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Refined 1D-Elements for multifields analysis.

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In the field of aeronautics, shape morphing has been used to identify those aircraft that undergo certain geometrical changes to enhance or adapt to their mission profile. In spite of that, there is not a clear definition of “shape morphing”. In general it is agreed that conventional hinged control surfaces or high lift devices, such as flaps or slats, cannot be considered as “morphing ” devices since they undergo discrete geometry changes. Reich and Sanders [1] listed the following major challenges of the shape morphing aircraft design: the requirement for distribuited high-power density actuation, structural mechanization, flexible skins and the control law development. Active materials are primary need to smart structures. These materials include piezoelectric materials, shape-memory-alloys, electrostrictive and magnetostrictive materials. Among them, piezoelectric materials, and in particular piezoelectric ceramics, are the most exploited. When inserted in lightweight structures, these materials can significantly affect the stiffness distribution. They do not only provide the sensing and actuating functions, but also carry the structural loads, becoming an important component of a composite structure. This raises the need for modeling and design tools which, by including the active material, are able to accurately estimate the mechanical, electric and coupling properties of the composite structure as a whole.

In the recent past, the Carrera Unified Formulation (CUF) has been used to refine two-dimensional models able to analyse multilayered structures in the case of multifield problems [2, 3]. In this work CUF was employed to develop one-dimensional models able to analyse multilayered structures in the case of multifield problems in order to study smart wings. CUF models are hierarchical since the order of the model is a free parameter of the formulation. This fundamental capability is obtained by exploiting the fundamental nucleus of the problem matrices. The fundamental nucleus is an $n \times n$ array whose formulation is independent of the order and the class of the model. The fundamental nucleus is exploited for the hierarchical assembly of the stiffness, mass and loading arrays with no need of *ad hoc* formulations. In the case of multi-filed problems n depends on the number of fields considered. For an electro-mechanical analysis n is equal to four because the variables considered are the three displacements (u,v,w) and the electric potential (ϕ).

This work deals with the analysis of a composite beam with piezoelectric layers. Figure 1 shows an example of the structure considered. A three-layer cantilever beam constituted by a substrate (bottom layer), adhesive (middle layer) and piezoelectric material (top layer) is considered. The substrate is made of isotropic aluminum of Gr/epoxy composite The beam dimensions are the following: $L = 0.1524$ m, $b = 0.0254$ m, $h_{piezo} = 0.001524$ m, $h_{adhesive} = 0.000254$ m, $h_{alum} = 0.01524$ m. The material properties are the following:

PZT
$(E_{33}, E_{22}, E_{11}, G_{32}, G_{31}, G_{21}) = (81.3, 81.3, 64.5, 30.587, 25.6, 25.6) GPa$
$(\nu_{32}, \nu_{31}, \nu_{21}) = (0.329, 0.432, 0.432)$
$(e_{14}, e_{24}, e_{15}, e_{25}, e_{31}, e_{32}, e_{33}, e_{36}) = (0.0, 12.72, 12.72, 0.0, -5.20, -5.20, 15.08, 0.0)$ m/V
$(\chi_{11}, \chi_{22}, \chi_{33}) = (1.305, 1.305, 1.15102) x 10^{-8}$ F/m
Adhesive
$(E_L, E_T, G_{LT}, G_{TT}) = (6.90, 6.90, 2.49, 2.49) GPa$

$(\nu_{LT}, \nu_{TT}) = (0.4, 0.4)$
Aluminum
$(E_L, E_T, G_{LT}, G_{TT}) = (68.9, 68.9, 27.60, 27.60)GPa$
$(\nu_{LT}, \nu_{TT}) = (0.25, 0.25)$
Gr/epoxy
$(E_L, E_T, G_{LT}, G_{TT}) = (132.38, 10.760, 70, 56.5)GPa$
$(\nu_{LT}, \nu_{TT}) = (0.21, 0.24)$

Static analyses were carried out by means of 1D CUF finite elements. Fig 2(a) shows the deformation in the case of a 12.5 kV current applied across the thickness of the piezoelectric layer. Fig 2(b) shows the potential in the case of a point load (1000 N) applied to the tip of the cantilever beam. Further results will be shown in order to validate the model proposed, considering different beam geometries and materials and including the modal analysis.

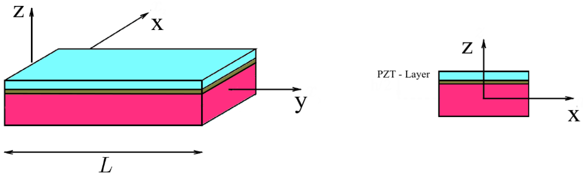
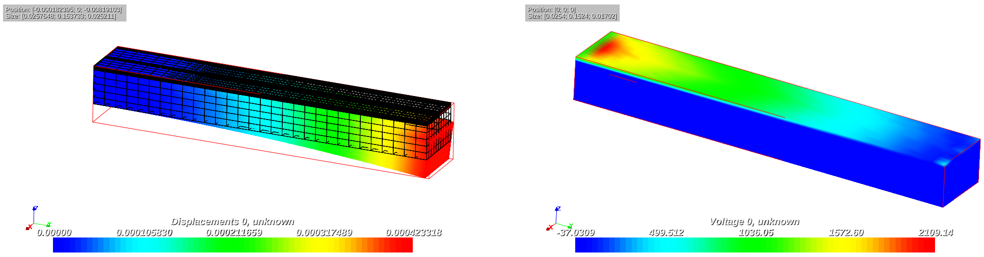


Figure 1: Piezoelectric Beam



(a) Actuating case

(b) Sesing case

Figure 2: Aluminum substrate beam in actuating and sensing cases

References

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