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Overview on metamaterials for acoustic applications

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The increasing requirement for bigger, faster and lighter vehicles has increased the demand of efficient structural arrangements, making sandwich constructions a well-established technique in lightweight component design. The weight reduction can be used to increase the payload, to increase the speed or just to reduce the energy consumption with maintained loading capability and/or max speed. However, lightweight design typically combines reduced weight and increased stiffness, leading to a deterioration of the noise and vibration attenuation performance. Consequently, merging lightweight and vibro-acoustic requirements results in a challenging and often conflicting task, for which novel low mass and compact volume solutions are sought.

New ideas, coupled with the expanding technologies of computational simulation and additive manufacturing, will produce the next generation of materials. Metamaterial is just this: a new concept, a new technology which properties derive not from the nature of the material itself but by from their newly designed structures. Their precise shape, geometry, size, orientation and arrangement gives them their smart properties capable to manipulate waves: by blocking, absorbing, enhancing, or bending waves, to achieve benefits that go beyond what is possible with conventional materials.

Metamaterial is a combination of "meta" and "material". Meta is a Greek word which means *something beyond, altered, changed*. To the letter metamaterial means: *material that does not exist in nature*; in physics *material with negative refractive index*.

Metamaterials found great interest in several applications for manipulating waves. First prototypes were built to manipulate electromagnetic waves at the end of the 19th century. Recently, metamaterials have found a great interest in vibro-acoustic field with favorable noise and vibration attenuation behavior, at least in some targeted and tunable frequency ranges, referred to as stop bands. Acoustic metamaterials (AMMs) are artificial structures made of subwavelength units such that their acoustic properties are new in comparison with that of the building units. Recent studies show that heterogeneous, poroelastic metamaterials can achieve considerable wave and/or vibration energy absorption. For instance, randomly embedding solid, metal inclusions into poroelastic foams improves the low frequency attenuation of the host media. Periodically distributing such inclusions also spawns bandgap phenomena to substantially increase low frequency vibroacoustic energy absorption via "trapped" mode effects.