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Numerical Study of Effects of Air Dam on the Flow Field and Pressure Distribution of a Passenger Car

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***Abstract*—**Everything that is attached to the outside of the vehicle to improve the driving performance of the vehicle by changing the flow characteristics of the surrounding air or to pursue the external personality is called a tuning part. Typical tuning components include front or rear air dam, also known as spoilers, splitter, and side air dam. Particularly, the front air dam prevents the airflow flowing into the lower portion of the vehicle and increases the amount of air flow to the side and front of the vehicle body, thereby reducing lift force generation that lifts the vehicle body, and thus, improving the steering and driving performance of the vehicle. The purpose of this study was to investigate the role of anterior air dam in the flow around a sedan passenger car using computational fluid dynamics. The effects of flow velocity, trajectory of fluid particles on static pressure distribution and pressure distribution on body surface were investigated by varying flow velocity and size of air dam. As a result, it has been confirmed that the front air dam improves the flow characteristics, thereby reducing the generation of lift force of the vehicle, so it helps in steering and driving characteristics.

***Keywords*—**Numerical study, computational fluid dynamics, air dam, tuning parts, drag, lift force.

I. Introduction

THERE are a number of tuning parts that change the flow characteristics to improve the traveling performance of the vehicle. Air dam (also known as front end spoilers), front splitter, rear end spoiler, diffuser, and side air curtain are known as representative external tuning components. In general, the front air dam is often used with a splitter. The main role of the air dam is to change the air flow in the front of the vehicle to reduce the drag force in the direction going and to improve the driving performance of the vehicle by reducing the lift force that might cause the vehicle unstable. These findings are referred to in a number of sources [1]-[4].

Since the role of those tuning parts is well known, it has not been studied academically, so there are not many results. In 2010, Mitra [5] investigated the mounting effect of an air dam through experimental studies, and reported that there was little drop in lift force and increased drag for the experimental conditions used. He concluded that the addition of those add-on parts like rear-end spoiler increases the aerodynamic stability of a basic car model, and hence, they can be used in real life, which will be an added advantage. Kumar et al. [6] investigated the role of rear spoiler as a drag decreasing part through the computational fluid dynamics. Their computational analysis shows that there is possibility of improving the aerodynamic performance of car by modifications in exterior design of car body. These modifications are helpful in reducing the coefficient of drag (Cd), i.e. Cd affects the fuel consumption. By these modifications, they reported, the Cd is reduced by approximately 2%. Also in 2014, Ali et al. [7] examined the possibility of increase of drag and decrease of lift force by the influence of air dam. They concluded that the optimization of vehicle body results in a considerable reduction of fuel consumption, an improvement of comfort characteristics, and a more favorable driving characteristics of ground vehicles. In optimization besides wind tunnel investigations numerical simulation of flow field has become more and more important.

Based on the previous studies, the computational fluid dynamics analysis was conducted to investigate the role of the frontal air dam which affects the driving performance of the vehicle. The aerodynamic effects of the air dam were investigated by varying the size of air dam and speed of the vehicle.

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II. Numerical Simulation

A. Problem Overview

The air dam, which is a typical tuning part, has various shapes. In this study, as shown in Fig. 1, the cross-sectional shape of the air dam was classified and analyzed. Fig. 1 (a) shows the case of the biggest air dam, which has the height of 230 mm, and the distance from the ground is only 54 mm. It is a scale that can be mounted on a professional racing car, not the usual form of an air dam. This type was named Air Dam 100% in this study. In contrast, Figs. 1 (b) and (c) show the smaller one relative to the 100%. They have heights of 115 mm and 57.5 mm, and apart from the ground with 169 mm and 226.5 mm, respectively. They are named 50% and 25%. Fig. 1 (d) shows the original body of the vehicle without an air dam.

The second parameter for the analysis is the speed of the car. In this study, three conditions: 12.5, 25.0, and 50.0 m/s, which are velocities representing 45, 90, and 180 km/h, respectively. It is the speeds set to consider the effect of the air dam in low, medium and high speed, respectively.

B. Numerical Simulation

The shape of the car used in this study is shown in Fig. 2. The exterior data of the car from K Company in Korea as shown in Fig. 2 are used as the data such as length and width of the vehicle. ANSYS program, which is a commercial computational fluid dynamics program, was used for the

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numerical analysis. The inlet and outlet conditions were used for the front and rear of the vehicle, and symmetry conditions were applied for the side and top. The total number of cells is 336,087, and the convergence condition is 10-6. A realizable k-ε turbulence model was selected.

In order to investigate the effect of the air dam on the flow and pressure distribution, the pressure distribution and the pathlines of fluid particles on the surface as shown in Fig. 3 were examined. We would like to define it as a longitudinal cross-section plane. In addition, the pressure distribution on the front part of the vehicle was also considered.

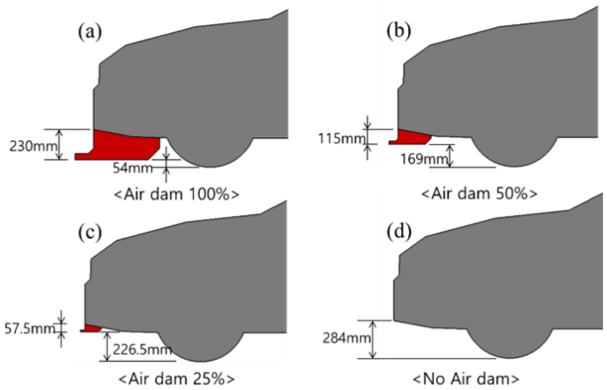

Fig. 1 Schematics showing shapes and heights of frontal air dams, and distances between air dam and ground

Length (mm)	4,855
Width (mm)	1,860
Height (mm)	1,465
Distance between Wheels (mm)	2,805

Fig. 2 Specifications of the vehicle of this simulation

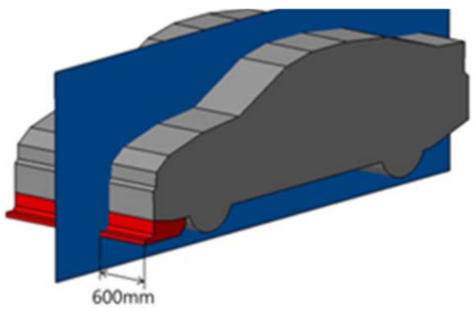

Fig. 3 Schematics showing longitudinal cross-section plane

III. Results and Discussion

A. Results from Longitudinal Cross-Section

As shown in Fig. 3, the longitudinal cross-section means a longitudinal section which is 600 mm away from the side of the car body. Figs. 4-6 show static pressures at the cross-section for the flow velocities of 12.5, 25, and 50 m/s, respectively, as a function of the size of the air dam. Although it is a qualitative result, it shows the change of the static pressure distribution around the car according to the speed and the size of the air dam. The black portion of the front is the portion above the upper limit of the scale bar, which is excluded due to the selection of the scale bar to see a wider area change. Compared to the case of without air dam, the static pressure increases at the front part as expected when the air dam is 100% and 50%. However, in the case of the 25% air dam, the static pressure was slightly decreased. It was unexpected result and needs to be checked with other results.

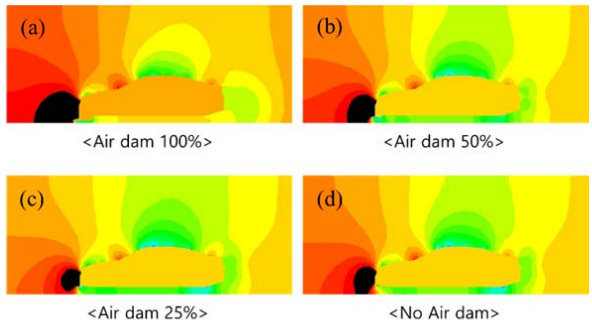

Fig. 4 Static pressure contours of cars with speed 12.5 m/s

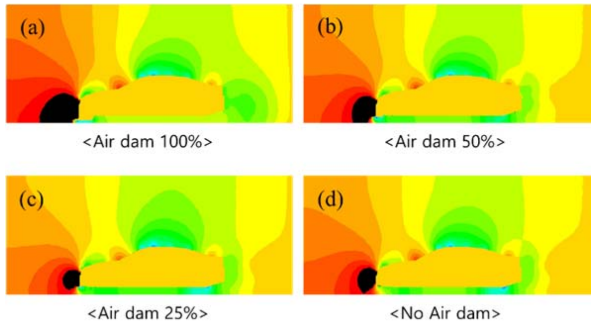

Fig. 5 Static pressure contours of cars with speed 25 m/s

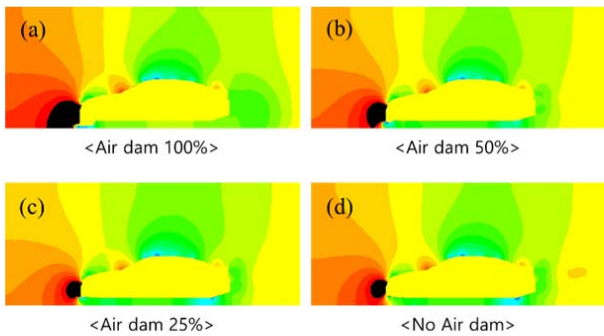

Fig. 6 Static pressure contours of cars with speed 50 m/s

Figs. 7-9 show the pathlines of the fluid particle with respect to the cross-section for the flow velocities of 12.5, 25, and 50 m/s, respectively, as a function of the size of the air dam. In the recirculation zones on the rear side, it can be seen that the recirculation area is reduced by the decrease of the top flow in the case of 25% air dam than in the case of without air dam.

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This can be interpreted as related with the result of decreased static pressure of the case of 25% air dam that when the air dam size is relatively small like 25% air dam, the flow might be induced to the lower portion or the side of the vehicle rather than the upper portion.

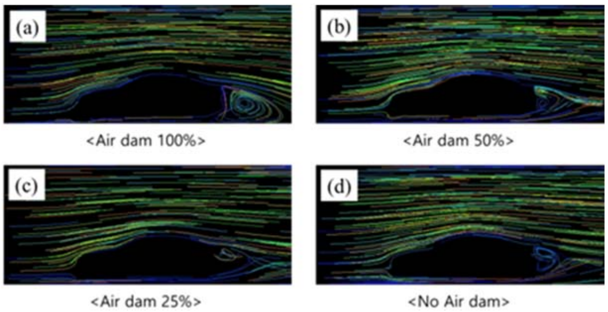

Fig. 7 Fluid pathlines near the cars with speed of 12.5 m/s

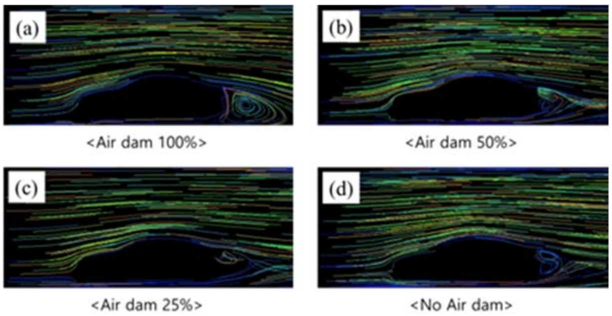

Fig. 8 Fluid pathlines near the cars with speed of 25 m/s

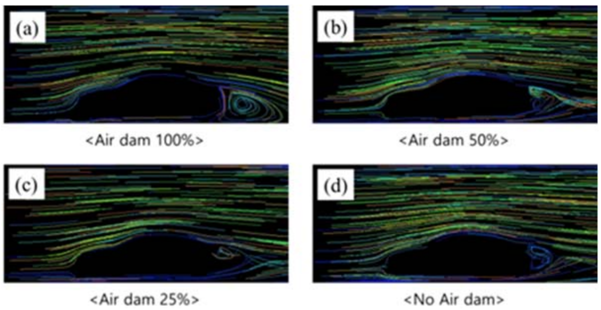

Fig. 9 Fluid pathlines near the cars with speed of 50 m/s

B. Pressure Distribution

The total pressure distributions of the vehicle surface for the flow velocities of 12.5, 25, and 50 m/s, respectively, as a function of the size of the air dam are shown in Figs. 10-12, to confirm the reason of unexpected result from the case of 25% air dam.

In the case of 50% and 100% of the size of the air dam, it is qualitatively known through the dark color that the inflow to the lower part of the vehicle is reduced and the amount of inflow into the side part and the front part increases. Results from all the three velocities show the same tendency of unexpected effect of air dam for the case of 25%. These are well coinciding with those of from Figs. 4-9.

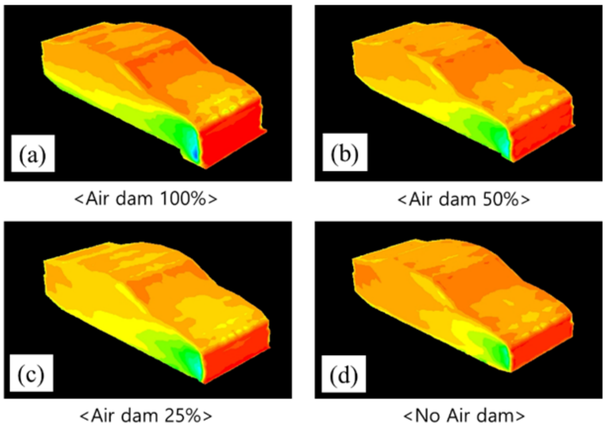

Fig. 10 Contours of total pressure with speed of 12.5 m/s

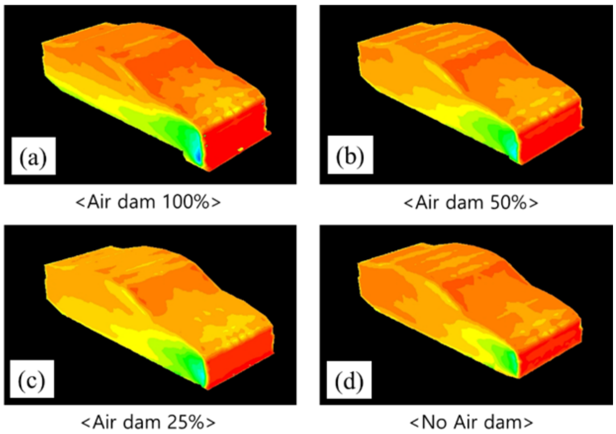

Fig. 11 Contours of total pressure with speed of 25 m/s

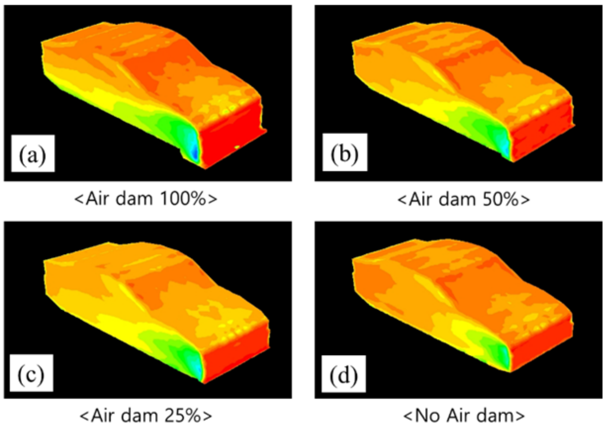

Fig. 12 Contours of total pressure with speed of 50 m/s

From these results, it can be concluded that the performance of the air dam is expected to be achieved when the size of the air dam is more than the proper level. In the case of this result, it is judged that the air dam did not play a role in the case of 25%-sized air dam.

IV. Conclusion

In this study, we tried to investigate the role of air dam by conducting computational fluid analysis on three types of flow velocity and four types of air dam. As a result, it was confirmed that the frontal air dam plays a role of reducing the drag through the distribution of the static pressure in the vicinity, and the pressure in the direction of the ground increases through the pressure distribution on the surface of the vehicle body. However, it might be not effective when the size of the air dam is relatively small with certain amount depending on the speed and shape of the vehicle.

Acknowledgment

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