Experimental Verifications and Temperature-Dependent Hysteresis Modeling of a Piezoelectric Cantilever for High Precision Motion Control

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The global research in the areas of modern mechatronic systems and micropositioning is expanding. Recently, high precision positioning techniques have become widely used in several applications related to semiconductors, biomedical science, optics, haptics, and microscopy. For example, theoretical work in molecular manufacturing has highlighted the need for fraction of a nanometer and accurate nano-positioning manipulators that simultaneously have a wide range of motion over a range of operating conditions. This, in turn, requires a dramatic improvement in two interrelated robotic components, namely, actuators and controllers.

Piezoelectric material-based actuators can perform sub-nanometer moves at high frequencies because they derive their motion from solid-sate crystalline effects. Indeed, manipulators driven by piezoelectric material-based actuators have been commercially available, which allows us to find reliable and practical control solutions that enable the manipulators to achieve high speed and position accuracy over a wide environment range. However, piezoelectric material-based actuators have shown strong hysteresis nonlinearities between the input voltage and the output displacement. It is important to mention that most of these actuators are sensitive to the variation of the surrounding temperature [1].

This study performs experimental work to characterize the effect of the temperature on the hysteresis nonlinearities of a piezoelectric material-based cantilever actuator. Then, a temperature-dependent generalized Prandtl-Ishlinskii (TD-PI) model is proposed and developed in order to have a hysteresis model considers the temperature as

$$y(t)=\Gamma[\mathrm{u}(t),\ T(t)]$$

where is $u(t)$ is applied input voltage, $T(t)$ is the input temperature, and Γ is a phenomenological operator-based hysteresis model considers the generalized Prandtl-Ishlinskii model [2] and the temperature effects. It is important to mention that the main objectives of this study are

- Performing laboratory experiments to characterize the temperature-hysteresis behavior of a piezoelectric cantilever under different operating conditions, and
- developing a temperature-dependent Prandtl-Ishlinskii model in order to propose a real-time control technique that reduces the positioning errors of piezoelectric material-based actuators in precision motion control under different temperatures.

Future work will consider robust control system [3] to reduce the hysteresis nonlinearities with temperature effects in real time system.

References

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