Research on the Technology of Integral Water Searching and Plugging for Two-Stage Casing Gas-Lift Wells in Sudan Oilfield

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Abstract. The combination structure of 9 \(5/8\)“ and 5 \(1/2\)“ casing is used in some gas-lift wells in Sudan Oilfield. The existing mechanical water searching and plugging technology cannot meet the technical requirements of this type of well, so an integral water searching and plugging string for two-stage casing gas-lift well is developed. The string is composed of two kinds of packers and one kind of regulator. The two kinds of packers are set by hydraulic pressure synchronously to seal the layers of two kinds of casing. After the packers are set, the steel wire is used to fish and drop the blanking plug and search the water layer by layer to realize the adjustment of production layers. This process string has the characteristics of accurate water layer searching, reliable sealing, dynamic adjustment, etc. The string can realize water searching and plugging for two-stage casing wells by one trip. The string has been applied in well JS-2 in Sudan. After adjustment and plugging, the water cut is 25.6% lower than before. The effect of water control and oil production increase is significant, and the production life of the well is prolonged.

1. Introduction
Sudan Oilfield mainly belongs to medium and high porosity and permeability sandstone reservoir. In the early stage, the technology policy of sparse wells with high production and rapid investment recovery was adopted. Making full use of the natural energy of the formation, large-scale combined production, large pressure difference production, high oil production speed resulted in water cut rising too fast after water breakthrough in the high-permeability layer, inter layer contradiction becoming more prominent and rapid production decline. The application of mechanical water searching and plugging technology in single well can effectively solve the contradiction between layers, control the water cut, prolong the life of oil well, and further improve the recovery degree and recovery rate. However, the heavy oil reservoir in some blocks of Sudan Oilfield adopts gas lift production method, and its well bore structure is mostly 9 \(5/8\)“ and 5 \(1/2\)“ combined casing. The existing mechanical water searching and plugging technology cannot meet the requirements of such well. For this reason, the research on the technology of integral water searching and plugging for two-stage casing gas-lift well is carried out.
2. String Introduction

2.1. String Structure
This string is mainly composed of gas lift valve, safety joint, Y441-208 packer, Y341-208 packer, Y341-114 packer, eccentric production regulator, blanking plug and end plug (Figure 1).

![String Diagram](image)

2.2. Working Principle
First, all eccentric regulators are closed on the ground. The string is put into the predetermined depth of the well. And then after adding 18MPa hydraulic pressure to the tubing, the different packers are set synchronously to realize the layer sealing of different casing. Among the string, Y441-208 packer can prevent the packer from being affected by the peristalsis of the string. Y341-208 packer can seal the upper 9 5/8" casing production layers, and Y341-114 packer can seal the lower 5 1/2" casing production layers.

After the string delivery, the Christmas tree is installed. Then the steel wire is used to fish the blanking plug in the first eccentric regulator to open the well for production and water content testing. When the test water content value becomes stable, the steel wire is used again to drop the blanking plug to close the first eccentric regulator and open the second eccentric regulator in the same way. After all layers are tested one by one, confirm the high aquifer according to the production data of each layer, close the high aquifer and open the low aquifer.

2.3. Technical Parameters
The string is suitable for 9 5/8" and 5 1/2" two-stage casing and meets the requirements of water searching and plugging for 6 layers. The temperature resistance of the string is 120°C, and the pressure resistance is 35MPa. The useful life of the string is 5 years.

3. Key Technologies and Tools

3.1. Key Technologies
Compared with single-stage casing production wells, the key technologies of two-stage casing production wells are as follows:
First, the string composed of different packers should achieve effective sealing in different casing layers. The different packers should be set synchronously under the same hydraulic pressure during the completion of the string. Due to different packers will produce different axial piston force, the stress of the string is uneven and unstable, which leads to process failure. Therefore, Y341-208 packer and Y341-114 packer should produce similar piston force during synchronous setting, so as to ensure uniform stress on the string.

Second, the inner diameter of Y341-208 packer and Y341-114 packer must be same, so as to meet the technical requirements of testing and layer adjustment for 9 5/8" and 5 1/2" combined casing production layers.

3.2. Key Tools

3.2.1. Y341-208 packer

(1) Structure
Y341-208 is mainly composed of sealing mechanism, locking mechanism, balancing mechanism, setting mechanism, unsealing mechanism, etc. (Figure 2) Its structure and principle are similar to that of Y341-114 packer.

(2) Structure design
Balance mechanism is designed at the upper part of Y341-208 packer. When the pressure of upper chamber of rubber cylinder is higher than that of lower chamber, liquid enters into upper balance piston and lower balance piston. Meanwhile, balance piston sleeve is pushed to reduce the shear force on unsealing pin, and the sealing performance and stability performance of packer are improved. When the pressure of the upper chamber reaches 35MPa, the pressure difference between the upper and lower chambers of the rubber cylinder meets the conditions for unsealing the packer which provide another way to unseal the packer. Y341-208 packer is designed with concentric double center pipe structure. The diameter of inner center pipe is Φ 62mm, which is the same as Y341-114 and Y441-208 packers’, meeting the requirements of steel wire testing and layer adjustment. The outer central pipe reduces the effective pressure bearing area of packer setting piston to match the setting pressure of Y341-114 and Y441-208 packer, and realizes synchronous sealing of different packers.

(3) Working principle
When setting, the hydraulic pressure from oil pipe is used to push the setting cylinder upward to compress the rubber cylinder, and the locking mechanism is used to lock the setting sleeve to realize the setting of the packer. In the production process, the upper balance mechanism makes the packer seal better under the condition of high pressure difference. When unsealing, the first way is to lift up the string and unseal it; the second way is to add casing pressure to 35MPa, cut off the unsealed pin, and unseal the rubber cylinder by its own elasticity.

(4) Technical parameters
The outer diameter is Φ208mm; the inner diameter is Φ62mm; the working pressure difference is 35MPa; the working temperature is 120°C; the setting pressure is 18MPa; the way of unsealing is to lift the string until 80KN or to pressurize the casing until 35MPa.

3.2.2. Y441-208 packer

(1) Structure
Y441-208 packer is mainly composed of sealing mechanism, anchoring mechanism and locking mechanism (Figure 3).
(2) Structure design
Y441-208 packer adopts two-way slip anchoring structure, the upper cone and locking mechanism are designed as a whole, the slip is supported by tower spring, which can effectively provide suspension and anchoring effect for a long time, and the validity period is more than 3 years. At the same time, the same concentric double center tube as Y341-208 packer is adopted. The inner pipe has the same diameter as Y341-208 packer, meeting the requirements of testing and layer adjustment; the outer pipe is used to reduce the pressure bearing area of piston, realize synchronous setting of two size packers, and cut the unsealing pin and trigger the slip unsealing mechanism when unsealing.

(3) Working principle
Y441-208 packer plays the role of anchoring and protecting casing in the whole string, and organically combines the two functional strings of gas lift and water searching and plugging. When setting, hydraulic pressure is applied to the oil pipe, the piston pushes the cone downward, slips are expended, and anchoring is realized; at the same time, the pressure sleeve upward compresses the rubber cylinder to achieve sealing. When unsealing, lift up the string, the outer central pipe drives the positioning body upward, cut off the unsealing pin, and the rubber cylinder recovers and unseals by its own elasticity; when the lower cone loses support, the slip recovers after lifting up, and the anchoring fails.

(4) Technical parameters
The outer diameter is Φ208mm; the inner diameter is Φ62mm. The working pressure difference is 35MPa; the working temperature is 120°C. The setting pressure is 18MPa; the maximum anchoring force is 780KN; the unsealing force is 80KN.

3.2.3. Other supporting tools
Y341-114 packer and eccentric production regulator are the same as 5 1/2” casing well water searching and plugging process string. Y341-114 packer is used to seal the 5 1/2” casing production layer at the lower part(Figure 4); the eccentric production regulator is opened or closed by dropping and fishing blanking plug with the steel wire, and is used for layer test and layer adjustment(Figure 5).

The main technical parameters are as follows: The outer diameter of Y341-114 packer is Φ114mm, the inner diameter is Φ62mm, the working pressure difference is 35MPa, the working temperature is 120°C, the setting pressure is 18MPa, and the lifting force of unsealing is 80KN. The outer diameter of the eccentric regulator is Φ114mm, the inner diameter is Φ46mm, the working pressure difference is 35MPa, and the working temperature is 120°C.
4. Field Test

The technology of integral water searching and plugging for two-stage casing gas-lift well has been applied in well JS-2 of Sudan Oilfield. After the well is put into production, the peak oil production is 5987 barrels per day, the average oil production is 2597 barrels per day, and the water content is 56.6%. After maintaining high production for a period of time, the water cut of the well increases gradually, the oil production decreases gradually, and the well is finally shut off. For this reason, the technology of integral water searching and plugging for two-stage casing gas-lift well is applied to the well. The production layers are divided into six, which are tested layer by layer for 4-6 days. The test results show that the 2, 5 and 6 layers are high aquifers. Therefore, it is decided to close 2, 5 and 6 layers and keep 1, 3 and 4 layers open.

| Layer | Days | Water cut(%) | Depth (m) |
|-------|------|--------------|-----------|
| 1     | 1    | 60           | 1434.0-148.0m |
|       | 2    | 55           | /         |
|       | 3    | 62           | /         |
| 2     | 4    | 90           | 1472.4-1493.2m |
|       | 5    | 92           | /         |
|       | 6    | /            | /         |
| 3     | 1    | 74           | 1497.0-1509.8m |
|       | 2    | 74           | 4         |
|       | 3    | 74           | 67        |
| 4     | 1    | 80           | 1820.0-1823.0m |
|       | 2    | 80           | 74        |
|       | 3    | 74           | 67        |
| 5     | 1    | 85           | 2350.0-2497.0m |
|       | 2    | 63           | 38        |
|       | 3    | 63           | 43        |
|       | 4    | /            | 44        |
| 6     | 1    | 92           | 2520.0-2785.0m |
|       | 2    | 94           | /         |
|       | 3    | 95           | /         |
|       | 4    | 83           | /         |

After adjustment, the water cut of the single well is 56%, which is 25.6% lower than the highest of 81.6%. The field application shows that the string can meet the needs of water searching and plugging technology of two-stage casing gas lift well, with accurate water searching, reliable plugging, dynamic adjustment, effective reduction of water cut and increase of oil production of single well.

5. Conclusion

1. In the field test of integral water searching and plugging technology string for double stage casing gas lift well, the running process is safe and stable, and the packers of different specifications can be set in the same time smoothly, which can effectively seal each layer.

2. The process string has the advantages of good stability, long service life, accurate water level finding, and multiple adjustment of production layers can be realized without pulling the string.

3. The process string can meet the technical requirements of water searching and plugging for 9 5/6" and 5 1/2" double-stage casing wells. After the testing and adjustment, the water cut decreases significantly and the water plugging effect is obvious.

6. References

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