Technologies and Mathematical Modeling of Fines-Assisted Oil and Gas Recovery

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A thesis submitted for the degree of Doctor of Philosophy (Ph.D.)

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# Table of Contents

Abstract ....................................................................................................................... iii

Statement of Originality .............................................................................................. v

Acknowledgment ......................................................................................................... vi

Thesis by Publication ............................................................................................... viii

Statement of Authors’ Contributions ......................................................................... x

1 **Contextual Statement** ........................................................................................... 1

  1.1 Thesis Structure ............................................................................................... 4

  1.2 How the Publications Are Related to This Thesis ....................................... 7

  1.3 References ....................................................................................................... 10

2 **Literature Review** ............................................................................................... 13

  2.1 Introduction ...................................................................................................... 13

  2.2 Suspension Transport in Porous Media ..................................................... 14

      2.2.1 Surface Interactions ............................................................................... 15

      2.2.2 Hydrodynamic Forces .......................................................................... 20

      2.2.3 Classical Filtration Theory ................................................................... 21

  2.3 Low Salinity Water-Flooding as an Improved Oil Recovery Technique .. 25

  2.4 References ....................................................................................................... 29

3 **Maximum Retention Concentration Function as a Model for Particles**

   **Detachment in Porous Media** ........................................................................... 33

   3.1 Particle Detachment under Velocity Alternation during Suspension

      Transport in Porous Media ............................................................................... 34

   3.2 Well Impairment by Fines Migration in Gas Fields ..................................... 60

   3.3 Effects of Fines Migration on Well Productivity during Steady State

      Production ........................................................................................................ 72

   3.4 Skin due to Fines Mobilization, Migration, and Straining during Steady

      State Oil Production .......................................................................................... 88
4 Analytical Model for Fines-Assisted Water-flood in Quasi 2-D Layer-Cake Formations

4.1 Effects of Induced Fines Migration on Water Cut during Waterflooding

4.2 Effects of Injected-Water Salinity on Waterflood Sweep Efficiency through Induced Fines Migration

5 Two-Phase Flow in Natural Rocks with Fines Lifting, Migration, and Straining

5.1 Improved Oil Recovery by Mobilizing Fines during Waterflooding (Laboratory-Based Incremental Recovery)

6 Modeling and Applications of Low Salinity Fines-Assisted Water-flooding (New Improved Oil Recovery Method)

6.1 Mathematical Model for Fines Migration Assisted Waterflooding with Induced Formation Damage

6.2 Fines Migration Assisted Improved Gas Recovery during Gas Field Depletion

7 Conclusions
Abstract

This is a PhD thesis by publication. It includes seven published/accepted for publication journal papers and two submitted papers in academic peer reviewed journals. The content of the thesis is also published in ten full volume technical papers of Society of Petroleum Engineering (SPE).

The thesis develops a theory for single and two-phase flow in porous media accounting for mobilization, migration, and straining of the natural reservoir fines. This phenomenon has been widely reported in laboratory studies and also well history data. The existing mathematical model, widely used in petroleum reservoir simulation, does not agree with laboratory observations. It contains phenomenological empirical constants which cannot be predicted theoretically.

The new closed system of governing equations, proposed in the current thesis, is free of the above mentioned shortcomings. The proposed system contains a new theoretical function describing the rock capacity to liberate fines so-called maximum retention function. This function is based on the micro scale conditions of mechanical equilibrium of fine particles in the porous space. The mechanical equilibrium condition is a torque balance of drag, lifting, electrostatic, gravity, and capillary forces. The maximum retention function is derived for both single-phase and two-phase flows in porous media. The comparison between the modified particle detachment model and the maximum retention function and laboratory and well data has shown a good agreement, which validates the model.

An exact analytical solution for single-phase flow in porous media with alternating velocity accounting for fines lifting has been derived, allowing for
mathematical description of a laboratory test on the suspension injection into reservoir cores with alternating velocities. Good agreement between the laboratory test results and the mathematical modeling predictions validates the theory developed.

Both analytical and numerical models for two-phase flow with induced fines migration have been developed. In reservoir scale approximation, the equivalence between the fines assisted water-flood and adsorption-free polymer flood has been investigated. It allows using the existing commercial simulators to model low salinity water-flood. The results of the modeling allow proposing a new technologically effective and economical method for improved sweep efficiency by fines assisted water-flooding.

Moreover, modeling of low salinity water injection shows that permeability reduction due to induced fines migration can slow down the encroaching water in oil/gas reservoir under strong water support. It decreases water production during pressure depletion of oil/gas reservoirs and improves the recovery. Also, a small volume injection of low salinity water can be used to reduce the water conning problem in oil/gas wells and prolong the wells production life.
Statement of Originality

This work contains no material which has been accepted for the award of any other degree or diploma in any university or other tertiary institution to Abbas Zeinijahromi and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text.

I give consent to this copy of my thesis when deposited in the University Library, being made available for loan and photocopying, subject to the provisions of the Copyright Act 1968.

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Thesis by Publication

Published Journal Papers


Papers Accepted for Publication

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Statement of Authors’ Contributions

This thesis comprises a portfolio of nine publications that have been published, accepted for publication and/or submitted for publications in accordance with ‘Academic Program Rules and Specifications 2012’. All journals to which the papers have been submitted are indexed in the ‘ERA 2012 Journal List’ database. The research summarized in the papers that constitute this thesis was undertaken within ‘Formation Damage and EOR Research Group’ at Australian School of Petroleum and with other universities and industry collaborators. Hence all the papers presented herein are co-authored and detail statements of relative contributions are endorsed by the co-authors.
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