Acoustic metamaterial for noise reduction in aircraft

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ACOUSTIC METAMATERIAL FOR NOISE REDUCTION IN AIRCRAFT

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Summary: Aircraft fuselage structures are characterized by their lightweight design. The reduction of the mass of a structure is an important issue in the engineering field since it leads to reduced emissions and operating costs. On the other hand, weight saving leads to an increase of vibration and noise transmission which can deeply affect pilots performances and passengers comfort. Since low frequencies are especially difficult to absorb with conventional materials, Metamaterials are here proposed for a broadband soundproofing of fuselage. The core concept of these materials is to replace the molecules with man-made structures, called unit cell, that are arranged in repeating patterns on a scale much less than the relevant wavelength of the phenomena they influence. In this way, metamaterials disrupt the propagation of low-frequency waves by scattering and refraction effects.
Advanced numerical tools based on Finite Element Method and Statistical Energy Analysis will be implemented for the characterization of metamaterials and the computation of their acoustic performances.

1 INTRODUCTION

The novel characteristics of metamaterials represent an emergent phenomenon in which the basic mechanism of resonances, when considered in aggregate, can give rise to material properties that are outside the real provided by Nature. A heterogeneous (HG) metamaterial is a new class of acoustic metamaterial [1]. It is defined as a composite system consisting of multiple small masses embedded within a passive poro-elastic matrix material. The embedded masses create an array of resonant mass-spring-damper systems within the material that operate at low frequencies where the passive poro-elastic material is no longer effective. By employing the poro-elastic material to provide the stiffness for the embedded masses, the HG metamaterial utilizes two passive control schemes: damping at high frequencies and dynamic absorption at low frequencies, into a single device for broadband noise reduction. The displacement of the masses against the foam stiffness at their low frequency resonance leads to an increase in mechanical damping losses and absorption. An increased effect of the embedded mass on the poro-elastic material is due to a mismatch in the impedance between the two materials. Several studies have been conducted concerning locally resonant metamaterial plates consisting of a single-layer homogeneous plate as a host plate [2-3]. These studies have confirmed that the metamaterial plate design is an effective technique to improve the sound transmission loss property. Furthermore, the mass ratio of the resonators to the host plate is shown to be a critical property in order to broaden the working frequency band. This paper mainly deals with the design of acoustic metamaterials to be employed in lining panels of aircrafts fuselage for reduction of noise and vibrations. Design studies have been performed to understand the effects of varying the density, size, shape, and placement of the embedded masses in poro-elastic material on the vibro-acoustic performances of the panel.

2 INVESTIGATION

The proposed sandwich panel consists of two facesheets made of glass fibre reinforced epoxy resin and a hybrid core made of a poro-elastic material (melamine) with a periodic arrangement of embedded aluminum cylinders. The proposed hybrid metamaterial is periodic and the geometry of its unit cell and panel is shown in Fig. 1. This hybrid metamaterial has excellent mechanical stiffness and strength, and hence is considered to be acoustically rigid in the following theoretical model.

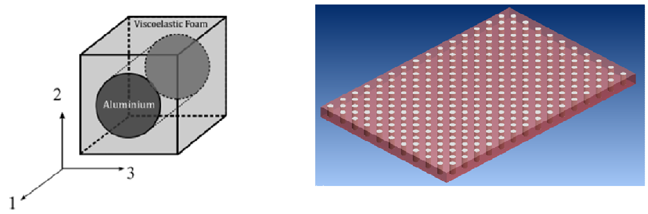

Figure 1: A skecth representation of an acoustic metamaterial unit cell and a view of a numerical model of a metamaterial panel.

3 CONCLUSIONS

A preliminary study based on a single-layer impedance approach has shown the potential of appropriately tuned stepped resonators to improve the transmission loss of metamaterial plates. The influence of the resonator is then further studied on the basis of finite element simulations, in which the radiation from the resonator is taken into account. It is shown that the bandwidth of the working frequency band associated with the stepped resonators is strongly dependent on the mass ratio and that the radiation effect of the resonators may affect the sound transmission loss property, especially at the resonance.

References

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