Technology Offer

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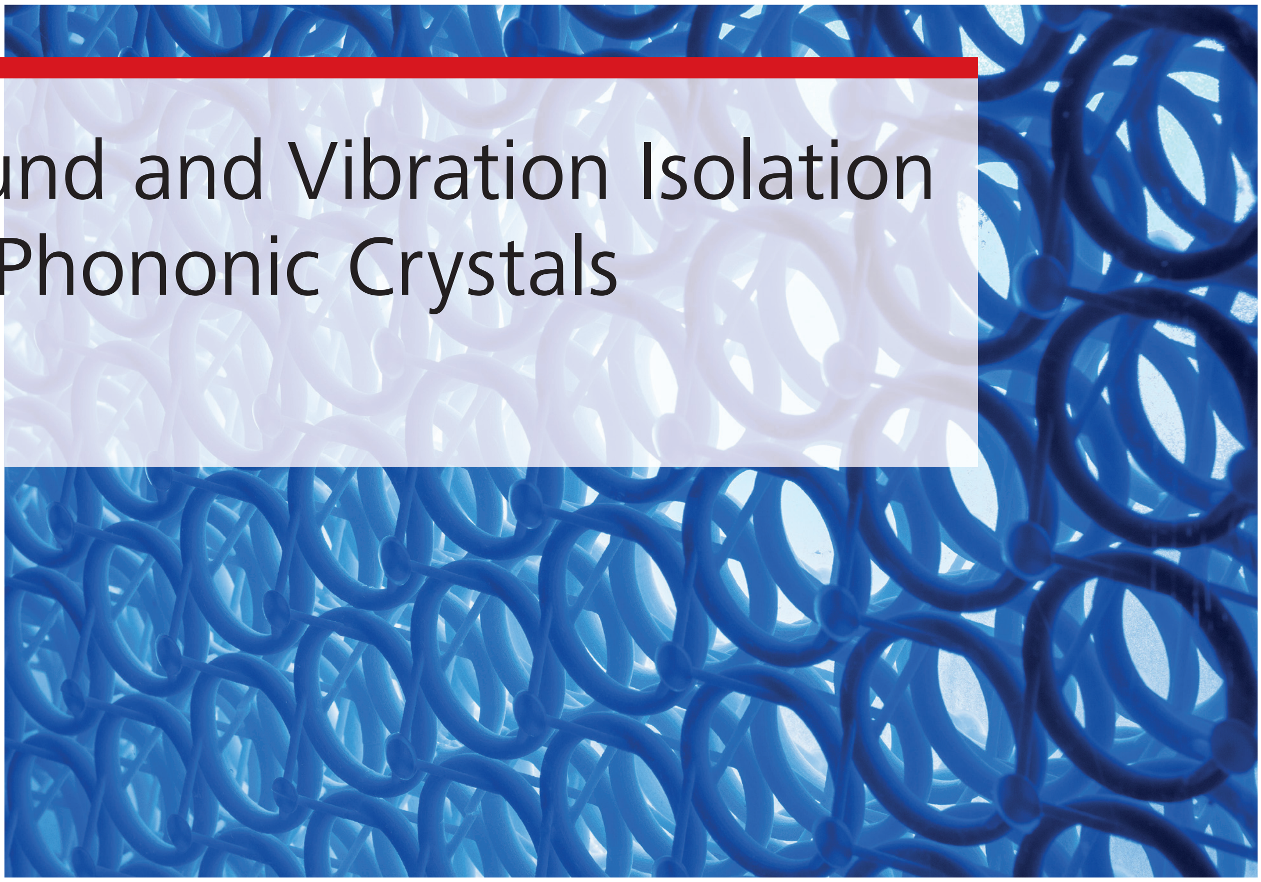
Empa
Materials Science and Technology

Sound and Vibration Isolation by Phononic Crystals



Invention

Phononic crystals (PCs) address the need to attenuate sound and vibration while providing stiff and lightweight mechanical structures. Commonly used viscoelastic dampers often add substantial weight and are typically characterized by low stiffness. The PCs developed by Empa are novel in their ability to stop low frequency waves while offering a favourable combination of low density and high stiffness.

Background

Mechanical structures carrying loads need to have a certain mimimal stiffness to fulfill their task. Stiffness, however, leads to undesired, but efficient transmission of low-frequency vibrations. Vibration dampers for low frequencies are heavy, bulky and rely on viscous materials with often unfavourable temperature dependency. An alternative solution, addressing the conflicting objectives of high stiffness, low density and low-frequency vibration attenuation, can be found in periodic meso- or macro-structures known as phononic crystals (PCs).

Natural crystals can keep waves from propagating through them in certain frequency ranges, by simply reflecting them due to the interference of their periodic arrangement with the incoming waves. In natural crystals, this effect is observed in the THz range. By making a magnified version of such a crystal (e.g., by additive manufacturing), the range of frequencies at which this effect is observed is lowered. So, phononic crystals with macroscopically large building blocks are able to stop sound waves in the audible range (100 Hz – 10’000 Hz).

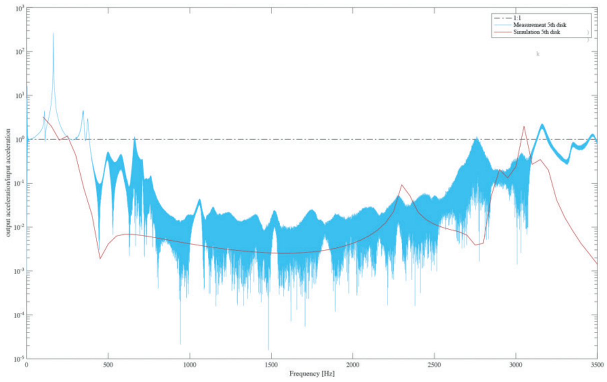
However, in order to interfere with such low frequency sounds, a compromise between stiffness, size and density has to be accepted which may not fulfill the requirements set for certain applications in mechanical and civil engineering, where stiffness and density of materials are important parameters.

Advantages

The PC design developed by Empa makes use of the fact that the mass elements in macroscopic, human-made crystals have a certain minimum size and can have special shapes (e.g., donut shape as in the cover figure) allowing to exploit the rotational inertia. This way, the waves moving through the PC experience a larger equivalent mass impeding their motion than they would with simple dot-shaped masses. This additional degree of freedom featured by Empa's PC design opens the doors to new methods to stop waves and vibrations in weight and stiffness sensitive applications, as there are many in mechanical and civil engineering.

Applications

Empa's PCs display a superior stiffness/density ratio, compared to state of the art PCs and can be tailored to specific needs. Applications could be in aerospace, marine, transportation engineering, where there is a need to decouple a vibration source (e.g., rotating machinery, moving parts with friction) from highly vibration sensitive devices (measurement equipment, precision instruments, passengers) or environments (laboratories, offices, conference rooms, cabin interiors). Special sound transmission properties (frequency selective filtering) can also be achieved. Given its scalability, the concept can be applied from the millimeter to the meter scale. While the properties of the material that the PC is made of, have an effect on the properties of the PC, their selection may be steered also by a number of additional application-specific requirements, such as material costs, optical (transparency) or chemical properties (e.g. corrosion resistance), environmental requirements (sustainability, recyclability) and many more.



Aluminum alloy load carrying phononic crystal, produced by additive manufacturing (left) and transmissibility curves (calculated and measured) of the device. A wide region of very low transmissibilty (attenuation of the order of 99%) is observed between approximately 400 Hz and 3000 Hz. This property allows, for example, to decouple the vibration of motors from the surrounding environment.

Ownership

Empa, Swiss Federal Laboratories for Materials Testing and Research, Überlandstrasse 129, CH-8600 Dübendorf; Patent pending

References

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Keywords

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