PiezoElectroMechanical (PEM) structures: the concept of distributed control of vibrations via piezoelectric transduction and analog electric waveguides

Recent and and continuously improving performances of piezoelectric transducers allow for the conception of new kinds of engineering artifacts showing unexpected behavior. (see e.g. [32] for the study of a piezoelectric actuator which is able to exert shear forces).
The concept which we want to present here concerns the exploitation of the piezoelectric transduction to transform mechanical energy into electrical energy and, eventually, trap the transformed energy in its electrical form, for instance by dissipating it in resistors.
The novelty of the presented results consists in the choice of i) distributing an array of actuators along the considered structure or structural member and ii) interconnecting the electric terminals of all this actuators via an electrical (possibly passive) waveguide.

Once a suitable optimality criterion is introduced (requiring multimodal damping performances and highest speed of damping) it is possible to prove that i) the conservative part of the electric waveguide must be governed by the same equations as the mechanical structure (i.e. it has to be its electric analog)ii) there exists a distribution of resistors to be added to the conservative waveguide which damp in the shortest possible time (for passive controllers) the electric excitations.

These results are presented in [49],[56] with general mathematical arguments proving optimality, in [41],[42] for beams, and in [52,[54],[55] for plates.
Then a study of more efficient electric circuits is presented in [58],[73],[74],[75] where the standard techniques of circuit synthesis, initially conceived for building analog computers are adapted to a different aim. A review of many results about PEM structures and a comparison of them is attempted in [65], while more sophisticated numerical methods for solving the problem of determining the motion of them are proposed in [67].
Some relevant further problems of circuit synthesis are then studied in [76] in order to prepare the experimental campaign of experiments presented in [77].
These experiments proved that the usually accepted modelling of the behavior of piezoelectric transducers and their interconnection needed to be improved: this was done in [78], [94], [79], [84] and [87] while in [80] the performances of the optimal circuits were compared with those of some other ones, which can be more easily constructed.
In the same spirit in [106] the performances of a less efficient vibration damper are studied, in order to establish when simpler experimental set-ups can be used and under which conditions. The whole research effort produced also a patent in the USA.

Many interesting research developments are conceivable. However most interesting seems the possibility to design new electrically active (or actionable) metamaterials whose microstructure is constituted by PEM elements. The continuum macro-modelling of these structures will require the introduction of generalized continua.

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