Rheological Behavior and Microstructure Characterization of Water-in-oil Emulsion Under Pipe Flow

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INTRODUCTION

Water-in-oil (W/O) emulsions widely exist in submarine pipelines and its flow characteristics are crucial to the safety of crude oil transportation. In this study, different water content emulsions are prepared and their variations of rheological properties during pipe flow are quantitatively investigated. Gel point and viscosity of the emulsions are found to increase over the flowing time. In order to explain this phenomenon from a micro perspective, microstructures of the droplets are observed and the micro-parameters are characterized. The results give an insight of relationship between micro-morphology and macro-rheology of W/O emulsions.

KEY WORDS: Water-in-oil emulsion; pipe flow; rheology behavior; microstructure characterization.

ABSTRACT

Water-in-oil (W/O) emulsions widely exist in submarine pipelines and its flow characteristics are crucial to the safety of crude oil transportation. In this study, different water content emulsions are prepared and their variations of rheological properties during pipe flow are quantitatively investigated. Gel point and viscosity of the emulsions are found to increase over the flowing time. In order to explain this phenomenon from a micro perspective, microstructures of the droplets are observed and the micro-parameters are characterized. The results give an insight of relationship between micro-morphology and macro-rheology of W/O emulsions.

Waxy crude oils normally behave as Newtonian fluids at temperatures above wax appearance temperature (WAT), but wax solidification and emulsion formation can significantly change the viscosity behavior (de Oliveira et al., 2018). When the wax components precipitate out as the oil temperature decreases below WAT, the wax crystals both grow in size and quantity, and gradually connect with each other to form a stable three-dimensional network structure (Li et al., 2015). This network structure is porous and the crude oil and water droplets can be entrapped, together with the interactions between droplets, the system mechanical strength can be improved. Thus, the rheological behavior of W/O emulsions is very complex, it mainly influenced by chemical composition of crude oil, water content, droplet distribution and size, surfactants, etc. (Tripathi et al, 2017, Masalova et al., 2003, Wang et al., 2013). Many researchers have focused on the rheological behavior of W/O emulsions in pipe flow and obtained some meaningful results. Kolotova et al. (2018) investigated the effect of aqueous phase content on W/O emulsions by using North Sea crude oil. It was found that the viscosity of W/O emulsion increased sharply and non-Newtonian properties presented as the aqueous phase content exceeded 20%. Maaref et al. (2018) studied the effect of brine salinity on W/O emulsion flow performance by using Iranian oilfield crude oil and synthetic brine with different salinity. The emulsion viscosity and interfacial tension were found to increase slightly with the increase of salinity but did not influence the flow behavior considerably. In addition, it was found that higher brine salinity can result in larger droplets. Ariffin et al. (2016) investigated the rheological behavior of crude oil from Bintulu, Sarawak and its mixture with water. The results showed that temperature, shear rate and water ratio have great impacts on the viscosity of W/O emulsion, the emulsions exhibit non-Newtonian flow behavior at low shear rate and Newtonian flow behaviour at high shear rate. Besides that, viscosity of the emulsion was strongly augmented by increasing the water volume and decreasing the temperature.

This research considers the rheological behavior of different water content W/O emulsions based on a waxy crude oil, and the distribution and size variations of water droplets during the pipe flow are characterized from micro perspective. The results of these analyses can help in the study of emulsion rheology and provide useful information on the operation of multiphase flow pipelines.