

Objective description of the required interior sound for exclusive passenger cars

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ABSTRACT

The interior sound is of high importance for exclusive passenger cars. Sound adds to the enjoyment of driving, to the recognition and identification with vehicle performance, reliability and even manufacturing quality.

Especially for sports cars and sports executive vehicles a brand sound is one of the important buying aspects for their owners and drivers.

The description of the optimum brand sound for exclusive vehicles on an objective basis is one major step to increase the efficiency of the acoustic development process, in setting objective targets, comparing competitive vehicles and implementing the required sound effectively to the car in sound engineering procedures.

1. ESTABLISHING A RELIABLE SUBJECTIVE DATABASE

For a valid objective description of vehicle interior sound the subjective perception of the individual drivers of such classes of passenger cars must be obtained as a basis for further correlation with psychoacoustic parameters. To derive useful results, the test series have to be carried out carefully as has been performed in recent AVL R&D noise quality work for passenger cars which resulted in a so called "AVL-Vehicle Noise Quality Map" for the objective analysis of passenger car interior noise quality (1,2,3,4). For establishing a database of the subjective perceptions of the sound for exclusive cars the individual feelings of the driver stereotypes of such cars had to be analysed in detail (5). For such an analysis not the predetermined opinion of acoustic engineers will lead to useful results, only a basic survey of the needs of the vehicle buyers and owners will produce a realistic basis for further R&D work. Such work has been performed in the last two years at AVL and is reported in (6,7,8).

2. DETERMINATION OF THE OPTIMUM SUBJECTIVE ASSESSMENT PROCEDURE FOR INTERIOR SOUND OF EXCLUSIVE PASSENGER CARS

The survey of the preference of main vehicle attributes by different driver stereotypes reported in (6,7,8) yielded the information which type of driver is interested in special acoustic features like a brand sound of his car.

The next step we performed was the subjective evaluation of luxury cars, sports cars and sports executive vehicles with respect to their optimum brand sound by the respective driver stereotypes.

Furthermore, we observed, that using in our subjective evaluation procedure a combination of very detailed acoustic aspects like pleasant and powerful etc. is not very useful. The test series are getting too complicated for the test persons and produce less reliable subjective results (see also 6,7,8).

One reason for this is, that for each assessor the optical sense, the feeling sense and the hearing sense, together with a very emotional view for such luxury cars, are in competition with each other when assessing an accelerating exclusive car in terms of interior sound aspects on the road. The combination of acoustic aspects like dynamic, powerful, pleasant etc. is perceived individually different according to the different strengths and contributions of their personal feelings and senses to the complete subjective perception and are therefore assessed individually in a different manner.

In order to produce reliable and useful subjective results as a basis to describe an interior sound or single aspects of the overall sound of exclusive cars by objective numbers one possibility is to evaluate single aspects alone (like e.g. sportiness).

3. RESULTS OF SUBJECTIVE INTERIOR SOUND ASSESSMENTS ON THE ROAD AND LABORATORY

To support the above mentioned facts, some results of a subjective evaluation of sports executive vehicles by selected assessors will now be discussed. After a number of pre-tests to select an optimum assessment procedure, 10 new sports executive cars (rented from local dealers) were evaluated on the road. The assessors were told to concentrate on interior sound only, and to neglect all other vehicle features. The evaluations on a scale from 1 to 20 were performed on the front passenger seat, the cars were driven always by the same professional drivers. A similar procedure has been established in the past and has been proven to be very reliable (1,4).

The result for these 10 cars at 5 operating conditions can be seen in Fig. 1. The average assessment value for the question "How do you judge the individual interior sound character with respect to this class of cars?" of 22 selected assessors is plotted for each operating condition and vehicle. The results look convincing, the spread scatter of the subjective judgements are within a range of 2 to 3 scale points.

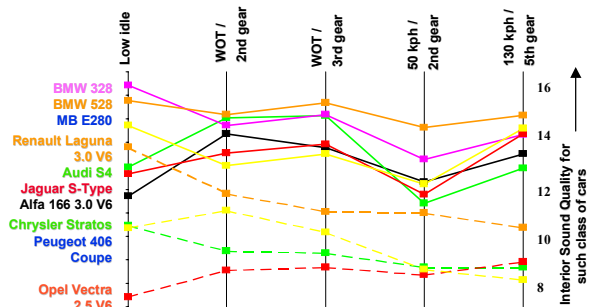


Fig. 1: Subjective Interior Road Evaluation of Executive Sport Cars

In another subjective evaluation procedure on the road the test persons we asked to judge two acoustic features of each vehicle at the same time. The assessors had to position each individual vehicle on a two dimensional plane made up by the features "how luxurious does this vehicle sound" and "how sporty does this vehicle sound". Both assessments were again performed by 22 test persons on a scale from 1 to 20 for 10 different vehicles at 5 different driving conditions. In Fig. 2 the results for a WOT acceleration in 3rd gear are shown. Again the position of the average judgements of each vehicle gives a clear picture. However, if we look at the spread scatter of the individual judgements for each acoustic feature we can see that there is a big overlap of the individual scores. The statistic survey showed, that this spread scatter is not dominated by single persons; the distribution of the individual judgements is quite uniform over the spread range. As mentioned in chapter 2 such a judgement of two acoustic features at the same time is complex and therefore produces this large spread scatter which reduces the reliability of such results.

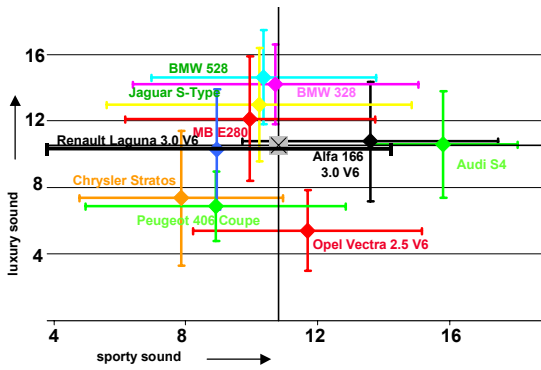


Figure 2: Subjective Interior Road Evaluation of Executive Sport Cars at WOT 3rd gear

The sound character evaluations as shown in Fig. 2 have been repeated in the laboratory (1) in such a way that the assessors did not know the driving conditions and the vehicles itself.

One important aspect for comparison between road and laboratory evaluations is, that the acceleration feeling is only present in the vehicle on the road and this acceleration feeling turned out to be one major factor to explain the differences between road and laboratory evaluations. As one example for the aspect sportiness the laboratory evaluation results can be modified by vehicle acceleration and engine power to match with a high correlation the road evaluation results. This is shown in Fig. 3.

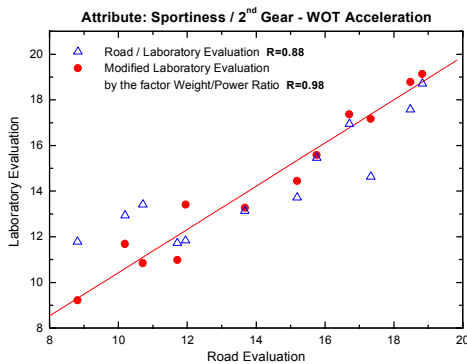


Figure 3: Comparison of Subjective Laboratory and Road Evaluation Results for 10 Sports Executive Vehicles

4. OBJECTIVE DESCRIPTION OF INTERIOR SOUND

For obtaining an objective description of different sound character aspects of exclusive vehicles, linear regression analysis (1) was used to extract the most important psychoacoustic parameters which describe the subjective impressions to the largest extend. It could be found, that for single important aspects of interior sound quality the combination and magnitude of higher engine orders in certain frequency bands is of significant importance to describe single sound aspects like sporty, powerful, luxury, pleasant, etc.

As an example the frequency dependence of the aspects of sportiness and powerfulness for sports executive cars are shown for full load acceleration in an engine speed – frequency map in Fig. 4. For some vehicles it is necessary to extent the area of sportiness which is shown in Fig. 4 by the dotted line.

It could be found, that the subjective perception of a luxury feeling is also dependent on distinctive engine orders in a similar frequency range which determines sportiness, however, the levels of the combination of engine orders are by 12 to 18 dB lower in such cars.

By knowing the hard facts which are necessary for sportiness, powerfulness and luxury interior sounds it is possible to determine the optimum combination of the distinct engine orders for composing a unique brand sound

suiting a special type of customer which prefers a typical vehicle brand.

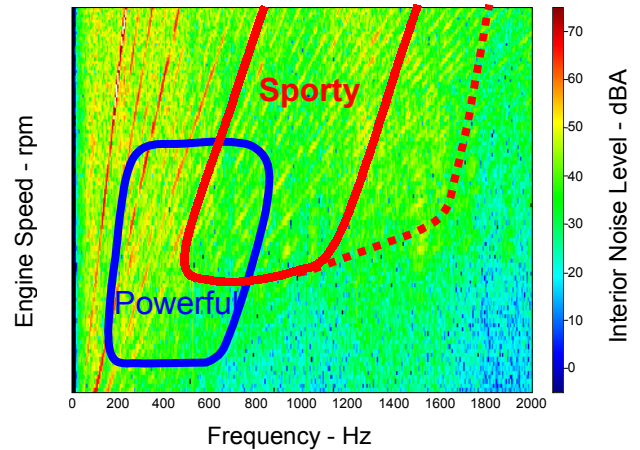


Figure 4: Range of Vehicle Interior Sportiness and Powerfulness on an engine speed / frequency map

The magnitude and combination of engine orders necessary are in the frequency range which can be best influenced by changes to the powertrain mounting, intake and exhaust system in parallel with sound cleaning procedures to reduce "background noise" by the necessary extend.

The description of certain sound aspects of exclusive cars is dependent on vehicle acceleration performance, on "combination of relevant engine orders" (CEO) and on the "ratio of engine orders to background noise" (REO). As an example the equations for the objective description of sportiness and luxury for sports executive cars can be written as:

$$\text{Sportiness} = f\left(CEO, REO_{sport}, \frac{\Delta rpm}{\Delta t}\right)$$

$$\text{Luxuriosity} = f(\text{BandpassLoudness}, REO_{Lux}, \text{NoiseQualityIndex})$$

A big advantage of this method is, that an optimum interior sound can now be created by this software tool to serve as a target for effectively supporting sound engineering procedures to create an optimum brand sound for such vehicles.

5. REFERENCES

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