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Broadband reduction of the specular reflections by using sonic crystals: a proof of concept for noise mitigation in aerospace applications

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Abstract

The broadband reduction of the specular reflections by sonic crystals (SCs) is theoretically and experimentally reported in this work. The analysed system consists of a sound source radiating a SC made of acoustically rigid scatterers embedded in water partially covering an open cavity. By comparison with a reference flat reflector, we observe that reflected waves spread in space as a consequence of the spatially modulated properties of the SC. Moreover, due to the different working frequency ranges of the SC a significant noise reduction is produced in a broadband region. Therefore, due to the spreading of the reflected waves, the system produces a broadband noise reduction in the area of the source. In particular, the noise reduction is close to 2 dB for the two octaves emitted by our source, which represents a decrease of 37% of the acoustic energy. The results shown in this work constitute a proof of concept for the use of SCs as broadband-noise reduction systems at the launch pad. An approach to the geometry of the Vega launch vehicle the European Space Agency is proposed and the limitations of the study are discussed.

Keywords: Sonic Crystals, Noise reduction, Diffusion, Insertion loss, Reflection.

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1. Introduction

Sonic crystals (SCs) are artificial structures made of periodic arrangements of solid scatterers embedded in a host fluid medium. The materials constituting the scatterers and the fluid host present high contrast in their physical properties (i.e., in density, ρ, and sound velocity, c) [1]. Usually SCs are made of solid cylinders of metal [2], plastic [3] or wood [4] embedded in a fluid (usually air [5] or water [6]). The dispersion relation of such systems has been dramatically exploited during the last years to control acoustic waves for several purposes, as for example noise reduction [7], waveguiding [4], focusing [8], collimating [9, 10] or localizing [11] waves. Perhaps, the most known property of SCs is the presence of band gaps, ranges of frequencies in which the propagation of waves is evanescent due to the destructive interference produced by the Bragg reflections. Figure 1 shows the dispersion relation of a small-scale additively manufactured SC with square periodicity in two dimensions (shown in the inset) when it is embedded in water (ρ_{host} = 1000 kg/m^3, c_{host} = 1450 m/s). Red regions represent the directional band gaps of the structure, appearing around the Bragg's frequency, $fa/c_{host} = 1/2$ (a being the lattice constant of the SC, i.e., the distance between the centre of the rods).

Reflection of waves by this kind of structures is, in general, non-specular and produces diffusiveness of the sound field. Particularly, SCs of finite dimensions have been shown as efficient sound diffusers not only in the high frequency range, but also at low frequencies, by means of different mechanisms, mixing both periodic and finite size effects [12]. SCs also improve the diffusion when compared to other structures proposed in the literature (being the Schroeder diffuser [13] the paradigmatic example), in particular at low frequencies.

In this work, we experimentally and theoretically report the broadband reduction of the amplitude of specular reflections by using a SC made of metal scatterers embedded in water. The analysed system consists of an acoustic source that radiates waves into a SC placed over an open cavity. By comparison with a reference flat reflector, we observe that the reflected waves spread in space as a consequence of the spatially modulated properties of the SC. Moreover, as the SC works in a large range of frequencies, the noise reduction is broadband. Therefore, due to the spreading of reflected waves, the system produces a broadband noise reduction in the area between the source and the SC.

The results of this study constitute a proof of concept in which the main motivation is to incorporate SCs in future launch-pad designs as a broadband noise reduction system for aerospace applications [14]. Recent studies show