RESEARCH AND APPLICATION ON INJECTION-PRODUCTION INTEGRATION TECHNOLOGY OF ESP FOR OFFSHORE HEAVY OIL THERMAL RECOVERY

by

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Combined with the requirements of offshore marginal oilfield/non-work over rig platform, the injection-production integration technology of electric pump is constructed by developing the Christmas tree of electric pump, wellhead cable and control pipe-line crossing device, production packer and safety joint. Indoor and field tests show that the test results show that the injection-production integrated supporting tool of cast-fishing electric pump has a temperature resistance of 180 °C and a pressure resistance of 21 MPa, which meets the needs of marginal oilfield/non-work over rig platform, shortens the operation cycle, reduces the operation cost, and has a high promotion and application prospect.

Key words: *heavy oil thermal recovery, cast fishing electric pump, production packer, injection-production integration*

Introduction

During the 14th five-year plan period, heavy oil entered the stage of large-scale development. Thermal recovery of heavy oil is the main technical means at present [1, 2]. In 2019, the integrated technology of jet pump injection and production was successfully tested in a certain offshore block, which reduced the direct operation cost by 81% and saved the operation time by 82% [3]. In July 2023, the injection-production integration technology of high temperature electric pump was successfully applied on the sea. What further proved the injection-production integration technology is the key core factor to realize the effective development of heavy oil [4, 5].

Zhongyuan Oilfield and CNOOC Zhanjiang Branch have developed an injection-production integration technology that can realize conventional pump inspection through coiled tubing operation without moving the string, and completed field application [6, 7]. To this end, the author's team has developed an integrated injection-production technology of offshore heavy oil thermal recovery pump for offshore unmanned platform/workover rig platform through technical research.

Engineering philosophy

Pipe string composition

The injection-production integrated string of the electric pump is composed of a heat pipe string and a fishing string.

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The injection heat pipe column (from bottom to top) is composed of the circular plugging, the injection allocation valves, the variable buckle, the high temperature deep well packer, the downhole safety device and the large size heat insulation tubing, as shown in fig. 1(a). The inner pipe string (from bottom to top) is composed of the electric pump unit, the production packer, the safety joint and the continuous pipe cable, as shown in fig. 1(b).

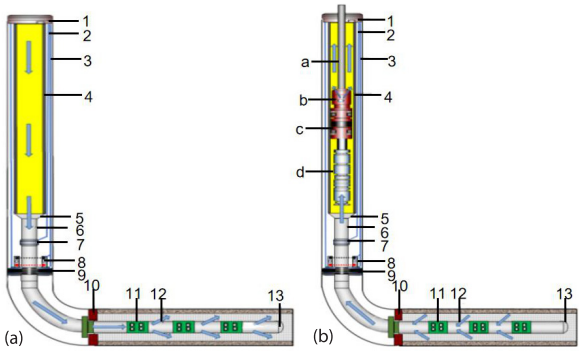

Figure 1. Schematic diagram of pipe string:
1 – mandrel hanger, 2 – hydraulic pipe-line,
3 – hydraulic pipe-line, 4 –large size insulated tubing,
5 – change buckle, 6 – ordinary tubing, 7 – subsurface safety valve,
8 – tubing joint, 9 – high temperature deep well packer,
10 – top packer, 11 – injection valve, 12 – oil line,
13 – round block, a – continuous pipe cable, b – safety joint,
c – production packer, and d – electric pump unit.

Process pipe-line principle

Before steam injection, the heat pipe string is run down, and the steam is injected into the bottom of the well through the large-size insulated tubing, as shown in fig. 1(a).

After the end of the heat injection, the electric pump unit, the production packer and the safety joint are carried down through the coiled tubing cable, as shown in fig.1(b).

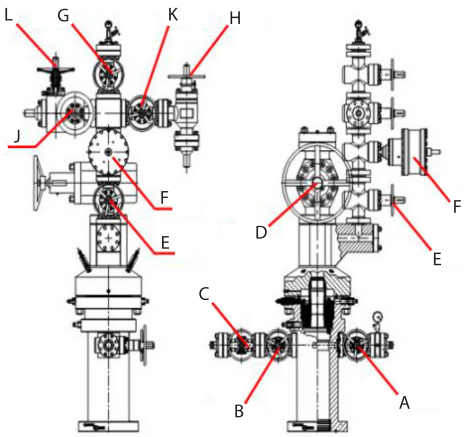

Figure 2. Structure diagram of fishing electric pump oil production tree

Key technology

Fishing electric pump oil production tree

Basic structure

Throwing and fishing electric pump oil production tree is mainly composed of the main valve, the paraffin removal valve, the ground safety valve, the tubing four-way left wing, and the tubing four-way right wing.

Principle of operation

As shown in fig. 2, during heat injection, A, B, C, E, F, J, L, and G valves are opened and D, K and H valves are closed. When the soak is well, A, E, F, and G are opened and B, C, D, L, J, K, and H valves are closed. When the heat injection is blowing out, A, E, F, K, H and G are opened and B, C,

D, L, and J valves are closed. During the production, A, E, F, K, H, and G valves are opened and B, C, D, Lm and J valves are closed.

Wellhead cable and control pipe-line crossing device

Basic structure

The wellhead cable and control pipe-line crossing device are shown in fig. 3, which is mainly composed of outer cylinder and inner sealing crossing. The outer cylinder mainly includes the main body of the outer cylinder, the outer cylinder cap and the pressure test hole.

Principle of operation

The wellhead cable and the control pipe-line crossing device are mainly used for the crossing sealing of the cable and the hydraulic control pipe-line. When the coiled tubing cable carries the electric pump unit to the specified position, the cable is cut off, and the cable and the hydraulic control pipe-line inside the coiled tubing cable are peeled off. Two hydraulic control pipe-lines are pierced out from the hydraulic control pipe-line crossing hole on the side of the internal sealing crossing device, and three cable cores are pierced out from the main channel above.

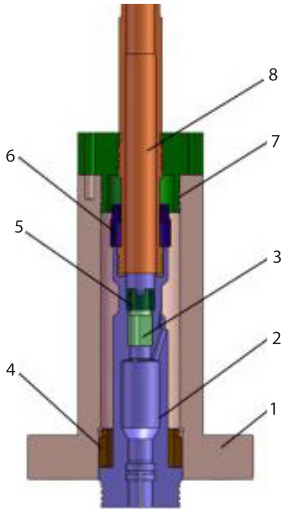

Figure 3. Structure diagram of wellhead cable and control pipe-line crossing device: *1 – barrel, 2 – internal sealed traversing device, 3 – cable seal, 4 – briquetting, 5 – sealing cap, 6 – adapter pressure block, 7– jacket cap, and 8 – adapter*

Production packer

Basic structure

The production packer is a kind of high temperature resistant cable crossing packer, which adopts hydraulic control pipe-line setting, hydraulic control pipe-line unsealing, and the main shaft has a conversion channel. The structure is shown in fig. 4.

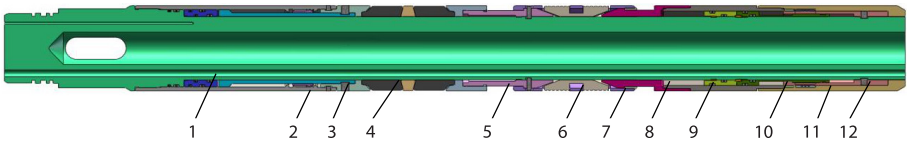

Figure 4. Production packer structure diagram: *1– mainshaft, 2 – sealed piston cylinder, 3 – sealing piston, 4 – lock tooth sleeve, 5 – rubber cylinder cap, 6 – rubber cylinder, 7 – upper cone, 8 – kava, 9 – lower cone, 10 – unsealing piston cylinder, 11 – unsealing piston, and 12– unsealing sleeve*

Principle of operation

Packer setting. The hydraulic pipe-line in the coiled tubing is pressurized, the setting shear nail is cut off, the upper cone goes down, the supporting slip is anchored to the casing, and the pressure continues to be pressurized. The piston pushes the rubber cylinder down, and the locking device locks the rubber cylinder.

Hydraulic deblocking. The hydraulic pressure is added from the hydraulic pipe-line, and the hydraulic pressure is transmitted to the packer through the pipe-line. The setting shear nail is cut off, the setting piston moves down, the lock block is released, the deblocking is realized, and the packer is directly lifted.

Laboratory test

Production packer indoor test

Cold test

The normal temperature test is carried out on the ground. The schematic diagram of the normal temperature test of the production packer is shown in fig. 5.

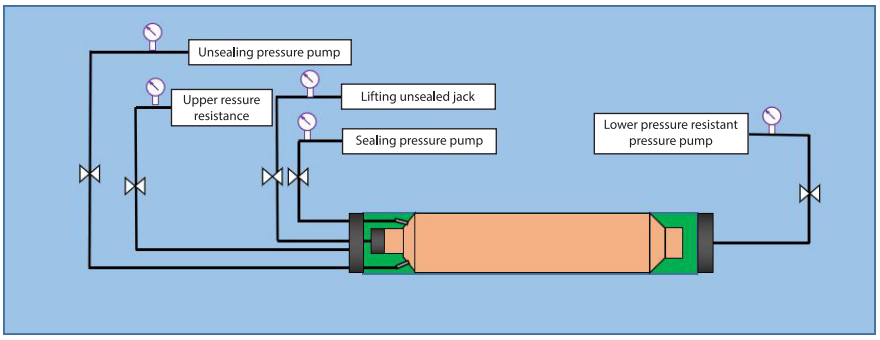

Figure 5. Production packer normal temperature test schematic diagram

In the test, the hydraulic control setting pressure of the packer is 3190-3500 psi, the upper pressure resistance is 3096-3161 psi, the lower pressure resistance is 3010-3061 psi, the hydraulic control release pressure is 2645-2610 psi, and the lifting and releasing force is 5000-5032 psi. The pressure drop is less than 1% at each stage for 15 minutes, which meets the design requirements.

High temperature test

The high temperature test was carried out in the heating tooling. The schematic diagram of the high temperature test of the production packer is shown in fig. 6.

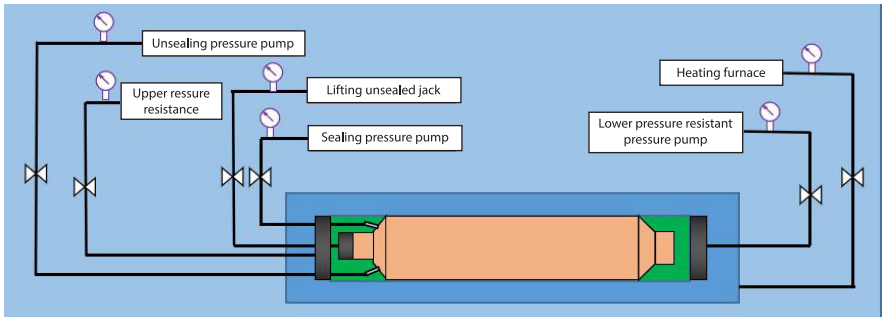

Figure 6. Production packer high temperature test schematic diagram

In the test, the hydraulic control setting pressure of the packer is 3190-3360 psi, the upper pressure resistance is 3012-3020 psi, the lower pressure resistance is 3014-3027 psi, the hydraulic control unsealing pressure is 2175-2276 psi, and the lifting and unsealing force is 4682-4714 psi. The pressure drop is less than 1% at each stage for 15 minutes, which meets the design requirements.

Sea test

From August 2023 to April 2024, the technology was tested in an oil well in a block of offshore oilfield. During the implementation of the injection-production integration technol-

ogy, it has gone through the stages of running heat injection string, heat injection, well soaking, blowout, running fishing string and starting pump production.

Compared with the injection-production two-time technology, the injection-production integration technology of cast-fishing electric pump reduces the direct operation cost by 78% and saves the operation time by 85%. Compared with the injection-production integration of jet pump/high temperature electric pump, there is no need to use the work over rig, and the direct operation cost can be reduced by 2 million per round.

Conclusion

The integrated technology of injection and production of coiled tubing and cable throwing and fishing electric pump realizes one trip of string to meet the needs of two processes of heat injection and production. The electric pump is lifted and lowered by coiled tubing and cable, and no work over rig operation is needed. It can be applied to heavy oil thermal recovery development without unmanned platform/work over rig platform. In the process of heat injection conversion, the technology does not need to move the string operation, which improves the heat injection effect. In the process of electric pump running in and out, there is no need for work over rig operation. The single maintenance pump can reduce the direct operation cost by 2 million, which reduces the cost of heavy oil development. The offshore test marks the first successful test of the injection-production integration technology of coiled tubing and cable cast-fishing electric pump. It is suggested that in the future, it should be promoted and tested on offshore platforms, especially in marginal/non-work over rig oilfields, so as to further improve the technology and promote the large-scale development of heavy oil.

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