Abstract

Numerical modelling techniques have become an indispensable part of many product design processes. In the context of optimising the design of mechanical systems, the acoustical and vibrational comfort of a product has taken up a predominant place among more traditional design criteria such as strength, durability and maintainability. Unfortunately, none of the virtual prototypes constructed using the most commonly applied vibro-acoustic simulation techniques are capable of adequately capturing this behaviour in the mid-frequency range. At these frequencies, the deterministic element-based approaches lead to unrealistically dense problem discretisations and unfeasibly long calculation times, while the basic assumptions required to adopt a statistical energy-based description are not yet fully met.

This dissertation fits in the development of an alternative Trefftz-based deterministic modelling approach which specifically aims at accurately capturing the low- and mid-frequency vibro-acoustic behaviour of complex mechanical systems at an affordable computational cost. Through the use of a set of wave-like basis functions for the approximation of the dynamic response variables, this so-called Wave Based Method provides a flexible way of analysing problems at higher frequencies. Unfortunately, as a direct result of the use of these functions, the efficiency of this approach can only be fully exploited for problems of moderate geometrical complexity. This dissertation presents two extensions to the Wave Based Method which allow this methodology to cope with two of the most limiting types of commonly encountered geometrical features. The limitations imposed by the presence of superficial geometrical details are overcome by extending the existing family of hybrid Finite Element-Wave Based approaches to fully coupled vibro-acoustic problems and by further improving this method's efficiency through the use of Finite Element model reduction techniques. In a parallel research line, the introduction of an innovative Multi-Level modelling framework allows the Wave Based Method to successfully and flexibly model multiple scattering and inclusion problems.

Throughout the dissertation, the newly developed methodologies are supported by an extensive set of numerical validation examples which illustrate the applicability and efficiency of the proposed approaches.