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Analysis of Piezoelectric Actuators Under Mechanical and Electrical Loads

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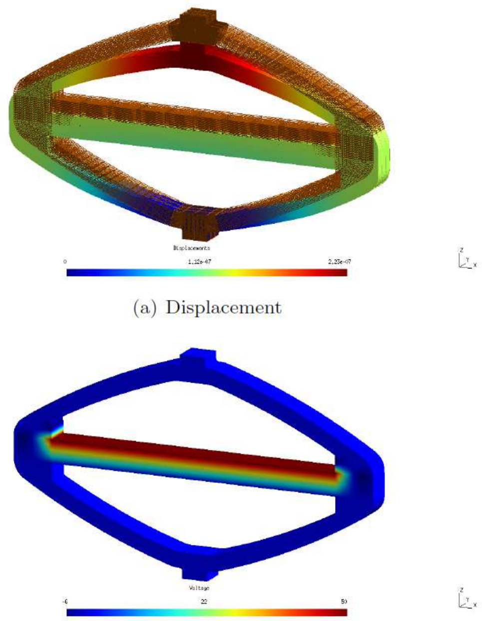
The use of piezoelectric actuators and sensors is very promising in engineering applications. Their performances, in terms of actuation frequency and accuracy, make these devices suitable for many applications. On the other hand, the design of piezoelectric devices requires refined computational approaches in order to deal with multi-field analysis. As it is known, the piezoelectric materials are, in fact, able to couple the electric and the mechanical fields. In other words, when an electric field is applied to a piezoelectric patch, a strain field is generated (actuator). Conversely, an electric field is originated if a deformation is imposed (sensor).



(a) Displacement

(b) Voltage

Figure 1: Actuation of the amplified piezoelectric actuator

This work presents the analysis of complex structures including piezoelectric material under mechanical and electrical loads. A refined electro-mechanical beam formulation is used to study structures including piezoelectric materials (see [1]). The structural model is derived using the Carrera Unified Formulation (CUF) that allows refined beam models to be derived in a unified form (see [2]). The displacement field over the cross-section is approximated using 2D Lagrange polynomials. Three- (L3), four- (L4), and nine-point (L9) polynomials, which lead to linear, bi-linear, and quadratic displacement field are considered ([3, 4]). Finite element approximation is realized by employing the principle of virtual displacement in conjunction with CUF. According to CUF, stiffness and mass matrices as well as the loading vector are expressed in terms of *fundamental nuclei*, which do not depend on the order of the beam model.

The first part of the present work is devoted to the introduction of 1D CUF models and a description of the electro-mechanical constitutive equation is briefly discussed. A step-by-step assessment of the multi-field higher-order beam model is then provided. The multi-field model assessed in the first part of the present work is subsequently applied to complex structures (e.g., see Fig. 1) in order to better highlight its capabilities.

The results reported in the present work show the enhanced capabilities of the present model when applied to multi-field analysis and its performances in terms of computational costs are demonstrated. The analyses of different structures under mechanical and electrical loads show, in fact, that the model proposed is able to correctly deal with three dimensional smart structures. These model peculiarity make the refined beam elements for electro-mechanical analysis a good instruments for the analysis of smart devices.

References

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