Experimental vibration analysis of a beam with ABH stiffeners

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Abstract - In recent years, acoustic black holes (ABHs) have gained attention as a promising method for passive vibration control in engineering applications. This work experimentally investigates the use of ABHs in a stiffened beam to mitigate its vibrational response. The ABHs are embedded in the stiffeners rather than in the beam. Therefore, the structural integrity of the system is maintained. The study presents measured vibration responses of two stiffened beams excited by an impact force. The first case is a stiffened beam with traditional rectangular stiffeners, while the second case has ABH stiffeners. The ABH stiffeners are designed to match the surface area and moment of inertia of the rectangular stiffeners at the contact point with the beam, ensuring that both cases have similar weight and static stiffness. The experimental investigation explores two configurations: stiffeners without damping layers, and with constrained viscoelastic damping layers. The effect of the damping layers on the vibrational responses of both stiffened beams is examined. Results demonstrate the effectiveness of replacing traditional rectangular stiffeners with ABH stiffeners for vibration mitigation, highlighting the potential advantages of ABH technology in vibration reduction of stiffened structures.

1 INTRODUCTION

Acoustic Black Holes (ABHs) have emerged as a promising passive control technique for reducing vibrations in elastic structures (Pelat, et al, 2020). This technique works due to gradually decrease of the thickness of a structure following a power-law profile, which leads to a decrease in the wave speed, concentrating the energy at the ABH tip (Krylov, 2001 and Krylov, 2007). This work aims to integrate ABHs with stiffeners to maintain the structural rigidity while simultaneously reducing the vibrational response. An experimental analysis was conducted to assess the effectiveness of replacing traditional rectangular stiffeners with ABH stiffeners on reducing the vibrational response of a beam. Figure 1 shows the two steel beams used in the experiments: one with rectangular stiffeners and the other with equivalent ABH stiffeners. The equivalent ABH stiffeners are designed to have the same moment of inertia (at the contact point between the beam and stiffener) and same mass as the rectangular stiffeners. Two cases were tested, stiffeners without a damping layer, and stiffeners with constrained viscoelastic layers (CVLs). Each beam was subjected to an impact force at $x = 0\ \mathrm{m}$ (on the stiffener). The vibrational response was measured using seven accelerometers placed along the beam, both directly above the stiffeners and between them, as depicted in Figure 1. These accelerometers were equally spaced at intervals of $d/2$, where d is the distance between stiffeners ($d = 0.2\ \mathrm{m}$). The geometric properties of both beams are detailed in Table 1.

Table 1 - Geometrical properties of the beam and stiffeners.

Parameter	Rectangular stiffener	ABH stiffener	Beam
Thickness, $h_{\mathrm{R,ABH,b}}$ (m)	0.007	0.010	0.010
Length, $L_{\mathrm{R,ABH,b}}$ (m)	0.124	0.200	1.000
Tip thickness, h_{tip} (m)	-	0.006	-
Damping layer thickness, h_{dl} (m)	0.004	0.004	-
Damping layer length, L_{dl} (m)	0.124	0.124	-

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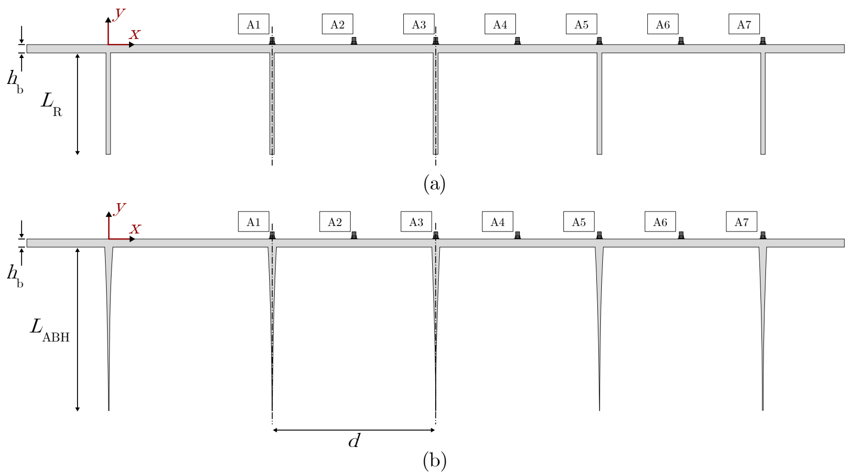

Figure 1 – Schematic of the finite beams and respective accelerometer positions. (a) rectangular-stiffened beam and (b) ABH-stiffened beam.

2 VIBRATION RESULTS

Figure 2 shows the transmissibility between accelerometers A1 and A7 for the cases (a) without damping layers and (b) with CVLs. When comparing Figures 2(a) and (b), it is noticeable that the addition of damping layers to the ABH stiffeners led to a higher mitigation of the vibration response when compared to the rectangular stiffened beam. From Figure 2(b), it can be seen that the ABH-stiffened beam is clearly more effective in attenuating the vibrational response, reaching up to a 33 dB reduction at 261 Hz. These results underscore the effectiveness of the ABH stiffener in reducing vibrational responses when compared to a traditional rectangular stiffener.

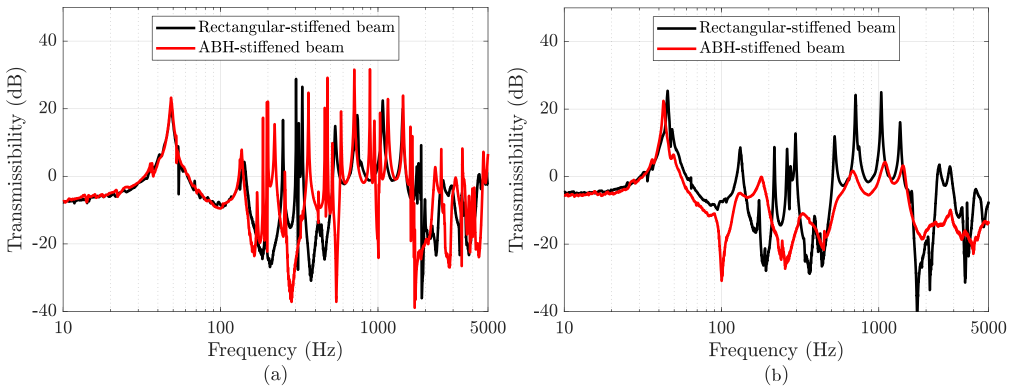

Figure 2 – Comparison of transmissibility between accelerometers A1 and A7, considering the stiffened beam with stiffeners (a) without damping layers and (b) with CVLs.

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