Performance of Heuristic Optimisation Methods in the Characterisation of the Dynamic Properties of Sandwich Composite Materials

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Of the fundamental dynamic properties (mass, damping, and stiffness), damping is usually the most difficult to quantify. This is perhaps particularly true for composite materials which tend to have substantially higher damping than comparable isotropic materials and therefore having an accurate representation is correspondingly more important. Accordingly, some heuristic optimisation techniques for the identification of the dynamic characteristics of honeycomb-core sandwich composite materials have been suggested, such as Particle Swarm Optimisation (PSO) and Genetic Algorithms (GA). Experimental measurements have been made of the dynamic responses (in the form of hysteresis loops) of a simply-supported beam and a simplified semi-empirical mathematical model has been developed for such a system when it is excited at its midpoint by sinusoidal displacement waves. The hysteresis loops that were obtained are for several frequencies and excitation amplitudes around the first mode of vibration. The basic model contains four unknown system parameters that must be identified. The performances of both optimisation methods are compared when used with computer-generated and experimental hysteresis loops. In addition, the effect of noise contamination in the signals has been studied in order to assess the search accuracy of the optimisation algorithms under such conditions.

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Nomenclature

f	– excitation frequency, Hz
f_n	– natural frequency of the system, Hz
$F(t)$	– forced response function, N
K	– PSO constriction factor
L	– additional population “add-on” level
M_{eq}	– equivalent mass, kg
N	– number of system parameters
p_{id}	– PSO previous individual best particle position
p_{gd}	– PSO global best particle position
φ_1	– PSO cognitive component factor
φ_2	– PSO social component factor
v_{id}	– PSO optimisation velocity
ω	– excitation frequency, rad/s
ω_n	– natural frequency of the system, rad/s
Ω	– PSO inertia factor
x	– displacement, m
x_{id}	– PSO particle position
X_0	– peak displacement excitation level, m
ξ	– linear elastic viscous damping ratio
$\xi_0, S_\xi, \omega_0, S_\omega$	– system parameters

1. INTRODUCTION

Composite materials are being used increasingly as an alternative to conventional materials for highly demanding structural applications, such as the construction of marine, automobile, and spacecraft structures, which include the equipment panels, payload platforms, solar panels, and antenna reflectors.[1] Composites are mainly used for this kind of applications because they have the desired properties of high specific strength, specific stiffness, tailorable design, and low mass. However, they can be quite different from isotropic materials, because the former may have (for instance) certain failure characteristics, such as core or matrix crazing, delamination, and interface debonding, which typically do not occur in more conventional materials.

Damping is one important parameter related to the study of dynamic behaviour of composite structures in general. There are numerous types of composites currently available, but the present study deals with the use of a specific kind of composite construction called “sandwich composite.” A sandwich composite (or “sandwich panel”) is a structure consisting of two thin faces bonded to a thick lightweight core.[2,3] The materials used to construct the faces are usually aluminum or a composite laminate, and the core can be a lightweight foam or a honeycomb structure of some other material. Chandra et al.[4] make an extensive review of damping mechanisms in composites, some of which are detailed below in order to enhance the understanding of this important physical phenomenon:

- Viscoelastic nature of matrix and/or fiber materials: the matrix shows the most significant contribution to the damping. In the case of high damping fibers, such as in carbon and kevlar composites, the effect of the fibers damping should be included in the analysis.
- Damping due to interfaces: the interfaces are the regions where adjacent surfaces exist. In fiber-reinforced composites, the interfaces are the areas where the fibers are in direct contact with the matrix. In sandwich composites, on the other hand, the interfaces are the areas where the different layers are in contact with one other.