Integrated and Distributed Adaptive Metacomposites for vibroacoustic control of Aerospace Structures

M. Collet(1), M. Ouisse(1), F Tatéo(1), M.N Ichchou(2)
CNRS - FEMTO-ST Institute, Dept Applied Mechanics, Besançon, France, manuel.collet@univ-fcomte.fr
Ecole Centrale de Lyon, LTDS, Ecully, France

Summary

Research activities in smart materials and structures represent a significant potential for technological innovation in mechanics and electronics. The necessity of controlling vibroacoustic behavior of industrial systems motivates a broad research effort for introducing active or passive technologies to control noise and vibrations. New processes are now available which allow active transducers and their driving electronics to be directly integrated into otherwise passive structures. This new approach could allow fine control of the material physical behavior for implementing new functional properties that do not exist in nature. In this sense, we can speak of "integrated distributed adaptive metacomposites" that merges with the notion of programmable material. Through two different examples dealing with active acoustical impedance and elastodynamical interface, this paper presents used theoretical tools for designing specific applications of this new technology.

Motivation

Constant research for developing new materials better adapted for more efficient human applications, incorporating more and more new constraints such as the environmental damage (environmental impact, noise, recycling ...) led to study a new class of artificial multifunctional composite materials: the Metamaterials. These new materials presenting specific physical properties due to their micro or nano structuring, were originally developed to synthesize new electromagnetic permittivity indices or negative permeability. But in recent years, new research efforts have shown that the concepts could be transcribed in other areas of physics such as acoustics, mechanics or even robotics. Thus, the realization of new structured materials has led to obtain very interesting new physical features that can lead to the design of integrated multi-functional structures.

In recent years, the technological revolution observed in the areas of Micro Electro Mechanical Systems can deeply extend the spectrum of future development of adaptive structures. One can now imagine full integration of hybrid systems consisting of adaptive materials, electronics, computing resources and power systems. The next generation of composite structures called "smart metacomposite" should take full advantage of these technological advances for optimizing their behavior[1]. This new technology should lead to new relevant applications for noise and/or vibration control, for achieving integrated surface actuators for adaptive applications.

The use of integrated and periodically distributed active systems of transduction could allow fine control of the material physical behavior. In this sense, we can speak of "integrated distributed adaptive metacomposites" conform to the notion of programmable material[2]. This new approach represents a new challenge for creating intelligent hybrid materials.

Results

This paper aims at showing specific applications of such new metacomposites for controlling mechanical and acoustical power flow into large space structure. In the first part, the concept of active acoustical skin is introduced and experimental validation is carried out (see Fig 1).

[1] M Collet et al, 2009, Active acoustical impedance using distributed electrodynamical transducers, Journal of Acoustical Society of America, 125(2), 882

[2] T. Toffoli, 1991, Programmable matter: concepts and realization". Physica D 47: 263

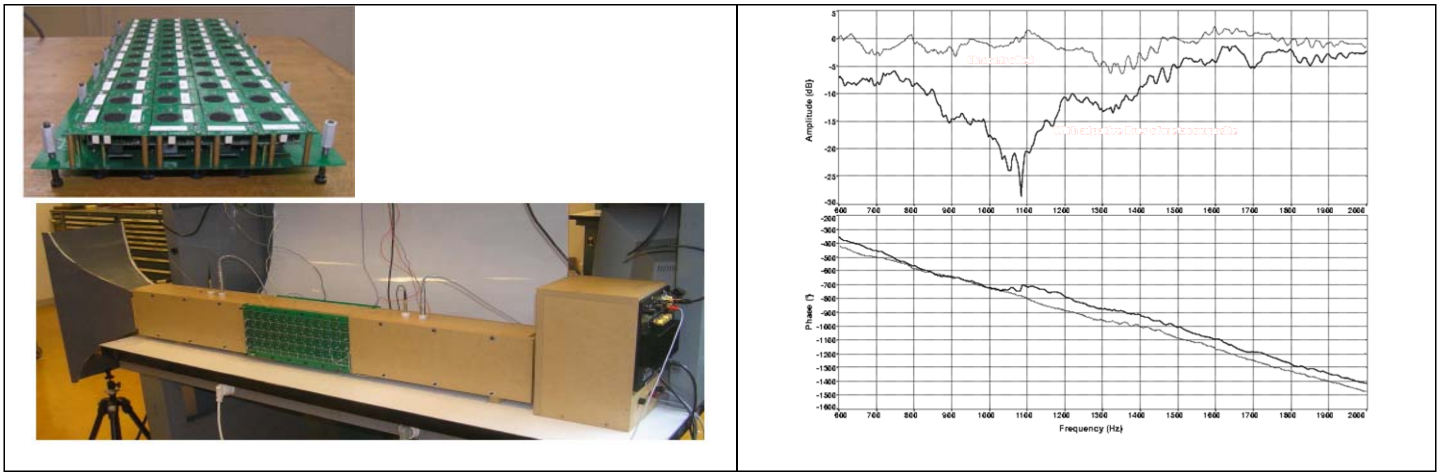

Fig. 1: Metacomposite for realizing acoustical active skin. Left: Individual active acoustic cells and general view of the realized liner made of 4x12 cells and acoustical experimental set-up. Right: Transfer function between the input and output microphone,—active surfaces with control; · without control

The second part deals with smart mechanical interfaces for controlling absorption and transmission of elastodynamical energy into a large plate by using periodically distributed set of shunted piezoelectric patches (see Fig 2).

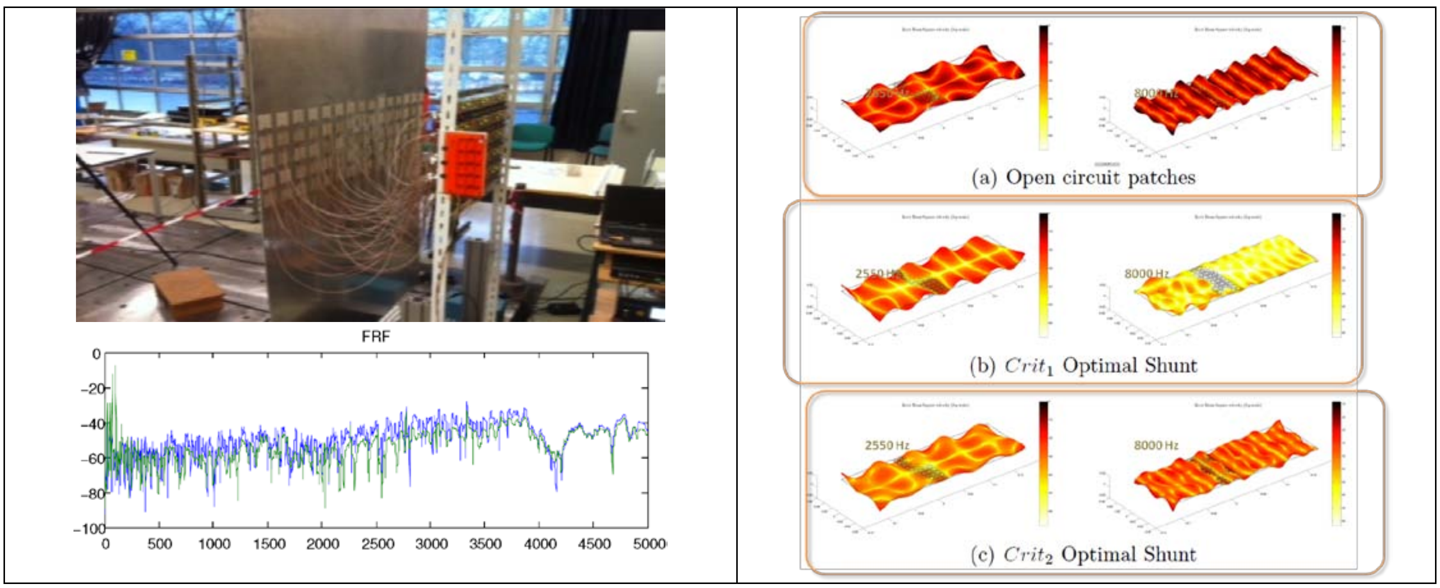

Fig. 2: Metacomposite for realizing smart mechanical interface filtering vibroacoustic power flow.
Left: Metacomposite made of piezocomposite cells and experimental FRF (free response in blue, controlled in green). Right: Energy distribution with absorbing and reflecting smart interface.

Perspectives

The studied adaptive metacomposite is totally apart from the existing technologies based on the use of non distributed and non integrated set of transducers. The main advantage stands on the capability of such system to guarantee robust efficiency of the systems but also the versatility and stability inherent to distributed control operators. From a technological point of view, size reduction of transducer’s cell often goes together with cost reduction in production, increased sensitivity, and reduced energy consumption. Therefore, for these applications when dense distribution is targeted, MEMS appears as a technology of choice.

The addressed scientific and technological challenges also appear very attractive for aerospace applications where new lighter and functional materials are of great interest. Specific design of such metacomposites may allow synthesizing programmable materials with news functionalities as structural health monitoring and prognostic, shaping control or structural vibroacoustic specific properties in terms of transparency, absorption or emissivity.