Vibro-acoustic modelling

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Extended abstract

Structural vibrations are a significant cause of sound radiation that are encountered in both daily live and industry. They can range from pleasant sounds, such as the sound radiating from a guitar, to annoying sounds, such as tire-road noise and machines in factories. The study of the interaction between vibrations and acoustics is commonly referred to as vibro-acoustics. This interaction can happen both ways: Vibrations can cause sound radiation, but sound waves can also cause vibrations.

Since sustainable product design is becoming the standard, mechanical structures are currently designed to be lightweight and stiff. However, this trend is disadvantageous from an acoustic perspective, since such structures easily radiate noise. On the other hand, the long term harmful effects of noise are becoming increasingly known and the regulations on noise are adjusted accordingly. The combination of both conflicting criteria means that designers have to already consider vibro-acoustic aspects during early design phases, instead of as an afterthought.

The multiphysical modelling of the vibro-acoustic behavior of a structure is quite complex and cannot be solved analytically, except for some simple cases. Therefore, numerical models have been gaining popularity for predicting vibro-acoustic performance, using methods as the finite element method (FEM) and the boundary element method (BEM).

In this seminar we will have an in-depth look into the construction of such a numerical model. We will start by considering the involved physics. In particular, wave propagation through a structure will be considered for different geometries. It is shown that the assumption of small dimensions as compared to the wavelength in one direction, such as is the case for plates and shells, leads to dispersive wave propagation behavior. Additionally, the introduction of boundary conditions due to the finiteness of the plate leads to structural modes that can induce far field sound radiation.

Then, it will be shown how to construct a (one or two way) coupled finite element model to model the steady-state vibro-acoustic response. A comparison is made between shell and solid elements for the structural part and implications of the dispersive behavior on the mesh discretization level are shown. Different formulations are shown that can influence the required calculation time of the resulting system of equations. Additionally, it is shown how the dynamic behavior can be decomposed in modes, leading to the possibility of applying modal reduction to reduce the calculation complexity of the problem. The seminar ends with some examples.

Recommended reading

[1] Fahy, F. et al (2007), Sound and Structural Vibration: Radiation, Transmission and Response, Second Edition, Academic Press, ISBN: 0-12-373633-1
[2] Cremer, L. et al (2005), Structure-Borne sound: Structural Vibrations and Sound Radiation at Audio Frequencies, Third Edition, Springer Heidelberg, ISBN: 3-540-22696-6
[3] Zienkiewicz, O. et al (2005), The Finite Element Method, Its Basis and Fundamentals, sixth edition, Butterworth-Heinemann