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Emulsified Polymeric Gels for Oil and Gas Applications: Emulsion Formulation, Stability and Rheokinetics Investigation

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Water production is a serious issue associated with hydrocarbon exploration and production. The production of water was reported to be in the order of 249 million barrels per day (BPD) globally. The U.S alone produced an average volume of 57.4 million BPD. Approximately, $40 billion is spent annually on handling the unwanted produced water from oilfields. Commonly, inorganic and organically cross-linked gels are used. Nevertheless, a risk will be taken, that is blocking the hydrocarbon-producing zones alongside the water zones. Hence, Emulsified gels are proposed as a smart method for shutting off unwanted water produced from the oilfields without risking their productivity. In this study, emulsified polyacrylamide (PAM) polyethyleneimine (PEI) system was developed for high-temperature high-salinity applications. Emulsifier (e.g. surfactant) selection for such jobs is critical and undoubtedly expensive. In this work, we used the hydrophilic-lipophilic balance (HLB) for surfactant selection. Diverse surfactants were examined including ethoxylates, poly (ethylene glycols), fluorinated surfactants, and amides; and new insights on structure-surfactant stability relationship, beyond the HLB approach, are provided for surfactant selection. Additionally, nanomaterials (i.e. Organoclay) was proposed as a substitute for classical surfactants used in such an application. Furthermore, the thermal stability of the emulsified PAM/PEI gels was extensively investigated. The influence of different parameters, such as surfactant concentration water-oil ratio, salinity, mixing intensity and temperature, on the droplet size and the emulsion thermal stability was studied. A relationship between the emulsified system droplet size and its thermal stability was developed. Moreover, the impact of emulsification, salinity and temperature on gelation kinetics and gel strength are examined through high-pressure rheometry and differential scanning calorimetry (DSC). The rheokinetics of the gelling solution is modeled using Avrami based model. Emulsification was found to slow down cross-linking rate, and the activation energy for emulsified gels was found to be ~ 10 times higher than non-emulsified gels. We believe that this is the first of its kind study on emulsified polymeric systems, used for water control in oil and gas field conducted under typical reservoir conditions.

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