Examining Influence of a Rooftop Cargo Carrier Position on Automobile Aerodynamics

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Abstract. Cargo Carriers (roof boxes) are containers mounted to a car roof, which provide extra cargo space enabling to travel in both comfortable and safe way. Adding a cargo carrier affects the car aerodynamics, modifies the pressure distribution and results in a change of forces acting on the car. In the presented work a number of numerical simulations using Computational Fluid Dynamics (CFD) were performed to examine how the roof box position affects the aerodynamical performance of the car.

INTRODUCTION

Cargo carriers (roof boxes) - containers mounted to a car's roof are a very common option to provide extra cargo space in a comfortable and relatively cheap way. However, they impact the aerodynamic performance of a car, namely changing the drag and lift forces and also potentially influence on the stability and driveability of a car. As the drag force is mainly connected with increased fuel consumption, the latter ones could affect the safety of driving. For cars moving with a speed greater than 60 km/h, aerodynamic forces are dominant compared to the mechanical friction, and the difference between them rises with the velocity [1]. It was shown that installing a rooftop box could increase the fuel consumption of a car by more than 3% depending on design [2]. As there is lack of more detailed study of the positioning of a rooftop box on a real car geometry, the aim of the presented work was to study the impact of the positioning of a rooftop box on the aerodynamical forces.

MATERIAL AND METHOD

In order to examine the influence of the roof box on car aerodynamics, a numerical model was prepared using commercial software ANSYS Fluent. As the geometry of a car, the generic body named DrivAer was used and combined with a roof box created in CAD software (Fig. 1). The model was meshed using ANSYS Meshing software using tetrahedral elements. A SIMPLE algorithm with the second order discretization schemes was used.

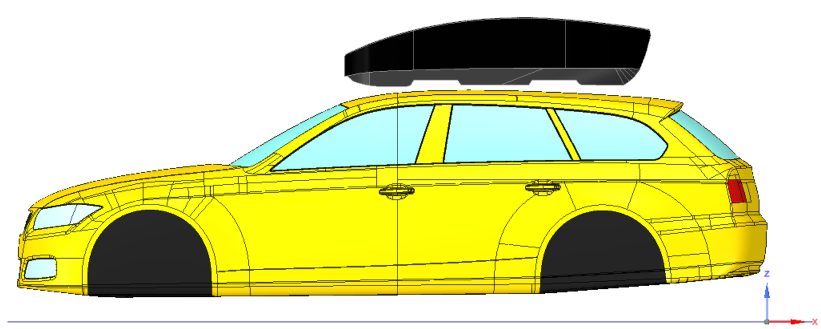

FIGURE 1. The geometry of the analyzed model – DrivAer body and the roof box.

Convergence was monitored based on residuals and force values. Different mesh sizes and turbulence models were tested. Results were compared with the wind tunnel studies performed at the Technical University of Munich [3]. Finally, the model with the relative error of 6.3% in the drag coefficient prediction was chosen, as the compromise between the computational cost and accuracy. Afterwards, 17 positions of roof box were examined. In order to reduce the time of generating new meshes, an Overset Meshing technique has been used. It allows changing the position of the box without generating the new meshes of the whole domain.

RESULTS AND DISCUSSION

The following positions of cargo carrier were examined:

- Reference Position (RP) which was a position compatible with the roof box producer's manual, with the carrier maximally taken back, but allowing collision-free opening of the car trunk (X0),
- 3 translations in the horizontal direction parallel to the car movement (X-axis) described by the distance from Reference Position in millimetres (ex. X50, X100),
- 7 translations in the vertical direction (Z-axis) described as ZP for translations to higher positions (ex. ZP50) and ZM for translations to lower positions (ex. ZM20),
- 5 rotations around horizontal axis perpendicular to the drive direction (Y axis) described as RP for rotations around +Y-axis (ex. RP3 for 3 degrees) and RM for rotations around –Y-axis (ex. RM1),
- The additional position described as X100_RP1 which is a combination of a translation 100mm to the +X direction and rotation of 1 degree around +Y-axis.

Relative changes of drag and lift forces for each position has been presented in Figure 2.

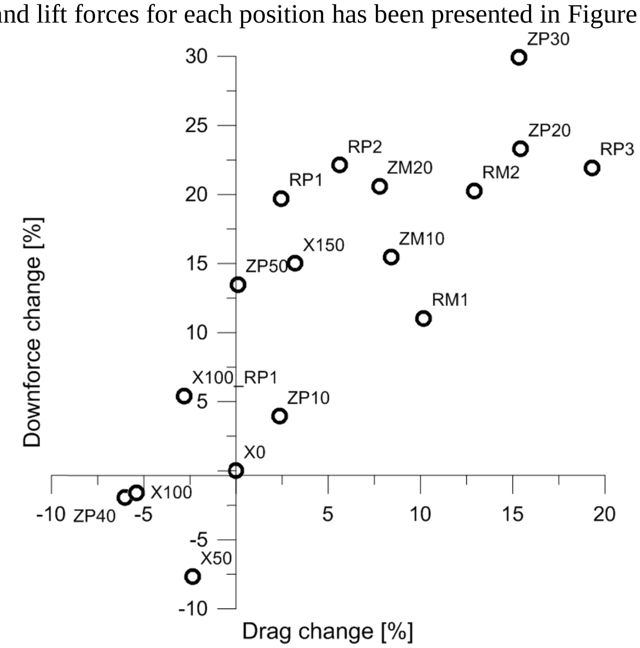

FIGURE 2 Drag and lift forces change of examined positions of the roof box in comparison to the Reference Position (X0).

Presented results confirm the significance of a proper roof box positioning. As the RP is located nearby the best ones, wrong positioning such as RP3 could lead to almost 20% drag increase, which may result in a great increase of the fuel consumption. Velocity and pressure distribution were examined and compared. It was also shown that the impact of positioning is hard to predict as it is connected with complex air flow – results could be different for different types of the car body.

References

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