Optimization of the Acoustic Systems

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INTRODUCTION

A genetic algorithm is a global search method based on a simile of the natural evolution. Genetic Algorithms have demonstrated good performance for difficult problems where the function to minimize is complicated. In this work we applied this optimization method to improve the acoustical properties of the Sonic Crystal (Martínez-Sala et Al.,1995) (Kushwaha et al., 1994), a kind of structures used in acoustics.

In the last few years the propagation of the acoustic waves in heterogeneous materials whose acoustic properties vary periodically in space have attracted considerable interest. The so-called Sonic Crystals are the typical example of this kind of materials in the range of the acoustic frequencies. These systems are defined as periodic structures with strong modulation of the elastic constants between the scatterers and the surrounding material.

Recently, the strategy to enhance Sonic Crystals properties has been based on the use of scatterers with acoustical properties added. The use of local resonators (Liu et al., 2000) or Helmholtz resonators (Hu et al., 2005) as scatterers have produced very good results Some authors also have built new structures with scatterers made up of porous material improving the attenuation capability of the Sonic Crystals (Umnova et al., 2006). However, the use of Sonic Crystals as outdoor acoustic barriers requires scatterers made up of robust and long-lasting materials. This is the reason why it seems interesting to analyze the possibility of optimizing the attenuation capability of Sonic Crystals made with rigid scatterers like wood, PVC or aluminium. The creation of vacancies in a Sonic Crystals improves the attenuation capability of the Sonic Crystals (Caballero et al., 2001). However, it does not exist any generic rule about the creation of vacancies in a Sonic Crystals. In fact, similar structures can produce very different acoustic fields behind of them.

Because of the complexity of mathematical functions involved in Sonic Crystals calculus, Genetic Algortihm turns up as a tool specially indicated for this kind of problems (Hakanson et al., 2004) (Romero-García et al., 2006). This procedure can work together with the Multiple Scattering theory which is a self-consistent method for calculating the acoustic pressure including all orders of scattering (Chen & Ye, 2001). Given a starting Sonic Crystals, the Genetic Algorithm generates quasi ordered structures offspring by means of the creation of vacancies that are classified in terms of a cost function based on the pressure values at a specific point. The sound scattered pressure by every structure analyzed by Genetic Algorithm is performed by a two-dimensional (2D) Multiple Scattering theory. In the present work, it is shown an improvement of the Genetic Algorithm based on Parallel implementation and as a consequence, new and better results are obtained to design Quasi Ordered Structures made with rigid cylinders that attenuate sound in a predetermined band of frequencies.

SONIC CRYSTALS

Sonic Crystals are arrays of scatterers placed periodically in space whose physical properties are different to the surrounding material. In the low frequency range, Sonic Crystals behave as an homogeneous medium with an acoustic impedance greater than that of the air. Then Sonic Crystals can work as refractive devices. Moreover, Sonic Crystals present band gaps, i.e., ranges of sound frequencies where the sound propagation inside the crystal is forbidden. The presence of these band gaps is explained by the well-known Bragg's law. The reflections inside the crystal, and consequently the position of the gaps depend on the lattice constant, i.e., on the geometry of the Sonic Crystals. The existence, in periodic media, of an absolute band gap where the propagation of sound is forbidden for every incidence direction, can have a profound impact on several scientific and technological disciplines, for example, in the design of acoustic filters or acoustic barriers.

Some studies have showed that there are three important parameters for the spectral gap creation (Economolu & Sigalas, 1994). One is the density ratio $y = \rho_s/\rho_h$ between the scattering material and the host material densities. The second one is the filling factor, $ff = Vs/V$, that shows the volume occupied by the scattering material respect to the total volume. The last parameter is the topology used to design the Sonic Crystals. It was demonstrated that the density ratio plays an important role in the gap creation: Sonic Crystals built with scatterers of high density embedded in a host material of low density are better to create the spectral gap than another kind of configurations. Moreover the optimum value of the filling factor, ff, to the gap creation has been ranged between 10% and 50%. In this work we use a Sonic Crystals built by aluminium cylinders of 2 cm of radius as scatterers embedded in air (Network topology). Due to the fact that those structures present a high density ratio, and the maximum filling factor is $ff = 0{,}36$, we ensure that our structure is well designed to the gap creation. Now we want to find the best filling factor and space distribution of scatterers that present the best acoustical properties. Genetic Algorithm together with the MST is a good procedure to achieve our objective.

COST FUNCTION AND CHROMOSOME DESCRIPTION

The mechanism used by Genetic Algorithm in this work is the creation of vacancies in the starting Sonic Crystals. Fig. 1 shows the starting Sonic Crystals and a Quasi Ordered Structures offspring generated by Genetic Algorithm by means of the creation of vacancies. Using this procedure we can vary the filling factor and, at the same time, evaluate different spaces of configuration. Each Quasi Ordered Structures will be considered as an individual. The chromosome that represents each Quasi Ordered Structures, is a real vector with values in $[0; 1]$ range. Each coordinate represents the existence or not of a cylinder at a specific position of the scatterer (beginning with the cylinder a the left top corner of the Sonic Crystals and following by columns until right bottom corner, see starting Sonic Crystals at figure 1). Values in $[0; 0{:}5[$ means there is a vacancy, in opposition values in $[0{:}5; 1]$ means there is a cylinder. In this work we are interested in maximizing the sound attenuation for a predetermined range of frequencies not dependent on the lattice constant, at a point located behind the crystal.

The acoustic attenuation in a point (x, y) and for a incidence frequency v is:

$$\text{Atenuación (dB)} = 20\log\left(\frac{1}{|\,P_{\text{interferred}}(x, y, Xcil, Ycil, v, r_1)\,|}\right)$$

where the interfered pressure is determined by the MST. This pressure depends on the position and on the radius of the scatterers and the incidence frequency. In the equation (1) we can see that for a point (x, y), a value of incidence frequency v and a value of cylinder radius r_l, it is possible to find a configuration of cylinders that minimize the $P_{interferred}$, that means, maximize the acoustic attenuation.

If we are interested in maximizing the sound attenuation in a predetermined range of frequencies at

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