NOISE SYNTHESIS USING HYBRID SUBSTRUCTURING APPROACH

Context

Noise is a key source of discomfort in urban areas and at workplace. It is a cause of hearing loss which is a major professional disease. The regulations and norms on noise are steadily getting tougher.

Competitive industrial production needs a reduction of time to market. Noise of a future product should be thus already dealt with at the design stage. In the other hand, noise cannot be predicted today entirely by computation. Besides, there is an increase in the demand of customers to hear noise before the start of production. Thus the challenge is not only to predict the future noise level but also to enable virtual noise reproduction. A new research effort is needed in this domain.

Noise of many industrial products is governed by the operation of some key components sources of noise, such as motors, pumps etc, integrated within an otherwise passive frame structure - housing. Under the action of these components the assembled structure modifies and often amplifies noise of the source. Typical examples of products which generate noise in this way are household appliances, HVAC installations, outdoor machinery, communication equipment, computation equipment etc. In these and similar products noise is transmitted to the surroundings as a direct air-borne noise, a structure-borne noise (via feet, supports, cables etc) and frequently a fluid-borne noise (via ducts, pipes etc). If a realistic noise synthesis is sought, all of these transmission paths have to be taken into the modelling approach.

Approach

Following a recent multi-partner EU research project Nabucco, a consolidated strategy of efficient noise design has been conceived by several EU universities: INSA Lyon, Salford University, KTH Stockholm. It aims at virtual noise prototyping applicable in real industrial conditions. This strategy is the hybrid sub-structuring (HSS).

HSS uses an evolution strategy for noise design. It builds on an existing generation of products with the aim of improving their noise performance. Some generic acoustic properties of the products belonging to the same class (e.g. home dishwashers) can be established from careful measurements or computation followed by some specific data processing. Once identified, these generic properties will be combined with data from real components – noise sources – in a computer analysis which will predict overall noise created by the assembled product. This should help the designer to synthesise the future product.

In general terms HSS consisting of following main steps:

• characterise noise sources by measurement
• characterise noise transmission paths by measurement and/or computation
• carry out noise synthesis by computation.

The first fundamental concept of HSS is that of a noise source which generates noise through an interaction with its structural assembly. Here, a source is taken into account in a realistic rather than a simplified way, the latter being the case when the prediction is carried out by computation only. This is achieved by carefully extracting out of specific measurements the
full noise information about the source – air-borne, structure-borne etc. The noise data are subsequently compacted, bearing in mind the coupling effects. The result is a noise descriptor, the Source Strength which intrinsically characterises the source. One source will usually have several source strengths.

The second fundamental concept of HSS is that of a Generic Structural Model. A Generic Model is a synthetic structure, either physical or virtual, which represents in a simplified way the frame of a real industrial product. The role of any Generic Model is to provide information on noise transfer from the source(s) either directly or via the connections and the frame structure to the listener’s ear. The Generic Model thus represents an artefact which unites dislike noise generating mechanisms (air-borne, structure-borne, fluid-borne) on a common basis and, in addition, provides quantified data on noise transfer from the source to the listener’s ears.

Once identified, the Source Strength and the Generic Model data are combined within a computer for carrying out the global noise prediction. Variation in current Generic Model parameters (e.g. characteristic mobility, modal density, damping) as well as variation in strength of different noise inputs from the source(s) will ultimately reveal the right measures for achieving noise reduction.

\[\text{Real (left) and synthesised (right) noise generation scheme.}\]

The connectivity of the source(s) and the frame is achieved by satisfying the continuity conditions at the interfaces. This is usually done by applying impedance/mobility concepts.

The completeness of HSS approach permits an audible reproduction of noise of the future product. This feature is meant to enable an assessment of sound quality of the product.

The originality of HSS approach emanates from two complementary positions:
- as a technical methodology it combines advantages of two alternative types of techniques, experimental and computational, to produce a synergistic added value.
- as a noise control strategy it places a noise source and its integrating structure – the noise transmitter – in a concurrent position with the goal of synthesising, comprehending and improving the noise performance of the assembled product.

**PhD subject**

The proposed PhD work will address the topic of virtual noise synthesis of industrial products using the sub-structuring approach described above. In view of the still upstream nature of
this research, simple products will be considered, built out of a small number of components such as domestic appliances. The research is expected to define the procedures of substructuring which are simple enough to be used in practice yet scientifically rigorous enough to provide acceptable quality of synthesised noise.

Particular attention will be paid to air-borne sound substructuring. The question is how to achieve interface continuity in computationally and experimentally feasible ways. This issue has not been yet successfully dealt with. Two methods have been formulated so far. One method uses substructuring via a spherical surface by developing the sound field into spherical harmonics (Yu. Bobrovnitskii, G. Pavić Modelling and characterization of airborne noise sources Journal of Sound and Vibration, 261 (3), 527-555, 2003). The other method uses the patch-impedance approach to replace the continuous coupling functions by discrete ones (G. Pavić Air-borne sound source characterization by patch-impedance coupling approach Journal of Sound and Vibration, 2010). Both methods show advantages and inconveniences which is why further research is needed on this subject.