

# **Polymer-Improved Oil Recovery**

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## Preface

The importance of oil in the world economy cannot be overstated, and methods for recovering oil will be the subject of much scientific and engineering research for many years to come. Even after the application of primary depletion and secondary recovery processes (usually waterflooding), much oil usually remains in a reservoir, and indeed in some heterogeneous reservoir systems as much as 70% of the original oil may remain. Thus, there is an enormous incentive for the development of improved or enhanced methods of oil recovery, aimed at recovering some portion of this remaining oil. The techniques used range from 'improved' secondary flooding methods (including polymer and certain gas injection processes) through to 'enhanced' or 'tertiary' methods such as chemical (surfactant, caustic, foam), gas miscible (carbon dioxide, gas reinjection) and thermal (steam soak and drive, *in-situ* combustion). The distinction between the classification of the methods usually refers to the target oil that the process seeks to recover. That is, in 'improved' recovery we are usually aiming to increase the oil sweep efficiency, whereas in 'tertiary' recovery we aim to mobilise and recover residual or capillary-trapped oil.

There are a few books and collections of articles which give general overviews of improved and enhanced oil recovery methods. However, for each recovery method, there is such a wide range of interconnected issues concerning the chemistry, physics and fluid mechanics of flow in porous media, that rarely are these adequately reviewed. This book provides a detailed state-of-the-art review of polymer-improved oil recovery, which includes discussion, where appropriate, of the underlying chemistry, physics, fluid mechanics, polymer science and porous medium flow. Following the Introduction, Chapter 2 describes the chemical structures of the main species used in polymer flooding: the synthetic material polyacrylamide (usually in its partially hydrolysed form) and the biopolymer xanthan. In subsequent chapters, the behaviour of aqueous polymer solutions, including the bulk rheology (Chapter 3) and chemical and mechanical stability (Chapter 4), are discussed. The following three chapters consider the fundamentals of polymer flow behaviour in porous media, and discuss polymer adsorption (Chapter 5), *in-situ* rheology (Chapter 6) and transport modelling (Chapter 7). The oil displacement mechanisms involved in reservoir systems are then described in some detail, mainly from a modelling/simulation

point of view (Chapter 8). Finally, there is an overview of the planning steps to be considered in the application of a field polymer flood (Chapter 9).

This book has grown from my research into polymer flow in porous media as it relates to improved oil recovery. The work began at the Winfrith petroleum research laboratory over ten years ago and has continued at the Department of Petroleum Engineering at Heriot-Watt University, which I joined three years ago. The book is aimed at scientists, engineers or researchers who have an interest in improved oil recovery in general, or polymer flooding in particular.

Throughout my work on polymer flooding research, many people have helped me through stimulating discussion, sound advice, constructive criticism and access to their work. I would particularly like to thank the following friends and colleagues: Peter Clifford, Bob Hawes, Randy Seright, Guy Chauveteau, John Fayers, Rex Wat, Mervyn Grist, Wilf Fox, Jacqueline Lecourtier, Bob Foulser, Alistair Fletcher and Gary Pope. My thanks also go to the staff at Blackie and Son who have provided the type of support that every reluctant author needs. Finally, the biggest thanks must go to my good friend and partner, Sheila Riddell, without whose support this book would never have been completed.

K. S. S.

*This book is dedicated to the memory  
of my father—the late Kenneth Sorbie  
Snr—and to Sheila, Annie and Bella,  
who are quite frequently late too*

## Foreword

The potential hydrocarbon resource left behind after the application of conventional oil recovery technology is so vast that the successful use of Improved Oil Recovery (IOR) must remain a major industry goal. For example, in the USA only about one third of the original oil reserves of over 500 billion barrels have been recovered and less than 30 billion barrels of oil remain as proven reserves. In time, a similar theme will emerge in many oil-producing countries and sedimentary basins around the world. Although the US Department of Energy has published estimates that over 70 billion barrels of additional reserve may be recovered by the application of IOR technology in the USA over the next ten years, the petroleum industry continues to view IOR technology with some reserve. The main technical problems relate to the variable success rate in field applications, the complexity of the basic physics and chemistry of the processes, and uncertainties in the oil recovery mechanisms at both the core and reservoir scale. In this respect, the importance of improved reservoir description has been recognised, but the task still remains to improve our understanding of the interactions between IOR mechanisms and complex heterogeneous geological features in the reservoir. Of the various IOR methods, polymer flooding is arguably the most straightforward to apply, as in its simplest form it is essentially an augmented waterflood. However, the process is still complex and there are many aspects of polymer flow in porous media that are still not fully understood. This book is a major contribution in outlining the current status of this particular IOR method.

In the late 1970s the UK Department of Energy initiated a major R&D programme into IOR by creating a centre of excellence at Winfrith (now part of AEA Petroleum Services) together with a supporting research programme in British universities. Within this programme, Dr Ken Sorbie and his team spent several years carrying out research on polymer flooding—involving both experimental and theoretical work—and made a number of valuable contributions to our understanding of polymer flow in porous media. This research experience at Winfrith, coupled with an extensive literature review and a selective coverage of polymer science ‘basics’, has resulted in the present book on the application of polymers in IOR. For the researcher in the general area of IOR, it will be indispensable, as it provides an authoritative appreciation of the literature and state of the science. For the reservoir engineer, it provides an understanding of the mechanisms and processes necessary for planning an oilfield application. Ken Sorbie has carried out a major service to the industry in writing this book and I hope that others will complement his work by producing similarly detailed works on gas displacement, surfactant flooding, and on the various thermal recovery methods.

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# Contents

<b>1</b>	<b>Introduction to polymer flooding</b>	<b>1</b>
1.1	Introduction	1
1.2	Mobility ratio and polymer recovery mechanisms	1
1.3	Background and early experience	3
1.4	Layout of this book	4
<b>2</b>	<b>Structure of the main polymers used in improved oil recovery (IOR)</b>	<b>6</b>
2.1	Introduction	6
2.2	The structure of xanthan biopolymer	7
2.2.1	Primary chemical structure of xanthan	7
2.2.2	Conformation of the xanthan molecule	9
2.2.3	Molecular weight and molecular weight distribution (MWD) of xanthan	14
2.2.4	Order–disorder transition in xanthan	15
2.3	The structure of partially hydrolysed polyacrylamide (HPAM)	19
2.3.1	The chemical structure of HPAM	19
2.3.2	Molecular conformation of HPAM molecules in aqueous solution	21
2.3.3	Molecular weight and molecular weight distribution of HPAM	21
2.4	Methods of detection and assay for xanthan and HPAM	24
2.4.1	Xanthan assay	25
2.4.2	The chemical detection of polyacrylamide	25
2.4.3	Size exclusion chromatography determination of HPAM	27
2.5	Manufacture of polymers for improved oil recovery	27
2.5.1	Biopolymer production	28
2.5.2	Polyacrylamide production	29
2.6	New polymers for IOR application	32
2.6.1	New synthetic polymers	33
2.6.2	Improved biopolymers	35
<b>3</b>	<b>Properties of polymer solutions</b>	<b>37</b>
3.1	Introduction	37
3.2	Solution viscosity of polymers	37
3.2.1	Viscosity and the generalised Navier–Stokes equations	38
3.2.2	How polymers viscosify	42
3.3	The molecular size of polymers in solution	43
3.3.1	The intrinsic viscosity: concentration and molecular weight relationships	43
3.3.2	Chain size and the molecular expansion factor	47
3.3.3	Relationships for flexible coil polymers	48
3.3.4	Equations for less flexible molecules	50
3.4	Introduction to polymer rheology	52
3.4.1	Steady shear flow of inelastic polymers	52
3.4.2	Viscoelastic polymers	56
3.4.3	Extensional flow	59
3.4.4	The viscosity of polyelectrolyte solutions	61

3.4.5	Salt, hardness and pH sensitivities of polyacrylamide and xanthan	62
3.4.6	Molecular basis of polymer rheology	64
3.4.7	Viscometry for polymer solutions	67
3.4.8	Capillary flow of Newtonian and non-Newtonian fluids	69
3.4.9	The Mooney–Weissenberg–Rabinowitsch equations	74
3.5	Thermodynamics of polymer solutions	75
3.6	Laboratory preparation and testing of polymer solutions	76
3.6.1	'Appropriate' laboratory solution preparation	77
3.6.2	Removal of microgel	78
3.6.3	Polymer dispersal in solution	78
3.6.4	Screen factor measurements on polymer solutions	79
<b>4</b>	<b>Polymer stability</b>	<b>83</b>
4.1	Introduction	83
4.2	Chemical stability of polymers for IOR	85
4.3	Mechanism of polymer chemical degradation	102
4.3.1	HPAM degradation mechanisms	102
4.3.2	Xanthan degradation mechanisms	107
4.4	Mechanical stability of polymers	114
4.5	Biological degradation of polymers	124
<b>5</b>	<b>Polymer retention in porous media</b>	<b>126</b>
5.1	Introduction	126
5.2	Polymer retention levels—units	127
5.3	Polymer retention mechanisms in porous media	128
5.3.1	Polymer adsorption	129
5.3.2	Mechanical entrapment of polymer	130
5.3.3	Hydrodynamic retention of polymer	133
5.3.4	Remarks on retention mechanisms	135
5.4	Polymer adsorption at the solid–liquid interface	136
5.5	Experimental measurement of polymer retention in porous media	139
5.5.1	Polymer retention from effluent analysis	139
5.5.2	Experimental refinements in retention measurements	140
5.6	Literature survey on polymer adsorption/retention	143
5.6.1	Introductory overview of polymer adsorption in porous media	143
5.6.2	Adsorption of HPAM and other flexible coil polymers	144
5.6.3	Adsorption of xanthan biopolymer in porous media	157
5.6.4	Polymer adsorption on mineral surfaces	159
5.6.5	Effect of adsorbed polymer on two-phase flow and relative permeabilities	161
5.7	Concluding remarks	163
<b>6</b>	<b>Polymer rheology in porous media</b>	<b>165</b>
6.1	Introduction	165
6.2	Models of porous media	166
6.2.1	Experimental examination of pore structure	166
6.2.2	Darcy flow in porous media and polymer apparent viscosity	168
6.2.3	Capillary bundle models	169
6.3	The flow of pseudoplastic fluids in porous media	171
6.3.1	General approach to <i>in-situ</i> rheology	171
6.3.2	Xanthan <i>in-situ</i> rheology: pseudoplastic behaviour	173
6.3.3	Xanthan <i>in-situ</i> rheology: apparent slip effects	178
6.3.4	Summary of experiments on the <i>in-situ</i> rheology of xanthan	182
6.4	The <i>in-situ</i> rheology of viscoelastic fluids in porous media	183

6.5	Theoretical analysis of polymer rheology in porous media	192
6.5.1	Summary of approaches to modelling <i>in-situ</i> rheology	193
6.5.2	Network modelling of non-Newtonian fluids in porous media	195
6.5.3	Rheological effects in the presence of depleted layers	202
6.6	Concluding remarks on polymer <i>in-situ</i> rheology	206
<b>7</b>	<b>Polymer transport in porous media</b>	<b>208</b>
7.1	Introduction	208
7.2	Tracer and polymer flow equations in a 1-D core	209
7.2.1	The convection–dispersion equation for tracer and polymer transport	210
7.2.2	Non-equilibrium effects in the CD equation	214
7.3	Polymer and tracer dispersion in porous media	216
7.3.1	Magnitude of polymer and tracer dispersion coefficients	216
7.3.2	Modelling of polymer and tracer dispersion	219
7.3.3	Non-equilibrium effects in polymer transport	224
7.4	Excluded/inaccessible pore volume effects in polymer transport through porous media	224
7.4.1	Interpretation of velocity enhancement in polymer transport through porous media	224
7.4.2	Underlying assumptions in the formulation of the transport equation in the presence of inaccessible/excluded pore volume effects	227
7.5	Equilibrium and non-equilibrium adsorption	230
7.5.1	The effect of adsorption/retention on polymer effluent profiles	230
7.5.2	Non-linear adsorption of polymer	230
7.5.3	Non-equilibrium polymer adsorption	234
7.6	Viscous fingering in polymer flooding	237
7.6.1	Inclusion of viscous fingering in the macroscopic flow equations	237
7.6.2	Graded viscosity banks	241
7.7	Polydispersity effects in polymer transport through porous media	242
7.8	Concluding remarks	244
<b>8</b>	<b>Oil displacement using polymers</b>	<b>246</b>
8.1	Introduction	246
8.2	Overview of the main oil displacement mechanisms	247
8.3	'Incremental' oil in polymer flooding	250
8.4	One-dimensional polymer flooding	251
8.4.1	Extended fractional flow theory for 1-D polymer flooding	252
8.4.2	Oil displacement by polymers in linear cores	258
8.5	Multiphase flow equations for polymer flooding	260
8.5.1	Overview of polymer simulation models	260
8.5.2	The two-phase flow/polymer transport equations	261
8.5.3	A simple finite difference strategy	262
8.5.4	Application of numerical scheme and comparison with 1-D analytical solution	266
8.5.5	The 3-D, two-phase polymer and heat transport equations	267
8.6	Improvement in areal sweep efficiency	270
8.7	Polymer recovery mechanisms in simple stratified systems	274
8.7.1	Description of basic flow mechanisms	275
8.7.2	The two-layer numerical model	277
8.7.3	Effects of vertical permeability on cross-flow	278
8.7.4	Ratio of horizontal permeability and layer thicknesses	280
8.7.5	Fluid mobilities	281
8.7.6	Effects of vertical permeability on oil production	282
8.7.7	Conclusions on polymer recovery mechanisms for a simple two-layer reservoir	284



8.7.8	Experimental verification of flow mechanisms in layered systems	285
8.8	The effects of polymer in real-field cross-sections	287
8.8.1	A simulation case study—the Brent Sands	287
8.8.2	Eight-layer cross-sectional model	292
8.9	Adsorption and degradation in field scale polymer floods	297
8.9.1	Polymer adsorption models in field calculations	297
8.9.2	Models of polymer degradation	299
8.9.3	Polymer adsorption effects in field systems	300
8.9.4	The effects of polymer degradation in the Brent Sands example	304
8.9.5	Polymer degradation in partly cooled reservoirs	306
8.9.6	Combining the effects of polymer retention and degradation	308
8.10	Summary and concluding remarks	310
<b>9</b>	<b>Application and planning of field polymer floods</b>	<b>312</b>
9.1	Introduction	312
9.2	Preliminary screening of candidate reservoirs for polymer flooding application	313
9.2.1	Background to the development of screening rules	313
9.2.2	Reservoir screening criteria for polymer flooding	315
9.2.3	Rapid polymer screening calculations	319
9.3	Design work for planning a field polymer flood pilot	320
9.3.1	Field studies	321
9.3.2	Laboratory tests	324
9.3.3	Computer simulations	332
9.4	Concluding remarks	340
	<b>References</b>	<b>341</b>
	<b>Index</b>	<b>355</b>

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