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Development of a novel ultrasonic motor resonator using topology optimization

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Abstract

The use of topology optimization in the design of a novel stator for an ultrasonic motor (USM) is investigated. The design challenge is to produce a stator, with two resonant modes whose frequencies are in a ratio of 1:2. When driven together, these modes result in a contact point trajectory in a figure of eight shape. As a result, only one electronic amplifier is required to drive the proposed device. In contrast traditional travelling wave USM, with elliptical contact point trajectories, require two modes with equal resonant frequencies to be driven 90° out of phase, and therefore require two amplifiers, one for each mode. To achieve a suitable stator design, a slightly unconventional topology optimization problem formulation is proposed, in which the objective function is to minimize the amount of material with intermediate density, while satisfying a constraint related to the frequency ratio of selected resonant modes. The planar design produced using the optimization procedure was refined using a detailed three dimensional finite element analysis. A prototype of the proposed stator design was manufactured and experimentally characterized. Scanning laser vibrometry measurements from two positions were used to measure the figure of-eight motion. Finally, the stator was fitted with a preloaded slider to form a simple linear motor demonstrator which was characterized experimentally. The prototype motor produced a slider speed of 14 mm/s reversibly and a maximum force of 50 mN.

Keywords Topology optimization – Lissajous pattern – Piezoelectric ultrasonic motor