

A VARIABLE KINEMATIC ONE-DIMENSIONAL MODEL FOR THE HYGRO-MECHANICAL ANALYSIS OF COMPOSITE MATERIALS

E. Zappino^{1*}, A. Pagani¹, S. Severino^{1,2}, M. Gigliotti², E. Carrera¹, Y. Pannier²

¹Mul² Team, DIMEAS, Politecnico di Torino, C.so Duca degli Abruzzi 24, Torino, Italy.

²Institut Pprime, CNRS, ISAE-ENSMA, Université de Poitiers, F-86962 Futuroscope
Chasseneuil, France

*e-mail: enrico.zappino@polito.it

Composite materials are widely used in many engineering fields. Their mechanical properties allow very stiff structures to be obtained with a mass reduction with respect to metallic materials. These materials are built using a polymeric matrix reinforced with high strength fibres, e.g. carbon fibres. The use of a polymeric matrix makes composite materials subject to aging effects and in particular their properties and performances may be reduced because of the moisture absorption. An accurate prediction of the deformations and of the internal stress field due to the hygro-mechanical effects is mandatory in the design of a composite structure exposed to a moisture concentration. Classical structural models, beams and plates, cannot provide a complete three-dimensional stress field because their kinematic assumption, e.g. rigid cross-section for the beam of constant thickness for the plates. These limitations make the classical models inaccurate when complex three-dimensional stress fields have to be evaluated as in the case of the hygro-mechanical problem, that is, a full three-dimensional model must be used.

The present paper proposes to use a refined one-dimensional model with variable kinematic, developed in the frameworks of the Carrera Unified Formulation (CUF), for the hygro-mechanical analysis of composite structures. Refined one-dimensional models are able to overcome the limitations of the classical beam models thanks to a refined kinematic fields, used over the cross-section, able to provide a full three-dimensional solution. In this work a model based on Lagrange functions is used. The hygro-mechanical model has been derived in the CUF frameworks, that is, the moisture concentration can be considered as a variable of the problem. The moisture concentration has been evaluated solving analytically the Fick law that is able to provide the moisture distribution after a certain time of exposure. The moisture concentration has been used as boundary condition in the hygro-mechanical problem in order to evaluate the displacement and stress fields.

The model has been assessed and the results have been compared with those from classical three-dimensional FE models. Displacements field, stress field and the volume variation have been used to compare the accuracy of the solution. The results show that the refined one-dimensional models are able to provide an accurate solution with a lower computational cost with respect to the full three-dimensional FE models.