SIMPLE PROCEDURE FOR CALCULATING SHEAR RATE IN THE RESERVOIR

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ABSTRACT: *In an enhanced oil recovery process (EOR), the sweep efficiency is dependent on the mobility ratio. It is desirable to have a displacing fluid with a lower mobility than the displaced fluid for higher recovery efficiency. In an EOR process utilizing polymers, the shear rate in the reservoir is required for determination of the mobility ratio. This paper presents a formula for estimating the shear rate in the reservoir.*

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INTRODUCTION

A secondary oil recovery technique in the form of water flooding is usually initiated after the depletion of the primary energy of the reservoir. However, up to 50% of the original oil place is left behind in the reservoir at the end of water flooding. Enhanced oil recovery (EOR) methods are the only way of producing the remaining oil. EOR methods can be divided into two major groups; namely, thermal processes and chemical flooding processes. In-situ combustion, steam injection and wet combustion fall into the first category whereas miscible flooding, alkaline flooding, surfactant flooding, polymer flooding, carbon dioxide flooding and inert gas flooding fall into the second category. Sweep efficiency is dependent on the mobility ratio. It is desirable to have a displacing fluid with lower mobility than the displaced fluid. This minimizes fingering and bypassing of oil, and results in a higher reservoir coverage. Figure 1 shows the relationship between a real sweep efficiency at break through and mobility ratio (ratio of the mobility of the displacing fluid to that of the displaced fluid) for a five-spot pattern. The role of the polymer in the chemical flooding process is to increase the viscosity of the displacing fluid which results in a more favourable mobility ratio. In an EOR process utilizing polymers, the shear rate of the fluid in the reservoir is required for determination of the mobility ratio because the viscosity of polymer solutions is dependent on the shear rate. Two published formulas for determining shear rate are shown below.

French proposed the following formula for determining shear rate.

$$Y = 268.4V\sqrt{\frac{\phi}{K}}$$

Y = Share rate, sec^{-1}
K = Permeability, md
V = Front velocity, ft./day
ϕ = Porosity (fraction)

This formula cannot be used for non-Newtonian fluids and the source of the constant "268.4" in the formula was not explained.

Dietzel *et al.* presented the following formula.

$$Y = \left(\frac{1+3n}{n}\right)\frac{V}{\sqrt{8K\phi}}$$

Y = Share rate, sec^{-1}
K = Permeability, md
V = Front velocity, cm/day
ϕ = Porosity, %
n = Power law exponent

This formula cannot be derived from basic physical laws.

In this paper, a formula for calculating shear rate of a fluid in the reservoir based on the power law rheological model is presented.

MODEL

From analogy between Hagen Poiseuille's law

$$V = \frac{R^2}{8u}\frac{dP}{dI} \quad (1)$$

And Darcy's law.

$$V = \frac{K}{\phi u}\frac{dP}{dI} \quad (2)$$

The following relationship can be obtained.

$$K = 12.66 \times 10^6 R^2 \phi \quad (3)$$

The power law rheological model can be presented as follows.

$$r = Hy^n \quad (4)$$

From this model, shear rate at the wall is:

$$Y = \left(\frac{1+3n}{n}\right)\frac{V}{R} \quad (5)$$

Combining equations (3) and (5) eliminates "R' which is not measurable and yields:

$$Y = 3558.4\left(\frac{1+3n}{n}\right)v\sqrt{\frac{\phi}{K}} \quad (6)$$

Where:
R= Radius, cm
r = Shear stress, $dyne/cm^2$
H = Power law constant
Y = Shear rate, sec^{-1}
K = Permeability, Darcy

V = Front Velocity, cm/sec

ϕ = Porosity (fraction)

n = Power law exponent

In field units the equation (6) becomes

$$Y = 39.7\left(\frac{1+3n}{n}\right)v\sqrt{\frac{\phi}{K}} \qquad (7)$$

Where

Y = Shear rate, sec^{-1}

K = Permeability, md

V = Front velocity, ft/day

ϕ = Porosity (fraction)

n = Power law exponent

For a Newtonian fluid, n = 1 and equation (7) becomes:

$$Y = 158.8v\sqrt{\frac{\phi}{K}} \qquad (8)$$

SAMPLE CALCULATION

The shear rate of a polymer solution injected during an EOR process will be determined.

Powers law exponent = 0.75

Porosity = 0.25

Permeability = 300 md

Front velocity = 3 ft / day

$$Y = 39.7\left(\frac{1+3\,X\,0.75}{0.75}\right)3\sqrt{\frac{0.25}{300}} = 14.9\,\text{sec}^{-1}$$

CONCLUSION

The importance of determining mobility ratio at the insitu shear rate cannot be over emphasized. A three fold increase in shear rate results in a 42% reduction in viscosity of a polymer with a power law exponent of 0.50.

Simple formula for estimating shear rate of a fluid in the reservoir consistent with known physical laws has been presented. The relationship presented here will aid in estimating a more realistic mobility ratio.

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