

Interior Sound Enhancement of Vehicle Acceleration for New Model ACCORD

- Transfer Path Analysis Using Principal Component Regression Method -

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ABSTRACT

The development of the new model ACCORD set targets for interior sound during acceleration based on target user characteristics, and analyzed sound transfer paths using the principal component regression method to enable these targets to be achieved. This method of analysis enabled the degree of contribution of structure-borne paths and airborne paths to interior sound to be clarified. Synthesized sound, produced on the basis of the results of the analysis, was incorporated in a sound quality evaluation system. This enabled identification of the areas in which measures should be applied, and the extent to which they should be applied, to satisfy interior sound targets. As a result, targets for interior sound in the new model ACCORD were achieved.

1. Introduction

Today, there is an increasing tendency to desire the interior sound of a vehicle during acceleration to match the vehicle concept. For example, while the vehicles may fall into the same category, the difference in the concepts of a sedan and a sports coupe results in different interior sound requirements on the part of users. This has led to the proposal of setting vehicle interior sound with consideration of differences in markets, user preferences, etc.⁽¹⁾

Transfer path analysis using principal component regression (PCR-TPA)⁽²⁾ has also been proposed as an effective method of realizing target interior sound. The major characteristics of this method as compared to conventional transfer path analysis are as follows:

- (1) The method can simultaneously analyze structure-borne and airborne paths, enabling evaluation of their contribution to overall interior sound.
- (2) Following separation of the contributions of the transfer paths, numerical processing can be employed to accurately reproduce the sound via sound synthesis, enabling a sound quality evaluation to be conducted.
- (3) Using the results of transfer path analyses and a sound quality evaluation system, the specific areas in which measures should be applied and the extent to which

measures should be applied to achieve the target sound can be determined.

These characteristics enable a transition from conventional transfer path analysis, in which the focus has been centered on the reduction of sound pressure and analysis of the target areas mainly limited to analysis of structure-borne paths, to a transfer path analysis that focuses on the enhancement of sound quality and takes the overall interior sound as its object of analysis.

The new model ACCORD sedan and ACCORD coupe share a basic platform, and targets were set for the interior sound in each vehicle during acceleration, based on the vehicle concept. This paper reports on the results of using PCR-TPA in order to realize these interior sound targets.

2. Interior Sound Matching Vehicle Concept

2.1. Target Vehicles

Different body, engine, and transmission combinations are employed in a number of new ACCORD models, but this paper focuses on a model featuring a V6 gasoline engine and 5-speed automatic transmission in a 4-door sedan body ("sedan" below), and one featuring a V6 gasoline engine and 6-speed manual transmission in a 2-door coupe body ("coupe" below).

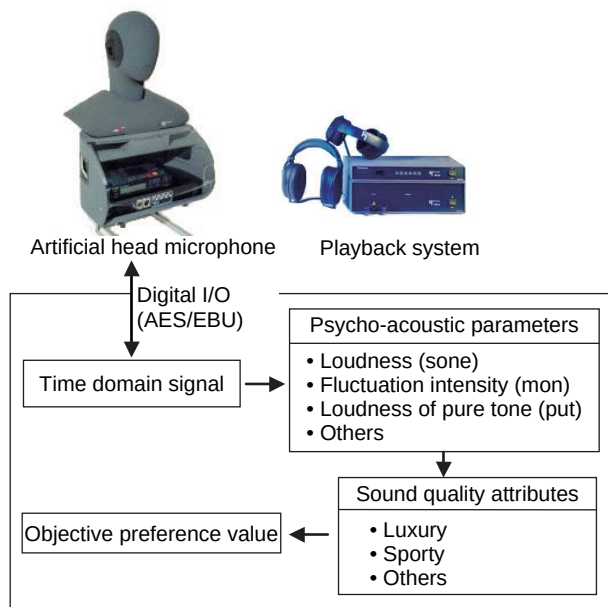
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2.2. Setting Target Sound

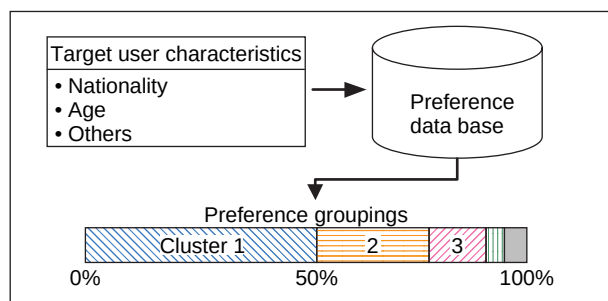
The objective preference evaluation system⁽³⁾ shown in Fig. 1 was employed in setting interior sound targets. In this system, sounds are classified in advance into different categories (“quiet and smooth,” “quiet and alive,” “powerful,” etc.), and the level of user preference is expressed as an objective numerical value.

Figure 1(a) shows the results of calculation of objective preferences for the previous ACCORD model using metrics for the level of auditory stimulus (“magnitude,” “fluctuation intensity,” etc.), and complex sound quality evaluation metrics (“alive,” “smooth,” etc.). Interior sound was measured using an artificial head microphone, and preference values calculated by applying numerical processing to the objective preference evaluation system.

Figure 1(b) shows the results of setting objective sound preference values based on the development concept for the new model ACCORD sedan and coupe, using a preference database as a reference and taking into consideration the age, nationality, and other characteristics



(a) Calculation of preference value

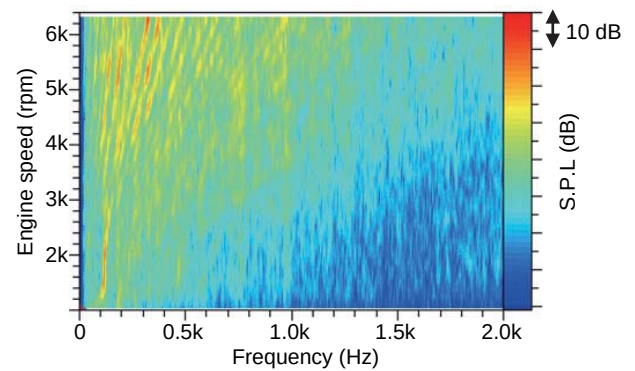


(b) Calculation of preference rate

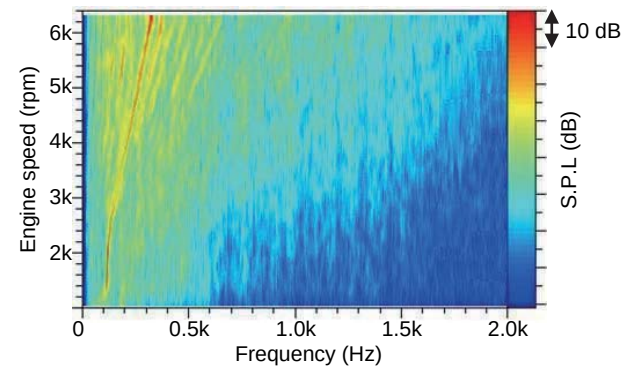
Fig. 1 Preference evaluation system

of target users. The clusters in the figure represent “quiet, smooth sound,” etc.

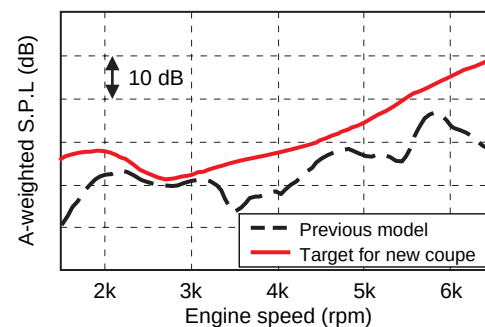
A variety of interior sound targets were established to enable the interior sound of the previous model to be modified to match the preferences established for the new model ACCORD sedan and coupe. Figure 2(a) shows a color map of the interior sound of the previous model, which served as the benchmark; Fig. 2(b) shows a color map of the target interior sound for the new sedan; and Fig. 2(c) shows the 3rd order component of the target interior sound of the new coupe, as well as the interior sound of the previous (benchmark) model against engine speed.



(a) Previous model



(b) Target for new sedan



(c) Target for new coupe (3rd order)

Fig. 2 Interior sound

The focus in the case of the target interior sound of the sedan was to achieve a sound that was suitable for a wide range of users by reducing the conspicuous high-frequency components against those of the previous model, and the sound pressure increase characteristic was set linear and appropriate for the main order components in relation to engine speed during acceleration.

In the case of the coupe, the focus was on users with a higher level of interest in cars than in the case of the sedan. During cruising and slow acceleration, the sound targets for the coupe were identical to those for the sedan, but during acceleration at WOT, the target was to highlight the sound pressure of the 3rd order component against engine speed.

3. Enhancing Interior Sound

The employment of PCR-TPA to analyze the interior sound of the benchmark model and the application of sound quality evaluation enabled the areas in which measures should be employed, and the degree of measures to be employed, to be specified to achieve the targets established for the interior sound of the sedan and coupe during acceleration.

3.1. Test Method

The previous ACCORD model, which featured a V6 gasoline engine and 5-speed automatic transmission in a 4-door sedan body, was used in the tests.

Measurement points for structure-borne and airborne transfer paths were set as shown in Fig. 3. Two response

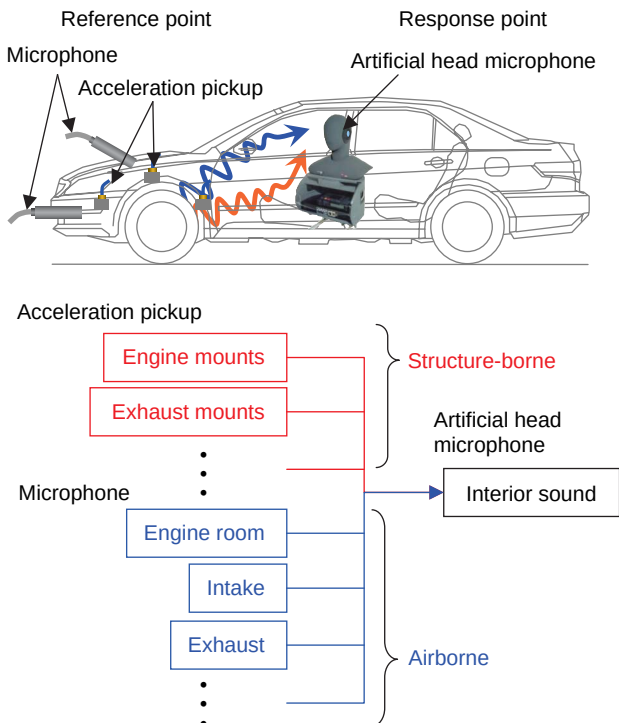


Fig. 3 Measurement setup

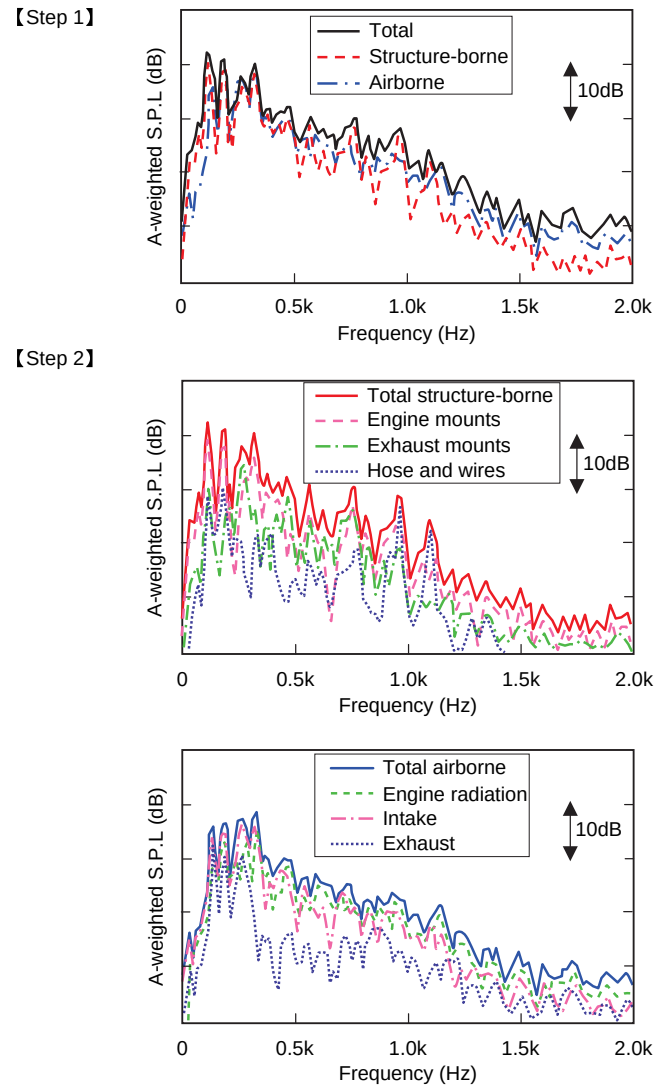
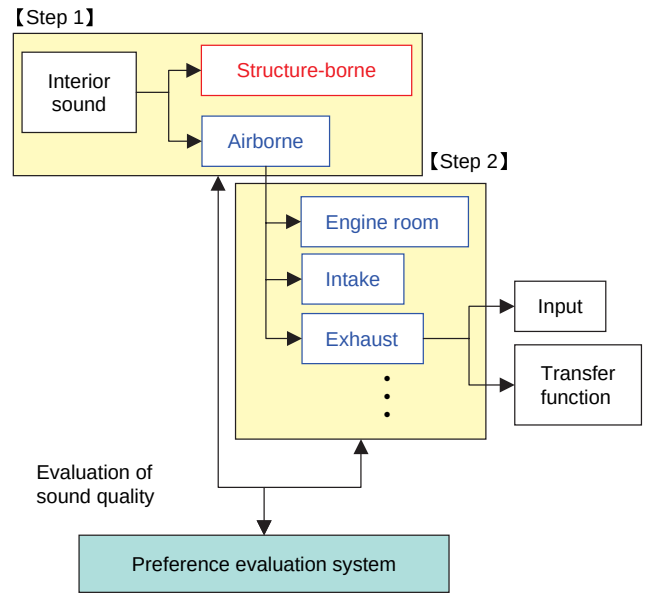


Fig. 4 Analysis result of PCR-TPA

points were employed, at the level of the left and right ears of an artificial head microphone in the passenger seat. The vehicle was placed in a chassis dynamometer that absorbed the torque of the drive wheels, and measurements were conducted under varying load conditions.

3.2. Study for Sedan

The results of an analysis of high-frequency components, conducted in order to increase quietness, are shown in Fig. 4 as a representative example of the results of PCR-TPA conducted to enable achievement of the interior sound targets for the sedan.

In Step 1, the structure-borne and airborne transfer paths were separated. The results showed that while the airborne transfer path made the greatest contribution to interior sound at 1.2 kHz and above, the contribution of the structure-borne transfer path was higher at around 750 Hz, 1 kHz, and 1.1 kHz. In Step 2, the structure-borne and airborne transfer paths were divided into engine mounts, exhaust mounts, engine radiation noise, intake noise, exhaust noise, etc., to determine the transfer paths for which measures should be applied, as well as the extent of the measures to be applied. The results of this analysis showed that the engine mount and exhaust mount paths were main factors in the sound at 750 Hz and overlap of these paths encourages sound of this frequency, while the paths for the hoses and wires that connect the engine and body of the vehicle were the main factor in the sound at 1 kHz and 1.1 kHz. In relation to airborne transfer paths, the engine housing and intake noise paths were selected for examination. On the basis of the results of these analyses, the transfer paths where measures should be applied were resolved into inputs and transfer functions, and measures were applied in the main areas.

This resulted in the achievement of the interior sound shown in Fig. 5.

3.3. Study for Coupe

Figure 6 shows the results of PCR-TPA of the 3rd order component of interior sound during acceleration at

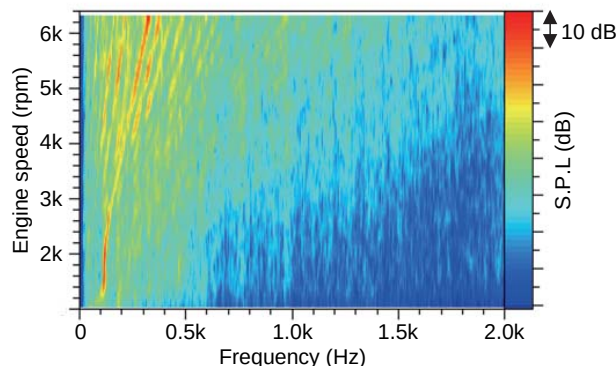


Fig. 5 Interior sound of new sedan

WOT, conducted in order to achieve the target sound for the coupe. These results show that at engine speeds less than 3000 rpm, the contribution of the exhaust noise transfer path was highest, while at engine speeds of above 3000 rpm, the contribution of the intake noise transfer path was highest. Considering that the target in this case was to maintain an identical interior sound to that of the sedan when the vehicle was cruising or accelerating slowly, it was more appropriate to apply measures to the intake and exhaust noise transfer paths than the structure-borne transfer paths. These two transfer paths were resolved into inputs and transfer function, and measures were applied to the main areas.

The interior sound that was achieved is shown in Fig. 7.

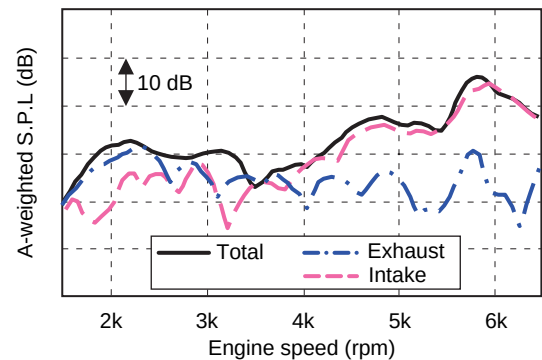


Fig. 6 Analysis result of PCR-TPA (3rd order)

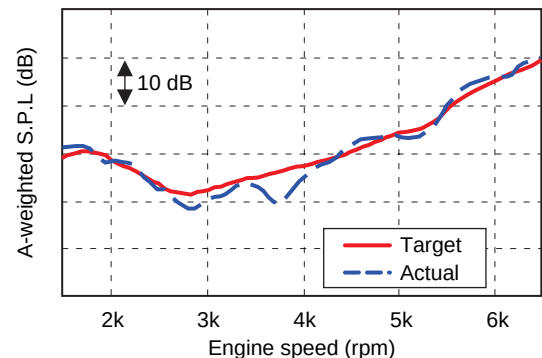


Fig. 7 Interior sound of new coupe (3rd order)

4. Conclusion

The project discussed in this paper used PCR-TPA to enhance the interior sound of the new ACCORD models during acceleration. The salient points of the project are as follows:

- (1) A system enabling evaluation of objective preferences with regard to sound quality was employed to establish targets for the interior sound of the sedan and coupe for target users.

- (2) The application of PCR-TPA to the benchmark vehicle and the analysis of the synthesized sound as a result using the sound quality evaluation system enabled the specification of the areas in which measures should be applied in order to achieve the interior sound targets for the sedan and coupe. The application of measures in these areas resulted in the achievement of the interior sound targets.
- (3) PCR-TPA was demonstrated to be an effective method of achieving interior sound targets, enabling the areas of highest contribution in structure-borne and airborne transfer paths to be determined, and targets for measures to be set.

References

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- (2) Noumura, K., Yoshida, J.: Method of Transfer Path Analysis for Interior Vehicle Sound Using Principal Component Regression Method, Honda R&D Technical Review, Vol. 18, No. 1, p. 136-141
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