Emulsified Water Fraction and Viscosity Characteristics of Oil-Water Mixture Under Flowing Conditions

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ABSTRACT

Multiphase transportation technology is widely used in subsea pipelines, while some necessary flow characteristics of the multiphase flow are difficult to obtain by traditional methods. In this study, the emulsified water fraction and equivalent viscosity of oil-water mixture under different flowing conditions were investigated with a novel stirring measurement method. Their relationship with total water fraction, temperature, and shear rate were established and analyzed based on the experimental results. This study is helpful to understand the phase distribution and flow characteristics of the oil-water two-phase flow in subsea pipelines.

KEY WORDS: Oil-water flow; emulsified water fraction; stirring method; viscosity; shear rate; subsea pipeline.

INTRODUCTION

In recent years, the petroleum resource of offshore oil fields has become an important proportion of oil production growth. The distance of subsea gathering and transportation pipelines has been increasing substantially. The phase separation operation is usually done onshore in order to reduce the construction area and costs of offshore platform, so multiphase transportation technology is widely used in subsea pipelines. The agitation and mixing effects from the pipe fittings and shear flow disperse one phase into another, forming complex and varying flow patterns (Sharma et al., 2011; Wang et al., 2011).

For oil-water two-phase flow, a small proportion of water may be entirely emulsified to form water-in-oil emulsion with oil phase (Xu, 2007; Sotgia et al., 2008; Klink et al., 2011). Nevertheless, when the water fraction is considerable, besides the emulsified water, the remaining part of water phase is co-existed with the emulsion as free water (Chen and Tao, 2005; Wen et al., 2014). The emulsified water in oil increases the effective volume of oil phase and changes the viscosity of oil-water mixture. Emulsified water fraction and viscosity, as important parameters of oil-water flow characteristics, are essential for the prediction of flow pattern and the hydraulic and thermodynamic calculation. However, they are difficult to be obtained by using traditional measurement methods.

The emulsifying behaviors are not only influenced by the properties of crude oil and water, but also closely related with the shear rate and temperature. Since the emulsifying behaviors in pipe flow are different from those in the static condition, emulsified water fraction needs to be determined under flowing condition in order to reflect the flow characteristics in pipelines. However, nearly all of the current research is aimed at emulsifying properties under stationary condition (Nenningsland et al., 2011; Azodi and Nazar, 2013), which is quite different from the actual situation.

In addition, for finely-dispersed and stable emulsion, many mature technologies and commercial instruments can be used for its rheological measurement. But for coarse-dispersed and unstable oil-water mixture, the density difference of oil and water may cause serious separated layers, so traditional viscometer cannot measure its viscosity due to the nonhomogeneous and unstable phase distribution state of flowing oil and water (Yu et al., 2013). Using flow loop experiment, the equivalent viscosity of oil-water mixture can be calculated based on the flow friction, but the conduction of flow loop experiment is device-complicated, difficult to operate, highly cost and oil-consumed.

In this study, the emulsified water fraction and viscosity of oil-water mixture under different flowing conditions were investigated with a novel stirring measurement method. Under proper stirring, unstable oil-water mixture can maintain uniform flow state and the stirring shaft torque exerted on the blades can reflect the actual flowing situation in pipelines. This study will be helpful to understand the phase distribution and flow characteristics of the oil-water two-phase flow in subsea pipelines.