Recent Advances in
Petrochemical Science
ISSN: 2575-8578

Juniper Publishers
key to the Researchers

Short Communication
Volume 6 Issue 1 - October 2018
DOI: 10.19080/RAPSCI.2018.06.555679

Recent Adv Petrochem Sci
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Liquid - Liquid Flow Through Small Diameter Pipe

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Submission: October 04, 2018; **Published:** October 11, 2018

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Abstract

In this study, the flow patterns of toluene-water have been investigated experimentally in a vertical and horizontal milli channel. The flow regimes were observed by a high speed video recorder in pipe with diameter of 3mm. The comprehensive visualization of toluene-water flow in a vertical and horizontal milli channel has been performed to realize the physics of such a liquid-liquid flow. Different flow patterns of toluene-water flow were observed simultaneously in the milli channel at different values of toluene and water flow rates. Consequently, the flow pattern map was proposed for flow in the milli-channel, in terms of superficial velocities of two different liquid.

Keywords: Flow pattern; Liquid-liquid flow; Superficial velocities; Milli channel

Introduction

Liquid-liquid flow through milli channel is widely encountered in various industry; namely; petroleum, pharmaceutical and fine chemical industry. In petroleum industry, oil and water are often produced and transported together [1]. The flow behaviour of oil - water mixtures is applicable to the design of pipelines, downstream separation facilities and pumps, and in the areas of corrosion prediction and production instrumentation interpretation [2]. A sound understanding of oil-water systems is also a platform to the understanding of more complex flows, such as the oil - water -gas ones. Multiphase tubular reactors of small diameter channels are mostly used for continuous production in pharmaceutical industry [3,4]. Optimal design of such facilities relies on substantial knowledge of the flow inside a pipe.

It is not possible to identify the two-phase flow phenomena without a clear understanding of the flow patterns encountered [4-8]. Flow patterns has significant influence on the two-phase pressure drop, holdup, and system stability, exchange rates of momentum, heat and mass during the phase-change heat transfer processes. Different experimental works have been reported in the literature to enhance the understanding of liquid-liquid flow in small diameter tube. In this paper experimental observation of toluene-water down, up and horizontal flow in different pipe diameters are presented [8-12]. Experiments have been performed over a wide range of superficial velocity of both the liquids to investigate the hydrodynamics of toluene - water flow through small diameter pipes. The present industrial trend has also triggered the demand for a comprehensive understanding of the hydrodynamics of liquid - liquid flow through such small diameter pipes in order to advance their design and process control [13-15].

Experimental

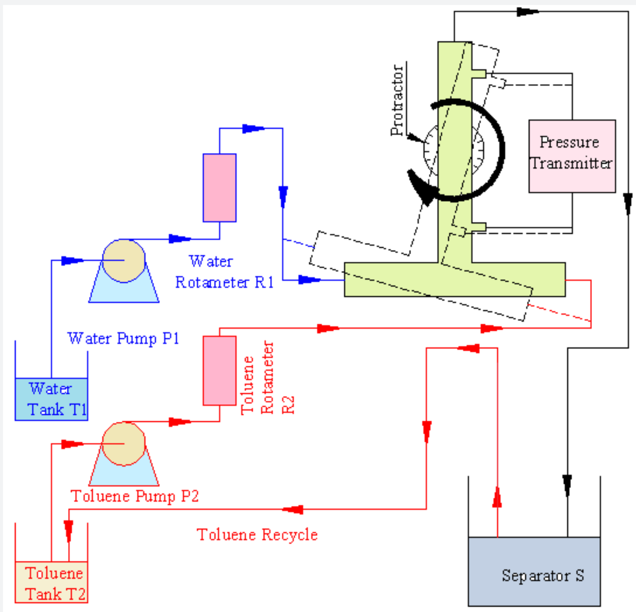

Figure 1: Schematic of experimental set up.

Figure 1 shows a schematic of the experimental set up. It comprises of a capillary glass tube of length 1m and diameter 3mm. Glass tube was used for better visual observations and photography of the flow phenomena. Water and toluene was used as test fluids. Both liquids were pumped by centrifugal pumps (P1 and P2) from respective storage tanks (T1 and T2) as shown in Figure 2. The inlet flow rate of the test fluids were metered using rotameters (R1 and R2). The fluids enter the separator (S) after flowing through the test and exit sections. Various combinations of water and toluene were observed visually with photograph by high-speed digital camera. Different flow patter maps were identified by visual observation of all images. Photographs were taken for a number of combinations of flow rates of water and toluene for different orientations. They were identified visually as well as by the photographic method.

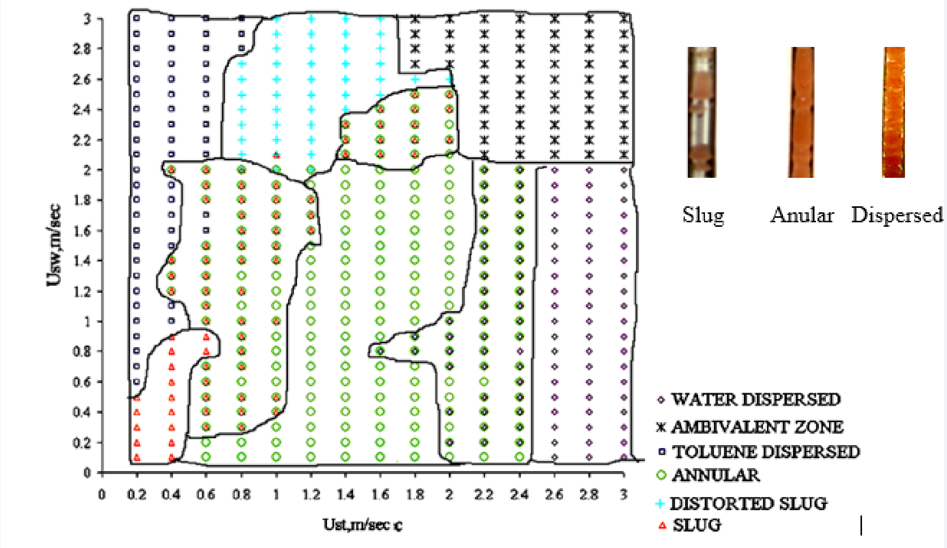

Figure 2: Flow pattern map for two components up flow.

Results and Discussion

Flow pattern from visual and photography

The Flow pattern as observed from visual and photographic recording has been discussed for different orientation of tubes. A digital still camera is used with proper light arrangement for photography. The ranges of existence of the different patterns have also been depicted in the form of flow pattern maps. The superficial velocities of both the phases have been selected as the co-ordinate axes.

Toluene water two phase upward flow in vertical pipes

A number of different flow patterns are observed during upward flow of toluene and water in 3 mm tube diameter. Figure 2 shows flow pattern map of up flow of toluene and water. The map shows that at lower superficial velocity (Ust=0.2-0.4m/s and Usw=0.1-0.5m/s), toluene slugs propagate through the continuous water phase [16-18]. The toluene slugs assume a Taylor bubble like shape and hence this flow pattern is termed as the "slug flow pattern". At very high water (Usw > 1m/s) velocity and low toluene flow rate (Ust < 0.6m/s) dispersion of toluene through water has been observed [18-20]. The pattern exhibits annular flow characteristics with further increase in toluene velocity at low water flow rates. As the toluene velocity is increased (> 2.6m/s) at low to moderate water velocity (0.2m/s < Usw < 2m/s) the pattern exhibits water dispersion through toluene.

Flow of toluene water in horizontal pipes

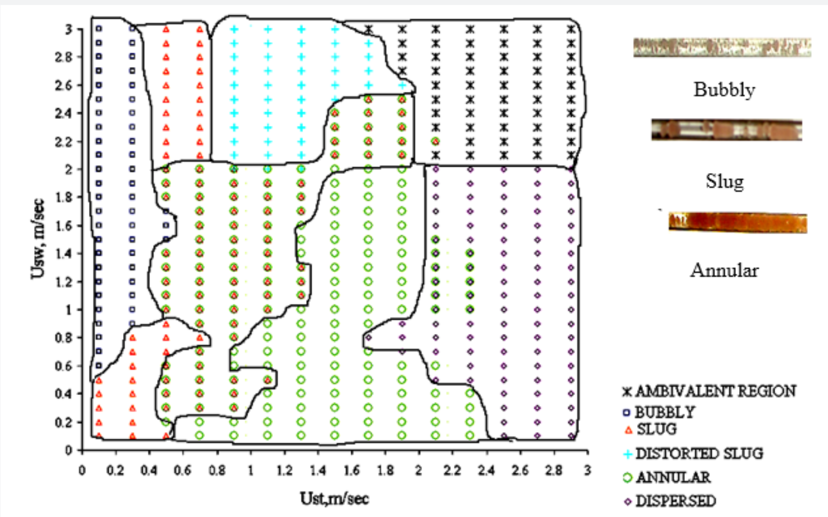

Figure 3: Flow pattern map for two components horizontal flow.

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The map shows the pattern at low water and toluene flow rates is slug. Bubbly flow as shown in Figure 3 is characterised by spherical or non-spherical bubbles which may be of a size equivalent or less than that of the channel diameter. At high water and low toluene velocities, spherical bubbles were observed as shown in Figure 3. As the toluene velocity is increased further with low water flow rate, annular flow was observed. At very high water and toluene velocity, dispersed flow is observed [21].

Air water two phase downward flow in vertical pipes

A schematic of flow pattern and their range of existence are given in the flow pattern map of Figure 4. This pattern extends for the range of 0.1m/s to 2.8m/s of toluene velocity and 0.1m/s to 3m/s of water velocity. At very high water velocity (> 2m/s) annular flow regime has been observed. At very low velocity of water and toluene slug flow has been observed [18-21]. Dispersed flow has been identified at very high velocity of water and moderate velocity of toluene.

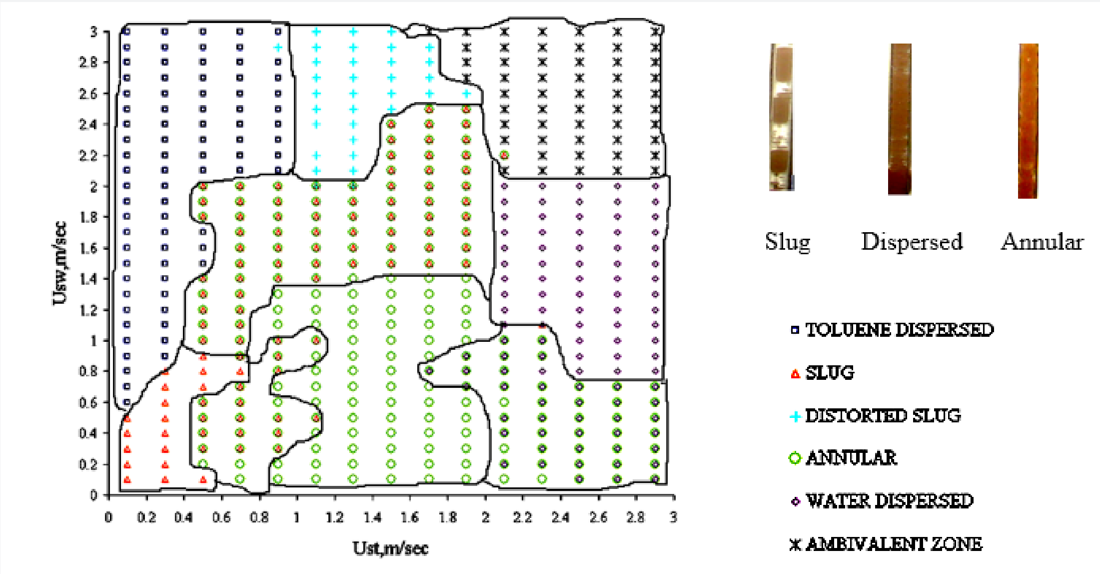

Figure 4: Flow pattern map for two components down flow.

Conclusion

In this paper, flow patterns of liquid - liquid flow were investigated experimentally for milli channels with diameter of 3mm. An image processing technique was used for detection of flow patterns from pictures derived from films recorded with a high speed digital camera. Various types of flow regime were observed during up flow of toluene water; namely; slug, annular, dispersed. Bubbly flow was observed for horizontal flow. Annular flow was indentified at moderate velocity of toluene with low velocity of water during down flow. Water was dispersed at very high velocity of toluene with moderate flow rate of water during down flow. In case of horizontal flow dispersed flow was observed at high velocity of toluene and low to moderate velocity of water. The obtained flow patterns reveal that there was no new type of flow pattern during up flow and down flow of toluene water.

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DOI: 10.19080 RAPSCI.2018.06.555679

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