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Magnetically Driven Traveling Wave Propagation in Magnetically Active Elastomers

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This work presents an experimental study of traveling waves in magnetically active elastomers (MAEs). MAEs consist of magnetic particles embedded in silicone matrices, allowing them to respond to external magnetic fields. Piezoelectric actuators are among the most widely used actuation mechanisms for conventional small-scale robotics, but their rigidity limits their applicability in soft robotic systems. This work explores the adaptation of piezoelectric traveling-wave actuator principles to soft robotics using MAEs.

Vibrating MAE systems have previously been explored for locomotion applications [1]. They utilize asymmetric structures to generate the friction required for directional movement. Conventional piezoelectric actuators employ the superposition of vibration modes to generate a traveling wave [2]. The experiments presented here apply the same operating principle to MAEs. Each point along a traveling wave follows an elliptical trajectory, where the horizontal motion at the wave peaks generates translational force. Reversing the phase shift of the applied magnetic fields changes the propagation direction of the traveling wave.

An MAE beam containing hard magnetic particles was permanently magnetized so that it could both attract and repel under externally applied magnetic fields. Two electromagnetic coils were positioned beneath the beam ends and driven with sinusoidal signals generated by an arbitrary waveform generator. High-speed videos were recorded to track selected points on the beam surface. The elliptical trajectories of these points were analyzed to evaluate their consistency in direction and aspect ratio. The excitation frequency was varied until the elliptical trajectories became increasingly uniform. The convergence of these trajectories validates the formation of a traveling wave and demonstrates the potential of MAEs as traveling-wave actuators for soft robotics.

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