HIGH FREQUENCY ACOUSTIC ANALYSIS via ENERGY FINITE ELEMENTS

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SUMMARY

Vibro-acoustics can sometimes be considered as a 'dark' science. Dark in the sense that we cannot easily 'see' acoustics phenomena by simply observing and/or hearing. It is not as intuitive as structural problems, where for example we know that if we load in the centre a simply supported beam, this load point will move in the direction of the load. However, if we excite acoustically the middle point of a pipe it may not be so obvious where the peak in acoustic pressure may occur. This depends on several variables such as length of the pipe, frequency of study and boundary conditions on the ends. Therefore, the solving of vibro-acoustic problems can be highly dependent on experience and intuition.

Simulation of a vibro-acoustic case then becomes vital to help to visualise what the problem actually entails. Relying only on trial and error testing and experience on specific individuals can be costly and limiting at the same time.

During the last ten years or so acoustics and Noise-Vibration-Harshness (NVH) have moved from being an issue at prototype stage to become a key objective from the design stage.

The Finite Element Method (FEM) and the Boundary Element Method (BEM) are well known and implemented tools for the solution of low and middle frequency problems. However, there is always a compromise between the highest frequency of interest and the size of the structure and/or acoustic cavity. The size of the meshes needed at high frequencies can make run times impractical and the high density modal content can make difficult to interpret results efficiently.

In addition to the increasing interest in noise reduction there is another less understood and very subjective acoustics branch, which is sound quality. It is in this area where high frequencies can be of most interest. Certain frequencies do not need to be the loudest to affect the perception of poor sound quality in a final product. Statistical Energy Analysis (SEA) is a fairly established method to simulate high frequencies in structures. More recently the Energy Finite Element

Method (EFEM) has come along as a very attractive approach. This document presents an introduction to EFEM for acoustics as it has recently become commercially available.

1: Main features of the Energy Finite Element Method

The main features that characterise the EFEM are:

- Vibrations are represented by stored, dissipated and transferred energies.
- The variable is time and space averaged energy density.
- Structural and acoustic domains are represented via finite elements.
- Allows spatial variation of energy within a sub-system.
- Allows localised damping.
- Allows for local excitations such as point loads.
- Allows multi-layered Noise Control Treatment (NCT) such as trimming, etc.

2: Case 1: Sound Transmission Loss (STL) through multi-layered wall

This application illustrates the simulation of a standard test procedure for the calculation of the STL through a multi-layered wall. The size of the source and receiver rooms is typically of several cubic meters, which would make it a difficult problem by making use of the traditional FEM or BEM methods. The NCT configuration comprised the following five layers: copper-plywood-rock wool-gypsum-wood. The excitation was applied to simulate a reverberant environment in the source room.

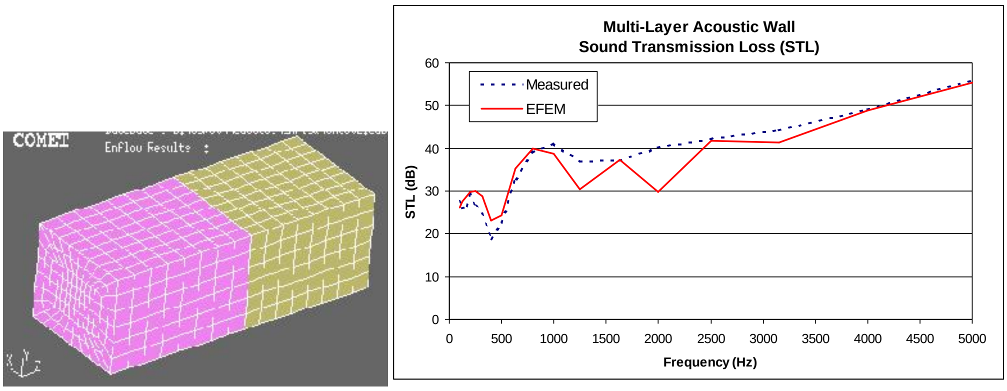

Figure 1: EFEM mesh and predicted vs. measured STL(dB) through wall

Figure 1 shows the simplicity of the EFEM mesh with the source and receiver rooms in different colours. The wall was modelled as a structural plate with NCT layers applied. A total of 1568 elements were used. The calculation only takes a few seconds for all frequencies. The results show good correlation with measurements. The discrepancies at some frequencies are believed to be due to the lack of detailed material information for the absorptive layers and also to the unknown damping values due to assembly of the wall in the test chambers.

3: Case 2: Sensitivity to mesh density in EFEM

The problem described in 'Case 1' was recalculated with a coarser mesh density and results were compared.

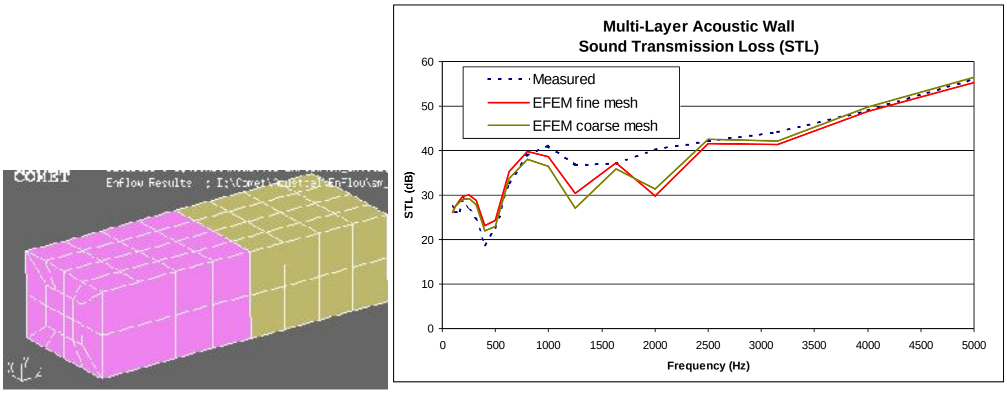

Figure 2: EFEM coarse mesh and fine mesh vs. coarse mesh STL(dB)

The EFEM coarse mesh comprised 168 elements; i.e. with the use of approximately a tenth of the original mesh density we arrived to very similar results. The EFEM is not as sensitive to element size as traditional FEM and BEM analysis at high frequencies.

4: Case 3: Structural-Acoustic analysis of truck cabin

This case presents a comparison of vibro-acoustic EFEM predicted results vs. measurements. The cabin was excited by an acoustic excitation through a loudspeaker. Measurements in the air of the cabin and on structural surfaces were taken at several locations and through five different experiments. Then the averaged responses were calculated in order to compare to EFEM results. The cabin EFEM also featured absorptive properties on roof (lining), floor (carpet) and seat assembly with trimming on external surfaces.

Some assumptions were taken into account at this stage such as the door sealing areas were assumed welded to the rest of the structure. In reality, some local damping should be applied if available from experiments.

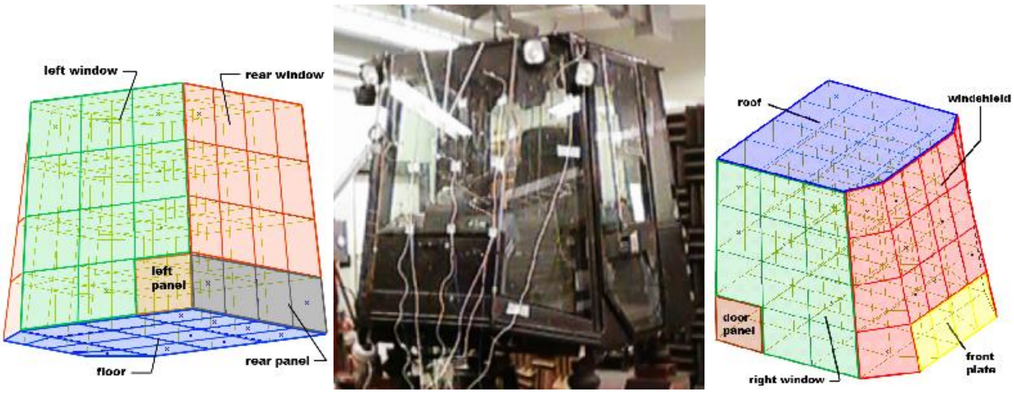

Figure 3: Truck cabin EFEM mesh and experiment set-up

The EFEM mesh featured beam elements to model the main frame of the cabin coupled with shell elements for windows and panels and all structural domains coupled to the interior acoustic cavity.

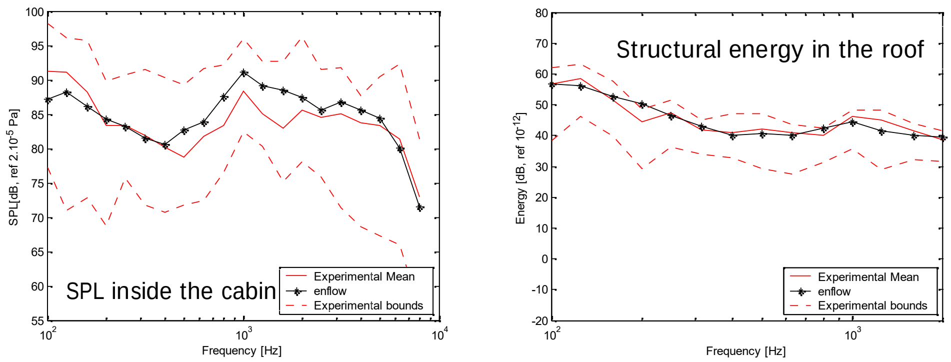

Figure 4: EFEM vs Experiment: SPL in air and structural energies on roof

Figure 4 shows graphs comparing EFEM predicted results with measured ones. In general there is close correlation. The discrepancies at certain frequencies are believed to be due to the lack of detailed information on local damping at door sealing and joints along glass and frame components.

Overall, the agreement with measurements is very promising with results extracted up to 8000Hz. It demonstrates that the EFEM approach is a strong contender as a high frequency analysis tool for vibro-acoustic problems. It is a very attractive option since it makes use of a well known work frame such as finite elements.

REFERENCES

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