Accepted Manuscript

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PII: S0263-2241(17)30635-8
DOI: https://doi.org/10.1016/j.measurement.2017.10.011
Reference: MEASUR 5013

To appear in: *Measurement*

Received Date: 19 August 2016
Revised Date: 15 July 2017
Accepted Date: 3 October 2017

Numerical and experimental assessment of water absorption of wood-polymer composites

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Abstract

This article focuses on the evaluation of the water immersion properties of wood-plastic composite (WPC) made with industrial wood residues. The effects of fiber type and proportion on the dimensional stability of WPC were studied. The water absorption of WPC samples was studied using modeling techniques. Samples were prepared according to a process in two steps: (i) extrusion compounding and (ii) injection molding. The results showed that the water absorption and swelling varied with fiber source and increased proportionally with fiber proportion. The variations of the water absorption and swelling have been represented following the theoretical model of the Fick's law of diffusion. The parameters of this diffusion process such as diffusion and Fick's coefficients are subsequently identified and modeled by both numerical and experimental approaches. The novel modeling includes short term diffusion and long term diffusion parameters for a better representation of the complex sorption behavior of WPC.

Keywords: Diffusion, Wood plastic composite, Swelling, Fick's law

1. Introduction

The rapid expansion of wood-plastic composite (WPC) in the last two decades is largely attributed to its durability for exterior applications such as decking and railing. Other factors such as low maintenance and color stability also contributed to the market growth of WPC. Moisture content (MC) is a key factor for durability because water is a physiological condition requirement for the growth of fungi (Shmulsky and Jones 2011). It is generally recommended to use pressure-treated lumber above 20% moisture content. Chromate copper arsenate has been the most commonly used preservative for decades but it is now prohibited for home applications because of environmental and health issues (Shmulsky and Jones 2011). The lack of environmental preservatives played in favor of WPC.

Wood material is hydrophilic whereas polyolefin polymers used in WPCs are mostly hydrophobic (Niska and Sain 2008, Karakus *et al.* 2016). Wood expands as it swells water from bone dry condition to the fiber saturation point (FSP) and shrinks as it dries. Sorption phenomena are completely reversible. Water adsorption from zero MC to the FSP is considered as chemically bonded and is accompanied by dimensional variations. Water interacts with polar chemical functions of wood polymers, such as hydroxyl functions in cellulose. Water absorbed beyond the FSP is commonly called free water and does not causes dimensional changes. Wood is a porous material and void volume can be calculated using its density and the cell wall density, which is in around 1.5 kg/m³ for all species. Water can penetrate through wood in the fiber cell walls and in the voids. In softwoods, sap flow through the tracheids and fiber lumens, mainly in longitudinal directions. Hardwoods have vessels for conduction of sap in longitudinal direction. Sap also moves in transversal directions, mainly through cell pits (Shmulsky and Jones 2011, Siau 1984).

Siau (1984) reviewed the transport processes in wood materials. Many studies focused on the diffusion through the wood below the FSP. The Fick's laws have been applied for steady-state and isothermal conditions. The coefficient for the transport of water is most commonly expressed in terms of the coefficient of diffusion D. The coefficient D increases exponentially with moisture content from dry state to the FSP. This may be explained by a lower bonding energy between the sorption sites and the bound-water molecules at higher moisture contents. This bonding energy should approaches zero at the FSP where subsequently added moisture is essentially free water, held by relatively small capillary forces. The