Numerical techniques for acoustics and vibrations: virtual tools for real problems

Wim Desmet
KU Leuven – Department of Mechanical Engineering, Noise and Vibration Research Group, Celestijnenlaan 300 B, B-3001 Leuven, Belgium

Abstract

Over the last decades, customer demands regarding acoustic performance, along with the tightening of the legal regulations on noise emission levels and human exposure to noise, have made the acoustic properties of products and processes into an important criterion in many design problems. In the automotive and aerospace industry, for instance, the passengers' acoustic comfort has become an important commercial asset. This affects the efforts in reducing the weight of cars and aircraft, which are mainly motivated by potential fuel savings but, quite often, induce substantial noise and vibration levels.

There is also a growing interest in the use of acoustics in a context of condition monitoring and predictive maintenance, as (changes in) acoustic emissions may typically reveal information on the (possible gradually degrading) state of a product or process.

In order to incorporate these acoustic criteria in the design process or monitor them during the operational lifetime, there is a strong need for numerical prediction tools that provide the necessary insights in the physical phenomena which govern the acoustic behaviour of complex real-life systems. These insights allow a reliable evaluation of different design alternatives and they provide also the necessary relations between acoustic emissions and the associated mechanical (possibly impaired) condition of products and processes.

Despite the advent of ever increasing computational resources and the tremendous R&D efforts that are being spent on numerical techniques for acoustic and vibration simulations, there are still some hurdles to take to allow for the widespread industrial use of these techniques for non-expert design and maintenance engineers. These include the need for techniques that can cover the entire audio frequency range at affordable costs and that can account for uncertainty and variability in geometrical, material and manufacturing properties. Automated techniques that allow for a proper identification of model inputs and model parameters as well an automated digital link between geometrical design models and functional performance models would make numerical tools more accessible to a non-expert engineering community.

This presentation describes several research activities, performed at the KU Leuven Noise and Vibration Research Group, to reduce or possibly remove the aforementioned hurdles.

Over the years, an innovative Wave Based Method has been developed, along with its hybrid coupling with Finite Element, Boundary Element and Ray Tracing methods, to obtain computationally efficient schemes for broadband vibro-acoustic analysis. In addition, interval methods and complex residue theorem based schemes are designed to assess the vibro-acoustic response scatter induced by uncertainty and variability.

Novel isogeometric simulation techniques are being developed to allow to recycle the approximation functions, used in the digital geometrical description of a system, for acoustic performance analysis.

Advanced frequency-based techniques and dedicated test rigs have been designed for the identification of poro-elastic and visco-elastic materials.

A growing attention is being paid to efficient time-stable model order reduction schemes for time-domain coupled vibro-acoustic simulations. These schemes are combined with a limited set of affordable measurement sensors in advanced Kalman filters to obtain virtual sensing scenarios for coupled input-parameter-state estimation. In this way, relevant dynamic system information can be retrieved in an on-line and in-situ manner, and becomes available amongst others for material identification and condition monitoring purposes.