Identification of vibration damping in 3D-printed lattice structures

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Abstract

As metallic 3D-printing opens the design space for lightweight structural applications, it also raises challenges in terms of low level vibration damping. Reducing the number of parts is avoiding some classical damping phenomena due to friction mechanisms in mechanical assemblies. In addition, metallic materials do not exhibit intrinsic viscous properties that could significantly contribute to structural damping. In this work, the damping properties of lattice-based structures and possible design solutions offered by Powder Bed Fusion are investigated. In particular, auxetic behaviour [1], passive energy transfer [2], and viscoelastic shear layer [3] could be considered. The approach consists in identifying promising concepts from numerical simulations, and validate them experimentally. Underlying questions of predictive capability of damping simulations and identification of damping properties from experiments are addressed. In this work, focus is put on the passive energy transfer.

I. Passive vibration absorber using beams : Numerical model

Nowadays, this problem is well known and well addressed using springs and masses. However, Powder Bed Fusion expand design freedom in such way that damping function can be implicitly integrated in the part design. In this work, absorbers are conceived as small circular beams connected to the skin of the sandwich beam (core is composed of lattice and connected with two skins, as shown in Figure 1). In this first technological demonstrator, resonators positions and geometry were randomly located with the single constraint to avoid contact between them.

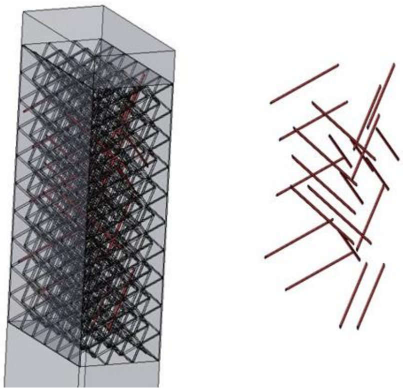

Figure 1 : Sandwich beam composed of two skins in black and 22 passive resonator beam in red

A Finite Element Model simulation was performed on Abaqus 2022 to estimate the absorbers' performance. The sandwich beam is excited in the massive base region (random response simulation with a constant PSD level) and the acceleration is measured at the top. The simulation results are shown in Figure 2. The energy dissipation brought by these 22 beam resonators leads to the reduction of acceleration from $12g$ to $10g$ (about 16%). The added mass of these beams compared to the whole system is about 0.8%, which is very low for that kind of passive vibration absorber. **Erreur ! Source du renvoi introuvable.**

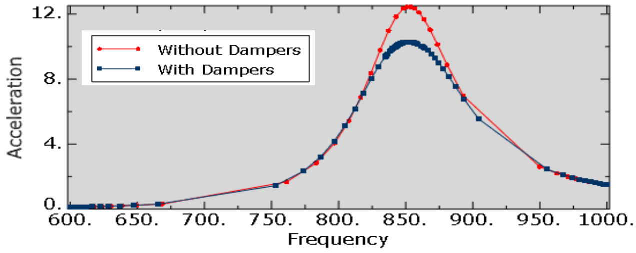

Figure 2 : Results of a random white noise excitation at the top of the beam

II. Passive vibration absorber using beams : Experimental results

A technological demonstrator was manufactured using Powder Bed Fusion process in aluminum (AS7G06), Figure 3. These two demonstrators were tested on a $10kN$ electrodynamic shaker using a sine sweep excitation of $0.1g$, $1.5g$ and $3.0g$ from 500 to $2000\ Hz$. The results of this test lead to a reduction of 50% of the amplification factor for the test at 1.5 and 3g. However no effect has been exhibited at 0.1g (Figure 4).

Figure 3 : Manufactured demonstrator (left without resonator ; right with resonators)

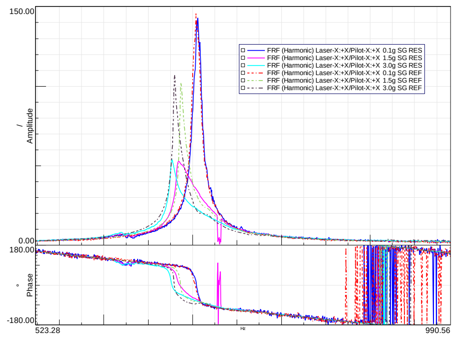

Figure 4 : Test results for the first resonance mode for 0.1g, 1.5g and 3g of acceleration

III. Conclusion and Perspectives

In conclusion, the use of beams as passive vibration absorbers has shown promising results in vibration damping (with a reduction of 16% of the acceleration in simulation and around 50% of the amplification factor in experimental tests) with a really small amount of added mass (around 0.8%). It is worth noting that the position and geometry of the beams was not yet optimized which mean these performances could be further improved.

The quantitative comparison of the simulation and experimental results highlights a difference in the natural frequency of the first resonance mode (848 Hz for the simulation and 705 Hz in experimental test) which requires further investigation, in particular the “as-manufactured” geometry and material properties of the demonstrator could play a significant role. It is also important to note that the simulation does not take into account any non-linear phenomena.

References:

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