Optimised location and orientation of passive viscoelastic dampers for lightweight sandwich structures.

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1. INTRODUCTION

Sandwich structures are in wide use because of their high strength and stiffness-to-mass ratio [1], and often in environments liable to high vibration excitation which promotes high cycle fatigue damage, reduces fuel efficiency, and can adversely affect passenger comfort. A common treatment for such vibrations is a Constrained Layer Damper (CLD), which consists of a thin layer of viscoelastic material sandwiched between the vibrating structure and a stiff layer. This arrangement constrains the viscoelastic layer to deform in shear and at relatively higher strain thereby efficiently dissipating vibration energy as heat [2]. The Double Shear Lap-Joint (DSLJ) [3], [4] is a new damping technology which has been recently developed by the authors. It similarly elevates shear strains in a viscoelastic layer, but is suitable for internal placement in structures such as lightweight sandwich panels. An illustration of the CLD and DSLJ dampers is shown in Fig. 1. The DSLJ damper can be orientated along three directions in the regular hexagonal cell of the honeycomb structure, as shown in Fig. 2.

The aim of a damping treatment is to minimise the vibration of the structure to which it is attached. Additionally for lightweight applications, the mass added by the damping treatment should also be minimized, since extra mass defeats the primary purpose of such structure, i.e. fuel efficiency as well as potentially lowering excitation frequencies and aggravating fatigue problems. However, the two objectives of damping vibrations and minimizing additional mass are generally contradictory. In such a multi-objective problem such as this an optimisation technique is often an efficient technique, in this case to determine the best location of a damper on a vibrating structure. A number of studies in the literature using optimisation approaches for location of CLDs have tackled this problem.

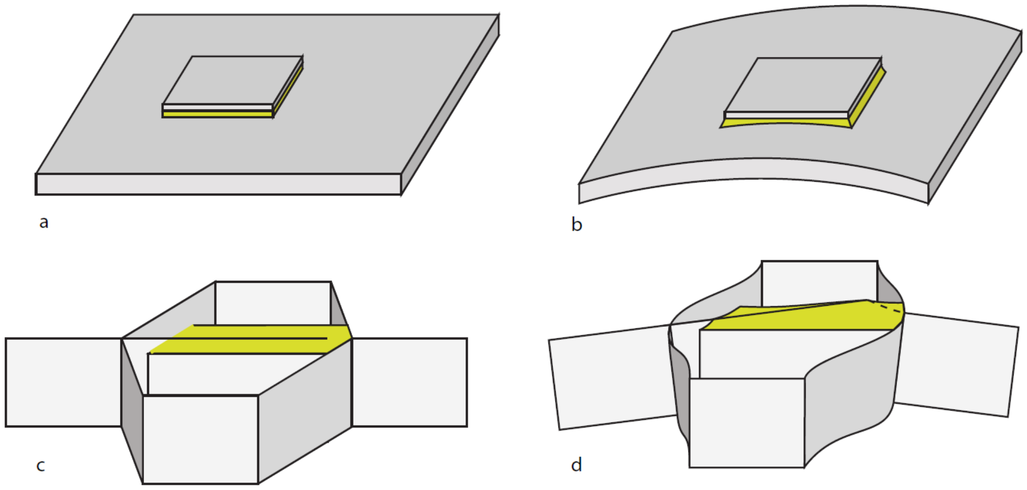


Fig. 1: A typical constrained layer damper, Figs. 1a and 1b, and a double shear lap-joint damper, Figs. 1c and 1d. The structures shown in 1b and 1d are deformed under load.

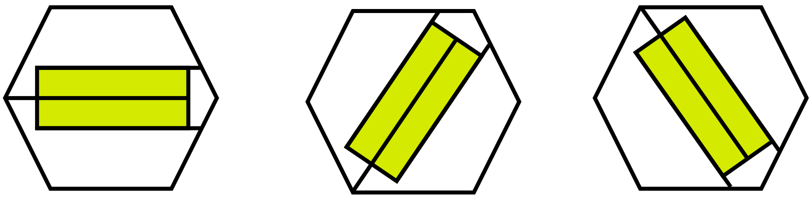


Fig. 2: Three different orientation of the DSLJ damper within the hexagonal cell of the honeycomb structure.

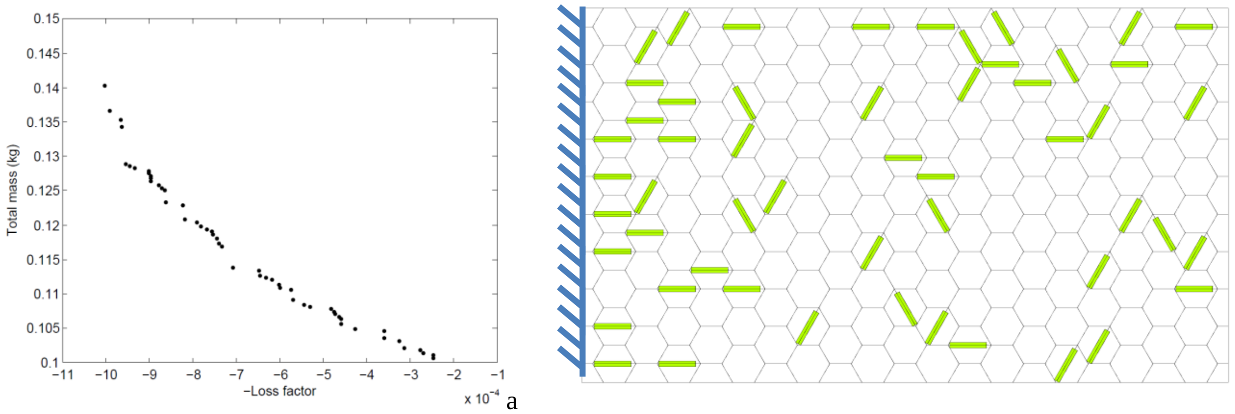
2. SCOPE AND THEMES

This work considers the optimal location and orientation of DSLJ dampers within a simplified honeycomb sandwich structure, as an example of a lightweight structure subject to vibration, under typical idealised boundary conditions. The properties of the DSLJ inserts and the sandwich structures were simulated in Finite Element (Ansys 14.0). The Modal Strain Energy method is a commonly adopted technique (described by Johnson and Kienholtz [5]) which estimates the modal loss factor of a structure under harmonic excitation, and used here to calculate loss factors for all structures.

The Pareto Archived Evolutionary Strategy (PAES) [6] was used as a multi-objective algorithm to maximise the modal loss factor whilst minimising the additional mass of the DSLJ inserts. It is an efficient evolutionary algorithm ideally suited to this problem with rapid convergence properties. PAES maintains an archived set of non-dominated solutions, which is actively used in the optimisation process. The algorithm was originally developed for continuous space problems; as such we develop representation and variation subroutines for our specific problem. Optimal configurations of DSLJ insert arrays within the sandwich core were identified for several of the dominant vibration modes.

3. RESULTS

Fig. 3a shows non-dominating solutions on a Pareto front after 6000 iterations on a cantilevered honeycomb sandwich plate. Similar results were found for a cantilever beam and simply supported plate and cantilever. The 52 optimal configurations that have the minimal added mass and the maximal modal loss factor are localised on the Pareto front. The potentially optimal configuration is plotted in Fig. 3b.



a b

Fig. 3: 3a. Non-dominating solutions on the Pareto front after 6000 iterations. 3b. A potentially optimal configuration of DSLJ damper on a cantilever honeycomb sandwich plate.

4. CONCLUSION

The PAES algorithm was successfully implemented and some optimal location and orientation of DSLJ dampers have been identified on a cantilevered honeycomb sandwich plate excited at its first mode of vibration. The optimal configuration has a high loss factor (0.0071) for a relatively low mass (0.114). It is clear that most of the DSLJ inserts tend to be located at the root of the cantilevered structure and orientated along the longest dimension of the plate. This configuration may act to maximise the shear strain energy in the viscoelastic material when the structure is vibrating given the dominant first mode is flexure.

References

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