Behaviour and Applications of Elastic Waves in Structures and Acoustic Metamaterials

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Over the past years, metamaterials (MMs) have shown great potentials in many disciplines of science and technology. Although a universally accepted definition of MMs does not exist yet, there is no doubts that they owe much to crystallography, a specific branch of **Solid State Physics**. The prefix *meta* comes from Greek and means *beyond, above, over*. Thus, the word MM can be seen as denoting a particular class of artificial materials that exhibits properties commonly not found in nature.
The idea behind MMs is that as electrons in a semiconductor can only occupy certain energy bands, a MM allows elastic and/or electromagnetic waves in specific frequency ranges to travel through via the "pass bands" meanwhile the other frequencies are inhibited by the so called "frequency band gaps".
Therefore, the keen interest of scientists in MMs is mainly due to their capacity of manipulating light as well as elastic waves replacing the "atoms" composing matter with man-made structures, viewed then as "artificial atoms".
The presentation focuses on propagation problems of a specific class of elastic waves, the so called guided waves (GWs), in acoustic metamaterials and in the framework of Non-Destructive Evaluation for impact/defect identification.
In particular, a *novel strategy for impact and damage detection based on time reversal and acoustic metamaterials* will be discussed. The procedure will be presented via numerical analyses and some preliminary experimental measurements will be discussed. This innovative methodology may pave the road through new non-destructive and versatile techniques, applicable in the field of composite laminates (material of last generation) as well as in other fields of engineering (mechanical, civil, aerospace).
In the second part of the presentation, a general introduction and a brief review of the basic definitions necessary to describe acoustic MMs will be provided. Starting from a numerical approach to extract dispersion properties in such structures, solid-solid and solid-fluid phononic systems will be discussed. Band diagrams and transmission power spectra, predicted for 1P-2D, 2P-2D and 2P-3D phononic systems, will be investigated. In addition, experimental results confirming the numerical predictions will be presented in matter of attenuation bands in the ultrasonic as well as in the sonic frequency regimes.

As the BG nucleation derives from the overall structure rather than from their composition, it is not hard to imagine that introducing bio-inspired hierarchical structure levels (i.e., creating a system characterized by the existence of structures at different length scales) may produce BGs nucleation, annihilation or shifting phenomena on the ordinary acoustic MMs dispersion map at multiple frequency scales. The idea is to perform a numerical campaign to find the ideally suited hierarchical level to open larger BGs.
Finally, the feasibility of an innovative passive isolation strategy based on gigantic elastic metamaterials is numerically proved to be practical for civil structures. In particular, attenuation of seismic waves is demonstrated via finite elements analyses. Further, a parametric study shows that depending on the soil properties, such an earthquake-proof barrier could lead to significant reduction of the superstructure displacement.