INTERNATIONAL JOURNAL OF
NUMERICAL ANALYSIS AND MODELING
Volume 2, Supp , Pages 138–142

FULL IMPLICIT NUMERICAL SIMULATOR FOR POLYMER FLOODING AND PROFILE CONTROL

SIQIN TONG AND JINGXIA CHEN

Abstract. In this paper, taking account of the major physical and chemical mechanisms, such as: for polymer, shearing propertypermeability reduction, adsorption, inaccessible porous volumes, for gel, gelation speed, water viscosity changing with gel, permeability reduction, adsorption and retention in reservoir rocks, a three-dimensional, three-phase (oleic, vapor, aqueous) and six-component mathematical model has been established for polymer flooding and profile control. By use of full implicit finite difference method and calling PETSc linear solving system, the full implicit polymer flooding and profile control simulation software has been developed on PC-Linux environment based on black oil simulator, water flooding, polymer flooding and profile control simulation methods are integrated and applied into practice.

Key Words. numerical simulator, polymer flooding, profile control, full implicit, mathematical model.

1. Preface

With polymer flooding in Daqing, we have to face the problems, such as: a lot of polymer sewage was injected to stratum, polymer depth profile control and project setting, etc. In order to resolve actual problems and take full advantage of reservoir numerical simulation, it is urgent to require the technical support of polymer flooding and profile control simulation software.

Currently, there are some problems for POLYMER software used in Daqing, such as pinch and fault disposal and rock compressibility, etc. VIP-POLYMER upgrade software is applicable, whereas it is impossible of large scale application because of licence limit, profile control simulation software needs to be improved and refined.

In order to develop independent and practical simulation software for polymer flooding and profile control, a three-dimensional, three-phase (oleic, vapor, aqueous) and six-component (water, oil, gas, polymer, gel, cross-linker) mathematical model has been established for polymer flooding and profile control. Based on isothermal black oil model, the major physical and chemical mechanisms and other important factors are considered in the model, By use of full implicit finite difference method, the full implicit polymer flooding and profile control simulation software has been implemented on PC-Linux environment, water flooding, polymer flooding and profile control are integrated and applied into practice.

2. Mathematical model

According to mass balance equation, the basic differential equations of oil, water, gas, polymer, cross-linker and gel are derived and established as followed [1, 2]:

$$\text{(1)} \qquad \text{Oil:} \quad \nabla\left[\frac{K_{ro}K}{\mu_o B_o}\nabla(p_o-\gamma_o\nabla D)\right]+\frac{q_o}{B_o}=\frac{\partial}{\partial t}(\frac{\phi S_o}{B_o})$$

$$\text{Water:} \quad \nabla\left[\frac{K_{rw}K}{\mu_w B_w}\nabla(p_w-\gamma_w\nabla D)\right]+\frac{q_w}{B_w}=\frac{\partial}{\partial t}(\frac{\phi S_w}{B_w}) \tag{2}$$

$$\text{Gas:} \quad \nabla\left[\frac{K_{rg}K}{\mu_g B_g}\nabla(p_g-\gamma_g\nabla D)\right]+\nabla\left[\frac{K_{ro}K}{\mu_o B_o}R_s\nabla(p_g-\gamma_g\nabla D)\right] + \frac{q_g}{B_g}+\frac{R_{so}q_o}{B_o}=\frac{\partial}{\partial t}[\phi(\frac{S_g}{B_g}+\frac{R_{so}S_o}{B_o})] \tag{3}$$

$$\text{Polymer:} \quad \frac{\phi}{\phi_p}\nabla\frac{K_{rw}K}{R_{kfp}\nu_w\mu_p}C_p\nabla(p_w-\gamma_w\nabla D)-\phi\frac{S_w}{\nu_w}D_p-\phi\frac{S_w}{\nu_w}R_p-C_pq_w = \frac{\partial}{\partial_t}(\phi\frac{S_w}{\nu_w}C_p+(1-\phi)\frac{\rho_r}{\rho_w\nu_w}\hat{C}_p) \tag{4}$$

$$\text{Cross-linker:} \quad \frac{\phi}{\phi_p}\nabla\frac{K_{rw}K}{R_{kfp}\nu_w\mu_p}C_\chi\nabla(p_w-\gamma_w\nabla D)-\phi\frac{S_w}{\nu_w}R_\chi-C_\chi q_w = \frac{\partial}{\partial_t}(\phi\frac{S_w}{\nu_w}C_\chi+(1-\phi)\frac{\rho_r}{\rho_w\nu_w}\hat{C_\chi}) \tag{5}$$

$$\text{Gel:} \quad \frac{\phi}{\phi_p}\nabla\frac{K_{rw}K}{R_{kfg}\mu_g}C_g\nabla(p_w-\gamma_w\nabla D)+\phi S_w R_g-C_g q_w = \frac{\partial}{\partial_t}(\phi S_w C_g+(1-\phi)\frac{\rho_r}{\rho_w}\hat{C}_g) \tag{6}$$

$$\text{where} \quad R_i=k_iC_\chi^dC_p^f \tag{7}$$

$$D_p=-\alpha C_p \tag{8}$$

The main influences are considered in the model, such as: for polymer solution, shearing propertypermeability reduction, adsorption, inaccessible porous volumes; For gel, gelation speed and water viscosity changing with gel, permeability decrease, adsorption and retention in reservoir rocks, etc..

3. Numerical model

We adopt fully implicit difference scheme to make the mathematical model dispersed, and then obtain nonlinear algebraic equations. These unknowns in equations are grid phase pressure, grid phase saturation, grid component concentration (polymer, gel and cross-linker) and well production/injection rate or well flowing pressure. By expanding equations with Taylor series, linear system is produced. We solve the equations using linear equation solver (SLES) in PETSc. The equations are:

$$[J]^k\cdot\overrightarrow{u}^{k+1}=-\overrightarrow{r}^k \tag{9}$$