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Determining Residual Resistance Factor of Weak Gel Through Physical and Numerical Simulation

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Abstract

The residual resistance factor of weak gel plays an important role in predicting gel flooding performance. Physical and numerical simulation was employed to determine this parameter for Faulted Block 6 in Region 1 of Gangdong Oilfield. Sandpack models with various permeability properties were built to simulate different formations. Different values of the factor were determined through physical simulation of weak gel flooding with the models. Numerical simulation was conducted subsequently to match the history performance of the physical simulations through modifying the primary values of the residual resistance factor. Finally a relationship between this factor and the formation permeability was established.

Key words: Weak gel flooding; Residual resistance factor; Physical simulation; Numerical simulation; History match

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INTRODUCTION

Faulted Block 6 in Region 1 of Gangdong Oilfield has been under operation for nearly 40 years. It is urgent to employ weak gel flooding instead of water flooding to improve its recovery performance for its watercut has amounted to 97.5%. The residual resistance factor is key to the weak gel flooding performance when using CMG's STARS, a commercial numerical simulator, to simulate the response of weak gel flooding. Extensive studies have been conducted on weak gel's properties and mechanisms. Among these studies, physical simulation is generally used to determine the residual resistance factor of weak gel[1-5]. However, the inherent measurement error and instability of experiment leads to non-negligible error in this experiment-determined parameter. As a remedy, numerical simulation can be used to match the experiment performance history through modifying the values of the residual resistance factor, thus providing a reliable parameter for field-scale numerical simulation.

1. PHYSICAL SIMULATION

1.1 Experimental Materials and Procedure

On the basis of the formation permeability range of Faulted Block 6 in Region 1 of Gangdong Oilfield, three permeability values were selected to build 40-mesh, 100-mesh and 200-mesh sandpack models. The parameters of the models were shown in Table 1.

Liquids used in the displacement experiment were the formation brine of Faulted Block 6 with viscosity of 0.48 mPa·s and the simulation oil with viscosity of 4.83 mPa·s. The weak gel solution was specifically formulated for the flooding in the target block.

A self-made experiment apparatus was employed for the displacement experiment. The experiment procedure is following. (a) Build sandpack models, saturate them with water, measure the permeability to water phase, and measure the porosity by means of the weighing method. (b) Saturate models with oil with residual water left and inject water into them until the watercut reaches 98% at the outset. (c) Inject 0.01 PV weak gel solution, resume water injection until the watercut reaches 100% at the outset, and measure the permeability to water phase. Inject water at the rate of 1.0 ml/min, and inject weak gel solution at the rate of 0.25 ml/min. Record liquid production and water production at a number of time points during the whole experiment procedure.

Table 1
Parameters of Sandpack Models Used in Experiment

No.	Quartz sand particle/mesh	Length /cm	Diameter /cm	Porosity /%
1	40	33.00	2.50	35.19
2	100	33.00	2.50	33.95
3	200	33.00	2.50	32.72

1.2 Experiment Results

Response of weak gel flooding was obviously observed during experiment. The watercut at the outset fell dramatically after the weak gel solution was injected into the models. A residual resistance factor is defined as the ratio of the water permeability before weak gel flooding to water permeability after weak gel flooding. The values of the residual resistance factors for the three models can be seen in Table 2.

Table 2
Results of Physical Experiments

No.	Lowest watercut during experiment	Water permeability before gel flooding /10^{-3} μm^{-3}	Water permeability after gel flooding /10^{-3} μm^{-3}	Residual resistance factor
1	0.22	8.71	0.34	25.61
2	0.11	4.89	0.15	32.60
3	0.02	0.91	0.02	45.50

2. NUMERICAL SIMULATION

2.1 Numerical Models

A 3-layer homogeneous numerical model with identical layer thickness was built for each sandpack model on the basis of the real size, porosity, permeability and saturation. There were 30 grids in X direction, 3 grids in both Y direction and Z direction of a numerical model. A grid was 1.1 cm in X direction, 0.74 cm in both Y direction and Z direction. The porosity, permeability and saturation of a numerical model were equal to those of its corresponding sandpack. The real relative permeability data of the target block was used. No difference existed in water and oil viscosity between numerical and physical simulation. Real concentration-viscosity relationship was adopted for the weak gel solution. One injection well was set at the inlet and one producing well at the outlet of a model. Wells in numerical simulation shared the same production constraints with those in physical simulation.

2.2 History Match

The histories of both injection rate and liquid production rate were fully matched (Shown in Figures 1-3). It can be seen that the trends of watercut variation in numerical simulation were similar to those in physical simulation, despite the fact that more dramatic flunctuation existed in physical simulation.

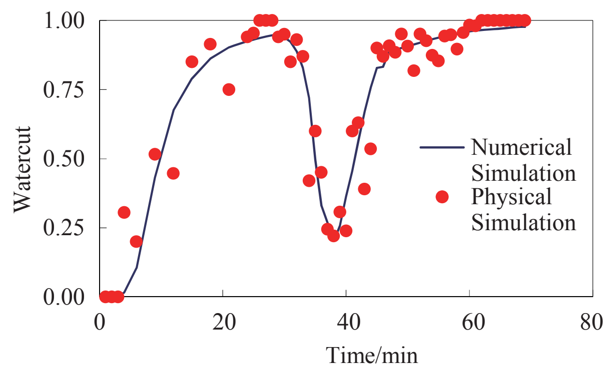

Figure 1
History Match Results for the 40-Mesh Model

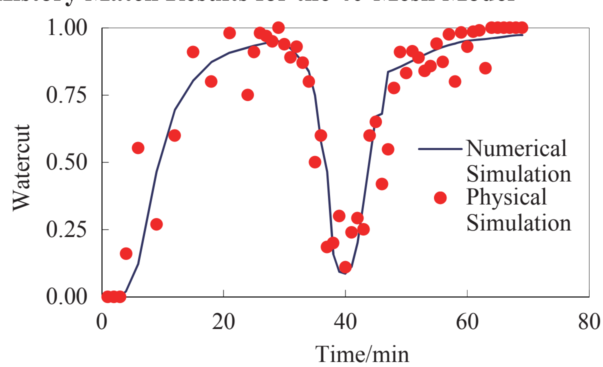

Figure 2
History Match Results for the 100-Mesh Model

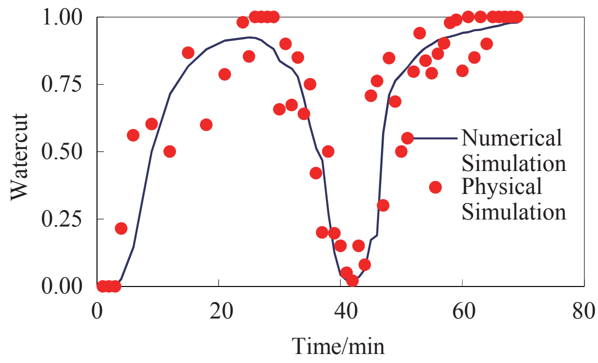

Figure 3
History Match Results for the 200-Mesh Model

2.3 Results of Numerical Simulation

With some modifications to the residual resistance factor values of weak gel solution, satisfactory history matches were achieved between physical and numerical simulation. Consequently, the residual resistance factor values obtained through numerical simulation were reasionable. According to the results of numerical simulation, the residual resistance factor values respectively corredponding to the 40-mesh, 100-mesh and 200-mesh sandpack models were close to 20, 30 and 50.

For the weak gel solution specifically formulated for the target block, a relationship can be found between formation permeability K and residual resistance factor F_R, that is, $F_R = 0.3086K^2 - 6.8152K + 55.946$. This equation is available for computing F_R for formations different in permeability K.

CONCLUSION

(a) Weak gel solution flooding was useful in lower watercut as verified by physical simulation. According the results of physical simulation, the residual resistance factors for the 40-mesh, 100-mesh and 200-mesh sandpack models had the values of respectively 25.61, 32.60 and 45.50.

(b) With some modifications to the residual resistance factor values of weak gel solution, satisfactory history matches were achieved between physical and numerical simulation. Consequently, the residual resistance factor values obtained through numerical simulation were reasionable.

(c) According to the results of numerical simulation, the residual resistance factor values respectively corredponding to the 40-mesh, 100-mesh and 200-mesh sandpack models were close to 20, 30 and 50.

REFERENCES

[1] Liu, Q. W., & Fan, Z. Z., & Wang, D. J. (2000). *Weak gel flooding technique*. Beijing, China: Petroleum Industry Press.

[2] Bai, B. J., Tang, X. F., & Liu, G. H. (2001). RNJ-L low-temperature weak gel. *Oilfield Chemistry*, *18*(4), 347-351.

[3] Wu, X. C., Zhu, W. Y., & Ma, Q. K. (2006). The non-linear percolation characteristics and mathematical model of movable gel system. *Petroleum Drilling and Production Technology*, *28*(5), 42-45.

[4] Yao, T. Y., & Li, J. S. (2009). The blocking properties of movable gel and its effects on percolation characteristics. *Petroleum Drilling and Production Technology*, *31*(4), 102-104.

[5] Men, C. Q., & Liu, R. W. (2009). Movable gel profile modification technique and its application. *Oil and Gas Academic Journal*, *31*(5), 353-356.