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Drastic Increase of Wave Dissipation within Metastructures Having Negative Stiffness Inclusions

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Abstract : A concept of a simple linear oscillator, incorporating a negative stiffness element is demonstrated to exhibit extraordinary damping properties. This oscillator shares the same overall (static) stiffness, the same mass and the same damping element with a reference classical linear SDOF oscillator. However, it differs from the original SDOF oscillator by appropriately redistributing the component spring stiffness elements and by re-allocating the damping element. Despite the fact that the proposed oscillator incorporates a negative stiffness element, it is designed to be both statically and dynamically stable. Once such an oscillator is optimally designed, it is shown to exhibit an extraordinary apparent damping ratio, which is even several orders of magnitude higher than that of the original SDOF system, especially in cases where the original damping of the SDOF system is low. This damping behavior is not a result of a novel additional extraordinary energy dissipation mechanism, but a result of the phase difference between the positive and the negative stiffness elastic forces, which is in turn a consequence of the proper re-distribution of the stiffness and the damper elements. This fact ensures that an adequate level of elastic forces exists throughout the entire frequency range, able to counteract the inertial and the excitation forces. Next, Acoustic or Phononic Meta-materials are considered, in which one atom is replaced by the concept of the above simple linear oscillator. The results indicate that not only the damping of the meta-material verifies and exceeds the one expected from the so-called "meta-damping" behavior, but also that the band gap of the meta-material can be significantly increased.

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