

Deposition and Corrosion Mitigation using Surface Treatments

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ABSTRACT

In order to provide flow assurance for a subsea line, there are many factors that must be accounted for, which are often specific to the well or field. Chemical additives are frequently used to control the deposition of one species or another, but these chemicals are costly and there exist few solutions which can address multiple depositing species at once. Among flow assurance concerns, clathrate hydrates, asphaltenes, waxes, scale and corrosion make up a large number of potential challenges. These species will deposit under different conditions, depending on thermodynamic and compositional conditions inside the pipeline. Under certain conditions, several of these species may nucleate, precipitate, and deposit all at once.

For this work, a surface treatment was created with the potential to resist deposition from multiple species, while also protecting pipe surfaces from corrosion. Due to a combination of low surface energy, oleophobicity, and low surface roughness, this surface treatment has been shown to resist deposit formation for multiple flow assurance species. Data from static and flowing systems have been used to show the treatment's effectiveness.

INTRODUCTION

Deposition can occur based on many species present in oil production lines. Some components, such as waxes and asphaltenes come from species contained within the produced oil, while others such as hydrates and corrosion form due to interacting species, such as a water phase. Regardless of the origin of the depositing species, material can easily build up to hazardous levels over time, causing stenosis of the pipeline, decreasing flow and increasing pressure drop. Treatments for deposition vary widely based on both the depositing species as well as the thermodynamic (temperature, pressure, composition) conditions. Frequently, chemical treatments are employed, which can be costly and may have detrimental effects on other compounds in the oil.

Asphaltenes represent a complex fraction of the oil phase which is soluble in toluene but insoluble in n-heptane [1]. This fraction of the oil phase can be sensitive to changes in temperature, pressure, or composition, which can lead to the precipitation and agglomeration of solid asphaltenes. Deposition of asphaltenes is most commonly avoided through the addition of dispersants, typically surfactant molecules which work to keep asphaltene solids suspended in the bulk oil, avoiding agglomeration and deposition [2,3]. However, due to the high degree of variability within crude oils and the still limited understanding of their nature, chemical additives do not always perform in the field as predicted in lab testing, and failures may occur even while treatment is active [4].

In order to clear deposits which have formed, mechanical cleaning is the preferred method. Regular pigging can prevent deposits from getting too large and increasing pressure drop in the pipeline. However, asphaltene deposits can be very hard, and if a plug is formed, pigs can get stuck in the line. In such cases, or where pigging is unfeasible, chemical cleaning using aromatic solvents is possible, though it can have major drawback such as expense, safety hazard, and environmental concerns.

Waxes are a natural component in many oils, comprised of long chain saturated hydrocarbons (paraffins) [5,6]. In some oils, the wax is dissolved and at high temperature; however, if the temperature at the pipe wall drops below the wax appearance temperature (WAT) of the oil, then precipitation and deposition of the wax can begin to occur on the pipe walls. Certain areas, such as subsea or permafrost lines, make such conditions common.

In order to remediate wax deposits, similar mechanical methods can be used as for asphaltenes, in addition to thermal or chemical remediation [7]. Thermal methods can be preventative, as in the case of heating flowlines, or remediate wax deposits, as with hot oil treatments. Chemical treatments can also vary, from solvents which dissolve the wax to crystal modifiers and surfactants that work to keep precipitated crystals from agglomerating or depositing [8].

There are currently no solutions which can effectively treat multiple flow assurance challenges, as each depositing species will present differently, and chemical treatments can vary widely. Mechanical cleaning frequently remains the most effective means of treatment but requires specific knowledge of the requirements in order to minimize downtime and maintenance. It can also be very important to determine if treatments for one species might be detrimental for another [9]. In this paper, a surface treatment is investigated which has previously been demonstrated to resist hydrate deposition has been investigated for interactions with asphaltenes and waxes. This method represents a potential solution which is applicable for a variety of flow assurance species.

EXPERIMENTAL PROCEDURE

Corrosion testing was performed in a salt fog chamber designed to accelerate natural conditions and show extreme corrosion behavior. The procedure for corrosion testing followed ASTM B117 - Standard Practice for Operating Salt Spray (Fog) Apparatus [10], and tests were performed for up to 500 hours in the salt fog chamber. Coated and uncoated samples were added at the same time for comparison, and

samples were kept near each other for the duration of the tests. Contact angle measurements were performed using a Rame-Hart Goniometer. Approximately 10 μ l of DI water were used for each measurement.

To investigate the adhesion of wax to a variety of metal substrates, the shear forces necessary to remove wax deposits from the surface of the coupon were measured. The procedure for these experiments begins with creating wax deposits with uniform contact areas on different coupon types. Cuvettes open on both ends measuring 1 cm on each side were placed onto four types of coupons: Pristine carbon steel, corroded carbon steel, coated pristine steel, and coated corroded steel. Approximately 0.5g of melted paraffin wax was deposited into the cuvette and allowed to cool completely. It was ensured that wax was not able to leak under the edges, ensuring that the contact area remained constant between experiments. Once the wax was completely cooled to room temperature, the coupon was mounted against a backstop and an Imada Force Gauge set to measure the peak force was used to steadily apply pressure against one side of the cuvette (see Figure 1). The maximum force needed to remove the coupon from the substrate was recorded. A minimum of 6 repeat measurements were taken for each substrate type.



Figure 1 – Apparatus for testing wax adhesion to various metal surfaces.

In addition to adhesion studies, a cold finger apparatus was constructed to investigate deposition behaviors of waxes. This apparatus consists of an oil/wax bath which is heated to the desired temperature using a water bath. Two pipes (coated and uncoated), running in parallel, are submerged into the oil bath through a u-bend in the middle of the pipe (as seen in Figure 2). Water at a temperature lower than that of the oil bath (and below the wax appearance temperature for the wax/oil mixture) is circulated through the pipes to induce precipitation of the wax onto the pipelines. For these experiments, a model system consisting of 20% paraffin wax/80% Mineral Oil 70T by weight was used. The bath was maintained at 56°C while the circulating water was 34°C. The WAT for this mixture is 37°C. A high wax content oil mixture was used to speed deposition; less waxy mixtures may take significantly longer to form deposits.

Both the coated and the uncoated pipe are weighed before each experiment. After the experiments are complete, the pipes are removed from the oil bath and allowed to drain the excess oil for several hours before being reweighed to determine the amount of wax that deposited on the pipe surface.