Accurate FEM investigation of acoustic properties in aerospace sandwich structures with metamaterial core

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Abstract: It is well known that, to compete in the global market, the design of modern aircraft is driven by the continuous improvement of the safety and cabin comfort. The surrounding environment and particularly noise and vibration (N&V) can deeply affect passengers and pilots in cabin and cockpit, especially during long haul flights. On the other hand, spacecraft and its payload are subjected to high structural vibrations, during launch phase, that are crucial in view of the overall success of a spacecraft's mission. In this sense, reducing the acoustic loads plays a significant role in cost optimization of the mission. A possible solution to the problem of noise is the conception of high-performance acoustic treatments for the trim panels of aerospace vehicle.

An overarching challenge is the design of 2D structures capable of providing exceptional sound insulation on a wide frequency range, especially in the aerospace field where the materials are required to obey several criteria that usually clash with the acoustic one, such as lightness, thinness, mechanical strength, fire-resistance, etc. Low frequencies are especially difficult to absorb with conventional materials, as the order of magnitude of the wavelength is much greater than the reasonable thickness of trim panels. Therefore, a new research field has emerged to study acoustic metamaterials (AMM).

Aircraft noise is due to the combination of different sources such as powerful propulsion systems, high-speed aerodynamic flow over vehicle surfaces and operation of on-board systems, as air conditioners, pressurization system, etc. In order to evaluate noise levels and vibration transfer paths in the whole frequency range, there are various methods to consider, because none of them has shown a complete reliability, but can be used only in a limited frequency region. In the low frequency range, the behavior of a structure is deterministic and the basic tool applied for the analysis of vibration problems is the finite element analysis on the numerical side [101].

The Finite Element Method (FEM) is well-established and yields accurate results for the structural analysis of any geometrical shapes. However, the metamaterials require a mesh of all the details of the constituent unit cells, so this method can become very costly in computational time when large components are analyzed. Efficient FEM models have been recently implemented on the basis of Carrera Unified Formulation (CUF) to perform the vibro-acoustic analysis of advanced materials coupled with fluid [2] and the dynamic characterization of composite metamaterials [3].

Applying these innovative models, the present work aims to analyze the transmission loss properties of sandwich structures with metamaterial core. The metamaterial configurations considered are inspired to the work

[4]. The results demonstrate that a new concept of sandwich light-weight structures can be conceived by taking into account the acoustic requirement in the design of aerospace trim panels. The Figure 1 shows an example of metamaterial core considered and some curves of transmission loss computed with the advanced FEM models employed in this work.

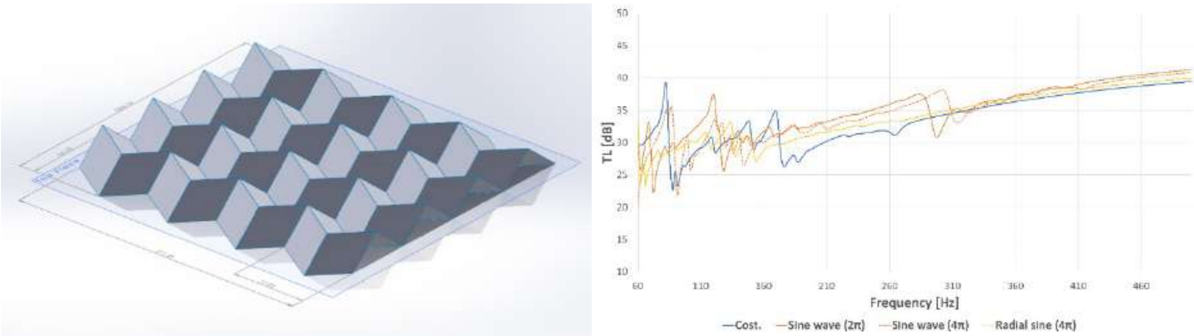

Figure 1: Miura-ori phononic structure and transmission loss curves computed for different AMM configurations.

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