Equilibrium distributions of asphaltenes in the presence of GOR gradients

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Modeling of hydrocarbon fluids in oilfield reservoirs is essential for optimizing production. In particular, the often large compositional variations of reservoir crude oils need to be understood and modeled. Two of the most important chemical constituents that govern many chemical and physical properties of subsurface crude oils are the dissolved gas content described by the gas-oil ratio (GOR) and the asphaltene content. Modeling of GOR variations in crude oils in reservoirs has been practiced routinely for decades. However, modeling of asphaltenes and heavy ends of reservoir crude oils is only now becoming possible because of recent advances in the understanding of the molecular and colloidal structure of asphaltenes in crude oils.

Here, we present a thermodynamic model of asphaltene grading caused by both gravitational and solubility effects. The model for the equilibrium distribution of asphaltenes in an oil column is based on a two-component Flory-Huggins model combined with a gravitational contribution. The variations with depth of the maltene properties are calculated from the equation of state. We show that the asphaltene distribution depends on three terms. The first is the gravity term, which depends strongly on the size of the asphaltene particle. The second is the solubility term, which depends not only on the size of the asphaltene particle, but also on the solubility parameter, which is strongly affected by the GOR and its gradient. The third term is the entropy term, which arises from the difference in size between the asphaltene particles and the maltene molecules, and tends to counteract the effect of the first two terms.

We apply this model to two case studies. One is a condensate oil column, where the size is found to be consistent with the asphaltene or colored component being molecularly dispersed. In this case, the variation in GOR is the dominant effect determining the asphaltene distribution. The second example is a black oil where the asphaltenes are in nanoaggregates and the gravitational term has the largest influence on the asphaltene equilibrium distribution. We also discuss heuristics for determining when the solubility effects will be significant.

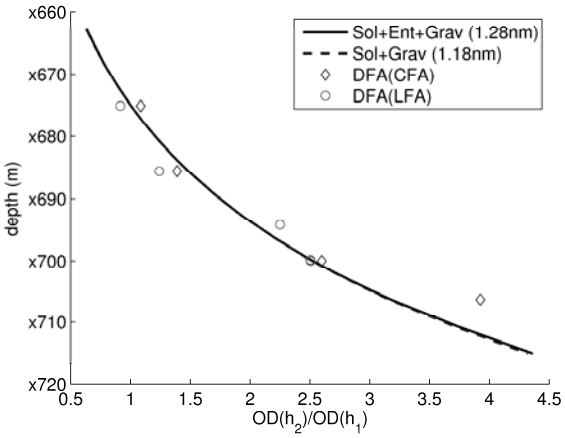

Fig. 1. Color variation in a condensate oil column as measured by DFA. The theoretical curve with just the solubility and gravity effects is shown with the dashed line, and the curve with the solubility, gravity and entropy effects is shown with the curved line. In the first case, the fit to the model give a diameter of 1.18nm and, in the second, a diameter of 1.28nm, respectively.