DYNAMIC WETTING OF POLYMERS ON FIBERS: EFFECT OF TEMPERATURE

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Abstract

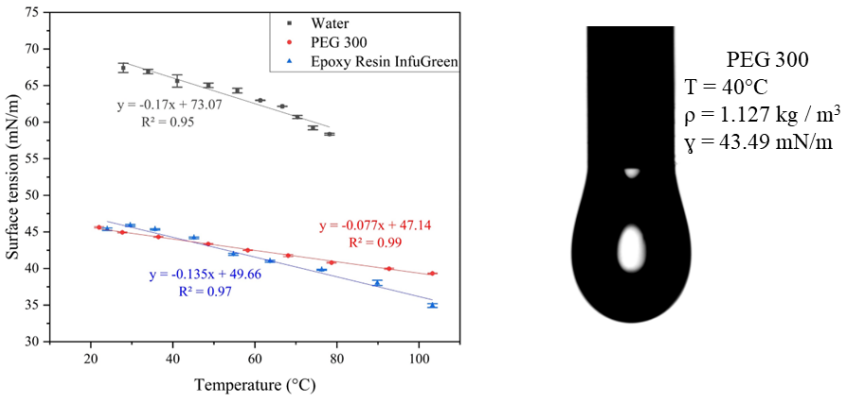
Composite materials future relies on achieving lighter parts through integrating sustainable materials, with bio-based and/or circular materials. To meet the requirements of industrial applications, different thermoplastic matrix, like Poly Ether Ether Ketone (PEEK), Polypropylene (PP) and biodegradable PolyLactic Acid (PLA), can be reinforced by reclaimed carbon fibers, basalt fibers and biodegradable flax fibers [1]. Automated Processes (AP) like Automated Fiber Placement (AFP) and Automated Tape Laying (ATL), using fiber-reinforced tapes, are performant processes for the manufacturing of this kind of composites. Some studies are focused on the quality of the interface and the reduction of defects (voids) in composites manufactured by AP [1], but few studies are focused on the quality of interface in the tape during semi-product manufacturing.

The main objective of this study is to investigate the dynamic wetting of molten polymer on fibers to control fiber/matrix interface formation at the micro and mesoscales of the thermoplastic tape. Furthermore, the understanding of dynamic wetting mechanisms as a function of temperature is also relevant for advanced control in Liquid Composite Molding (LCM) processes. Wetting dynamic depends on different properties of the constituents, and it has been usually related to the capillary number (Ca) and the definition of a dynamic contact angle θ_d [2]. The dimensionless capillary number, considering capillary and viscous effects, is defined by the ratio between the liquid viscosity (η) multiplied the liquid speed (v) and the liquid surface tension (γ_L).

The current work focuses, firstly, on the surface tension determination of polymers as a function of temperature, using Pendant drop and Wilhelmy plate methods. Surface tension tests for several liquids were performed using the two methods at room temperature, showing similar results to the ones reported in literature [3]. Moreover, a reliable procedure to determine this surface tension variation along with temperature was applied using the Wilhelmy plate method. Some results are shown in Figure 1(a), proving that the liquid surface tension decreases linearly as the temperature increases, in accordance with Eötvös law [4], also for a polyethylene glycol (PEG 300) and an epoxy resin. Comparable results are obtained by the Pendant drop method (Figure 1(b)). In this case, implementing an external heating chamber allows to measure the surface tension of polymers at elevated temperatures. The density of the tested liquid at each studied temperature is also needed and determined.

In parallel to the surface tension determination, other experimental procedures are developed for determining the interfacial tension, the polar and dispersive components of polymers as a function of temperature, followed by dynamic wetting analysis on single fibers.

Basalt fibers are used for dynamic wetting tests to determine dynamic contact angles. The surface energy (γ_S), polar (γ_S^p) and dispersive (γ_S^d) components of these fibers as received and thermally treated were previously determined by Ravel et al. [5]. Values are shown in Table 1.



(a) (b)

Figure 1: (a) Surface tension against temperature, by Wilhelmy plate method; (b) Surface tension result of PEG 300 at 40°C, by Pendant Drop method.

Table 1: Surface energy and components of basalt fiber, as received and thermally treated.

Basalt fiber	γ_s^P (mN/m)	γ_s^d (mN/m)	γ_s (mN/m)
As received	30.6 ±2.1	17.9 ±0.4	48.5 ±2.5
Thermally treated	37.5 ±2.3	16.8 ±0.1	54.3 ±2.4

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