Application of Acidizing and Plugging Removal Technology in Chang 2 Reservoir of CH Oilfield

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Abstract. In view of the serious scale and blockage in Chang 2 reservoir of a certain oil production plant, in recent years, based on the scientific and technological project "Acidification technology test of Chang 2 reservoir in XX-YY District" completed in 2013, a series of blockage removal workers suited to different blockage characteristics in this area have been formed by studying and analyzing a large number of indoor data, optimizing the acidification formula. The dosage of additives is increased, thus protecting oil pipes, rods and pumps, and preventing new pollution caused by precipitation of Ca²⁺, Mg²⁺. In view of the specific situation of reservoir blockage, 222 wells have been carried out with various blockage removal measures, such as compound acidification, blockage removal and so on. The cumulative oil increase is 7894.8 tons, with an average of 38.7 tons per well, which has made a positive contribution to the stable production of oil production plants.

Keywords: Composite plugging removal; Low permeability; Acidizing formula.

1. Introduction

The purpose of blockage removal is to remove formation plugging. The reasons for formation blockage are complex and manifold. As far as formation damage is concerned, formation plugging is the result of the combination of potential damage factors and external factors of reservoir itself [1]. Potential damage factors of reservoir itself include reservoir sensitivity, rock surface properties, fluid properties, reservoir temperature and reservoir pressure, which are affected by external conditions, resulting in permeability reduction; while external factors refer to the formation of seepage channels in various operations such as drilling, cementing, perforation, fracturing, production and workover [2]. The following is a brief analysis and summary of the potential factors, plugging mechanism and feasibility of plugging removal for Chang 2 reservoir of CH oilfield.

It is mainly judged by core analysis data such as lithological and physical characteristics of reservoirs and fluid properties. Because of the potential damage factors inherent in the reservoir itself, the
sensitivity of the reservoir to the outside world is different after it is put into development, thus various types of blockage are formed. Foreign fluids mainly refer to various foreign water-based working fluids such as well washing fluid and fracturing fluid in the process of production and workover [3]. Due to the characteristics of medium and strong water sensitivity and low porosity and permeability, the damage caused by the above foreign fluid is particularly prominent. The production volume of some oil wells is obviously lower than that of adjacent wells after well washing or fracturing. There are two main situations:

1) Contamination caused by well washing during production. Because of the low formation energy, a large amount of well washing fluid leaks into the formation during well washing, which causes the formation clay minerals to expand hydration and damage.

2) Pollution caused by fracturing fluid in reservoir during fracturing. Because fracturing fluid backflow is not timely or gel breaking is not thorough, it causes damage to formation permeability, reduces reservoir permeability, and reduces the production of oil wells.

With the extension of oil well production time, the formation temperature and pressure drop, resulting in inorganic scaling and blockage. Taking the mixed samples of formation water and single well scale for analysis, it is known that carbonate scaling is the main form of scaling in the long 2-layer produced water, supplemented by sulfate scaling and a small amount of colloid and wax. In production, the main manifestations are stuck and pumped, blocked flower tube and low liquid level in wells, which lead to frequent pump inspection, and seriously lead to low production and shutdown of oil wells [4].

2. Plugging removal technology

The blockage removal work of the plant started in 2013. Chemical blockage removal methods such as acidizing blockage removal and WL-1 composite blockage removal were carried out. Through analyzing and comparing the blockage removal effects of various blockage removal methods of different blockage types, a series of blockage removal technologies suitable for different reservoirs in the plant were summarized, which improved the blockage removal efficiency and prolonged the effectiveness. The oil well output is increased and the pump inspection cycle is prolonged. According to the reservoir characteristics and serious scaling of Chang 2 reservoir, the bottom production and shutdown of oil wells are caused. Since 2014, we have intensified the acidification of Chang 2 reservoir. The technology of deep acidizing and plugging removal is adopted. Deep acidification is to inject acid liquid prepared according to requirements from the ground through wells into the formation, dissolve the blocking material in the formation near the bottom of the well, and restore the original permeability of the formation; dissolve some components of the formation rock, increase the formation pore, communicate and expand the fracture extension range, increase the acidizing radius, increase the oil flow channel, and drop. Low resistance increases production and injection [5].

3. Recipe optimization

Based on the analysis results of scaling samples in oil wells and the reservoir characteristics of Chang 2 reservoir, a series of acidizing plugging removal schemes suitable for Chang 2 reservoir are summarized in combination with recent work practice. On the basis of previous earth acidification, we added fluoroboric acid and anti-swelling agent, and used the formula of combination of earth acid and fluoroboric acid. The optimized formula was hydrochloric acid 10%+glacial acetic acid 2%+fluoroboric acid 3%+hydrofluoric acid 2%+corrosion inhibitor 1%+activator 1%+drainage aid 1%+clay stabilizer 2%+iron ion stabilizer 1%+anti-swelling agent 1.5%+paraffin remover 1%. The main reaction of the acid and rock is as following:

\[ \text{CaCO}_3 + \text{HCl} \rightarrow \text{CaCl}_2 + \text{H}_2\text{O} + \text{CO}_2 \]

\[ \text{SiO}_2 + \text{HF} \rightarrow \text{SiF}_4 + \text{H}_2\text{O} \]

The plugging removal mechanism of this formula is as follows: firstly, the formation is pretreated with hydrochloric acid to dissolve carbonate cements and some calcareous and aluminium in Chang 2 reservoir, so as to avoid hydrofluoric acid contacting with them to form water insoluble substances such
as calcium fluoride and magnesium fluoride, which will cause new plugging after precipitation (due to the reaction rate ratio of fluoroboric acid to rock). Conventional soil acid is much slower, and the effective acid has a far distance. When removing skin damage near wellbore, the treatment effect is not as good as that of conventional soil acid. Secondly, hydrofluoric acid is produced by hydrolysis of fluoroboric acid into formation, which dissolves siliceous minerals in formation, removes deep formation blockage and restores and improves permeability. High efficient iron ion stabilizer, activator, clay stabilizer, drainage aid and corrosion inhibitor are added in order to prevent secondary precipitation after acid reaction and form soluble complex, on the other hand, active acid can be formed, reaction time can be prolonged and clay expansion can be controlled. At the same time, the ability of the residual liquid to return after plugging removal is increased. Finally, in order to prevent the leakage of the residual liquid into the formation and cause secondary pollution, we add anti-swelling agent in the residual liquid.

4. Well selection and Implementation

The wells with high initial production, fast production reduction, water cut less than 70% and low production at present are selected. The analysis shows that there are wells with blocking pollution or scaling. In order to ensure the acidizing effect and improve the efficiency of plugging removal, a production monitoring team composed of development department, production team and construction party is formed before and after acidizing construction to track and measure the production of oil wells in order to grasp the production situation of oil wells before and after acidizing and provide basis for further acidizing. A total of 183 wells were constructed. According to the characteristics of low porosity, low pressure and low permeability of Chang 2 reservoir, we adopted a three-step acid extrusion method with small displacement of less than 0.4 m³/min in the process of acid extrusion. That is, injecting front fluid, treating liquid and post liquid. The specific construction procedures are: producing production string and acidizing pipe string.

(1) Pressure test to ensure no puncture and no leakage during construction.
(2) Acid extrusion with a displacement of 0.4 m³/min.
(3) The shut-in reaction for 2 hours, the acidizing pipe string will be installed and put into operation.

Take 83XY well as an example:

**Well 83XY:** The well was completed on March 20, 2010 with a completion depth of 575 M. The completion mode is perforated completion fracturing. Chang 2 oil layer is 19 m thick. Perforation interval 537.5-539.5 m, thickness 2m, porosity 14.85%, permeability 5.95×10⁻³ m, oil saturation 31.62%, comprehensively interpreted as oil-water same layer.

The construction date is April 25, 2015. The well was shut down before acidizing operation. In November, 2014, December and January, 2015, three times of overhaul were carried out. After repair, the liquid level was low. The dynamometer chart indicated that the liquid supply was insufficient. Scaling phenomenon of different degrees was found in the pump barrel and flower barrel of the well during the three times of pump inspection.

(1) Solutions

In view of the present situation of the well and the field observation and analysis of the string and pump barrel, it is considered that the main reason for the well not to be liquid is that with the prolongation of the production time of the well, formation temperature and pressure drop, CaCO₃ dissolved in crude oil precipitates, causing formation scaling and blockage, which leads to the shutdown of the well. It is necessary to use acidizing to remove plugging, remove blockage, restore formation permeability and maintain normal production of oil wells.

(2) The formulation and dosage of drugs were shown in the following Table 1.
Table 1. Formulation and dosage form of agents

| Agent                     | Hydrochloric acid 10% | Hydrofluoric acid 2% | Fluboric acid 3% | Clay stabilizing agent 1% | Corrosion inhibitor 1% | Active agent 1% | Drainage agent 1% | Iron stabilizer 1% | Glacial acetic acid 2% | Dewaxing agent 1% | Bulkproofing agent 1.5% |
|---------------------------|-----------------------|----------------------|------------------|--------------------------|------------------------|------------------|-------------------|---------------------|------------------------|---------------------|------------------------|
| Consumption              | 2000kg                | 200kg                | 250kg            | 100kg                    | 100kg                  | 100kg            | 100kg             | 100kg                | 200kg                  | 500kg               | 100kg                  |

(3) Yield measurement
In order to accurately grasp the situation of oil well production increase after acidification, on May 18, 2005, the production measurement team measured 8319 well. The well produced 0.1 tons of oil per day before operation, 2.65 tons per day after operation, 20 days per month in the first week (including one day of power failure) and 53 tons of oil per month.

5. Implementation effect
From the production situation of 183 acidizing wells under construction, we can see that the production has increased in varying degrees, with an increase of 7411.5 tons and an average increase of 40.5 tons. The output of acid well in the 44-mouth area in 2015 was tracked and analyzed.

Table 2. The statistics output after acidification in the oilfield

| Well | Before operation | First month after operation | Second months after operation | Third months after operation | Operation pressure (MPa) | Term of validity (d) | Accumulative oil (t) |
|------|------------------|-----------------------------|-------------------------------|-------------------------------|--------------------------|----------------------|----------------------|
|      | Liquid (t/d)     | Oil (t/d)                   | Water (%)                     | Liquid (t/d)                  | Oil (t/d)                | Water (%)             | Liquid (t/d)     | Oil (t/d)                  | Water (%) | Liquid (t/d)     | Oil (t/d)                  | Water (%)             | Liquid (t/d)     | Oil (t/d)                  | Water (%) |
| 8228 | 0.3              | 0.12                        | 60                             | 4.4                          | 1.32                     | 70                    | 3.0                  | 1.05                     | 65                     | 3.2                      | 0.8                     | 75                     | 3                     | 0.3                   | 180                   |
| Yu26 | 0.1              | 0.05                        | 50                             | 3.8                          | 1.52                     | 60                    | 3.2                  | 1.44                     | 55                     | 2.6                      | 0.9                     | 65                     | 4                     | 120                   | 74.4                   |
| 8310 | 0.2              | 0.12                        | 40                             | 2.5                          | 1.50                     | 40                    | 2.0                  | 1.10                     | 45                     | 1.2                      | 0.5                     | 60                     | 5                     | 210                   | 54.4                   |
| 8332 | 1.3              | 0.13                        | 90                             | 9.0                          | 0.45                     | 95                    | 8.0                  | 0.40                     | 95                     | 8.0                      | 0.4                     | 95                     | 3                     | 180                   | 17.2                   |
| 8328 | 0.2              | 0.05                        | 75                             | 1.2                          | 0.24                     | 70                    | 0.8                  | 0.16                     | 70                     | 0.7                      | 0.2                     | 70                     | 0                     | 180                   | 13.2                   |
| 8320 | 0.2              | 0.08                        | 60                             | 6.0                          | 1.50                     | 75                    | 3.0                  | 0.75                     | 75                     | 2.6                      | 0.7                     | 75                     | 3                     | 230                   | 53.2                   |
| 8319 | 0.2              | 0.10                        | 50                             | 5.5                          | 2.75                     | 50                    | 3.6                  | 1.44                     | 60                     | 0.7                      | 0.4                     | 50                     | 4                     | 180                   | 84.8                   |
| 8330 | 0.2              | 0.08                        | 60                             | 6.5                          | 1.63                     | 75                    | 4.6                  | 1.15                     | 75                     | 6.0                      | 1.5                     | 75                     | 3                     | 210                   | 80.7                   |
| 8152 | 0.7              | 0.49                        | 30                             | 1.6                          | 1.12                     | 30                    | 1.2                  | 0.84                     | 30                     | 1.3                      | 0.9                     | 30                     | 0                     | 160                   | 28                     |
| 8163 | 0.4              | 0.28                        | 30                             | 1.5                          | 1.05                     | 30                    | 1.2                  | 0.72                     | 40                     | 1.1                      | 0.8                     | 30                     | 3                     | 160                   | 34                     |
| 8535 | 0.2              | 0.12                        | 40                             | 0.9                          | 0.63                     | 30                    | 0.7                  | 0.49                     | 30                     | 0.6                      | 0.4                     | 35                     | 0                     | 160                   | 23                     |

As can be seen from the above table:

(1) Among the 14 wells with obvious oil production effect, after plugging removal, the water cut and oil production increased slightly while the liquid production increased sharply. Such as 8310, remaining 26, 8319, 8017, 8265 and 8066 wells, according to statistics, the 14 wells have accumulated 880.96 tons of oil increase, with an average increase of 62.9 tons.

(2) There are 11 wells with general oil-increasing effect. Although plugging removal has certain oil-increasing effect, the oil-increasing is not obvious. The cumulative oil-increasing is 267.26 tons, with an average increase of 24.3 tons, such as 832, 8328, 8152, 8535 and other wells.
6. Comparative analysis of operation data and effect

(1) Pressure analysis through statistical data and on-site construction:
   ① After acidification, the stable production time of wells with high liquid content and low water cut is longer, and the validity period is more than 200 days; the stable production time of wells with high liquid content and high-water cut is relatively short, and the validity period is about 60 days.
   ② According to the well with high injection pressure, the relative stimulation time is longer and the production is higher, whereas the stimulation time is shorter and the production is lower.
   ③ According to the statistical analysis of three months’ production, acidification tends to be stable gradually, with an average monthly yield reduction of 0.25 tons.

(2) Comprehensive analysis shows that the combination of earth acid and fluoroboric acid can prevent the formation from leaking and secondary pollution by adding anti-swelling agent to the post-fluid while increasing the radius of acidizing plugging removal. The dosage of additives is increased, thus protecting oil pipes, rods and pumps, preventing precipitation of Ca\(^+\), K\(^+\), Na\(^+\), and causing new pollution.

   In the construction process, we strictly control the construction site tracking of each acidizing well, sampling and analysis of each drug, so as to ensure that the construction process is strictly in accordance with the design, and that the quality of each drug is qualified and the content of each drug meets the design requirements, thus ensuring the acidizing effect.

7. Economic benefit evaluation

At present, 183 wells are constructed, the cost of single well is 42 thousand Yuan, and the total investment cost is 7 million 686 thousand Yuan. At present, the actual cumulative oil production is 7411.5 tons, and the crude oil per ton is calculated at 2000 Yuan:

   Output value = 2000 Yuan × 7411.5 = 14 million 823 thousand Yuan;
   The economic benefits =1482.3 million Yuan -768.6 million Yuan =713.7 million;
   The input output ratio is: 1:1.93.

8. Summary and recommendations

(1) It is suggested that in the future, the "combination of anti-blocking and anti-blocking" technology should be adopted to relieve formation blockage. For some oil wells with serious scaling, scale inhibitors should be added regularly according to scaling cycle to prolong pump inspection cycle and maintain normal production of oil wells.

(2) It is suggested to increase mutual solvent and change the surface properties of rocks in part of high water cut in order to control water and increase oil production, raise reservoir protection awareness and minimize pollution to oil wells in workover operations.

(3) By adopting deep acidizing plugging removal technology, the production of the two and six layers of the plant director can be increased to varying degrees. It is suggested that the two layers of the plant director can be popularized and applied in the future.

(4) Some oil wells are blindness in plugging removal. Whether individual wells are lack of energy or plugging and scaling results in low production and shutdown of oil wells is unclear, which affects the efficiency of plugging removal.

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