An Overview of AutoSEA2

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1. Overview

This paper provides an overview of the AutoSEA2 statistical energy analysis (SEA) code and discusses various analysis capabilities and applications.

2. Statistical Energy Analysis

The statistical energy analysis (SEA) method [1] was introduced in 1960's as a means with which to predict the vibro-acoustic response of rocket payloads subjected to broadband excitation during launch. Since then its use has become widespread and it is currently used in a multitude of different applications ranging from shipboard noise [2] to automobile acoustics [3]. SEA is well suited to predicting the response of complex structural-acoustic systems over a large frequency range (typically 50 – 20,000 hz), and it can be used to model both random and tonal sources.

As a computer-based simulation method, SEA at first appears to offer the same time-saving and cost-saving relief from prototype build & test methods as other computer-aided engineering (CAE) tools such as finite element (FE) analysis. However, FE methods often have serious limitations when applied to the design process [4]. Typically, FE models need a great deal of detail which is not available in the early design process; the models take a long time to build and the output information is often so complex that only the analyst - not the designer - can understand it. The product designer today needs faster design feedback earlier in the design process and in terms of the physical design parameters over which he or she has some control [5].

An additional problem, that becomes apparent at higher frequencies, is the misconception that a detailed deterministic analysis of a statistically uncertain dynamical system can yield meaningful response information. Ongoing research work on probabilistic approaches to FE are an acknowledgement of this important issue [6]. By contrast, SEA is based on a probabilistic formulation which requires much simpler - but still physically meaningful – models. The underlying theory of SEA is based on the principles of statistical mechanics and conservation of energy and there are many parallels between an SEA analysis and a thermal analysis.

SEA is essentially a sub-structuring analysis method, where noise and vibration levels are estimated from the space, frequency and ensemble average energy contained within various mode groups in each sub-structure region. The transmission problem is represented as a "diffusion" or flow of energy from regions of higher modal energy to regions of lower modal energy. The underlying behavior of the physical system can then be characterized without the need for a detailed description of the response of individual modes (which is advantageous for complex structural-acoustic systems which can contain millions of modes). The equivalent thermal analogy is that, when looking at the thermodynamic response of a system, one is not usually interested in the response of individual particles at a molecular level but rather the space and time averaged energy of a group of particles (their temperature). Relaxing the noise and vibration response estimate to the spatial average response within a given frequency band – as for room acoustics – allows a simple but powerful statistical reduction in the description of each local region's modal parameters and for the dynamics of each junction's energy transmission characteristics [1].

As such, SEA can be classified as a "node-connector" type of modeling, similar to network analysis in thermal, electrical and fluid flow problems. In this case, the SEA "nodes" represent the reverberant energy level of resonant mode groups in each substructure region and the "connectors" represent the energy flow paths between nodes. Most older generation SEA codes use this network paradigm extensively as the basis for modeling.

The network approach is attractive for simple problems in one or two dimensions with only a few sub-structure regions. However, for larger problems and general 3 dimensional structures, the network approach soon becomes unworkable - except by a few very devoted SEA analysts. This is partially illustrated by the pictorial comparison in Figure 1, which shows one of the simplest 3-dimensional SEA problems – predicting the noise level in a room bounded by a floor, a roof and four wall panels.

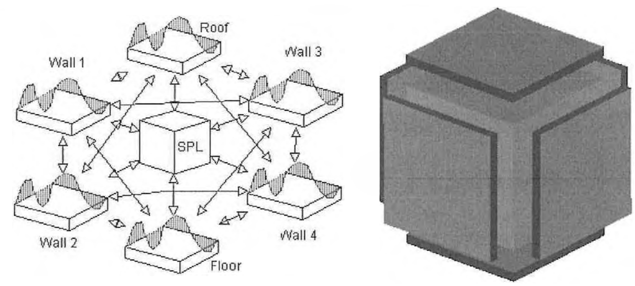

Figure 1. Comparison of model representations for a simple SEA room acoustics application; Network model (left) and more intuitive 3D model (right)

The development of AutoSEA2 now enables analysts and designers to create SEA models using a 3D modeling interface rather than the older network paradigm.

3. AutoSEA2

As shown in Figure 2, each member of the AutoSEA2 family of subsystems essentially provides a mapping between the actual (typically non-uniform) shape of a region of the real system being modeled and the library of "ideal" SEA subsystems, for which the statistical dynamic formulations are known. This mapping essentially consists of computing the characteristic lengths, areas and volume using regression to obtain the best-fit SEA parameters for a given subsystem. Figure 3 shows a typical AutoSEA2 automobile model constructed from the various generic subsystems.

Subsystem	Wavefields	SEA Idealisation	Nodal Geometry	Faceted 3D Solid
BEAM	Bending Ixx Bending Iyy Torsion Extension			
FLAT PLATE	Transverse Bending In-plane Extension In-plane Shear			
SINGLY-CURVED SHELL	Transverse Bending In-plane Extension In-plane Shear			
CYLINDER	Transverse Bending In-plane Extension In-plane Shear			
DOUBLY-CURVED SHELL	Transverse Bending In-plane Extension In-plane Shear			
ACOUSTIC DUCT	1D Acoustic wave			
ACOUSTIC CAVITY	3D Acoustic wave			

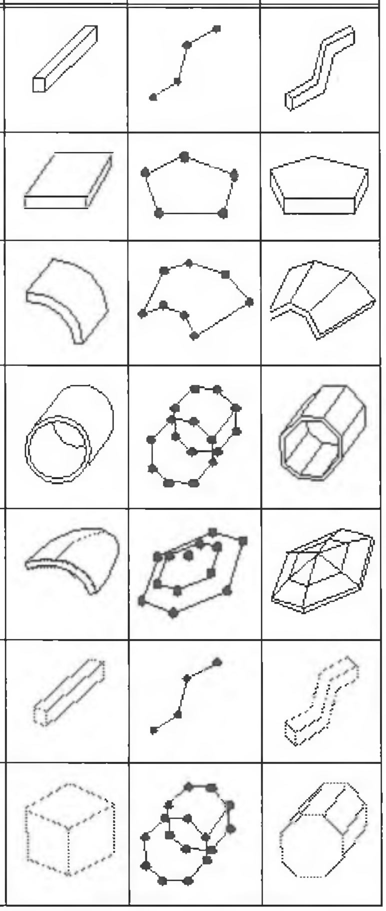

Figure 2. Summary of the AutoSEA2 family of 3 dimensional SEA subsystems

The physical sub-structures in AutoSEA2 are called subsystems - consistent with SEA convention – because they encompass both structural and acoustic regions. However, each physical subsystem typically supports multiple mode groups, each with its own unique dynamic properties (eg. wavespeed, modal density and damping loss factor) and its own unique reverberant energy level. In AutoSEA2, these different mode groups are denoted "wavefields". The full SEA solution matrix [7] is formulated to correctly account for the coupling of the wavefield components and resultant energies, even though the user defines only a single physical subsystem.

Considerable new development in AutoSEA2 has been devoted to the modeling of energy transmission junctions. This includes automatic junction creation directly from 3D geometry; general "multi-port" junction configurations; correct statistical treatment of junction properties and modeling of local junction detail. A direct consequence and major advantage of modeling all AutoSEA2 subsystems explicitly with 3D node points is that the energy transmission junctions can be automatically detected and computed uniquely from the connected subsystem properties and the global junction geometry. The creation of logical point-, line- and area-junctions is implemented as an "auto-connect" algorithm. Subsystems with common node numbers are considered connected – common contiguous node numbers define a line junction and common non-contiguous node numbers define a point junction.

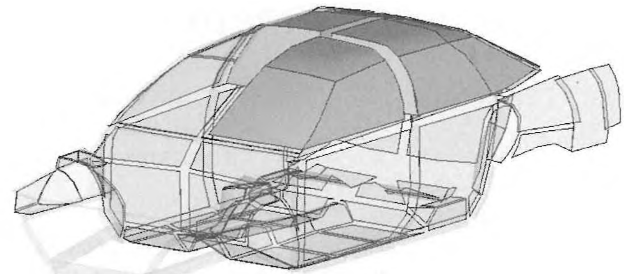

Figure 3. AutoSEA2 model of an automobile containing beam, shell and acoustic cavity subsystems.

4. Summary

AutoSEA2 contains many new-advances which assist in the creation, management and solution of complex SEA models. The 3D subsystem formulation makes the SEA modeling process more intuitive and minimizes cumulative "guestimation" errors. The auto-connect function greatly reduces modeling time and avoids manual data input errors. The implementation of full wave transmission theory improves accuracy and minimizes the need for user expertise in modeling junctions. The fast solution times and thermogram diagnostic plots encourage the engineer to understand the model better; and empower the engineer to find more globally-optimal noise and vibration solutions and to provide more practical feedback to product designers.

While AutoSEA2 still requires the engineer to build a 3D geometry-based model, the "super-element" nature of the SEA subsystems make this process at least an order of magnitude faster that FE model building. In summary, the latest advances in SEA software development have demonstrated the power of AutoSEA2 as a general purpose computer-aided engineering tool. It delivers a new "design evaluation" solution which may mean that designers can now address noise and vibration performance issues even before the structural and thermal FE analysts have completed their first analysis cycle.

5. References

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