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Locally resonant vibro-acoustic metamaterials as innovative lightweight NVH solution

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Plenary Abstract

Ever more strict economic and ecological requirements compel the transportation industry to introduce lightweight materials and designs in a wide range of engineered structures. Lightweight structures are often designed for higher strength and stiffness to enhance, amongst others, structural integrity, drivability and passenger safety. However, as a consequence of their increased stiffness to mass ratio, often a reduced Noise, Vibration and Harshness (NVH) insulation performance results.

Classical control measures for noise and vibration mitigation often involve adding mass or volume, such as heavy layers, foams and Tuned Vibration Absorbers (TVAs), which are effective at high frequencies. However, these countermeasures are inefficient at the low frequency range and may require significant mass and volume additions to achieve a desired insulation performance. As a result, these approaches can lead to heavy and bulky NVH solutions, which directly contradicts the trends towards lightweight designs. Therefore, novel low-mass and compact measures are needed to effectively address low-frequency noise and vibration while maintaining a lightweight design at a reasonable cost.

Recently, locally resonant vibro-acoustic metamaterials have emerged as potential candidates for noise and vibration insulation, offering not only a good NVH reduction performance but also a lightweight and compact design. Such materials consist of subwavelength assemblies of resonant structures attached to a host structure. The dynamic interactions between these resonant elements and the host structure enables the formation of stop bands, which are tunable frequency regions where free wave propagation is prohibited. In these frequency zones, superior noise and vibration insulation performance can be obtained, also in the ever-challenging low frequency range.

The presented work explores the potential of locally resonant vibro-acoustic metamaterial solutions for noise and vibration mitigation in five industrially relevant applications, employing various production processes and materials. Firstly, structure-borne noise reduction of a vehicle's shock tower with 3D printed resonant metamaterial patches is discussed. Secondly, structural-borne tyre noise mitigation by milled rubber resonant metamaterials is presented. Subsequently, the enhancement of the acoustic insulation performance of an aircraft's lining panel through a resonant metamaterial solution composed by lasercut plexiglass resonators is studied. Next, vibration reduction along industrial piping via resonant metamaterials formed by lasercut aluminum strips is shown. Lastly, sound transmission reduction with a locally resonant metamaterial thermoformed panel is demonstrated.