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THE EFFECTIVE USE OF NOISE PREDICTION IN THE DESIGN PROCESS

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1. INTRODUCTION

Design for low noise is becoming increasingly important for products to succeed in the marketplace. In the past, the noise aspects of products tended to be considered late in the development phase. This is no longer acceptable, as early design decisions often compromise the ability to meet noise specifications.

This paper is intended to illustrate the current state of the art with respect to integration of low noise design within the overall design process. This is no longer a luxury only available to projects with the highest budgets or most critical noise targets. Modern predictive methods are readily available, are easy to use, and yield accurate results for applications which, up to a few years ago, were considered to be too complex for any but the most advanced acousticians or mathematicians.

2. TECHNICAL OVERVIEW

Current commercially available finite element and boundary element codes provide an easy to use environment for solution of a wide range of acoustic problem types. The different tools have different applications, as summarised :

Application	Usual Methodology	Examples
Structural Free Vibration	Finite Element	Massive structure modes, e.g. IC engine blocks

Acoustic Free Vibration	Finite Element	Passenger Compartment cavity modes
Structural Forced Vibration	Finite Element Local Modal synthesis	
Acoustic Transfer Functions		
- internal	Finite Element, Boundary Element	Silencer systems
- external	Boundary Element	Sensitivity prediction
Acoustic Radiation (uncoupled)	Boundary Element	Engine Noise
Acoustic Radiation (coupled)	Boundary Element	Vehicle body noise, Loudspeakers Domestic White goods

The above table is by no means comprehensive. For example, large scale external radiation problems may be best dealt with using ray tracing methods.

3. EXAMPLE APPLICATIONS

Exhaust Silencer

The prediction of transfer functions (or insertion loss) in exhaust silencers requires modelling of the geometry of the system, plus a knowledge of the distribution of acoustic properties within the silencer.

Various calculation methodologies are applicable. Traditional methods rely upon a knowledge of the transfer function of each component of the assembly, (e.g. 4 pole matrix methods). The main problem with these methods is lack of knowledge of the transfer functions for specific geometries.

Finite element methods may be used, but have high mesh generation requirements. Computational Fluid Dynamics (CFD methods) have similar requirements but are limited by the upper frequency of analysis. CFD methods are currently the only reliable method of including mean flow in silencer predictions.

Boundary element methods provide a rapid facility for prediction of the performance of both reactive and absorptive silencers. The main disadvantage of the boundary element method is that it is currently not possible to include the effects of mean flow.

Fig 1. Exhaust Silencer Model

The acoustic properties of exhaust gas are partly dependent upon gas temperature. It is thus necessary to be able to include the variation in property of the fluid in different regions of complex silencers. Figure 1 illustrates a typical silencer box, Figure 2 presents the calculated insertion loss of this silencer across the frequency range.

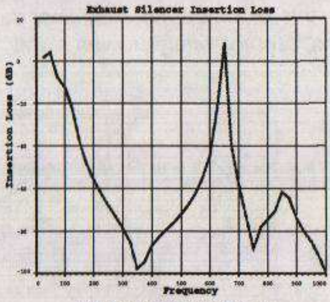

Fig. 2 Calculated Insertion Loss

As an illustration of the effort required to perform such an analysis, it may be noted that data preparation and post processing for this example took less than 3 man hours. Solution (on a low end IBM RS6000 machine) took a total of 15 minutes.

Loudspeaker

The domestic loudspeaker provides a good example of a coupled, internal plus external acoustic problem. Figure 3 presents an overview of a typical system. The significant parts of the system are :

- Loudspeaker cone. This is flexible, the free modal parameters of this as mounted on the flexible support are found using conventional finite element methods (with the implicit assumption that the cone is in vacuo).

N.B. All calculations in this paper were performed using ABAQUS and COMET/Acoustics

- Flexible support. This ring of supporting structure is significant due to its partial control of the rigid body motions of the cone.

- Cabinet. As a first approximation, the speaker cabinet may be assumed to be rigid

- Sympathetic bass resonator. This is effectively a non-forced speaker cone, the motion of which is driven by the relative pressures of internal and external fluids (usually air)

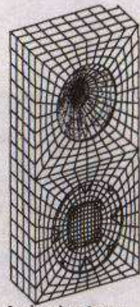

Fig 3. Loadspeaker System

- Coil. The cone motion is driven by forces applied at the coil.

In this example, no additional damping media are used inside the cabinet : the fluid for analysis was air at 19°C. Figure 4 shows the radiated sound power as a function of input force at the coil, plus a mean velocity for the sympathetic bass resonator over the frequency range. Figure 3 includes a typical predicted instantaneous velocity distribution for the speaker and bass resonator cone at high frequency, showing that these parts do not always behave as rigid bodies.

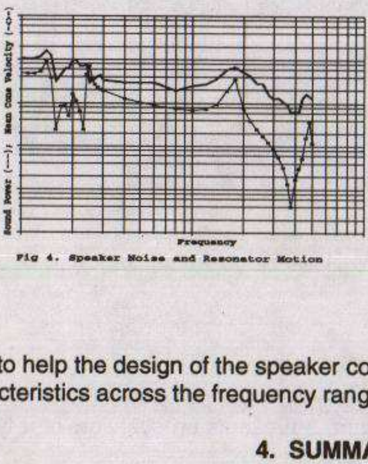

Fig 4. Speaker Noise and Resonator Motion

Results such as these may be used to help the design of the speaker components to obtain even radiation characteristics across the frequency range.

4. SUMMARY

The examples presented illustrate the ability of modern numerical analysis software to aid the design process. These tools are mathematically competent, relatively easy to use, and return results within a timeframe acceptable for real world design cycles.