# Proceedings of the Institute of Acoustics



## CONTRIBUTION ANALYSIS FROM LOUDSPEAKER RADIATING SURFACES


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## 1. INTRODUCTION

Finite and boundary element methods are being used in many industries as part of the design cycle, where they permit more rapid evaluation of new designs and offer a greater level of understanding of product performance. Many aspects of loudspeaker design could benefit from these techniques. This has been discussed previously [1]. It should be noted that to obtain accurate results good input data describing the geometry, material properties and boundary conditions is required. However material data for cones, surrounds and spiders is likely to be only approximately known. Even under these conditions it is possible to use the finite and boundary element methods to estimate general trends of performance [2].

The current work follows on from the previous paper [3] of the author. The importance of using a fully coupled analysis is investigated. The contributions to the pressure from the cone, surround and dustcap of a loudspeaker are examined, illustrating the type of detailed information which analysis can produce. This type of output may be of assistance in making design decisions.

## 2. FULLY COUPLED/UNCOUPLED ANALYSIS

When a structure vibrates in an acoustic medium two conditions are satisfied on the fluid-structure interface. There is continuity of normal velocity and continuity of pressure in the fluid with negative the normal stress in the structure. For a completely accurate analysis both conditions should be satisfied. When the fluid is dense, eg, shell structures vibrating in water, it is absolutely essential to perform a fully coupled analysis. However when the fluid is light, the fluid loading is often insignificant compared with other forces exciting the structure. For an engine block vibrating in air it is quite sufficient to use an uncoupled acoustic analysis. The structure is analysed initially without any fluid loading and then a secondary acoustic analysis is performed using the surface vibrations of the structure as a loading condition on the fluid domain. Thus only the first of the above two conditions is satisfied. It is also a computationally cheaper method. For a loudspeaker cone vibrating in air the fluid is light, but so too is the structure. The extent to which a fully coupled analysis is necessary for accurate was investigated using the cone/surround/dustcap model of [3], shown in figure 1, using both fully coupled and uncoupled analyses. The comparison is shown in figure 2 for a point in front of the loudspeaker and in figure 3 for a point behind. There is a noticeable difference of up to nearly 1dB. The surrounding fluid will have both an added mass and a damping effect on the structure. The extent of these effects will depend on the mass of the cone, dustcap, surround and voice coil and also the amount of damping in the mechanical system. Thus other drive units may be affected differently by the fluid loading, but perhaps 1dB is a general guide to the accuracy lost from using uncoupled analysis.

## 3. PRESSURE CONTRIBUTIONS

When a structure is vibrating in contact with an acoustic domain then the radiating surface can often be naturally decomposed into several regions or panels. The pressure at a particular point in the fluid can be considered as arising from contributions from these different panels. There are several different ways that these contribution factors can be defined. The author had considered evaluating panel contributions using the Helmholtz formula;

$$p(\underline{x}) = \int_{\Gamma}\left( p(\underline{y})\frac{\partial g(\underline{x},\underline{y})}{\partial n_y} - \frac{\partial P(\underline{y})}{\partial n_y} g(\underline{x},\underline{y})\right) d\Gamma(\underline{y}) \qquad (1)$$

which expresses the pressure in the fluid as an integral over the radiating surface involving the surface pressure P, the pressure normal gradient $\frac{\partial p}{\partial n}$, the Green's function g and its normal derivative. It is fairly simple to evaluate contributions to the integral from different parts of the surface area $\Gamma$. However these contribution factors do not provide the designer with information which is easy to interpret and use. Perhaps a more useful definition of panel contributions are those based on velocity sensitivity. The ith panel contribution at the point $\underline{x}$ is the pressure at this point when the ith panel is vibrating normally but the remaining panels are assumed to be held rigidly fixed. The panel contributions are complex numbers which sum to give the complex pressure value. They can conveniently be plotted on an Argand diagram together with the resultant sum. It is then obvious which panels are contributing in a positive sense to the total pressure (sources) and which have a negative contribution (sinks). These type of panel contributions are used in the automotive industry for the interior vehicle compartment [4].

Panel contributions have been computed for the 3D loudspeaker example of reference [3]. Three panels have been defined, cone, dustcap and surround. In this analysis the speaker box was assumed to be rigid. Figures 4 and 5 show panel contributions at 1800Hz at a point 1 m in front of the front board and 1m behind the front board respectively. The results seem to have a surprisingly high contribution from the surround. However inspection of the mode shape, reference [3], show that at this frequency the surround is vibrating with large amplitude and the cone is vibrating with largest amplitude at its outer edge.

## 4. CONCLUSIONS

Results presented in this paper suggest that for accurate results in vibroacoustic modelling of radiation from loudspeaker drive units, a fully coupled model is best. Panel contributions can be used to provide useful information to the designer of loudspeakers.

## 5. REFERENCES

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[3] P C Macey
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Figure 1

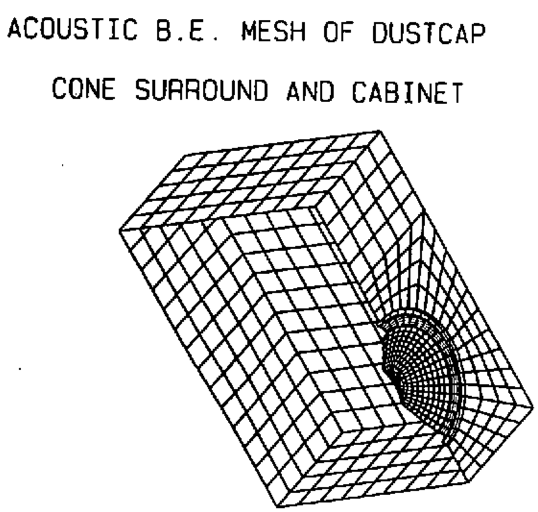

Figure 2

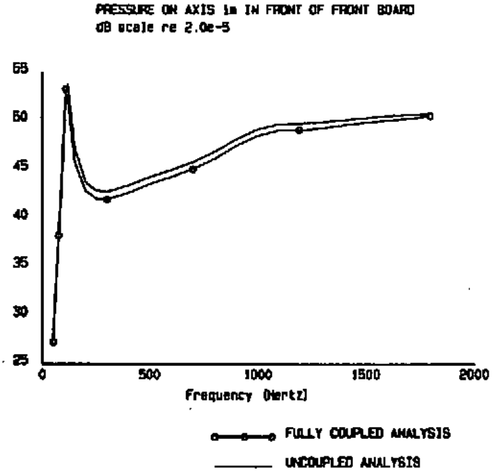


Figure 3

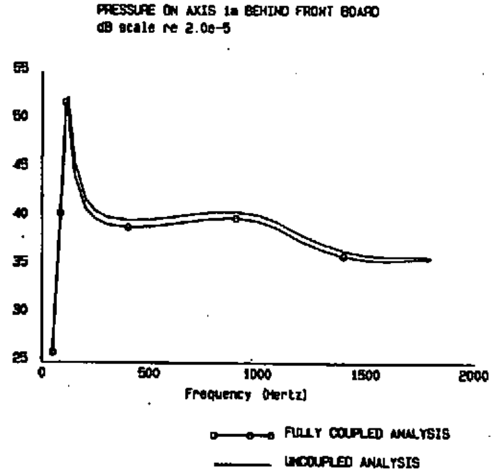

Figure 4

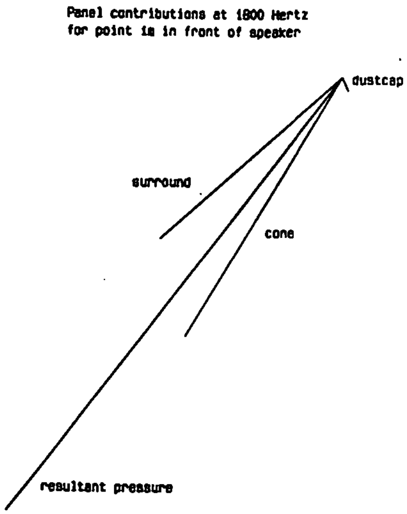


Figure 5