BRAGG BANDS GENERATION IN BEAMS AND PLATES FOR MASS REDUCTION AND VIBROACOUSTIC PERFORMANCE

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1 Introduction

Most of the existing approaches for designing locally resonant metamaterials involve addition or inclusion of elements such as tuned mass dampers or masses following a periodic pattern [1]. Modifications to the geometry can also provide interesting results in the case of beams with corrugations [2] or for plates using periodic structuring [3, 4]. The primary focus of this study is on the generation of band gaps (Bragg bands) in aluminum cantilever beams and plates following a subtraction-based approach. Periodic cells are created by using a simple machining operation, that is periodically removing material in the thickness direction. The goal is to design structures that are lighter than their homogeneous versions, but that can nevertheless exhibit similar or improved vibroacoustic behavior.

2 Band gap generation in beams by periodic material removing

Regarding beams, the effects of the number of periodic cells along length and the thickness removal are studied for a fixed beam length. The upper part of Figure 1 shows the considered problem (the left part of the beam is clamped and the right part of the beam is free). The proposed cantilever beam configurations include a regular pattern that is created by periodic material removal. The beam consists of a base thickness denoted by h_1, with specific regions featuring a reduced thickness of h_2. Each unit cell within the periodic beam has a length of *d*, wherein a cell comprises two halves: the first half has a length of *d/2* with a thickness of h_1, followed by the second half with a length of *d/2* and a thickness of h_2. Several key parameters define the periodic beam, including *n* the number of cells, *L* the overall length of the beam, *w* the beam width and *f* the beam's section on which no material removal is achieved. The tested configurations include aluminum and polylactic acid (PLA) cantilever beams excited close to the clamped side. An automatic modal hammer vImpact-63 was used to apply a transient force with a mean amplitude of 10 N. Vibration velocity measurements are taken along the beam with a multipoint laser Doppler vibrometer (Polytec MPV-800) and processed using the extension Structural Dynamics Toolbox (SDT) from Matlab (simulations are also conducted using this toolbox). Ten consecutive measurements were performed for each beam with 10 seconds of waiting time between each test and *Complex average* was used to average the responses. Eight measurement points are positioned along the beam whose positions respect to the clamped end are indicated in the lower part of Figure 1.

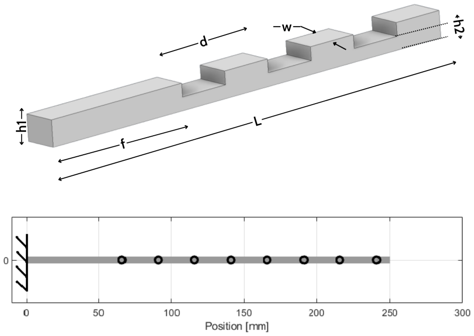

Figure 1: (Upper part) Illustration of the considered beams including discontinuities; (Lower part) Position of response measurement points.

The numerical and experimental results obtained for one of the beams (aluminium, 3 discontinuities, L = 250 mm, w = 20 mm, h1 = 3.2 mm, h2 = 1.6 mm) are provided in Figure 2. The measurement (thick gray line) and simulation (dashed black line) results for the machined beam are in good agreement. When compared with calculations made for a beam of homogeneous thickness (3.2 mm) or a beam of equivalent mass (a uniform beam with a thickness that would provide the same mass), these results also indicate a reduction of the vibration level in the whole frequency range, but especially above a frequency of 4500 Hz.

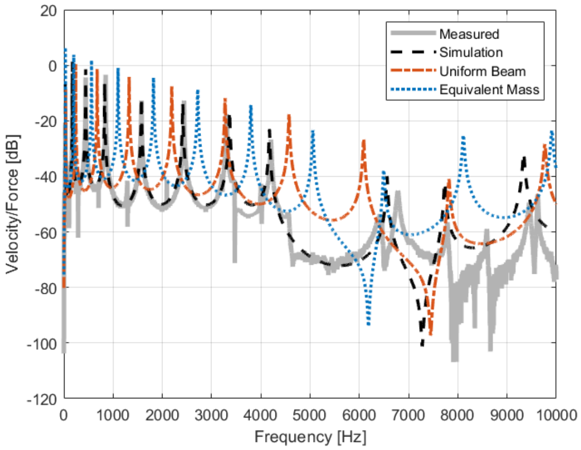

Figure 2: Simulation and measurement results for beam A5 (50 % thickness removal over three periodicities).

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3 Band gap generation in plates by periodic material removing

For plates, the results obtained in terms of sound transmission loss (STL) are provided. STL was evaluated for one homogeneous plate and one plate that includes periodic material removal along the diagonal direction (see Figure 3). The plates dimensions are 480 mm × 420 mm × 3.2 mm (length times width times thickness).

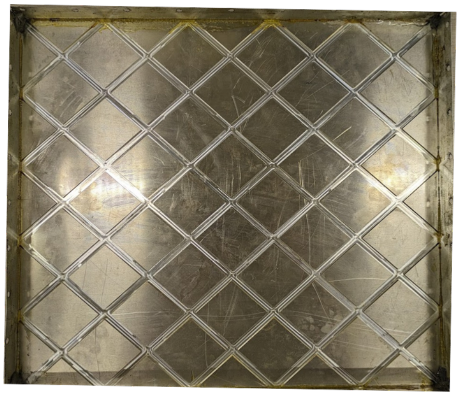

Figure 3: Picture of a panel machined in the diagonal direction.

Simply supported boundary conditions are achieved along the four edges of the panels using a dedicated procedure, and a double wall structure was built around the panel with silicone sealing along the edges to prevent acoustic leaks. The panels were mounted in the test window between coupled reverberant-anechoic rooms using a frame made of plywood with acoustic sealant and subjected to a Diffuse Acoustic Field excitation. Following standards, STL is determined using measurements of the spatially averaged sound pressure level in the source room L_p and of the spatially averaged average sound intensity level L_i over a scanning surface S_m on the receiving side (both in dB), STL $= L_p - L_i - 6 - 10\log_{10}(S_m/S)$ (with S the effective panel area, considered equal to the scanning area S_m so that the last term was neglected). L_p was obtained using a rotating and three fixed quarter-inch PCB microphones on the reverberant room side, while the average radiated sound intensity level L_i was measured in the anechoic room using a Bruel & Kjaer sound intensity probe composed of two half-inch microphones and a 12 mm spacer. Manual scanning was performed at a distance of 5 cm from the panel surface following recommended scan patterns. Results are provided in $1/3$th-octave bands in the 50-5000 Hz frequency range. The obtained results show that :

- The homogeneous panel performs better than the machined one in the 50 Hz and 63 Hz third octave bands (TOB), this being attributed to a reduction of the static stiffness,
- The results are nearly equivalent between the 100 Hz and 200 Hz TOB, a STL reduction is observed for the machined panel at the 250 and 315 Hz TOB and an equivalent STL for both panels in the 400 and 500 Hz TOB,
- From the 630 to the 5000 Hz TOB, the STL values obtained with the machined panel are always larger than its homogeneous equivalent, even in the critical frequency region (acoustic critical frequency ≈ 3750 Hz for standard 6061 aluminium).

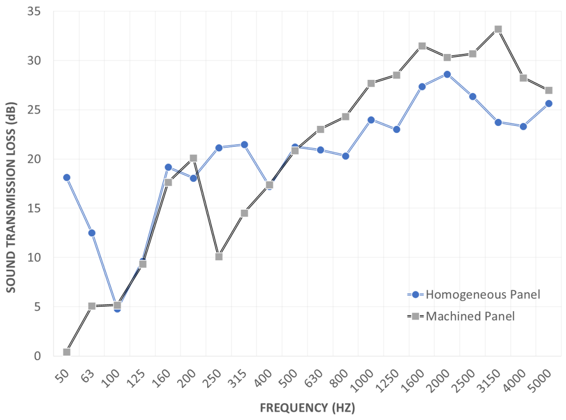

Figure 4: Sound transmission loss measurement results for an homogeneous panel and a machined panel.

4 Conclusion and perspectives

The obtained results generally indicate that periodic material removal using machining operations can be a simple but efficient way for the generation of band gaps in beam-like and plate-like structures. Compared with their homogeneous equivalents, the machined structures lead to an overall mass reduction together with generally improved vibroacoustic behavior.

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