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# NUMERICAL MODELLING IN ACOUSTICS, DYNAMICS AND VIBROACOUSTICS

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## 1 INTRODUCTION

For many design problems in acoustics and dynamics a great deal can be achieved using relatively simple prediction methods based on well-established analytical, empirical or semi-empirical models and standards. Inevitably there are some problems that require the application of more sophisticated methods, either because of the unusual nature of the problem, or because of particularly demanding performance targets.

A wide range of software packages to predict complex problems using numerical modelling methods such as Finite Element Analysis, Boundary Element Analysis, Statistical Energy Analysis and ray acoustics are now readily available, and this paper illustrates the application of these methods to a range of engineering problems. The overall aim of the paper is to highlight how the choice of numerical method is dependent on the frequency range, physical domain and size of the system to be modelled, and how it is important to capture the physics of the problem whilst constraining the complexity of the model.

## 2 NUMERICAL MODELLING METHODS

The advent of CAD modelling for general engineering design, and the increasing power of desktop computers, means that detailed modelling of complex problems in acoustics and dynamics has never been more accessible. As a result, numerical modelling is now part of the mainstream design process, but the appropriate prediction method will vary with the physical problem and with different scales of frequency and size of structure. The case studies in the next section illustrate a few particular applications, but it is useful to first set out the general scope and limitations of the various methods.

### 2.1 Dynamics

The most widely used numerical modelling technique is the application of Finite Element Analysis (FE) to predict the dynamic response of a structure to excitations at low-mid frequencies. The definition of this frequency range depends on the size of the system, and the examples given below are for the design of machinery foundations in a yacht up to about 200Hz to control structure-borne noise, and the prediction of vibration transmission in a science building to protect sensitive equipment at frequencies up to 50Hz. Problems are generally aggravated if forcing frequencies coincide with natural frequencies of vibration, so predicting the modal frequencies is often the first step in assessing results from a model.

An FE model is generally produced by importing a simplified CAD model of the structure into the FE meshing software, which is then used to discretize the structure into a number of elements connected through discrete nodal points. Elements representing sections of beams, shells or solids are available, and the motion of each node provides up to six degrees of freedom in the model. The mechanical properties of each element are used to construct mass, stiffness and damping matrices representing the complete system. Models normally comprise many thousands of degrees of freedom, but large FE models with millions of degrees of freedom are not uncommon, and may require a significant amount of computer time and resource to solve.

The size and detail of the model is likely to depend on the stage through the design process. The starting point for initial design work may be to use a very simple model to estimate natural frequencies of vibration, or the local level of response for a single force input, so that a full model of the system is not generated until the later stages of design.