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The Application of Multi-hydrogen Staged Acidizing Technology in M31-6 Well

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Abstract. M31 fault-block with reservoir permeability at around 9 md, belongs to low permeability reservoir with more strata and poor water absorption. Its daily water injection is 10 m³ per day and pressure is 30Mpa, and 10 m³ per day. Oil wells with low yield and low liquid badly need stratum energy. Aiming at this kind of low permeability sandstone reservoir, it researched piecewise hydrogen acid acidification technology to overcome the limitations of conventional mud acid acidification such as small effective radius and acidification sediment secondary pollution; also mutual influence between different layers was reduced. The implementation of the technology to M31-6 Wells got obvious effect of augmented injection, which has very important practical significance for the development of low permeability sandstone oil field and improves the ultimate recovery of oil field.

1. Introduction
M31 fault-block has strong heterogeneity, poor physical property, low porosity and low permeability. The daily water injection is difficult to meet the requirements of injection, and the reservoir pollution near the well zone. If the conventional acidification method is used to acidification of the reservoir, many construction needs to be carried out, the period is long and the cost is high, and two times of pollution will be caused by multiple wells. Therefore, we carry out the research of hierarchical multi hydrogen acid acidification process.

Polyhydric acid multi-layered acidification process is a special acidification process developed on the basis of conventional acidification process. It has the advantages of slow reaction speed, strong solubility, good anti scale and dispersing properties, and can inhibit the formation damage near the borehole and effectively control two precipitation. At the same time, the multilevel and layered acidification tube column is easy to operate and is convenient and practical. It can separate multiple layers through multistage packer and slide sleeve switch. According to the pollution cause and pollution degree of different layers of oil layer, it can be squeezed into the targeted acid liquid system and amount respectively, thus improving the water absorption section and increasing the effective water injection. And so on.

The results of field application show that the acidification effect of the process is obvious and the profile improvement is remarkable. It provides an effective technological means for the improvement of the low permeability, multi-layer and heterogeneous reservoir section. It is suggested to increase the application of the process.
2. General situation of M31-6 well

The M31 block is located in the third series wide slow anticline tectonic belt of the ancient submersible mountain belt. The base rock of Qianshan is fogihshan formation, and the shatch structure, such as the development of Kongdian formation, the Shahe Street formation and the Dongying formation on the denudation surface, is mainly deposited in the shallow lake.

The reservoir is mainly light gray sandstone, with gray brown limestone and sandy mudstone, mudstone is pure, brittle and hard, and calcium is weak; sandstone is mainly quartz, feldspar is second, and contains a small amount of dark minerals. Calcareous cement dense sandstone oil, oil is not uniform. The porosity of the reservoir is 12.2%~15.4%, and the average air permeability is \((0.1\sim2.7)\times10^{-3}\mu m^2\), and the oil saturation is 35%~67.2%, which has the characteristics of low porosity and low permeability.

Well M31-6 well is a water injection well, which is put into operation in December 1993. The water injection well is 3307.4-3422.4m of Es3, a total 60.3m/4 layer, the injection mode is positive injection, the pump pressure is 30Mpa, the oil pressure is 30Mpa, the daily injection amount is 10.81m³, and the cumulative injection of water \(3.4926\times10^4\) m³ by the end of October 2015, the daily injections gradually descend to the insufficient 2m³ in October. To meet the requirement of distribution, we should stop acidification in October 20th and wait for the next acidification.

3. Technical difficulties

Due to the low permeability of oil reservoir, it is characterized by low productivity of single well, serious leakage of formation and small radius of oil release, because the reservoir is in the development of natural energy, the development time is long, the pressure of formation is low, and the leakage of drilling fluid leads to low production capacity when drilling fluid leakage, and the reservoir is shown vertically. Multi-tier development, interlayer permeability gap is large, resulting in uneven use, the contradiction between layers is outstanding. Conventional acidification is easy to form two precipitation and cause new damage to formation.

With the development of oil field, the plugging phenomenon of oil and water wells is becoming more and more complex. Ordinary acidification and fracturing removal can only plug the blockage in the near well zone, which cannot reach the purpose of completely blocking the oil well, and the daily oil increasing of the single well is declining year by year, and the proportion of the water cut well is large, which brings great difficulties to the production of oil field production.

According to the reservoir of these problems, to carry out research on multi-hydrogen staged acidizing technology.

4. Technological Scheme

4.1. Selection of acid

4.1.1. Acidizing mechanism of multi-hydrogen acid

Multi-hydrogen acid is a mixture of phosphate complex and villiaumite and contains multiple hydrogen ions. In the multi-hydrogen acid system, phosphate complex plays the same role as hydrochloric acid in hydrochloric-hydrofluoric acid system [5]. Phosphate has multiple hydrogen ions, and releases hydrogen ions sequentially by multi-stage ionization under different stoichiometric ratios. The concentration of released hydrogen ions remains at a lower level, which prevents the corrosion of rock and the recompaction of formation near wellbore by excessive acid concentration. Sandstone mainly consists of sand and cement. The main components of sand are quartz-feldspar and various rock debris. The main constituents of cement include clay, carbonates, siliceous cements and ferruginous cements. The acidizing of sandstone is different from limestone and is controlled by surface reaction instead of diffusion mass transfer, indicating that once acidizing begins, the reaction rate would be fairly fast. The faster the acidizing reaction rate is, the shorter the penetration distance of
acid fluid is and the worse the acidizing performance is. Hence, the retardance of sandstone acidizing is critical.

Multi-hydrogen acid fluid formulation is the phosphate complex reacts with villiaumite to yield HF. HF is actually the substance reacting with the sandstone reservoir. The hydrogen ions produced by the ionization of phosphate complex keeps at a lower level at low PH value. Phosphate complex and villiaumite form a buffering system. The equilibrium of the buffering system is broken when HF is consumed partially by rock mineral. The equilibrium moves towards the direction of HF formation, and the concentration of hydrogen ions of the system decreases. Meanwhile, the ionization equilibrium of phosphate complex is broken. The phosphate complex continuous releases hydrogen ions until a new equilibrium is established. Consequently, the concentration of HF of acidizing fluid and the reaction rate between acidizing fluid and rock mineral maintain constant as long as the concentration of acidizing fluid is large enough.

4.1.2. Technical characteristics of multi-hydrogen acid

Slow releasing of hydrogen ions: An interlayer made of aluminium silicate-phosphate film with the thickness less than 1 μm is formed at the clay surface for the chemical absorption at the beginning of the reaction between multi-hydrogen acid and formation. Weak acid (HF acid / carbonic acid) has poor solubility of this film followed by organic acid. While the film dissolves fast in HCl solution. This thin film can block the reaction between clay and acid, reduce the solubility of the clay and prevent the decomposition of the formation. The surface layer of clay is soluble in acid. Therefore, the solubility of clay can be adjusted by adding small amount of hydrochloric acid and formic acid to achieve optimal design.

Reaching distant formation: The acidizing for far bore zone formation can be achieved using multi-hydrogen acid because of the sustained releasing effect of multi-hydrogen acid and high speed injection during acidizing process. The treatment radius of multi-hydrogen acid is 2.5 m, while the treatment radius of regular acid is lower than 2 m.

Strong reactivity with quartz: The reaction between HF and quartz can be catalysed because multi-hydrogen acid has extremely high absorption capability and water-wet characteristic. The solubility of quartz will increase over time.

Inhibiting secondary precipitation: Multi-hydrogen acid is a good dispersing agent and has sub stoichiometric chelate property. It is also a excellent scale inhibitor and can inhibit the formation of the precipitate effectively in near borehole zone. The titration experiment of multi-hydrogen acid and silicate shows that no precipitate is formed. The active acid still exists in the formation pores when stopping injecting multi-hydrogen acid. The delayed acid fluid flows backwards and keeps reactivity. The acid can only react with quartz because the clay is protected by the thin film. In consequence, the permeability of the formation is further improved.

Multi-hydrogen acid also has complexion ability to polyvalent metal ions. Even at low concentration of multi-hydrogen acid, the metal ions are chelated and can not form precipitate in the solution. Meanwhile, multi-hydrogen acid has strong absorption ability to Ca2+, Na+ et al. Consequently, they can not react with F-, SiF4- to form precipitates, thus inhibiting secondary precipitation and avoiding secondary contamination.

4.2. Acidizing tube

Due to the influence of formation heterogeneity, low permeability reservoirs can not be effectively improved due to conventional acidification, resulting in more prominent inter layer contradictions. While the general layered acidification technology can be used to achieve quantitative acidification of the reservoir monolayer, but in the construction, the liquid in the pipe column is squeezed into the reservoir, causing the deep damage of the reservoir. Therefore, it is necessary to design a new type of multi-level and layered acidification tube column. It can be reformed one by one for multi layers, greatly improving the degree of acidification, strong pertinence, and good effect of increasing injection.
The acidizing section is 3404.0-3422.4m, 18.4m/1 layer, 3361.0-3374.2m, 13.2m/1, 3342.0-3348.5m, 6.5m/1 layer, 3307.4-3329.6m and 22.2m/1 layer.

The construction pipe column (from the bottom to the top) is the cycle sitting joint + sprayed acid (grade I) +K344-114 non slip sleeve packer (grade I) + sliding sleeve acid shot set (class II) +D73.02mm plus 3 +K344-114 slider packer (II) plus thick oil pipe (class II) + sliding sleeve spray acid device (grade III) +D73.02mm plus thick oil pipe, +K344-114 slider packer (grade III) ) + slip sleeve spray acid (grade IV) +D73.02mm plus 3 +K344-114 slippery casing packer (grade IV) with thick oil pipe (IV) + hydraulic anchor +D73mm outer thickening joint + safety joint + circulation valve +D73.02mm outer thickening oil pipe thick oil pipe to the well mouth.

Working principle: by opening the sliding sleeve switch, we control the packer step by step sealing and acid spraying. When the first layer is acidified, the first grade acidification and grade I packer is opened to realize the acidification operation of the top seal packer. When the second layers are acidified, the grade II and class II packers are opened, and the class I and II packers are sealed to realize the single layer acidification of the double packer card; the third layers are acidified with second layers, and when the grade III packer is used as the packer. After opening, the double seal card single acidification operation is achieved with the second stage packer. The fourth level acidification is the same as the third level acidification. When the grade IV packer is opened, the double seal card single acidification operation is achieved with the third stage packer.

Features: a multistage acidification of a pipe string can circulate the liquid in the tubing and prevent the liquid in the tubing from being pushed into the stratum, resulting in reservoir contamination. It has strong controllability. According to pump pressure, casing pressure and displacement, we can judge the joints of packers, such as sealing, pin shearing, sliding sleeve opening and acid spraying. After acidizing, turn on the slip sleeve. When drilling, avoid the liquid in the tubing to be brought to the wellhead and prevent wellhead contamination.

5. Field application
According to the construction design, in November 5, 2015, the M31-6 water injection well was finely constructed by multi acid and acid acidizing.

Construction difficulties: M31-6 well is a water injection well with high wellhead pressure and poor water absorption capacity. Under 0.5m3/min displacement, the construction pressure reaches 48MPa. The construction process is stable, and the packer is reliable. The acidification construction is successful, and the curve response characteristics are obvious at all stages. The results show that the multi-stage hierarchical acidizing string meets the requirements for the acidizing construction of high pressure water injection wells.

The M31-6 well is a water injection well. After the stratified acidification of polyhydric acid in November 5, 2015, the water injection pressure was reduced to 22.4Mpa before the measure of 30MPa. The average daily water injection was less than 10m3, and the average daily water injection was about 35m3, and the effect of increasing injection was obvious.

6. Conclusions
i. The slow speed performance of polyhydric acid comparison soil acid is more suitable for sandstone reservoirs with high temperature, low permeability and high clay content. It can significantly reduce the rate of acidification, reduce the production of two precipitation, increase the acidification distance and improve the acidification effect.

ii. The advantages of the process are time and cost saving, reliable tool performance, high acidification radius and strong pertinence, and high return rate after the measures, which can effectively prevent the two pollution of the formation.

iii. In view of the M31-6 water injection well with great difference in interlayer water absorption, this process can effectively avoid the interaction between different layers and obtain significant effect of pressure lowering and increasing injection, which provides valuable experience for the repeated acidification construction of this kind of low permeability reservoir in the future.
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