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Simulation of noise transmission into the Hyundai Simplified Model with PowerFLOW

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1. Introduction

For conventional cars, external aero-acoustic noise is an important source of noise inside the cabin above 100 kph. With the development of electric cars, and the removal of other sources of noise, aero-acoustic noise becomes even more important. It is an aspect of car development that just can't be ignored, and that every car OEM has now integrated in their development cycle.

The present work falls under a validation effort initiated by HMC to assess the quality of existing methods that have been developed to simulate the transmission of noise from the source to the ears of the driver.

The method proposed here rests on two types of modeling. First, the airflow must be modeled properly. For this, PowerFLOW is used. Aero-acoustic noise comes primarily from the fluctuations of the flow field as air flows over a solid body. It is the unsteadiness of the turbulent flow structures generated around edges and corners that produce the vortices that are interacting with each other and with the solid boundaries to create the fluctuating pressure field that contains acoustic noise. So it is essential to use a CFD approach that can reproduce the real unsteady flow over the body with the appropriate flow structure interactions.

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To simulate the noise transmission through a solid structure to the interior, a structural model of some kind must be used. A SEA model is used in the present approach. A coupling is necessary between the CFD simulation and the SEA model. The pressure load computed in CFD needs to be processed to define the input to the SEA model.

With the proper unsteady flow field, the proper transformation of the load to define the inputs of the SEA, a good estimation of the noise level inside the cabin can be achieved [8].

2. Experiment and Simulation

2.1 Experimental setup

The Hyundai Simplified Model (HSM) was tested in the Hyundai wind-tunnel to provide the reference results to compare the simulation results to. The HSM is a wedge box directly mounted on the floor of the wind-tunnel. It was used previously to study sunroof buffeting and was now adapted for noise transmission. A windshield and two side windows were added to mimic part of the greenhouse of a car (see Figure 1).

The HSM was tested at two different wind speeds, 110 kph and 130 kph, and at two different yaw angles, 0° and 10°.

The driver side window was equipped with 5 flush mounted microphones and the interior noise was measured using two different microphones representing the driver inner and outer ear positions (see Figure 2).

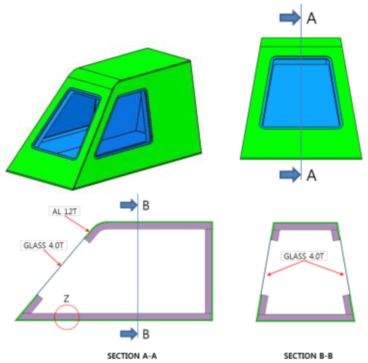

Figure 1 Configuration of the HSM tested in the Hyundai wind-tunnel.

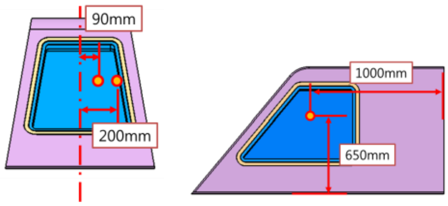

Figure 2 Positions of the two microphones inside the HSM.

2.2 Setup and simulation procedure

A completely analytical simulation of interior wind noise is performed in two steps. The first step simulates the flow field around the vehicle at speed using PowerFLOW (version 4.4d) and predicts the fluctuating pressure loads on the exterior panels of the vehicle. PowerFLOW is a Lattice Boltzmann Method (LBM) based CFD software using a VLES turbulence model. It is a very efficient transient flow solver used by many OEMs in the development of car worldwide. The background of the method and the details of its implementation can be found in the references 1-7.

The second step predicts the interior noise in the cabin using PowerACOUSTICS 3.0a. In this step the predicted transient pressures are analyzed in the frequency domain to develop load cases for the noise transmission module in PowerACOUSTICS (based on a Statistical Energy Analysis approach) and predict the interior noise in the cabin. The details of the computational fluid dynamics model and the noise transmission model are described in detail in Lepley et al [8] and thus are not repeated here.

A variable resolution scheme with the finest cell size of 1mm was used in the flow simulations. Fine resolution was used around the front and side faces to capture the flow critical to acoustic evaluation accurately. The resolution was progressively coarsened away from the critical regions for computational efficiency. Simulations were executed for a physical time of 0.75 seconds with initial conditions seeded form a coarse run.

2.3 Simulation Results – 0° yaw

The stricking characteristic of the flow over the HSM is the size of the A-pillar vortices. Because of the very flat face, the large wedge angle and the sharpe edges of the A-pillars, the A-pillar vortex of the HSM take a proportion that is much larger than what is found on a modern car. The isosurface of Cp total = 0 is shown in Figure 4. It gives a good indication of the volume taken by the A-pillar vortex.

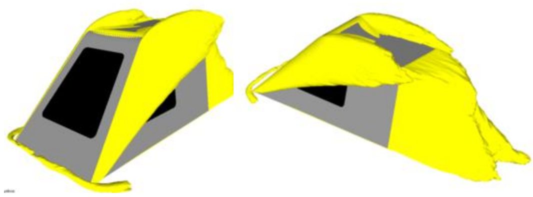

Figure 4 Flow averaged isosurface Cp tot = 0, 110 kph, 0° yaw.

A second flow structure that can be easily identified is the presence of a strong horseshoe vortex located at the base of the HMS. This vortex is due to the presence of a boundary layer developing upstream of the HSM on the wind-tunnel floor. This vortex interacts with the base of the A-pillar vortex and is likely to have limited impact on the flow structures at the level of the side windows.

The surface streamlines on the side of the HSM also gives a good indication of the size of the A-pillar vortex. Figure 5 shows that most of the side window is covered by the A-pillar vortex. Re-attachment is only occurring in the lower right corner of the window. This indicates that the side window will be subjected to very strong pressure excitation.

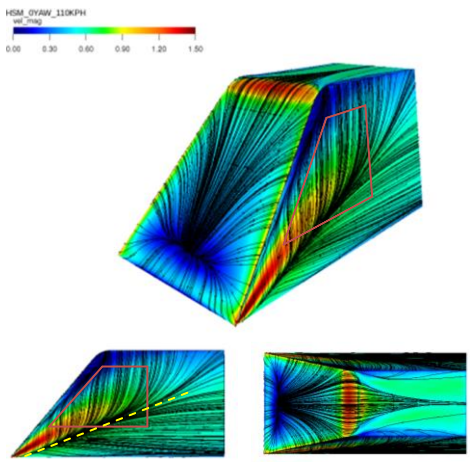

Figure 5 Averaged flow surface streamlines and non-dimensional surface velocity magnitude.

3. Conclusions

The interior noise generated by aero-acoustic effects over a simplified model was tested in the Hyundai wind-tunnel. Two yaw angles and two wind speeds were used. The simulation of the four combinations was performed using PowerFLOW and PowerACOUSTICS to assess the accuracy of the simulation. Comparison of results will be provided in the full paper.

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