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Optimization and Application of Large-Scale Acidification and Multi-Stage Injection Technology

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Abstract

With the increasing demand for clean energy in China, the development of natural gas is constantly intensifying, and deep carbonate reservoirs are important production areas for natural gas. In recent years, large-scale acid fracturing has become a major trend in the transformation of carbonate reservoirs, with a large potential market in the acid fracturing industry. At present, good results have been achieved in blocks such as Yuanba, Daqing, and Pengzhou. At present, the large-scale deep acid fracturing technology for ultra deep acid gas wells at home and abroad is based on the "high-temperature and high corrosion inhibition gel+high-temperature diversion" acid system and the "multi-stage alternating injection+soft and hard material composite temporary plugging" process. This year, large-scale composite acid fracturing can achieve long-distance and deep penetration transformation of reef and beach reservoirs, providing technical support for the production capacity construction of major marine oil and gas reservoirs around the world. Currently, through the self-developed online acid supply system, multi-stage continuous acidification construction with a scale of over 2000m^3 has been achieved, realizing various process technologies such as no reduction in displacement and temporary plugging without stopping pumps during the acidification construction process.

Keywords

Large-Scale Acid Compression; Continuous Acid Supply; Multi-Stage Acid Compression; Multi-Stage Liquid Supply System.

1. Introduction

The project focuses on the large-scale acid pressing supporting process technology with high acid content, high displacement, and special process characteristics. Through technical research, technological transformation, research and on-site testing, the traditional acid mixing system has been technically transformed, and new acid mixing equipment and systems have been developed and designed; Technical optimization has been carried out on the liquid supply system; To solve the three major problems of acid pressure supply and acid preparation technology with a current scale of 2000 m^3 and above: (1) the overall preparation time of acid solution is relatively long, and the prepared acid solution is prone to layering and other problems after long-term storage, which cannot effectively meet the required performance of the design. (2) The acid tank area is relatively wide, and due to the excessive number of water supply pipelines and gates, it is easy to encounter problems such as insufficient liquid supply pressure, acid tank emptying, and tank leakage during the operation project, resulting in quality problems such as reduced construction displacement and pump shutdown. (3) In large-scale and long-term operations, equipment and pipeline leaks are prone to occur, which can reduce the overall construction efficiency and even affect the overall construction quality. To achieve the goal of improving the overall quality of acid solution and ensuring good supply of liquid and equipment during the construction process. We have achieved high quality, stability, timeliness, safety, airtightness, convenience, and economy in the acid dispensing system. A liquid supply system that can effectively add, accurately measure, operate conveniently, connect tightly, and ensure safety standards has been formed, providing strong guarantees for successful acid fracturing operations.

2. Continuous Preparation Technology of Acid Solution

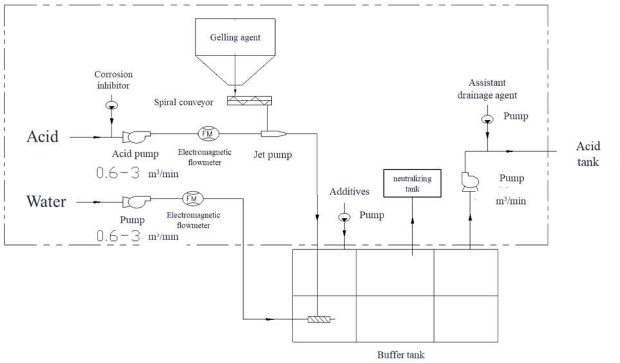

Figure 1. Schematic diagram of continuous acid supply and distribution equipment 1

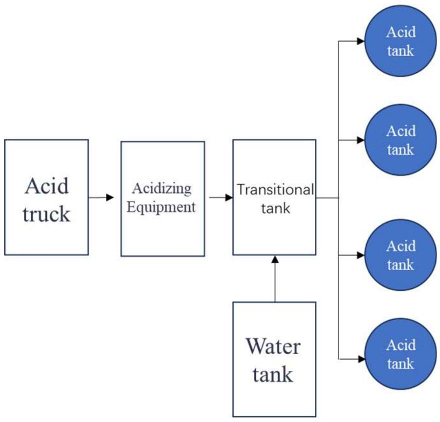

Figure 2. Schematic diagram of continuous acid supply and distribution equipment 2

Considering the current large-scale acidification construction, limited by the total liquid volume of the acid tank, and on-site site issues, for ultra large scale acidification construction, the production preparation cost in the early stage of construction is high. Moreover, in large-scale acidification wells, uneven material mixing can easily lead to sedimentation during long-term construction. Therefore, by developing continuous acid mixing equipment, a series of problems that existed in the early stage can be solved.

One is to optimize the internal structure of the circulation device, so that the flow state of the acid liquid is transformed from the traditional circulation device's flat and clockwise rotating flow system to the two flow states of the bottom and upper liquid surface, which are mutually converted, forming a stirring effect on the powder molecules, achieving the best swelling effect of the gel powder and greatly shortening the swelling time; The second is to optimize the speed of acid solution preparation. The acid preparation equipment can reduce manual material handling time, integrate all material additions into the acid preparation equipment, and achieve an acid solution preparation speed of 900m³/day, which is more than 80% higher than the traditional acid preparation speed of 500m³/day. Therefore, the use of continuous acid preparation technology not only improves the quality of gel acid preparation, but also plays an important role in saving site area and reducing production costs.

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3. Multi Stage Alternating Injection Acidification Liquid Supply Technology

3.1 Optimization of Grouping Method for Acid/Liquid Tanks

Due to the large number of acidification acid tanks/liquid tanks limited by the site, and in order to reduce the distance of remote acid tank supply, it is necessary to group and place the acid tanks/liquid tanks in order to optimize the supply capacity. The grouping principle was established through on-site practice:

(1) The acid tank group and fracturing fluid tank group should be separately divided for easy operation and switching. Due to the fact that most large-scale acidizing operations involve alternating injection, if there are fewer acidizing operations in the base tank, the working fluid can be switched between the inlet gate and the tank gate. If there are too many acid tanks and liquid tanks, relying solely on the water inlet gate and liquid tank gate to control them will result in long operation time, more personnel displacement, and the two working fluids will flow into each other, which can easily lead to construction failure. Therefore, a new liquid supply connection method for pipelines and tank groups has been redesigned, which includes "connecting without crossing, replacing the main valve, and distinguishing between the two".

(2) The fracturing fluid tank group should be located as close as possible to the supply equipment to prevent pressure fluctuations during alternating injection operations. When alternately injecting, it is necessary to first close the acid outlet and then open the fracturing fluid outlet. When opening the fracturing fluid outlet, there may be insufficient supply pressure. If the outlet is close to the supply equipment, it will be relieved.

(3) The clear water tank should be located as close as possible to the acid tank group and the liquid supply equipment. The number of clear water tanks is limited, and the connected outlet pipelines are also limited. During the replacement process, if the distance from the liquid supply equipment is too far, there will be insufficient liquid supply pressure, which will affect the construction.

(4) Vertical acid tanks should be selected as much as possible for remote acid tanks. Due to the use of a horizontal acid tank, which is similar to a combination tank, the liquid supply height is about 30cm less than that of a vertical acid tank, resulting in insufficient liquid supply pressure when used remotely.

(5) The volume of a single acid tank shall not be less than one-third of the total acid volume. It is advisable to group acid tanks into 3 groups, as too many groups can lead to excessive distance and an increase in supporting equipment. Taking 2000m³ alternate injection as an example, 1500m³ acid solution+500m³ fracturing fluid requires 2 sets of horizontal acid tanks, 5 sets (10) per set, and 25 vertical acid tanks.

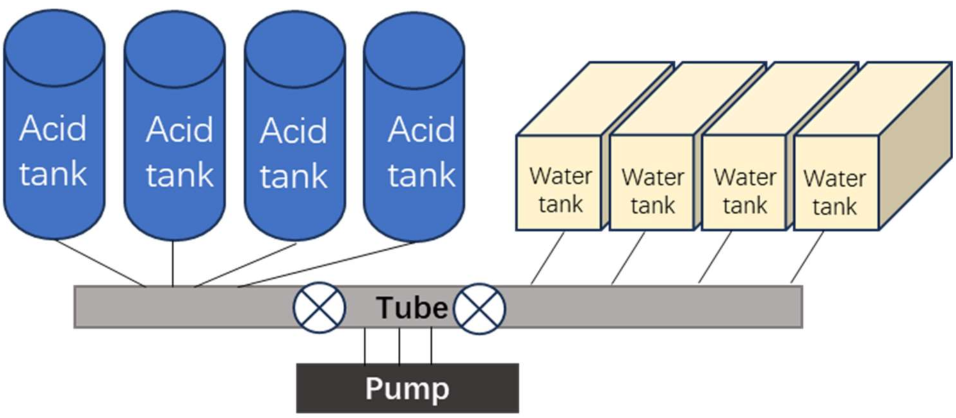

Figure 3. Acid&Water Tank Connection Diagram

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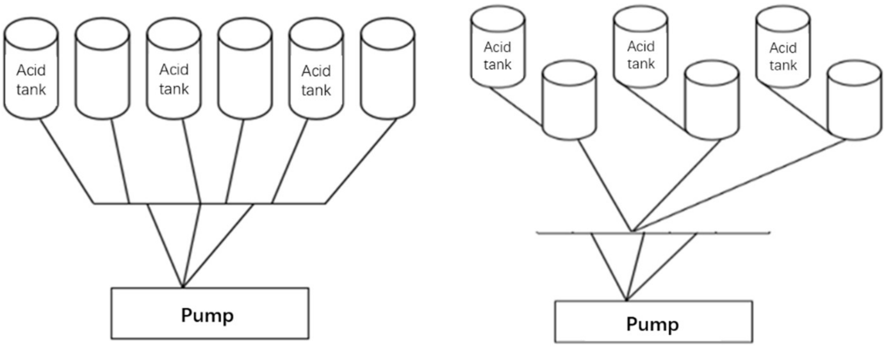
3.2 Optimization of Low-voltage Process Connection Method

The large acid pressure displacement can reach 6-12m³/min, and the number and diameter of the water inlet on the injection lever can fully meet this displacement range. However, if there are too many water inlet pipelines in the traditional pipeline connection method, it is difficult to control and control the acid tank gate in the later stage of construction, which poses a risk of acid tank emptying and insufficient liquid supply. Therefore, it is necessary to improve the connection method of the water inlet pipeline to solve this problem. The study suggests that the use of a series connection of all acid tanks, with equal water supply, combined with gradient control of the acid tank liquid level, can solve this problem. This connection method enables any acid tank to be supplied with acid through any upstream water pipeline, and can also achieve a balanced decrease in the liquid level of the tank group, providing a guarantee for the large-scale injection of acid solution in the later stage of acidification construction. Equal water supply does not refer to equal distribution in quantity, but to equal flow. If there are many tank groups, acidification collection and remote multi pipeline connections can be used to achieve equal water supply.



Before improvement After improvement

Figure 4. Connection Diagram

At the same time, gradient liquid supply is carried out for the acid tank group. Gradient liquid supply refers to the pyramid shaped liquid supply achieved by the acid tank liquid level. As shown in the following figure:

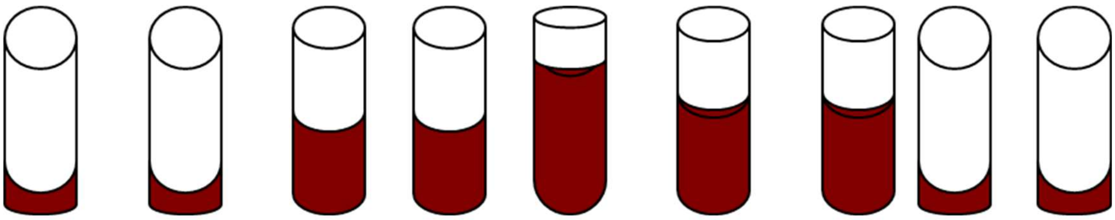


Figure 5. Schematic diagram of gradient liquid supply

Practice has proven that the current low-pressure water supply pipeline can achieve a minimum liquid supply capacity of 1.5m³/min, which means that the number of high-level acid tanks can be obtained by dividing the maximum designed displacement by 1.5 and rounding it up. Here is an example to illustrate:

X well has a designed acid capacity of 400m³ and a designed displacement of 6m³/min. It is calculated that 16 acid tanks are required, and at least 4 high-level acid tanks are needed. In this case, a gradient liquid supply method can be used, which includes 4 high-level acid tanks, 6 medium level acid tanks, and 6 low-level acid tanks. By the end, the acid in the other 12 acid tanks has been used up, and the

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operator only needs to pay attention to the last 4 high-level acid tanks. When the high liquid level changes to the low liquid level, due to the effect of acidification, the flow rate supply can still be guaranteed.

4. Application Effect

The optimized acid mixing and supply technology has successfully achieved large-scale acidification construction in multiple wells, with a total scale of 3210m³ for X6-3D acid fracturing, 3220m³ for X6-6D acid fracturing, 3150m³ for X5-1D acid fracturing, and a maximum construction displacement of over 8m³/min. In large-scale acidification construction, acid blending has been effectively used, with a success rate of 100% in a single formulation. The use of acid tanks in series can ensure a construction displacement of 8-10m³/min during construction. In application, ground supporting technology embodies high quality and stability, high timeliness, high safety, high airtightness, high convenience and economy, which can achieve effective addition, accurate measurement, convenient operation, standardized construction safety, and a success rate of 100%.

On site application of X6-3 well, construction parameters: 120m³ of reducing acid, 1:270m³ of gelling acid, 2:2040m³ of gelling acid, 780m³ of fracturing fluid, 33m³ of liquid nitrogen, 4000kg of temporary plugging agent, 200kg of fiber, total scale of 3210m³, construction displacement of 4-7m³/min.

Table 1. Acid Mixing Parameters Table

	Liquid type	Visual viscosity (mPa. s)		Relative density (g/cm³)		pH value		Preparation quantity(m³)	
	contrast	Design value	Actual value	Design value	Actual value	Design value	Actual value	Design value	Actual value
Liquid performance parameters	Reduce acidity	/	/	1.075±0.02	1.075	/	<1	120	120
	Gelatin acid 1	≥20	21	1.1±0.02	1.1	/	<1	270	270
	Gelatin acid 2	≥20	30	1.1±0.02	1.1	/	<1	2040	2040
	Fracturing fluid	51-60	51	/	/	6-7	6	780	780

a. Due to the large scale of acid solution in X6-3 well, multiple acid tanks and liquid tanks, and the distance between the acid tanks and the main pressure zone (about 150-160 meters), a "multi machine remote supply" mode is considered to supply liquid to the main pressure equipment.

b. Divide the tank group and low-pressure manifold into liquid supply zone one, liquid supply zone two, and liquid supply zone three. The tank group and manifold correspond to each other as shown in the figure.

c. The main liquid supply equipment uses a 12m³/min liquid supply sled. In the early stage of construction, the butterfly valve in zone 1 is closed and the butterfly valve in zone 2 is opened. Normally, according to the pump injection procedure, the use of reducing acid and cementing acid 1 is used. When injecting cementing acid 2, both zones 1 and 2 are used to supply liquid simultaneously (from far to near use, overlapping acid tanks use the lower tank acid first, and if the liquid supply pressure is unstable, the vertical acid tank is immediately opened);

d. During the mid-term of construction, close the butterfly valve in Zone 2 and use an auxiliary sled to collect the remote acid tank in Zone 3 to ensure the supply pressure of the liquid;

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In the later stage of construction, the remaining acid solution is concentrated in the second liquid supply area. While the main sled is used for liquid supply, two auxiliary sleds are used together to achieve the effect of collecting acid while assisting in liquid supply.

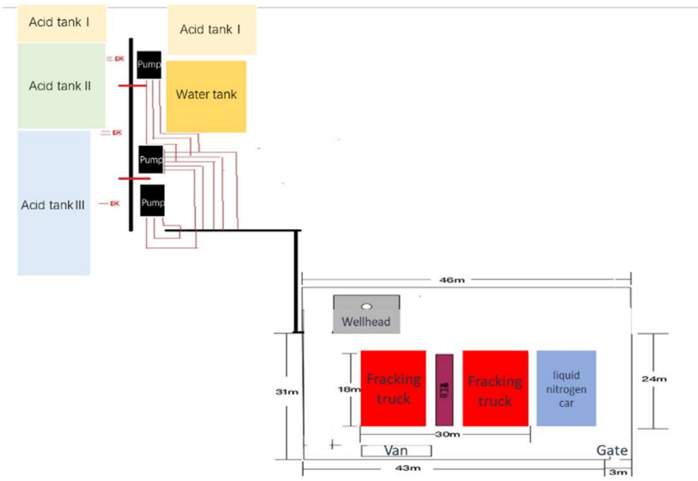

Figure 6. Schematic diagram of the X6-3 well site

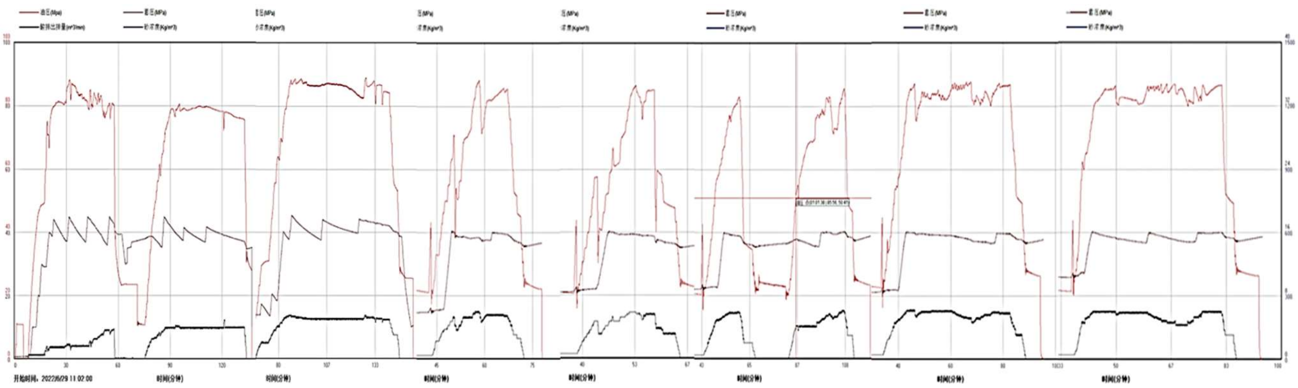

Figure 7. Construction Curve

At present, this process has completed large-scale acidification construction for 11 wells, with a cumulative construction acid volume of 24560m³ and a construction success rate of 100% (Table 4-1).

Table 2. Statistics of Cumulative Homework Volume Data

Project results		workload	Utilize status
Acid preparation system	Gelatinous acid	21000m³	All qualified and of good quality
	Conventional acid	3560m³	All qualified and of good quality
Liquid supply system	Single working fluid	11 wells	Successful utilization of all wells
	Alternating injection	11 wells	Successful utilization of all wells

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5. Conclusion

Based on the comprehensive on-site application situation, the research results of this project have the following advantages and characteristics: ① Acid preparation system: high quality and stability, high timeliness, high safety, high airtightness, high convenience, and economy. ② Liquid supply system: accurate measurement, convenient operation, tight connection, and safety standards. By using a continuous acid mixing system, the problems of long acid preparation time and difficult on-site acid supply in large-scale acidification have been solved, providing strong support for multi-stage acid fracturing construction in deep marine wells.

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