Research and Application of Segmentation Unblocking Technology for Horizontal Well Screen

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Abstract. Horizontal well screen completion process has its own advantages, but there are also some problems, in which the screen blockage seriously affects its efficacy. However, due to various factors (such as heavy components in crude oil plugging the sand filter), the implementation of conventional pickling and sand washing operations is not ideal. In response to this problem, this paper proposes a new unblocking technology - segmentation unblocking technology for horizontal well screen. Firstly, on the basis of studying principle of the technology, optimization of water jet method and hydraulic sanding nozzle, nitrogen foam water jet experiment and water jet construction displacement experiment are carried out for horizontal well screen, which laying the foundation for application of segmentation unblocking technology. Further, horizontal well screen segmentation unblocking experiment and oilfield application are carried out. Optimization results of water jet method show that, For large displacement construction with still wellhead, whole section construction selects type of inlet liquid through annulus between oil pipe and casing pipe and outlet liquid through oil pipe. For small displacement construction with frequent dynamic wellhead, segmentation construction selects type of inlet liquid through oil pipe and outlet liquid through annulus between oil pipe and casing pipe. Optimization results of hydraulic sanding nozzle show that Streamlined nozzle is better than nozzle with iso variable. Experiment results of horizontal well screen segmentation unblocking show that, segmentation unblocking technology can effectively improve productivity of horizontal well and oilfield application achieved good results. Five wells were shut-in, periodic shut-in or low production before segmentation unblocking. After segmentation unblocking, daily oil increment can reach 23.57 t, and interval cumulative oil increment can reach 4756 t.

Keywords: First Keyword, Second Keyword, Third Keyword.

1. Introduction
Unconsolidated sandstone reservoirs generally are shallow reservoir, loose cementation, high or medium permeability, poor compaction, and easy to produce sand. Reservoir lithology is siltstone and fine sandstone. part of oil layers have high clay content[1-4]. The Minghuazhen formation, Guantao
formation, some Dongying formation and Shahejie formation in Liaohe, Dagang and Shengli oilfields in Bohai Bay belong to unconsolidated sandstone reservoirs [5-7]. This type of reservoirs often uses horizontal well screen completion [8]. Screen completion technology for horizontal Wells is mainly implemented by cementing tools such as pipe outer packer, grading stirrup, blind plate (drill-free plug tool) and sand filter pipe. Sand filter pipe is used to complete Wells in the main reservoir section and cementing is used in the upper well section, which can effectively plug upper water layer and ensure sand control effect. It also can improve wellbore seepage condition, save investment and increase productivity [9]. The technology takes into account common characteristics of sand filter pipe completion and cementing completion. Additionally, it has been widely applied in oil field and has achieved good results. However, horizontal well screen completion technology still has some problems: The space between sand filter pipe and well wall has residual mud and oily mud sand, which makes it difficult for oil flow to enter sand filter pipe; Mud cake formed by drilling well wall is not completely removed, and oil flow is difficult to enter sand filter pipe; Colloid and asphaltene in crude oil plugs sand filter pipe.

In order to solve above problems, current commonly used technologies are acidification and water jet unblocking [10,11]. However, conventional acidification and water jet unblocking technology also has some problems. For example, conventional acidification cannot effectively remove mud cake formed in drilling process, and the cost is high. In addition, acid corrodes screen pipe and other pipes seriously [12,13]. Conventional water jet unblocking technology is unable to carry out homogeneous unblocking for strong heterogeneity formation, and maintenance time of effect is short [14]. According to this situation, this paper puts forward a new segmentation unblocking technology for horizontal well screen. Carrying out test on the basis of optimized construction method and device. Finally, applying this new technology to oilfield and obtaining good application effect.

2. Theory of Horizontal Well Screen Segmentation Unblocking Technology

2.1 Technology Theory
The technology uses high pressure water jet unblocking and nitrogen foam flowback to improve cleaning effect of horizontal well screen outer blockage. Mud cake at sand control screen and in near wellbore area outside screen is destroyed segmentally. Then, this destroyed mud cake flows back to ground by nitrogen foam flowback, along with drilling mud, mud silt sand near wellbore area, and heavy oil mixture. So as to achieve the aim of homogeneously improving permeability near wellbore area. Figure 1 is downhole string schematic diagram of horizontal well screen segmentation unblocking technology.

![Fig 1. Downhole string schematic diagram of horizontal well screen segmentation unblocking technology.](image-url)

2.2 Construction Procedure
Construction procedure of horizontal well screen segmentation unblocking technology is as follows.

(1) Perforation: Positive and negative well flushing channel is established by perforating 1-2 m at the bottom of horizontal well screen.

(2) Segmented pulsed jet flushing unblocking outside screen: Outer blockage of screen is flushed out of ground with special tool, and longitudinal coherent well flushing channel is formed outside
(3) Whole well nitrogen foam jet flushing unblocking outside screen: Outer blockage of screen is flushed out of ground by high volume nitrogen foam with special tool, and longitudinal coherent well flushing channel is formed outside screen. Old wells with serious plugging, and new and old wells with horizontal section more than 150 m should implement step 1, step 2 and step 3. New wells, new and old wells with horizontal section less than 150 m, and old wells with less serious plugging should implement step 1 and step 3.

(4) Plugging: Using releasing packer and internal well flushing valve to plug. The packer has secondary flushing channel.

(5) Filling outside pipe: Filling by external filling pipe string.

Figure 2 is schematic diagram of ground construction equipment and device.

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2.3 Technical Feature

According to above technology theory and construction procedure, technical feature is as follows.

(1) Uniform acid distribution and complete pickling: Traditional increased resistance pickling near well section of increased resistance device has good effect. However, most pickling at well horizontal section has poor effect. Improved segmented high pressure pulsed water jet technology can achieve uniform acid distribution through nozzle jet (ground jet experiment is shown in figure 3). So that oil layer in horizontal section and plugged sand control screen in whole horizontal section can achieve three-dimensional effect. Schematic diagram is as shown in figure 4.

(2) Complete flow back: Mixture can be completely flowed back to ground through the bottom mud cake cleaner by combining with nitrogen foam mixing flow back technology, which reducing the risk of corrosion damage to screen caused by residual acid.

(3) Filling outside screen for sand control: After pulsed jet unblocking, if sand control is need, sand carrying agent and quartz sand directly through oil pipe fills outside screen for sand control.

Therefore, horizontal well screen segmentation unblocking technology can effectively remove pollution near well zone, increase oil drainage area, reduce production pressure difference, and improve formation flow conductivity.

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Fig 2. Schematic diagram of ground construction equipment and device.

![Fig 2](image)

Fig 3. Ground jet experiment

![Fig 3](image)
3. Optimization of Water Jet Method and Device

3.1 Optimization of Water Jet Method
Horizontal well high pressure water jet unblocking technology, through high speed water flushing and carrying, flushes blockage, mud, mud silt sand and heavy oil mixture out to ground, so as to achieve the aim of evenly improving permeability near well zone. Therefore, only on the basis of positive and negative well flushing circulation mode, the technology can flush blockage out. The key of technology is high flow rate of well flushing fluid. At present, construction method of water jet technology can be divided into two types. One type is inlet liquid through oil pipe and outlet liquid through annulus between oil pipe and casing pipe. Advantages of this type have good self-sealing effect, simple construction and high construction success rate. However, due to small flow area, large friction and high construction pressure, it is not suitable for large displacement construction. Other one type is inlet liquid through annulus between oil pipe and casing pipe and outlet liquid through oil pipe. Advantages of this type have good self-sealing effect, large flow area, small friction, low construction pressure and high construction success rate. So it is suitable for large displacement construction.

According to comprehensive consideration of construction safety, construction pressure, and need of whole section construction and segmentation construction. Whole section construction selects type of inlet liquid through annulus between oil pipe and casing pipe and outlet liquid through oil pipe. It is suitable for large displacement construction with still wellhead. Segmentation construction selects type of inlet liquid through oil pipe and outlet liquid through annulus between oil pipe and casing pipe. It is suitable for small displacement construction with frequent dynamic wellhead.

3.2 Optimization of Hydraulic Sanding Nozzle
Commonly used nozzles are streamlined nozzle and nozzle with iso variable, as shown in figure 5 and 6. Jet test and simulation result shows that streamlined nozzle is better than nozzle with iso variable.
4. Experiment

4.1 Nitrogen Foam Water Jet Experiment

Parameters of high pressure pipe string: pipe string is uniform as equal-diameter jointless tool with 74 mm outer diameter and 51 mm inner diameter. Total length is 200 m. Parameters of high pressure nozzle: 1.5 mm diameter, 5 hole/m, 45° helical distribution. Experimental results are shown in table 1.

| Test length/m | Pump truck displacement/m³/min | Nitrogen displacement/Nm³/h | Outlet throttling pressure/MPa |
|---------------|--------------------------------|-----------------------------|-------------------------------|
| 100           | 0.5                            | 0                           | 0.2                           |
| 100           | 1.0                            | 0                           | 1.3                           |
| 100           | 1.5                            | 0                           | 2.4                           |
| 200           | 0.5                            | 1500                        | 1.7                           |
| 200           | 1.0                            | 1500                        | 3.5                           |
| 200           | 1.5                            | 1500                        | 6.0                           |

It can be seen from table 1 that throttling pressure and displacement basically have a linear relationship, that is \( P = kQ \) (\( k = 3.5 \sim 4.0 \), and \( k \) is related to nozzle parameters). Accordingly, if construction displacement increases to 2.5~3.0 m³/min, throttling pressure \( P \) can reach 9.0~12.0 MPa. Under this pressure, intensity of end jet can reach 8~10 m. According to experimental results, sand blasting perforation effect of nitrogen truck and cement truck is better.

4.2 Construction Displacement of Water Jet Experiment

Construction displacement of water jet experiment results are shown in table 2.

| Test length/m | 1.5mm nozzle/10 each/m | Equivalent diameter/mm | Pump truck displacement/m³/min | Outlet pressure/MPa | Nitrogen displacement/m³/h |
|---------------|------------------------|------------------------|-------------------------------|---------------------|---------------------------|
| 100           | 1000                   | 47                     | 0.5                           | 0.2                 | 0.0                       |
|               |                        |                        | 1.0                           | 1.3                 |                           |
|               |                        |                        | 1.5                           | 2.4                 |                           |
| 100           | 1000                   | 47                     | 0.5                           | 2.0                 | 1500.0                    |
|               |                        |                        | 1.0                           | 3.7                 |                           |
|               |                        |                        | 1.5                           | 6.0                 |                           |
| 250           | 2500                   | 75                     | 0.5                           | 1.7                 | 1500.0                    |
|               |                        |                        | 1.0                           | 3.5                 |                           |
|               |                        |                        | 1.5                           | 5.5                 |                           |
It can be seen from table 2 that:

1. At the same displacement, friction resistance of foam is 2-3 times/100 m that of water.
2. In the case of 1.5 m$^3$/min displacement and 250 m test length (2500 nozzles, 1.5 mm in diameter and 75 mm in equivalent), jetting height can reach 4–5 m.
3. According to 14 each/m nozzle in dual-pipe water jet string, so 250 m has 3500 nozzles. Diameter of each nozzle is 3 mm. The equivalent diameter is 178 mm, which is 2.4 times that of test pipe string. Jetting height can reach 2 m (1.5 m$^3$/min displacement).
4. Jetting height of nozzle at 250 m can reach 4-5 m with 1.5 m$^3$/min, indicating that friction resistance has little influence on jetting, and main influence is displacement. Minimum displacement should be 1.5 m$^3$/min. Foam carrying sand should achieve two conditions: First is large foam density, or not enough to carry sand. Second is large construction displacement. Experimental data shows that in the case of 1.5 m$^3$/min displacement and 5.5 MPa pressure, compressed volume of nitrogen is 0.45 m$^3$/min, and foam displacement can reach about 2.0 m$^3$/min. In this case, sand carrying capacity is relatively good, and foam density is 0.75 g/cm$^2$. Therefore, foam density is best controlled above 0.5 g/cm$^2$.

### 4.3 Segmentation Unblocking Technology for Horizontal Well Screen

Exploration well X1115H is taken as experimental object for horizontal well screen segmentation unblocking experiment. Its tubular structure is shown in figure 7. Experiment results are shown in table 3.

![Fig 7. Exploration well X1115H tubular structure.](image)

**Table 3.** Experiment results.

| parameter                           | unit      | Pre-experiment value | Post-experiment value |
|-------------------------------------|-----------|-----------------------|-----------------------|
| Wellbore storage factor             | m$^3$/MPa    | 0.76246               | 0.96                  |
| Horizontal effective permeability   | $10^{-3}$μm$^2$ | 2.696                 | 26.1                  |
| Vertical effective permeability     | $10^{-3}$μm$^2$ | 0.2907               | 0.94                  |
| Formation coefficient               | $10^{-3}$μm$^2$.m | 13.48                 | 70.49                 |
| Mechanical skin factor              | Dimensionless | 13.5                  | -10.42                |
| Pseudo skin factor of horizontal well | Dimensionless | -1.7                  | -14.34                |
| Distance between horizontal well and bottom of reservoir | m | 2.5                   | 2.5                   |
| Effective interval of horizontal well | m | 100.45                | 125.4                 |
| Detection radius                    | m          | 30                    | 65                    |
| Formation pressure                  | MPa        | 16.725                | 21.21                 |

It can be seen from table 3 that segmentation unblocking technology can effectively improve permeability in near-well zone, improve imperfect well to improved well, and make formation pressure closer to real formation pressure. In addition, through two pressure build up test, main reason
for low productivity is that reservoir is polluted. Water jet segmentation unblocking technology can effectively improve productivity of horizontal well.

5. Field Application
Horizontal well Yang1H1 was put into production in 2008. Due to poor liquid supply, well Yang1H1 started long shut-in in January 2015. In May 2019, the well applying segmentation unblocking technology. Then the well opened after unblocking, and daily oil increment can reach 10.88 t.

Up to now, Yang1H1 well, Kong1045H well, Yang1H12 well, Kong1057H1 well, and Kong59-17H3 well have carried out segmentation unblocking. Success rate is 100%. Five wells were shut-in, periodic shut-in or low production before segmentation unblocking. After segmentation unblocking, daily oil increment can reach 23.57 t, and interval cumulative oil increment can reach 4756 t.

6. Conclusion
Conclusion is as follows.
(1) For large displacement construction with still wellhead, whole section construction selects type of inlet liquid through annulus between oil pipe and casing pipe and outlet liquid through oil pipe. For small displacement construction with frequent dynamic wellhead, segmentation construction selects type of inlet liquid through oil pipe and outlet liquid through annulus between oil pipe and casing pipe.
(2) Streamlined nozzle is better than nozzle with iso variable.
(3) Experiment results show that segmentation unblocking technology can effectively improve productivity of horizontal well.
(4) Segmentation unblocking technology of horizontal well screen has been applied in oilfield and achieved good results.

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