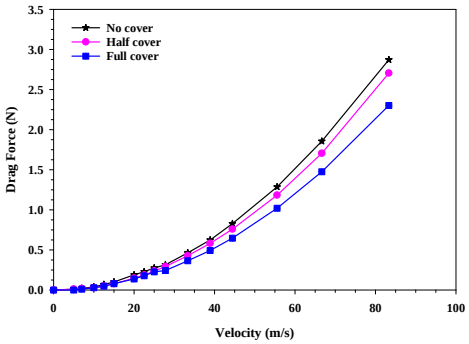


Figure 4 Computational results of all configurations (5 - 83.33 m/s)

IV. DISCUSSION

Improving the aerodynamic properties of the vehicle is an important factor to achieve high speeds, improve fuel economy and reduce environmental impacts. The present study characterized the aerodynamic properties of an add-on cover on the rear wheel, half mounted cover and full mounted cover. Results indicated that the magnitude of drag force increases exponentially with the increase of applied the velocity.

The mounted cover on wheel exhibited less drag properties compared to no cover on wheel. Previous studies [1],[5],[7],[8] found that the coverage area of the rim plays an important role in reducing the aerodynamic drag. The present work manifested that the drag coefficient of no cover, half cover, and full cover on the wheel were 0.42, 0.34 and 0.28, respectively. Significant reduction in the drag coefficient was observed with the application of half cover and full cover on the rear wheel by 19% and 33% compared to no cover, respectively. Bolzon et al. [1] noticed that full cover wheel showed 23% less drag coefficient than 10 spoke wheels configuration. The add-on curved cover significantly enhances the performance of the motorcycle by improving the overall aerodynamic.

FUNDING

The study was funded by a grant from the Australian University [grant number: IRC-2020/2021-SOE-ME-PR04]

CONSENT FOR PUBLICATION

All authors whose names appear on the submission made substantial contributions to the conception or design of the work, or the acquisition, analysis, or interpretation of data. All authors reviewed the results and approved the final version of the manuscript.

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