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Study on the Influence of Inaccessible Pore Volume of Polymer Development

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Abstract. In this paper, laboratory experiment and numerical simulation methods show that: (1) For reservoir formations with different permeability, there exists an optimal molecular weight for injection, and as the permeability increases, the optimal molecular weight gradually increases; (2) Inaccessible pore volume is too large, the polymer solution to reduce the volume; Inaccessible pore volume is too small, the polymer adsorption loss increases, affecting the polymer flooding effect. Therefore, there is an optimal value for the inaccessible pore volume; (3) At different times into polymer flooding, the optimal inaccessible pore volume will change, and the later the transfer time, the best access to the larger inaccessible pore volume. For example, the optimal unobtainable pore volume at 90% water injection is 0.4, while the optimal inaccessible pore volume at 30% aqueous transfer is 0.3.

1. Introduction

A large number of experiments and field tests show that polymer flooding is an effective method to improve oil recovery and has been widely used in various fields. Polymer flooding works by adding a high molecular weight polymer to the injected water, increasing the viscosity of the injected water and decreasing the aqueous phase permeability to a lower aqueous phase flow rate, increasing the conformance efficiency. However, due to the relationship between polymer molecular weight and formation porosity, there is an inaccessible pore volume in the process of polymer injection. This parameter has an important influence on efficient polymer development. Therefore, this paper analyzes and analyzes this parameter.

2. Physical simulation research

2.1. Experimental equipment

Straddle Pump, Pressure Transducer, Standard Digital Pressure Gauge, Vaccum Pump, Vacuum Gage, Incubator, Hand-Operated Pump, Magnetic Stirring Apparatus and Middle container.

2.2. Experimental conditions
(1) Experimental model: Artificial core, the appearance of the core is about (60×60×4.5) cm, and the gas permeability is about (200, 500, 1000 and 1500)× $10^{-3}\mu m^2$ respectively.

(2) Experimental water: Clear water, water salinity 1000mg /L.

(3) Experimental oil: Dehydration of crude oil and kerosene prepared from simulated oil, the viscosity of the simulated oil at 50 ℃ under the conditions of about 8.0mPa•s.

(4) Experimental temperature: experiments were carried out at 50℃ conditions.

2.3. Single-layer core experiment
Polymer concentration of 1000mg / L, water flooding to 90% water-containing polymer flooding, the total amount of polymer 1000mg/L·PV, after the subsequent waterflooding. By calculation, it can be seen that the unobservable pore volume corresponding to the optimal molecular weight for different permeability reservoirs is about 0.4, indicating that the unaccessible pore volume can be used as an indicator for optimizing the optimum molecular weight of reservoirs with different permeability.

Table 1. The recovery rate of different permeability core.

Permeability ($10^{-3}\mu m^2$)	water drive recovery efficiency (%)	Optimal molecular weight ($\times10^4$)	Polymer-flooding recovery (%)
200	42.36	1000	52.56
500	48.24	1500	61.78
1000	52.43	2000	67.77
1500	55.72	2000	69.47

2.4. Multilayer heterogeneous core experiment
Four groups of flooding experiments were conducted on three parallel tubes of heterogeneous cores with permeability of (200, 500 and 1000)× $10^{-3}\mu m^2$. Experiments show that for different permeability reservoirs, polymer solutions with different molecular weights better than a single molecular weight are preferred.

Table 2. The recovery rate of different permeability core.

Permeability ($10^{-3}\mu m^2$)	water drive recovery efficiency (%)	Different molecular weight combinations ($\times10^4$)	Polymer-flooding recovery (%)
200-500-1000	46.69	1000-1000-1000	60.43
		1500-1500-1500	63.19
		2000-2000-2000	---
		2000-1500-1000	66.47

3. Numerzcal simulation research
By using CMG software, an ideal model was established, univociated porosity was analyzed by univariate analysis to determine its effect on development effectiveness. At the same time, the physical experiment results are verified.

3.1. Study on the Influence Law of Inaccessible Pore Volume
Firstly, the univariate analysis of the effect of the unacceptable pore volume on the development of polymer flooding was carried out to establish a homogeneous model.

When 90% water content and 30% water content are converted to polymer flooding, the recovery rate will not change with pore volume as shown in Fig.1 and Fig.2.

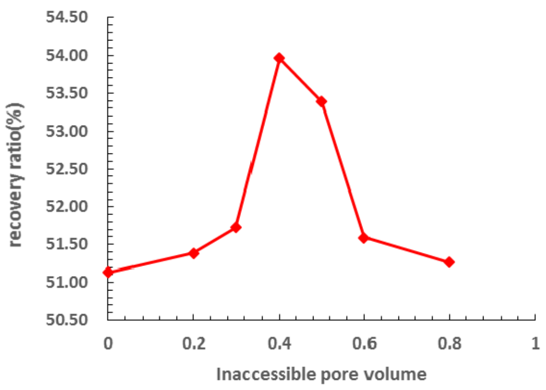

Figure 1. The curve of recovery ratio with the change of Inaccessible Pore Volume

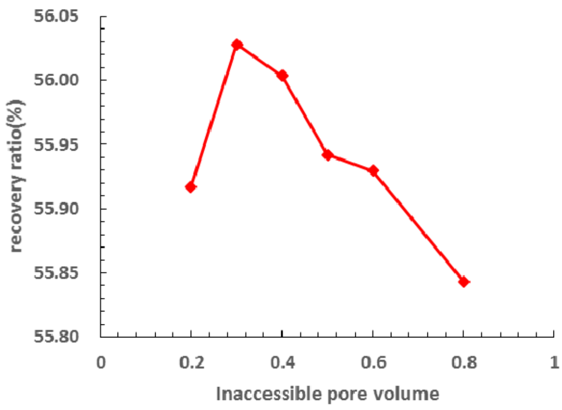

Figure 2. The curve of recovery ratio with the change of Inaccessible Pore Volume

It can be seen from the calculation results that there is an optimal value for the inaccessible pore volume, and the difference between the optimum value and the recovery value of the difference value is more than 2.0%. When the void volume is too large, the amount of polymer-displacing crude oil decreases, while the blocking effect on the high permeation channel (for example, the main stream line) is weakened. When the void volume is too small, the polymer will adsorb a large amount on the rock surface, Affect the development of polymer flooding effect.

Different injection timing situation, the best access to the pore volume and there are differences. The best unobtainable pore volume is 90% when water is 90%, while the best unavoidable pore volume is 0.3 when water content is 30%. The reason is that when the water content is low, the residual oil is more in the pores. In this case, the smaller unreachable pore volume polymer can displace more crude oil to obtain higher recovery. When the water content is high, the remaining oil in the pores is less, at this time the larger inaccessible pore volume polymer can play a better flow control, so that the sweep efficiency increases.

3.2. Result verification

The physical simulation results of three parallel pipes (200, 500 and 1000)× $10^{-3}\mu m^2$were verified.

Table 3. Numerical simulation scheme and results.

Permeability ($10^{-3}\mu m^2$)	Plug the polymer molecular weight in each stage ($\times 10^4$)	Polymer-flooding recovery (%)
200-500-1000	1000-1000-1000	40.01
	1500-1500-1500	53.69
	2000-2000-2000	52.98
	2000-1500-1000	55.12

The results show that the numerical simulation of the optimal slug combination is in good agreement with the physical simulation results. The optimal slug combinations are both slug combinations (2000-1500-1000) × 104, indicating that the molecular weight of the first-stage slug is higher than the optimal molecular weight, increasing the second-stage plug (main plug) is the optimal molecular weight and enters the oil-water mixed pores to better displace the crude oil. The molecular weight of the third-stage plug should be lower than the optimal molecular weight, this is conducive to the polymer into the infiltration of water does not affect the pores, expanding the volume involved, is conducive to enhanced oil recovery, while reducing the amount of polymer and reduce economic costs.

4. Conclusion

(1) In the process of polymer flooding, for the formations with different permeability, there exists an optimal injected molecular weight, and as the permeability increases, the optimal molecular weight gradually increases.

(2) Inaccessible and pore volume is too large, reducing the volume of polymer waves; can not reach the pore volume is too small, increasing the polymer adsorption loss, affecting the poly flooding effect. Therefore, there is an optimal value for the inaccessible pore volume.

(3) For different opportunities to polymer flooding, the best access and pore volume changes. For example, the optimal unobtainable pore volume at 90% water injection is 0.4, while the optimal unavoidable pore volume at 30% aqueous transfer is 0.3.

References

[1] Song Kaoping. The method of enhanced oil recovery through change viscosity [J]. Journal of Daqing Petroleum Institute, 2010, 34 (5):71-74.
[2] Wu Wenxiang, Zhang Tao, Hu Jinqiang. Oil displacement of high concentrated polymer solution effects of injection and slug ensemble [J]. Oilfield Chemistry, 2005 (04).
[3] Gao Ming, Song Kaoping, Ye Yinzhu, et al. An experiments research of high concentration polymer flooding EOR to the sub-layers in lamadian oilfield [J]. Oilfield Chemistry, 2010 (02).
[4] Yan Wenhua, Geng Shulin. Experimental study on polymer flooding and its adsorption properties in Xing 13 block of Class Ⅲ reservoir [J]. Journal of Petrochemical Universities, 2014 (03).
[5] Xia Huifen, Liu Xiaoxiao, Xu Miao, et al. Study on mobility control of polymer flooding in heterogeneous reservoir [J]. Journal of Petrochemical Universities, 2015 (03).
[6] Su xu, Dong Jienan, Zhao Peng, et al. The physical simulation of binary flooding flat affect law of offshore oilfield [J]. Journal of Petrochemical Universities, 2015 (05).
[7] Zheng Bo, Hou Jirui, Zhang Man, et al. Study on the matching relationship between cross-linked polymer and reservoir permeability by using CT technology[J]. Journal of Xian Shiyou University(Natural Science Edition), 2015 (06).
[8] Chen Xinyu, Tian Yanchun, Zhao Xin, et al. Optimization of the ASP flooding injection pattern for Sub-Layers in Daqing Oilfield[J]. Acta Petroleisinica, 2012 (03).
[9] Li Lili, Liang Yunlong, Liu Yuanliang, et al. Optimization of Pre-Slug injection parameters of ASP flooding for the Pu Ⅰ reservoir in the Nan Ⅰ area of the Daqing Oilfield[J]. Special Oil & Gas Reservoirs, 2011 (01).