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Effect of glycerol addition on phase inversion in horizontal dispersed oil–water pipe flows

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ABSTRACT

The effect of interfacial tension on the phase inversion process during horizontal pipe flow of an oil-aqueous solution was investigated. Interfacial tension was varied by adding small amounts of glycerol in the water phase. At these glycerol concentrations the density and viscosity of the aqueous phase changed by 1% or less. Exxsol™ D140 (5.5 mPa s, 828 kg m^{-3}) was used as the oil phase. The experiments were carried out in a 38 mm ID acrylic test pipe. The phase continuity and appearance of phase inversion were investigated using conductivity (wire and ring) probes and an Electrical Resistance Tomographic (ERT) system. The ERT also provided diagrams of the phase distribution in a pipe cross section. Drop size distribution was monitored using a dual impedance probe. It was found that starting from a water continuous flow with increasing oil fraction at constant mixture velocity the mixture inverted initially in the middle of the pipe (measured at 19 mm from the top pipe wall) while a higher oil fraction was required for inversion at the top (measured at 4 mm from the top pipe wall) and finally the rest of the pipe. The addition of glycerol did not affect the phase fraction where the initial inversion occurred but caused an increase in the oil fraction needed to complete the inversion. The drop size measurements were used to explain this behaviour. Pressure drop was found to decrease with increasing oil fraction but this trend reversed when inversion spread to the pipe wall and the oil continuous phase came in contact with it.

1. Introduction

The pipeline flow of two immiscible liquids, usually an aqueous and an organic, is commonly encountered in process industries and during oil production. Depending on the flow rates and phase fractions, dispersed flow can establish where either the water (O/W) or the oil (W/O) is the continuous phase. At some critical operational conditions, phase inversion occurs whereby the initial dispersed phase becomes continuous and the continuous phase becomes dispersed. The change in phase continuity can have a significant effect on the mixture rheology and on frictional pressure drop while the nature of the continuous phase is related to pipeline corrosion and to the rate of the mixture separation at the end of the process. It is important, therefore, to understand and be able to predict the conditions under which inversion appears.

Many factors have been reported to affect phase inversion and the *phase inversion point*, i.e. the volume fraction of the liquids at inversion. Experimental work has mainly been carried out in stirred vessels (for a review see [1]) where it was found that phase inversion is affected not only by the fluid properties such as viscosity, density and interfacial tension, but also by the stirred vessel geometric configuration (e.g. type of impeller), the vessel and impeller material wettability and the experimental setup (e.g. the phase that the impeller is in at the beginning of the experiment). In contrast to stirred vessels, there is less information available on the effect of various parameters on phase inversion during pipeline flows. Apart from fluids properties, parameters such as mixture velocity, rate at which the dispersed phase is added in the continuous, size of the pipe and wettability of the pipe material have also been found to influence phase inversion [2–5]. There is also work on the appearance of phase inversion during multiphase flow metering (e.g. [6]).

Among the fluid properties, viscosity is considered to have a significant impact on phase inversion. Selker and Sleicher [7] found that as the viscosity of one phase increases, its tendency to be dispersed also increases, i.e. the minimum fraction that the phase can be continuous will decrease and the maximum fraction that it can be dispersed will increase. Notably, many models for the prediction of the phase inversion fraction are based on the liquid viscosities [8–11]. Density does not seem to affect inversion significantly especially when the density difference between the two liquids is small but it will influence the homogeneity of the dispersion ([7], [12]). However, systems with large density difference between the phases show an increased tendency to invert [13].

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