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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