Long-stroke hydraulic damping device and verification of its vibration characteristics

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Abstract. This study proposes a new origami-type axially free folding hydraulic damper to improve the structural characteristics of the conventional cylindrical shape with a limited effective stroke relative to the overall length. Firstly, the basic design equations for the proposed paper-folding hydraulic damper are derived by demonstrating that the folding line cylinder on the sidewall always satisfies the foldable condition of the paper-folding hydraulic damper. Next, the fluid flow characteristics inside the origami hydraulic damper and in the flow path were analyzed; it was determined that the actual damping force exerted on the origami damper was proportional to the square of the velocity of motion. Equations of motion were developed considering the derived damping force equation, and a vibration analysis method using the Range–Kutta numerical analysis technique was established. A validation test system with an origami hydraulic damper in a mass-spring vibration system was developed, and vibration tests were performed with actual seismic waves to verify the damping characteristics and effectiveness of the origami hydraulic damper.

Introduction

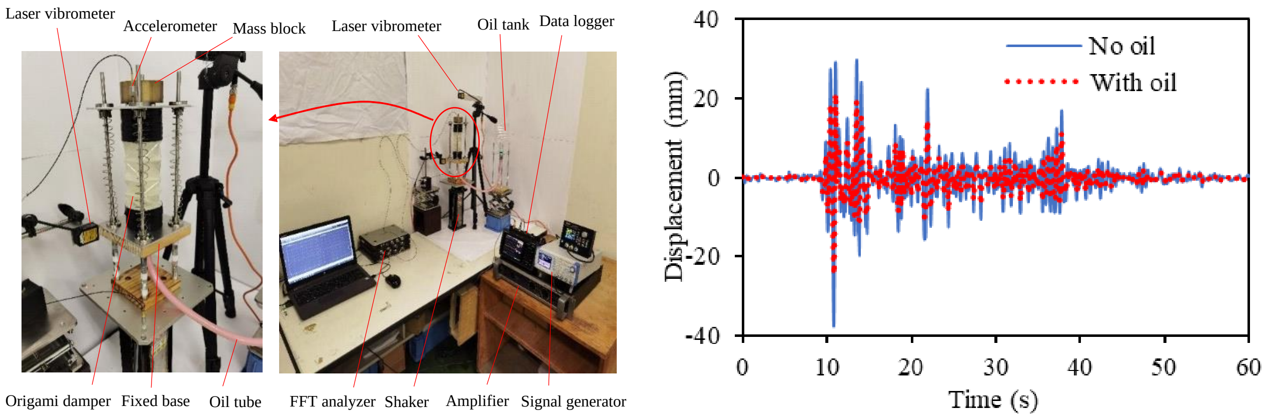
Hydraulic dampers are primarily used as components for absorbing vibration and shock energy. Nevertheless, the majority of existing hydraulic dampers are of the metal cylinder type, wherein the actual lengths of extension and contraction are limited compared to the total axial length, which limits their applicability when the installation space is limited. New techniques are required for weight reduction by replacing metal cylinders with dampers made of lightweight nonmetallic materials.

Therefore, an experimental setup, shown in Figure 1a, was developed to study the performance of an inverted spiral origami-type hydraulic damper. The experimental setup was composed of an origami damper, elastic spring, mass block, frame, fixed plate, moving plate, and oil tube. As shown in the figure, a validation test system was fabricated to perform practical vibration tests.

Results and discussion

Figure 1b shows the response displacement of the time series when shaking was measured using seismic waves. The solid blue line indicates the measurement results without hydraulic oil, whereas the red dotted line indicates the measurement results with hydraulic oil.

The results in Figure1b indicates that the response displacement of the scenario wherein hydraulic fluid is included are apparently smaller than the response displacement of the scenario in which no hydraulic fluid is included when vibrations are applied using seismic waves. It was evident that the proposed origami hydraulic damper provided a dependable damping effect under complex excitation conditions and could be used as a vibration-damping device.



(a) (b)

Figure 1: (a) Origami damper device and vibration experiment system. (b) Spectral distribution of displacement.

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