Optimization Design of Polymer Flooding Scheme for Class II Reservoir in Sazhong Development Zone

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Abstract. At present, Daqing Oilfield has entered the stage of high water cut, high difficulty and high cost development. The polymer injection blocks of the main oil layers are gradually reduced, and the reserve potential of the oilfield is obviously insufficient, and the potential of stable production replacement is reduced. Therefore, the polymer flooding development of the second type of oil layers has become one of the main ways to replace the production capacity of the oilfield, which is an important guarantee for the sustainable development of the oilfield. The optimization degree of oil displacement scheme for Class II reservoir directly affects the ultimate recovery of polymer flooding. Therefore, according to the development characteristics of Class II reservoir in Block A of Sazhong Development Zone, this paper carries out the optimization design of polymer flooding scheme based on different parameter design methods, laboratory experimental research results and mature experience of other Class II reservoir blocks that have been injected.

1. Introduction
Since the promotion of industrialized polymer flooding measures in Daqing Oilfield, nearly 1/5 of the polymer injection wells are concentrated in the high permeability layer at the late polymer injection stage, with the production ratio less than 50%, and the low polymer circulation efficiency is very serious [1]. At the same time, the amount of oilfield chemicals is increasing year by year, and the oil production index per ton of polymer is decreasing year by year, which is only 1/2 of the current peak and cannot meet the development needs of low cost and high efficiency. Therefore, it is necessary to optimize the design of polymer scheme for the second type of reservoirs.

2. Optimization Design of Polymer Flooding Scheme for Class II Reservoir
On the basis of fine geological research, according to different parameter design methods, relying on laboratory experimental research results [2], drawing on the mature experience of other type II reservoir blocks that have been injected, the injection parameters of the whole area are optimized.

2.1. Design of polymer molecular weight

2.1.1. Determination of polymer molecular weight based on reservoir permeability distribution in block.
The results of laboratory experiments show that the molecular weight of polymer has a linear correlation with the lower limit of permeability [3]. When the polymer concentration is 1000 mg/L, the medium-
and high-fraction polymer can be successfully injected into the reservoirs above 130 mD and 180 mD (Fig.1). The permeability classification of injection wells in Block A is statistically analyzed. The effective thickness of the reservoirs with effective permeability greater than 0.18 μm² accounts for 90.7%. The molecular weight of polymer determined by laboratory experiments matches the lower limit of permeability of reservoirs. The medium- and high-fraction polymer is selected in Block A, and the effective thickness above 90% is suitable.

2.1.2. Determination of polymer molecular weight based on polymer flooding control degree. Studies have shown that the degree of polymer flooding control has a significant impact on oil displacement effect [4]. When the degree of polymer flooding control is higher than 70%, the recovery factor is the best. The greater the permeability is, the lower the degree of polymer flooding control is (Fig.2). According to statistics, the control degree of middle and high molecular polymers in block A is 73.8% and 67.6% respectively, so the middle molecular polymer is selected.

2.1.3. Determination of polymer molecular weight based on polymer flooding control degree. There are large differences in the development of single wells and strong heterogeneity in the injected second-class reservoir blocks. Therefore, the injection of two kinds of polymers mainly focuses on the injection high fraction in the high permeability layer in the early plugging adjustment, and the expansion of swept volume in the displacement process displacement process. Combined with the mature experience of polymer flooding block, the high and medium molecular weight polymer was injected into the pre-plugging section of block A, and the medium molecular weight polymer was injected into the medium displacement section and the late protection section.
2.2. Design of polymer concentration

2.2.1. Concentration determination based on laboratory experiments and regional permeability K80. Laboratory core experiments show that the reservoir with permeability less than 0.2μm$^2$ is suitable for injection of medium polymer, and the concentration is below 1500mg/L. Permeability less than 0.3μm$^2$ reservoir is suitable for injection of high molecular polymer, below 1700mg/L concentration [6]. The permeability K80 of the injection well in Block A is 0.249 mm$^2$. According to the matching relationship chart between the molecular weight and concentration of polymer in core flow experiment and the permeability of oil layer (Fig.3), the oil layer corresponding to K80 is suitable for the medium and high-fraction polymer below the injection concentration of 1500mg/L.

![Figure 3](image)

**Figure 3.** Matching relationship between molecular weight and concentration of polymer and reservoir permeability

2.2.2. Determination of the lower limit of concentration based on the lower limit of viscosity. According to the control requirements of polymer flooding fluidity [5], the lower limits of polymer flooding viscosity with different permeability levels were designed (Table 1). According to the polymer concentration viscosity curves of different systems (Fig.4), the suitable lower limits of concentration for oil layers with different permeability levels were determined. The suitable lower limits of concentration for oil layers corresponding to permeability K80 (0.249 mm$^2$) were 850mg/L and 700mg/L, respectively.

| Effective permeability (mD) | ≥500  | ≥300  | ≥200  | ≥100  |
|---------------------------|-------|-------|-------|-------|
| Wellhead viscosity (mPa·s) | ≥50   | ≥40   | ≥30   | ≥20   |
| Medium concentration (mg/L) | ≥1100 | ≥1000 | ≥850  | ≥700  |
| High concentration (mg/L)  | ≥950  | ≥850  | ≥700  | ≥600  |

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![Figure 4](image)

**Figure 4.** A Block Polymer Concentration Viscosity Curve
2.2.3. Design of injection polymer viscosity combined with viscosity of injected block. Referring to the dynamic change law of the similarly developed injection type II reservoir blocks, the wellhead viscosity of the pre-plugging section in Block A is designed as 50 mPa be 50 mPa s, the viscosity of the plug wellhead in the medium-term displacement section is designed to be 40 mPa s, and the viscosity of the protective slug in the late stage is up-regulated for some well-developed wells, and the viscosity of the wellhead is designed to be 40–45 mPa s.

2.2.4. Design of injection pore volume and injection rate. According to the development status of type II reservoir in Block A, combined with the experience of injected blocks, the size of pre-plugging polymer slug is designed to be 0.05 – 0.06PV, and the injection pore volume is 1.0PV in the whole area. Reasonable injection rate can reduce the shear degradation of polymer solution, so as to maintain a high injection viscosity [6]. Considering the injection-production capacity of injection-production wells and the upper limit of allowable injection pressure, the relationship between injection-production well spacing and injection intensity, the injection rate of the second type reservoir in block A is determined to be 0.14–0.18 PV/a. Combined with the adjustment purpose of each slug in the second oil layer of block A, the low-speed injection of the pre-plugging slug is designed to be 0.14–0.15PV/a.

2.2.5. Design results of injection parameters. The specific scheme of polymer flooding in Class II reservoir of Block A is as follows (Table 2). In the process of polymer injection production and development, the injection parameters should be adjusted in time according to the actual situation and needs of production to ensure the optimal injection effect.

Table 2. A Block Type II Reservoir Polymer Flooding Injection Parameters Design Results Table

| Injection stage            | polymer                  | polymer concentrations (mg/L) | wellhead viscosity (mPa•s) | injected water volume in pore volume (PV) | input pickup rate (PV/a) |
|----------------------------|--------------------------|-------------------------------|-----------------------------|-----------------------------------------|--------------------------|
| Pre-adjusting plug         | Polymer+middle molecule  | 1050                          | 50                          | 0.05–0.06                               | 0.14–0.15                |
| Medium-term displacement slug | middle molecule         | 1000                          | 40                          |                                         | 0.16–0.18                |
| Post-protection slug       | middle molecule         | 1000–1050                     | 40–45                       |                                         | 0.16–0.18                |
| Total                      |                          |                               |                             |                                         | 1                        |

3. Understandings
After optimizing the polymer flooding parameters of #2 reservoir, the matching degree with the reservoir is improved, and the polymer injection quality is improved. At the same time, it lays the foundation for expanding the swept volume and improving the oil displacement efficiency. The indirect economic benefits are reflected in the advance of the effective period of polymer injection, the increase of the decrease of water cut and the extension of the effective period of oil increase.

On the basis of strict implementation of the overall oil displacement scheme, the guiding ideology of ensuring individual injection, ensuring injection-production balance, ensuring stable pressure and ensuring injection quality is taken to strengthen the tracking adjustment in the process of polymer injection, so as to ensure the goal of improving oil recovery by scheme design.

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