Efficient Computational Model of Hysteresis

A useful approximate model applies to quasistatic displacements.

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A recently developed mathematical model of the output (displacement) versus the input (applied voltage) of a piezoelectric transducer accounts for hysteresis. For the sake of computational speed, the model is kept simple by neglecting the dynamic behavior of the transducer. Hence, the model applies to static and quasistatic displacements only. A piezoelectric transducer of the type to which the model applies is used as an actuator in a computer-based control system to effect fine position adjustments. Because the response time of the rest of such a system is usually much greater than that of a piezoelectric transducer, the model remains an acceptably close approximation for the purpose of control computations, even though the dynamics are neglected.

The model (see Figure 1) represents an electrically parallel, mechanically series combination of backlash elements, each having a unique deadband width and output gain. The zeroth element in the parallel combination has zero deadband width and, hence, represents a linear component of the input/output relationship. The other elements, which have nonzero deadband widths, are used to model the nonlinear components of the hysteresis loop. The deadband widths and output gains of the elements are computed from experimental displacement-versus-voltage data. The hysteresis curve calculated by use of this model is piecewise linear beyond deadband limits.

Figure 2 presents a plot of the measured displacement of one piezoelectric transducer versus the applied potential. Overlaid on this plot is the piecewise-linear displacement-vs.-voltage curve computed by use of the model. In this case, the use of 13 parallel elements in the model was found sufficient to make the model approximate the experimental data within acceptably small error.

This work was done by Joel Shields of Caltech for **NASA's Jet Propulsion Laboratory.** *Further information is contained in a TSP (see page 1).*

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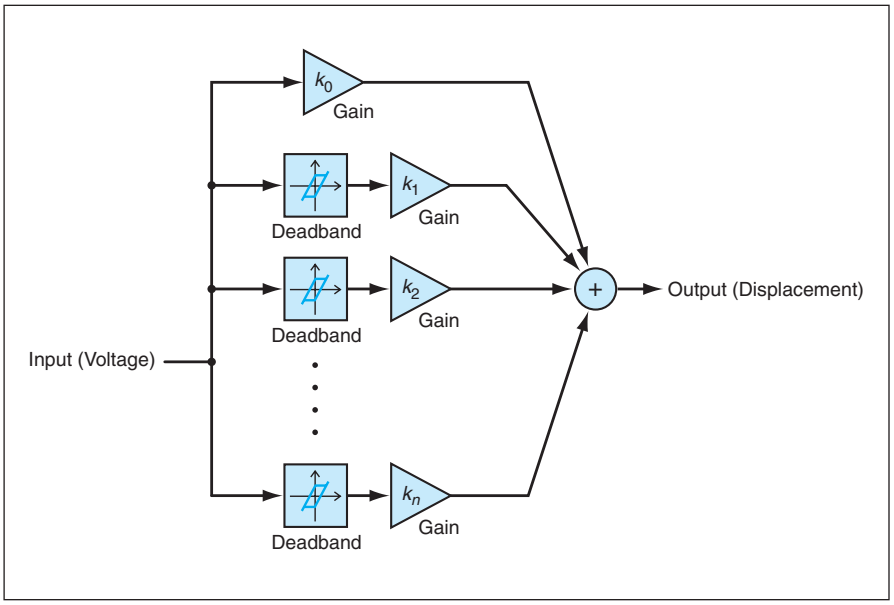

Figure 1. **Backlash Elements** comprising deadband and output-gain subelements are combined to construct a piecewise-linear mathematical model that approximates the nonlinear hysteretic response of a piezoelectric transducer.

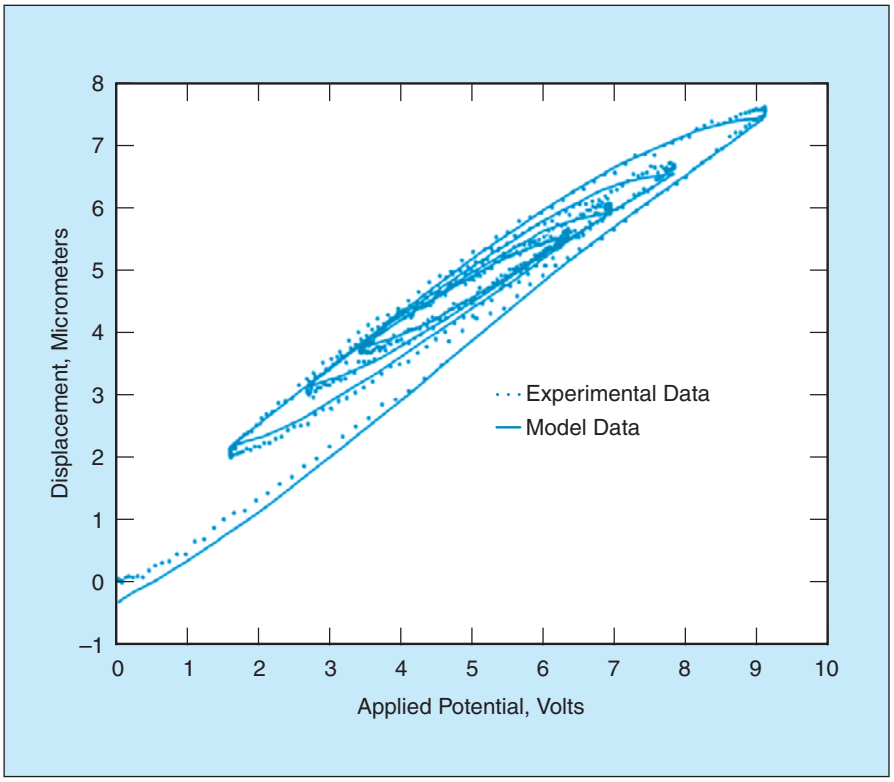

Figure 2. The **Displacement of a Piezoelectric Transducer** in response to an underdamped step voltage command was measured. It was also calculated by use of a model like that of Figure 1.