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MODELLING AND VALIDATION OF A PASSENGER CAR DOOR TRANSMISSION LOSS WITH SEA

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1. INTRODUCTION

The accelerated development cycle of new car models requires an increased use of computer-aided-engineering methods, which can be used in early design stages, often before hardware exists. Statistical Energy Analysis (SEA) which was developed in the early 1960's [1] is being applied more and more often in the car industry as a prediction and optimization tool of vehicle noise and vibration. Historically, vehicle noise and vibration prediction has been performed with finite element methods and more recently boundary element methods. However, the practical upper frequency limit of these methods is below frequencies which are important in the design and development of effective vehicle sound packages. Due to its statistical nature, the prediction accuracy of SEA increases with increasing frequency. In addition SEA captures real manufacturing and material variability without the enormous computational expense of permuted deterministic methods.

In the remainder of this paper, the results of a vehicle door model are presented. The model was created using the commercially available AutoSEA software [2], and includes the door sheet metal, window glass, trim and leakages. The results of the SEA calculations are compared with noise reduction measurements that were taken at the HP-Pelzer acoustic center in Witten, Germany. In addition, the influence of acoustic leaks and weak points are calculated and compared to measured results.

2. SEA-MODELING

The acoustical performance of modern vehicles is primarily dominated by leakage resulting from pass-throughs and insufficiently sealed components. AutoSEA provides methods of modeling leakages (slit, rectangular,and circular), which allow a realistic door model that has good correlation with the measured transmission loss. The door of a middle class car was modeled with the following subsystems:

- Window - Door sheet metal outer
- Door water shield - Door trim
- Air gap between sheet metal and the door watershield
- Air gap between door water shield and the door trim
- Leakages of: -door sheet metal (e.g. drainage holes)
  -door sealing and window sealing
  -door trim, water shield and mirror corner.

The AutoSEA model subsystems and coupling connections, including all leakages used for comparison with laboratory measurements, are illustrated in Fig. 1.

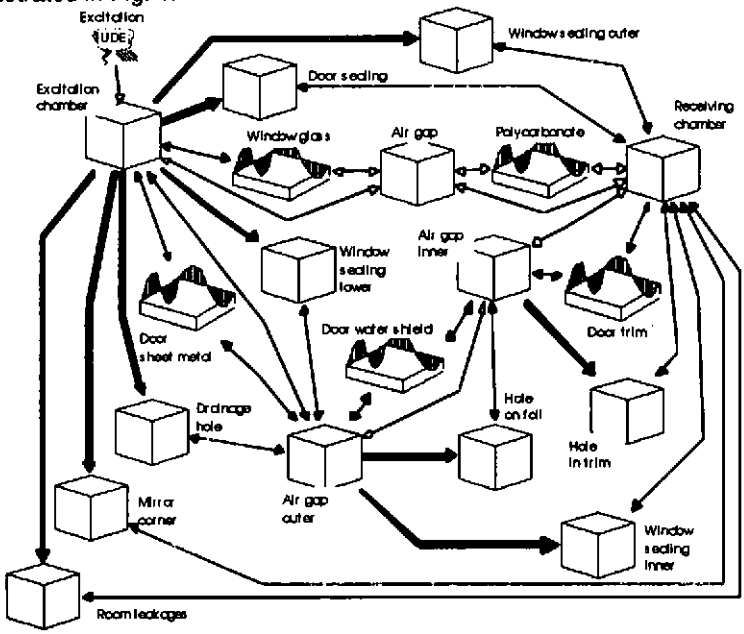

Fig. 1: SEA-Model of a vehicle door

3. MEASUREMENTS AND RESULTS

In order to correlate the model with measurements, a complete door including frame and auxiliaries was mounted in a window between two test chambers. Using white noise excitation, the noise reduction of the door was measured for the following conditions:

A: Baseline
B: Configuration A + double wall glass
C: Configuration B + improved sealing of important leakages (mirror corner, window seal, and door seal)

The absorption characteristics of the source and receiving room were included in the AutoSEA model. The calculated subsystem power inputs into the receiving chamber for the baseline configuration are shown in Fig. 2. It is seen that the most important subsystems are the resonant window glass behaviour, mirror leakage, door sealing, and the window mass-law transmission. Based on the dominant energy flow paths, the window glass was modified to include the original 3.2 mm glass, a 10 mm air gap and an outer 4 mm polycarbonate layer. This modified glass configuration will be referred to as the "double wall glass", and the door side with the original window glass (incl. all leakages) will be referred as the "baseline".

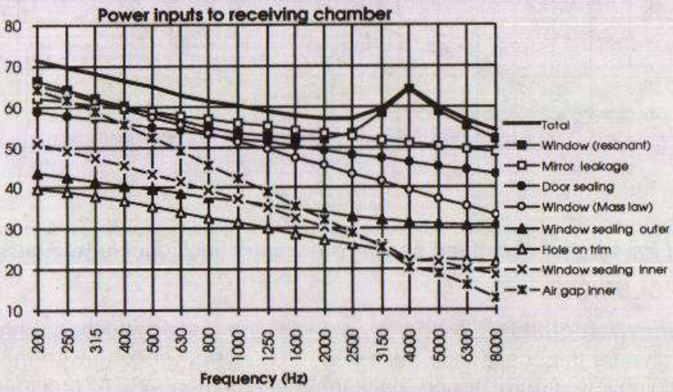

Fig. 2: Ranking of the noise sources (baseline configuration)

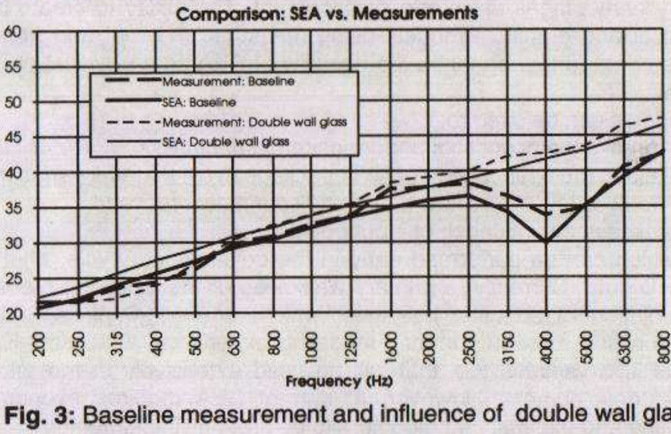

Fig. 3: Baseline measurement and influence of double wall glass

The modeled and measured noise reduction, for both the baseline and double glass, is shown in Fig.3. The effects of the mirror leakage, door and window seal (with double wall glass in place) are illustrated in Fig.4. The change in coincidence with the double wall glass in place is clearly seen in

Fig.4, and the effects of the door seal leakage is seen to be 2 to 3 dB across a wide frequency band. For all cases, the difference between the modeled and measured results is not more than 4 dB for any frequency, and is less than 1 dB over much of the mass-law frequency range.

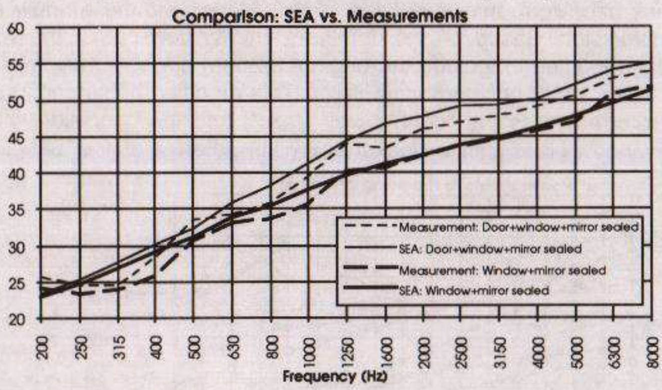

Fig. 4: Influence of the sealings/leakages (incl. double wall glass)

4. CONCLUSIONS

The correlation of the SEA door model with the noise reduction measurements give us the confidence necessary to continue working with the SEA methodology in future sound package development. SEA provides the NVH engineer with a prediction and optimization tool that can be used in the very early stages of vehicle development. The ability to create hybrid theoretical and empirical models using measured material and transmission loss data further enhance the usability of SEA as a practical engineering tool.

SEA models can be used to:

- predict the acoustical performance of structures,
- aid in the optimization of NVH-packages with material variation,
- rank order energy flow paths and sound sources, and
- assess the influence of input powers.

All of which can be performed early in the development cycle, often with only CAD data. Currently, a primary weakness of the modeling process is the prediction of acoustic leakages, which requires empirical data for correlation and more importantly modeling experience. Statistical Energy Analysis is a valuable tool that will be used extensively in the future of acoustic development. However, at current SEA requires experimental verification and experienced modelers to be properly implemented.

5. REFERENCES

[1] R.H. Lyon, Statistical Energy Analysis of Dynamical Systems, MIT,1974
[2] AutoSEA - User Guide, Rev. 1.4, Vibro-Acoustic Sciences Limited,1995