Chemical Engineering Science 143 (2016) 130–138

Contents lists available at ScienceDirect

Chemical Engineering Science

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

Dynamic interfacial tension in water/*n*-pentane system: An experimental study using the oscillating-jet method

Yasuhiko H. Mori

Department of Mechanical Engineering, Keio University, 3-14-1 Hiyoshi, Kohoku-ku, Yokohama 223-8522, Japan

HIGHLIGHTS

- Reports the water–hydrocarbon dynamic interfacial tension for the first time.
- Interfacial-tension measurements were made using the oscillating-jet method.
- Water was jetted into a mixture of saturated common vapors of *n*-pentane and water.
- The interfacial tension decreased to its equilibrium value during the first ~50 ms.
- The relaxation of the tension was formulated based on an adsorption kinetics model.

ARTICLE INFO

Article history:
Received 31 August 2015
Received in revised form
8 December 2015
Accepted 20 December 2015
Available online 6 January 2016

Keywords:
Interfacial tension
Surface tension
Adsorption
Physical properties
Water

ABSTRACT

The interfacial tension working at an interface created by sudden contact of liquid water with saturated common vapors of *n*-pentane and water under atmospheric pressure (0.101 MPa) was experimentally studied, focusing on the behavior of its relaxation to an equilibrium value in response to the progress of the adsorption of *n*-pentane molecules onto the interface. The oscillating-jet method was used to measure the *dynamic* interfacial tension, i.e., the interfacial tension varying with time during a short relaxation period (less than 0.1 s) after the creation of the interface. It was observed that during the first ~50 ms after the creation of the interface, the tension quasi-exponentially decreased from the normal surface-tension value for pure water (70.5 mN/m) to the equilibrium value (61.5 mNm) which had been obtained in a previous study using the pendant-drop method. An attempt was made to correlate the obtained "interfacial tension versus time" data based on an adsorption/desorption kinetics model.

© 2016 Elsevier Ltd. All rights reserved.

1. Introduction

In certain types of phase-change and gas-absorption processes in relation to energy and environmental technologies, water (or an aqueous solution) in the liquid state is brought into contact with the vapor (or vapors, vapor + gas, vapors + gas) of chemical species other than water. Typical examples of such processes are the direct-contact heat exchange between an aqueous liquid (e.g., geothermal brine, industrial waste water, etc.) and a volatile hydrophobic fluid (e.g., a light hydrocarbon or fluorocarbon) causing its liquid-to-vapor or vapor-to-liquid phase change (see, for example, Siqueiros and Bonilla, 1999; Dammel and Beer, 2003; Haustein et al., 2009, 2013; Mahood et al., 2015; and previous papers cited therein), the wet scrubbing for removing CO_2 and/or some toxic species, such as H_2S and N_2H_4, from a flue gas by making contact with an aqueous absorbent (e.g., Pakdehi and Taheri, 2010; Komae et al., 2013; Elhajj et al., 2014; Hosseini et al., 2014), and the production of clathrate hydrates from natural gas by making contact with water for the purpose of natural-gas storage and transport (e.g., Mori, 2003; Tang et al., 2006; Yamaguchi et al., 2008, Kondo et al., 2014). The efficiencies of such processes may significantly depend on the geometry and motion of the formed liquid–vapor (or liquid–gas) interfaces or the mutual contact behavior of the three phases (two liquid phases and a vapor or gas phase, or, in the case of hydrate formation, liquid, gas and solid phases), which should in turn depend on the interfacial tensions working at such phase boundaries (Higeta et al., 1979; Mori, 1985; Dammel and Beer, 2003; Fotland and Askvik, 2008; Haustein et al., 2009). However, the available quantitative data of these interfacial tensions for multi-species two- or three-phase systems are very limited, despite considerable efforts that have been devoted to collecting such interfacial tension data (see, for example, Jho et al., 1978; Mori et al., 1984, 1990; Matsubara et al., 1988; Sachs and Meyn, 1995; Kashefi et al., 2015). Reviewing the results of these previous studies, the following points are noted:

E-mail address: yhmori@mech.keio.ac.jp

http://dx.doi.org/10.1016/j.ces.2015.12.028
0009-2509/© 2016 Elsevier Ltd. All rights reserved.

(1) the interfacial tension at each interface between a vapor (or gas) phase and an aqueous phase (liquid water in which a tiny amount of other vapor-phase-forming species is dissolved) is significantly reduced from the surface tension of pure water at the same temperature due to the adsorption of the other species at the interface, and (2) all such interfacial tension data ever reported in the literature represent the values under phase-equilibrium conditions. No information is available as to how such interfacial tensions evolve with the ages of the relevant interfaces and how fast (or slowly) they approach their equilibrium values. This study is the first attempt at investigating the evolution of the interfacial tension at an interface between a liquid water phase and a vapor phase composed of common saturated vapors of a hydrocarbon and water. The time span of interest is the duration in which the interfacial tension continuously changes from its initial value, σ_0, to the final equilibrium value, σ_e, as a result of the adsorption of hydrocarbon molecules onto the interface. The initial value σ_0 is of the interface at zero age when the interface is free from any adsorbed hydrocarbon molecules, and hence it is considered to be equal to the intrinsic surface tension of water, i.e., the surface tension of water in contact only with, and in equilibrium with its own vapor. The interfacial tension at each transient stage during the evolution period, σ, may be called, after the conventional terminology in surface chemistry (Adamson and Gast, 1997; Rusanov and Prokhorov, 1996; Defay and Pétré, 1971), the *dynamic interfacial tension* or alternatively *dynamic surface tension of water in contact with a hydrocarbon-vapor*.

Concerning the dynamic surface tension of aqueous surfactant solutions, many studies have been reported in the literature. These studies dealt with aqueous solutions suddenly released in

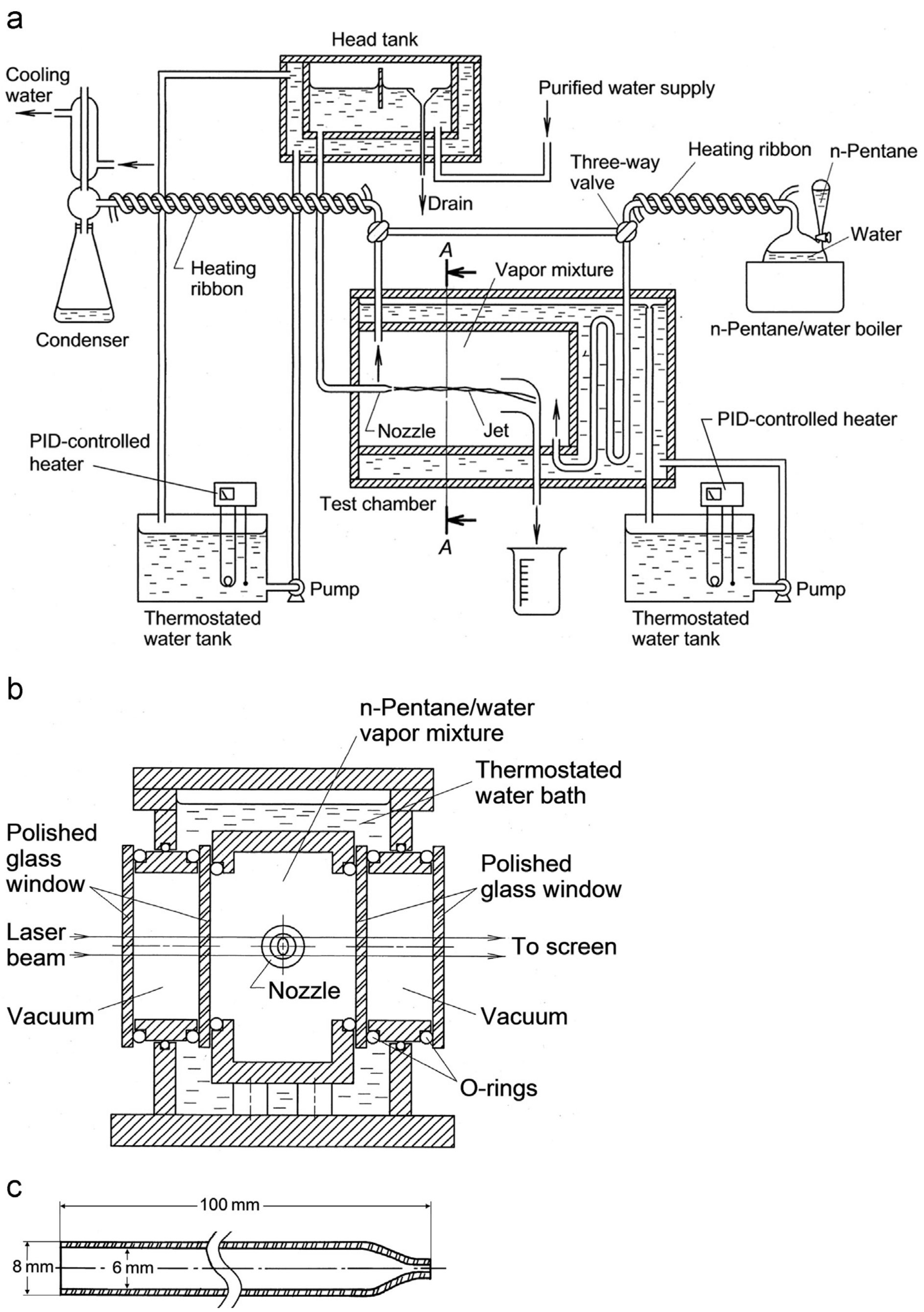

Fig. 1. Experimental apparatus. (a) layout of the experimental setup; (b) cross section *A–A* [indicated in (a)] of the test chamber; and (c) the geometry of the bell-shaped nozzle used for water-jet injection. The major axis of the elliptic nozzle outlet was vertically oriented.

Download English Version:

https://daneshyari.com/en/article/154520

Download Persian Version:

https://daneshyari.com/article/154520

Daneshyari.com