

Prediction Model for Acoustic Leakage through Automotive Door Seal Gaps Using Finite Element Method

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Leakage noise through door-seal gaps is an important contributor to aeroacoustic-noise. Predictive tools are required to guide seal geometry and mitigation strategies. Empirical leakage-noise models depend on experiments, so predicting noise from design geometry is difficult. Development therefore relies on drawing checks and full-vehicle tests and often requires late-stage fixes. This paper presents a 3D FEM acoustic transmission method that reproduces gap and internal sound fields and enables early-stage design assessment.

Acoustic FEM models are generated by wrapping CAD geometry, remeshing surfaces to wavelengths at the highest analysis frequency, and creating solid elements. Small gaps can cause many invalid elements during remeshing, so this study used a level-set wrapper less prone to such issues and configured it to capture a critical 2 mm beltline gap. The remeshed solids defined an acoustic FE subsystem for the door interior and an APLM subsystem for the infinite cabin domain, coupled at the beltline trim–glass gap. Analysis covered 1–6.3 kHz, solved via a direct nodal method, with a point source (1 Pa at 1 m) near the door mirror. Corner pieces (CP) are installed at the lower part of the fixed glass (1CNR) and at the rear end of the beltline (4CNR). To assess the effect of each CP on leakage noise, comparisons were made under the following conditions: (a) with CPs, (b) without CPs, and (c) without the CP at 1CNR.

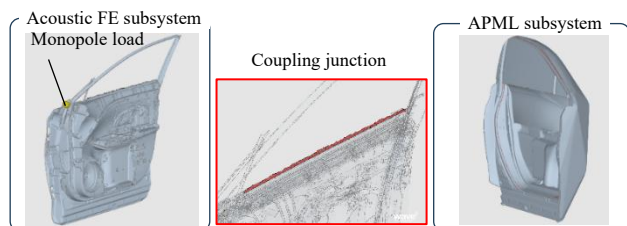


Fig.1 Analysis model

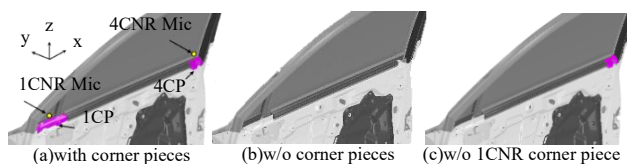


Fig.2 Comparison conditions

The computational results yielded the difference in in-cabin sound caused by removing the CPs. For sound near 4CNR, the presence or absence of the 4CNR CP produced a larger difference than that of 1CNR. This indicates that sound propagates through the door interior and transmits into the cabin from 4CNR.

Adding acoustic absorbers is considered an effective countermeasure against leakage noise. To determine the most effective placement, an energy-flow analysis was performed. The energy-flow analysis divided the door interior volume and calculated the acoustic intensity on the boundary surfaces by integration. The analysis showed that, in the 2 kHz band, propagation paths were observed near the beltline and along the lower part of the door, whereas in the 4 kHz band the primary path was only near the beltline.

Acoustic excitation tests using an actual vehicle, the results largely agreed with the computational predictions.

These results confirmed that effective mitigation locations can be identified from the sound transmission paths.

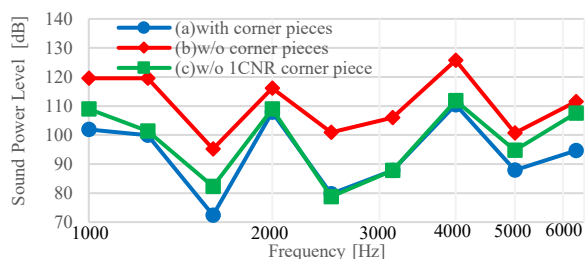


Fig.3 Comparison CPs at 4CNR (CAE Result)

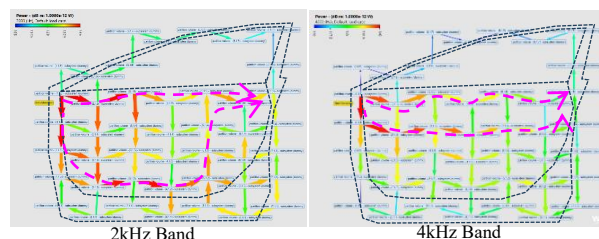


Fig.4 Result of Energy Flow Analysis