VISUALIZATION OF THREE PHASE WATER-ASSISTED FLOW OF HEAVY CRUDE OIL AND GAS

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Summary This paper presents a study of three-phase flow of a viscous crude oil, gas and water inside horizontal and vertical pipes of different pipe sizes. To overcome the difficulties related to the pipelining of viscous crude oil (thousands of times more viscous than water) the technique of water-assisted flow was used, which derives directly from the core-flow technique and allows visualization of flow structures. The intrinsic complexity of such three-phase flows suggests the use of visualization by means of high-speed imaging, to better understand the flow patterns and the effect of the presence of gas on the flow structure. Results are presented in the form of pictures, movies and graphics for measurable quantities such as pressure drop, phase velocities and thicknesses of the lubricating water layer.

RELEVANCE

In several industrial activities the issue of how to viabilize the flow of viscous fluids at high flow rates and reasonable pressure drop has been crucial. Among those activities, the production and transportation of heavy oils from deep reservoirs – frequently located offshore under deep water layers – up to surface facilities has been the object of concern [1], due to the high cost of the installation, requiring production at high flow rates through a production line whose diameter is limited by the well size. The lateral injection of water in the line via a secondary pump has been proposed by different authors [2, 3, 4] as an efficient and cheap method to get high oil flow rates for viscous crudes of above hundreds of mPa.s viscosity. This is the so-called *core-flow* technique. However, once bubble-point pressure is attained, the viscous crude starts to release gas in an increasing proportion as pressure decreases, attaining about ten times the amount of oil on surface. In such a circumstance, the oil core is broken up by the fast moving gas, leading to several new flow structures and patterns. Preliminary flow visualization studies in our laboratory indicate that, if the amount of water added is not too small, all of such three-phase flow patterns may still be characterized by the presence of a lubricating water layer that avoids direct contact of the viscous oil with the wall, justifying the broad term *water-assisted flow* to comprise patterns where the oil-core is not continuous.

OBJECTIVES

This study presents the results obtained for the pressure drop and kinematic/geometric aspects of viscous oil-water-gas flow obtained by means of high-speed imaging. Several glass pipes with different sizes and orientations have been used.

METHODOLOGY

The study was developed in different flow loops of the State University of Campinas-UNICAMP, Brazil. Methodology was essentially experimental, consisting in measuring flow rates, pressure drops and use of high-speed imaging to visualize and measure important variables such as phase volume fractions and velocities. Comparisons of three-phase pressure drop with single-phase oil and two-phase oil-water are shown with the purpose of appraise the influence of gas. A new tool developed in LabView® was proved very useful to reconstruct phase interfaces and provide useful information on the flow geometry and kinematics of such complex flows. In special, the effect of the presence of gas on the oil body and the determination of phase volume fractions are emphasized.

RESULTS

Some illustrative results are shown in the following pictures.

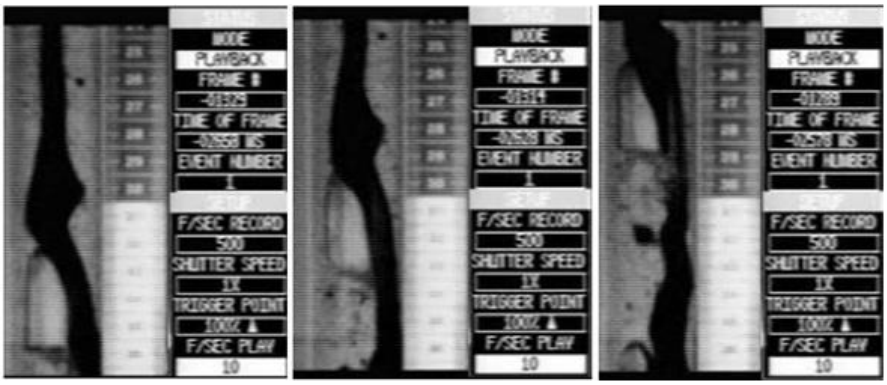

Fig. 1 – Deformation of oil core caused by the passage of a gas bubble.

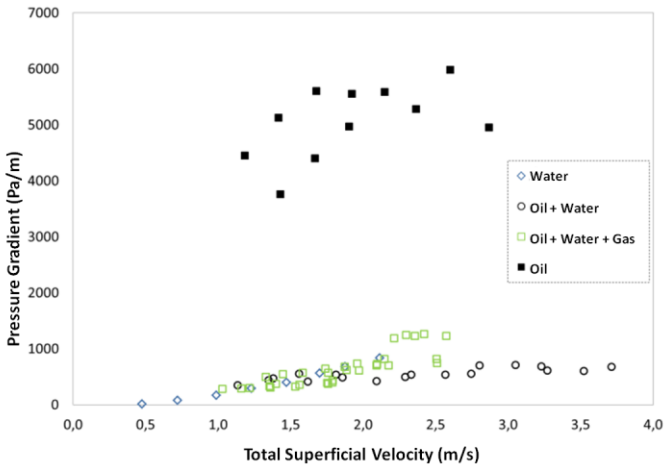

Fig. 2 – Comparison between different pressure drops for a horizontal 69 mm i.d. pipe.

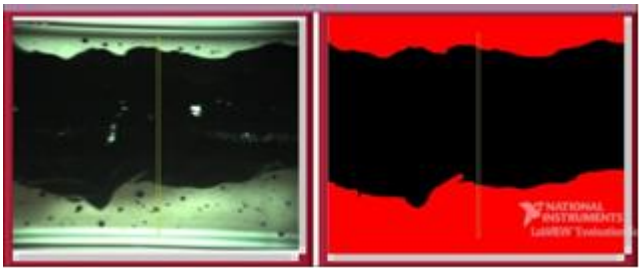

Fig. 3 – Image reconstruction of oil-water interface by means of a tool developed in LabView®

CONCLUSIONS

This paper is aimed to show that the visualization of complex three-phase flows such as viscous oil-water-gas by means of high-speed imaging is very useful to understand flow structure without causing any perturbation in the flow (non-intrusive technique). The development of tools for imaging analysis further allows determination of several important parameters such as phase fractions and velocities.

References

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