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The Effect of Elasticity on Displacement Efficiency in the Lab and Results of High Concentration Polymer Flooding in the Field

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Abstract

The elasticity of polymer solution is usually disregarded in the studies of polymer flooding. The common viewpoint is that the displacement efficiency is determined by the ratio of the pressure gradient and interfacial tension in the system. But new studies show, when the pressure gradient and interfacial tension are constant, that visco-elastic polymer flooding can achieve higher displacement efficiency (*De*).

In this paper, based on theoretical analysis and through large amounts of core tests on homogeneous water-wet and slightly oil-wet artificial cores, the influence of visco-elasticity of polymer solutions with different concentrations on *De* were studied at different capillary numbers (determined by the ratio of pressure gradient to interfacial tension). The results show that when the capillary numbers are the same, the higher the flooding fluid's elasticity, the higher the *De* and the lower the residual oil saturation in both oil-wet and water-wet cores. In the range of these tests, the effect of elasticity on *De* is about the same as that of ultra-low interfacial tension chemical flooding. It can also been seen that residual oil starts to mobilize at a lower capillary number with higher elasticity driving fluids.

In addition, flooding experiments in the lab on heterogeneous cores by high concentration polymer fluid show that the higher the concentration and viscosity of the driving fluid, the higher the *De*. High concentration polymer flooding was tested in 3 fields and show that the additional recovery is nearly 2 times that of conventional polymer flooding, obtaining an incremental recovery of more than 20%OOIP.

This conclusion is useful in further understanding the mechanism of polymer flooding, and it can provide further basis for choosing chemicals and determining chemical flooding designs in the field.

Key words: elasticity, capillary number, displacement efficiency, polymer flooding

1. Introduction

The most commonly accepted mechanism on polymer flooding is that the displacement efficiency (*De*) is determined by the viscous pressure gradient and the retention force on residual oil. The former is proportional to the viscosity and velocity of the driving fluid ($v\mu$), the latter is proportional to the IFT (σ), the ratio is defined as capillary number ($Nc = \mu v / \sigma$), so the capillary number determines the displacement efficiency. In polymer flooding, the IFT between polymer fluid and crude oil is near to that between water and crude oil, and for a certain reservoir system, the macro pressure gradient can not be increased largely, then the *Nc* of polymer flooding is near to that of water flooding. Therefore, by the commonly accepted mechanism, the *De* for polymer flooding should be the same as that for water flooding.

However, numerous test results in the lab and field show that the *De* of polymer flooding is higher than not only that of water flooding, but also that of viscous fluids (for example: glycerin) flooding, the theory of *Nc* determines the *De* can not explain the increase in *De* after polymer flooding. The *Nc* is defined as the ratio of macro driving force and retention force, the driving force is a viscous force, which only reflects the effect of the driving fluid viscosity, so the *Nc* theory is accurate in predicting the results of Newtonian fluids flooding, for a certain fluid-rock system, the increase in viscosity can not increase the *De* when the macro pressure gradient maintains constant. While in viscoelastic polymer flooding, the macro pressure gradient can not explain the increase in De, so the increase in *De* is caused only by other forces which do not change the macro pressure gradient (unrelated to the viscosity), besides, these forces should be associated with the elasticity of the driving fluids (Demin Wang, 2007).