Practice and Understanding of Well Completion Technology Using Coiled Tubing with Preset Cable

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Abstract. Artificial life method using the submersible plunger pump is a kind of lifting technique without sucker robs. The permanent magnet linear motor in the well which is connected with the submersible plunger pump by the supporting cable is the power source of whole system to drive the pump working. The supporting cable fixed on the outside of the pipeline runs down the well along with it. There is an energy-efficient technique, but have two drawbacks that need to be solved. The supporting cable lying outside the pipeline is prone to fiction with the casing. And the clamp installed in the middle of the pipeline is not firmly fixed, resulting in the problem of up and down movement, which increases the possibility of the supporting cable damage caused by friction. In order to improve the working efficiency, and reduce the probability of friction damage in the process of operation, the field tests try to place the casing inside the tubing. Drawing on the advantages of efficient coiled tubing operation, the power and signal cables are laid in the coiled tubing wall. The problem that the submersible supporting cables are easy to be worn during the process of workover is avoided. The well completion technology of preset cable coiled tubing has been developed successfully. Three kinds of preset cable are rested inside the pipeline. They are power cable, electric heating cable and signal transmission cables. The three cable system can provide power for the downhole permanent magnet linear motor and realize the functions of electric heating and submergence depth monitoring. 2 wells were tested in the field test. The experiment shows that this technique can meet the production demand of submersible plunger pump well. But during the test, one of the two wells experienced overloading shutdowns two times. However, after the electric heating function was activated for 2 h, normal production was resumed. The conclusions of the field test show that this technique could meet the demand of production. The field test provides a reference for the popularization and application of the preset cable coiled tubing completion technology.

Keywords: Preset cable · Coiled tubing · Submersible plunger pump

The main purpose of the technical research of oil production project is to improve the development efficiency of low-yield liquid well and reduce the production capacity investment and production maintenance cost. The technological breakthrough has gone through four stages: development test, improvement, expansion and popularization. At

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present, the high efficiency lifting technology of submersible oil plunger pump is adopted to achieve the goal. Compared with the traditional pumping unit lifting technology, the main advantages of this lifting technology are: less investment, simple maintenance, low energy consumption and high system efficiency. At present, our application scale exceeds 300 wells.

The high efficiency lifting technology of submersible oil plunger pump is a rodless lifting technology. The power of the well lifting fluid comes from the downhole permanent magnet linear motor. Supporting cable can provide power to the artificial lift system. The cable goes down the well along with the oil pipe and is fixed outside the pipe by specialized clamp. The supporting cable applied to the tubing is easy to be damaged by friction with the casing, which will increase the maintenance workload. This kind of wear mainly occurs during directional well completion. In addition, the unstable fixture will also increase the possibility of cable friction damage.

The purpose of developing the preset cable coiled tubing completion technology is to improve the operation efficiency and reduce the probability of friction damage during operation. The technology was developed by taking advantage of the high efficiency of coiled tubing. The cables are laid inside the tubing to avoid the problem of cable wear during the operation. The preset cable set includes power, electric heating and signal transmission cables, which can simultaneously provide power, electric heating and submergence monitoring functions for the downhole permanent magnet linear motor. At the same time, a pressure monitoring device is installed at the wellhead. This device can monitor casing pressure changes in real time. The monitoring results can provide a detailed basis for tracking and judging the production condition of oil Wells.

1 Development of Coiled Tubing Technology

1.1 Coiled Tubing

Coiled tubing is made of low carbon alloy steel or new composite materials. The equipment has the character of good flexibility and also known as flexible tubing. A coil of coiled tubing can be thousands of meters in length. Coiled tubing generally has an outer diameter range from 0.75 to 5 inches. Commercial coiled tubing with a single drum wound has a length of more than 9,000 m [1].

1.2 System Composition

Coiled tubing equipment is mainly composed of drum, hydraulic injection head, operation room, hydraulic power system and well control device. The functions of each part are as follows (System composition is shown in Fig. 1):

(1) Drum: storage and delivery coiled tubing;
(2) Injection head: provide power for making up and breaking out coiled tubing;
(3) Operation room: staff monitor and control coiled tubing here;
(4) Power system: hydraulic power source required for operation of coiled tubing equipment;
(5) Well control device: wellhead safety device for coiled tubing with pressure operation.

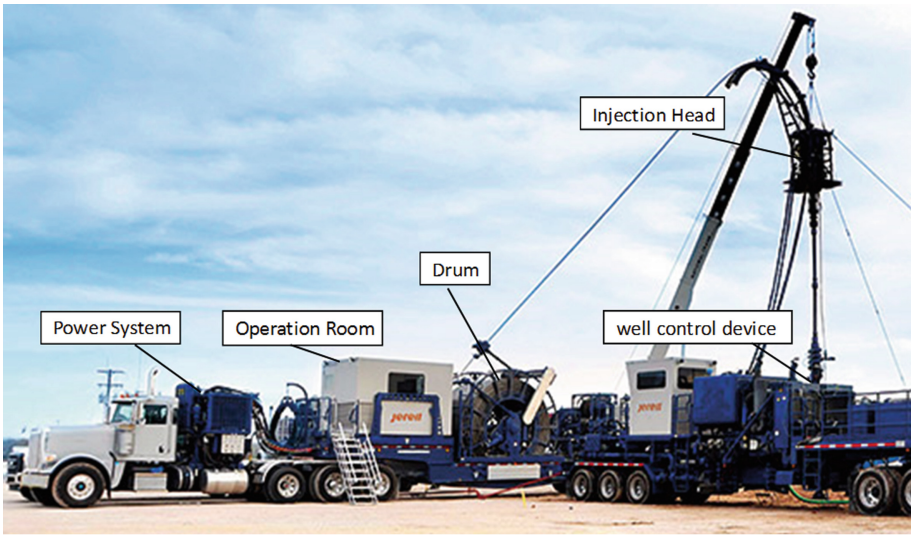

Fig. 1. Coiled tubing equipment system composition.

1.3 Workover Characteristics

Compared with conventional technique, coiled tubing technique has some technical advantages [2].

(1) Could realize operation without well killing to reduce the reservoir pollution;
(2) Could realize operation without pulling out the pipe string to protect the production tubing;
(3) Able to complete some operation that cannot be done by conventional methods;
(4) Do not need to connect the string in order to improve the operation efficiency;
(5) Could realize cost saving, simple and time-saving, safe and reliable, and widely used.

2 Preset Cable Coiled Tubing Completion Technology

The preset cable coiled tubing is made from fiber, resin and polymer. Normal service life is more than 10 yrs. The cable can realize the functions of downhole permanent magnet linear motor power, monitoring downhole temperature and pressure, and electric heating to improve the temperature of well fluid. Two Wells have been tested in the field.

2.1 Tube Structure

The preset cable coiled tubing structure consists of six layers: lining layer, annular layer, skeleton layer, inner drawing layer, outer drawing layer and protective layer.

Non-adhesive design is adopted among each layer. When the tube body is bent, this property ensures that the layers are drawn independently of each other. These functions can avoid the tube body damage caused by the different tensile rate of each layer.

(1) Lining layer: Extruded from polymer material. The inner surface is smooth and flat. This layer is directly contacted with the oil flow;
(2) Circumferential layer: Placed outside the lining layer. It is formed by fiber and resin composite winding;
(3) Skeleton layer: Formed by fiber and resin composite winding, which is located outside the annular layer;
(4) Inner drawing layer: Formed by composite winding of fiber and resin. The power cable and electric heating cable are embedded in the outer drawing layer;
(5) Outer drawing layer: Made of fiber and resin composite winding. The signal transmission cable is embedded in the tensile layer;
(6) Protective layer: Compound after extruding from polymer material, and could protect the tube.

2.2 Preset Cable Structure

Three kinds of power, electric heating and signal transmission cables, adopting spiral wiring which can avoid damage of cable by tube extension deformation, are built inside the pipe wall.

The cross section of power cable is a rectangle with rounded corners. The cross-sectional area is 15 mm^2. The maximum resistance is 1.2 Ω/km at the temperature of 20 °C. The power cable adopts two-layer combination insulation design. The inside layer is the insulating paint layer and the outside layer is the polytetrafluoroethylene sheath layer. Composite insulation layer thickness is not less than 0.8 mm.The insulation layer is sintered together with the conductor for durability. The working voltage is no more than 1140 V, which can meet the working demand of 40–50 kW equipment. The production meets the needs of our factory's submersible plunger pump wells.

The electric heating cable is arranged in the whole tube, the working voltage is less than or equal to 400 V, and the normal production voltage is 380 V. The design heating power is 40 W/m. The length of the cable applied in the field is 1250 m and the total heating power is 50 kW.

The signal transmission cable is connected to the downhole pressure gauge, which is installed on the pump to obtain temperature and pressure data. Pressure data can reflect the degree of submergence, so that managers can master the production capacity of the well in detail, adjust the production parameters in time, and give play to the best production capacity of the well.

2.3 Specifications

Preset cable coiled tubing has a variety of specifications to meet the needs of different production environments, the specific specifications are shown in Table 1. The minimum wall thickness of the reinforcement layer in Table 3 meets the requirements of the operating temperature below 70 °C. When the operating temperature is higher than

Table 1. Specification and model of preset cable coiled tubing.

Nominal pressure MPa	Inside nominal diameter	Lining minimum wall thickness mm	Inside diameter deviation mm	Enhancement layer minimum wall thickness mm	Minimum wall thickness of protection layer mm	Pipe diameter mm	Minimum bend radius mm
25	DN40	4	−1.0 ~ + 0.5	11	3	76	900
	DN50	4	−1.0 ~ + 0.5	12	3	88	900
	DN62	4	−1.0 ~ + 0.5	14	3	107	1100
	DN80	4	−1.0 ~ + 0.5	16	3	126	1340
32	DN40	4	−1.0 ~ + 0.5	13	3	80	940
	DN50	4	−1.0 ~ + 0.5	15	3	94	960
	DN62	4	−1.0 ~ + 0.5	16	3	111	1150
	DN80	4	−1.0 ~ + 0.5	19	3	132	1400

Table 2. Enhancement layer minimum wall thickness temperature coefficient.

Temperature (t), °C	$70 < t \leq 80$	$80 < t \leq 90$	$90 < t \leq 95$
Temperature coefficient	1.11	1.25	1.35

70 °C, the minimum wall thickness of the reinforcement layer is the dimension in Table 1 multiplied by the temperature coefficient in Table 2. Our test use the specifications for the size of DN40, 25 MPa pressure, temperature 85 °C .

3 Field Test and Understanding

3.1 Field Text

The first test well opened in November 2017. During production, the well suffered two times of overload shutdowns. For the first time, the well ran up after 2 h' electric heating. And then resumed normal production after the next 2 h' heating. For the second shutdown, 2 h heating directly resumed the normal production after the well ran up. Now, the upstream current is 22 A and the downstream current is 3 A, and the well runs smoothly.

The second test well opened in September 2018. This well located in the same platform well to the first well and shared the same electric heating control box and saved one set of equipment. The drawback is that these two cannot be heated at the same time. The well is equipped with a jacketed pressure monitoring sensor at the wellhead. The sensor could help to obtain casing pressure data. True submergence can be obtained by calculating the difference between wellhead sleeve pressure and downhole pressure. These real data can accurately guide field management. At present, the upstream current is 25 A and the downstream current is 5 A, and the well runs smoothly.

3.2 Field Test Understanding

Field tests show that the preset coiled tubing completion technology can meet the production requirements of submersible plunger pump Wells. The electric heating function can effectively solve the problems caused by overload and wax blockage, and avoid the long- time well closed. The advantages and disadvantages of the completion technique are as follows:

Advantages:

(1) Continuous operation to improve operation efficiency;
(2) The preset cable inside pipe can avoid the problem of cable wear in the process of operation;
(3) The electric heating function can solve the problem of overload stop well;
(4) The downhole pressure, temperature and wellhead casing pressure data can be obtained to facilitate the guidance of production management.

Disadvantages:

(1) the cost of preset cable coiled tubing equipment is relatively high;
(2) the operation equipment is larger than conventional equipment, which has high requirements on the well path and well site;
(3) It is unable to operate in winter.

Greatly reducing the cost of preset cable coiled tubing and minifying the auxiliary equipment are the future development direction and the basis for large-scale application of the technology.

4 Conclusion and Understanding

(1) This technology avoids the problem of submersible cable wear in the process of operation. It has a variety of specifications and models which can meet the production requirements of submersible oil plunger pump Wells.
(2) Power, electric heating and signal transmission cables are preset inside pipes. At the same time, electric heating and submergence monitoring functions are both realized, which is convenient to guide production management.
(3) The preset cable coiled tubing completion technology has initially achieved the goal, but the equipment durability needs to be further tracked.
(4) This technology has the disadvantages of higher cost and larger operating equipment, which requires higher requirements on well site and well access. These defects limit its application scope.

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