The capture of small variations in interior noise levels using PowerFLOW

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ABSTRACT

Hyundai Motor Company is proposing the fourth evolution of their Hyundai Simplified Model as benchmark results for the validation of CFD codes in aeroacoustics and noise transmission to the interior of a cabin. The focus of this benchmark is on variations in noise level induced by small typical geometry changes that can be found in a car development program. This article presents the noise transmission results obtained with PowerFLOW in combination with a SEA model and shows that it is possible to capture small variations in noise level with a lattice Boltzmann method based code.

1. Introduction

Five years ago, Hyundai Motor Company (HMC) has developed the Hyundai Simplified Model (HSM), an evolving wedge box shape model designed intended to benchmark test CFD codes. The first version of the HSM had very strong A-pillar vortices on the side of the box and was aiming at verifying the accuracy of the wall pressure fluctuations simulated by CFD codes. In the second version, a sunroof type of opening was made on the roof to produce buffeting inside the HSM2. In the third evolution the HSM3 was modified to include a windshield on the front face and windows on each side. The benchmark was then focusing on noise transmission to the interior of the cabin.

It is now the fourth version of the Hyundai Symplified Model (HSM4). The model is a direct evolution of the HSM3, and it is aiming at benchmarking the capacity of CFD codes to capture the difference in noise produced by different external elements typically found on cars and for which information is sought during the development process (side mirror, rain gutter). Interior noise and exterior microphones are used to assess the quality of the simulation results.

The simulation of the external flow field is done with PowerFLOW, and the unsteady pressure field obtained is the used to feed information to a SEA model that takes care of transmission of noise to the interior of the cabin. It is essential to simulate the unsteadiness of the flow to capture the interaction of the flow structures with the body and the interactions of the vortices within the flow. Then the proper sound generation mechanisms can be reproduced.

2. Experiment and Simulation

2.1 Experimental setup

In the previous versions, the HSM was sitting directly on the floor. In the present version the model is standing on 100 mm feet to elevate it from the ground to avoid the generation of a horseshoe vortex at the nose of the model. As in the previous version, the model is equipped with a front windshield and two side windows. The interior is padded with sound absorbing material to consider only the sound transmitted through the windows.

The benchmark is composed of three cases:

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- Base. The base model is equipped with a rounded A-pillar cross-section with a slanted edge on the windshield side (see Figure 1).
- Base + rain gutter. In this case the A-pillar edge on the windshield side makes a 90° with the windshield (see Figure 2).
- Base + side mirror. Here the base case geometry is used with side mirrors mounted on each side of the model (see Figure 3).

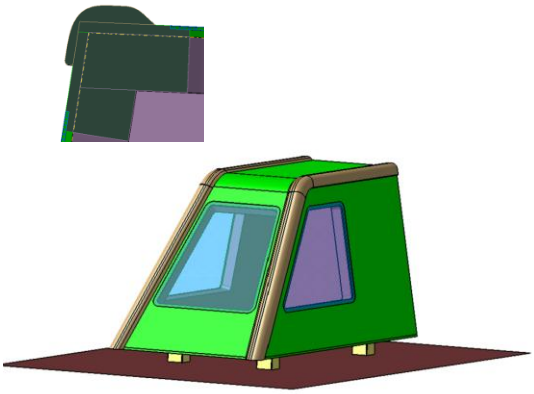

Figure 1 Base case geometry

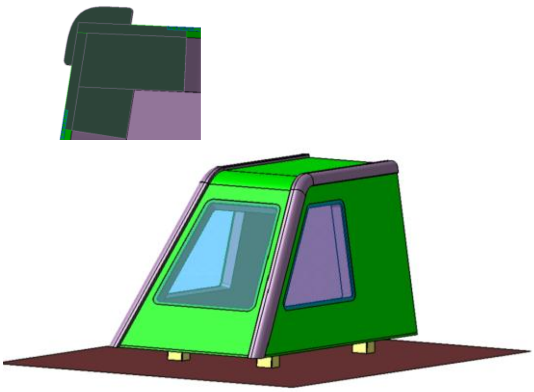

Figure 2 Base + rain gutter geometry

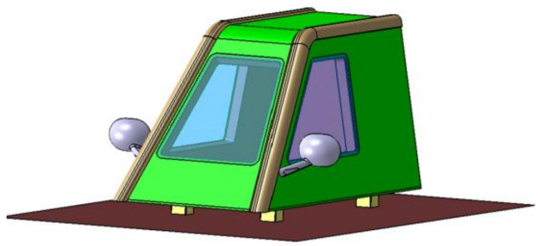

Figure 3 Base + side mirrors geometry

The test was performed in the Hyundai wind-tunnel at 110 kph. Measurement of noise level was done inside the cabin and five surface microphones were used to measure the pressure fluctuation on the left side window in each of the cases. The position of the five microphones is indicated in Figure 4.

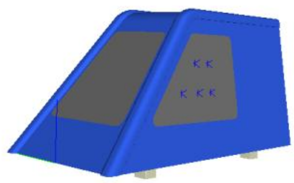

Figure 4 Position of the surface microphones

2.2 Setup and simulation procedure

The simulation of the three cases was done with PowerFLOW (version 5.0c). PowerFLOW is a CFD code used throughout the automotive industry based on lattice Boltzmann method (LBM). PowerFLOW uses a very large eddy simulation (VLES) turbulence model that models turbulence structures that are not resolved in the flow field. By its nature, PowerFLOW computes a transient flow field that provides the fluctuating pressure around and on the surface of the body. The description of the numerical method behind PowerFLOW can be found in references 1-6, so it won't be detailed here.

The finest voxels (cubic volume cell) have 0.5 mm and are used on the front and side of the body. The boundary conditions of the computational domain are fixed velocity upstream and constant pressure downstream. The physical simulated time was 1 sec out of which 0.5sec was used for the post-treatment.

The flow field results are then treated to extract the relevant excitation over the three windows, that is then used as the inputs to a SEA model that computes the noise transmission to the inside. The SEA model relies on physical properties of the glass as well as on acoustics characteristics of the inner volume. The sound pressure level (SPL) is then obtain as a function of frequency and will be compared to experimental results in the final paper. The details of the SEA model used can be found in reference 7.

2.3 Simulation Results

The base case has a much smaller A-pillar vortex than on the previous versions of the HSM. The design of the new A-pillar section made it much more comparable to the A-pillar vortices encountered on real cars.

The rain gutter made a very small difference in the flow structures with only a difference appearing in the Cp total = 0 isosurface on the upper surface of the A-pillar indicating slightly more losses in the flow when coming from the windshield (see figure 5 and 6).

The flow field around the side mirror has a strong impact on the flow around the A-pillar. The flow is accelerated between the mirror and the side glass and reduces the size of the separation locally as can be seen on figure 7.

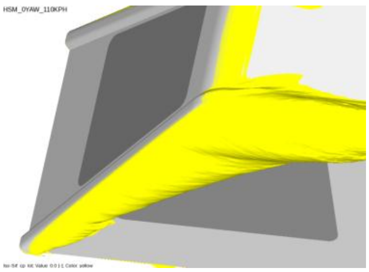

Figure 5 Base, isosurface Cp tot = 0

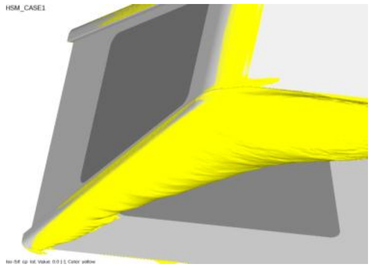

Figure 6 Base + rain gutter, isosurface Cp tot = 0

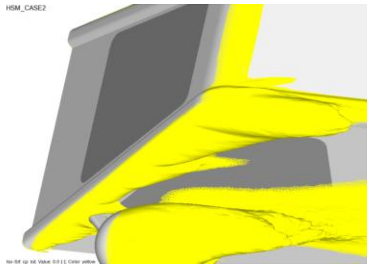

Figure 7 Base + side mirror, isosurface Cp tot = 0

The overall SPL on the side window and on the windshield indicate a very small difference between the base case and the rain gutter as suggested by the isosurface of Cp total = 0. The diference between the base and the side mirror case is only noticable at lower frequencies on the sideglass and at higher frequencies on the windshield. There is obviously an upstream effect of the side mirror on the windshield SPL. The overall SPL on the sideglass and on the windshield are shown in figure 8.

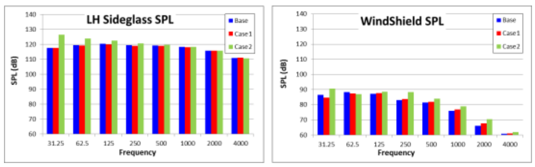

Figure 8 Overall SPL on sideglass and windshield

Additional results will be available in the final version of the paper including surface dB maps, acoustics dB maps and interior noise.

3. Conclusions

The transient flow field was computed around three versions of the Hyundai simplified model in order to compute the surface pressure fluctuation and the noise transmission to the inside of the model. Small variations were captured between the base case and a modified rain gutter, and a larger variation was observed when side mirrors were mounted on the model.

Comparison to experimental results will be provided in the final version of the paper.

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