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Experimental and Modeling Studies of Wax Deposition in Crude Oil Carrying Pipelines

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Abstract

Wax deposition can be a serious problem in crude oil carrying pipelines operating in cold environments. The primary mechanisms of wax deposition at the wall are diffusion of dissolved wax and transport of particle wax. Diffusion of dissolved wax has long been recognized to be highly causative in deposit formation, very prominently evident at high heat fluxes. However, the contribution of particle transport and the fundamental mechanisms responsible for this transport have not been conclusively drawn. An adequate particle distribution and deposition theory was found to be lacking in the current wax deposition literature. This work provides experimental studies of the particle wax's radial distribution in laminar pipe flow and its co-relation to the deposition phenomena at the pipe wall.

An experimental flow loop was designed and built for visualization. A transparent model oil was constituted and solubility studies were done based on a novel Fourier Transform Infrared Spectroscopy (FTIR) method. High Temperature Gas Chromatography - Simulated Distillation (HTGC-SimDis) carbon number characterization and densitometry measurements were also performed. Laser Light Scattering (LLS) by flow particles was used to view a diametrical plane along the test-section axis. The particle distribution in the pipe cross-section was obtained from the images grabbed there from.

Of mechanistic relation to particle transport, shear dispersion was seen to be acting away from the wall, whereas Brownian diffusion was identified as the major mechanism responsible for particle transport to the pipe wall during laminar flow. Also, deposition was observed under all conditions of heat flux (positive, negative or zero) as long as the wall temperature was below the Wax Appearance Point (WAP). The combined effect of flow rate, heat flux and deposition surface topology were seen to play a role in the morphology and strength of the final deposit.

Introduction

In cold environments, oil-carrying pipelines lose heat rapidly. This is especially true for subsea pipelines or uninsulated, overground pipelines in colder regions of the world. It is seen that, starting at the pipe wall, if the temperature of the oil falls below the 'Wax Appearance Point' (WAP), wax generally deposits on the pipeline wall. Decreased pipe diameters are a major concern to oil transportation companies as they represent a major increase in pumping costs, not to mention the loss of throughput and quality of oil. In the aforementioned extreme cases of deposition, routine shutdown has to be scheduled to pig the pipeline. Hence, establishing mechanisms of wax deposition would help in identifying the parameters that would need to be controlled in order to prevent or minimize wax deposition.

When oil cools below the WAP, wax crystals form in the pipe cross-section. If a temperature gradient exists (which will if the oil is losing heat), then dissolved wax and precipitated wax exhibit a concentration profile in the pipe cross-section. The widely recognized transport methods contributing to wax thickness on the pipe wall are molecular diffusion of dissolved wax, particle transport of precipitated wax and sloughing of previously deposited wax. All researchers in this area agree with molecular diffusion of dissolved wax to be the most important contributor in wax deposition. However, the particle transport mechanism has not been conclusively drawn and there remains uncertainty as to its role in the overall wax deposition phenomenon.

In this study, it was decided to study the deposition phenomena, especially in relation to particle transport, at all types of heat fluxes (positive (cooling), negative (heating) and zero). The flow system used in this study was also made transparent to gain visual access to the pipe interior and observe most of the deposition as it takes place. An added advantage of this was that we