Contraction Performance of a Structure Contracted by Sound Waves for Mechanical Metamaterials

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Recently, the artificial materials, so-called metamaterials[1] have attracted attention due to their special properties. According to the progress of 3-D printing technologies, mechanical metamaterials[2] have also been studied. In the mechanical metamaterials, various artificial material properties can be designed by the structure of the unit cell of the regular structures.

In this study, the actuation performance of a mechanical metamaterial that responds to sound waves was investigated. A schematic figure of the unit cell of the metamaterial is shown in Figure 1, right. Hexagonal frames are connected, and a membrane is attached to the upper frame. The bottom of the lower frame is fixed, and sound waves having the resonant frequency are applied to the membrane surface. The unit cell can keep the contraction deformation during the sound wave application. The deformation performance of the unit cell was investigated theoretically and experimentally, as shown in Figure 1, middle, and an equation below. The shape of the membrane and the frame were improved by the results of the theoretical investigation.

$$\frac{m_1(d^2-z^2)+(m_2+m_3)z^2}{d^2-z^2}\ddot{z}+\frac{(m_2+m_3)d^2}{(d^2-z^2)^2}z\dot{z}^2+\frac{c_1(d^2-z^2)+(4c_2+c_3)z^2}{d^2-z^2}\dot{z}$$
$$+\frac{z(4dk_2+dk_3+\sqrt{d^2-z^2}(k_1-4k_2-k_3))}{\sqrt{d^2-z^2}}z=F\cos\theta$$

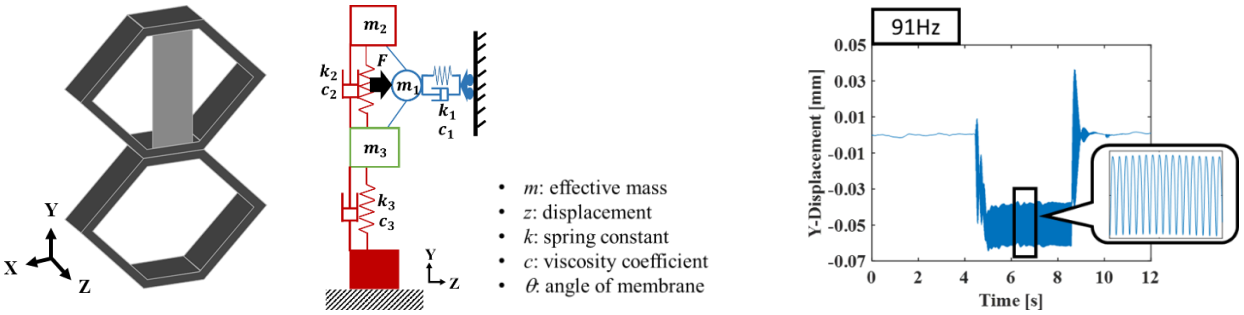

Figure 1. Schematic figure of the unit cell, left, the mechanical model for the theory, middle and the displacement profile obtained by an experiment, right.

The y-displacement profile at the top of the unit cell from an experiment is shown in Figure 1, right. The sound waves having a resonant frequency were applied for about 4 seconds from 4 to 8 seconds. The unit cell then kept the contraction displacement. It is expected that the mechanical metamaterial using the developed unit cell will be realized in the future.

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