Contribution ID: **222** Type: **Oral 20 Minutes**

A new approach for linear rheological characterization and modeling of viscoelastic surfactant systems under shear components in porous media

Tuesday, 15 May 2018 14:55 (15 minutes)

Viscoelastic surfactant solutions have a wide range of applications across many industries. In oil and gas applications, they are often used as hydraulic fracturing or displacement fluids due to their low damage inside the porous media, and their ability to improve the displacement efficiency. Recently, the microscopic displacement efficiency has been related to the rheological behavior of the viscoelastic solutions while flowing through porous media and micro-channels. To comprehend how the rheological behavior of viscoelastic systems affects the flow kinematics and hence the microscopic displacement, it is necessary to understand how the shear components and different conditions such as temperature and concentrations, affect the rheological behavior of these solutions. It is also of immense importance to develop models that properly predict the behavior of viscolestic fluids in linear and nonlinear regimes.

In this study, we present a complete and systematic rheological evaluation of two sets of viscoelastic surfactant solutions including non-ionic, and zwitterionic/anionic surfactant solutions to address a new approach for accurate and practical rheological modeling. The non-ionic solutions are composed of commercial Aromox APA-TW (APA-TW) and calcium chloride (CaCl2), while the zwitterionic/anionic systems of N-tetradecyl-N,N-dimethyl-3-ammonio-1-propanesulfonate (TDPS), sodium dodecyl sulfate (SDS) and sodium chloride (NaCl). The effect of temperature (up to 65 ℃), different concentrations, and resting conditions are studied using steady-state and oscillatory measurements in linear regime. The results show that at high temperatures, APA-TW/CaCl2 become more viscoelastic while TDPS/SDS/NaCl system loses its viscoelasticity. The addition of surfactant/salt improves the viscoelasticity on both systems, and, for the zwitterionic/anionic mixture, increasing the resting temperature stimulates its viscoelasticity.

Moreover, a novel semi-empirical rheological model is derived based on Cates theory and the wormlike micellar dynamics, showing the dependence of relaxation time on frequency. This semi-empirical mathematical expression can replace the conventional relaxation time in the simple Maxwell model, leading to a new model called the "Continuous Maxwell Model". The proposed model considerably improves the predictions of the traditional Maxwell model for frequency sweeps of viscoelastic solutions (from this study and literature data) for a wide range of surfactant/salt concentrations and temperatures by introducing, for first time, a continuous spectrum of relaxation time.

References

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Session Classification: Parallel 5-G

Track Classification: MS 1.17: Flow of Non-Newtonian and Complex Fluids Through Porous Media