2nd INTERNATIONAL CONFERENCE ON RESEARCH IN SCIENCE AND TECHNOLOGY
Istanbul-Turkey 14 March 2016
RSTCONF
دومین کنفرانس بین المللی پژوهش در علوم و تکنولوژی
ترکیه - استانبول ۲۴ اسفند ۱۳۹۴

Formation Damage Caused by Asphaltene Deposition in a well of Carbonate Reservoir

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Abstract

When during oil production the thermodynamic conditions within the near-wellbore formation lie inside the asphaltene deposition envelope of the reservoir fluid, the flocculated asphaltenes cause formation damage. Mathematically, formation damage is a reduction in the hydrocarbon effective mobility, λ ($\lambda = ko/\mu = kkr/\mu$). Asphaltenes can reduce the hydrocarbon effective mobility by a) blocking pore throats thus reducing the rock permeability, k, b) adsorbing onto the rock and altering the formation wettability from water-wet to oil-wet thus diminishing the effective permeability to oil, ko, and c) increasing the reservoir fluid viscosity, μ, by nucleating water-in-oil emulsions. In the most frequently encountered case of asphaltene-induced formation damage where an under-saturated oil is being produced without water, the most dominant damage mechanism is blockage of pore throats by asphaltene particles causing a reduction in rock permeability k. This paper presents a rather simple, yet realistic way of modeling asphaltene-induced near-well formation damage caused by blockage of pore throats by asphaltene particles. The model utilizes both macroscopic and microscopic concepts of the pore throat blockages. It also utilizes an existing asphaltene phase behavior model. The new asphaltene near-well formation damage model is applied in one case where it is used to track the degree of formation damage as a function of time and the effects on near-wellbore and wellbore hydraulics. Similarly the model can be used to preliminary study of the economics of developing a reservoir known to contain an under-saturated asphaltenic oil.

Keywords: Formation damage, Near wellbore, Particle size

Introduction

In this paper, the primarily concerned is asphaltene deposition that occurs when the pressure of an under-saturated reservoir fluid drops below the onset of asphaltene flocculation pressure, PAF, inside the formation. This can occur when the well is produced at high flow rates (or drawdowns). In this study, a mathematical model is presented for simulating organic formation damage near a wellbore caused by flocculation and deposition of asphaltenes.

Organic Formation Damage Mechanisms

The formulation of the organic formation damage model and the producing scenario under which it applies are described in this section. Referring to Fig. 1, there is a well producing an undersaturated reservoir oil (with zero water cut) at such a flow rate that the bottom hole flowing pressure, PW, is less than the onset of asphaltene flocculation pressure PAF. PAF is of course less than the reservoir pressure, Pe. If this fluid did not flocculate and deposit asphaltenes (inside the formation), the flow would be "Steady State", i.e., there would be no change in the pressure profile. Pe is assumed here not to change during the time interval under study. This would be the case, for instance, if the reservoir had a strong water drive and/or a large gas cap drive. Under this scenario, although the flow rate can be kept constant by opening the choke to compensate for the loss in pressure due to the formation damage caused by asphaltenes, the situation is not steady state. Pe and PAF (asphaltene flocculation pressure), re (external radius) and rAF (radius at which the pressure is PAF) respectively are constant if the flow rate, q, is kept constant. But Pw is continually decreasing (the drawdown is increasing) to maintain the production rate at q. It may be called as temporary "pseudo-steady state". It is temporary because, when the choke is fully opened, q will start decreasing and both re and rAF will decrease as well. Actually, re could become less than the original pseudo-steady state value of rAF, and rAF could become zero. Under these conditions no asphaltene flocculation would be occurring inside the reservoir and, if there is no deposition in the tubing (say due to chemical injection), the system would reach a true steady state condition. Hence, ideally, asphaltene induced formation damage can reach a maximum limit dictated by the system conditions such as reservoir pressure and temperature, oil phase behavior, and wellbore hydraulics. Although at this steady state condition the production rate may not be economical.

As mentioned above, at the pseudo-state condition the production rate q remains constant by opening the choke to offset or compensate for the asphaltene-induced formation damage. At this time the choke is not completely opened and it has been assumed that no deposition is occurring in the tubing (or, if there is, it is not impeding the oil flow significantly or it is being cleaned immediately, possibly through continuous chemical injection). This situation is also depicted in Fig. 2. As it is seen in the inset of the figure, some pore channels or throats become plugged or "bridged". In general, there are three forms of asphaltene-induced formation damage:

- Physical Blockage or Permeability Impairment
- Wettability Alterations
- Viscosity Increase or Emulsion Formation

From the above three mechanisms of asphaltene-induced formation damage the first one appears to be the dominant mechanism, although occasionally the second and many times the third mechanisms will playing a role under certain circumstances. If there is no water production, then no emulsion of water-in-oil is expected. Hence, any viscosity increase measured in the laboratory would have to be attributed to asphaltene particle concentration increase as the reservoir fluid approaches the wellbore. Past experiments have shown that asphaltene flocculation in-of-itself does not result in a significant viscosity increase. Also, based on the researchers' experience, reservoirs that have asphaltene problems seem to be mixed-wet to oil-wet even before production commences. It evidents then that the major cause of asphaltene-induced formation damage in asphaltenic reservoirs occurs via the first mechanism.

Results and Discussion

For illustration of the application of this asphaltene deposition model, after prediction the asphaltene deposition envelope (ADE) and the asphaltene particle size distribution (PSD) as a function of the thermodynamics of the oil–asphaltene system according to Leontaritis et al. (1994) and Leontaritis and Mansoori (1987). The typical asphaltene deposition envelope (ADE) predicted by Leontaritis method and using the data of the reservoir sample and correlating by experimental data from Schlumberger Figure 5 shows a typical asphaltene particle size distribution (PSD) predicted at reservoir conditions above the bubble-point pressure and inside the upper ADE. The well and formation data are presented by as the following. The wellbore radius: 0.29 ft, asphaltene damage radius: 20 ft, well drainage radius: 1060 ft, reservoir porosity: 25%, reservoir permeability: 100 mD, mean hydraulic diameter of the reservoir formation is 1 micron, reservoir temperature: 220F, reservoir pressure: 8500 psia, onset pressure of asphaltene deporition is 7800 psia, flowing bottomhole pressure: 7090 psia, well productivity index: 2.5 bbl/day/psi, and oil production rate: 3200 bbl/day.

Conclusions

• Physical blockage or permeability impairment is the most dominant mechanism of asphaltene-induced formation damage.
• A mathematical description of pore throat blockages by asphaltene particles formed in-situ by asphaltene flocculation was described.
• The model presented incorporates two constants, γ and A. Both constants have recommended values which can be refined by history-matching existing well data. The value
of both constants are expected to range between 0.0 and 1.0.
• The model was applied in a mock, partly real case to simulate the bottom hole pressure decline and loss of permeability and porosity in the near-wellbore formation due to asphaltene deposition. The results were realistic and within the expected trends.
• The van Everdingen-Hurst skin factor attributed to asphaltene-induced formation damage was also calculated by the model as a function of time.
• The results show that the model can be used to simulate production declines and formation damage in asphaltene-afflicted wells. This information can be used to estimate the amount of asphaltenes that need to be removed and thus design and plan well stimulation treatments, work-over, and general maintenance.
• The model needs further validation via application to real field cases with asphaltene-induced formation damage. The expectations are positive.

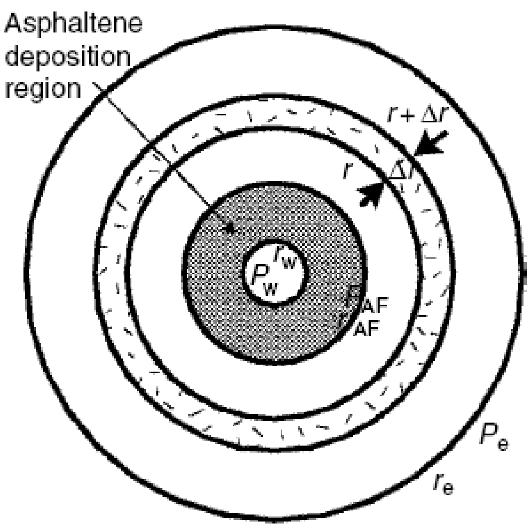

Figure. 1 Producing reservoir drainage area (modified after Leontaritis, 1998

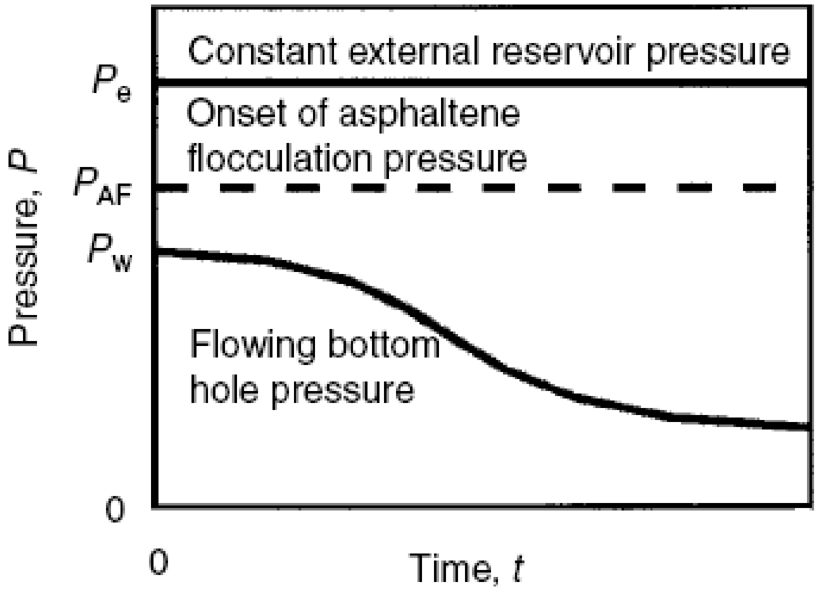

Figure.2 Variation of the flowing bottomhole pressure during constant rate production (modified after Leontaritis,).

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