The influence of different runup slopes on sound quality evaluation in vehicle interior sounds

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Introduction

For the image of modern vehicles a customized acoustic outfit becomes more and more important. Besides physical data like sound pressure level or frequency distribution, which could be measured with a microphone or an artificial head, sensational data like loudness or roughness, evaluated by monaural or binaural hearing models, give the acoustician a deeper insight into how a sound is perceived. Nevertheless for the final judgement of a vehicle sound design experts and customers have to rate the sound of the vehicle in a drive appraisal. During such an appraisal the judgement is influenced more or less by the performance, visual design, smell and many other attributes of the car. Listening studies in a laboratory give the opportunity to suppress attributes like visual design or smell, which are not related to the recording. Other attributes like performance, which directly influence the recording situation e.g. wide open throttle run ups, could not be eliminated easily even for the laboratory playback.

Stimuli Preparation

For laboratory investigations of vehicle interior sounds, artificial head recordings of different driving scenarios are useful. In order to keep the efforts small these recording are usually not made on a roller dyno but on a normal road or test track. This also has the advantage of a natural recording situation with the usual balance of wind noise, road noise and powertrain sound contribution. Different torque, gearing and the driving resistance of vehicles result not only in different soundmaps and engine order balance for the various vehicles but also in different acceleration plots during a recording of a wide open throttle driving scenario.

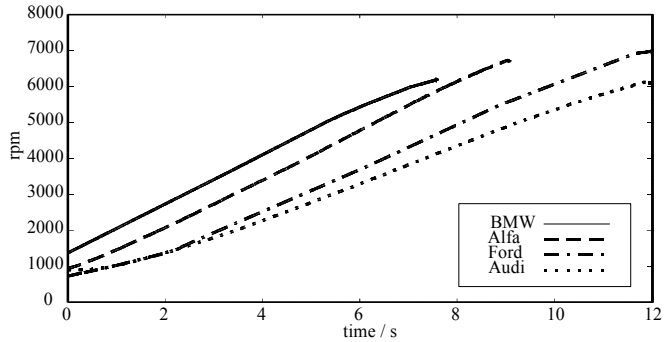

Figure 1: Typical run up slopes for 2nd gear wide open throttle (4 vehicles)

Figure 1 shows the differences in run up slopes of 4 competitive vehicles. The time for a 2nd gear wide open throttle run up differs between 7.5 seconds and 12 seconds. In order to eliminate the influence of the different run up slopes on listening test results all sounds have to be aligned to the same run up slope.

For that reason the sounds of the different vehicles have to been analysed, characterised and stored in the rpm domain. If this analysis is aurally adequate it must be possible to create a sound synthesis fitting to the analysis method which leads to a re-synthesised sound that should be comparable to the original sound without any audible artefacts or modification. With this synthesis it is possible to align all vehicle sounds to the same run up slope.

This analysis/synthesis which also could be understood as an time to rpm transformation has been implemented in the mathematical environment Matlab and tested for different driving situations with different vehicle with petrol engines. There was nearly no audible difference between the original sound and the re-synthesised sound for all vehicles.

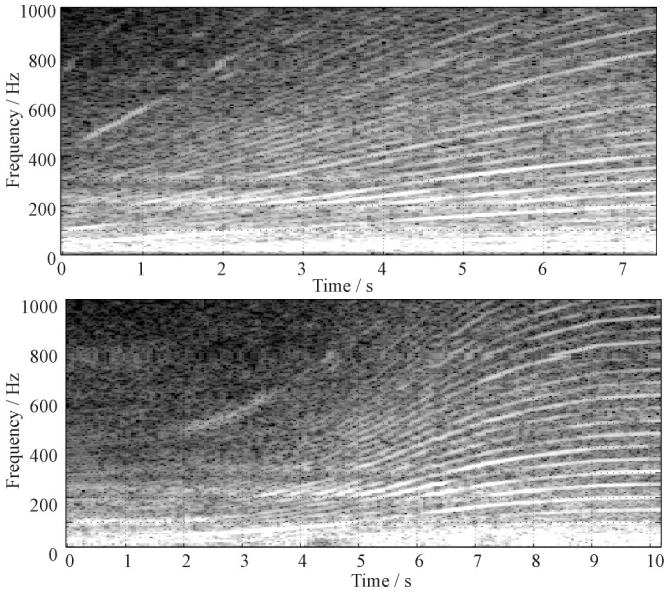

Figure 2: Spectogram of BMW vehicle run ups. Top original measurement ; Bottom sound synthesis with diesel rpm slope.

Figure 2 shows the original run up of a BMW 4 cylinder engine, which has been re-synthesised with a diesel engine, like torque curve. Nearly all sound characteristics could be transferred to the re-synthesis.

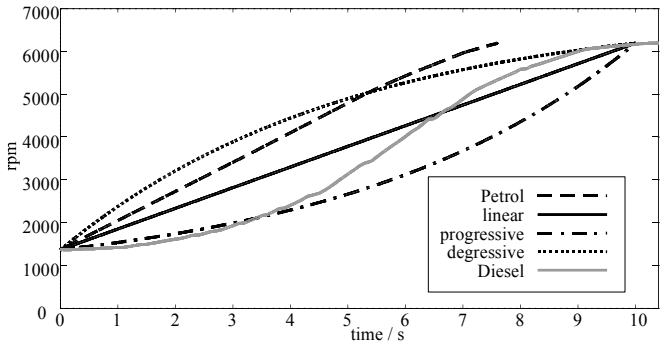

Figure 3: Synthetic run up slopes for the different test stimuli

To investigate the influence of the rpm slope to the jury evaluations the analysis has been applied to 4 vehicles (BMW, Audi Alfa, Ford). All vehicles were equipped with comparable engines but

have a differing sound character. These vehicle sounds have been synthesised with 5 different run up slopes.

Figure 3 shows the time plot for the 5 different run up slopes, which have been used for the auralization of the vehicles sound. The petrol a diesel slope have been measured from real vehicles while the other 3 slopes have been created from a mathematical function.

Listening study

With these 20 sounds (4 vehicles x 5 slopes) a listening study has been performed. 75 people (8 female; 66 male) joined the listening study. The test was carried out as a group test with an absolute scaling. The unipolar scale was a seven point scale from 1 to 7. The task for the subjects was to rank the stimuli with regard to the attributes “Sporty” and “Pleasant”. In the beginning of each test session there was an introduction in German and English. In order not to bias the test persons no information regarding the genesis of the sounds and the main focus of the listening study was given. In every stimulus the run up was played twice. After each stimulus the test persons had 5 seconds to give their judgement

Results

Figure 4 and 5 show the results of the listening study. Plotted are the average values of the various stimuli for all participants with error bars representing the standard deviation.

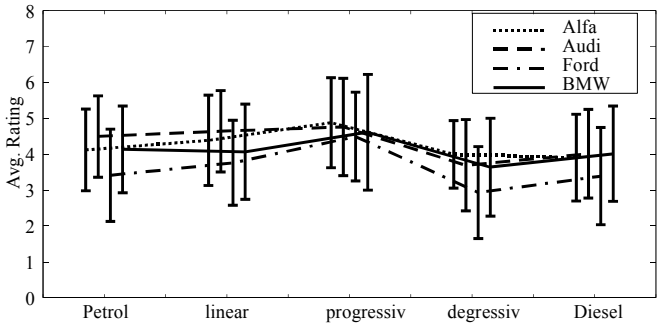

Figure 4: All subjects average values for the attribute “Pleasant” for different vehicles and different run up slopes

In Figure 4 the ranking of the attribute Pleasant is discussed. The judgements for the different vehicles are grouped around every run up slope. In relation to normal AB comparison or individual listening test the standard deviation is relatively large. This is based on the fact that variation of the absolute ranking regarding these two attributes is relatively large between the test persons. The average values of all stimuli differ from 2.9 for the lowest value to 4.9 for the highest value. The basic slope of the curve is similar for every vehicle. This means the influence of the run up slope is similar for all different vehicle sounds regarding the attribute “Pleasant”. Sounds with the progressive slope seem to be more pleasant than the other sounds. On reason for this judgement could be that fact that the upper rpm region is played relatively quick in relation to the lower rpm region so that the louder and more annoying part of the run up is played only for a short time. Just in contrast to the perception of this sound stands the perception of the sound with the degressive run up slope. In this sound the upper rpm region is played much longer in relation to the lower rpm region and so the sound has been perceived as less pleasant. In general the rating variance by the influence of different run up slopes is stronger than the variation of the sounds through the different vehicles. This means that for the given set of stimuli the run up slope has a significant influence on the voting for the attribute “Pleasant”.

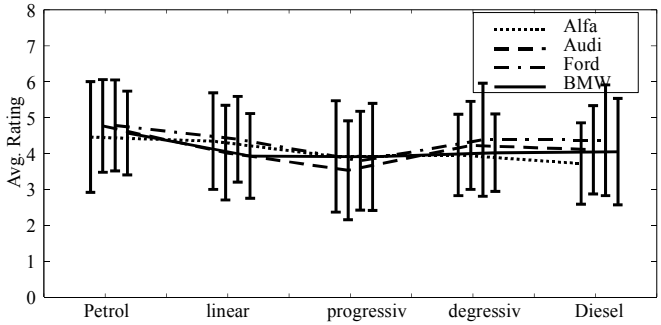

Figure 5: All subjects average values for the attribute “Sporty” for different vehicles and different run up slopes

In Figure 5 this same plot is displayed for the attribute “Sporty”. As the same as for the judgement of the attribute ”Pleasant” all vehicles show a similar behaviour for the different run up slopes. The variation in the average values is less for this attribute. It reaches from 4.8 for the highest value to 3.5 for the lowest value. The influence of the different run up slopes is less for this attribute but still the same or even bigger than the influence of the different vehicle sounds. The progressive sound is perceived as less sporty. The reasons for this voting should be the same as the reasons for the good result for the attribute “Pleasant”. The short Petrol run up has been perceived as most sporty.

Summary and Outlook

The influence of different run up slopes on the outcome of sound quality listening studies has been investigated in this paper. A set of 4 competitive vehicles from the CD-Segment has been analysed and re-synthesised with 5 different run up slopes. A listening study has been carried out and showed a significant influence of run up slope on the perception of the attribute “Sporty” and “Pleasant”. For further listening studies it is advisable to eliminate thed influence of the run up slope by setting all sounds to the same run up slope. If it is not possible to eliminate the influence the run up slope its effect on the outcome of the study must be considered.