講演番号	024

Development of Evaluation Technology for Tire External Noise and Investigation of Generation Mechanism (2nd Report)

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KEY WORDS: **Noise, Exterior noise, Evaluation technology**, Tire noise, Acoustic propagation, Wheel house acoustics [B3]

To comply with increasingly stringent exterior noise regulations, including UN-ECE R51-03 Phase 3, this study investigated body-side countermeasures for reducing tire-related pass-by noise. For internal combustion engine vehicles, exterior noise reduction requires mitigation of engine, tire, exhaust, and intake noise, whereas for electric vehicles the primary challenge shifts to tire noise due to increased vehicle mass and higher acceleration. Both the radiation characteristics of tire noise and its transmission paths through the vehicle body were therefore examined.

First, a single-tire test system was developed using a chassis dynamometer and a trailer-based tire support rig, with consideration given to safety, simplicity, and consistency with actual vehicle conditions. Measurements showed that sound radiated from the tire–road contact region propagated predominantly in the longitudinal direction—forward and rearward relative to the vehicle. Sound intensity was calculated from the measured sound pressure levels and multiplied by the effective cross-sectional area of each propagation path to estimate the acoustic energy entering the underbody and wheelhouse regions. The results indicated that specific forward and rearward paths contributed significantly to energy transmission into the vehicle body, and that increasing the acoustic room constant, enlarging the absorbing surface area, and improving absorption efficiency were effective approaches for reducing near-tire sound pressure.

Based on these findings, a sound confinement concept was proposed in which tire noise was guided into body cavities before radiating to the exterior. The target cavities included the region behind the front bumper, the interior of the rocker panel moldings, and the region behind the rear bumper. Connecting openings were introduced between these cavities and the tire vicinity to allow acoustic energy transmission while preventing ingress of debris and water; sound-guiding plates were also incorporated. Vehicle tests using IDPB measurements showed small but measurable pass-by noise reductions: approximately 0.2 dB for the front bumper and engine-room cavity, 0.1 dB for the rocker panel molding, and 0.2 dB for the rear bumper cavity. However, excessive area contraction of the guiding plate increased reflected sound, raising the inlet sound pressure by 3.2 dB and reducing overall effectiveness. These results indicated that reflection control—such as applying sound-absorbing material to the guiding plate—is essential for maximizing performance.

Residual sound not captured by the body cavities was then examined. Measurements and model experiments showed that this sound propagated upward through the narrow, quasi-parallel gap between the tire and fender liner, increased in level in the upper wheelhouse region, and was subsequently radiated laterally through gaps between the tire and fender or between the brake disc and wheel. A simplified parallel-plate experiment confirmed that sound propagated with little attenuation through a narrow resin–resin gap, whereas partial replacement of one surface with nonwoven material reduced propagation significantly. Based on this mechanism, a prototype fender liner incorporating partial nonwoven material was developed. Bench tests showed a noise reduction of approximately 4 dB in the tire region, corresponding to a 60% decrease in acoustic energy, and vehicle IDPB testing confirmed a pass-by noise reduction of approximately 0.5 dB.

In summary, the radiation and propagation mechanisms of tire noise were clarified, and two effective body-side countermeasures were demonstrated: confinement of longitudinal tire noise within body cavities, and suppression of upward sound propagation in the wheelhouse through the use of nonwoven fender liner material.

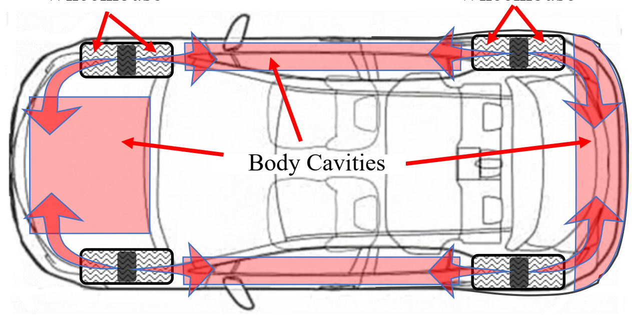

Fig. 1 Conceptual diagram of tire noise introduction into body cavities

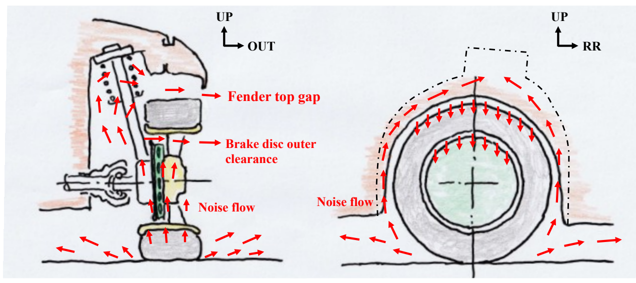

Fig. 2 Proposed mechanism of tire noise propagation and lateral radiation from the wheel house

2026 JSAE Annual Congress (Spring) - Summarized Paper
Issued on May 22, 2026