

Development of a Prediction Method for Ventilation Noise Reduction in Air-Cooled Battery Units

- Prediction of Duct Attenuation -

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In the air-cooling system for batteries installed in hybrid vehicles, increasing the blower rotational speed to enhance cooling performance also increases the airflow noise generated by the rotation of the blower impeller. This noise propagates through the duct and is radiated from the duct inlet inside the cabin, resulting in an unpleasant noise for vehicle occupants. Therefore, in the development of battery air-cooling systems, it is important to design ducts that can simultaneously suppress blower noise while maintaining a high airflow rate.

This paper focuses on blower noise in the HEV battery air-cooling system and proposes a duct attenuation prediction method that enables performance prediction and countermeasure evaluation during the design phase. Since directly predicting sound pressure levels using CFD entails a high computational cost and is therefore impractical for the short development cycle of duct design, the prediction target is redefined as the amount of sound attenuation within a duct section ("duct attenuation").

Prior to the development of the prediction method, experiments were conducted to investigate the characteristics of duct attenuation. In both the experiments and the prediction method, duct attenuation is defined as follows:

$$\Delta P_{duct}(f) = P_{unit}(f) - P_{blower}(f)$$

where f denotes frequency, P_{unit} is the sound pressure level measured at the air inlet when the duct and blower are connected ("Unit airflow noise"), P_{blower} is the sound pressure level measured at the air inlet when the blower operates alone ("Standalone blower noise"), and ΔP_{duct} represents the duct attenuation. The experimental results confirmed that duct attenuation is affected more significantly by the geometry of the sound transmission path than by the acoustic excitation generated by the blower.

The duct attenuation prediction method consists of three steps that follow the experimental procedure. First, the standalone blower noise is predicted using an unsteady compressible flow simulation with PowerFLOW Version 19. Based on the characteristics identified from the experiments, this analysis only needs to be conducted for a single representative operating condition. Furthermore, this analysis does not need to be repeated for units that use the same blower, resulting in a significant reduction in computational cost. Second, the unit airflow noise is predicted using an acoustic simulation with ACTRAN Version 19, where the sound pressure profile obtained in Step 1 is applied as the excitation boundary condition. Finally, the duct attenuation is calculated according to the equation defined above.

As a validation of the proposed prediction method, changes in duct attenuation caused by different duct shapes and the addition of sound-absorbing materials were compared with experimental measurements (Fig.1). The predicted results accurately captured the experimental trends in attenuation across the frequency range. These results confirm that the proposed model can appropriately represent both the effects of the acoustic propagation path geometry and the acoustic properties of the sound-absorbing materials.

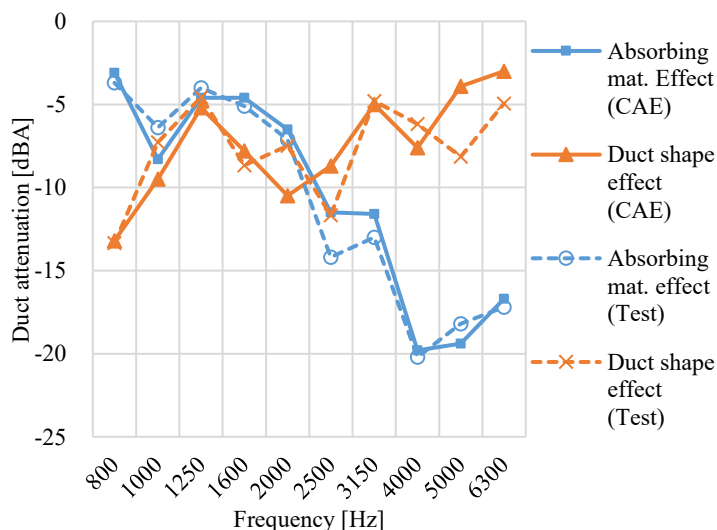


Fig.1 Duct attenuation change: Test vs. CAE(1/3 oct.)