1. Introduction

This study starts with a simple question: can we efficiently reduce the vibration of plates or beams using a lightweight structure that occupies a small space? As an efficient technique to dampen vibration, we adopted the concept of an Acoustic Black Hole (ABH) with a simple modification of the geometry. The original shape of an ABH has a straight wedge-type profile with power-law thickness, with the reduction of vibration in beams or plates increasing as the length of the ABH increases [1].

Kyllov et al. increased the damping performance of ABH by attaching a thin damping material to a small region of the ABH tip [2]. O'Boy et al. experimentally and numerically evaluated the effect of damping material attached to the tip of the ABH and the exponent m on the damping performance of ABH [3]. Bowyer et al. experimentally investigated the effects of geometrical and material imperfection of the ABH tip on the damping performance [4]. Lee et al. proposed a curved ABH with Archimedean spiral shape, which can increase space efficiency maintaining the damping performance, and numerically investigated its damping performance [5].

However, in real-world applications, there exists an upper bound of the length of an ABH due to space limitations. Therefore, in this study, the authors propose a curvilinear shaped ABH using the simple mathematical geometry of an Archimedean spiral, which allows a uniform gap distance between adjacent baselines of the spiral [2].
2. Generalized Geometry and Experimental Validation

The curved ABHs manufactured in this study are divided into arc shaped ABH with constant curvature and spiral ABH with varying curvature. The spiral shape of the spiral ABH follows the Archimedean spiral with a constant gap distance between the baseline and slow change in curvature. The polar equation of the Archimedean spiral is given in Eq. (1).

\[ r = a + b\theta \] (1)

Parameter \(a\) determines the angular rotation of the spiral profile, and \(b\) determines the gap distance between the baseline. The Archimedean spiral used in our study was determined from \(a = 0\) mm and \(b = 1.91\) mm/rad for 240 mm arc length. Figure 1 shows the geometry of ABHs manufactured here.

Now, let’s compare the numerical simulation results and the experimental results for a 240 mm arc shaped ABH of \(\kappa = 6.55\) m\(^{-1}\). For numerical simulation, the governing equation is the Navier’s equation and free boundary condition was imposed on every boundary. Three-dimensional analysis was performed by applying a harmonic load to the center point of the ABH-attached plate. The reference driving point mobility was 1 m/s/N in the frequency response function throughout the paper. Numerical simulations were performed from 20 Hz to 6000 Hz at 20 Hz with an increment of 20 Hz in the frequency domain. Figure 2(a) shows the geometrical shape of ABH used for experimental validation, and Fig. 2(b) is the comparison of the simulation results and the experimental results. As depicted in Fig. 2(b), the simulation result shows good agreement with the experimental results.

![Figure 1](image1.png)
Figure 1. (a) Spiral ABH, (b) Arc ABHs for \(\kappa = 2.18, 6.55, 13.09,\) and \(19.64\) m\(^{-1}\)

![Figure 2](image2.png)
Figure 2 – Comparison of simulation results and experimental results for arc ABH for \(\kappa = 6.55\) m\(^{-1}\)
3. Conclusion

Acoustic black holes with geometrical modification by using arc and spiral curves were introduced as a generalized definition of ABH. In addition, the spiral ABH was manufactured using the EDM and the vibration damping performance was experimentally verified. The arc shaped ABHs with constant curvatures were manufactured and the experimental results and simulation results were compared to investigate the effect of curvature on the driving point mobility. The effects of arc length of spiral ABH and damping material treatment on vibration damping were experimentally investigated. The experimental results from the manufactured spiral ABH show that the driving point mobility is effectively reduced by the combined effect of the power-law profile of the spiral ABH and the small amount of damping material. The spiral ABH is expected to be an alternative of conventional vibration damping technique for their lightweight and compact size while maintaining the damping performance.

REFERENCES