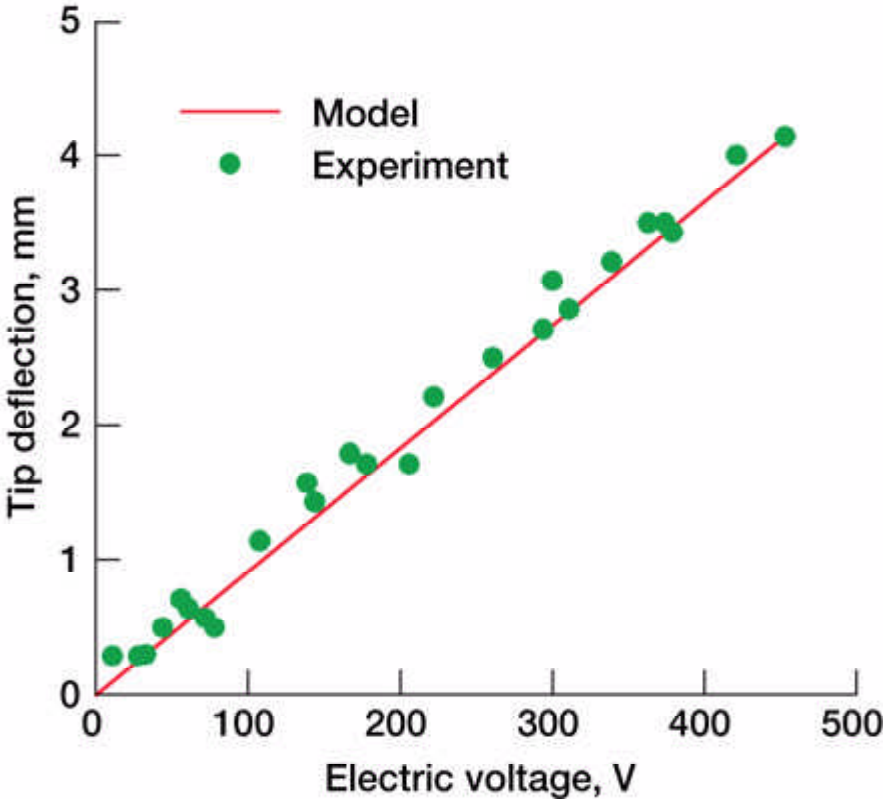
Finite Element Analysis of Morphing Piezoelectric Structures Studied

The development of morphing aerospace structures that optimize their shape offers the potential to significantly improve the performance of existing airplanes. These morphing vehicles will operate with new capabilities to reduce noise, damp vibrations, manipulate flow, and monitor damage. Piezoelectric materials represent one of the popular materials currently being investigated for applications in morphing structures.

In-house research efforts at the NASA Glenn Research Center have been directed toward developing comprehensive analytical models to facilitate the experimental characterization of piezoelectric materials. These materials present unique modeling challenges because of their complex, coupled mechanical, electrical, and thermal behaviors. To develop analytical models, we implemented a unique layerwise representation that captures the coupled responses at the constitutive level and introduces the electric potential and temperature, along with the displacements, as state variables in the analysis. This unified representation leads to the inherent capability to model both the sensory and active behavior of piezoelectric materials. Corresponding finite element equations were derived and implemented into beam, plate, and shell elements to provide a flexible computational tool for the static and dynamic analysis of arbitrary piezoelectric structures.



Model prediction of a piezoelectric polymer bimorph beam under applied active voltages compared with experimental results.

Long description Predicted free-end displacements of a piezoelectric polymer bimorph beam obtained by applying active voltages between 0 and 500 V compared with experimental results.

Current research efforts have successfully validated the accuracy of the finite element codes with published experimental results (ref. 1). The graph shows the predicted deflection of a piezoelectric-polymer bimorph beam under various applied active voltages, along with the experimental results. Good agreement is observed between the current analysis and experiment. The bimorph beam represents one of the common actuator configurations of piezoelectric materials that will be used as elements of morphing structures.

Reference

1. Lee, Ho-Jun: Finite Element Analysis of Active and Sensory Thermopiezoelectric Composite Materials. NASA/TM-2001-210892, 2001.

Glenn contact: Dr. Ho-Jun Lee, 216-433-3316, Ho-Jun.Lee@grc.nasa.gov
Author: Dr. Ho-Jun Lee

Headquarters program office: OAT
Programs/Projects: RAC