Influence Factors on Viscosity Loss of Injection System in A Test Area

DanDan Yuan
(The Third Oil Recovery Factory of Daqing Oilfield Limited Liability Company Heilongjiang Daqing 163113)
Email: yuandandan@petrochina.com.cn

Abstract: As the first ASP flooding test in the transitional zone, it was put into pre polymer flooding in October 2018. However, the viscosity of single well cannot meet the design requirements at the initial stage of production. In view of the viscosity loss of polymer solution in the process of surface injection, by investigating the concentrated viscosity of each node of polymer injection process and single well injected outside the station, this paper analyzed the field test data and water quality report, found out the key links affecting the viscosity of polymer solution, and proposed various technical measures to reduce the viscosity loss. It is found that the viscosity loss is mainly formed after the mixing of polymer mother liquor and high-pressure sewage, and it is concluded that the main reason is the influence of injected water quality. Based on the analysis of salinity, bacterial content and iron ion in water quality, it is found in this paper that the viscosity of polymer injection increases by 40% when a fresh water pipeline is laid and the waste water is diluted on site.

1. A Survey of the Test Area and the Process in the Station

1.1. Overview of the Test Area
The test area is located in the transitional zone area, and the 125×125m five-point pattern is adopted. The average thickness of single well drilled sandstone is 16.2m, with 12.1m of effective thickness, and the average effective permeability is 0.296 μm2.

1.2. Process in the Injection Station of the Test Area
The injection station is constructed by combining the preparation station with the injection station. The 5000 mg/L mother liquor is prepared by the station. Mixed with polymer dry powder through the dispersion device, it can be prepared into polymer mother liquor after aging. Then it can be transported to the injection well after transfer, filtration, buffering, injection pump boosting and high-pressure valve group mixing. The 32 injection wells in this station adopt the injection technology featuring one pump and multiple wells and low-pressure and high-pressure binary mixture injection, with a design injection pressure of 16.0mPa, and an average injection volume of 25-60m3/d.

2. Brief Introduction of Viscosity Loss at the Initial Stage of Production
Although pre polymer flooding in this test area was put into operation in October 2018, the viscosity of single well was not up to standard after injection. In the initial stage of production, the polymer injection concentration is 1220mg/L, and the polymer injection viscosity is 22mPa.s; the actual polymer injection viscosity is about 12.6mPa.s, and the whole process viscosity loss is 68.2%. In order
to understand the shear degradation of polymer solution during the injection process and determine the key points of polymer viscosity loss, samples were taken along the injection system to analyze the loss.

![Configuration Station](image1)

![Injection Station](image2)

1-ripening tank  
2-coarse filtration, fine filtration  
3-mother liquor tank  
4-plunger pump  
5-flow regulator  
6-static mixer  
7-injection well

Fig. 1 simple flow diagram of polymer injection in test area

According to the injection process, the viscosity loss of seven links including the outlet of ripening tank, fine filter, mother liquor tank, polymer injection pump, mother liquor regulator, static mixer and wellhead have been investigated. A total of 1810 samples has been tested, which can better reflect the current situation of viscosity loss during injection. According to the test data, the viscosity loss of the outlet of mother liquor tank, the back of static mixer and the wellhead is the largest, and the viscosity retention rate of the whole process is only 50.0%.

3. Viscosity Loss Analysis and Solution in Polymer Injection Process

3.1. Node 1: Injection Distribution End (Coarse Filter→Fine Filter→Polymer Dispersion→Aging Tank)

In order to ensure the accuracy of polymer mother liquor concentration, based on the test concentration standard, do a good job of comparison between the test concentration and the calculated concentration, and the comparison between the dispersed blanking amount and the set concentration, the viscosity loss of the preparation station since it was put into operation must be less than 5.0%.

![Viscous Damage % vs Date](image3)

Fig. 2 viscosity loss curve of compounding end

3.2. Node 2: Polymer Mother Liquor Part at Injection End (Polymer Mother Liquor Tank→Plunger Pump→Polymer Mother Liquor Flow Tank)

3.2.1. Polymer Mother Liquor Tank

The viscosity loss test of mother liquor was carried out under indoor conditions, and the viscosity gradient test was carried out for 30 hours for the samples taken from the mother liquor box. The results showed that with the passage of time, the bacteria in the mother liquor increased gradually, and the viscosity of polymer mother liquor was obviously reduced. Measures to reduce the viscosity loss in the mother liquor tank: lower the liquid level of mother liquor in the maturation tank and mother liquor tank, and shorten the residence time of mother liquor in the preparation system. The liquid level of mother liquor tank was reduced from 1.2 m to 0.6 m, and the residence time of mother liquor in
preparation system was reduced from 30 hours to 6 hours. After optimization, the joint viscosity loss reaches the normal level.

Fig. 3 variation curve of mother liquor viscosity with residence time

3.2.2. Flow Controller of Polymer Mother Liquor
In case the polymer injection process with one pump and multiple wells is compared with that of single pump and single well, the flow regulator will be added, and the probability of polymer solution degradation will be increased, and then the viscosity loss will also increase. In order to understand the influence of the opening of flow regulator valve on the viscosity loss, the viscosity loss investigation group and the technical personnel of the control valve manufacturer held a field seminar in the test area, and carried out disassembly research on the valve body. The single well mother liquid consumption of the injection station is generally less than 0.5 m³/h, the instantaneous consumption is low, and the average opening of the valve is 9.68%. After analysis, it is found that the viscosity loss exceeds the standard due to the multiple shear action of the control valve. The multi-stage control design adopted by the mother liquor control valve is an important reason for the excessive viscosity loss of the control valve.

Fig. 4 Relationship between opening and viscosity of single well regulating valve

Two injection wells were selected to test the relationship between the opening of regulating valve and viscosity, and the opening of mother liquor flow regulating valve was adjusted by controlling the pressure of plunger pump. Through the experimental results, it can be found that the larger the opening of mother liquor regulating valve is, the lower the viscosity loss is, and vice versa.

3.3. Node 3: After Mixing Polymer Mother Liquor at Injection End with High-Pressure Sewage (Static Mixer Injection → Well Wellhead)

3.3.1. Static Mixer for Injection Well
Static mixer is widely used in injection station to ensure mixing quality. In this test area, one X unit and one K unit are used for static mixing of single well. In order to verify the influence of static mixing on viscosity loss, a well is selected to remove the static mixing unit for viscosity loss test. It can be seen from the results that the viscosity loss does not improve after all the static mixing units removed. However, it becomes more serious, because the scheme may affect the mixing effect of mother liquor, and the viscosity loss fails to significantly improve after removing unit X alone. The research on the viscosity loss of mother liquor control valve shows the static mixed viscosity loss is a secondary factor, which is not a key consideration.
3.3.2. Wellhead of Injection Well
From the previous investigation, we found that the viscosity loss rate from the single well manifold to the wellhead was not large. We replaced the wellhead samplers of five old injection wells with online samplers, and the test results showed little difference. We always aimed at improving scheme compliance rate, monitored the instantaneous mother liquor and sewage, daily ratio error of mother liquor and sewage, calculated the completion rate of mother liquor and sewage injection, and checked the daily injection error of mother liquid and sewage to ensure that the injection rate of single well is more than 98.0%.

After mixing polymer mother liquor with high-pressure sewage at the injection end, the injection viscosity decreased significantly, with viscosity loss of 20.0%. However, through comprehensive and detailed investigation and treatment, the viscosity loss caused by internal components of static mixer, instantaneous flow rate of injection well and wellhead sampler was excluded. The viscosity loss mainly occurred after mixing polymer mother liquor with high-pressure sewage. The main reason was the impact of injected water quality.

3.4. Solutions
After the whole process of viscosity loss analysis, it is found that the large pressure difference between the pump pressure and the injection pressure of a single well can easily lead to the increase of viscosity loss. In order to reduce the viscosity loss caused by large pressure difference, we have established a reasonable grouping and pressure dividing system. According to the change of injection pressure of single well, 32 injection wells were divided into three manifolds of high, medium and low pressure, and timely tracking and adjustment were carried out, and the single well with oil pressure rising was re matched every day. The “three ones” means that “the injection volume of a single well is checked once a day; the pump displacement is calculated once a day; and the injection pressure of a single well is adjusted once a week”, so as to ensure that the number of wells under the jurisdiction of each partial pressure skid is similar and the total injection error is minimum.

4. Analysis and Countermeasures of Viscosity Loss Caused by Sewage
The injection water quality was continuously densified and sampled for 1040 well times. The influence of the following indexes on viscosity was analyzed.

4.1. Effect of Salinity on Viscosity of Mother Liquor and Polymer Solution
The change of viscosity of polymer solution with salinity is usually called salt sensitivity. Because the cations in inorganic salts have stronger electrophilic property than even polar water, they give priority to or replace water molecules, and form anti ion pairs with carboxyl groups on polymer chains, thus shielding negative charges on polymer chains and discharging some bound water molecules. The stretching conformation tends to curl conformation gradually, which reduces the effective volume of molecules and reduces the viscosity of solution. The injection station adopts low-pressure oxygen aeration sewage preparation and high-pressure oxygen aeration sewage dilution. The high-pressure and low-pressure sewage are from the upstream mixing station. Continuous detection of low-pressure and high-pressure sewage shows that the salinity concentration of sewage is high and fluctuates greatly, which has a certain impact on the injection viscosity.

From the viscosity concentration curve, it can be seen that the viscosity concentration curve (mineralization degree is about 7000mg/L) under the current water quality condition is compared with the viscosity concentration curve (mineralization degree is 5578mg/L), under the same polymer injection concentration, the viscosity decreases by 4-16mPa.s, which meets the injection viscosity (40mPa.s) required by the scheme, and the injection concentration needs to be increased by more than 200mg/L.

4.2. Effect of Bacteria on Viscosity of Mother Liquor and Polymer Solution
In order to study the main reason of the viscosity loss rate exceeding the standard, the bacterial content
of the prepared solution was detected. It was found that sulfate reducing bacteria and iron bacteria exceeded the standard seriously. Due to the shear of polymer solution, small molecule degradation products are produced. The “-COO-” of these small molecules can be used as electron donors to provide more nutrients for SRB bacteria. The number of SRB in polymer solution increases after shearing. When the number of sulfated reducing bacteria reaches 2.5×10^5 cells/ml, the main chain of polymer is obviously broken. After aging for 3 days, the viscosity decreases greatly, and then the viscosity decreases slowly. When aging for 30 days, whether shear or not at the same concentration of polymer solution, the viscosity difference is small, and the viscosity retention rate is very low. The viscosity loss rate of HPAM solution increased with the increase of inoculation amount, but when the inoculation amount increased to a certain extent, the viscosity loss rate of HPAM solution did not increase significantly. This may be due to the insufficient growth space and nutrition supply caused by the increase of inoculation amount, and the growth and reproduction were restricted. The metabolites of sulfate reducing bacteria and iron bacteria have great influence on polymer viscosity, while TGB metabolites have relatively little effect.

4.3. Effect of Iron Ion on Viscosity of Mother Liquor and Polymer Solution
FeSO₄ solution was added to the polymer mother liquor diluted by deionized water, and the viscosity of polymer solution with different Fe²⁺ content was measured. With the increase of Fe²⁺ content in sewage water, the viscosity of polymer solution first decreased sharply and then tended to be gentle. When the content of Fe²⁺ was 10.0mg/L, the viscosity loss of polymer solution reached 90%, and Fe²⁺ had a strong influence on the viscosity of polymer solution. It is the redox reaction of Fe²⁺ in polymer solution, which acts as catalyst and makes the viscosity of polymer solution decrease sharply.

4.4. Solutions
In order to ensure that the injection viscosity on site can meet the requirements of the scheme as soon as possible, a fresh water pipeline was laid again. The transformation was completed on March 27 to change the pattern of the sewage distribution and dilution into clean water distribution and sewage dilution, so as to ensure that the injection viscosity reaches the standard. Through a lot of work, the pilot area will carry out the pattern of clean water distribution and sewage dilution in March 2019 (clean water: sewage=1:1.5). At present, the polymer molecular weight is 12-16 million. The plan requires polymer injection concentration of 1238mg/L, viscosity of 30mPa.s, salinity of high-pressure sewage of 7671mg/L, iron content of 15.4mg/L, oil content of 15.8mg/L, suspended solids of 32.0mg/L, oxygen exposure of 0.8mg/L, average polymer injection concentration of 1245mg/L, viscosity of 24.8mPa.s. The viscosity increased by 40% before modification.

5. Conclusion and Comprehension
1. In view of the viscosity loss in the process of polymer injection, the residence time from curing tank to mother liquor tank is shortened, the opening of needle type regulating valve for mother liquor is optimized, the influence of plunger pump screen and static mixer components on viscosity loss is tracked, and the nodes with large viscosity loss is disassembled and cleaned to reduce the shear effect of equipment.
2. According to the injection wells with different injection pressure, the pressure groups are carried out to reduce the pressure difference before and after the flow regulator and reduce the viscosity loss.
3. The salinity, bacteria and iron ion content have great influence on the viscosity of mother liquor, and the viscosity of mother liquor decreases obviously with the increase of indexes.
4. This study excluded the influence of each node in the preparation process on the viscosity of polymer injection, and analyzed that the most important factor affecting viscosity degradation was injection sewage. In the next step, we will continue to investigate and analyze the viscosity loss of polymer solution from the aspect of wastewater quality.
References

[1] Xiang-guo Lu, et al. Viscosity loss of polymer solution prepared with produced water from polymer injection and its influencing factors[J]. Petroleum Recovery Efficiency, 1997, 4 (1): 28-32.

[2] Feng-Huang, et al. Study on biodegradation of partially hydrolyzed polyacrylamide by sulfate reducing bacteria[J]. Petroleum Processing and Petrochemicals, 2012, 30 (1): 33-36.

[3] Bao-jiang Wang, et al. Test of using fresh water to formulate sewage dilution polymer Solution[J]. Petroleum Geology & Oilfield Development in Daqing, 2011, 20 (2): 86-88.