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Hybrid lightweight composite pyramidal truss sandwich panels with high damping and stiffness efficiency

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ABSTRACT

Hybrid composite pyramidal truss sandwich panels combined with multiple damping configurations are fabricated in this work. Modal and quasi-static compressive tests are carried out to investigate the damping and stiffness efficiency of the candidate structures. Experimental results show that such structures combined with damping materials would significantly improve the damping loss efficiency but decrease simultaneously the stiffness efficiency in varying degrees compared with the bare hybrid sandwich panels. In order to evaluate the compatible effect of total damping and stiffness efficiency of the present sandwich structures, a synthetic evaluation criterion is developed, which shows that bare sandwich panels filled with hard polyurethane foam (B-II-HPF) and soft polyurethane foam (B-II-SPF) can yield the best performance up to 2–4 times higher than the base hybrid sandwich panels. It is also shown that multiple patch damping treatments based on the finite element-modal strain energy (FE-MSE) approach are suitable and effective to further improve the total damping efficiency.

1. Introduction

Sandwich structures generally consist of two thin face sheets bonded to a thick and lightweight core with any topological configurations using adhesive interface layers. The insertion of a lightweight core increases the structural bending stiffness and strength substantially without adding much weight compared with single-layer homogenous structures [1,2]. For the high strength and stiffness to weight ratio, sandwich structures are widely used in many engineering applications including aircraft, automotive and construction industries. Various types of topological configurations of sandwich cores including metal alloys and composites have been developed [3–6] and at the same time mechanical properties such as compression, shearing, bending, impacting and vibration damping of sandwich structures have been extensively studied [7–13]. Unfortunately, lightweight and stiff materials and structures are usually associated with relatively low damping [14–17] which can cause early mechanical damage caused by resonant vibration. Owing to the outstanding designability of sandwich structures, an excellent combination of stiffness and damping can be obtained by choosing suitable materials and geometric configurations of the face sheets and cores. The method of constrained layer damping (CLD) that was first proposed by Ref. [18] and has been proven effective in vibration suppression [19,20]. In addition, filling of the core voids with foam or viscoelastic material have been also investigated in order to improve the structural damping loss factors [21,22]. However, the insertion of the damping material inside the face sheets and core of the sandwich panel increases the extra mass which is undesired and always significantly changes the dynamic properties. Therefore it is also a main topic concerned by design engineers to efficiently use the CLD treatments. Previous works [23,24] have confirmed by theoretical analysis and experiments that the base structure partially covered with CLD was more mass efficient than with complete coverage. Based on that, varieties of comprehensive studies have been conducted to optimize CLD, location and dimensions in order to maximise the structural damping while minimising additional mass. To tackle this problem and its related filed, many optimization techniques such as Genetic Algorithm [25], Moving Asymptotes method [26], Topology Optimization method [27], modal strain energy method [28] and recently Double Shear Lap-Joint configuration [29,30] were successfully adopted. To date, most of the research about structural damping optimization focused on simple CLD beams, panels and shells using theory and numerical simulations, which usually lack of experimental verification. However, to the authors' knowledge, there are only few reports on vibration damping optimization of composite sandwich structures

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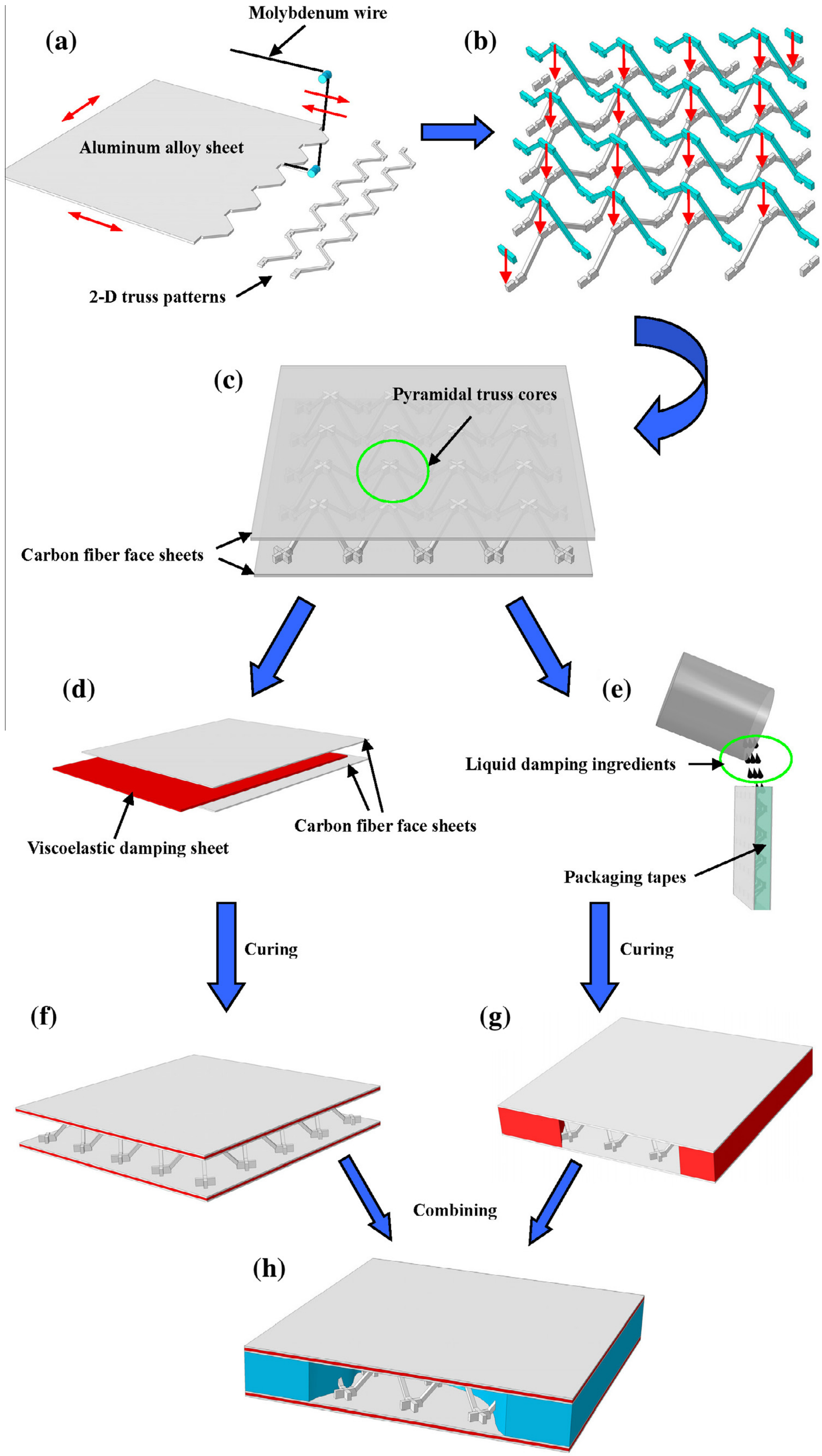

Fig. 1. Fabrication processes of hybrid composite pyramidal truss sandwich panels.