VIPROM

Virtual Prototyping of Vibro-Acoustic Systems in the Mid-frequency Range

Funding: European (5th RTD Framework Programme)
Duration: Dec 2000 - Dec 2004
Status: Complete with results

Background & policy context:

A majority of noise and vibration problems occur in the range between the low and high frequency range (the so-called mid-frequency range), but a general predictive approach is lacking in the mid-frequency range. Deterministic methods such as the Finite and Boundary Element Method (FEM and BEM) are too computationally intensive to be applicable for real-life engineering problems, while statistical methods such as Statistical Energy Analysis (SEA) are not reliable enough. An adequate solution allowing design engineers to virtually prototype in the mid-frequency range by numerical simulation is of crucial importance.

The VIPROM proposal has been initiated after recognizing that the mid-frequency modelling crisis can be overcome by combining deterministic and statistical methods.

Objectives:

The VIPROM training program has coped with predictive modelling of structural-acoustic systems in the mid-frequency range. The objective was to establish, evaluate and validate (from the industrial point of view) coupling mechanisms between deterministic and statistical methods in order to resolve the mid-frequency modelling gap.

The strategy of addressing potential solutions from all possible view-points led to three complementary objectives:

1. To extend high frequency techniques towards the mid-frequency range. State-of-the-art methods must be studied, including statistical energy analysis (SEA, both numerical and experimental), Energy flow analysis, and so on.
2. To extend low-frequency methods upward to the mid-frequency range. Advancements must be achieved in low-frequency techniques (FEM, BEM) in order to increase their validity up to higher frequencies. This required research into advanced (trim) modelling techniques, parallelisation and efficient solver strategies, component mode synthesis (CMS) for faster design iterations, and so on.
3. To tackle dedicated mid-frequency issues such as the effect of uncertainty and variability on the functional performance response, which becomes ever more important with increasing frequency range.

Methodology:

The project started with investigating the first path on coupling FEM and SEA methods. This hybrid method consists of the partitioning of the problem variable (e.g. velocity, pressure, etc) into long- (global) and short- (local) wave length deformations. Though the hybrid SEA/FEM methodology was giving promising results for simple rods, the application to beams revealed several major difficulties when one would further extend the methodology to plates and more complex structures. These difficulties led to the decision to explore promising methodologies from the complementary low-frequency perspective.

Therefore, research continued on extending low-frequency methods upward to the mid-frequency range. In this second phase of the research, targeting breakthrough methodologies from the low- up to medium-frequency perspective, two main approaches have been investigated:
• including uncertainty and variability for allowing more accurate predictions for higher frequencies;
• improving performance (e.g. accuracy, calculation speed) of deterministic techniques such that they can be effectively used for medium-frequency problems. In particular, vibro-acoustic problems were addressed.

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Partners:
Leuven Measurements and Systems International NV (LMS International) - Belgium (coordinator)

Organisation: International
Address: Interleuvenlaan, 68
Zipcode: 3001
City: Leuven
Contact country: Belgium
Telephone: (+32) 16 38 42 00
Fax Number: (+32) 16 38 43 50

Key Results:
The following research results have been achieved:

1. The incorporation of realistic parameter uncertainty and variability in the FEM modelling process, which allows accurate predictions for higher frequencies, where the effects of scatter in physical properties become more apparent. A novel approach referred to as the “Short Transformation Method” has been developed which provides efficient predictions of dynamic response uncertainty when structures are considered with eigenfrequency values that are monotonic in the uncertain inputs. Also, a literature study of the presented methods for reliability analysis has been performed. The different reliability methods have been fine-tuned and tested on a range of structural analysis examples.

2. Improved methodologies and state-of-the-use of substructuring techniques, allowing to increase the mesh density of component models and hence improved accuracy for higher frequencies, or equivalently, faster predictions for a given accuracy.

3. Combining uncertainty and variability method with substructuring techniques, the impact of connection properties on the functional performance predictions has been addressed. In a realistic assembly, uncertainty and variability are most pronounced in these connection properties, so improved modelling of realistic scatter is a vital step towards extending the use of element based techniques towards the medium frequency range. In particular, a study of spot welding has been performed, the predominant assembly technique in the automotive industry.

4. Investigation on the fluid-structure coupling for non-congruent meshes.

5. The development of parallel computation and domain decomposition techniques for interior acoustic solutions. Such a method based on sub-domain decomposition techniques enables to distribute the computation effort among several processors or computers. This is seen as another alternative approach to overcome the computational cost of mid-frequency vibro-acoustic problems. Investigations revealed that the sub-domain decomposition method presents weaknesses in its robustness due to its implemented theoretical methodology. To overcome this issue, a new algorithm has been developed which introduced more stability to the system to solve. This new algorithm has been applied to coupled linear systems describing interior acoustics. A significant improvement in performance was observed.

6. Investigation on

Technical Implications

1. The Wave-Based Substructuring Method (mentioned above) has been further developed after the completion of the VIPROM project in the frame of various other projects, and has been patented by LMS International, “Method and System for Dynamic Analysis of Complex Systems”, Filed as U.K. Patent, priority date April 15, 2005; patent application to EU and US is pending.
2. The attention to connector modelling in VIPROM has resulted in a recommendation to perform a dedicated study on multi-attribute requirements for connector modelling (spot welds, seam welds, etc...) in vehicle industry. This has been indeed a vital input towards the definition of the Flemish national-level project IWT-040433 “Analysis Leads Design” (ALD) – Frontloading Digital Functional Performance Engineering), which has been executed from 01/07/2004 to 31/12/2007.

3. At the end of VIPROM, it had become clear that additional attention to uncertainty and variability in the structural dynamics modelling context was mandatory towards accurate predictions up to the medium and high-frequency range.

Policy implications

1. The VIPROM project has sparked attention to uncertainty and variability in the structural dynamics modelling process, in view of achieving improved vibro-acoustic calculations up to the mid-frequency range. This notion has led to the definition of the EC FP6 RTN project “MADUSE” (MRTN-CT-2003-505164), which has further strengthened the knowledge base and methodology portfolio in this challenging domain within a 9-partner R&D network consisting of both industry and academia.

2. The mid-frequency modeling & simulation lessons learned in VIPROM have been a relevant input into the definition of the EC FP7 ITN 214909 “MID-FREQUENCY”, targeting CAE Methodologies for Mid-Frequency Analysis in Vibration and Acoustics, which has started per 1 October 2008.

STRIA Roadmaps: Vehicle design and manufacturing
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Geo-spatial type: Other