Applied Thermal Engineering 49 (2012) 41–47

Contents lists available at SciVerse ScienceDirect

Applied Thermal Engineering

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

Two- and three-phase mixtures of highly-viscous-oil/water/air in a 50 mm i.d. pipe

Pietro Poesio [a,*], Domenico Strazza [a], Giorgio Sotgia [b]

[a] Università degli Studi di Brescia, Dipartimento di Ingegneria Meccanica e Industriale, Via Branze 38, 25123 Brescia, Italy
[b] Politecnico di Milano, Dipartimento di Energia, Via Lambruschini 4, 20156 Milano, Italy

ARTICLE INFO

Article history:
Received 20 October 2010
Accepted 8 April 2011
Available online 12 August 2011

Keywords:
Three-phase flows
Core-annular
Heavy oils

ABSTRACT

A three-phase flow of oil, water and gas through a pipeline often occurs in industry. It is important to study such flows in order to be able to design a three-phase flow pipeline. To that purpose experiments with oil, water and air in a 50 mm i.d. plastic pipe have been carried out to derive a new data set for a three-phase flow in horizontal configuration. First, we investigate the pressure drop showing the influence of air injection on the two-phase flow reference flow pattern. Then we underline the strong link between the qualitative behavior of the three-phase pressure drop reduction factor and the two-phase flow reference flow pattern.

1. Introduction

Despite the efforts toward new alternative energy resources, oil is still one of the most important. The growing consumption of light oil reserves has forced oil industries, engineers, and scientists to think to heavy oil as a suitable alternative to conventional resources. As can be seen from Fig. 1, heavy oil reserves are comparable to conventional ones; in addition to that, heavy oil is becoming more and more interesting due to geopolitical reasons, since located outside middle-east countries (Fig. 2).

The major difficulty for heavy oil production and transportation are the huge viscosity (from 1000 to 100,000 times more viscous than water) and the higher densities (greater than 1000 kg/m^3 for extra heavy oils). Few strategies have been proposed for its transportation: heating-up the pipeline, blending with low viscosity hydrocarbons, and formation of oil-in-water emulsions.

All those techniques have negative aspects: they are expensive or environmental unfriendly. On the other hand, water-lubricated pipelines seem to be a promising way to transport heavy oil. In this technique (liquid–liquid core-annular flow or CAF), a thin layer of water flows around a core of viscous oil, which never touches the pipe wall. In such a way, the pressure drop is largely reduced respect to what it would be for oil alone and it is comparable to the pressure drop of water alone, see Refs. [2–4].

Several problems have to be overcome before taking CAF out of the lab and to the field application. The influence of gas on liquid–liquid core-annular flow has attracted little attention and only recently researchers are getting interested into it. Prof. G.F. Hewitt gave momentum to that topic in 1995 delivering a lecture entitled "Three-Phase Liquid–Liquid–Gas Flow: a new Challenge" in which he pointed out the complexity of involved phenomena [5].

Initially, we looked only at the pressure drop caused by the addition of a third gaseous phase to the liquid–liquid core-annular flow. In addition to data set on 21 mm, 28 mm, and 40 mm inner diameter pipe [6,7], we proposed a simple model to predict the pressure drop combining a classical two-fluid model to compute the pressure drop of liquid–liquid flow with a well-known Lockhart–Martinelli model to account for the presence of the gas phase [6].

The aim of this paper is to step forward in the direction of larger diameter pipes, presenting a new data set (both concerning the two and three-phase flow) for a 50 mm inner diameter pipe.

2. Experimental set-up

The set-up consists of a 11 m long acrylic pipe with 50 mm i.d., see Fig. 3. Oil and water densities are $\rho_o = 890$ kg/m^3 and $\rho_w = 1000$ kg/m^3 respectively. The interfacial tension is $\sigma_{ow} = 20$ mN/m. Oil and water viscosity are $\mu_o = 0.9$ Pa s (20 °C) and $\mu_w = 1.026$ mPa s respectively. The pressure drop is measured 6 m downstream the injection point and over a length of 3.7 m. Oil, water, and air superficial velocities are in the ranges $J_o = 0.13 \div 052$ m/s, $J_w = 0.04 \div 0.85$ m/s and $J_g = 0.25 \div 4$ m/s respectively. Water flow rate is measured by a magnetic flow meter,

* Corresponding author.
E-mail address: pietro.poesio@ing.unibs.it (P. Poesio).

1359-4311/$ – see front matter © 2011 Elsevier Ltd. All rights reserved.
doi:10.1016/j.applthermaleng.2011.04.052