



SPE 115293

Wax Deposition in Pipelines: Flow-Loop Experiments and Investigations on a Novel Approach

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This paper was prepared for presentation at the 2008 SPE Annual Technical Conference and Exhibition held in Denver, Colorado, USA, 21–24 September 2008.

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Abstract:

Models used to predict wax deposits in oil production pipeline are based on thermodynamic properties coupled with several Fick's diffusion mechanisms. These models generally need fitting parameters to match computational results to experimental data, and moreover they do not explain all aspects of this phenomenon. One of these aspects is the "sticking" of the deposit to the wall. In this study, it is demonstrated that the deposit could result from flow patterns caused by rheological factors. Indeed, thermodynamic properties create the onset of wax crystals, and diffusion mechanisms result in the displacement and accumulation of wax in a particular region. This results in rheological changes that modify the flow pattern and create an unyielded region near the wall, namely a wax deposit. To highlight this process, experimental tests of wax deposition were performed on the Lyre loop at IFP-Lyon in Solaize, France. This loop is 140 meter long with a 2 inches internal diameter and is fully temperature-controlled. A wax deposition section consisting of a 7 meter sub-cooled section is integrated in this loop. A one-meter spool piece can be retrieved to observe and sample the wax deposit. Temperature, pressure drops and flow rate were monitored. The wax deposit was observed after 4h, 24h and 72h and was sampled for rheological measurements. The experimental results are presented in this paper. In addition, to analyse this experimental data, a numerical model based on the previously described physical aspects is implemented, and the results show good agreement with experimental data.

Introduction:

Waxy Crude Oils (W.C.O) contain normal paraffin (n-paraffin) which are linear chains alkanes. Taken individually, n-paraffin, under ambient conditions, are in gaseous state when the carbon atoms chain are less than four atoms (C_1 to C_4), in liquid state from C_5 to C_{16} and finally in solid state beyond C_{16} . This last point is extremely important since although the presence of other hydrocarbons and impurities in crude delay their solidification, n-paraffin are mainly responsible for wax deposit in pipeline during W.C.O production and transportation. Consequently production capacity is reduced, or even blocked. Temperature, at which the first n-paraffin crystal appears, is called Wax Appearance Temperature (WAT). Oil and gas companies use some traditional tools to prevent the n-paraffin crystallization or to remove the existing wax deposit. These solutions imply the use of chemical products, pipeline electrical heating or, in some cases, mechanical scrapping to periods up to day. Pipelining the crude oil from western of Kazakhstan to Samara in Russia (about 1400 km) has required heating stations each 100 km. Expenses used to remedy to this concern could be optimized by using a software that could "predict" as accurately as possible the amount of wax deposit formed, its aging, its location and finally the wax deposit formation rate. That is why work have been carried out to improve knowledge about this phenomenon. Noteworthy advancements in the understanding of wax deposits were achieved in the early 1980's (Burger et al. 1981). Prediction models were presented in several studies (Hsu et al. 1994; Lund 1998; Kok et al. 2000, Hernandez et al. 2003). However mechanisms responsible for the wax deposit growth are widely debated (Azevedo et al. 2003; Singh et al. 2000; Burger et al. 1981). The main mechanism used in the current models is molecular diffusion which is a spontaneous movement of dissolved particles from an area with a high concentration of dissolved molecules to an area with a low concentration of dissolved molecules. Indeed, when the pipeline wall temperature is less than the WAT, wax crystals appear at the wall which induces a radial gradient of the dissolved normal paraffin concentration in the pipeline, leading to molecular diffusion from the central core of the flow to the pipe wall. This approach considers the wax deposit as a fluid layer of entirely solidified normal paraffin. However, experimental observations note that