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A Comprehensive Solubility Model for Asphaltene Flocculation Prediction at Field Conditions

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Abstract

A large set of field data has been collected over the last decade related to various facets of asphaltene instability problems at our production facilities. These problems include compatibility of heavy oil with hydrocarbon diluents in a Venezuelan operation, commingling of live oil and condensate in a North Sea production facility, compatibility of drilling mud base oil and miscible injectants with reservoir fluids in Alaskan operations. In each of the field cases, significant lab data were generated by titrating the dead crude oil with n-alkanes with and without solvents (such as toluene or dead condensate or base oil) to study the asphaltene issue. We have applied available asphaltene prediction techniques (Heithaus^{1,2}, I.A. Wiehe^{3,4,5}, S.I. Anderson⁶, J.X.Wang and J.S. Buckley^{7,8,9}, and K.J. Leontaritis¹⁰) to explain the field data. None of the models alone has been found comprehensive enough to explain flocculation at all of the conditions including the flocculation that occurs at ambient conditions in the presence of paraffinic diluents, stability enhancement that occurs upon addition of aromatic solvents, and the instability that occurs in a live fluid due to changes in composition, pressure and temperature. To handle a complex crude oil system, these models made some simplifying assumptions which enabled them to make the problem tractable. In doing so, they lose some predictive capability. We found that there are two forces that need to be accurately captured – dynamics of the alteration of solubility parameter of the hydrocarbon matrix and change in entropy of mixing – to model the asphaltene behavior. The later has been either empirically estimated by extrapolating the ambient titration data or neglected in many of the previous models. The basic parameters for our model can be calculated from lab data generated by titrating the dead crude oil with n-alkanes with

and without known solvents at different temperatures. So far this model has been applied to various field conditions in the production facilities and found successful in matching the field data. The final validation of the model to reservoir conditions is ongoing. We hope to present a comprehensive study in this paper.

Introduction

Asphaltenes are generally defined as the fraction that is soluble in aromatic solvents such as benzene or toluene and insoluble in light normal alkanes such as n-pentane or n-heptane¹¹. Asphaltenes are typically stable in a live fluid at reservoir condition. Once the drilling and production starts, the change in pressure, composition and temperature, can cause asphaltenes to destabilize. Asphaltene precipitation and deposition in the production and operation are undesirable situations that are quite expensive to remediate.

The solubility parameter concept which was first described by Joel H. Hildebrand¹² was used as a compatibility indicator such that if the solubility parameter of any mixture was greater than the solubility parameter at the onset point of precipitation, that mixture was stable otherwise it will create asphaltene precipitation problem.

This paper focuses on the development of a comprehensive asphaltene precipitation model based on the solubility parameter concept. A successful model should be able to predict onset of asphaltene flocculation under any field condition. Several field projects are also included in this paper to show the wide application of the asphaltene precipitation predictor in several different circumstances. For example, asphaltenes can precipitate in an incompatible blend of two or more hydrocarbon liquids in a sales pipeline or refinery; asphaltenes can cause sludge formation and emulsion issues during mixing of two or more live hydrocarbon liquids in surface facilities (flow line or separators), asphaltenes can drop out during depressurization of a live oil near well bore during production and commingling of miscible injectant (MI) with a live oil in the reservoir during enhanced oil recovery.

Relevant field examples are presented along with a chronological development (simple to complex) of the asphaltene flocculation model. The model complexity increases as the operating conditions change from stock tank conditions to medium pressure/temperature conditions in the topside facilities to high temperature/pressure conditions in the reservoir. In this paper, the experimental techniques are discussed in the next section and then the asphaltene

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