Dynamic analysis of periodic structures and metamaterials via finite element modeling and wave approaches

Subject: Periodic structures are frequently encountered in engineering applications, e.g., in the aeronautic (fuselages, turbines) and railway industries. Also, they appear interesting to passively control the vibration levels of mechanical systems. Metamaterials are periodic structures which possess such interesting features, i.e., the fact that they do not convey vibrational energies on some frequency bands – referred to as band gaps – which as such yield low vibration levels. Well-known examples of metamaterials are periodic structures made up of resonant cells where band gaps occur in the vicinity of the resonance frequencies of the cells. There exist plenty of works in the literature about the analysis of the wave propagation in 1D or 2D periodic structures and the related band gap effect. However, the forced response of such structures is not well reported. This especially means developing numerical models able to predict the dynamic response of periodic structures of finite dimensions with various kinds of boundary conditions, or assemblies involving several periodic structures and other non-periodic components which are systems of practical interest in engineering applications. In this case, the analysis of the band gap effect do not only rely on the wave propagation properties, but also on the boundary and coupling conditions which induce energy conversion between waves.
This Ph.D. proposal aims at investigating several numerical approaches for predicting the dynamic response of periodic structures and metamaterials. Wave approaches and finite element (FE) based model reduction techniques will be explored with a view to obtaining the response functions of the structures at a low computational cost. To target the analysis of 1D periodic structures – e.g., structures of finite lengths made up of complex 2D cells along a main direction –, or the analysis of 2D periodic structures of infinite extent (bi-periodic plates), the wave finite element (WFE) method will be used. On the other hand, the analysis of 2D periodic structures of finite dimensions, or assemblies of finite dimensions involving 2D periodic structures and other structural components, will be handled via appropriate FE procedures. This might include component mode synthesis techniques for modeling the cells, but also, less straightforward approaches (matrix interpolation). Disordered periodic structures involving random properties for the cells will be investigated as well. Optimization techniques of the shapes of the cells will be finally developed to improve the attenuation properties (band gaps) of periodic structures.

Keywords: Periodic Structures, Metamaterials, Wave Approaches, Finite Elements.

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Additional information: This subject is part of the research topics developed within the Dynamics Group of the LaMé Laboratory.