NMR Characterisation of Water-in-Crude Oil Emulsions: Effects of ICD-Induced Shear and Naphthenic Acids

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Introduction: Water-in-crude oil emulsions present persistent challenges in oil production, increasing viscosity and complicating phase separation. These emulsions may form due to mechanical shear encountered in wellbore components such as Inflow Control Devices (ICDs) (Figure 1) and may be stabilized or destabilized chemically through surface-active compounds such as naphthenic acids (NAs).

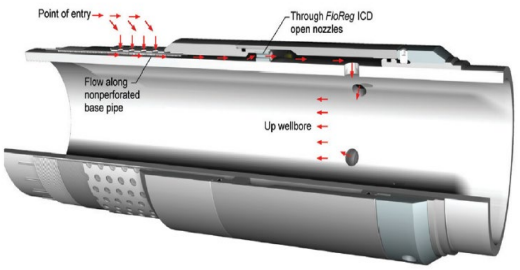

Figure 1: Nozzle type ICD

Methods: We employed Pulsed Field Gradient Nuclear Magnetic Resonance (PFG-NMR) and ^{1}H spectroscopy to quantify droplet size distributions (DSDs) [1], water content, and phase behaviour in opaque crude oil emulsions. An ICD-mimicking homogenizer was developed to simulate short-residence, high-shear mixing [2]. For chemical destabilization studies, commercial and indigenous NAs were added to crude oil samples emulsified with water, with samples analysed over time using PFG-NMR [3].

Results and Discussion: The ICD experiments revealed partial emulsification at high shear and low residence time, with median droplet size and emulsion viscosity increasing with water cut. In NA experiments, commercial NAs induced significant coalescence and phase separation (Figure 2) while indigenous NAs showed negligible effect. DSD broadening and a reduction in emulsified water signal were captured effectively by NMR, with bottle tests visually confirming separation trends.

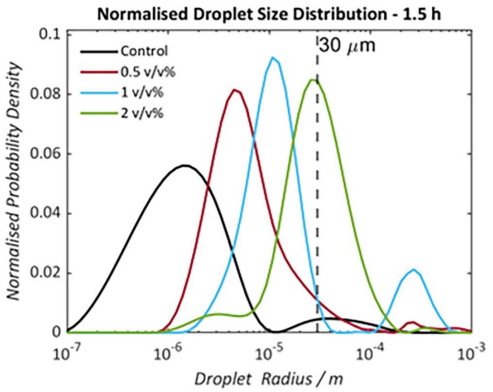

Figure 2: Saline (3.5wt %) crude oil A emulsion samples doped with 0 (black), 0.5 (red), 1 (blue), and 2 (green) v/v% Naphthenic Acid (Commercial).

Conclusion: This work highlights the utility of NMR for in situ, non-invasive crude oil emulsion characterisation and provides new insight into both mechanical and chemical drivers of emulsion stability relevant to petroleum transport and separation strategies.

References: [1] Hollingsworth, K.G., Magnetic Resonance Imaging (2003). [2] Jackson, M., Geoenergy Science and Engineering (2024). [3] Shilliday, E. R., Journal of Dispersion Science and Technology (2024).