WETTING BEHAVIOUR OF MOLTEN POLYMERS ON FIBRES FOR ADVANCED THERMOPLASTIC COMPOSITE MANUFACTURING

R. ALAWAR[1], P.J. LIOTIER[2], R. RAVEL[2], and M.F. PUCCI[1]

[1]LMGC, IMT Mines Alès, University of Montpellier, CNRS, Alès, France
Email: rami.alawar@mines-ales.fr
Email: monica.pucci@mines-ales.fr
[2]PCH, IMT Mines Alès, Alès, France
Email: pierre-jacques.liotier@mines-ales.fr
Email: romain.ravel@mines-ales.fr

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Abstract

The next generation of composite materials will be driven by sustainable routes that enable lightweight designs, notably using bio-based or circular resources. Depending on several industrial sectors, transportation for example but not only limited to it, thermoplastic matrices such as Polyether Ether Ketone (PEEK), Polypropylene (PP), and the biodegradable PolyLactic Acid (PLA) can be reinforced with reclaimed carbon fibers, basalt fibers, or biodegradable flax fibers [1]. Automated Fiber Placement (AFP) and Automated Tape Laying (ATL) offer efficient manufacturing of fiber-reinforced composites. While several studies have investigated interfacial quality and defect minimization (void formation) in composites produced through automated processes [1], comparatively fewer studies have addressed the interfacial quality within the tape itself during semi-finished product fabrication.

The primary objective of this study is to examine the wetting behavior of molten polymers on fibers, with the aim of controlling the fiber/matrix interfacial formation at both the micro and mesoscopic scales within thermoplastic tapes. The wetting dynamics of polymers on fibers are influenced by various properties of the constituent materials and are commonly characterized by the dynamic contact angle (θ_d) as a function of the capillary number (Ca) [2]. The dimensionless capillary number, which accounts for the balance between viscous and capillary forces, is defined as the ratio of the product of liquid viscosity (η) and velocity (v) to the liquid surface tension (γ_L).

The current work focuses, firstly, on the surface tension determination of several liquid polymers (*e.g.* polyethylene glycol, epoxy) and molten thermoplastics (*e.g.* PP, PLA) as a function of temperature, using Pendant drop method [3]. Results showed a linear decrease of the surface tension against temperature [4]. On the other hand, according to a developed experimental procedure, the interfacial tension versus temperature was measured, allowing the determination of the polar and dispersive components of polymers as a function of temperature [5]. These values have not been previously reported in the literature. The surface properties of the tested polymers were then correlated with the dynamic wetting behavior observed on single fibers. Indeed, both static (θ_s) and dynamic (θ_d) contact angles were obtained as functions of polymer temperature and immersion speed, thereby enabling the evaluation of wetting behavior with varying capillary numbers (Ca). Figure 1a presents the dynamic wetting results of basalt fibers with a polyethylene glycol (PEG300) and a biobased resin (bio resin) at room temperature. Furthermore, a visual methodology was developed to enable the measurement of the static contact angle formed between a single fiber and a molten thermoplastic (Figure 1b). The surface energy (γ_S), polar (γ_S^p) and dispersive (γ_S^d) components of the basalt fibers as received and thermally treated were previously determined by Ravel et al. [6].

Understanding the mechanisms governing dynamic wetting as a function of temperature is also crucial for optimizing Liquid Composite Molding (LCM) processes with specific resins and adapting the process parameters to the physico-chemical properties of the fiber/polymer couple.

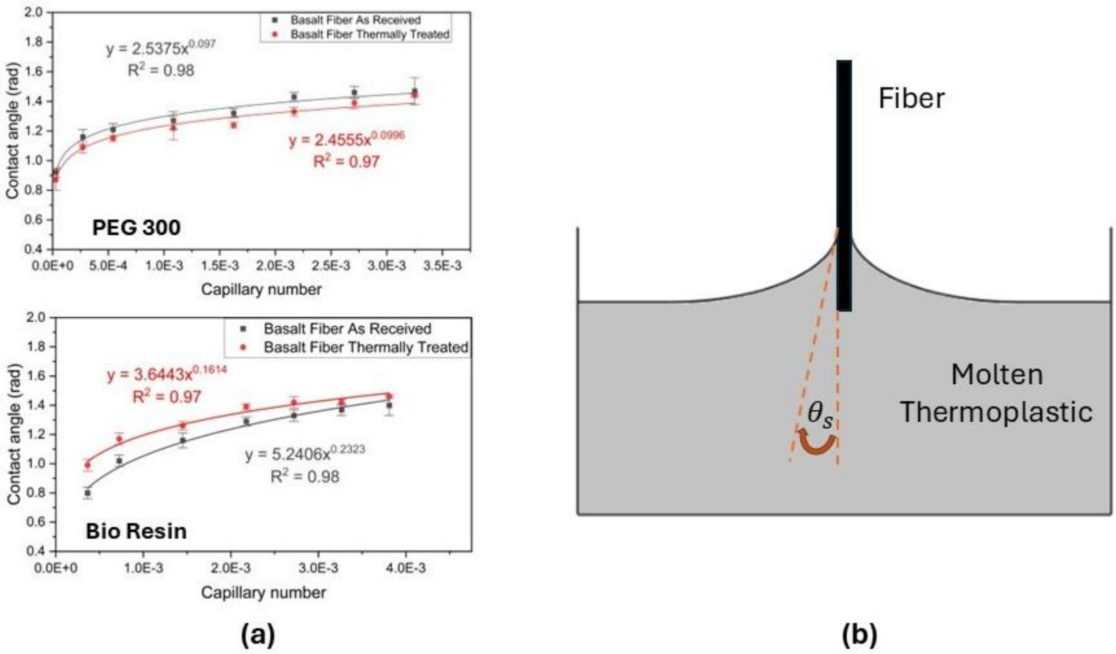

Figure 1: (a) Dynamic wetting of basalt fibers by polyethylene glycol and bio resin; (b) Representation of the visual method for molten thermoplastic static contact angle measurement.

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