Abstract

In recent years, the industrial design process has become increasingly dependent on numerical CAE tools to replace the time-consuming and expensive prototype testing. A competitive market driven by a consumer focus urges designers to take into account many product properties. Amongst those, the acoustic characteristics are quickly gaining importance; a trend which is amplified by recent legislations regarding noise and acoustic comfort.

A survey of the state-of-the-art techniques reveals that the construction of an accurate and reliable numerical model of an acoustic problem is not a trivial task. Dedicated techniques have been developed to successfully solve the acoustic problem both at low and high frequencies. However, both approaches fall short in covering an important mid-frequency range, in which the typical wavelengths are neither very large nor very small compared to the problem dimensions. The unbounded nature of many acoustic problems — think of an object radiating sound into the environment — further complicates matters: many simulation techniques based on a problem discretisation can only be used after a reformulation of the problem to an equivalent bounded form.

The work presented here is framed in the development of the Wave Based Method (WBM), a novel simulation technique for steady-state dynamic problems. Using a wave-like Trefftz basis, the WBM is able to deliver accurate predictions in the difficult mid-frequency range. Until now, the development of the WBM focussed on bounded acoustic problems. A first contribution of this work consists in the further development of the method to efficiently deal with unbounded problems, including radiation, scattering and diffraction.

The second contribution focusses on the geometrical limitations of the WBM. The flexibility of the method is an important point of attention: the use of a Trefftz basis is very efficient, but imposes some constraints on the problem geometry. A multi-level framework for WBM calculations is proposed, which allows an elegant and efficient solution of complex multiple-scatterer problems. Moreover, an extension of the existing hybrid FE-WBM to unbounded problems enables the treatment of scatterers with a geometrically detailed surface.

Both contributions are validated through a series of numerical examples, illustrating the applicability and efficiency of the developed techniques, in relation to the current state-of-the-art.