Research and Application of Chemical Blockage Removal Technology for Unconsolidated Sandstone Heavy Oil Reservoirs in D Oilfield

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Abstract. The proven reserves of heavy oil reservoirs in China exceed 10 billion tons. The unconsolidated sandstone reservoirs of heavy oil reservoirs in D oilfield are mainly located in Minghuazhen and Guantao formations. It is characterized by high porosity and permeability, complex lithology, loose cementation and development of edge and bottom water. This paper systematically analyzes: the lithology and fluid characteristics of the unconsolidated sandstone reservoir in D oilfield, and the composition of blockage material in injection and production Wells, summarizing the characteristics of production data from blockaded wells,and the difficulties of chemical production and injection enhancement measures. Combined with the pre-process suitability analysis, We have optimized the system and process of quick cleaning and viscosity reduction technology for conventional blockaded wells, deep viscosity reduction acidizing technology for special lithologic reservoirs, and low cost injection technology for polymer injection Wells. A total of 45 Wells have been deployed over the past three years. This technology improves the chemical blockage removal effect of heavy oil reservoir, reduces the energy consumption of equipment, and improves the development benefit. It provides a good reference for the selection of chemical stimulation and injection measures of unconsolidated sandstone reservoir with heavy oil.

Keywords: Heavy oil reservoirs · Unconsolidated sandstone · Chemical blockage removal · Production and Injection increase

Heavy oil reservoirs account for a large proportion of the world's oil and gas resources. Its geological reserves have exceeded 800 billion tons. The typical foreign representatives are the Alberta region of Canada and the Orinoco heavy oil belt in Venezuela. More than 70 heavy oil reservoirs have been discovered in China. Viscous oil fields are distributed in various regions in Liaohe, Xinjiang and Bohai etc., accounting for more than 20% of the total petroleum resources, with proven reserves of more than 10 billion tons. At the same time, most of the heavy oil reservoirs are unconsolidated sandstone reservoirs which bring a lot of difficulties for choosing right technologies to increase output stably.

1 Geological Conditions

The heavy oil reservoirs of D Oilfield are mainly developed in the unconsolidated sandstone reservoirs of the Minghuazhen Formation and Guantao Formation with mainly

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medium-fine sandstone. The storage space is mainly composed of primary intergranular pores. The oil layer is loosely cemented and has extremely high permeability. The measured formation temperature is about 45 °C, the average porosity is 34%, the average permeability is 5.2D, the vertical depth is 400–600 m, and the horizontal section length is generally above 1000 m. The non-clay phase inhibitory water-based polymer system drilling fluid is used in the reservoir section. The relative density of crude oil at 50 °C is 0.9575 g/cm^3, the viscosity of degassed crude oil is about 2×10^4mPa·s, and the freezing point is 38 °C. It has the characteristics of high viscosity, high density, and high heavy metal content, which is not conducive to mining and transportation. The oil layer has shallow burial, loose cementation, easy to produce sand, easy to collapse, low formation pressure, low dissolved gas-oil ratio, low mobility, low initial production of horizontal wells in cold production, and large curvature radius of shallow horizontal wells, which has a large degree of process restriction.

Table 1. Statistics of reservoir classification in each block of D Oilfield

Oilfield	Classification					
	Mobility,$10^{-3}\mu$ m^2/mPa·s		Permeability,$10^{-3}\mu m^2$		Iscosity, mPa·s	
	Value	Classification	Value	Classification	Value	Classification
Y3	1.23	Extra-low	1223	Extra high	991.06	Heavy oil
K	2.01	Extra-low	2117	Extra high	1054.46	Extra heavy oi
ZB	2.26	Extra-low	1128	Extra high	499.9	Heavy oil
Y2	31.8	high	2720	Extra high	85.53	Heavy oil

2 Analysis on Blockage Characteristics of Injection and Production Wells

The blockage problem during the injection process of injection-production wells is caused by the mismatch of the injected liquid itself, the blockage of inorganic substances, the adsorption and deposition of asphaltenes, the adsorption and retention in the process of polymer injection, or the cross-linking with the metal ions in the pipe string and the reservoir, etc. These factors work together to form a high-quality concentration, high-viscosity organic blockage, which blocks the reservoir. The plugging strength of unconsolidated sandstone reservoirs is low, and the main components are flocs formed by polymer, oil dirt and scale. The blockage feature is that the injection has been stably completed under the current injection pressure, and the injection volume decreases when the injection is resumed after the injection is stopped.

Table2. Composition analysis of the blockage

Components		Spectroscopic analysis					
Oil content, %	Moisture content, %	F	O	Ca	Na	Mg	Fe
12.99	41.68	4.2	50.9	20.2	11.8	7.6	5.2

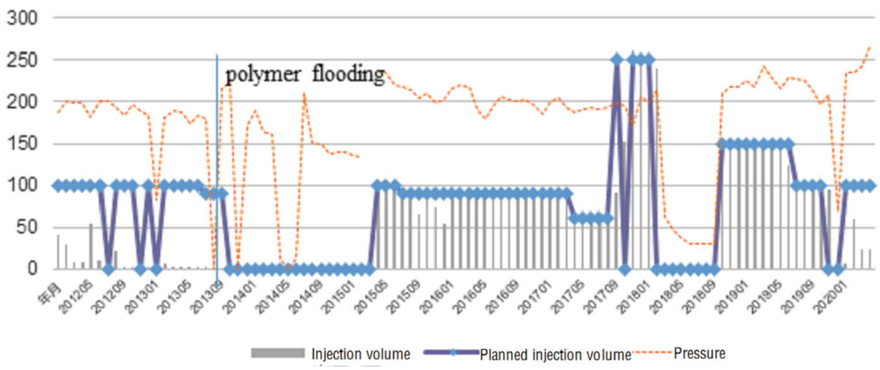

Fig. 1. The blockage feature of injection wells

3 Analysis on Technical Difficulties of Output Increasing and Reconstruction

3.1 Intrusive Damage

Unconsolidated sandstone reservoirs have high porosity and high permeability, large pore throat radius, low formation pressure, and easy intrusion of solid and liquid phases during operation. The positive pressure difference in drilling, cementing, and completion operations will cause a large amount of entering fluid and solid particles to enter the reservoir, causing reservoir pollution [1]. In addition, the fluid that enters the well is used as an external fluid. And the more it leaks into the formation, the greater the damage causes.

3.2 Reservoir Blockage

The heavy oil reservoirs in D Oilfield have high viscosity and freezing point. The circulation and intrusion of fluid into the well can easily cause changes in conditions such as temperature and pressure. On one hand, the crude oil in the reservoir will solidify and settle, reduce fluidity and block screens; On the other hand, it will emulsify the crude oil in the pores near the well. From the perspective of percolation, the original single-phase flow (oil) becomes two-phase flow (oil, water) [2]. Meanwhile, general pickling cannot clean the entire screen section, and the acid solution can only handle a small part of the well section.

3.3 Sand Production Influence

Unconsolidated sandstone reservoirs have shallow burial and loose cementation. At the same time, heavy oil reservoirs have high crude oil viscosity and relatively strong sand-carrying capacity. Sand production in the reservoir is difficult to avoid. Due to the easy compaction of the reservoir and the migration of particles, the physical properties of the unconsolidated sandstone reservoir will continue to deteriorate during the actual development process, resulting in a rapid decline in oil well production [3].

4 Optimization on Chemical Production and Injection Technology

D oilfield unconsolidated sandstone heavy oil reservoir chemical production stimulation and injection enhancement technology is mainly carried out on the chemical viscosity reduction of heavy oil, acidification synergistic production increase, polymer injection well plugging removal and injection enhancement.

Table 3. Evaluation table for viscosity reduction performance of heavy oil in different blocks

Block	Viscosity of degassed crude oil mPa.s	Viscosity after cleaning, mPa.s	Viscosity reduction rate,%	Crude oil cleaning rate,mg/(mL.min)	interfacial tension,10–3m N/m
Z35	7896.71	844.95	89.3	4.2	3.76
Z78	1642.32	308.76	81.2	3.8	1.98
J25	12987.14	571.43	95.6	4.9	4.57
G141	6921.55	574.49	91.7	4.3	2.73

4.1 Optimum Cleaning and Viscosity Reduction System

The cleaning and viscosity reduction technology is applied to the early stage of production of heavy oil unconsolidated sandstone reservoirs, which can effectively reduce the viscosity of crude oil and improve the fluidity of the crude oil, while taking into account the removal of heavy oil asphaltene deposits in screens and water lock damage near the well. At the early stage of ingestion, it can effectively clean the remaining oil in the reservoir, prevent the crude oil in the pore medium from emulsifying and reduce the permeability of the reservoir, and achieve the purpose of stabilizing the water injection pressure.

Experiments were carried out with heavy oil samples of block J. The viscosity reducer selected by the viscosity reducer system by evaluating its viscosity reduction rate, emulsification and dispersibility and other indicators should have the characteristics of low dosage and good emulsion fluidity. The selection of viscosity reducers is mainly based on the stability and viscosity of the system. In order to remove the blockage of asphaltene deposits in the screen and near the well, it is necessary to select the cleaning components to dissolve and disperse the deposited flocs while avoiding asphaltene accumulation [4]. Through orthogonal experiment, compound cleaning component and viscosity reducing component, using 2% concentration, 50 °C to reduce viscosity of J block heavy oil pressure, asphaltene dissolving and dispersing rate, and bitumen dissolving rate as evaluation indicators to determine The distribution ratio of the cleaning and viscosity reduction group. Viscosity reducing component: cleaning component = 0.8:02. The cleaning viscosity-reducing system was configured with simulated formation water into different concentration solutions, and the mixture was mixed at 50 °C according to the oil-water ratio of 1:1 to test its emulsification and viscosity-reducing ability.

4.2 Optimization of Acidification and Plugging Removal System

Acidification and plugging removal technology is applied to heavy oil unconsolidated sandstone wells that have produced sand and caused a plugging zone near the well. At this time, the main cause of reservoir blockage is that the migrated solid particles adsorb the heavy components in the produced fluid. And gather in the area near the borehole wall, blocking the seepage channel. In order to prevent the increase of sand production tendency after acidification, the acid concentration in the main acid should be reduced, and the action distance should be extended to avoid massive consumption of acid in the near-well zone and damage the reservoir framework. The lithology of unconsolidated sandstone reservoirs in Block J is dominated by medium-fine sandstone, with siltstone and mudstone locally developed. The clastic minerals are mainly composed of quartz. The content of feldspar particles and cuttings is relatively small, and the content of clay minerals is relatively low. However, the heterogeneity is strong, and the content of acid-sensitive minerals such as pyrite is relatively small.

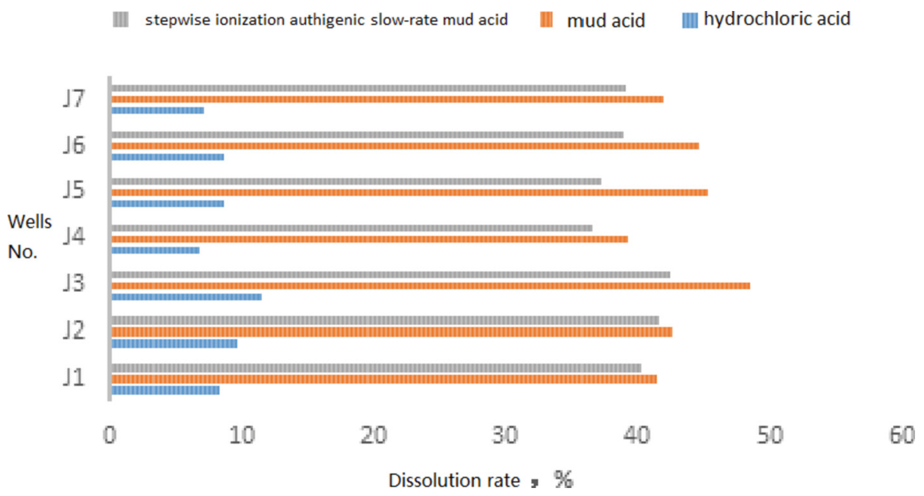

Fig. 2. The dissolution ability test

Take the cuttings of block J to evaluate hydrochloric acid, mud acid, and stepwise ionization authigenic slow-rate mud acid respectively, and the dissolution ability after reaction at 50 °C for 2 h. In order to extend the distance of the acid solution, the stepwise ionization authigenic slow-rate mud acid should be selected as main acid in the system.

While optimizing the main acid solution with strong corrosion ability and longer processing radius, in order to prevent the incompatibility of acid solution and crude oil from forming acid residue and precipitation, the compatibility experiment of acid solution and crude oil was carried out. Through formula adjustment, the crude oil was in the acid solution gradually softens without acid residue and precipitation when the temperature increases.

4.3 Optimization of Technologies of Plugging Removal and Injection Enhancement in Polymer Injection Well

Analysis shows that the main reason for high pressure/under-injection of polymer injection wells in unconsolidated sandstone heavy oil reservoirs is polymer cross-linking blockage caused by free metal ions in the well bore. Therefore, well bores with the characteristics of degrading and breaking cross-linked polymers and reducing the influence of metal ions in the well bore are preferred. And low-cost plugging removal system in the near-well zone, and at the same time, for the different needs of different layers of injection wells, and the conventional plug-removing requirements such as metal ion cross-linking, scaling blockage, and reservoir residual oil deposition/emulsification in the well bore and near-well zone. Using a single-stage liquid system + "grab-grab" formula structure, through the compounding of existing additives, the general injection well single system directional plugging removal and the split injection well balance transformation are realized.

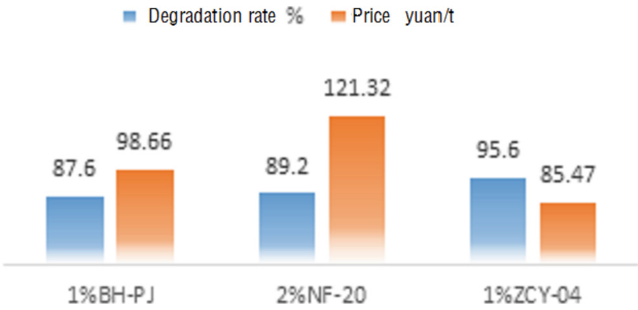

Fig. 3. Optimization of low cost degradable plugging remover

5 Application Situation at Spot

5.1 Application of Unconsolidated Sandstone Cleaning, Viscosity Reduction, Stable Injection and Injection Increase Technology

Comparing the unconsolidated sandstone heavy oil re-injection wells Z4–24-5 and Z4–24-1 wells with similar geological conditions in the same block, the injection pressure rise rate of re-injection wells without cleaning and viscosity reduction is 2 times faster than that of the treated injection wells in the first month.

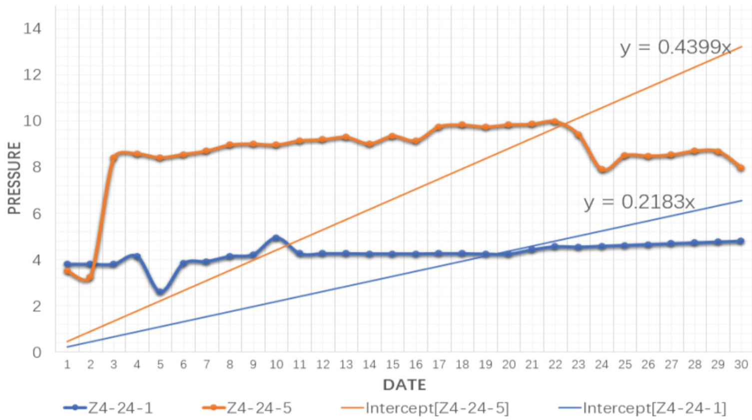

Fig. 4. Comparison of pressure changes in the first month of injection for cleaning and viscosity reducing wells

5.2 Application of Viscosity Reduction and Acidification Technology for Heavy Oil Reservoir in Long Well Section

Field experiments are made based on unconsolidated sandstone heavy oil horizontal well production well K5-H which was put into production in March 2014 with much lower-liquid production than neighboring wells in the same region. The possible reason by analysis is the clogged slotted screen caused by freezing of high-viscosity crude oil. Thus, with water jet tool, the viscosity-reducing acidification and blocking-removing system is used. During process, 50 m^3 viscosity-reducing cleaning agent are injected, the well is closed before the measures being taken. 4.52t crude oil is increased per day after the measures.

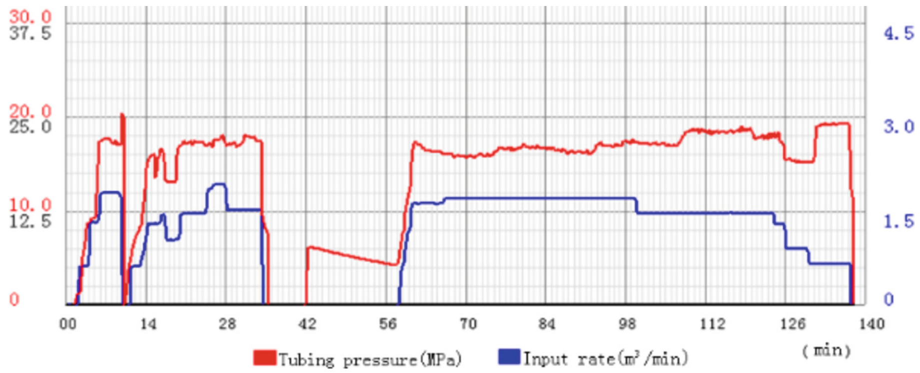

Fig. 5. Construction curve of well K5-H

5.3 Application of Low-Cost Plugging Removal and Injection Enhancement Technology in Polymer Injection Wells

In the high-permeability block of the D oilfield, polymer injection wells were implemented for 3 well times at low cost and quickly, and the injection was increased by 4376 cubic meters. According to the SY/T 5849–2018 oil and water well chemical agent plugging effect evaluation method, it was calculated that the efficiency was 871,300 yuan, and it was put into production at ratio 1:5.8.

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