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ASPECTS OF MESH DISTORTION AND LOCKING PHENOMENA IN FE MODELING OF THIN-WALLED PIEZOELECTRIC ACTIVE STRUCTURES

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ABSTRACT

During the last few decades, the idea of active structures has evolved into a new generation of high-performance structural and mechanical adaptive systems with integrated sensing, actuating and control capabilities. The development and design of active/adaptive systems are strongly influenced by available numerical tools for their modeling and simulation. The main requirements from such tools are reliability, accuracy and numerical efficiency. At the present state-of-the-art, the finite element method (FEM) as a predominant one is almost inevitably addressed on this matter.

The focus of this paper is put on certain aspects of the FE modeling of thin-walled piezoelectric active structures. Piezoelectric materials (e.g. PZT, PVDF) have established their place as materials for distributed sensors and actuators in active/adaptive structures. Hybrid composites – a combination of fiber-reinforced and piezoelectric laminae – are especially very powerful material systems. They offer a superior combination of mechanical properties of fiber-reinforced composites and multifunctionality of piezoelectric materials. The considered structures are subject to study by a large number of authors, which proves the complexity and, at the same time, the attractiveness of this field of research.

Modeling of thin-walled structures is driven by the recognition that the nature of their global behavior allows the condensation of the complex 3D-field to the essential ingredients of the structural response described by a 2D approach. They may consist of an arbitrary number of layers, a certain number of which is of piezoelectric nature. The piezoelectric layers are considered to be poled in the thickness direction and they operate on the "e_{31}-effect", which means that they couple the electric field applied in the thickness direction with the in-plane strain components. Generally, it is dealt with structures, the shape of which is double-curved in space, i.e. shells. Therefore, a "degenerated shell" finite element (Fig. 1) has been developed for modeling and simulation of the global behavior of both piezoelectric active and passive thin-walled structures [1]. The aspects that are considered in this paper are the influence of the mesh distortion and locking phenomena on the quality of the obtained results for coupled-

field problems. From that point of view, it is important to emphasize that the developed element belongs to the displacement-based finite elements, it uses full biquadratic shape functions and is an isoperimetric element, has 6 mechanical degrees of freedom at each of the 9 nodes and 1 electrical degree of freedom per piezoelectric layer.

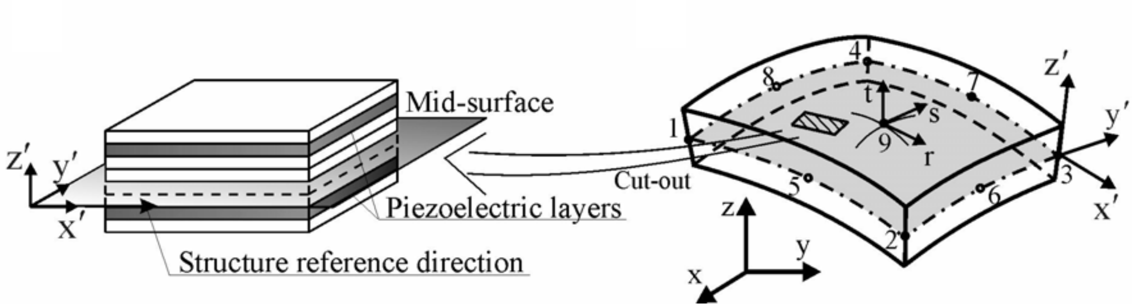

Fig. 1 Degenerated shell element for shell-like piezoelectric active structures

The influence of the mesh distortion and locking phenomena in the cases dealing with the purely mechanical field are well elaborated in a number of papers and text-books (e.g. [2]), covering a wide range of finite elements. However, the problem is of higher complexity when it is dealt with coupled-field problems. Regarding mesh distortion, especially the difference between the actuator and sensor cases is to be emphasized and closer discussed. Regarding locking problems, it is a well known fact that the elements of the degenerated shell type are susceptible to both shear and membrane locking. This paper is not meant to propose new solutions, but to assess the developed element with respect to mentioned numerical problems and to demonstrate the efficiency of the technique known as reduced integration for alleviating locking problems. Of course, one needs to be aware of the possible limitations and drawbacks of this technique in order to use it appropriately.

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