EXACT 3D COUPLED HYGRO-ELASTIC SHELL MODEL FOR MULTILAYERED STRUCTURES

S. Brischetto[1], R. Torre[2] and D. Cesare[3]

[1] Department of Mechanical and Aerospace Engineering, Politecnico di Torino, corso Duca degli Abruzzi 24, 10129 Torino, Italy, salvatore.brischetto@polito.it, http://www.dimeas.polito.it/personale/scheda/(nominativo)/salvatore.brischetto

[2] Department of Mechanical and Aerospace Engineering, Politecnico di Torino, corso Duca degli Abruzzi 24, 10129 Torino, Italy, roberto.torre@polito.it, http://www.dimeas.polito.it/personale/scheda/(nominativo)/roberto.torre

[3] Master's degree student at the Politecnico di Torino, corso Duca degli Abruzzi 24, 10129 Torino, Italy, domenico.cesare@studenti.polito.it

The present exact 3D coupled hygro-elastic shell model is employed for the hygroscopic stress analysis of constant radii of curvature shells and plates in multi-layered configuration. The coupled hygro-elastic model combines the 3D elastic equilibrium equations and the 3D Fick diffusion equation in the same system. This system of partial differential equations in the z thickness coordinate is defined in an orthogonal mixed curvilinear coordinate system (α, β, z) for spherical shells, cylindrical shells and plates. A layer-wise approach for multi-layered structures and the exponential matrix method for the partial differential equation solution are here employed. Simply-supported boundary conditions and harmonic forms for displacements and moisture content are used.

The moisture content is imposed in steady-state conditions at the external surfaces of the structures, and then it is easily introduced in the system of equations. Therefore, both displacements and moisture content are primary variables of the model; they are obtained directly from it without any external calculation tool. On the contrary, in un-coupled hygro-elastic models, the moisture content profile in steady-state conditions must be separately defined: it can be calculated from the 3D Fick diffusion equation, it can be evaluated from the 1D version of the Fick diffusion equation or it can be a priori assumed as linear through the thickness direction. The so-defined moisture content profile becomes a known term in the 3D differential equilibrium equations of the un-coupled model.

The hygro-elastic stress analysis for plates and shells is proposed and discussed for several thickness ratios, geometries, lamination schemes, materials and moisture content values. The coupled hygro-elastic model gives the same results obtained via the un-coupled hygro-elastic model when the moisture content is externally calculated by separately solving the 3D Fick diffusion equation. In both cases, thickness and material layer effects are included. The un-coupled hygro-elastic model using the 1D Fick diffusion equation discards the thickness layer effect. The un-coupled hygro-elastic model using a priori linear assumed moisture content profile discards both thickness and material layer effects.