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Laboratory Experiment on Inaccessible Pore Volume of Polymer Flooding

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Abstract

The research on inaccessible pore volume is completed on the basis of laboratory experiments. The experiment prepared 4 different kinds of polymers, whose molecular weight are 8 million, 12 million, 16 million and 20 million whose molecular coil size are measured by light blockage counter. Through kerosene mass method we can get pore cumulative distribution of field cores and finally plot the relation between the inaccessible pore volume and molecular coil size of polymer. The size of small pore where primary water was taken as the minimum number polymer coils can be passed. Then the polymer molecular weight with better compatibility with rock pores is optimized.

The study shows with the increase of polymer relative molecular mass, pore volume increased linearly. The conclusion can better guide the selection of the polymers in practical production.

Key words: Inaccessible pore volume; Kerosene mass method; Light blockage counter; Polymer relative molecular mass

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INTRODUCTION

Polymer flooding is widely used in the major oil fields at home and abroad as an important way to enhance oil recovery at the present stage during the tertiary oil recovery. The polymers used in oil field are mostly macromolecule polymers, and their molecular weight is up to 10 million[1]. Polymer is a group of atoms with a certain molecular size, high elasticity and plasticity[2]. In low permeability polymer flooding reservoir, polymer cannot pass a part of the pore throat because its diameter is smaller than the polymer molecular coil size or stuck throat for the adsorption effect of polymer on the inner wall of the throat, they both further hinder the subsequent entry of polymers. This part of pore is called inaccessible pore because the polymer can't be entered in, the volume of this pore is the inaccessible pore volume[3-4]. The purpose of polymer flooding is to enlarge the swept volume of the reservoir and to improve the production of oil reservoir as far as possible. But the existence of the inaccessible pore is contrary to the purpose, so it is necessary to study it. The formation of inaccessible pore is mainly due to retention and obstruction of polymer caused by adsorption of polymer in the inner wall of the throat, but in the end is made from relative size between polymer molecular coil dimension and throat diameter, which belongs to the category of microscopic oil displacement, so we can do experiment in the laboratory[6-8]. Through the experiment of relationship between molecular size coil of polymer and inaccessible pore volume, finally put forward the optimization method of polymer in polymer flooding process.

1. DETERMINATION OF POLYMER MOLECULAR COIL DIMENSION

Since the inaccessible pore volume size is determined by the polymer molecular and throat diameter relative size of the decision, so the first is to complete the determination of polymer molecular coil dimension. The experiment prepared 4 different kinds of polymers, whose molecular weight is 8 million, 12 million, 16 million and 20 million. The test used light blockage counter to determine molecular coil size of polymers.

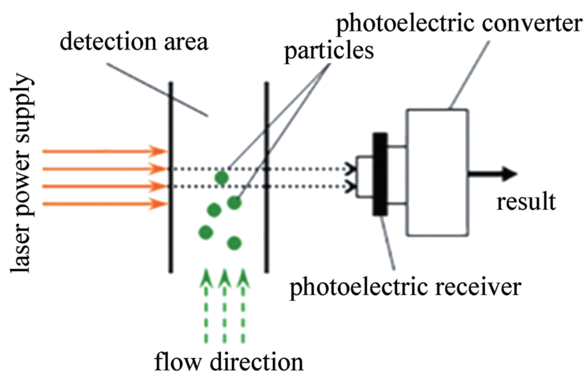

Figure 1
Principle Diagram of Light Blockage Counter

The light blockage counter uses the shielding effect of particles on the light to measure the particle size.

Its principle are shown in Figure 1: The particles in the liquid will block vertical flow direction into the light when go through the narrow detection area, and light intensity changes cause the variation of sensor output signal, the signal intensity is proportional to the particle size change, so as long as each change of light intensity be accurately measured can get the molecular coil size of polymers.

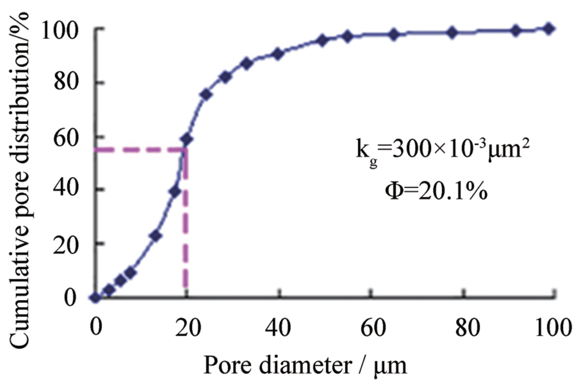

Figure 2
Distribution Curve of Molecular Size in Polymer Solutions

In order to make the conclusions better guide the field operations, water used to configure solution was from field groundwater in the experiment containing calcium, magnesium, bicarbonate, sulfate plasma and concentration of polymer solution was all 300 mg/L. Light blockage counter for four kinds of polymer size measurement results are shown in Figure 2: 95% cluster size of 4 kinds of polymer solutions whose molecular weight are 8 million, 12 million, 16 million and 20 million relatively distributing in 0.52-1.68 μm, 0.52-1.96 μm, 0.52-2.11 μm and 0.52- 2.27 μm range.

2. TO SOLVE THE INACCESSIBLE PORE VOLUME

Figure 3 is the cumulative distribution curve of the pore volume of a core determined by saturated kerosene method. The permeability of the core is $300\times10^{-3}\mu m^2$, and the porosity is 20.1%. The vertical axis in Figure 3 represents the percentage of the pore volume which pore diameter is less than the corresponding value on the horizontal axis of the total pore volume. In theory the polymer molecules are regarded as molecular coil with certain hydraulic diameter, so when the polymer molecules go through the smaller pore and throat will be blocked. For example, the molecular coil dimension of polymer solution is 20 μm, when it passes the core aforementioned, the pore volume which less than 20 μm is inaccessible pore. In the cumulative distribution curve, pore diameter 20 μm corresponds to the ordinate of 54.6% that is the IPV proportion of the total pore volume when the polymer solution passes the core.

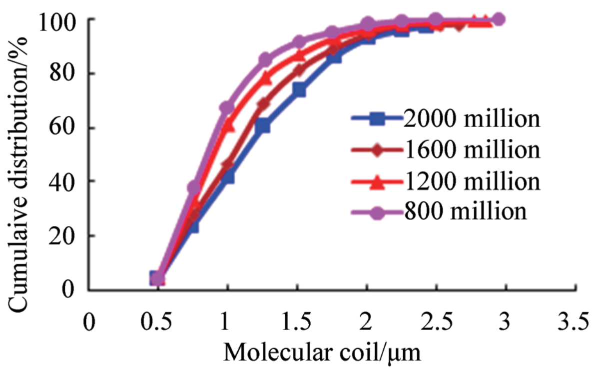

Figure 3
Distribution Curve of Pore Cumulative

In the experiment, we used saturated kerosene method to measure the pore volume of 10 core provided by scene P1—P10 and drew the cumulative distribution curve of pore volume corresponding to each core.

According to the molecular size distribution curves of 4 kinds of relative molecular mass of polymer solution have been measured is finally obtained the corresponding relationship between the permeability under the condition of inaccessible pore volume and polymer molecular size, the results shown in Figure 4.

Figure 4 shows that the average permeability in different cores, with the increase of permeability, the ratio of inaccessible pore to total pore decreased and with the growth of permeability become larger, inaccessible pore volume reduction ratio is more and more small. The main reason is that the average permeability increases, average porosity, average pore diameter is often greater and the pore connectivity is better, the possibility of polymer molecules enter into the pores during polymer flooding is larger; in the same core, with the increase of the polymer molecular coil dimension, inaccessible pore increases linearly, and with permeability become constantly larger, the increase speed of inaccessible pore become slow, the main reason is that with the growth of polymer molecular coil size, part of polymers can't pass resulting in some pore throat diameter are smaller than polymer molecular mass hydrodynamic diameter, but with the increase of average permeability, on the one hand, the average pore size becomes larger, on the other hand, the connectivity is also improved, so the double improvement shows that the permeability increases and the pore growth slows down.

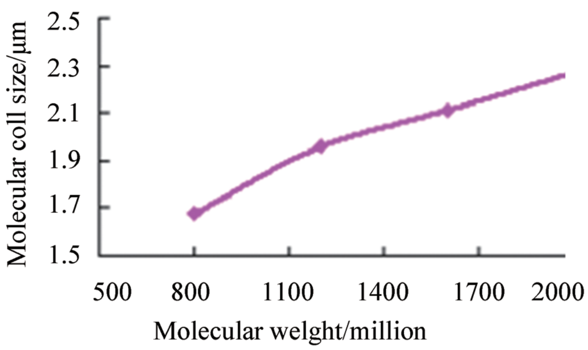

Figure 4
Relationship Curve Between Polymer Molecules Size and IPV

Table 1
Information Table of Field Core Data

Number	Depth m	Average permeability $10^{-3}\mu m^2$
P1	966.51	20
P2	987.67	65
P3	996.92	299
P4	996.92	568
P5	996.92	800
P6	996.92	1009
P7	996.92	1753
P8	1000.41	1902
P9	1103.5	2999
P10	1212.36	4509

3. OPTIMIZATION OF POLYMER RELATIVE MOLECULAR MASS

Through the above research it is shown that in the polymer flooding process, if the size of molecular coil polymers for configuring displacement fluid is too big, it will make the inaccessible pore volume increased, thus affecting the swept volume of polymer. But if the size of molecular coil polymers is too small, we can't guarantee the displacement fluid's viscosity to better improve the mobility ratio. As a result, in the process of polymer flooding polymer size is too big or too small can't achieve the ideal oil displacement effect, only suitable size of the polymer can ensure polymer flooding to achieve the expected effect.

The original water saturation refers to the ratio of primary water accounted for pore volume to rock pore volume in the oil reservoir. Considering the existence of primary water, polymer should be avoided in the process of polymer flooding. If the primary water pore diameter is smaller than that of polymer molecules, it can guarantee the polymer molecules only enter into oil larger pore, not only save polymer, also can better displace the oil. So we can take the size of small pore where primary water be as the minimum number polymer coils can be passed, that is IPV = S_{wc}. On this basis, through the relation curves of Figure 4 we can find the corresponding IPV = S_{wc} polymer molecular coil dimension, finally will be able to find the appropriate molecular weight of polymer and to select polymers molecular weight having better compatibility with core pore, the results are shown in Figure 5.

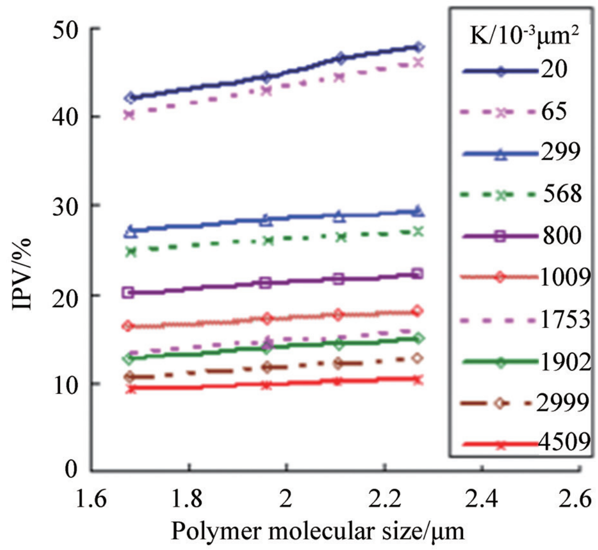

Figure 5
Relationship Curve Between Polymer Molecular Weight and Coil Size

Need to be aware that the application of the method of polymer molecular coil size and IPV relation curve is based on the analysis of obturated coring data of the initial stage of production, which is more suitable for low water content, the producing degree of oil is low. At home and abroad, however, oilfield most basically in the later period of water flooding development, water content is overall high and even a lot of high permeability layer are water-flooded. In the present stage, the relative molecular mass of the polymer chosen by this method should be the lower limit of the optimization, and the polymer with higher molecular weight should be selected as far as possible. In the high water flooded layer with ineffective circulation, the high molecular weight polymer even polymer gel should be selected for profile control and displacement.

CONCLUSION

(a) Inaccessible pore volume size is determined by the relative size of the relationship between rock throat diameter and the molecular size of the polymer.

(b) In the process of polymer injection in the reservoir with the increase of polymer relative molecular mass, and pore volume increased linearly, and with the increase of the permeability, the growth of pore volume began to slow down.

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