Available online at www.sciencedirect.com
ScienceDirect
Mathematics and Computers in Simulation 81 (2011) 1257–1271
MATHEMATICS AND COMPUTERS IN SIMULATION
www.elsevier.com/locate/matcom

Modelling droplet motion and interfacial tension in filters collecting liquid aerosols

B.J. Mullins [a,*], R.D. Braddock [b], I.E. Agranovski [b]

[a] *Centre of Excellence in Cleaner Production, School of Civil and Mechanical Engineering, Curtin University of Technology, GPO Box U1987, Perth, WA 6845, Australia*
[b] *School of Environmental Engineering, Griffith University, Nathan, QLD 4111, Australia*

Received 11 December 2009; received in revised form 13 April 2010; accepted 7 May 2010
Available online 15 May 2010

Abstract

Extensive experimental investigations have shown some of the differences between the behaviours of the barrel and the clamshell shapes of droplets on filter fibres in flow fields. Realistic flow velocities (such as those used in many industrial filter systems) were utilised. The forces acting are air drag, interfacial tension and gravity. The properties of the interfacial restoring force are modelled, and show agreement with the experimental results, at least in the linear extension region before the onset of oscillatory behaviour of the droplets (induced by instability of the flow field). The model for the oscillatory behaviour is explored, and the natural frequencies of oscillation in the radial and transverse directions are shown to be the same, for the barrel shape. The clamshell shape also has the same natural frequencies, but they are different to those of the barrel shape. The coupling of the radial and transverse oscillation modes is explored for both the barrel and clamshell shape. Some contact angle results are given, both without airflow acting on the droplet and with increasing airflow.

Keywords: Droplets; Fibres; Oscillation; Interfacial tension; Contact angle

1. Introduction

Industrial activities in the manufacture of composite materials, electronic components, textile manufacture and cleaning, and also in coating processes, use fibre wetting processes as an essential part of their operations. Furthermore, fibrous filters are commonly used for the industrial collection of liquid aerosol particles, in both phobic and philic fibre/droplet combinations. The interaction of droplets of liquids of various properties with the fibres, involves an investigation of the interfacial forces and surface tensions, gravity and the air drag on the droplet, due to the carrier gas. Kumar and Hartland [3] provided one of the few studies which have considered the effects of surface tension and gravity on the shape of large droplets on fibres. However, in addition, the air flow and drag forces on the droplets needs to be studied in the filtration of liquid aerosols, and this involves the dynamics of the moving droplet.

Barrel and clamshell shapes are the two primary shapes of liquid droplets on fibres [7]. Barrel shaped droplets are generally formed by the break up of a thin film along a fibre into droplets, through the Plateau–Rayleigh instability.

* Corresponding author. Tel.: +61 8 9266 2267; fax: +61 8 9266 4811.
E-mail address: b.mullins@curtin.edu.au (B.J. Mullins).

0378-4754/$36.00
doi:10.1016/j.matcom.2010.05.008