Accepted Manuscript

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PII: S1359-8368(16)32891-8

DOI: 10.1016/j.compositesb.2017.02.046

Reference: JCOMB 4933

To appear in: *Composites Part B*

Received Date: 29 November 2016

Revised Date: 1 February 2017

Accepted Date: 28 February 2017

Please cite this article as: Peret T, Clement A, Freour S, Jacquemin F, Effect of mechanical states on water diffusion based on the free volume theory: Numerical study of polymers and laminates used in marine application, *Composites Part B* (2017), doi: 10.1016/j.compositesb.2017.02.046.

Effect of mechanical states on water diffusion based on the free volume theory: numerical study of polymers and laminates used in marine application.

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Abstract

The humid aging of composite materials is often interpreted assuming a constant diffusivity and most particularly independent on the mechanical fields. However, some experimental investigations highlight a coupling between the mechanical fields and the water diffusion in polymer based materials. In this work, this hygro-mechanical coupling is implemented through the semi-empirical free volume theory. The transient coupled problem is numerically studied using the classical finite element method. The problem is solved with the commercial code Abaqus©. Three numerical examples, emphasizing the interest of using such models in the investigation of the aging of composites, are presented. In the two first cases, the aging of pure resin specimen, under mechanical loading, is analyzed. In the last instance, the impact of the stiff reinforcements, assumed hydrophobic, on the water absorption behavior of an uni-directional laminate is studied.

Keywords: Composite materials, moisture diffusion models, Finite Element Method, strain-diffusion coupling, multi-physics, transient hygro-mechanical problem.

1. Introduction

Efficiency is the ultimate goal in many industrial sectors and most specifically for transport and energy. The lightest the structure is, the best are the performances. Thus, mass reduction appears as one of the main targets in structural design. Nowadays, the use of composites is growing. For instance, Glass Fiber Reinforced Polymer (GFRP) are widely used in marine and wind energy conversion industry, mainly for economical reasons, but reinforcements made of carbon may be preferred in tidal turbine blades design [1, 2]. The better specific properties of composites compared to those of conventional metallic materials [1, 3, 4, 5, 6] explain the enthusiasm in their use. Moreover, composite materials are resistant to fatigue [2, 7]. Besides, they do not suffer corrosion and their maintenance is easier [6]. Furthermore, Bragg grating

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