11th International Conference on Mechanics of Composites
(Mechcomp11)
Conference Timetable and Book of Abstracts

2 to 4 September 2026

A072
3D exact shell model for hygro-magneto-electro-elastic analysis of composite structures

Salvatore Brischetto; Domenico Cesare

Politecnico di Torino (Italy)

Composite structures are widely used in several engineering fields, including aeronautical, civil, and naval applications. These structures are extensively studied in terms of delamination, fatigue, static response, and free vibration behavior. Recently, increasing attention has been devoted to multifield approaches for the design of composite structures. Such approaches are particularly important in engineering applications where different physical fields interact with each other. The study of hygro-magneto-electro-elastic smart structures enables the investigation of the physical field coupling effects that can exist, such as the swelling induced by moisture absorption and the sensor/actuator behavior typical of piezomagnetic and piezoelectric structures. These effects can be fully understood only by considering the complete coupling between all the involved physical fields.

To have an accurate description of orthotropic hygro-magneto-electro-elastic composite structures, taking into account the full coupling among the four physical fields, a 3D analytical model is developed. The proposed 3D analytical model includes the full coupling of 3D equilibrium equations for spherical shells, the 3D divergence equation for magnetic induction, and the 3D Fick diffusion equation. Spherical shells are analyzed by considering the mixed curvilinear orthogonal reference system. Thanks to the mixed curvilinear orthogonal reference system, different geometries (plates, cylinders, cylindrical panels, and spherical panels) can be analyzed, properly evaluating in-plane radii of curvature. The resolution methodology used to solve the set of 3D hygro-magneto-electro-elastic equations is based on the Navier harmonic forms in the in-plane directions and the exponential matrix method in the thickness direction. A layer-wise approach is implemented in the model by imposing interlaminar continuity conditions on displacement components and transverse shear/transverse normal stress components. This enables an accurate representation of 3D effects in thick, thin, curved, and flat structures.

The results section includes a preliminary assessment of the capabilities of the present 3D hygro-magneto-electro-elastic analytical model to capture effects like hygro-magneto-electro-elastic coupling, thickness and material layer effects, and zigzag effect. Some comparisons are made against other hygro-magneto-electro-elastic models available in the literature. After identifying the proper parameters for the exponential matrix method and the number of mathematical layers, new cases are proposed for the four different geometries, in different stacking sequence configurations and for different thickness ratios. In this way, it is possible to highlight the influence of multifield coupling effects in hygro-magneto-electro-elastic composite structures.