Development of a New Wax Scraper

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Abstract: Wax removal and prevention in oil wells is an important work in field management. This paper introduces the process of developing a new type of loose-leaf wax scraper by using TRIZ method. At the same time, 48 schemes, 33 feasible schemes and 5 patent plans have been obtained by using this method, and certain economic benefits have been obtained.

1. Preface
Wax deposition in oil wells is the most common problem encountered in Daqing oilfield since its development. During the upward migration of crude oil along the tubing, the composition, temperature and pressure of crude oil change. Part of the wax is precipitated from the oil. Then they gather and adhere to the tubing wall. Waxing on the tubing will reduce the production of the oil well and even block the tubing to stop production. Therefore, oil well wax removal and prevention work is an important work for field management.[1]

At present, the wax removal method for electric pump wells in oilfields is mainly mechanical wax removal: the wax scraper connecting weighting rod moves downwards to scrape wax under the action of gravity, and the scraped wax is taken out of the wellbore by liquid flow. After the wax scraper goes down to the well section without wax deposition, start the winch to pull the wax scraper up to the wellhead to complete wax removal.

With the development of oilfields, the implementation of new oil extraction technologies such as polymer flooding and ASP flooding, wax deposition in oil wells is becoming more and more serious. The wax removal period of oil wells is becoming shorter and shorter. And the wax removal time of single wells is also gradually increasing. How to prolong wax removal period and shorten wax removal time has become an urgent problem to be solved.

2. System Analysis

2.1 System analysis-Nine Screen diagram[2]
According to the method of nine screen diagram, we put forward the technical scheme of installing intelligent paraffin removal system to realize unmanned paraffin removal.

### 2.2 System analysis-Causal chain analysis\([3][2]\)

![Figure2.Causal chain analysis](image)

According to the cause and effect chain analysis, we put forward five technical schemes: using smooth or coated tubing, using tubing that is not easy to wax, reducing polymer injection, speeding up the flow speed of crude oil in the pipeline, and improving the temperature of produced fluid.

### 2.3 System analysis-Function analysis and cutting\([2]\)

![Figure1.Nine Screen diagram](image)
According to the function analysis and cutting, we propose to change the diameter of the wax scraper to prevent it from being stuck by wax or downhole tools; increase the weight of the weighted rod to speed up the speed of wax scraping; change the shape of the wax scraping piece to speed up the speed of wax scraping.

2.4 System analysis-Resource analysis[2]

Table 1. Resource analysis

| Species            | Material resources                  | Energy resources          | Information resources       | Space resources   | Time resources       | Functional resources         |
|--------------------|-------------------------------------|---------------------------|------------------------------|-------------------|----------------------|-----------------------------|
| System resources   | wax scraper, high temperature cleaning car, lubricator, | mechanical energy, potential energy, thermal energy | patent, professional technology, | well pad, wellbore space | wax scraping time | wax scraper, thermal medium hardening |
| Subsystem resources| driving car, steel wire, cable, weighting rod, wax scraper, wax scraping slice | mechanical energy, potential energy | driving technology, steel wire bearing, weighting rod, shape of wax scraper | lubricator, annular space of oil sleeve, | wax scraper time | wax scraper, lifting and lowering of wax scraper |
| Super system resources | wellbore environment, personnel | mechanical energy, thermal energy, electric energy | production, water content, physical properties of crude oil | well pad space, wellbore space | well production time | crude oil lifting |

According to the resource analysis, we put forward three technical schemes: winch capacity to speed up the speed of paraffin scraper; using optical cable well test car to electrify and heat the paraffin scraper to speed up the speed of paraffin scraper; using oil well power resource to change to electric winch.

3. Using TRIZ method to solve problems

3.1TRIZ Tool-Ultimate ideal solution[2]

Table 2. Ultimate ideal solution

| IFR Implementation deduction 6 Steps | Analysis results                                      |
|-------------------------------------|-------------------------------------------------------|
| 1. What is the ultimate goal of design? | Downhole string does not need wax removal           |
| 2. What is the final understanding of the problem? | The downhole string does not wax itself in the production process |
According to the final ideal solution, we put forward five plans: changing the nature of crude oil, keeping wax not separated from crude oil in the process of exploitation; maintaining the pressure of exploitation system, preventing wax from precipitation in crude oil; ensuring the temperature of crude oil in the process of exploitation, preventing wax from precipitation; changing the material of downhole pipe string, making wax unable to be adsorbed on the pipe wall; designing the inner wall of pipeline as smooth surface, preventing wax from adhering.

### TRIZ Tools—Scientific effects base

| 1. What is the function of the problem? | Control the movement of the wax scraper and increase the temperature of the wellbore and the wax scraper |
| 2. How to find the function code? | F6 control object displacement, F3 raise temperature |
| 3. What are function and phenomenon? | E15, E2, E64, E91, E93, E44, E92, E98, E49, E75, E76, E82, E24, E26, E57, E42, E25, E84, E39, E73, E67, E72, E80, E71, E69, E101 |
| 4. Screening effect phenomena | E49 Inertial Force, E82 Displacement, E57 Joule-Lenz's law, E73 Thermal Radiation, E71 Thermoelectricity phenomenon, E98 Vibration, E92 Hydrodynamics |
| 5. The use of screening effect and phenomenon | E49 inertial force, E73 thermal radiation, E71 Thermoelectricity phenomenon, E98 vibration, E92 hydrodynamic |

According to the scientific effect library, we put forward five plans: changing the nature of crude oil, keeping wax not separated from crude oil in the process of exploitation; maintaining the pressure of exploitation system, preventing wax from precipitation in crude oil; ensuring the temperature of crude oil in the process of exploitation, preventing wax from precipitation; changing the material of downhole pipe string, making wax unable to be adsorbed on the pipe wall; designing the inner wall of pipeline as smooth surface, preventing wax from adhering.

### TRIZ Tool—Information Interaction Theory

According to the theory of information interaction, we put forward five ways to remove wax: using tungsten weighting rod, mechanical paraffin scraper with chemical agent; using tungsten weighting rod, mechanical paraffin scraper with heat wash pump; using tungsten weighting rod, mechanical paraffin scraper with steam car; using tungsten weighting rod, mechanical paraffin scraper with glass inner liner string; using tungsten weighting rod with movable paraffin scraper Technical proposal.
3.4 Using TRIZ method to solve problems—Technical contradictions [2]

According to the technical contradiction diagram, we determined that the technical contradiction to be solved is TC-1, which occurs between wax removal speed and wax application effect, and under the condition of changing the diameter of the wax scraper.

In the model of this problem, the parameter we improve is the quality of wax scraping; the parameter we deteriorate is the speed of wax scraping. The solution can adopt the performance conversion method, dynamic method, self generated and self abandoned method and mechanical vibration method in TRIZ scientific effect library. We put forward the technical scheme of lowering the finer paraffin scraper to the bottom of the well, increasing the diameter of the paraffin scraper, and using the mechanical power of the winch to lift the paraffin scraper to scrape the wax.

3.5 Using TRIZ method to solve problems—Physical contradictions [2]

According to the physical contradiction diagram, we determined that the diameter of the wax scraper should be large to meet the requirements of wax removal effect, and the diameter of the wax scraper should be small to meet the requirements of wax removal speed. According to the principle of space separation, time separation, condition separation, whole and part separation, we put forward to put the tubing out of the well bore and put it into the bottom of the well after paraffin removal, paint special coating inside the well bore to delay paraffin deposition, install automatic paraffin scraper in advance in the well bore, push the paraffin scraper with air or hydraulic pressure, inject fluid to push the paraffin scraper upward, and increase the speed of paraffin removal. After separating the paraffin scraper from
the steel wire rope, put it into the shaft to scrape the wax by itself, and put the steel wire rope fishing and other technical schemes after the paraffin scraper reaches the bottom of the well.

3.6 TRIZ tool-Goldfish method[2]
According to the goldfish method, we put forward five technical schemes: changing the string to be anti wax material; powering up the downhole string, using the electric thermal effect to remove wax; increasing the weight of the wax scraper, using the gravity of the wax scraper to speed up the wax removal speed; releasing the wax melting agent in the process of wax scraper scraping; adding the automatic heating device in the wax scraper, and using the heat energy to cooperate with the wax scraping in the process of wax scraping.

Table 4. Goldfish method

| 1. Divide the problem into two parts: reality and fantasy | Reality: the wax deposition of downhole string affects oil well production  
Fantasy: no wax on downhole string |
|---|---|
| 2. Why the fantasy part can't be realized? | The nature of crude oil leads to wellbore wax deposition |
| 3. Under what conditions can the fantasy part become reality? | Crude oil wax cannot be separated out or does not adhere to the pipe wall after precipitation |
| 4. List the available resources in subsystem, system and super system | Downhole string, high temperature steam truck, sucker rod, mechanical energy, electrical energy, thermal energy and gravity |
| 5. From the perspective of available resources, put forward a possible solution to the problem | Use the electric heat flow effect to remove wax, and use the scraper and weighting rod to cooperate with gravity to remove wax |

3.7 TRIZ tool—STC algorithm[2]

Table 5. STC algorithm

| 1. Imagine the solution of infinite size (S∞) of the research object | The wellbore diameter is infinite and wax removal is carried out by large mechanical equipment |
|---|---|
| 2. Imagine the solution of infinitesimal size (S0) of the research object | Propose to remove wax from the surface outside the well |
| 3. imagine the solution of infinitesimal (T∞) of working process time or object movement speed | The downhole string shall be made of wax-free material |
| 4. imagine the working process of time or object movement speed infinity (T0) solution thinking | Downhole string has been electrified heating to prevent wax precipitation and adhesion |
| 5. imagine that the cost of expenditure (allowable expenditure) is infinite (C∞) | Improve the temperature of wellbore produced fluid |
| 6. imagine that the cost of expenditure (allowable expenditure) is infinitesimal (C0) the solution | Put a low-cost wax scraper into the wellbore and then flow out automatically with the produced fluid |

According to STC operator, we put forward five technical schemes: removing the downhole string and removing the wax; using the non wax material to avoid the wax adhesion; improving the temperature of the produced fluid in the wellbore to prevent the wax precipitation; the downhole string has been electrified and heated; putting the paraffin scraper into the wellbore and scraping the wax by gravity, and flowing out with the produced fluid after scraping the wax.

3.8 Using TRIZ method to solve problem-Matter-Field Model[2]
According to the matter field model, we put forward two technical schemes, which are electrifying the paraffin scraper, electric paraffin cleaning and mechanical paraffin scraping at the same time, adding self-heating material into the paraffin scraper, putting it into the wellbore to scrape wax, and speeding up the paraffin cleaning speed.
3.9 Using TRIZ method to solve problems—Little People method[2]

According to the Lilliputian method, we put forward the technical scheme of reducing the diameter of the paraffin scraper, enlarging the diameter of the paraffin scraper after running into the bottom of the well, and using the pulling force of the winch to remove the wax.

4. Technical Route and Summary of Scheme

4.1 Technical Route[5]
Figure 8. Technical Route

4.2 Summary of Scheme

Table 6  Summary of Scheme

| Serial number | Innovation tool                           | Scheme (number) | Feasibility scheme (number) | Patent Intention (number) |
|---------------|------------------------------------------|-----------------|-----------------------------|---------------------------|
| 1             | Nine Screen diagram                      | 1               | 1                           | 1                         |
| 2             | Causal Chain analysis                    | 5               | 2                           |                           |
| 3             | Function analysis and cutting             | 3               | 3                           |                           |
| 4             | Resource analysis                        | 5               | 1                           | 1                         |
| 5             | Ultimate ideal solution                  | 5               | 1                           |                           |
| 6             | Scientific effects base                  | 1               | 1                           |                           |
| 7             | Information interaction theory           | 6               | 3                           | 1                         |
| 8             | Technical contradictions                 | 5               | 5                           | 1                         |
| 9             | Physical contradictions                  | 5               | 3                           |                           |
| 10            | Goldfish method                          | 5               | 5                           |                           |
| 11            | STC algorithm                            | 5               | 3                           |                           |
| 12            | Matter-Field model                       | 2               | 2                           |                           |
| 13            | Little People method                     | 1               | 1                           | 1                         |
| total         |                                         | 48              | 33                          | 5                         |

5. Application of achievements
We have adopted the movable leaf structure of the wax scraper to reduce the resistance in case of wax retraction when going down the well. After going down to the specified depth, the wax scraper can be removed under the action of the lifting force of the spring and winch. The overall design of the wax scraper and the weight bar is that the front section is a cone-shaped guide to minimize the downward
resistance. The three wax scraper pieces are set at 120 degree intervals, and each wax scraper piece is provided with a reverse flow slope to make the wax scraper open. In the process of lifting, the device rotates to enhance the effect of wax scraping.[4]

![Design drawing of movable leaf wax scraper](image)

**Figure 9.** Design drawing of movable leaf wax scraper

6. Conclusion
After using the paraffin scraper, the working efficiency is improved. First, the working time of single well paraffin removal is reduced, and the average working time of single well paraffin removal team is shortened by 14 minutes. The second is to extend the paraffin removal period, and the average paraffin removal period of the whole mine electric pump well is 0.77 times longer. It also reduces costs. Due to the shortening of paraffin removal time and the prolongation of paraffin removal cycle in single well, the cost is effectively saved. The whole mine can save 160000 yuan of labor cost, 5000 yuan of fuel cost and more than 30000 yuan of other costs.

This achievement won the second prize of technical innovation of the third oil production plant and the second prize of major technical innovation achievement of Daqing Oilfield Co., Ltd.

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