Journal of Innovation and Development
ISSN: 2958-4752 | Vol. 13, No. 3, 2025

Development and Practical Application of Pressure-Drive Water Injection String

Cong Wang

Research Institute of Petroleum Engineering, Shengli Oilfield Company, SINOPEC, Dongying, Shandong, 257000, China

Abstract: To address the challenge of "difficulty in water injection and oil production" in low-permeability reservoirs, Shengli Oilfield has developed three pressure-drive water injection development modes--"advanced pressure drive, three-dimensional pressure drive, and differential pressure drive" through continuous research, practice, and iterative upgrades. As a key carrier for technical implementation, the pressure-drive water injection string has formed a supporting model dominated by "multi-cycle zonal pressure-drive string and integrated pressure-drive water injection string". The technical indicators are: applicable casing size 4½in-7in; working pressure difference ≤50MPa; working temperature ≤150℃. By the end of 2023, a total of 107 well applications have been implemented with a sealing efficiency of 92.7%. Among them, the multi-cycle zonal pressure-drive string has been applied in 62 wells, with a maximum water injection pressure of 47MPa, a maximum formation temperature of 150℃, and a maximum injection rate of 1800m³/d. The integrated pressure-drive water injection string has been applied in 45 wells, with a maximum water injection pressure of 49MPa, a maximum formation temperature of 148℃, and a maximum injection rate of 2800m³/d.

Keywords: Pressure-drive Water Injection; Zonal Pressure Drive; String; Packer; Shengli Oilfield.

1. Introduction

The developed geological reserves of low-permeability reservoirs in Shengli Oilfield are 9.4×10^8 t, with undeveloped reserves of 2.1×10^8 t, showing great development potential [1]. With the advancement of exploration technology, the proportion of low-permeability reservoir reserves in the proven petroleum geological reserves has been increasing year by year [2, 3]. The low-permeability reservoirs in Shengli Oilfield are characterized by great burial depth (51% of reserves are in reservoirs deeper than 3000m), low abundance (58% of reserves have an abundance of less than 100×10^4 t/km²), and poor physical properties (48% of reserves have a permeability of less than 10 mD). During water injection development, the average daily water injection per well is low (51.1% of water wells have an injection rate below 20 t/d), and the average daily liquid production per well is small (51.0% of oil wells have a liquid production rate below 5 t/d), resulting in the problem of "difficulty in water injection and oil production" [4,5].

To solve this problem, since 2020, Shengli Oilfield has drawn on Daqing Oilfield's large-volume water injection huff and puff technology, and developed three pressure-drive water injection development modes—"advanced pressure drive, three-dimensional pressure drive, and differential pressure drive"—through continuous research, practice, and iterative upgrades [2]. As a key carrier for technical implementation, the pressure-drive water injection string has higher requirements compared with conventional water injection strings: (1) Continuous reliability under high-temperature (150℃) and high-pressure (50MPa) conditions; (2) Meeting the needs of multi-cycle pressure drive and conversion to conventional water injection after pressure drive. Through continuous research and practice, a supporting model of zonal pressure-drive strings dominated by "multi-cycle zonal pressure-drive string and integrated pressure-drive water injection string" has been gradually formed.

2. String Structure and Principle

At present, there are two main types of pressure-drive water injection strings in Shengli Oilfield (see Figure 1): The multi-cycle zonal pressure-drive string, shown in Figure 1a, is mainly composed of a pressure relief sliding sleeve, pressure-drive packer, pressure-drive injector, constant-pressure water distributor, and bottom screen plug, and is used for zonal pressure drive of 2-4 layers. The integrated pressure-drive water injection string, shown in Figure 1b, is mainly composed of a pressure relief sliding sleeve, pressure-drive packer, integrated pressure-drive water injection distributor, constant-pressure water distributor, and bottom screen plug, and is mainly used for zonal pressure drive and zonal water injection of 2 layers.

Principle: Multi-cycle zonal pressure-drive string: Its main feature is realizing layer switching by fishing and running sealing rods. Taking Figure 1a as an example: The string is run into the well → The pressure-drive packer is set → The constant-pressure water distributor is opened to conduct pressure drive on the lower layer; The corresponding pressure-drive sealing rod (matching the pressure-drive injector) is run in: The lower layer is closed and the upper layer is opened; Pressure drive is conducted on the upper layer → The sealing rod is fished out: The upper layer is closed and the lower layer is subjected to pressure drive... Thus, the demand for multi-cycle zonal pressure-drive injection is realized.

Integrated pressure-drive water injection string: Its main feature is realizing zonal pressure drive and zonal water injection with one trip of string. Taking Figure 1b as an example: The string is run into the well → The pressure-drive packer is set → The constant-pressure water distributor is opened to conduct pressure drive on the lower layer → A ball (matching the integrated pressure-drive water injection distributor) is run in: The lower layer is closed and the upper layer is opened → After the pressure drive of 2 layers is completed, a tool is run in to open the integrated pressure-

drive water injection distributor (closed), so as to realize conventional water injection of 2 layers. During the later string pulling operation, a ball is run in and the pressure is increased to open the pressure relief sliding sleeve, realizing communication between the tubing and casing.

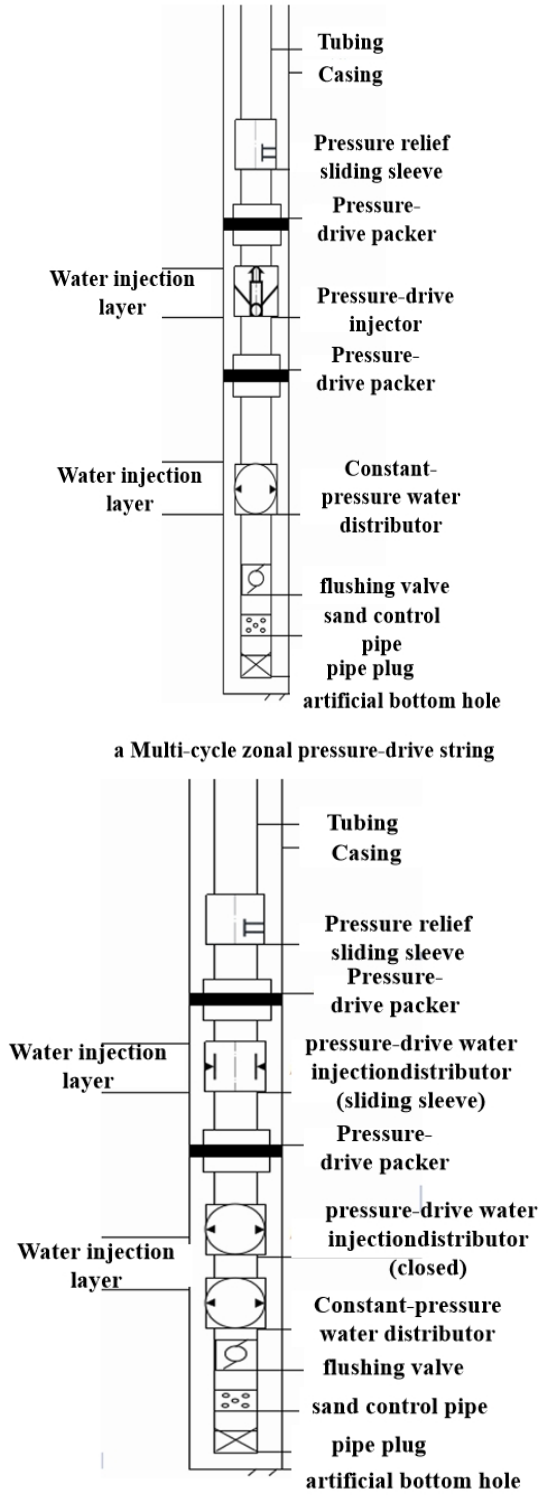


Fig 1. Structure diagram of zonal pressure-drive string

3. Main Supporting Tools

3.1. Zonal Tools

Combined with the characteristics of pressure-drive injection, the zonal tools are mainly composed of Y531 type packer, Y521 type packer, and Y541 type packer:

The Y531 packer adopts a large-channel design, ensuring the passage of fishing tools and realizing multi-layer zonal pressure drive.

Table 1. Main indicators of pressure-drive string

Item	Indicator		
Applicable casing, in	$4^1/_2$	$5^1/_2$	7
Number of zonal injection layers	2-4		
Working temperature, ℃	≤150		
Working pressure difference, MPa	≤50		
Unsetting force, kN	100-150		
Maximum outer diameter of tool, mm	92	115	150

The Y521 packer is supported by lower slips, mechanically set by the weight of the tubing, which can compensate for string expansion and contraction and reduce string creep.

The anchoring body of the Y541 packer is controlled by external pressure, effectively preventing scaling and string sticking.

Fig 2. Physical diagram of Y531 packer

3.2. Injection Tools

As shown in Figure 1, the injection tools of the zonal pressure-drive string mainly include constant-pressure water distributor, pressure-drive injector, integrated pressure-drive water injection distributor (sliding sleeve), and integrated pressure-drive water injection distributor (closed).

The constant-pressure water distributor is an injection tool of the pressure-drive string and one of the pressure-drive injection channels; meanwhile, the constant-pressure opening ensures the reliable setting of the hydraulic setting packer.

The pressure-drive injector is one of the main supporting tools of the multi-cycle zonal pressure-drive string, which is used with the sealing rod to realize injection and layer switching (see Figure 5).

The integrated pressure-drive water injection distributor (closed) is used with the integrated pressure-drive water injection distributor (sliding sleeve). The former (see Figure 6) provides the injection channel for conventional water injection after pressure drive, and is always in the closed state during pressure drive, so that the supporting constant-pressure water distributor provides the pressure-drive injection channel. The latter (see Figure 7) provides a common channel for pressure drive and conventional water injection, and realizes layer switching by running a ball and pressing.

3.3. Others

The pressure-drive pressure relief sliding sleeve is a supporting tool of the pressure-drive string and a channel for communication between the tubing and casing during the later string pulling operation. After the pressure-drive pressure relief sliding sleeve is run into the well with the pressure-drive string, it remains sealed during tubing pressure boosting and production. Before the later string pulling operation, a ball is run into the tubing.

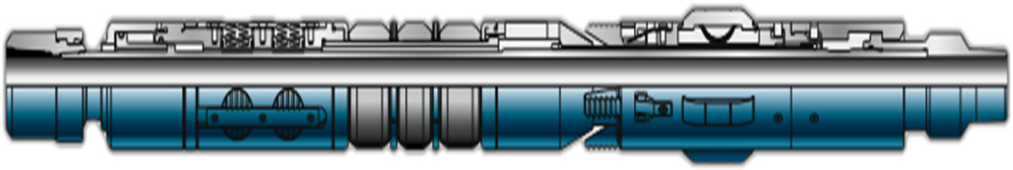


Fig 3. Schematic diagram of Y521 packer

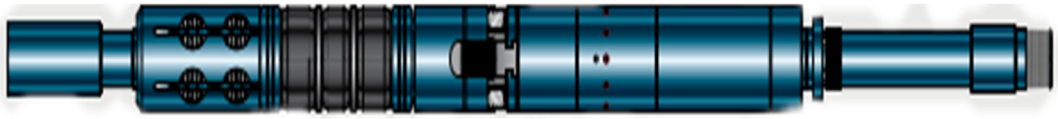
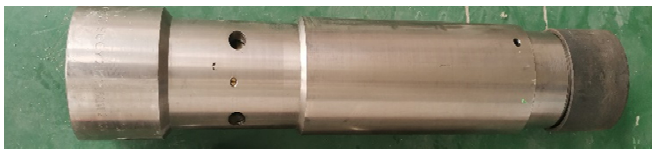


Fig 4. Schematic diagram of Y541 packer

Table 2. Main indicators of zonal packers

Item	Technical Indicator		
	Y531	Y541	Y521
Working pressure difference, MPa	50	50	50
Working temperature, ℃	120	150	150
Well deviation,°	<50	<50	<35
Setting start-up pressure difference, MPa	7-12	10 -12	-
Setting pressure difference, MPa		25-28	-
Unsetting force, kN		≤120	≤20
Setting load, kN		-	120-160



a Pressure-drive injector

b Sealing rod

Fig 5. Pressure-drive injector and sealing rod

Fig 6. Integrated pressure-drive water injection distributor (closed)

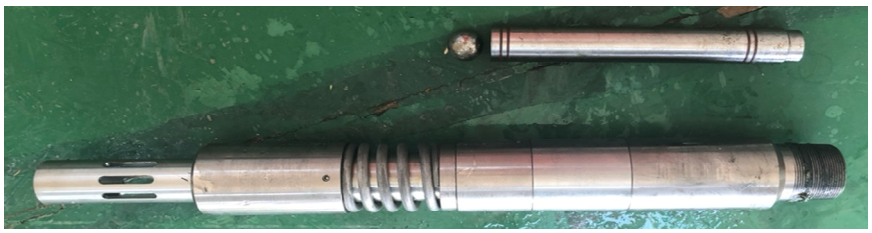


Fig 7. Integrated pressure-drive water injection distributor (sliding sleeve)

After a certain period of time, the steel ball falls into the sliding sleeve to form a seal, and the tubing is pressurized. When the pressure rises to a certain value, the shear pin is sheared, the sliding sleeve moves downward, and the water outlet hole on the main body is opened to connect the tubing and casing. For overflow wells, well killing operation can be realized. During string pulling, the liquid in the tubing can be discharged into the well to avoid blowout operation, playing a role in safety and environmental protection.

Fig 8. Physical diagram of pressure-drive pressure relief sliding sleeve

4. Field Application

By the end of 2023, a total of 107 well applications of zonal pressure-drive strings have been implemented, with a cumulative water injection of 213×10^4 m³; the sealing efficiency is 92.7%, and the layer switching success rate is 94.4%. Among them, the multi-cycle zonal pressure-drive string has been applied in 62 wells, with a maximum water injection pressure of 47MPa, a maximum formation temperature of 150℃, and a maximum injection rate of 1800m³/d. The integrated pressure-drive water injection string has been applied in 45 wells, with a maximum water injection pressure of 49MPa, a maximum formation temperature of 148℃, and a maximum injection rate of 2800m³/d.

5. Conclusion

(1) The multi-cycle zonal pressure-drive string realizes pressure-drive layer switching by fishing and running sealing rods, which can meet the multi-cycle pressure-drive injection needs of wells with 2-4 layers and casing sizes of 4½in-7in. The integrated pressure-drive water injection string realizes zonal pressure drive of 2 layers and subsequent conventional water injection with one trip of string, avoiding the problem of long well occupation cycle during the conversion between pressure drive and water injection. The technical indicators meet: working pressure ≤50MPa; working temperature ≤150℃.

(2) The existing zonal pressure-drive strings can meet the long-term pressure-drive injection needs of current reservoirs, realizing the original design intention. However, manual operation at the wellhead is still required for pressure-drive layer switching. Meanwhile, the pressure diffusion in low-permeability reservoirs is relatively slow, which poses greater challenges to various testing operations requiring tools to be run into the string.

References

[1] Yang Yong, Zhang Shiming, Cao Xiaopeng, et al. Practice and understanding of low-permeability reservoir pressure-drive development technology in Shengli Oilfield[J]. Petroleum Geology and Recovery Efficiency, 2023, 30(6): 61-71.

[2] Cao Xiaopeng, Liu Haicheng, Ren Yunpeng, et al. Progress and prospect of low-permeability reservoir development technology in Shengli Oilfield[J]. Petroleum Geology and Recovery Efficiency, 2024, 31(5): 48-55.

[3] Guo Jianchun, Lu Cong, Ma Li. Optimization and field application of pressure-drive engineering scheme for low-permeability reservoirs in Shengli Oilfield[J]. Daqing Petroleum Geology and Development, 2024, 43(4): 204-214.

[4] Sang Congyu, Wang Peng. Study on influencing factors of pressure-drive effect in low-permeability reservoirs[J]. Journal of Beijing Institute of Petrochemical Technology, 2023, 31(01): 27-32.

[5] Yang Yong, Wang Jian. Practice and understanding of pressure-drive development technology in Shengli Oilfield[J]. Petroleum Geology and Recovery Efficiency, 2023, 30(03): 87-93.