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Optimization of the Material Composition of Functionally Graded Piezoelectric Bending Actuators

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Summary

Piezoelectric bimorph actuators and sensors are widely used in engineering. In order to generate a bending deformation, it requires two bonded piezoelectric layers with opposite polarization direction or two electric fields with opposite direction along the thickness of the bimorphs. In traditional bimorph, the bonding interface of piezoelectric layers and electrodes is not strong enough for long-time service due to weak adhesive layer and large stress discontinuity and concentration. Nowadays, the concept of functionally graded material (FGM) was introduced into the fabrication of piezoelectric bimorphs to improve the stress concentration due to the discontinuity of materials in traditional bimorphs. Moreover, the gradient of the material properties, including the elastic constants, piezoelectric coefficients and dielectric constants, has remarkable influence on the performance of the bimorph, such as generated output displacements or electric potential. Consequently, the design of the gradient of the material is possible to obtain the optimal objective. This work develops a sub-parametric graded finite element to model the FGM piezoelectric bimorph based on two-dimensional theory of piezoelectricity. Unlike iso-parametric element, sub-parametric element has a lower degree of interpolation on the coordinates than on the displacements. It is specially available for the straight-sided eight-node quadrilateral or twenty-node brick to save the calculation effort without loss of accuracy. Moreover, if the shape of the element is rectangular or cuboid, the analytical expression of the stiffness matrix of the element can be obtained. It offers the most advantage in the optimization procedure, in which structure analysis based on FEM must be repeated multiple times to search the optimal objective. Simultaneously, the analytical expression can also be obtained for the gradient of the stiffness matrix with respect to design variables, which is very useful in the sensitivity analysis. Sequential quadratic programming (SQP) method is then adopted to construct the optimization algorithm and it is implemented by MATLAB. Finally, some numerical examples are presented to demonstrate the present method.

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