Simulation and analysis of polymer dispersed dissolution process on offshore platforms

Shijie Zhu 1,2*, Shanshan Zhu2, Leiting Shi2, Hong Zhang3

1School of Petroleum, Engineering Chongqing University of Science & Technology, Chongqing 401331, China;
2State Key Laboratory of Oil & Gas Reservoir and Exploitation Engineering, Southwest Petroleum University, Si Chuan, Chengdu 610500, China;
3Tianjin Branch of CNOOC Ltd. Tianjing, 300000, China;

*Corresponding author Shijie Zhu’s e-mail: 289045557@qq.com

Abstract: When the offshore oil field polymer flooding carried out field experiment to expand the scale of polymer injection, the polymer dispersed and dissolved poorly, and with floc output, because of the existing process used the previous construction parameters. Therefore, it was found that the process/method of the two-stage preparation of the mother liquor in the offshore oil field was reasonable and feasible through the parameter analysis of the dispersion process on the offshore platform. The mixing effect of the water and powder in the dissolving tank was further studied in terms of the stirring rate and stirring position of the fan blade which could change the water speed and changing the feeding position of the polymer powder. The simulation results showed that increasing the stirring rate to form a consistent circulation state with the inlet water and feeding the powder into the main stream line of the circulation were beneficial to the dispersion and dissolution of the polymer powder. Thus, the purpose of fully dispersing and dissolving polymer powder during the preparation of high concentration of polymer mother liquor was achieved.

1. Introduction
The matching technology of polymer flooding in offshore oilfield refers to the mature matching process technology of onshore oilfield [1,2], and through continuous optimization and improvement of equipment, a skid type injection allocation process system suitable for narrow platform space has been formed [3,4]. The technology of "online dissolution, centralized preparation and dispersed injection" has laid a good foundation for the successful field test of polymer flooding in offshore oilfield [5-7]. However, in order to further expand polymer injection, the increase of injection rate will inevitably bring some difficulties to the application of existing process equipment. Taking an offshore platform as an example: the space volume of the platform is 60m³-70m³, and the liquid flow time is more than 40min at the existing liquid dispensing flow rate of about 90m³/h, which can meet the dissolution time (40min) requirements of the existing hydrophobically associating polymer, and also meet the current injection requirements. However, with the increase of injection rate, the existing process parameters and conditions can not completely dissolve the polymer dry powder, and polymer flocs appear [8,9]. The flocculation is mainly caused by insufficient dispersion and dissolution of polymer and high local concentration of polymer mixed with water, resulting in adhesion between dry powder particles [10].

Therefore, it is necessary to analyze the dispersion and dissolution of polymer around the existing
dispersion and dissolution device of offshore platform, so as to reduce the generation of flocs in the production process, so as to guide the smooth development of the process technology for expanding the field of polymer injection.

2. Introduction of dispersion dissolving device for offshore platform

The whole dispersing and dissolving system of offshore platform is composed of metering and conveying powder unloading device (screw feeder), dispersion dissolving device, grinder, venturi, mixer (combination of screw mixer and static mixer), etc. The dispersive contact between dry powder particles and water is carried out in the dispersion dissolving tank. The grinders, venturis and mixers are all designed to further promote the tensile dissolution of water powder after mixing. The two-stage mixing mode is adopted for the dispersion and dissolution of the platform: ① The screw feeder in the metering and conveying device (the maximum feeding amount is 500kg/h) is mainly used to transport the polymer dry powder particles into the dispersion dissolution mixing tank, which is mixed with the primary incoming water (20m³/h-30m³/h). ② After initial mixing, the water/powder mixture enters the grinder to grind polymer particles, and then further mixes with secondary incoming water (50m³/h-60m³/h) through venturi jet. Finally, it enters the mixer to complete the dispersion and dissolution of the whole process.

The dispersion degree of polymer dry powder contacting with water in the dispersion dissolving device will have a great influence on the preparation of polymer solution. Therefore, it is necessary to study the relevant parameters of dispersion dissolving tank.

2.1 Process parameters of dispersion dissolving unit

The total volume of the whole dispersion dissolving tank is 0.87m³ and the water capacity is 0.65m³. The first stage liquid inlet is located at the upper end of the liquid level line and forms an angle of 45° with the central axis. The inlet radius is 3 inches and the inlet flow rate is 20m³-30m³. The outlet is located in the center of the bottom of the tank, and the outlet radius is 4 inches. The agitator is a two blade spiral agitator, which is located at 45° angle of the central axis. The inclination angle of the agitator blade is 11° to the horizontal axis, and the stirring rate is 48 rpm. The powder outlet is above the axis directly opposite to the inlet, and the maximum feeding speed is 500kg/h.

2.2 Establishment of physical model of dispersion dissolving unit

Based on the analysis of the main parameters of the on-site dispersion dissolving tank, DM modeling is carried out, and unstructured grid generation and processing are carried out in icem-cfd. The grid of water inlet, powder outlet, liquid outlet and fan blade is mainly refined, as shown in Fig.1.

![Fig.1 The simulation model and grid diagram of the dispersed dissolving tank](image)

2.3 Dynamic simulation under existing conditions

According to the situation of mother liquor prepared on site, the feeding speed is 30m³/h, the feeding speed is 150kg/h, and the stirring speed is 48rpm. The velocity of polymer dry powder and streamline characteristics of injected water body are simulated. The results are shown in Fig.2.
Fig. 2 Velocity flow field and X cross section field diagram at the stirring speed of 48rpm

It can be seen from Fig. 2 (left) that the whole flow state of the fluid in the tank is relatively disordered, and the fluid velocity distribution in the tank body is quite different. The disordered flow state can promote the contact between polymer dry powder particles and water in the high flow rate region, but it will force the dry powder particles to slow down in the low flow rate area, resulting in uneven dispersion to a certain extent. However, it can be seen from section X of Fig. 2 (right) that part of the fluid close to the tank wall outside the agitator does not fully participate in the swirling flow, and only flows close to the wall. The weak fluidity may cause the dry powder particles to gather and swell in this part, resulting in the loss of solution viscosity.

In order to clearly distinguish the running track of dry powder particles, the method of marking dry powder particles is used to re describe, as shown in Fig. 3.

Fig. 3 Polymer powder tracking map

It can be seen from Fig. 3 that the dry powder particles quickly enter the outlet of the lower part along with the water flow after blanking, and there is no uniform sweep in the whole process. The dry powder particles are relatively concentrated, and the circulation flow time in the dissolution tank is short. In the premise of a small amount of dry powder, it will not be affected too much; if the amount of dry powder is too large, it is easy to cause adverse effects and block the grinder installed at the lower outlet.

3. Parameter optimization of polymer solution dispersion and dissolution device

In the dispersion dissolving tank, whether the water and polymer powder can be fully dispersed and mixed mainly depends on the overall flow condition of the flow field; in theory, the mixing degree has a certain relationship with the flow pattern of the fluid and the position of the dry powder.

Therefore, it is necessary to carry out further analysis and research around (1) measures to change the flow state (stirring speed and rotating position of the agitator) and (2) the position of polymer powder loading to improve the dispersion and dissolution effect of polymer.
3.1 Analysis and Research on fan blade stirring speed

In the above model, after adjusting the impeller stirring speed to reduce 8 rpm and increase 8 rpm to 40 rpm and 56 rpm respectively, the tracking status and flow state of powder particles were studied. The results are shown in Fig.4 and Fig.5.

![Fig.4 Flow state at the stirring speed of 40rpm](image)

![Fig.5 Flow state at the stirring speed of 56rpm](image)

It can be seen from Fig.3 and Fig.4. When the stirring speed is reduced to 40 rpm, the swirl state in the whole tank becomes stable (see a). Under the influence of the first stage water injection, a swirling state with high external velocity and low internal velocity is formed. The swirl state of solution in the tank is weaker than that of 48rpm (see B). When the polymer dry powder particles contact with the water flow with higher flow rate, the dispersion contact uniformity is weak (see C). As can be seen from Fig.5. When the stirring speed is increased to 56 rpm, the influence of the injection flow with constant flow rate on the overall flow pattern in the tank body is reduced, and the water flow in the upper part of the tank is small, and the water flow in the whole middle and lower part is in a high speed state (see D). It can improve the circulation effect of the liquid in the tank, and the overall distribution of the fluid is relatively uniform (see E), which is conducive to the contact between the dry polymer powder and water. From F, it can be seen that the dispersion state of dry powder is obviously stronger than that under the conditions of stirring speed of 48 rpm and 40 rpm.

This means that the contact state of dry powder and polymer can be improved by increasing the rotational speed, and the swirling state formed by the stirring rate should be consistent with the primary incoming water.

3.2 Study on the position optimization of polymer dry powder discharge port

As shown in Fig.5, the dry powder is spread out around the place where the powder is laid. Other relevant parameters remain unchanged, and the stirring speed is 56 rpm. The simulation is carried out from the reconstructed model to the center. The result is shown in Fig.6.
Fig. 6 Flow chart of the lower powder adjustment center position

It can be seen from Fig. 6 that after changing the position of powder discharge, the particles do not gather in large area at the upper part of the swirl flow. This is because the positions of the powder entering the water flow line are different. The powder can contact with the water flow with high flow rate and enter the mainstream line quickly, so as to disperse more quickly and promote the water/powder contact. The contact between polymer powder and water flow with different swirl states directly affects the dispersion state of polymer powder in water, and the simulation effect of the adjusted powder position is better, which can promote the mixing of water and powder.

3.3 Analysis and Research on mixing position of fan blade

To study the mixing position of the fan blade, it is necessary to readjust the model position. After the fan blade is moved down 20 cm, according to the optimized speed of 56 rpm, other parameters remain unchanged. The simulation results are shown in Fig. 7.

Fig. 7 Simulation effect of fan blade falling 20cm (Left is powder tracking, right is X cross section)

According to the simulation effect analysis of powder tracking in Fig. 7 (left), it can be seen that the feeding position of polymer dry powder is facing the first stage water inlet. After the position of spiral fan blade is lowered, the swirl control of upper part fluid by fan blade rotation is weakened. With the strong injection of the first stage water, most of the falling dry powder particles are directly blown to the corresponding tank wall, and a few particles enter the swirl flow. As can be seen from the flow velocity of section X in the right figure, when the fan blade moves downward, the vortex flow driven by the blade rotation is very weak at the upper part of the tank body. The strong impact is formed by the injection of the first stage water, which changes the swirl state within the impact range, and finally leads to the dry powder particles washed away with the strong water flow in the left figure.

Compare the original position of the fan blade with the tracking state of the polymer powder moving up 100 mm and moving down 200 mm, as shown in Fig. 8.
Fig. 8 Tracking status of polymer dry powder at different fan positions

It can be seen from Fig. 8 that the position of the lower or upper fan blades is not reasonable, and the original position is relatively reasonable. When the position of the fan blade moves up, it is difficult to control the lower fluid by the rotating fluid of the fan blade, and the polymer dry powder will be retained under the higher swirling flow in the upper part of the tank, which is not conducive to dispersion. However, when the fan blade moves down, it loses the swirl control of the upper fluid, forcing the dry powder particles directly into the opposite tank wall and sinking to the bottom outlet of the tank under the injection speed brought by the injection flow rate of 30m³/h of primary water inflow, which can not achieve the purpose of dispersion.

4. Conclusions
It is found that the process / method of two-stage mother liquor preparation in offshore oilfield is reasonable and feasible. The equilibrium relationship between the stable circulating water flow and the injected water flow of the dissolving tank determines the whole water circulation state, which will directly affect the contact dissolution effect and dispersion degree of the polymer powder. Changing the impeller stirring speed and stirring position of water speed and changing the position of polymer powder feeding can improve the water powder mixing contact effect of the dispersion dissolving tank, increase the stirring speed and form a circulation state with high consistency with the injected water flow. The powder feeding into the main circulation line is beneficial to the dispersion and dissolution of polymer.

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