Study on Clear Water Acidic Fracturing Increasing Injection Technology in Sandstone Oilfield

Cha Na*
Exploration and Development Research Institute of Daqing Oilfield. Co Ltd, Daqing, China

*Corresponding author e-mail: chana@petrochina.com.cn

Abstract. In view of the fact that it is difficult for some water injection wells in low permeability oilfields to absorb water and the general effect of conventional measures to increase injection, clean water acid fracturing technology research and field test of sandstone in low permeability reservoirs have been carried out. On the basis of fully investigating the adaptability of acid fracturing in sandstone reservoirs and combining with the actual development of low permeability oilfields in our factory, the technology of clear water fracturing and balanced acid fracturing is organically combined. After a lot of theoretical calculation, the construction parameters are optimized, and the suitable fracturing technology is optimized, which greatly reduces the requirements of surface construction equipment. At the same time, through indoor experiments, the suitable well entry fluids are screened to ensure the construction effect. At present, the technology has been tested in 6 wells and achieved good injection increase effect.

1. Introduction
Acid fracturing is mainly used in carbonate reservoirs, and stimulation measures of sandstone reservoirs are mainly fracturing. Sandstone reservoirs generally do not undergo acid fracturing, the main reasons include: first, acid may produce a large number of precipitation blockage channel; second, some sandstone reservoirs cementation is loose, may be due to a large number of acid solution to rock loose, resulting in premature sand production of oil wells. In order to solve the problem of difficult water absorption in water injection wells of low permeability oilfields and the general effect of conventional measures for increasing injection, on the basis of fully investigating the adaptability of acid fracturing in sandstone reservoirs and combining with the actual development of low permeability oilfields in our factory, the technology of clear water fracturing and balanced acid fracturing is organically combined to carry out the technical research of increasing injection of clear water acid fracturing in sandstone. Research and application, explore a new way of low cost plugging removal and injection.

2. Another section of your paper Principle of increasing injection of clear water acid fracturing in sandstone
Clear water is injected from the tubing with a discharge higher than the reservoir can bear, so that the pressure can be rapidly established in the wellbore until it exceeds the compressive stress of the formation and the tensile strength of the rock, thus fracturing the formation and forming a fracture with
a certain length. Then acid is injected to dissolve the wall of artificial fracture, forming acid-etched fracture, which has higher conductivity than the original formation.

2.1. Injection Enhancement Mechanism

Fresh water is injected from the wellhead with variable displacement, and the formation is subjected to multiple high-pressure water shocks. Because of the instantaneous generation of impact force and the extremely fast speed, the perforation hole and the original particles attached to the surface of the matrix vibrate and peel off, which improves the pore structure. When the impact force is greater than the fracture pressure of the formation, multiple micro-fractures are generated near the wellbore.

2.2. Technological superiority

Clear water acid fracturing is an organic combination of the advantages of clear water fracturing and balanced acid fracturing on the basis of parameter optimization and in-well fluid laboratory study. It can make full use of its technical advantages, improve seepage capacity near wellbore zone, change seepage mode and expand seepage surface through clear water fracturing and acid solution of artificial fracture wall. Product. The main advantages are:

Firstly, fracturing with clear water fracturing fluid ensures fracture length.
Secondly, the amount of acid is small and the action distance is large, which can realize three layers of acid fracturing in one trip.
Thirdly, the construction equipment is simple and the cost of measures is low. Clear water acid fracturing is constructed with low displacement, and 2-3 700 pump trucks can meet the construction requirements.

Table 1. Contrast Table of Clear Water Acid Fracturing and Acid Fracturing Acidizing Process.

| Technology          | Construction pressure(Pi) | Injection rate | Flow and dissolution modes                                                                 | Scope of application                                                                 |
|---------------------|---------------------------|----------------|-------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------|
| Clear water acid    | Pi > Pf                   | Greater than the radial suction velocity of formation | The effective action distance of flow reaction along the crack to form artificial crack can reach tens of meters to hundreds of meters. | Formation of artificial fractures in rock reservoirs to relieve pollution near wellbore zone, change reservoir flow pattern and communicate with deep oil and gas areas can greatly improve water injection capacity. |
| fracturing          |                           |                | Formation of artificial fractures in carbonate reservoirs to relieve pollution near wellbore zone, change reservoir flow pattern and communicate with deep oil and gas areas can greatly improve water injection capacity. |
| Acid fracturing     | Pi > Pf                   | Greater than the radial suction velocity of formation | The effective action distance of flow reaction along the crack to form artificial crack can reach tens of meters to hundreds of meters. | Formation of artificial fractures in carbonate reservoirs to relieve pollution near wellbore zone, change reservoir flow pattern and communicate with deep oil and gas areas can greatly improve water injection capacity. |
| matrix acid         | Ps<Pi<Pf                  | Less than the radial suction velocity of formation | Solution range of radial flow along formation pore and formation plugging material is limited. | Removing pollution near wellbore zone or increasing formation permeability near wellbore can increase production without increasing water and gas production. |
| acid washing        | No external force or slight agitation | Positive and reverse circulation without flow or along wellbore | Corrosion wellbore or perforation hole | Cleaning wellbore scaling and screw oil removal of perforated hole for reservoir skin plugging removal |
2.3. Theoretical basis

Clear water fracturing: Clear water containing drag reducing agent, clay stabilizer and necessary additives is used as fracturing fluid for fracturing, which can maintain certain conductivity after fracture closure and is suitable for low permeability oilfields.

Equilibrium acid fracturing: After the formation fracture is opened by acid hydraulic pressure, the acid injection amount and filtration amount reach equilibrium. The pressure in the fracture is lower than the fracture extension pressure, and the fracture keeps open, but does not continue to expand. The acid solution further dissolves the fracture wall and improves the fracture conductivity.

Characteristics of water injection wells: After acid fracturing, the effective closing pressure on the wall of acid-etched fracture is smaller, and the acid-etched fracture closes less under low closing pressure, and its conductivity is higher. In addition, for the injection process of water injection wells, the fluid flow pushes from the wellbore to the periphery, and the pore area increases rapidly. After acidification, trace secondary precipitation and clay mineral dispersed particles are pushed to the depth of the formation, which is not easy to form blockage. Therefore, acid fracturing of water injection wells in sandstone reservoirs is more successful.

3. Acid fracturing technology of clear water in sandstone

Sandstone acid fracturing is more complex than conventional sandstone fracturing and carbonate acid fracturing, because sandstone acid fracturing may face three challenges:

First, acid fracturing may produce a large number of sediments to block the runner.

Second, the acid solution dissolves the rock evenly along the fracture wall, and can not form obvious grooves. After acid fracturing, most of the cracks are closed and the effective fracture conductivity is low.

Thirdly, some sandstone reservoirs are unconsolidated. During acid fracturing, the rock may be loose due to the large amount of acid solution to the rock, resulting in sand production.

3.1. Quantitative Well Selection Principle

In order to ensure the effective injection of clean water acid fracturing technology, the process of selecting test wells and target zones pays attention to the combination of reservoir engineering and oil production engineering. Based on reservoir sand body diagram, the history of continuous development wells of oil and water wells is studied, and the production performance is analyzed. By comparing the logging curves, sand body diagram and water injection situation of water injection wells with difficulty in absorbing water. Analyse and determine the following well selection principles:

(1) Reservoir physical properties are relatively good, and there are 1-2 layers with good physical properties in the whole well.

(2) Reservoir connectivity is good, there are more than three connected oil wells around and the physical properties of the connected oil wells are good.

(3) Water absorption is better in the initial stage of water injection, and all kinds of reasons lead to abrupt non-water absorption or decline of water absorption capacity of wells.

3.2. Optimum acidic liquid system

The reservoir rock types of Fuyu reservoir in the experimental area are mainly feldspathic lithic sandstone and lithic feldspathic sandstone.

| Mineral content | quartz | feldspar | Debris | Argillaceous matter | Interstitial material | IMON mixed layer |
|----------------|--------|----------|--------|---------------------|----------------------|-----------------|
| Range          | 2~20%  | 1.61~19.4%| 0.64~1.36%| 0.21~0.42%         |                      |                 |
| mean value     | 20%    | 25%      | 45%    | 1.64                | 1.02                 | 0.33            |
In order to ensure that acid etches effectively the fracture wall of sandstone and forms etching grooves with supporting function and high conductivity, combined with construction technology and reservoir conditions in the test area, the acid system was optimized by laboratory experiments, and the basic acid system was determined to be earth acid. In order to satisfy the needs of sandstone acidification, the acid system is composed of HF + HCl + corrosion inhibitor + expansion inhibitor + iron ion stabilizer + surfactant by dissolution rate experiment, swelling inhibition performance experiment, corrosion inhibition performance experiment and compatibility experiment.

In order to ensure the effective etching of crack wall by acid solution, the acid reaction rate was measured. The core dissolution rates were measured at 90°C for 5 min, 10 min, 20 min, 40 min, 80 min and 160 min.

The experimental results show that the corrosion rate of acid solution reaches 15.8%, the breakage rate is 1.75%, the reaction rate before crack closure is 86.3%, and the corrosion inhibition rate is 95.67%, which can meet the needs.

3.3. Construction displacement

The key to crack opening is that the displacement is larger than the filtration volume, and at the same time it meets the construction pressure requirements. In order to form a certain scale of fractures, the formation filtration in the fracturing stage of clean water fracturing is calculated theoretically, and the reasonable construction discharge is designed according to the filtration.

Filtration loss is affected by formation (permeability and porosity, etc.), fluid pressure difference, fracturing fluid viscosity and other factors. When the fracture is not fractured, the initial filtration loss at critical fracture pressure is calculated by using the measured water absorption index curve. It is predicted that small fracturing wells are poorly absorbed wells. Considering the filtration and construction friction, in order to ensure fracturing formation and fracture extension, the designed construction displacement is 1.5mm³/min.

3.4. Construction pressure

Construction pressure = bottom hole fracture pressure 45 MPa + pipe string friction 6 MPa + hole, fracture friction 5 MPa - liquid column pressure 22 MPa = 34 MPa

According to the data of tubing diameter, reservoir depth, reservoir fracture pressure and reservoir pressure of construction wells, the simulation is carried out. The water fracturing of 62mm and 76mm tubular columns with displacement of 1.5m³/min was simulated.

According to the simulation results, the ground construction pressure of 76mm pipe string is predicted to be about 35 MPa.

Through theoretical calculation, according to the changes of reservoir loss and construction friction, the construction displacement and pressure are optimized. When the construction displacement is
1.5 m³/min and the construction pressure is 35 MPa, 2-3 700 pump trucks can be used to achieve the purpose of reservoir jointing and reduce the requirements of construction equipment.

3.5. Optimum selection of construction pipe string
Considering that after the application of simplified construction equipment, cracks should be etched by acid injection, and the shut-in reaction should be 12 hours after the end of extrusion. In order to meet the different technological requirements of field test, two kinds of construction pipe string are designed: one is layered plugging removal construction pipe string; the other is single layer plugging removal construction pipe string.

In order to improve the efficiency and pertinence of the measures and achieve the goal of layered transformation, slip sleeve layered fracturing string is used in multi-layer acid fracturing. The construction sequence is from bottom to top. At the end of the first floor construction, the upper sandblaster sliding sleeve is opened by throwing the ball, the finished layer is sealed and the next layer is constructed until the end of the construction of all the target layers.

In order to simplify the tools and ensure the success rate of the process, a single-layer fracturing string is designed for single-layer reformation of test wells.

In order to ensure the successful fracturing of clear water fracturing fluid and the efficient utilization of acid fluid, the construction parameters of clear water fracturing, acid injection and displacement stages are optimized.

3.6. Determination of Construction Parameters
1. Determination of Construction Parameters of Clear Water Fracturing
Considering the influence of formation filtration and frictional resistance comprehensively, the designed fracturing scale is 30 m³ and the designed displacement is 1.5 m³ per minute.

2. Determination of construction parameters of acid injection. In order to facilitate calculation, assuming that the acid etching wall is a cuboid model, and considering the operation cost, the acid one-way treatment depth is designed to etch cracks effectively. Considering the utilization ratio of acid, the amount of acid can be increased by 2-5 m³ in combination with reservoir conditions and the pollution degree of the wells. In order to achieve effective etching of cracks, an acid injection displacement of 1.0 m³/min was designed.

3. Determination of Construction Parameters for Substitution. The purpose of replacement is to fully push acid into formation and make full use of acid, but in order to avoid excessive replacement, 1:1 displacement is adopted.

In order to ensure that acid fills cracks as soon as possible, variable displacement is used to design displacement of 1.5 m³/min at the initial stage of displacement. After acid fills cracks, in order to prolong the reaction time between acid and cracks and limit the extension of cracks, displacement of 0.8-1.0 m³/min is designed at the later stage of displacement.

4. Field test results
In the field test of acid fracturing in clear water, there are 14 layers in 6 wells and 12 fractured fracture zones. The success rate of the process reaches 85.7%. The effective rate of the measures is 100%. Up to now, the longest validity period of a well has reached 291 days, with a cumulative injection increase of 5201 m³ and a good injection increase effect has been achieved. The long-term effect remains to be observed.


Table 3 Statistical results of acid fracturing test wells with clear water

| Serial number | Well number | Sandstone thickness (m) | Effective thickness (m) | Before measure | Initial stage of measure | at present | Cumulative injection (m³) | Time (d) |
|---------------|-------------|-------------------------|------------------------|----------------|-------------------------|-----------|--------------------------|---------|
|               |             |                         |                        | Oil pressure (MPa) | Daily allocation (m³/d) | Daily flooding (m³/d) | Daily allocation (m³/d) | Daily flooding (m³/d) |          |
| 1             | M1          | 2.0                     | 2.0                    | 21.8            | 20                      | 18.9                   | 20                       | 20                  | 19       |
| 2             | M2          | 3.5                     | 2.2                    | 21.6            | 15                      | 17.1                   | 15                       | 15                  | 20       |
| 3             | M3          | 8.2                     | 5.0                    | 21.7            | 14                      | 17.5                   | 14                       | 14                  | 15       |
| 4             | M4          | 4.4                     | 1.4                    | 21.7            | 10                      | 13.8                   | 10                       | 12                  | 17       |
| 5             | M5          | 5.1                     | 1.0                    | 21.7            | 10                      | 18.5                   | 10                       | 12                  | 20       |
| 6             | M6          | 5.2                     | 2.9                    | 21.7            | 15                      | 14.2                   | 15                       | 16                  | 15       |
| Total         |             |                         |                        | 28.4            | 14.5                    | 28.4                   | 14.5                     | 14.5                | 155      |
| Average       |             |                         |                        | 4.7             | 2.4                     | 4.7                    | 2.4                      | 2.4                 | 155      |

Before the measures, the oil pressure was 21.6 MPa, which did not absorb water. In the initial stage, the oil pressure decreased by 4.5 MPa and increased by 15 m³ per day. After the adjustment of the plan, the oil pressure was 17.6 MPa and the water injection was 20 m per day. It has been produced for 249 days, with a cumulative increase of 4481 M.

5. Conclusion
1. This technology has a certain theoretical basis. After acid fracturing with clear water in sandstone reservoir, a fracture with certain conductivity is formed in the formation, which changes the radial seepage near the bottom of the well into linear seepage. While dredging the formation, changing the fluid flow state can improve the water absorption capacity of the injection well.
2. From the test results of six wells, clear water acid fracturing technology is successful. The effect of plug removal and injection increase is obvious in the initial stage. The longest effective period of a well has reached 291 days, with a cumulative injection increase of 5201 m³ and the long-term effect remains to be observed.
3. Clear water acid fracturing technology has been successfully applied in water injection wells, and the effect of micro-fractured oilfields is more obvious. However, the application conditions and block adaptability of clear water acid fracturing technology in sandstone oilfields need to be further explored.

Acknowledgments
The work was financially by National Science and Technology Major Special Project "Demonstration Project of Dense Oil Development in Songliao Basin" (Number 2017ZX05071).

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