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TRANSMISSION LOSS OF DOUBLE WALLS: SEA MODELIZATION VERSUS EXPERIMENT

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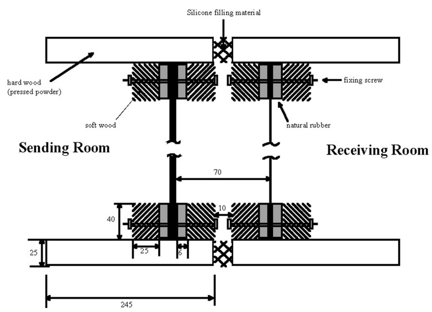
ABSTRACT
The acoustic transmission loss of different double wall configurations (thin aluminum panels of $\sim$1m^2 area) has been investigated both experimentally and by simulation using Statistical Energy Analysis (SEA). The interior double wall cavity was studied under three conditions: (i) empty, and (ii, iii) filled with two different sound absorbing foams. The calculations were performed with the commercial code AutoSEA2. The SEA model takes into account possible flanking transmission paths through the mounting frame of the panels as well as the low frequency mass-air-mass resonance behaviour. By choosing appropriate parameters for the mounting frame's flexible coupling, an excellent agreement between measurement and calculation results can be obtained for all studied cases.

1 - INTRODUCTION
Sound transmission behaviour is an important field for the optimization of lightweight vehicle structures at high speeds (aircraft, high speed trains and cars). Statistical Energy Analysis [1, 2] has become an accepted predictive tool for the high frequency range where the response behaviour of the subsystems is mainly "resonant" and governed by a high modal density. For an efficient overall design of a system, one is however tempted to extend the application range also to the mid and low frequency range ($n_{mod} \approx 1$) where in the case of sound transmission, non-resonant response of the component subsystems can play a dominant role. The aim of the present investigations was to validate the SEA description of basic double wall systems in view of a future application to a complete coach modelization of high speed trains.

2 - EXPERIMENTS
Fig. 1 shows the fundamental setup of the experiments. Two thin aluminum panels were mounted in individual wooden box frames (high density press board) by use of a soft rubber sealing. The two frames were connected by a silicone coupling and mounted into the transmission window between two reverberant rooms. The area of the plates was approx. 1m ^{2}; the thickness 1mm and 2mm respectively. The separation of the two plates was 70mm. In a first setup, the interior cavity between the plates was left empty. In two further investigations different absorbing foams were attached to the interior plate which partially filled the cavity:

- "grey foam", d=50mm, density ρ=28.7 kg/m^3, flow resistance Ξ=1.7 $\times 10^4$ Rayl/m,
- foam "Illmid", d=30mm, density ρ=8.5 kg/m^3, flow resistance Ξ=4 $\times 10^5$ Rayl/m.

In all cases the resulting structural damping loss factors of the plates were measured in order to use these data for the SEA models.
As a basic reference also the single wall configuration was studied by just eliminating the interior plate (Plate 2) facing the receiving room. Fig. 2 shows a summary of the measured spectral noise reduction



(a): Cross section view showing panels and wooden frame.

(b): Photo of rubber-isolated panels and silicone connection region between frames.

Figure 1: Double wall mounting.

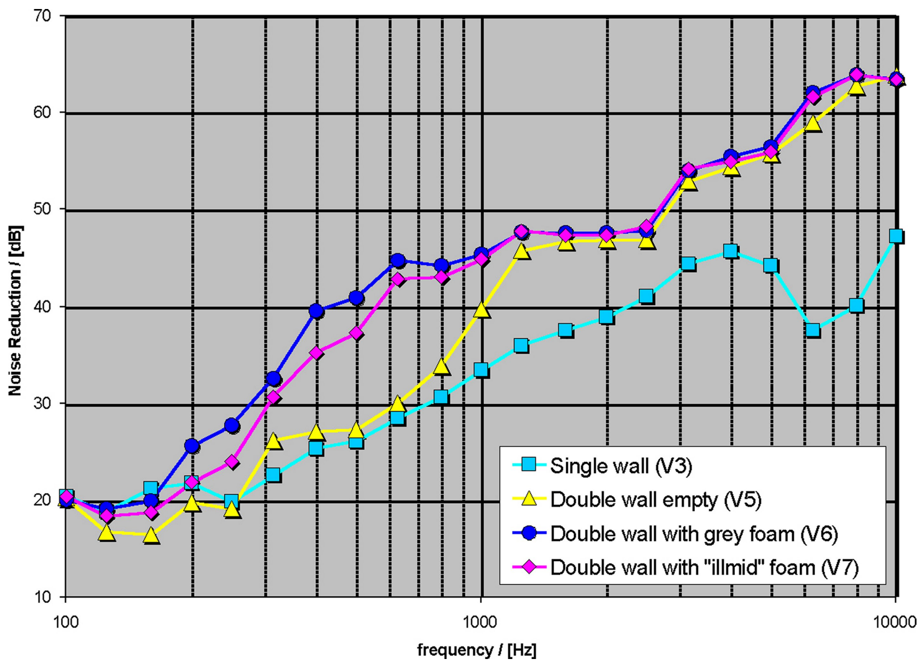


Figure 2: Experimental results for the noise reduction of double wall configurations.

(sound pressure level difference between sending and receiving room) for all configurations. It can be seen that the influence of the absorbing foam is apparent only in the frequency range up to 1250 Hz. The insensitivity to cavity damping above 1250 Hz was attributed to flanking paths. The SEA model described below, confirmed the presence of structure-borne noise flanking via the wooden frame.

3 - MODELING APPROACH

The AutoSEA2 program [2] was commercially released in March 1999 and offers a completely new geometric 3D visualization of the structure thanks to a node oriented FE-like description of SEA subsystems. Fig. 3 shows the exploded view of the double wall model (”Sending” and ”Receiving” subsystems have been suppressed).

For a good modelization, a careful description of the material parameters is very important. The structural damping of the aluminum plates as well as the acoustical damping of the rooms was taken from the experiments. The absorption of the foams was calculated with the multi-layer foam module which is implemented in AutoSEA2, the most important input data being the flow resistance values. For the damping characteristics of the wooden frame and the elastic behaviour of the rubber and silicone sealing, no experimental data were available. Empirical values were chosen and tuned to best fit the results on the empty doublewall case.

An SEA formulation for sound transmission across double wall panels was first published by Price & Crocker [3]. They included the direct ”non-resonant” paths. That is, transmission between resonant

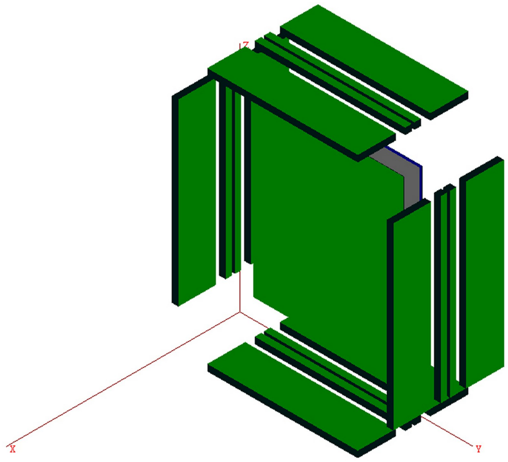


Figure 3: Exploded 3D view of SEA model.

acoustic subsystems due to mass-controlled response of the intervening panel. This SEA model correlates well with TL test data for massive panels which are structurally-isolated and separated by a large air gap. For frequencies below the lowest panel critical frequency, sound transmission is mainly via the sequential panel mass-law paths.
The AutoSEA2 model used in this study uses SEA formulations equivalent to Price and Crocker, but includes three additional energy transmission paths:

- the structure-borne noise fanking path [2] in the wooden box frames
- the mass-air-mass "double wall resonance" path, and
- the panel-air-mass path, estimating forced response of panel 2 by resonance in panel 1.

The double wall resonance effect is often observed to cause a pronounced "dip" in TL of constructions with small panel separation, with lightweight panels and when cavity damping is low. The frequency of the TL dip is described by Fahy [4] as a mass-air-mass resonance phenomenon. The non-resonant, limp masses of the two panels are coupled by the compressive stiffness of the air gap. In AutoSEA2, Fahy's infinite panel wave impedance model is used to calculate a "double-wall resonance" transmission coefficient and a corresponding coupling loss factor between the sending and receiving acoustic cavities. For this path, the elastic modulus of each panel is nulled to simulate only the limp mass effect.
The panel-air-mass path has been identified by Craik [5], with reference to lightweight trim panels on heavy walls. It is used here to describe the non-resonant "forced" response of a limp mass panel driven across a cavity air spring coupling by an adjacent resonant panel. AutoSEA2 uses an insertion loss approximation for this path, as described by Cimerman [6].

4 - CALCULATION RESULTS

Fig. 4a-4c shows the noise reduction calculation results. For all cases, good agreement with the measured data was achieved. In Fig. 4e-4f the power input to the receiving room is analyzed and separated into the different transmission path contributions. The results confirm that the flattening of all NR spectra in the mid frequency range is due to the influence of the wooden frame flanking radiation. Effectiveness of sound insulation is always controlled by the "weakest acoustic link" (i.e. strongest transmission path) in a system. The comparison of Figs. 4e and 4f shows that the effectiveness of the absorbing foam is limited to the low frequency range because the wooden frame flanking contribution dominates above 1,000 Hz.

5 - CONCLUSION

The application of SEA to the double wall transmission loss problem shows that it is possible to predict the noise reduction very accurately provided a detailled model is built. The presented cases also show the capability to reveal and analyze the influence of flanking paths. This may in the future help to better prepare experimental setups which avoid unwanted sound and vibration transmission.

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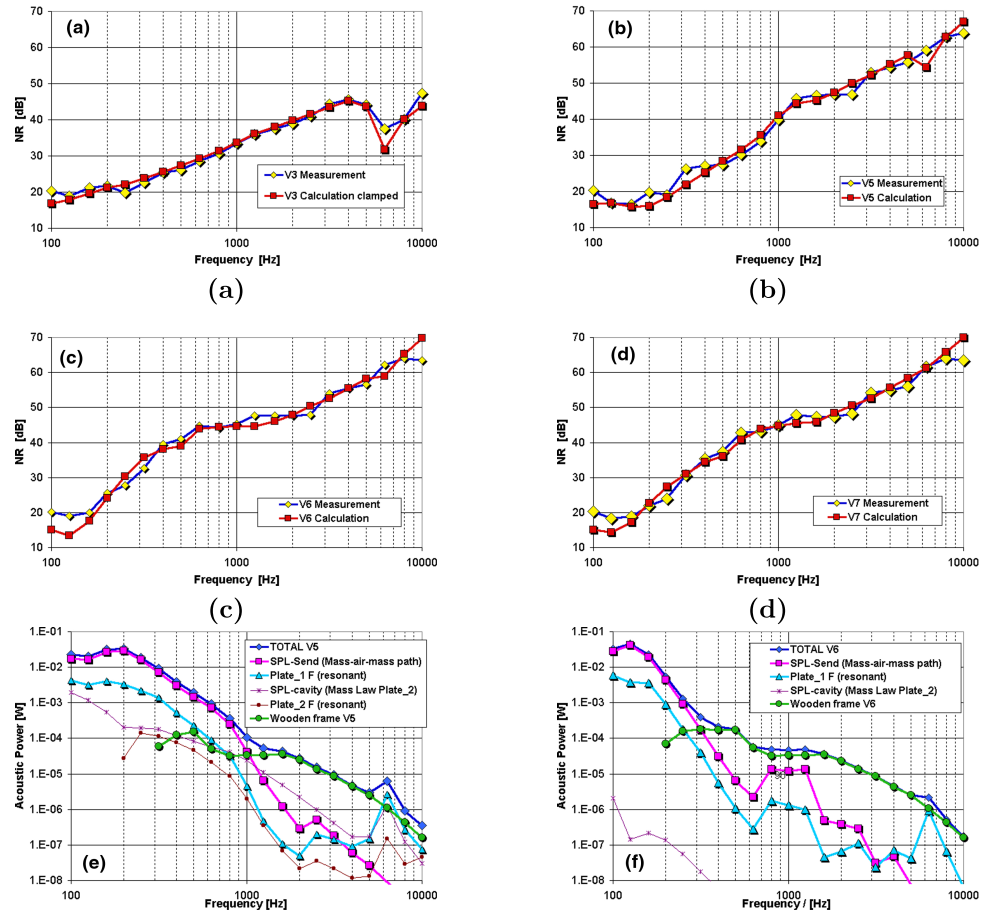

(a) (b) (c) (d) (e) (f)

Figure 4: Calculation results compared to measurements; noise reduction (NR) for − single wall (a); empty double wall (b) and double wall with absorbing foams (c-d); also, separation of transmission paths by acoustic power input analysis to receiving room for − empty double wall (e) and double wall with grey foam (f).

REFERENCES

1. **R. Lyon and R. DeJong**, *Theory and application of Statistical Energy Analysis*, Butterworth-Heinemann, 1996

2. **P. Bremner**, AutoSEA2 - A new design evaluation tool for noise & vibration engineering, In *Proc. ASME Design Engng. Conf.*, DETC-VIB-8193, Las Vegas 1999

3. **A. Price and M. Crocker**, Sound transmission through double panels using SEA, *J. Acoust. Soc. Am.*, Vol 47(3), pp 683-693, 1970

4. **F. Fahy**, *Sound and Structural Vibration*, Academic Press, 1987

5. **R. Craik**, Sound transmission through cavity walls, In *Proc. Internoise*, Leuven, 1993

6. **B. Cimerman**, Incorporating layered acoustic trim materials in body structural-acoustic models, In *Proc. SAE Noise & Vibration Conf.*, Traverse City, 1995