Force control using internal spring in electrostatic linear motors and switching between position and force control

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Abstract—This paper proposes a method for controlling force and position in a synchronous direct-drive electrostatic linear motor. Using a spring-like behavior of synchronous motors, the proposed controller regulates the contact force in a manner similar to that of series elastic actuators. Discussions regarding similarities and differences between series elastic actuators and the proposed method imply that their dynamic behaviors are different. The proposed controller consists of a force control part and a position control part, one of which is automatically selected based on the operating conditions. The position and force controllers each independently command the velocity based on the position or force error. The lower of the two velocities is selected, allowing a smooth automatic transition between the two control modes. Based on the selected velocity, the driving signal is calculated under the assumption of synchronous operation and fed to the actuator. The proposed control method is simulated and experiments are performed using prototype electrostatic linear motors. The experimental results confirm the smooth transition between the position and force control modes, as well as the good controllability of the contact force.

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