SOUNDSCAPE DESIGN – ACOUSTICAL CHALLENGE

PACS REFERENCE: 43.50 Rq

Genuit, Klaus
HEAD acoustics GmbH
Ebertstrasse 30a
52134 Herzogenrath
Germany
Tel.: +49-2407-577 20
Fax: +49-2407-577 99
E-mail: klaus.genuit@head-acoustics.de

ABSTRACT

The sound quality of a soundscape is very important to the feeling of human beings. It does not only depend on the A-weighted sound pressure level, but on the spectral distribution on the one hand and the time structure on the other hand. At the end besides these objective describable parameters the personal attitude and expectations in combination with the cognitive aspects of sounds are influencing the sound quality of a soundscape perceived.

INTRODUCTION

The urban soundscape is mainly dependent on traffic noise. Resulting negative effects lead to a significant reduction of the A-weighted sound pressure level due to governmental regulations. But, this does not mean that today traffic noise is considered as less annoyant as in earlier years. This may partly be caused by the increase in transportation miles itself but is shows additionally the insufficient use of the A-weighted sound pressure level as a descriptor for the subjective judgement of exterior car noise. Psychoacoustical knowledge, already basis of research work in interior car sound, needs to be transferred into suggestions for the design of exterior noise; exterior noise itself has to be seen as a kind of „language" with several aspects.

In the following the main important topics will be explained and suggestions for a future-oriented development of exterior car noise will be presented. This should help the acoustical engineer to see this particular part of research work as a multi-dimensional approach for the realization of several demands on vehicles.

BASICS OF EXTERIOR NOISE OF CARS

The exterior noise of cars may be divided into the following main categories:

- Engine
- Intake and Exhaust
- Tire/Road
- Wind Noise
- Transmission [1]

The contribution of each particular subsystem depends on several technical aspects, e.g. engine type and vehicle classes, but also on the operational conditions, such as speed and gear. Therefore, a general declaration of each individual contribution is not possible. In any case, the following statements are valid:

- In the 2nd gear, the engine is dominant for nearly all driving conditions
- In the 3rd gear, the contribution of the tire/road noise is dominant
- The contribution of the tire/road noise to the overall exterior noise has increased in the last decade due to the striking SPL reduction of the engine
- The SPL of the exterior noise is below any dangerous value in terms of healthiness.

For a typical (European) mid-range diesel vehicle it can be said that the engine leads to approximately 50% of the overall level (intake and exhaust ≈ 25%, tire/road ≈ 20%) in the 2nd gear while the corresponding values for the 3rd gear are 30% (engine), 15% (intake/exhaust) and more than 50% (tire/road) [2].

The reduction of the resulting overall level is topic of numerous publications and will not be emphasized in this paper. Here, we would like to focus on the following topics: Even minor shares of the engine do not mean missing annoyance. (The same is valid for all other subsystems). Even relatively low SPL's often cause annoyance. And finally, exterior noise must not only mean something disturbing, something that has to be avoided; it may also be regarded as part of an integrated design concept and product philosophy.

SOUND QUALITY AND EXTERIOR NOISE OF CARS

As mentioned above, a reduction in the SPL of the exterior noise must not lead to a reduction of annoyance - and it is in general not a design tool. (In our context we are not considering disturbing noises such as brake squealing.)

In a first approach we should regard the acoustical „image" of a car - expressed by its exterior noise - analogous to the optical image. The exterior noise means also a set of opportunities. It may transmit messages such as pleasantness (for the environment), corporate identity (for the car manufacturer), vehicle character, e.g. luxury or sportive (for customer), and acceptance (for drivers and society).

The last mentioned item is becoming of significant importance: Vehicles are seen more and more as part of a social context. Their appearance - including the acoustical appearance - has to fit with the resulting requirements: No exaggerated show effect, but integrated part of the environment; no uniform product, but individual character.

For the fulfillment of such requirements and for the design of exterior sound, the term „sound quality" is of major interest. Although a definition of sound quality always is context sensitive, we may use an operational definition: It may be defined as the degree to which the totality of the individual requirements made on an auditory event are met. Acoustic quality comprises three different kinds of actuating variables: physical (sound field), psychoacoustic (auditory perception), and psychological (auditory evaluation).

Interpretation of acoustic quality is a multidimensional task. Physical and psychoacoustic measurement procedures alone do not allow a general and unequivocal definition of acoustic quality. This is because listeners primarily classify perceived auditory events in terms of their experience, expectations and subjective attitudes [3].

While the physical aspect is partly considered when dealing with the A-weighted SPL, all other aspects need further knowledge, such as psychoacoustics, but also approaches which are still under development (or simply not known at present). Examples for such approaches are explained in the following.

Sound quality considers the several aspects of sound that are represented in Fig. 1:

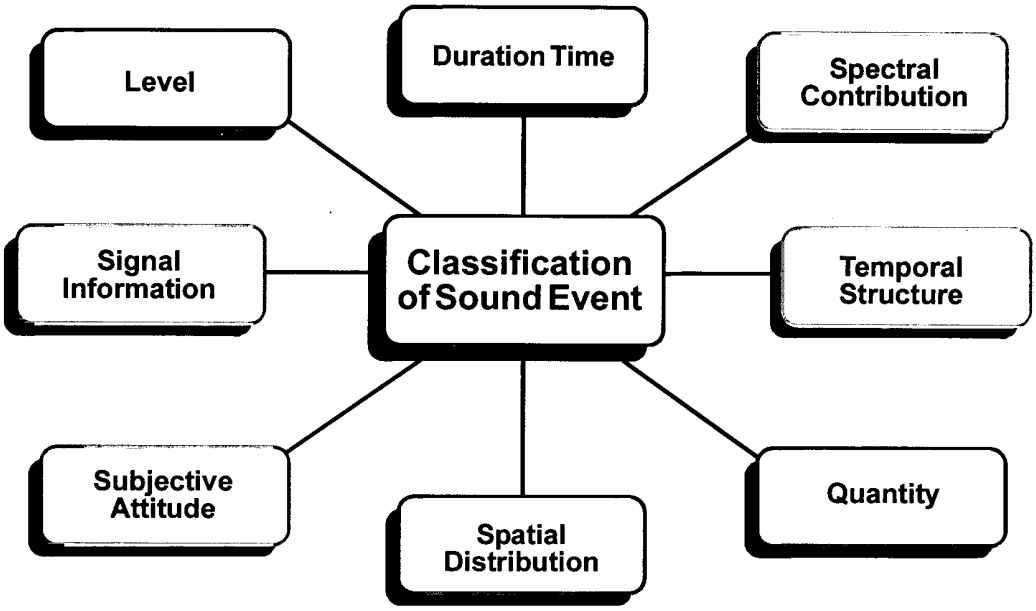


Fig. 1.- Parameters relevant for the classification of sound using human hearing [4].

METHODS AND TOOLS

If we understand the exterior noise of vehicles as described in the previous chapters, the consideration of the particular characteristics of subjective sound judgement is essential. The knowledge acquired in the field of vehicles interior noise may be transferred as a suitable basis for future research work. It includes the knowledge of psychoacoustics, but goes one step beyond: Here, the understanding of sound „language" - with its relevant information - and the objective evaluation of subjective judgement have to be integrated. Based on this, the engineer may determine those sound characteristics that are relevant - or necessary - for a particular sound image, i.e. distribution of harmonics and subharmonics for a sportive „design" or the spectral distribution for a luxury sound. If those characteristics - and their meaning for the subjective judgement - are understood comprehensively it will be possible to describe for the customer - and all people concerned - why an exterior sound is designed in a particular way. This will additionally allow an task-oriented definition of target sound.

Two further approaches should be mentioned in this context although they are not completely available at present:

Firstly, simulation tools for the exterior noise of vehicles. A suitable tool should allow the prediction of an expected sound situation by means of binaural representation and sound quality evaluation. In a first step, „hybrid" binaural models may be used which include measurements of transfer and vibrational characteristics on one hand and the simulation of the binaural acoustical situation dependent on modifications, etc. The usefulness of such a tools has been proven in several projects dealing with interior noise [5].

Secondly, the creation of a „virtual" exterior sound may be possible in the future. This includes the formation of desired sound components based on the use of sound generation via loudspeaker(s) etc. It may seem a kind of unrealistic, but today's acoustical behavior not only of upper range cars is so quiet for numerous driving conditions especially in cities that the creation of a particular, pleasant sound image seems possible. The technical problems are soluble, it is more a question of customers' acceptance.

THE LANGUAGE OF SOUND

Whenever a product is used in daily life, it emits a characteristic sound. This sound can be regarded as a specific kind of language which the product employs to tell the user something about itself, e.g., its position, its task, its status of operation, and its quality. In addition that sound contributes significantly to the "character" of a product. A customer who has the choice between several products will thus strongly be influenced in his decision by the product sound. In the daily use of the product the sound will significantly contribute to the satisfaction of the user.

Noise is judged subjectively and this judgement is also described subjectively. Additionally, sound means not only an acoustical event, but also transfers information. This may include aspects of quality, functionality, danger, environment and may be divided into main categories. The described items deal with perception. Another part of the story is the technical realization. Here, the language of sound normally is reduced to an "objective" single value measure. Something that is significantly different from subjective evaluation. Subjective parameters are best determined statistically because of the variability of human responses to a particular (acoustical) situation. It is difficult and means a complex tasks to describe ("objective") parameters from them. For this purpose, an objectively based and aurally-equivalent sound measurement technology is useful.

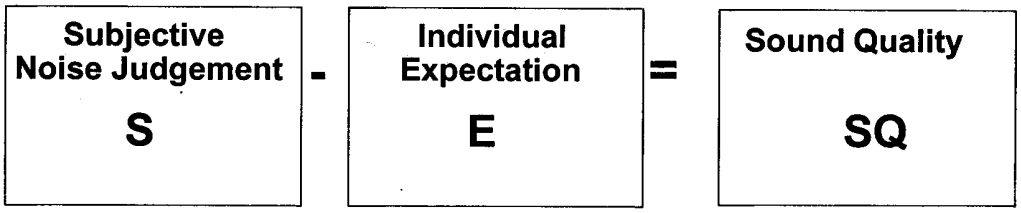
Therefore, the main objective must be the integration of all relevant information for the subjective evaluation in the technical measure. This requires the understanding of the key factors of sound language dependent on particular tasks. For example, the time structure and spectral distribution of an acoustical event, the contextual situation, but also the information included in the sound. It also requires in any case the consideration of human hearing as it is possible when using binaural technology [6].

An effective and optimal design of product sounds has been hindered until now by the fact that the structures of the specific product "languages" are not yet understood. The most prominent branch confronted with this problem is one of Europe's most important industries - car manufacturers. Hence, the overall goal of OBELICS [7] is to develop methods for an objective evaluation of car sounds.

Based on the experience in this context the following conclusion is valid: Because sound events and their evaluation are extremely complex and depend on the contextual situation, a practicable procedure of the work on sound language must always be task- (or product-) orientated: No "general" description using one single index for all purposes will be possible.

There exists a certain relation between sound quality, subjective noise judgement and the individual expectation as represented in fig. 2: If the subjective judgement is better than the individual expectation then the customer is very satisfied, meaning a high sound quality is realised. Obviously, this can be transferred for the opposite case: If customer's expectation is higher than the subjective judgement than the resulting sound quality is poor.

Considering the requirements for product sound quality, the resulting acoustic behaviour has to support the positive characteristics of the product and its quality. It has to give a feedback of product's functionality and operation. If we are using a dish-washing machine it is quite nice to realise very low sound pressure levels especially, if this device is installed in the kitchen close to the living room. But if we do not hear anything we probably will be irritated. Sometimes the customer does not only want to have a feedback of functionality and operation, but also requires information in which stage of operation the product works.



S - E = K

S > E = high SQ - customer is very satisfied

S = E = expectation fulfilled - satisfied customer

S < E = low SQ - customer is not satisfied

Fig. 2.- Relation between Sound Quality, subjective judgement and individual expectation

Finally, product sound quality has to consider the influence on the environment. That means, it has to correspond not only with the expectation of the customer but of those peoples being exposed to the product. This is probably important with respect to vehicles due to their social context: Sportive cars and sportive sound primarily based on high loudness levels and booming noise probably will embarrass citizens of a city. Here, a more restrained sound characteristic giving the driver the feedback of high performance during acceleration phases may be more suitable. The task of acoustical engineers is to find the best solution for the requirements by manufacturers, customers and society.

SUMMARY

An understanding of the language of sound that is appropriate for acoustical engineering is in the early beginning. That means, comprehensive research work for the determination of the key factors for sound evaluation is required. This probably will be focused on particular applications while a global solution will not be possible.

Another future development maybe the set-up of a multimedia sound library including sound, video and database modules. Such a sound library could be combined with an easy-to-handle binaural measurement device for trouble shooting and trouble solving. A complete solution may also include the possibility for analyses in a worldwide networking environment that allows nearly online communication about particular sounds and their definition.

BIOGRAPHICAL REFERENCES

[1] J.W. Biermann
Umdruck zur Vorlesung: Geräuschverhalten von Kraftfahrzeugen
Aachen, 1988

[2] K. Hieronimus, G. Hellmer
Die Absenkung der Außengeräuschemissionen von Pkw - eine Herausforderung für den Akustik Entwicklungsingenieur
Haus der Technik 1992

[3] K. Genuit
Background and Practical Examples of Sound Design
EAA-Tutorium, 31.03.1996, Antwerpen, Belgien

[4] K. Genuit; J. Poggenburg
New Approaches to Transferring the Term 'Sound Quality' into Practice-related Solutions
EIS-Conference, 23.10.1996, Peterborough, England

[5] K. Genuit, N. Xiang
Binaural "Hybrid"-Modell for Simulation of Engine and Wind Noise in the Interior of Vehicles
SAE'97, 20.-22.05.97, Traverse City, Mi, USA

[6] K. Genuit
Grundlagen der Psychoakustik
HDT-Essen „Fahrzeugakustik", 03.-04.12.1996, Essen

[7] W. Krebber, M. Adams, F. Brandl, N. Chouard, K. Genuit, T. Hempel, R. v. Hofe, G. Irator, P. v. d. Ponseele, B. Saint-Loubry, B. Schulte-Fortkamp, R. Sottek, R. Weber
Objective Evaluation of Interior Car Sound – the OBELICS project (BRPR CT96-0242)
DAGA 2000, 20.-24. März 2000, D-Oldenburg