Simulation of a Dual Axis MEMS Seismometer for Building Monitoring System

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Abstract

A dual axis MEMS seismometer targeted for building monitoring system has been simulated for a full scale of ±5g acceleration. The design uses the capacitive effect for vibration sensing. This comb drive capacitive MEMS seismometer consists of 8 springs with two proof masses. The device is very low cross axis sensitive (almost negligible cross axis error). The cross axis sensitivity of x-axis is 0.001% towards y-axis, while the y-axis cross axis sensitivity towards x-axis is 0.000005% when maximum input acceleration of 5g is applied. COMSOL Multiphysics® software has been used to compute the eigenfrequencies and static responses of the device. From simulation results, the displacement sensitivities of x-axis=0.114μm/g and y-axis=0.204μm/g while capacitive sensitivities of X-axis=0.551pF/g and Y-axis= 0.346pF/g were calculated.

Two designs were evaluated in order to get a final desired design. The first design with a crab leg and the second one with a folded springs on x-axis were simulated and compared the cross axis errors. After finite-element method (FEM) simulations using COMSOL Multiphysics, the second design was selected on the basis of their low cross axis sensitivities (almost negligible) and desired resonant frequencies. The crab leg and folded springs were simulated and evaluated by applying force on x-direction and checking the deformation on y-direction. Folded spring was found to be low deformed toward y-direction, as shown in Figure 1. Figure 2 shows the final selected design.

For mechanical analysis, the design was simulated using COMSOL Multiphysics to investigate the mode shapes, deflections, and cross axis sensitivities. It has been reported in various studies [8-10] that COMSOL Multiphysics can give accurate results with high confidence for developing customized solutions.

In study 1, the first six resonant modes were analyzed in which the first two modes of interest are shown in Figure 3.

Study 2 illustrates the normal operation of a seismometer by applying the input acceleration from -5 to 5 g and computing the resulting displacement of the proof mass. The input acceleration is simulated as a load vector in two directions.

Minimum cross-axis sensitivity indicated a good sensor design. Measurement results show that the deflection is very low towards other direction when a maximum input acceleration of 5g is applied in the main direction. The cross-axis sensitivities of the proposed seismometer have been summarized in Figure 4.

Reference

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Figures used in the abstract

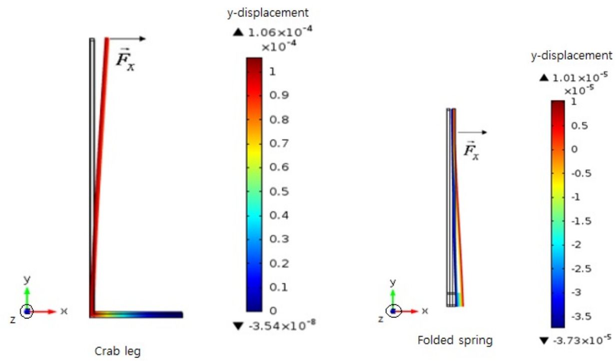

Figure 1: Springs submitted to a force in x-direction; colors show the deformation in y-direction.

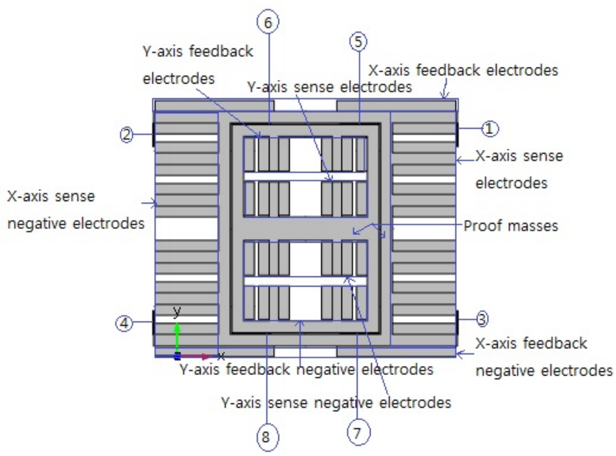

Figure 2: Schematic and operating principle of the proposed dual axis-seismometer. (1) x-axis spring. (2) x-axis spring#2. (3) x-axis spring#3. (4) x-axis spring#4. (5) y-axis spring. (6) y-axis spring#2 (7) y-axis spring#3. (7) y-axis spring#4. (8) y-axis spring#5.

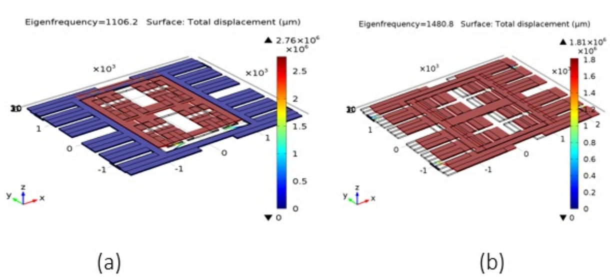

Figure 3: The Eigenfrequency simulation results for the desired modes (a) y-axis and, (b) x-axis.

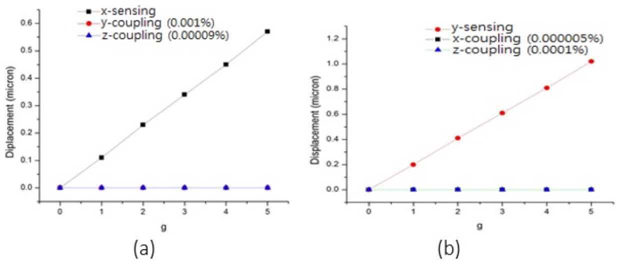

Figure 4: Cross-axis sensitivity of, (a) x-axis towards y- and z-axes, and (b) y-axis towards x- and z axes.