



FAST 7 Proposal OILFIELD SCALE MANAGEMENT: FUNDAMENTALS TO FIELD Duration: 1 April 2019 – 31 March 2022

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FAST 7* Joint Industry Programme

OILFIELD SCALE MANAGEMENT: FUNDAMENTALS TO FIELD

THEME 1: Scale Inhibition Performance and Retention Mechanisms (Lead – Ken Sorbie)

THEME 2: Reservoir Geochemical Modelling and Squeeze Modelling (Lead Eric Mackay)

THEME 3: Effect of Solid Surface on Scale Deposition and Inhibition (Lead Anne Neville)

*Items new to FAST 7 identified in red throughout rest of presentation

SCALE INHIBITOR COUPLED ADSORPTION/PRECIPITATION: **Modelling of coupled Adsorption/Precipitation experiments and** field SI squeeze treatments. Sandpack 3: DETPMP_Ca precipitate dissolution in Ca 2000ppm, T = 20°C

Adsorption **Precipitation**









2. SCALE PREDICTION – EQUILIBRIUM AND KINETICS: Building on the FAST Scale Prediction code to develop a new state-of-the-art software package - ScαleFAST.



3. CARBONATE RESERVOIRS: The transport, geochemistry, adsorption/ precipitation and modelling of SI treatments in carbonate reservoirs.



10000

12000

4. MUTUAL SOLVENTS: The role of mutual solvents in scale inhibitor squeeze treatments. This topic was introduced in FAST 6 and 1 PhD has been completed on phase behaviour. The work will concentrate on mutual solvent propagation and impact on inhibitor retention.

 PV
 0.09
 0.26
 0.43
 0.60
 0.78
 0.95
 1.12
 1.29
 1.46
 1.64

 Bisplaced Brine
 Displaced Brine
 MS/Crude/Brine



MS Pre-Flush Sample Images





5. SCALE FORMATION IN EOR PROCESSES: This was first introduced in FAST 6 and has several parts, including impact of EOR polymer on SI retention and on inhibition efficiency, and may include further work on silicates arising during ASP flooding.



SULPHIDE SCALE STUDIES: Experimental and modelling studies of 6. sulphide scale formation and prevention including FeS, ZnS/PbS.

60

- **Carbonate system** $CO_2 + H_2O \rightleftharpoons HCO_3^- + H^+$ $HCO_3^- \rightleftharpoons CO_3^{2-} + H^+$
 - **[Fe], [Zn], [Pb], mg/l** 30 20 10 10 correction factor) X solution Sulphide **Scale Inhibitor** solution Exp.Fe2+ — Pre.Fe2+ 0 0 2 8 12 14 4 6 10 рH 19 XS $HS^- \Rightarrow S^{2-} + H^+$ Ο ≡ ICP 24 h 2 h Components Concentrations (mg/L) Cations Anions Analysis PVT Nnt K+ Scale Inhibitors Neutrals 417 Ţ Ca2+ Ma2+ Fe2+ $Ca^{2+} + CO_3^{2-} \rightleftharpoons CaCO_3(s)$ Ba24 Sr24 Zn2+ $Fe^{2+} + CO_3^{2-} \rightleftharpoons FeCO_3(s)$ Ph24 Li+ $Fe^{2+} + S^{2-} \rightleftharpoons FeS(s)$

Compound Ksp

5.08E-21 (1.29E-19*

- Sulphide system $H_2S \rightleftharpoons HS^- + H^+$
- **Precipitation/dissolution Reactions**

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7. SQUEEZE MODEL DEVELOPMENT: SQUEEZE will be developed to include extended optimisation, precipitation, and MS preflushes.



8. COUPLING OF ScαleFAST PREDICTION MODEL TO PVT CODES AND FLOW MODELS: Coupling to research and commercial PVT models and to flow models at reservoir, wellbore and pore scales.



9. RESERVOIR SCALE MODELLING OF EOR PROCESSES: Impact on scale management of CO2 WAG and chemical EOR (polymer, ASP, altered brine) and application to field cases.



 $H_2O \leftrightarrow OH^- + H^+$ $CO_{2 (aq)} + H_2O \leftrightarrow H^+ + HCO_3^-$

 $\mathrm{HCO}_3^- \leftrightarrow \mathrm{H}^+ + \mathrm{CO}_3^{2-}$

 $CaCO_{3(s)} \leftrightarrow Ca^{2+} + CO_3^{2-}$







10. RESERVOIR BRINE ANALYSIS: Analysis of produced brine compositions from many reservoirs using data supplied by sponsors to understand chemical EOR and scale risk.



11. SCALE MANAGEMENT DURING UNCONVENTIONAL PRODUCTION: Field data analysis and modelling of scale formation in unconventional oil and gas developments, and design of inhibition.



12. KNOWLDEGE TRANSFER OF SCALING AND FLOW PROCESSES: 3D micromodel printing, visualisation and modelling of reactive transport, Formation and Produced Waters Atlas, and dScale.



Formation and Produced Waters Atlas

dScale.org

UPCOMING EVENTS

SQUEEZE Two Day Course November 7 - November 8

Polymer EOR Part II Corefloods (2.3 MiB)

oir Geochemistry (1.7 MiB)

Scale Management during Unconventional Recovery (926.5 KiB) SI Adsorption & Precipitation in Carbonates (2.0 MiB)

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THEME 3: Effect of Solid Surface on Scale Deposition and Inhibition

13. SURFACE SCALE IN MULTI-PHASE CONDITIONS: Experimental studies to evaluate the challenges in surface scale inhibition in oil/water systems



- Understand how oil affects deposition and precipitation
- Interactions between inhibitor and oil
- Techniques; cryo SEM, FBRM

THEME 3: Effect of Solid Surface on Scale Deposition and Inhibition

14. SURFACE DEPOSITION STUDIES: Studies of scale deposition on surfaces – how this differs from bulk scale formation, kinetics, and how surfaces can be engineered to reduce scale





- Induction time
- Growth rates

Growth rate dm/dt as a function of flow, roughness, surface energy, SR, T etc



Existing PhD Studentships

Report to all FAST Steering Meetings

- 1. Scale during CO2 EOR CNPq and Galp – Hydra Rodrigues
- 2. Scale during ASP Flooding PDO – Mandhr Al Kalbani
- 3. Surface studies University of Leeds/FAST Loubna Gargoum
- 4. Surface studies University of Leeds/FAST Kabir Raheem

Report to <u>some</u> FAST Steering Meetings

5. Dispersion free simulation of reservoir scaling Energi Simulation / HWU / ETP - Masoud Ghaderi

New Externally Funded PhD Studentships

Report to all FAST Steering Meetings

- 1. Automatic Optimisation of Squeeze Treatment Designs OGIC / James Watt scholarship - Vahid Azari
- 2. Mutual Solvents CONACYT (Mexico) scholarship - Hugo Sanchez
- 3. Experimental / modelling BaSO₄ reaction kinetics DHRTC scholarship - Hamid Rafiee
- 4. Sulphide Inhibition

Saudi Aramco scholarship - TBC

Report to some FAST Steering Meetings

- 5. Visualisation of Pore Scale Reactive Flow EPSRC - Alexandros Dimou
- 6. Multiscale Reactive Flow Modelling James Watt scholarship - Ebuka David

New PhDs if Funding Available in FAST7

- 1. Silicate scaling
- 2. Scale management during polymer EOR
- 3. Unconventionals
- 4. Inhibition mechanisms
- 5. Scale formation under extreme conditions
- 6. Others?

Two other companies expressed interest in funding scholarships

Major Deliverables

- 1. Report sections and presentations
- 2. Publications and theses
- 3. SQUEEZE 11++
- 4. HW Scale Prediction Code (ScαleFAST)
- 5. Book on Oilfield Scale
- 6. Online Formation and Produced Water Atlas
- 7. Technical notes and methods
- 8. <u>dScale</u> Knowledge Transfer portal
- 9. Sponsor staff training and consultancy
- **10. Link to FASTrac** (later Mike Singleton)

Book on Oilfield Scale

- 1. Introduction
- 2. Mineral Scale Formation and Prediction
- 3. Scale Dissolvers
- 4. Scale Inhibitors and How They Work
- 5. Inhibitor Transport and Retention in Porous Media
- 6. Scale Inhibitor Squeeze Treatments
- 7. Squeeze Design and Optimisation
- 8. Impact of Reservoir on Scale Prediction and Prevention
- 9. Sample Preservation and Inhibitor Analysis
- **10. Designing a Field Treatment and Testing Programme**
- **11. Field Case Studies**

Online Formation and Produced Water Atlas

- Database populated with data from operators with support of OGA Stewardship
- Sections on collection and use of data:
 - Sample preservation
 - Sample quality control
 - Overall synthesis for basin
 - Identification of end member brine compositions
 - Comparison of supplied formation water compositions and those interpreted from produced water data
 - Scale prediction
 - History matching of reservoir simulation model with well rates and compositions as matching parameters
 - Derivation of Cation Exchange Capacities from field data
 - Updating of thermodynamic equilibrium parameters for field conditions
 - Updating of kinetic rate parameters for production conditions
 - Implications for water management during unconventional production
 - Impact of brine composition on carbon storage
 - Implications of brine composition on chemical EOR prospects

Ticket Price and Budget

£48,500 per annum for three-year term

Seeking 18 sponsors



Ticket price

Project budget



NALCO Champion

An Ecolab Company



Oil & Gas Innovation Centre







Schlumberger











Shaping the future.