Separation and Purification Technology 204 (2018) 127–132

Contents lists available at ScienceDirect

Separation and Purification Technology

journal homepage: www.elsevier.com/locate/seppur

Measurement of inflection angle and correlation of shape factor of barrel-shaped droplets on horizontal fibers

M. Davoudi[a], M.M. Amrei[b], H.V. Tafreshi[b], G.G. Chase[a,*]

[a] Department of Chemical and Biomolecular Engineering, The University of Akron, Akron, OH 44325-3906, USA
[b] Department of Mechanical and Nuclear Engineering, Virginia Commonwealth University, Richmond, VA 23284-3015, USA

ARTICLE INFO

Keywords:
Drop
Droplet
Fiber
Inflection angle
Contact angle

ABSTRACT

The properties and shapes of drops attached to fibers are important for understanding the movements of drops on fibers in applications such as coalescing filters. One of the features of the shape of a drop attached to a cylindrical fiber is an inflection in the curvature of the drop profile near the contact line between the drop and the fiber surface. Depending on the drop volume, the point of inflection may occur very close to the drop-fiber contact line, and the angle at the inflection point could mistakenly be interpreted as the intrinsic contact angle. Measurement of the angle at the inflection point improves the characterization of the drop profile for a drop-on-fiber system. Many studies provide methods that apply droplet geometric symmetry to extract the profile of drops on flat surfaces. However, none of these methods can be easily applied to drops on fibers due to the curvature of the fiber surface and its effect on the shape of the drop. In the case of drops on fibers, drop properties such as drop length, thickness, inflection angle and volume are useful to obtain the wetting properties of the fiber surfaces without knowing the liquid properties. To determine inflection angles and volumes of axisymmetric barrel-shaped droplets on fibers from 2D images of droplets profiles a polynomial fitting method for fibers (PFMF) was applied. The strategy employed detects the location of the droplet boundary, fits a polynomial to the boundary, and calculates the inflection angle and the volume of the droplet. Volume measurements using the PFMF were consistent with calculations from Surface Evolver™ program. Using the PFMF, a new correlation was generated for a shape factor characterizing the asymmetry of barrel-shaped droplets as a function of liquid properties, fiber radius, and droplet volume.

1. Introduction

The study of wetting properties of surfaces is of significant interest in a wide range of industrial applications. While many previous studies have focused on the analysis of the shape of sessile drops on flat surfaces, more detailed studies need to be carried out to better understand the behavior and shapes of liquid droplets on cylindrical surfaces [1,2] and fiber surfaces, [3–6].

The understanding of drop interactions with single fibers is fundamental to understanding behavior of drops in contact with multiple fibers, as in coalescing filters. A recent review of coalescing filters is given by [7]. In future work the methodologies described here for droplet interactions with a single fiber may be extended to the more complex nature of multi-fiber interactions.

The chemistry and global geometry of the surface and liquid properties are key factors that influence the shape of liquid drops on surfaces [8]. The global geometry of cylindrical fibers can cause the drop to have a different shape compared to when it is placed on a flat surface. It has been shown that, even a contact angle of 0° results in droplet formation on cylindrical fibers [9,10]. The presence of gravity also has an important effect on the shapes of droplets as shown in Fig. 1. Fig. 2 shows the effect of wetting properties on the shapes of drops on fibers. Depending on the contact angle between the droplet and the fiber, the shape of a droplet on a non-wetting surface can range from a spherical cap to a near sphere [11].

As shown in Fig. 3 in general there is a difference between the intrinsic contact angle of a drop on a fiber and the inflection angle of its profile. The inflection angle is useful to characterize the shape of the drop along with a shape factor, $\varepsilon = \frac{X_1}{X_2}$. Accurate description of the drop shape is necessary when images of the drop are used to determine properties including drop volume and intrinsic contact angle.

Provided the Young contact angle is small, the axisymmetric barrel shape conformation occurs in systems where capillary rather than gravity forces define the shape of the drop. As reported in the literature [12,13], an axisymmetric barrel shape is the preferred conformation when Goucher number (or equivalently Bond number [14] defined as

* Corresponding author.
E-mail address: gchase@uakron.edu (G.G. Chase).

https://doi.org/10.1016/j.seppur.2018.04.033
Received 4 December 2017; Received in revised form 27 March 2018; Accepted 14 April 2018
Available online 16 April 2018
1383-5866/