Vibrations of Coupled Systems
Modeling and Simulation of Interfaces

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Introduction
Structure - Structure Interaction
(Low - Medium - High Frequency Domain)

- *Multibody dynamics with various types of joints.*
- *Truss Space Structures with various types of joints.*
- *Connections between complex substructures (local, continuous).*
- *Pyrotechnic shocks and their effects induced on equipments.*

Introduction
Fluid - Structure Interaction
(Low - Medium - High Frequency Domain)

- *Structural Acoustics and Vibration (noise reduction).*
- *Vibrations of Liquids in Reservoirs (including surface tension effects).*

Structure - Structure Interaction
Complex Structures with Complex Connections

- *If the joint plays a major role in the sense that there is a problem at the joint: a detailed modeling of the joint is mandatory.*

- *The dynamic behaviour of complex coupled structures strongly depends on the frequency domain: in mid-frequency (MF) and high frequency (HF) ranges, the dissipation at the joints between substructures are of prime importance.*

Complex Structures with Complex Connections
Extension of SEA method (HF domain)

- *The SEA (Statistical Energy Analysis) method describes the average behaviour of coupled structures and takes into account the uncertainties in the constitutive equations.*

- *The basic SEA model is presently reformulated in order to take into account dissipative joints and non uniform repartition of modal energies.*

Diffusion type equation for HF analysis

Let us mention an approach which has been mainly investigated in the 1D type of connections (also valid for axisymmetric structural vibrations) and which deserves some further investigations for more complicated structures:

Starting from the boundary value equations and using asymptotic considerations in order to describe the frequency behaviour of the displacement field, one obtains a partial differential equation satisfied by a global scalar field (the kinetic energy of the system). This equation is of ***diffusion type*** *(the initial russians authors have called it "heat equation" by analogy) and has been applied to simple 1D structures using finite element discretization procedures.*

Better Knowledge of the Coupling between Substructures
Extension of SEA method (HF range)

- *Experimental analysis is required in order to define the substructures, to measure the power introduced and the power coupling energy exchanges between substructures at the joints*
- *Due to the fact that some substructures are utilized under extremely severe conditions (variation of temperature, large deformations), the characteristics of joints present some dispersions (due also to the process)*
- *Another procedure consists in the coupling between SEA method and finite element methods*

Experimental Characterization of the Junctions

- *The junctions are usually known for simple geometries. Their behaviour is characterized by dissipative aspects, by transmission and reflections of energy towards the various elements and by wave conversion phenomenon.*
- *Those diffusion aspects may lead to energy transfer and fatigue phenomenon may then occur.*
- *An experimental characterization of the junctions may be carried out by the observation of the incoming and outgoing waves, and one may reconstruct the vibratory field in the joint by using a sensor network (or by making optical measurements) and then identify the parameters of the model.*

Truss Type Space Structures

Space Structures (such trusses) are characterized by ”some” kind of periodicity: this periodicity is broken, on side, by the fact that the structure is not infinite, and on the other side, by the fact that the joints may create some local imperfections in the overall system.

- *for an infinite periodic system, the theory is well-known and various methods exist in order to compute - through calculations on a single cell - the dispersion curves and the Brillouin zones.*

- *for ”disordered” structures, due to possible local imperfections and uncertainties, localization phenomenon may occur (so-called Anderson localization effects), which are connected with complex frequency curve veering analysis.*

Contact Problems

Contact problems involve the appropriate formulation of the geometry and the construction of appropriate interface constitutive equations (starting from the 3D local boundary value problem).

- *the contact area is not known a priori: the problem is non linear.*
- *constitutive equations for contact interfaces: the micromechanical behaviour is very complex as it depends upon surface roughness and it may create chemical reactions in the interface.*
- *the interface behaviour in the tangential direction is much more complicated (frictional response).*
- *one may also have thermomechanical contact (high contact precision).*

Micro-scale / Macro-scale Considerations

Some examples:

- *multilayer composite structures, sandwich structures (honeycomb for example), cellular structures (metallic foams, porous medium).*

- *effects of couple stress on the squeeze film between a sphere and a flat plate (microcontinuum theory).*

Micro-scale / Macro-scale Considerations

- *The construction of a plate theory from a 3D continuum depends on the wavelength of the phenomenon and also on the type of external forces: the micro-scale level could be resolvable but in many cases it could be* ***not resolvable*** *(see nanotechnology activities) and (see also homogenization methods) appropriate procedures should be developed.*
- *One could obtain a* ***global*** *(through some boundary integral operator for instance) constitutive equation or a* ***local*** *(which means point dependent) constitutive equation.*
- *In structural acoustic problems for instance, the viscothermal fluid/structure thin layer is sometimes ”replaced ” by a frequency dependent* ***local*** *impedance.*

CONCLUSION - OPEN PROBLEMS

- For specific joints, development of ”smart” joints (case dependent)

- Micro-scale / macro-scale analysis : long-term research, but valid for ”any” type of interfaces.

An intermediate analysis consists in the development of various ”parametric models” which are valid for typical frequency range. But, in this case, some a priori physical assumptions are required using, for instance, local informations obtained through experiments or refined MegaDOFs computations.