Flow analysis around a rotating wheel

Emmanuelle Thivolle-Cazat[1], Patrick Gilliéron[2]

1: Research Department, Renault, France, Emmanuelle.thivolle-cazat@renault.com
2: Research Department, Renault, France, Patrick.gillieron@renault.com

Keywords: PIV, Aerodynamics, Rotating wheels, Longitudinal vortices

During a car displacement, wheels' rotation is responsible of about 30% of the aerodynamic drag of passenger cars. Reducing this contribution is an interesting solution to diminish CO2 emissions and fuel consumption and to improve vehicle's road behavior. To control the flow and then to achieve a drag reduction, a better physical understanding of the flow mechanism is first needed.

Particle Image Velocimetry (PIV) and aerodynamic torque measurements have been carried out in a wind tunnel in order to analyze the flow around a rotating wheel located inside a wheel arch. This study has been realized in collaboration with RENAULT Research Department, Aero Concept Engineering and ISAT, Nevers University.

1. Experimental settings

Measurements have been conducted in the wind tunnel of Aero Concept Engineering in Magny-Cours (France). The wind tunnel has a moving ground with a boundary layer suction to approach road conditions. Test measurements have been conducted on a bluff body model representing a front left ¼ of a car-like shape at scale 2/5. The impact on drag of the volume variation between wheel and wheel arch has been investigated.

Values of aerodynamic forces have been acquired by an aerodynamic balance located inside the bluff body. In addition to this set up, PIV has been used to analyze the flow-field around the wheel and thus give an insight into the aerodynamics of shrouded rotating wheels.

The flow condition inside the wind tunnel is at constant wind velocity $V_0 = 30.ms^{-1}$ and the belt can be fixed or similarly moving at 30 $m.s^{-1}$. The flow is seeded with particles (mixing of water + Safex) and lighted by a mini Yag 50mJ laser. Images are acquired using a Flowsense camera (1600 x 1200 pixels) and treated with Flowmanager 4.5. Velocity fields are averaged with a statistic of 200 instantaneous vector fields taken at a sampling frequency of 16Hz. Velocity fields have a maximal size of 200mm x 200mm.

2. Results

Results of SCx aerodynamic torque measurements obtained from 16 configurations show a global increase of the drag coefficient SCx (S being the reference wetted area and Cx the drag coefficient) with the wheel arch volume. In the main paper, the impact of the radial and the transversal space between wheel and wheel arch are explored by PIV and discussed in more details.

Three out of the 16 configurations of wheel arch volume have been explored by PIV. Measurements are conducted in four horizontal and vertical planes in longitudinal and transversal directions of the flow.

Results obtained in the longitudinal planes allow a characterization of the wake dimensions with wheel arch volume. A global increase of the transversal dimensions of the wake is observed with increasing wheel arch volume. In details, the radial space between wheel and wheel arch has more impact on wake dimensions that the transversal space behind the wheel.

Results obtained in the transversal plane allow a three dimensional characterization of the flow. At the intersection with the longitudinal planes, vortex structures are identified. Their rotation directions are similar to the one observed in the bibliography and refer to longitudinal vortex structures such as "jetting" for the ones located at the wheel bottom.

In addition, flow structure differences between stationary and rotating wheel have also been observed for one wheel arch volume configuration.

3. Conclusion

The results obtained from PIV measurements are in agreement with aerodynamic torque measurements. On a moving belt, drag coefficient and wake dimensions increase with wheel arch volume. This increase is mainly due to the radial space between wheel and wheel arch. They have also shown that wake zones are larger with a stationary floor compared to a moving belt and flow structure between moving and stationary floor conditions is different.

Flow visualization obtained through PIV has been very useful to analyze qualitatively the wake vortex structures. However, quantitative characterization of the flow has not been done due to the relative complexity of the flow and measurements difficulties encountered. New experiments will permit to characterize three-dimensional effects more precisely and in particular the unsteady flow by making 3D PIV measurements at a higher spatial resolution.

4. Acknowledgments

The authors acknowledge the Aero Concept Engineering society for their help and the loan of their wind tunnel and ISAT, Nevers University for the preparation of the scaled model.