Multi-Axis Electromagnetic Moving-Coil Microactuator

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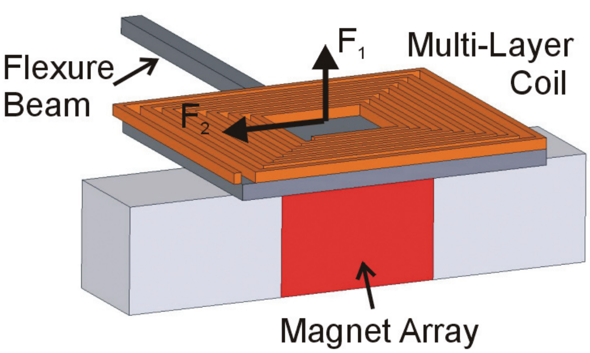
Sponsorship: NSF

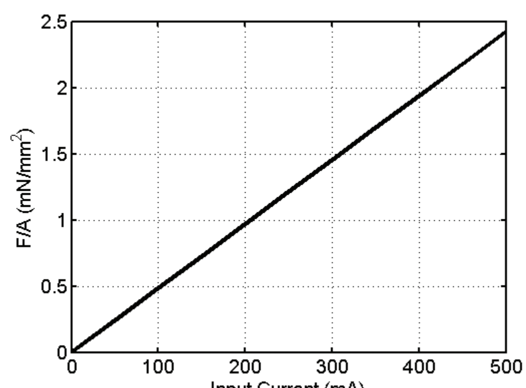
Electromagnetic (EM) micro-actuators are becoming increasingly important in micro-systems requiring moderate forces operating over a large range of motion. The applications that benefit from the performance advantages of EM micro-actuators include micro-scanning systems, micro-fluidic pumps, and positioning systems. Advantages of electromagnetic actuation over other classes of micro-actuators include low-voltage operation, moderate power density, large operating distances, linear response, multi-axis capability, and high bandwidth [1]. This work leverages the advantages of EM interactions to design a moving-coil micro-actuator that enables two-axes actuation with moderate forces (10+ mN) over large operating distances (10+ micrometers) at moderate mechanical frequencies (1+ kHz) using assembled permanent magnet field sources.

The two-axes electromagnetic actuator consists of moving coils suspended on compliant silicon flexure springs above an array of 3 rectangular permanent magnets, as shown in Figure 1. The phase of the stacked coils results in Lorentz forces that are independently controllable in-the-plane and out-of-the-plane. The coil-spring fabrication scheme includes electroplating of copper coils, followed by a deep reactive-ion etch (DRIE) to pattern and release the compliant springs. Millimeter-sized permanent magnets are then aligned to the spring layer using an alignment chip. Successfully fabricated micro-coil structures have been shown to sustain current densities over 1000 Amps per square millimeter.

A quasi-analytic electromagnetic force model for the device has been developed and experimentally validated against a centimeter-size bench-level prototype actuator. Figure 2 shows the predicted lateral-actuator force per coil-footprint versus current input for a typical actuator with 900-μm^2 coil cross section. The actuator will be implemented in a high-speed meso-scale nano-positioner with applications in nano-fabrication and scanning-probe microscopy. When equipped with this micro-actuator, the nano-positioner is expected to be able to position millimeter-sized samples in six axes of motion (x, y, z, tip, tilt, yaw) with repeatability better than 10 nanometers at frequencies greater than 1 kHz.



▲ Figure 1: Schematic representation of the electromagnetic moving-coil microactuator.



▲ Figure 2: Predicted force per coil area versus input current for a typical EM moving-coil microactuator.

REFERENCES

[1] O. Cugat, J. Delamare, and G. Reyne, “Magnetic micro-actuators and systems (MAGMAS),” *IEEE Transactions on Magnetics*, vol. 39, no. 5, pp. 3607-3612, 2003.