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Wax Deposition During Production Operations: SOTA

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Abstract

Arterial wax deposition has been problematic for the industry for many years. The development of new technology progresses in fits and starts. This deposition is differentiated from deposition in the geological sense. The particular characteristics governing the magnitude and occurrence of deposition are: (1) the temperature and pressure must be such that wax precipitates in the flowing phase and (2) there must be heat flow from the mobile phase to the pipe wall. We also know the deposits formed are not 100% paraffin wax. Yet, some of the relatively new methods proposed for modeling deposition defy some of these well established principles. Experimental challenges also exist. In general, the heat flux in flowing pipelines is far less than that in laboratory experiments. We also know the flow line is not isothermal yet only typically test at one set of temperatures. More serious work needs to be done to develop an understanding of deposition in turbulent flow conditions, deposition over longer time periods, deposition at low heat transfer, and devising methods to obtain credible field data for comparison and guiding research in this area. This presentation will review the current state of the art and propose ways forward.

Introduction

Wax deposition in production pipelines is one of the major flow assurance risks that need to be considered whether developing new fields or maintaining existing operations. The problems associated with wax deposition are reduced productivity, increased pressure drop and the risk of getting a pig stuck during maintenance operations. It is known that the production losses and remediation operations associated with paraffin deposition cost millions of dollars¹. Flow assurance risks, including wax deposition and wax gelation, become a bigger concern as the oil industry continues to expand deepwater operations to greater depths and distances in cold environments.

Precipitation of n-paraffins (waxes) is the precursor to wax deposition. The phase stability of crude oil is dependent on a multitude of factors including the composition of the oil, temperature, pressure, and other operating conditions. At reservoir pressures and temperatures, the paraffin molecules are typically fully dissolved in the reservoir fluid. As the temperature drops in the wellbore and production lines, these paraffins start precipitating out of solution due to solubility limits.

It is important to distinguish between the two phenomena – precipitation and deposition. Precipitation is a necessary, but not sufficient condition for deposition. Unfortunately, this issue seems to be a bit confused in common parlance in the oil industry. Precipitation is, sometimes, incorrectly referred to as deposition. It must be noted that deposition during production operations is a more complex phenomenon than precipitation. Wax precipitation is simply a thermodynamic phenomenon that is observed when the fluid temperature is reduced below the so-called Wax Appearance Temperature (T_{WAT}). As the fluid temperature is further reduced, more waxes precipitate out of solution, possibly leading to a point where the fluid loses mobility due to gelation. The industrial practice is to approximately measure the temperature of “no mobility” using the ASTM D97 method; this temperature is called the pour point temperature. The deposition mechanism is more complex and is described in the next section.

There is a plethora of literature dealing with wax precipitation and deposition. Holder and Winkler² described the wax appearance temperature and pour point phenomena by working with distillate fuels. They also showed that, with as little as 2% precipitated wax, the fluid can form a gel³. This observation has also been verified by other researchers. One of the important issues to be noted is that the wax deposit is not solid wax, but a gel that consists of solid wax crystals and trapped liquid. The deposit is also known to harden with time in a process termed aging^{4,27}. Several models have also been developed to describe the thermodynamics of wax precipitation⁵⁻¹¹. Different models predict different results when applied to a fluid under study; however, in most cases, the differences are not significant. When there are significant differences, the appropriate model can be chosen or a given model can be tuned based on experimental data on wax precipitation from that fluid. In our view, the available models are sufficiently advanced such that the precipitation can be reasonably modeled from a practical perspective. Modeling wax deposition, however, still has scope for advancement.