COMPARATIVE CFD STUDY OF OUTSIDE REARVIEW MIRROR REMOVAL AND OUTSIDE REARVIEW CAMERAS PROPOSALS ON A CURRENT PRODUCTION CAR

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ABSTRACT

This study refers to the Computational Fluid Dynamics, demonstrating a comparative between the drag coefficient and the frontal area of a current production car with the same values obtained from a conceptual proposal of removing the outside rearview mirrors of this same vehicle. Both cases were simulated in a virtual wind tunnel with moving ground and rotating wheels condition at speed of 100 kph, aiming to represent the best way a car moving on a highway. The main objective of this paper is improving the efficiency of automotive vehicles by replacing the current outside rearview mirror for cameras placed in smaller structures. The first simulation showed that by removing the outside rearview mirrors both the frontal area of the car and the drag coefficient, which has direct influence on fuel economy calculation, are smaller compared to current solution. As a complement for the study, two additional cases presenting alternatives on the camera positioning were simulated in similar condition of the study presented first and the drag coefficient, velocity path lines, pressure and wake were compared, demonstrating the performance of each case.

Keywords: CFD (computational simulation), Mirror (outside rear view mirror), Camera, Aerodynamics.

INTRODUCTION

Environmental responsibility of automotive industries is being encouraged by government programs and legal requirements. Efficiency improvements in propulsion systems such as engine, powertrain, driveline, tires, generate less emission and better fuel economy. But experts frequently find difficulties to improve these systems due to the high cost of some solutions. Aerodynamic of a vehicle is one factor that contributes to the performance of the system and must be a solution to be considered, once it does not have high cost.

Besides energy efficiency concerns, vehicle aerodynamics has a significant relation with wind noise generation, influencing on product quality and customer satisfaction.

The present paper provides a contribution to the growing trend of drag reduction. The main purpose is to evaluate outside rear view mirror influence on the aerodynamic properties focusing mainly on the drag coefficient and frontal area values of a production car, performing comparative analysis with the current situation, a “no-mirror” condition and two concepts of outside rear view cameras housing. Camera devices are alternatives to replace outside mirrors, aiming the drag coefficient reduction.

1. REFERENCE FOR HOUSING

Figure 1 shows the camera [7] used as reference for housing modeling. Dimensions are approximately 35 mm length and a diameter of 25 mm.

Figure 1. CMOS Camera Sensor.

CMOS image sensor is designed for machine vision [8] and it's one of the most common type of camera used in vehicles applications. It can be considered as part of Active Safety Systems, which is intended to act autonomously prior to an accident in order to avoid it. Another application for CMOS Cameras is inside smart and convenience packages like rear parking assist systems and front viewing features.

2. METHODOLOGY

The main focus of this paper is to determine the drag coefficient and the front area of a regular production car and evaluate two side rear view mirror substitution proposals by using video cameras using CFD tools and it was divided into two steps, similar to methodology proposed by reference [9]:

- First comparison: a comparison between drag coefficient and frontal area of a regular production car (Figure 2) and the same vehicle without side rear view.

- Second comparison: two video camera housing proposals will be evaluated in substitution of a regular side rear view mirror and their drag coefficient and frontal area values were compared with baseline car results.

Figure 2. Baseline car

For both steps, CFD simulations were performed considering a full regular production car with rotating wheels, CRFM drop pressures and full underhood representation. The vehicle is assembled in a virtual Wind Tunnel, with dimensions and parameters similar to GM Wind Tunnel [6], same proposal of [1] work. Parameters are exposed in Table 1:

Table 1. Parameters used for CFD simulations

Wind Tunnel Structure	General Motors (similar)
Air Speed	100 km/h
Outlet Pressure	Atmospheric Pressure
Turbulence Intensity	0.60%
Boundary Layer Suction	Beginning of the Test
Test Section Dimensions	(5.4 x 10.4 x 23.0) m
Turbulence Model	k-ε

The ground simulation for this paper is moving ground with rotating wheels as mentioned before, which is the condition close to the real operating condition, according to [5] and [11].

2.1. First Comparison

For the first comparison, the drag coefficient and frontal area of a baseline model, which is a regular production vehicle, will be compared to a proposed configuration which has no side rear view mirror. Both vehicle's configurations are shown in Figure 3.

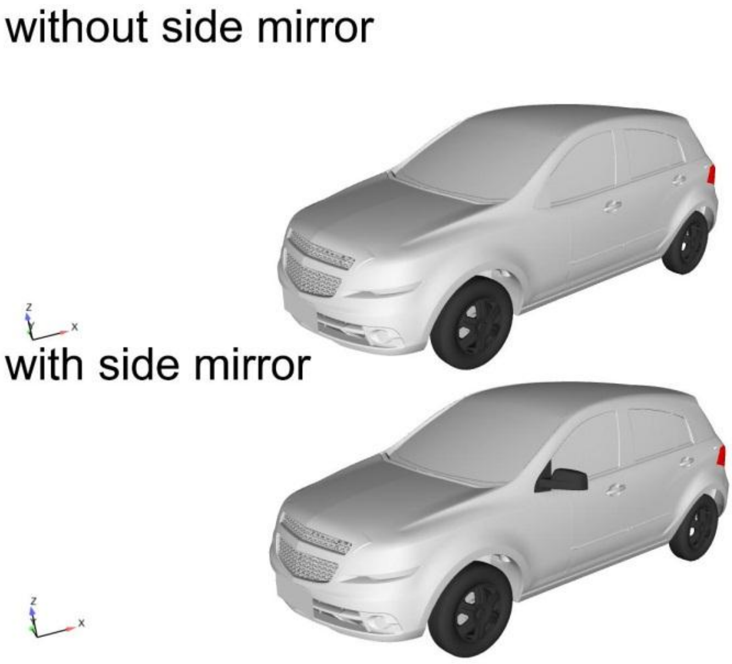

Figure 3. Vehicle's configuration without and with mirror

This first comparison was done to understand the influence of a side view mirror and its contribution to the drag coefficient and frontal area to the vehicle presented in this paper. It is expected a frontal area reduction due to the removal of the part but the simulation will also show the influence in the drag coefficient.

2.2. Second Comparison – Camera Housing Designs

Regulations do not allow cars without outside rear view mirrors, so the first comparison here presented cannot be implemented to regular production vehicles. Based on the regulations, a solution for this is by using video cameras pointed to the rear, which will have the same role of the outside rear view mirrors. Among the advantages of using video cameras for this kind of solution, the most important ones are the size, which are significant smaller than a regular outside mirror and also can be mounted in small aerodynamically developed housings.

With this, two camera housing proposals were evaluated in terms of drag coefficient and frontal area and results were compared to previous cases. The first housing design is a simple one, based on the outside rear view mirror neck dimensions. It is also assembled in the same place of the regular mirror and it is shown in Figure 4.

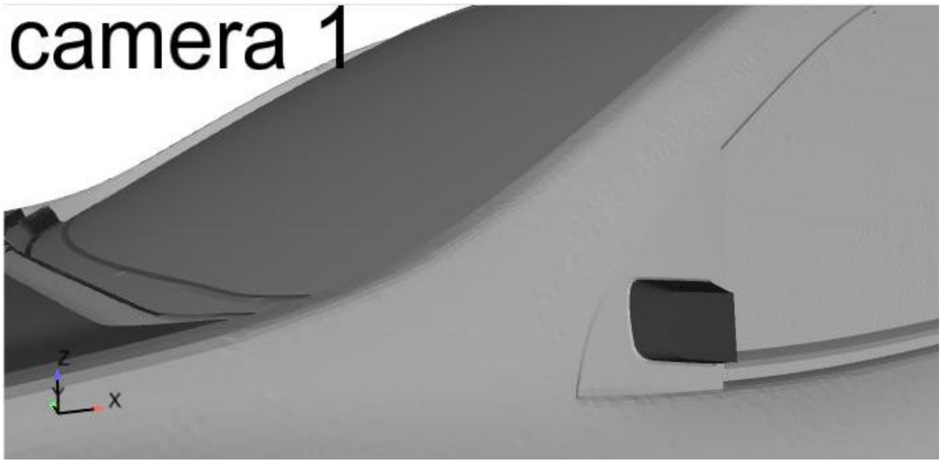

Figure 4. Design 1 for camera housing

The second camera housing design was based on foil profile attached to a cylinder which has the camera. It is a refined solution once it has several aerodynamic features. As the first design, this camera housing was also assembled in the same position of the regular outside rear view mirror and it is shown in Figure 5.

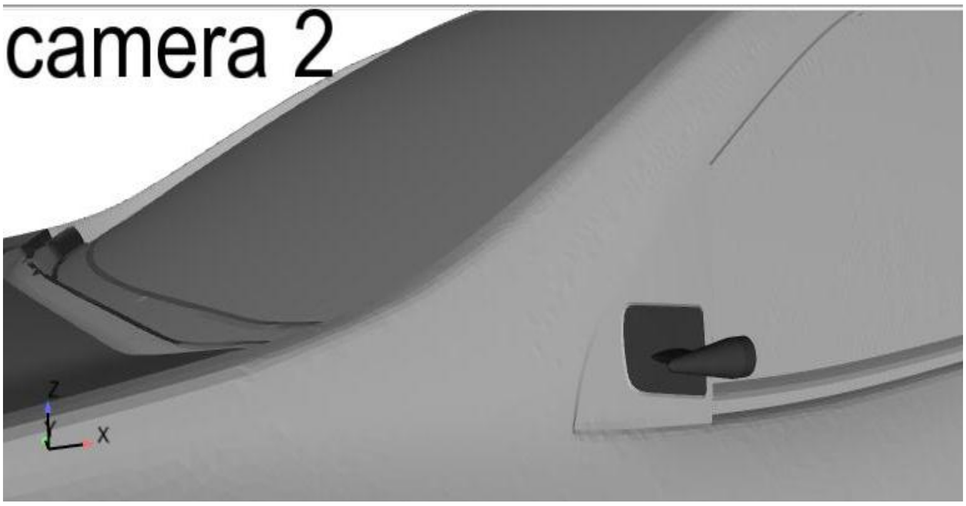

Figure 5. Design 2 for camera housing

3. RESULTS

3.1. First and Second Comparison

For both comparisons, the drag coefficients calculated by CFD and respective front areas are indicated in Table 2:

Table 2 – Drag Coefficient results

Model	Drag Coefficient (C_d)	Frontal Area (m^2)	
w/ mirror	0,444	2,129	First Comparison
w/o mirror	0,440	2,081	
Camera 1	0,440	2,108	Second Comparison
Camera 2	0,442	2,107	

CONCLUSION

Automakers are always seeking for solutions to improve vehicles performance. Improving aerodynamics and frontal area are good ways to have better fuel economy and also been green projects. Outside rear view mirrors are necessary to a safe drive and it is easy to conclude that by removing then, frontal area will be lower, improving the performance.

Once regulations do not allow cars without then, one alternative solution is the use of video cameras. Due to its size it is possible to allocate then in smaller housings compared to regular outside rear view mirror and some of them could be aerodynamically improved for better performance. In this paper, two housing solutions were presented and results compared to baseline production car.

First Comparison Conclusions

For the first comparison, removing the outside rear view mirror presented a reduction of 1% in the drag coefficient and also a 2.3% reduction in frontal area. Pressure contour and wake structure and velocity profile are shown in Figure 6, 7 and 8.

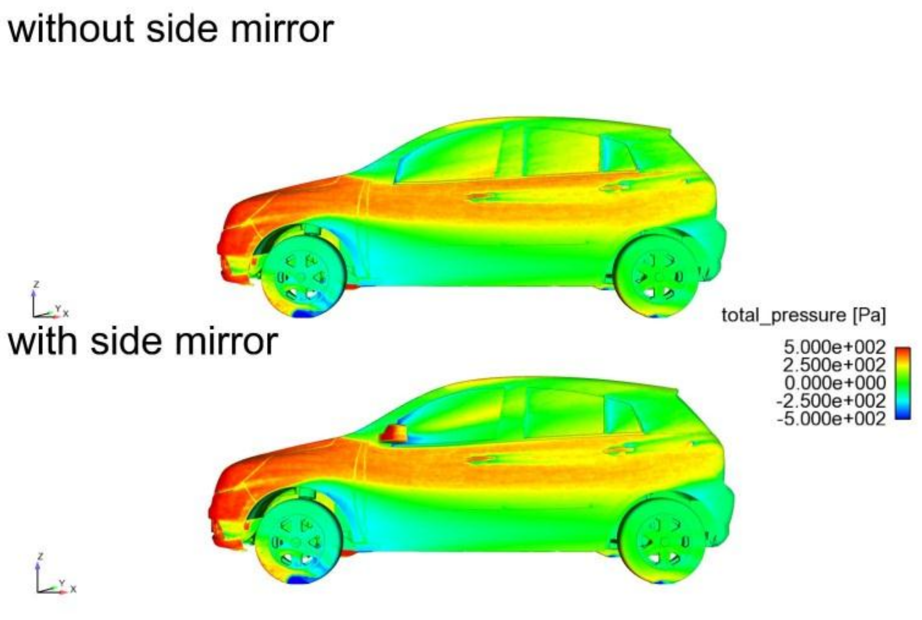

Figure 6. Pressure Contour for first comparison – side view

Pressure contour indicates high pressure on the mirrors and also a low pressure zone behind and above it, indicating flow detachment flow. Positive and high pressure zones indicate contributions to raise the drag coefficient. Once the case with mirror eliminates high pressure zones related to the mirrors, the drag coefficient of the proposal without mirrors should be lower than the current production car with regular outside rear view mirrors, confirmed by results presented on Table 2.

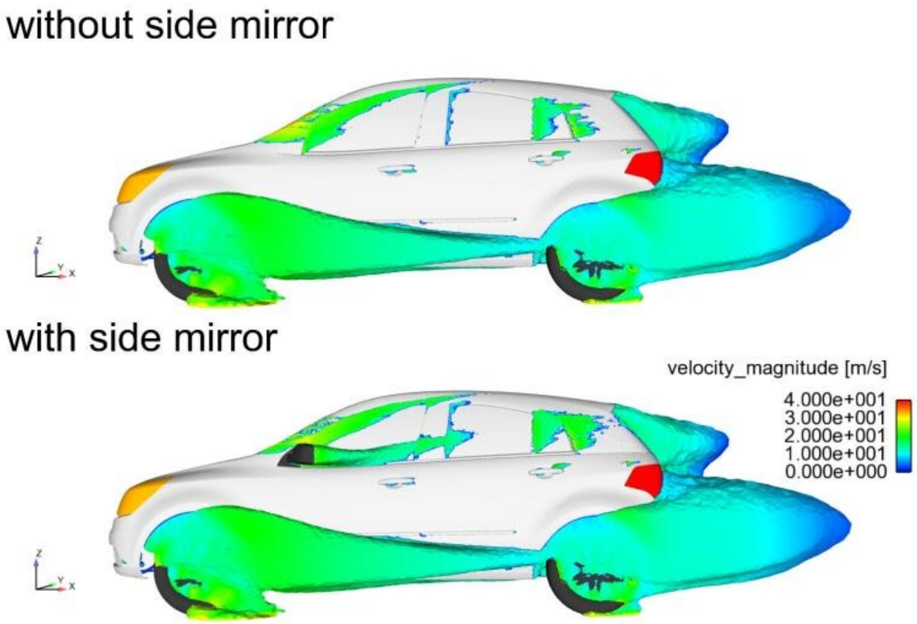

Figure 7. Wake profile for first comparison – side view

Wake profiles are similar for both cases, except for the region close to A-pillar, where is possible to see a reduction of the wake intensity in the case without mirrors. This also indicates drag coefficient and probable noise regions reductions.

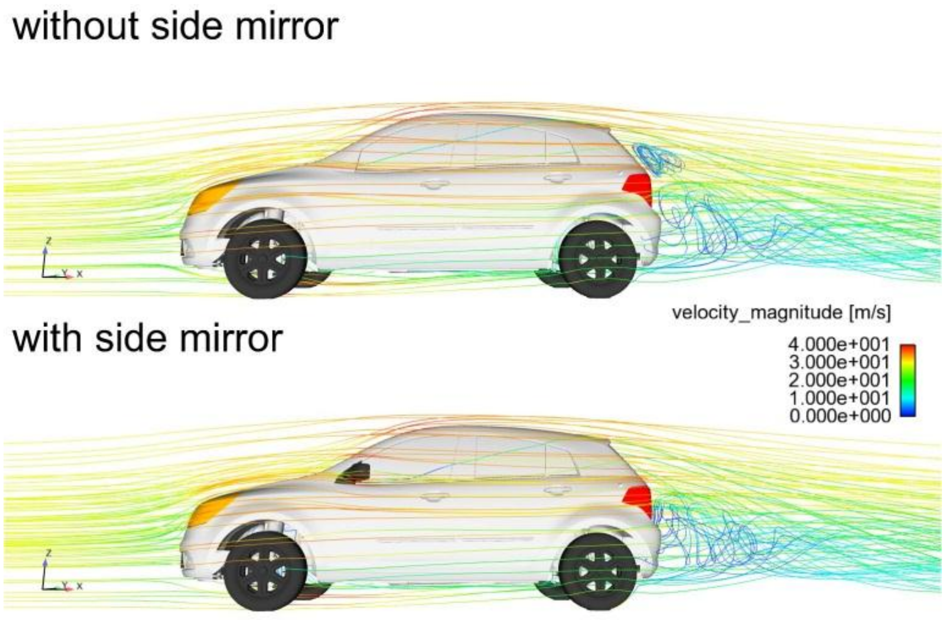

Figure 8. Velocity path lines for first comparison – side view

By removing the mirrors, one vortex was created at the rear end of the car, compared to the case with mirrors. This point is really important to emphasize that changes on the body can affect the aerodynamic properties in different ways and areas even if they are not direct related. In this specific study, one change at the front of the car affected the rear portion by adding a vortex which explains the 1% drag coefficient reduction.

Second Comparison Conclusions

As mentioned before, it is not possible to fully remove the outside rear view mirrors of one vehicle without proposing a solution for the driver to see what is happening with the traffic behind him. For both cameras 1 and 2 housing designs, the drag coefficient and frontal area values were reduced compared to the regular vehicle. Camera 1 presented a drag coefficient reduction of 1%, similar to the case without mirrors and Camera 2 reduced 0.5% in the drag coefficient. For the frontal area, Camera 1 is 1% smaller than the current production car with mirrors and Camera 2 is 1.2% smaller. Pressure contour, pressure contour details and wake structure are shown in Figure 9, 10 and 11.

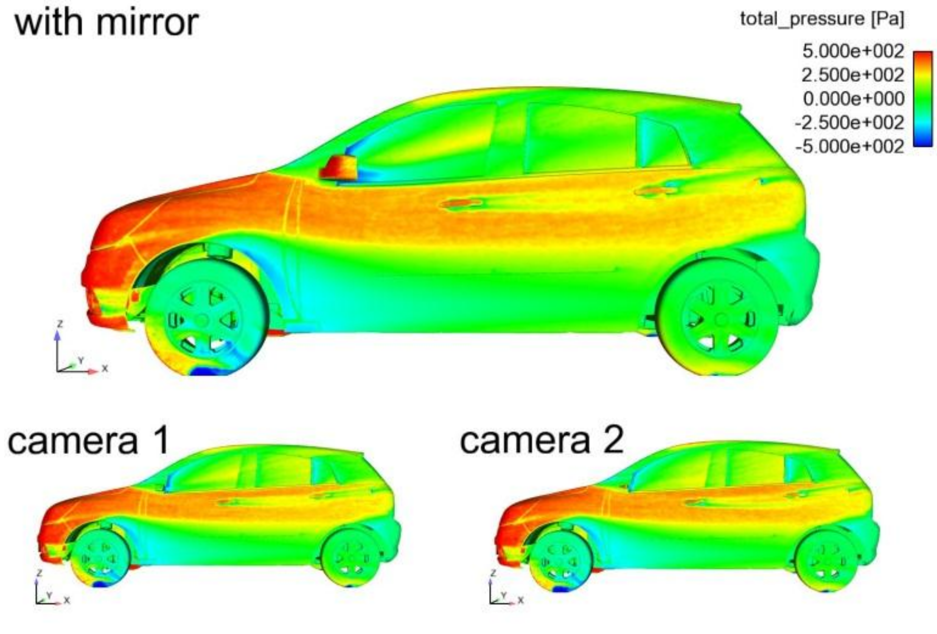

Figure 9. Pressure Contour for second comparison – side view

Pressure contour indicates similar profiles for both Cameras 1 and 2 and a pressure concentration on the case with mirror, which has the higher drag coefficient value of the three cases presented.

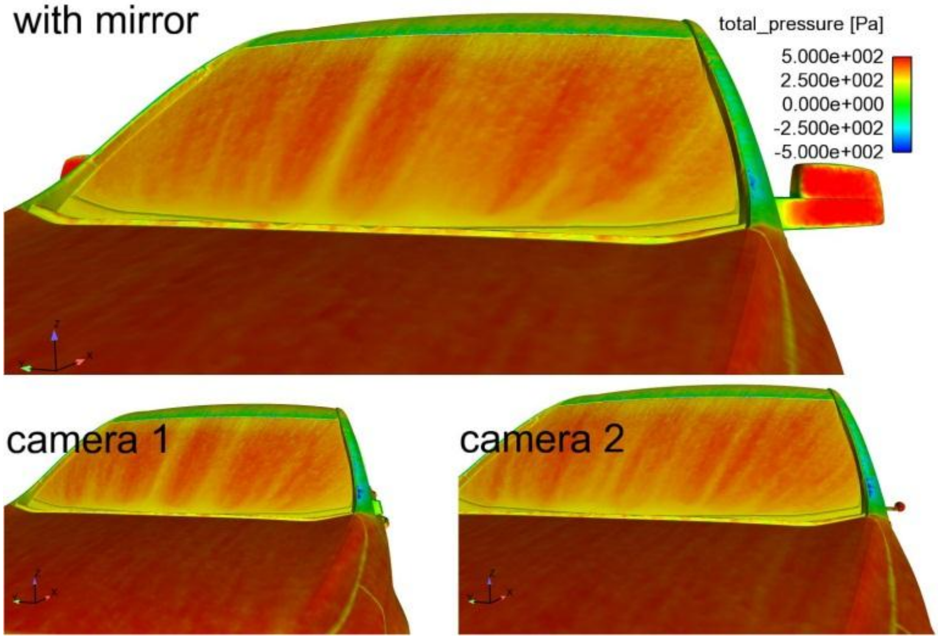

Figure 10. Pressure Contour details for second comparison – front view

Camera 2 also has a high pressure spot at the housing due to its design, compared to Camera 1 design, which explains the 2 counts difference between the proposals.

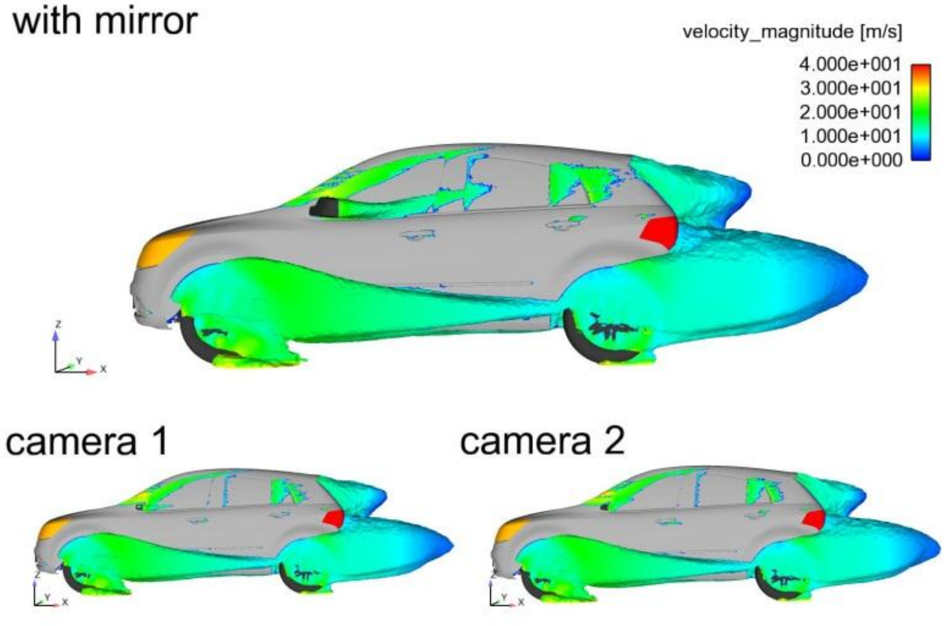

Figure 11. Wake profile for second comparison – side view

Wake profiles for Camera 1 and 2 are smaller than the one presented by the case with mirror, also explaining the drag coefficient value reduction. Camera 2 has a slight smaller wake due to the aerodynamic features compared to Camera 1. This fact also contributes to improve aero-acoustic performance of the vehicle.

Final Conclusions

This paper presented alternatives to replace traditional outside rear view mirrors, evaluating a mirror removal proposal, which is not possible to be implemented in production and a possibility to use video cameras pointed to the rear to replace the mirrors. Two camera housing designs were also evaluated using a proposed methodology to perform virtual CFD simulations considering a regular production vehicle. Analyses were divided into first and second comparisons in which the first comparison evaluated the drag coefficient and frontal area of the current production vehicle and the same car with the mirrors. The second comparison also evaluated the drag coefficient and frontal area values of two camera housing design proposals.

The best proposal was Camera 1 design, which lowered the vehicle Cd value in 1%, which was the same reduction of the proposal that fully removed the outside rear view mirrors. Also there was a frontal area reduction of 1% compared to the regular production vehicle.

The reduction in both Cd and frontal area are desirable once they are both related to fuel economy calculations by the mathematical expression Cd x A expression, which means Drag Coefficient times Frontal Area.

Determination of the fuel economy of the vehicle considering the new mirror replacement solutions and cost estimation of implementing the cameras would be good suggestions for further works.

Also studying the internal arrangements for the camera displays and aero-acoustic effects would complement this work.

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