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Sound Design of Broad-band Frequency Characteristics Based on the Perception of Electric Vehicle Powertrain Noise

Kazuma shibahashi [1)] **Tatsuya Kanazawa** [1)] **Soichiro Tanabe** [2)] **Takeshi Toi** [2)]

1) Chuo University, Graduate School of Science and Engineering
1-13-27 Kasuga, Bunkyo-ku, Tokyo, 112-8551, Japan (E-mail: kazuma_shibahashi @camal.mech.chuo-u.ac.jp)
2) Chuo University, Faculty of Science and Engineering
1-13-27 Kasuga, Bunkyo-ku, Tokyo, 112-8551, Japan

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A wide variety of automobiles have been developed in place of Internal Combustion Engine Vehicle, and in this study, we focused on the interior sound environment of Electric Vehicle (EV), which is suggested to be the most popular in the future. EV powertrain noise such as motor noise and broad-band noise such as road noise and window noise exist as noise perceived in the EV interior. In this study, the high-sensitivity parameters perceived from the sound quality evaluation based on the running condition are experimentally estimated, and the sound is designed by changing the frequency characteristics of the broad-band noise.

For a total of six order sweep components that were identified as order components on the spectrogram by acoustic measurements at the driver's seat position of the actual vehicle, we defined them as 1,2,3...6 order in order of slowest sweep speed, and assumed that they are components that can be perceived as motor order by the partcipants, and pseudo EV motor noise that incorporates multiple order components was created. On the other hand, for the broad-band noise, a noise with a frequency gradient (≈ -12 dB/octave) of the EV interior background noise in the bandwidth from 10 Hz to 10000 Hz was made by increasing the sound pressure over time assuming 0.1G acceleration of EV driving. And, the sound source that combines the above motor noise and broadband noise was used as the reference sound. Then, as shown in Table 1, the frequency characteristics of the broad-band noise were changed by increasing the sound pressure level by +10 dB in each frequency band. The evaluation method was a seven-step relative evaluation using the rating scale method for the five evaluation sounds in Table 1.

Fig. 1 shows the evaluation result, suggesting that the sound source condition (SD4) is changed frequency characteristics of 500-2000 Hz, which corresponds to the low to mid frequency band of broad-band noise, is the most effective in "Degree of perceived suppression of motor noise" without sacrificing "Appropriateness," "Comfort," "Quietness" and "Sense of driving" as the EV interior sound. In addition, the O.A. (Overall) shown in Table 1 has the advantage that the numerical difference from the "Ori.sound" is only about +1 dBA for the sound source of 500-2000 Hz (SD4). This is a reasonable sound design for O. A. adjustment when designing the sound quality in a car interior.

Table 1 Evaluation sound used in sound design

Sound symbol	Sound design method	O.A.
Ori.sound	Motor noise 6 order+ Broad-band noise	60.7 dBA
SD1	100-1000 Hz band noise level +10 dB	65.6 dBA
SD2	100-1700 Hz band noise level +10 dB	65.8 dBA
SD3	100-3750 Hz band noise level +10 dB	67.6 dBA
SD4	500-2000 Hz band noise level +10 dB	61.8 dBA
SD5	2000-3750 Hz band noise level +10 dB	60.9 dBA

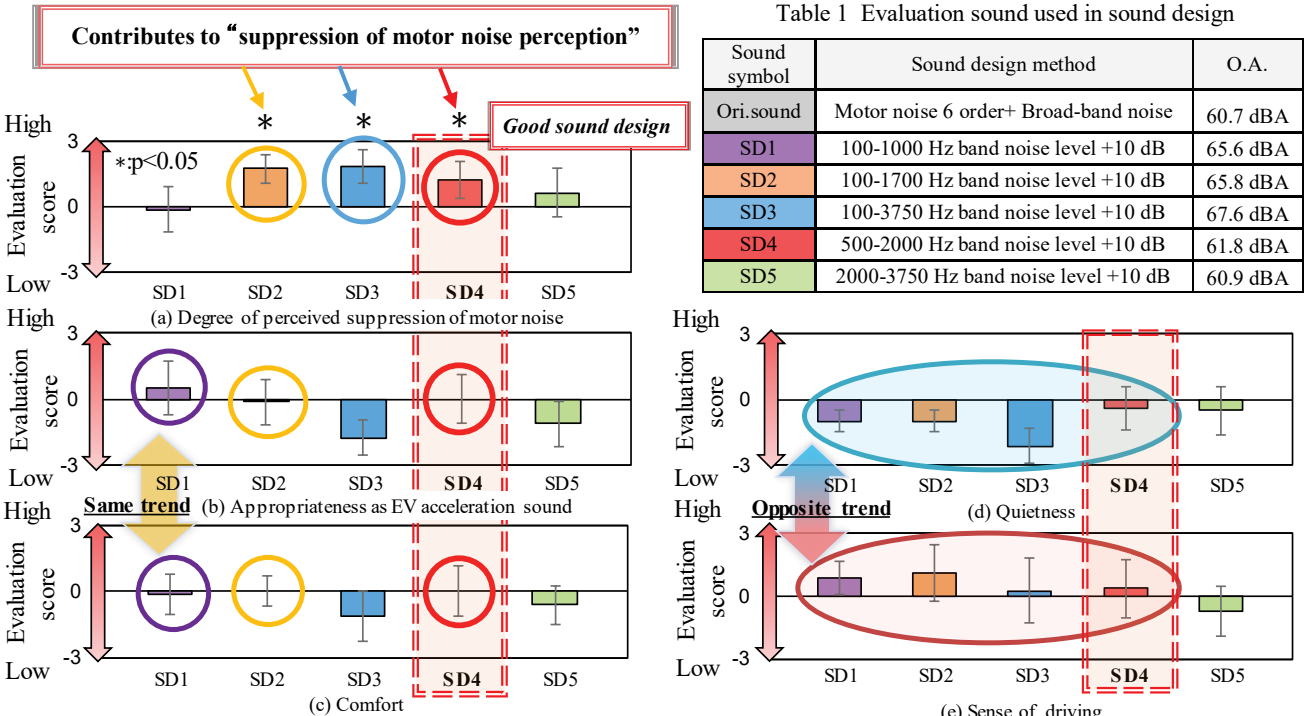

Fig. 1 Evaluation result