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Abstract: Elastic metamaterials have been mostly designed to control structural vibration for a specific frequency range. However, the stresses developed due to the wave propagation are not commonly consider in their design phase. This work proposes a multi-objective design optimization of a metamaterial-based interface to tune its dynamic characteristics, while keeping stresses below the allowed value.

Elastic metamaterials (EMMs) have drawn attention of researchers because of their unique wave control abilities, since they can be designed for steering incident waves at specific directions or to attenuate waves for specific frequency ranges (band gaps)[1]. Such unique features have instigated the development of EMM designs for protecting structures against dynamic loadings[2]; which can range from small applications, for instance, precision machines under external excitations, to large cases, such as fracture caused by a traffic collision.

The iterative design process of such EMMs usually consists of obtaining the dispersion relation (for a resonant unit cell with Bloch-Floquet periodic boundary conditions) or the transmission loss (for a finite structure formed by such unit cells) of different pre-defined resonant geometries until obtaining the band gap at the desired frequency ranges, which can be an extremely time-consuming approach. Besides, the EMM structural integrity during the impact wave propagation is normally not considered into the design process. Therefore, the desired functionality may not be guaranteed under real-time operation.

To overcome the identified limitations of EMM design process, we propose a design optimization through a multi-objective genetic algorithm to tune the EMMs band gaps while keeping the stresses under the allowed level. Instead of calculating the dispersion relation, here we adopt the effective mass density approach, whereby band gaps are identified at frequency ranges where the resonator moves out-of-phase in relation to the applied excitation. These ranges have shown to be associated to negative mass density values[3], which are used to define the first fitness function. Regarding to the EMM mechanical resistance, stresses are calculated by an equivalent static analysis; the dynamic load is replaced by a static load with magnitude equals to the maximum impact force multiplied by a dynamic load factor. Then, the second fitness function is defined as a ratio of maximum von Mises stress to yield stress of the EMM design. Through such optimization, the metamaterial can be used for vibration suppression and noise control of structures undergoing high amplitude impact loads.

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