

A Study on Vibration Devices for Vehicle Interiors

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Recent vehicles are providing an increasing amount and variety of information to drivers with the expansion of autonomous driving and Advanced Driver Assistance Systems (ADAS). Visual information such as instrument clusters, displays, and indicators, as well as auditory information such as warning sounds and voice guidance, have been widely used. However, visual information may require drivers to shift their attention, while auditory information may be affected by interior noise and surrounding conditions. Haptic feedback using mechanical vibration can complement these methods and can be applied to various interior components directly contacted by users, such as the steering wheel, seat, armrest, center console, and control interfaces.

An in-vehicle vibration feedback system generally consists of a control unit that receives vehicle or HMI signals, a driving unit, a vibration-generating unit, and a mounting structure. When information needs to be delivered, the control unit operates the vibration device according to a predefined pattern, and the generated vibration is transmitted to the user through the applied interior component. Depending on the type and importance of the information, single vibration, repeated vibration, changes in operating duration, and changes in vibration intensity can be used to distinguish different functions or warnings.

An in-vehicle vibration device should generate vibration that can be clearly perceived while remaining distinguishable from general vehicle vibration. If the vibration is too weak, it may be difficult to distinguish it from road-induced or surrounding vibrations, whereas excessive vibration may cause discomfort or fatigue. In addition, increasing the input to achieve higher vibration intensity may result in increased power consumption, heat generation, and operating noise. Therefore, an appropriate vibration level and operating pattern should be established rather than simply maximizing vibration intensity.

Vibration performance may vary depending not only on the vibration device itself but also on the material, shape, mounting location, and fastening conditions of the applied component. Since electrical components, wiring, switches, and fastening structures are installed within limited interior space, the mounting direction, wiring and connector locations, and interference with surrounding components should also be considered. Insufficient mounting stiffness or fastening may change vibration characteristics and cause unwanted vibration or noise. Therefore, stable mounting should be maintained under repeated operation, vehicle vibration, and shock conditions.

Continuous or repeated operation may generate heat in the electrical components and driving unit, and an increase in temperature may affect electrical and vibration characteristics. Since vehicle interiors are exposed to various temperature conditions, thermal characteristics should be evaluated under room-temperature, high-temperature, and repeated operating conditions. Unnecessary operating noise should also be minimized, as noise from the device, mounting structure, surrounding components, wiring, or connectors may be easily perceived in a quiet vehicle interior.

The basic performance of the vibration device can be evaluated under controlled fixture conditions by measuring vibration characteristics, current consumption, temperature, response time, and operating noise. To minimize measurement variation, the same fixture, fastening conditions, and sensor positions should be maintained. After confirming test repeatability, the evaluation should be extended to a structure similar to the actual application component. Vibration characteristics should then be measured at major contact locations, while changes in vibration performance and operating noise according to mounting location and fastening conditions should be compared. Interference with surrounding components, fastening stability, and abnormal noise should also be evaluated.

For vehicle applications, vibration performance, heat generation, operating noise, packaging, assembly, environmental stability, and repetitive durability should be considered comprehensively. Therefore, a stepwise validation process consisting of standalone performance evaluation, mounted-condition evaluation, thermal and noise evaluation, and environmental and durability evaluation is appropriate. Future work will obtain quantitative test data to analyze performance differences according to vibration-generation methods, mounting conditions, and component structures and materials, and to establish more detailed design and performance evaluation criteria for in-vehicle vibration devices.



Fig.1 Feedback in Automotive Interiors.