Study and Application of quickly putting into Production Technology without well killing in Shale Oil

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Abstract. Low-producing shale oil wells are put into production after reservoir modification. But the dynamic fluid level drops significantly in the initial stage, which result in a reduction in sand carrying capacity and a significant reduction in pumping efficiency. It also results in a significant shortening of the pumping inspection cycle. After the checking pump operation with conventional killing well, wells were found that the capacity recovery period was long. And the period of operating under pressure was long and costly. Checking pump cost increased significantly. Based on the situation of low-producing shale oil wells in the DA oilfield, by optimizing the downhole temporary plugging of the tubular column and simulating the timing of down pump, a quickly put into production technology of rod pump in shale oil is proposed. The technology can achieve downhole temporary plugging fast before checking pump, and lift out or lower pump without killing well. The field application shows that this technology can reduce the contamination of tight reservoirs result by killing fluid and significantly shorten the production recovery cycle.

1. Preface
The oil formation in the main area of shale oil exploration and development in the DA oilfield is buried at a depth of 3,700-4,200m, with a porosity of 0.57-5.1%, a permeability of 0.02-0.65md, a pressure coefficient of 0.93-1.34 and a geothermal gradient of 2.88-3.12, which is a normal pressure and temperature formation. The formation fluid shows the one low and four high characteristics of low viscosity, high specific gravity, high freezing point and high wax content. The internal diameter of the oil casing is Φ114.3mm. 18 wells have been put into production, including 6 horizontal wells, 2 large-slope wells and 10 straight wells, all of which are pumped with a rod pumping process.

2. Problems and analysis
With the current development and production situation, the following difficulties mainly exist.

2.1. Increasing times of changing pump operation resulted by rapid and large drop in liquid production and dynamic liquid level
The average daily production volume at the initial stage is 34.3 m³/d, with a decline rate as high as 53.2% in the first month; the dynamic liquid surface is deep, with an average dynamic liquid surface depth of 1,746 m. The liquid volume varies greatly and decreases rapidly, and pumping operations are carried out according to the changes in the liquid supply volume of the formation after production, resulting in an increase in the frequency of pump inspections.
2.2. Small production casing size
The production casing is small size casing with an internal diameter of Φ114.3mm, which requires a small entry tool size.

2.3. High frequency of minor repairs and short pump inspection cycle
The permeability of the developed formation is 0.02-0.65md, oil formation with this kind of permeability has no natural production capacity and requires reservoir modification before it can be put into production. After large-scale fracturing, the fracture sand returns to the wellbore, resulting in a rod pump jam or formation sand burial which requires pump check operations. The temperature analysis reveals (see Figure 1) that large-scale fracturing causes the formation temperature field to drop. The temperature decrease of wellbore fluid make the crude oil less fluid and the lateral force to increase, which exacerbate the rod and tube bias grinding. And the serious rod and tube bias grinding leads to a shorter pump check cycle too.

2.4. Long capacity recovery period after killing well operation
At present, rod pumping wells with conventional operations down pumping. Ultra-low pore permeability reservoirs require high reservoir protection. Workover fluid contamination of the formation increases the risk of formation damage and result in long capacity recovery period. Workover cost is increasing. The ground is equipped with an oil well pressure device to meet the needs of the down pumping without killing well during the process of pumping down the well. However, the operation under pressure period is 1.5-2 times longer than the conventional operation period and costs are higher. And later maintenance operations need to continue using operation under pressure; otherwise the killing well fluid will contaminate the oil formation and increase workover costs. Frequent pump checks result in higher operating costs and longer recovery periods with reservoir damage.

3. Optimizations for quickly put into production technology of rod pump in shale oil

3.1. Process scheme and technical characteristics
First, the sealing tool is lowered with a continuous oil pipe. Pressure-operated switching valve is connected under the sealing tool (Figure 2). Second, the pressure-operated switch valve is used to seal off the production formation by means of pressure control, through which well operation without killing well could be achieved. Three, to achieve production, the pressure-operated switch valve is opened by pressure to make wellbore communicate with the formation [2-5].

![Figure 1 Temperature field Change in wellbore before and after Fracturing.](image1)

![Figure 2 Schematic diagram of the temporary plugged tubular column.](image2)
Down the bridge plug: In shale oil wells that have stopped natural flowing or where the natural flowing potential is low after fracturing, a releasing bridge plug with a pressure-operated switch is lowered into the bottom with coil tubing. Add pressure to seat seal bridge plug and disconnect from the pipe column. Open the casing valve to observe the overflow. No overflow display indicates that the bridge plug seating seal is good, otherwise it is not. Close the casing valve. Add pressure to tubing to open the switch. If there is overflow display, pressure-operated switch valve is opened normally, otherwise it is not. Add pressure to tubing again to close the switch. If there is no overflow display, pressure-operated switch valve is closed normally, otherwise it is not.

Down pump: Finish pumping down the tubular column, install the oil recovery tree, turn on the pressure-operated switch and start pumping production.

Lift out of pump: If you need to lift out the downhole pump, turn off the pressure-operated switch to seal the formation temporarily. Then wash the well and lift out the downhole pump.

Technical characteristic: pressure-controlled mode, simple operation, high safety, repeatable opening and closing of the bridge plug, lifting out and lowering the pump without killing well, no contamination of the formation, rapid recovery of production capacity; no killing well for later maintenance operations, operating costs reduced. The single operation cycle is short and production is fast.

3.2. Matching tools selected

The working principle of the pressure-operated switch: the device goes down with the oil pipe and is closed default. When the wellhead is added pressure, the piston pushes the bearing seat and pin upwards and compresses the spring, the shaft pin is pressed to the top of the replacement rail. After the pressure is released, the shaft pin short track slots, the piston retract but have a short stroke, the central pipe inlet hole and the outer hole are connected and the switcher opens. If you want to close the switcher later, repeat the operation, the piston pushes the bearing seat and pin upwards and compresses the spring, the shaft pin short track slots, the piston retract but have a short stroke, the central pipe inlet hole and the outer hole are connected and the switcher opens. If you want to close the switcher later, repeat the operation, the piston pushes the bearing seat and pin upwards and compresses the spring, the shaft pin long track slots, the switcher can be closed by fully returning the sliding piston (cyclic operation).

Pressure-operated switch performance technical parameters: maximum outer diameter: Д106mm, maximum inner diameter: Д35mm, length: 1144mm, track change switch pressure: 17MPa, outlet orifice diameter: 30mm (600 m3/d), working differential pressure: 70MPa, working temperature: 150°C.

3.3. Optimization of sand stopper, pumping time and pump parameters

After large-scale fracturing, the fracturing sand returned and caused the rod pump to get stuck or the formation be buried by the sand, so the daily fluid production of a single well needs to be greater than the critical sand-carrying flow rate as much as possible. According to the experimental results of the
"Study on sand-carrying rule in vertical wellbore" [6], the diameter of the fracture sand returned is 0.16-0.6mm, and the free settling speed of the proppant in this well should be 0.053m /s for 114.3mm ID casing, so the daily fluid production rate should more than 23m³/d to carry the frac sand to the surface effectively. Analysis of the situation in the shale wells that have been put into produce shows that within 1 month after pumping, daily fluid production is reduced to 20m³/d or less, which is not sufficient to carry the back-spit fracture sand out of the wellbore. A sand stopper was added to the releasing bridge plug to prevent the sand from settling and affecting the normal closure or opening of the pressure-operated switch (Figure 5).

According to the calculation of fluid production, the design of φ38mm pump or φ44mm pump can meet the requirements of fluid volume (table 2). And choose small pumps for deep pumping as far as possible to maximize the production capacity of the oil formation, which also avoid the operation to deepen the pump later.

| Pump diameter (mm) | Stroke (m) | Stroke times (min⁻¹) | Flow range m³/d | Max. depth (m) |
|-------------------|-----------|----------------------|----------------|---------------|
| 38                | 6         | 2/3/4/5              | 13.8, 20.6, 27.4, 34.3 | 3540          |
| 44                | 6         | 2/3/4/5              | 18.4, 27.6, 36.8, 46.0 | 2836          |
| 57                | 6         | 2/3/4/5              | 30.9, 46.3, 61.7, 77.1 | 2106          |

Analysis of the production characteristics and production data change rules of the eight wells that have been pumped into production since the natural flowing period. Simulation of daily fluid production, daily oil production and water content change rules under different pumping timing conditions, analysis show that the production pressure difference is stable, the wellhead pressure is below 2MPa and daily fluid production is below 20m³/d, it is recommended to down the pump to produce(Figure 6).

4. On-site applications
Ye 3-1Z and Ye 3-2Z well were put into produce with quick putting into production technology of rod pump. Ye 3-1Z operation brief is as follows: connect tools, ground pressure test → tool put into well,
seating bridge plug → observe overflow (open casing valve, observe overflow for 25min, no overflow indication, indicating good seating of bridge plug.) → pressure-operated bridge plug switch verification (add pressure 18MPa to open pressure-operated switch, observe 20min, there is overflow display, pressure–operated switch valve is open normal. add pressure 18MPa again to close the pressure–operated switch, observe 30min no overflow, switch valve closed.) →lower pump →open the pressure–operated switch →commissioning.

Using coil tubing to down the well shut-in tubing column, add pressure to seating and release the dropping hand. The wellbore was sealing temporary in 3 hours precise. The two wells were produced with Φ38mm pump and Φ44mm pump respectively. The pressure-operated switch was turned on and the wells were put into production within 3 days.

Table 3 Capacity recovery cycles for both processes.

| Method                               | Well   | Production date | Stroke/ stroke times | Pump diameters (mm) | Pump depth (m) | Daily rate (T) | Recovery cycle (d) |
|--------------------------------------|--------|-----------------|----------------------|--------------------|----------------|----------------|-------------------|
| quickly put into production technology | Ye3-1Z | 2020.05.03      | 6m/2.2times/min      | 38                 | 2500           | 1.35           | 1                 |
|                                      | Ye 3-2Z| 2020.05.05      | 6m/2.2times/min      | 44                 | 2200           | 1.96           | 1.5               |
| killing well and lower pump          | Ye 24  | 2020.01.25      | 6m/2.2times/min      | 38                 | 3300           | /              | jam by sand       |
|                                      | Ye 1801| 2020.01.16      | 6m/2.2times/min      | 38                 | 2700           | 1.5            | 19                |
|                                      | Ye 32-62| 2020.03.16     | 6m/2.2times/min      | 44                 | 2201           | 1.8            | 15                |

Compared with the operation under pressure, the process of "drilling bridge plugs, changing wellheads - installing pressure devices - salvaging bridge plugs, releasing pressure - removing pressure devices" is eliminated, which is expected to save 3 days of operation cycle based on 4000m well depth.
The application of Ye 3-1Z and Ye 3-2Z shows that the quickly put into production technology can achieve rapid production and a short recovery period after workover operation. Recovery cycle of which is 14 to 17 days shorter than that of conventional killing well operation.

5. Conclusion

5.1 The quick putting into production technology of rod pumps achieves rapid production in shale oil well operations. The technology does not contaminate the reservoir, reduces operating costs, improves operating efficiency; reduce the waiting period for well repair.

5.2 Field application results show that it can significantly shorten the production recovery cycle and prevent contamination of extra-low-permeability reservoirs compared to conventional pressure pumping. It also saves operating time by eliminating several procedures compared to operation under pressure.

5.3 It can be evaluated in accordance with the economic and technical indicators of the comprehensive evaluation of lifting methods to maximize the economic benefits of crude oil production, and has far-reaching guidance significance for the sustainable and stable economic development of extra-low-permeability and low-production reservoirs.

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