Identification and Characterization of Powertrain Sound Quality Attributes

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INTRODUCTION

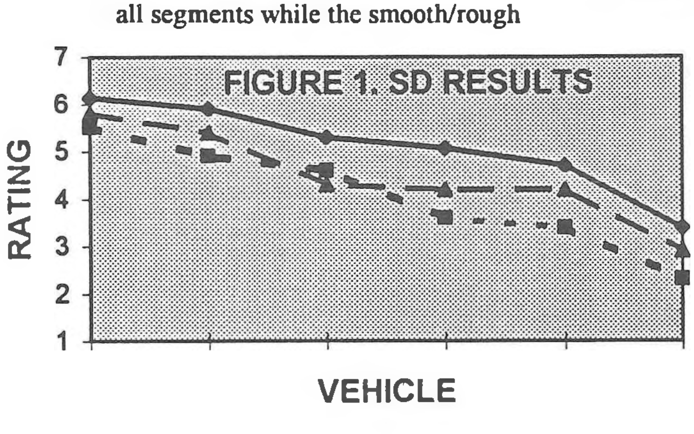
Powertrain sounds are probably the most distinctive and the most dominant automotive sound source. These sounds are also capable of generating a number impressions in the listener. This study attempts to identify and quantify these impressions for a series of powertrains with 4, 6, and 8 cylinder engines.

METHODS

Binaural recordings were made of first gear wide-open-throttle accelerations from three separate vehicle classes (compacts, entry level luxury and luxury sport sedan), each class having a different engine size (4, 6, and 8 cylinders respectively). For each vehicle segment, a separate listening clinic was conducted using owners of vehicles in the class. At least a hundred subjects participated in each of these clinics. The powertrain sounds were evaluated using a seven point semantic differential method as well as a paired comparison of preference. The adjective pairs for the semantic scaling were obtained from focus groups in which subjects described their engine sound. From this discussion, twelve semantic categories were defined. These consisted of acoustic terms (quiet/loud, rough/smooth), quality indicators (pleasant/annoying, cheap/expensive) and engine performance descriptors (stressed/unstressed, powerful/weak).

RESULTS AND DISCUSSION

We focus first on the semantic differential results within a vehicle segment. For each segment, significant rating differences are found in 8 of the 12 semantic categories. In addition, a good distribution of ratings among the vehicles is observed. Results from the V-8 study are shown in Figure 1 for three semantic categories; quiet/loud (solid), rough/smooth (dashed), pleasant/annoying (dotted). It is apparent that typical car owners have no difficulty evaluating powertrain sound quality attributes. The ratings for the acoustic categories are then correlated to objective sound quality metrics. The quiet/loud ratings correlate very well with peak loudness [1] for all segments while the smooth/rough ratings correlated with an internally developed roughness metric [2]. Of course, there are no metrics for the non-acoustic, impressionistic attributes. However, one can relate these to their underlying objective metric by correlation. For example, an engine sound is perceived as stressed if it is loud and perceived as reliable if it is smooth and quiet.



Cross-segment comparisons show no great differences between segments. In fact, the segment differences are much less than the differences between vehicles within a segment. This is largely because of the limitations of a seven point scale. Subjects use most of the rating range in all segments so one would not expect to see large segment differences. A cross-segment comparison which is meaningful is to look at how each sound quality attribute contributes to overall preference. This is done by correlating the semantic data to the preference results. If an attribute's semantic ratings correlate highly to the preference data, then that attribute contributes to preference. This type of contribution analysis shows some striking segment differences. For C class vehicles, the two most important sound attributes are not stressed and quiet. These results reflect the fact these owners use their engine sound as a diagnostic aid. On the other hand, the two least important attributes are powerful and expensive. Owners of these relatively inexpensive vehicles, with 4 cylinder engines, do not expect their powertrain to sound either powerful or expensive. Contrast this with the results for the entry level luxury vehicles, where smooth and expensive are the two most important sound attributes while engine stress is relatively unimportant. For the luxury cars, quietness is the biggest contributor to preference.

CONCLUSIONS

A method for measuring customer impressions of powertrain sounds has been presented. Using this method, vehicle owners can readily evaluate numerous engine sound quality attributes for a variety of vehicle segments. In addition, attribute contributions to preference can be measured and differences between segments identified.

REFERENCES

1. Zwicker, E., Fastl, H., Psychoacoustics: Facts and Models, Springer Verlag Berlin 1990.
2. Feng, B. J., Otto, N. C., Wakefield, G. H., "A Model of Roughness of Powertrain Noise," *Proceedings of Noise-Con 96*, Seattle 1996.