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Low and high frequency dynamic models and modes coupling in vibration of a non-linear lattice

Igor Andrianov, Vladyslav Danishevskyy, Bernd Markert

Abstract: Lattice-type models are widely used to describe vibrations in crystals, cellular structures, bone tissues, polymer molecules and atomic lattices. We study vibrations of a 1D monatomic cubically non-linear lattice. Continualization procedure is developed and coupled macroscopic equations for low frequency (acoustic) and high frequency (optical) modes are derived. Numerical simulations are performed using the Runge-Kutta procedure. Asymptotic solutions are obtained by the method of multiple time scales. Non-linearity gives rise to internal resonances and induces energy transfers from low to high order modes. In the continuous limit, an infinite number of modes can be coupled, so the system does not allow truncation. It is shown that heterogeneity compensates the influence of non-linearity and restricts energy transfers between the resonant modes. Therefore, it becomes possible to justify a truncation to only a few leading modes. The obtained results can be applied to facilitate the development of new methods of non-destructive testing. Measuring the characteristics of non-linear vibrations at different amplitudes allows one to receive more precise information about the properties of heterogeneous structures. Changing characteristics of the microstructure (e.g., using piezoelectric effects) makes it possible to tune the macroscopic dynamic response. This can be useful for a design of new acoustic control devices and smart materials. This work was supported by the Exploratory Research Space RWTH Aachen University through Theodore von Kármán Fellowship (for V.V. Danishevskyy).

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[1] Igor Andrianov, Professor: Institute of General Mechanics, RWTH Aachen University, Templergraben 64, 52062 Aachen, Germany (DE), igor_andrianov@hotmail.com.

[2] Vladyslav Danishevskyy, Professor: Department of Structural Mechanics and Strength of Materials, Prydniprovska State Academy of Civil Engineering and Architectute, Chernyshevskogo St. 24a, Dnipro 49600, Ukraine (UA), vladyslav.danishevskyy@gmail.com, the author presented this contribution at the conference in the special session "Perturbative model order reduction in dynamics" organized by I.A. Andrianov and V.V. Danishevskyy.

[3] Bernd Markert, Professor: Institute of General Mechanics, RWTH Aachen University, Templergraben 64, 52062 Aachen, Germany (DE), markert@iam.rwth-aachen.de.