OPTIMAL VIBRATION CONTROL OF SMART LAMINATED STRUCTURES

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Recently the application of active or passive vibration control has been becoming increasingly important, especially in order to meet the high precision requirements of large structures made of multilayered laminated composite materials. In this area the attention is mainly focused on the use of two different types of smart materials, i.e. 1) the piezoelectric sensor/actuators (S/As) – so-called active vibration control and 2) the embedded shape memory alloy fibers (SMA) – passive vibration control. Both types of materials have various advantages from the practical point of view. However, taking into account their physical description, they are similar and can be formulated in the frame of the 2-D classical lamination theory (understood in the sense of physical relations). Piezoelectric actuators are commonly described as layers (or patches) added to a base laminated structure in order to obtain the required electro-mechanical coupling. The modeling of SMA reinforced composite structures is based on the introduction of the recovery stress resultants to the fundamental equations which are equal to zero at the martensite phase and non-zero at the austenite phase. A broad discussion of physical relations in 2-D and 3-D relations for the above types of smart structures is given in Ref. [1].

The aim of the present paper is two-fold:

- to model and solve optimization problems for smart laminated structures with the use of the FE package ABAQUS,
- to analyse and discuss the influence of theoretical formulations (3-D vs. variants of 2-D theories) on optimal results.

Two optimization problems are considered, i.e. searching for: the minimal (or maximal) natural frequencies and the minimal deformations of structures – a normal deflection. For composite structures vibration characteristics are highly affected on material properties of laminates. Thus, fiber orientations, properties and orientations of SMA, dielectric properties of S/As and laminate/hybrid topology constitute one group of design variables that can be called as physical design variables since they have a great influence on values of terms in the stiffness matrix. However, it is necessary to have in mind the second group of design variables associated with a structural geometry of constructions, understood in the sense of a shape of plate/shell mid-surfaces, external boundaries, structural thicknesses and/or positions of piezoelectric, local patches – so-called geometrical design variables. The discussed problems are solved with the use of evolutionary algorithms combined with the FE package in the similar manner as it is presented in Ref. [2]. In addition, the sensitivity of optimal solutions on variability of design variables is presented with the use of the fuzzy set theory – see Ref. [3].

Various numerical examples dealing with laminated beams and plates have been solved in order to demonstrate: a) the effectiveness of the proposed numerical algorithms, b) discrepancies in optimal solutions for 3-D and 2-D formulations, c) differences in optimal results for SMA and S/As control of vibrations and deformations.

References:

[1] Muc A. "*Optimization of composite structures and technological processes of their manufacturing*", Księgarnia Akademicka, Kraków, 2005 (in Polish).
[2] Muc A. and Gurba W. "Genetic algorithms and finite element analysis in optimization of composite structures", *Composite Structures*, 54, pp. 275-281, 2001.
[3] Muc A. and Kędziora P., "Application of Fuzzy Set Theory in Mechanics of Composite Materials". *Soft Computing in Textile Sciences*

(L.M.Sztandera, Ch.Pastore, edts), Physica-Verlag, Heidelberg, New York, pp.16-50, 2003.