Thermo-Piezo-Elastic analysis of beam structures using node-dependent kinematics one-dimensional models

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The use of advanced materials may lead to a step forward in the performances of next-generation structures. The piezoelectric effect has been known since the 19^{th} century when the Curie brothers first noticed it. It consists of the conversion of mechanical to electrical energy and vice-versa. The use of such materials in structural design is very attractive because of their properties, and a great deal of efforts has been made to include the piezoelectric contribution in structural models. The coupling between piezo-ceramic and metallic materials can be an issue when the device has to operate at high temperatures. The large difference between the thermal expansion coefficients (CTE) could lead to large deformations [1]. On the other hand, this effect can be exploited in many applications, as in the energy harvesting [2].

This paper presents a new class of advanced FEM beam models with node-dependent kinematics for the accurate thermo-piezo-elastic analysis of beam structures. ESL (Equivalent Single Layer) models and LW (Layer-Wise) models have been used to derive FEM beam models with different kinematic descriptions from node to node in order to reach an optimal balance between accuracy and numerical solution costs. The models proposed are obtained by adopting the Carrera Unified Formulation (CUF) [3], which separates the displacement field into functions defined on the cross-section of a beam and nodal shape functions depending on the axial coordinates in the context of FEM. This feature permits the definition of different kinematics on each node and the interpolation of them over the element axial domain, leading to advanced beam models with a kinematic transition.

The present numerical models have been assessed using several results from literature and obtained using the commercial FEM code ABAQUS. The assessed models have then been used to analyze complex structures considering the effects of constant end variable thermal field. The piezoelectric material has been considered both in the case of an actuator as well as in the case of a sensor. The results show that the use of node-dependent kinematics models could lead to a reduction in the computational costs without a reduction in the accuracy of the results.

References

[1] *Zappino E., Carrera E., Rowe S., Mangeot C., Marques H., "Numerical analyses of piezoceramic actuators for high-temperature applications", Composite Structures (2016), 151, pp. 36-46.*

[2] *Zakharov D., Lebedev G., Cugat O., Delamare J., Viala B., Lafont T., Gimeno L. and Shelyakov A., "Thermal energy conversion by coupled shape memory and piezoelectric effects", Journal of Micromechanics and Microengineering (2012), 22(9).*

[3] *Carrera E., Cinefra M., Petrolo M., Zappino E. Finite Element Analysis of Structures through Unified Formulation, John Wiley & Sons Ltd (2014).*