High-pressure heavy oil saturation treatment method of outcrop core based on loose sandstone heavy oil reservoirs

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Abstract. The unconsolidated sandstone heavy oil reservoir is dominated by heterogeneous elastic-plastic reservoir with complex structure. The core demand is large in the study of reservoir lithology and physical properties. Although the high-cost freezing and encapsulation processes are used in the process of coring site and indoor processing, they are still easy to damage in the process of extracting cores. Moreover, the physical parameters of ordinary artificial cores are too different from those of producing cores to obtain accurate lithology and physical parameters. So, replacing the production cores with outcrop cores may become an important method to study the physical parameters of reservoirs. In this paper, the micro-velocity displacement method and saturated heavy oil method are used to study the lithology and physical property parameters of outcrop cores. The results show that compared with those of producing cores, the rock mechanics parameters of outcrop cores after high-pressure heavy oil saturation treatment are basically consistent with those of field cores. Therefore, it can be used to replace the core to study the physical parameters of rocks in special cases.

1. Introduction

Loose sandstone heavy oil reservoirs are widely distributed in China except Sichuan Basin [1]. Therefore, this type of oil reservoir has high research value. The use of cores to study reservoir lithology, physical properties and sensitivity is currently the most commonly and effective method. Canadian workers used uniaxial and triaxial compression experiments to study the lithological characteristics of unconsolidated sandstone heavy oil reservoirs in the Lenghu and Athabasca oil fields [2]; PetroChina International used triaxial experiments to analyze the lithology of the core of the Fula oilfield in Sudan [3]; R. CK. WONG et al. used frozen core to conduct uniaxial compression experimental study on Athabasca oil field [4].

In this paper, the loose sandstone heavy oil reservoir in Xinjiang is taken as the target. The multi-function core displacement experimental device and the high-temperature and high-pressure rock comprehensive test system are used to compare and analyze the lithology and physical property parameters of the field production core, the untreated outcrop core and the outcrop core saturated by high-pressure heavy oil. The feasibility of replacing the production core with the outcrop core is explored, which provides a reliable basis for solving the problem of studying the lithology, physical property and sensitivity of the loose sandstone heavy oil reservoir without the production core.

2. On-site core physical parameter testing

2.1 Experimental equipment and materials

(1) Experimental materials: 4 rock cores of field production layer .

(2) Experimental device:

Figure 1. High-temperature and high-pressure rock comprehensive test system.

Figure 1 shows the GCTS high temperature-pressure rock comprehensive test system, which can be used for triaxial compression test, uniaxial compression test, fracture toughness test, etc. The maximum allowable confining pressure is 210 MPa, and the load measurement

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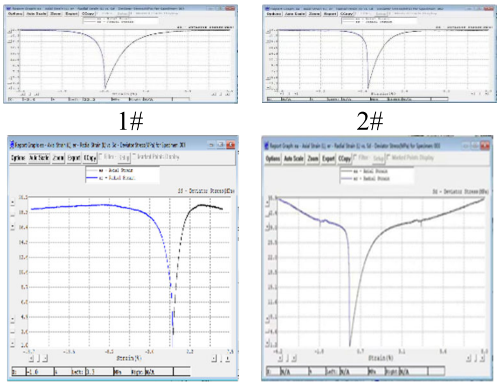
accuracy is 0.25%. It is suitable for 25, 38, 50, and 100 mm specimens, and meets the requirements of experimental conditions.

2.2 Analysis of experimental test results



1# 2# 3# 4#

Figure 2. Field core stress-strain curve.

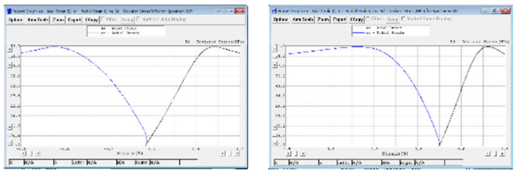
Table 1. Field test results of core physical parameters.

Core number	1#	2#	3#	4#
Confining pressure, MPa	10	10	15	20
Compressive strength, MPa	22.5	23.2	24.2	35.9
Shear strength, MPa	3.75	3.87	4.03	5.98
Young's modulus, GPa	2.393	2.235	1.936	2.560
Poisson's ratio	0.17	0.08	0.05	0.03
Maximum principal stress, MPa	21.3	21.6	24.7	38.1
Minimum principal stress, MPa	10	10	15	20
Medium principal stress, MPa	10	10	15	20

Figure 2 and Table 1 show the stress-strain curve of the core in the production layer and the test results of lithology and physical parameters. It can be seen from the figure that the reservoir is a weakly cemented elastic-plastic reservoir. Due to the loose degree of cementation of this type of reservoir, it is easy to be broken during the coring process, so that it is difficult to obtain formed core samples. If artificial cores are used to study the physical properties of the reservoir, large errors will occur. Therefore, replacing the production core with the outcrop core may become the only method to study the lithology and physical parameters of the reservoir.

3. Outcrop core physical parameter test

3.1 Analysis of experimental test results



L1# L2#

Figure 3. Stress–strain curve of outcrop core saturated without high-pressure heavy oil.

Table 2. Physical parameters of outcrop cores saturated with unpressurized heavy oil.

Core number	L1#	L2#
Confining pressure, MPa	15	20
Compressive strength, MPa	53.9	69.3
Shear strength, MPa	8.98	11.55
Young's modulus, GPa	5.15	5.82
Poisson's ratio	0.77	1.03
Maximum principal stress, MPa	42	59.7
Minimum principal stress, MPa	15	25
Medium principal stress, MPa	15	25

By comparing Table 1 and Table 2, the following conclusions can be drawn: under the same confining pressure loading, the mechanical parameters of outcrop core without high-pressure heavy oil saturation treatment are obviously larger than those of field core. Relevant laboratory experiments and numerical simulation studies on the treated outcrop cores will greatly mislead the on-site construction and are extremely dangerous. Therefore, in order to ensure that the lithology and physical parameters of deep cores stored for countless years are closer, it is necessary to use a multi-functional core displacement experimental device for high pressure heavy oil saturation treatment.

4. Physical parameter test of aged heavy oil outcrop core

4.1 Experimental equipment and materials

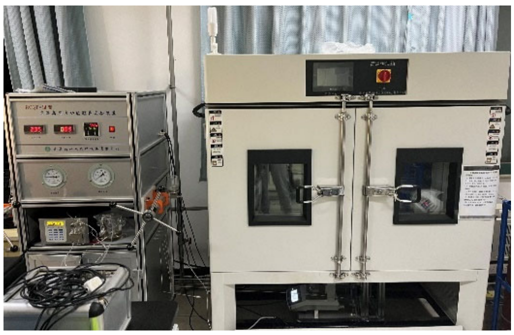


Figure 4. Multifunctional Core Flooding Device.

The multi-function high pressure core displacement device was used in this experiment. It is mainly composed of advection pump, intermediate container, core holder, confining pressure pump, data acquisition system and export metering system. The advection pump is HLB-100 / 10 flow pump, which can realize constant flow rate displacement of 0.1 ~ 99.9 ml / min.

4.2 Experimental procedure

(1) Load the core: before starting the experiment, put the core in a thermostat at a high-temperature of 51°C to 12 hours to make it fully dry, then put the core into the core holder to center the core, and add the upper core plugs on both sides. Tighten the plug.

(2) Add confining pressure: after tightening both ends, use an advection pump to press the annular space of the core holder until the confining pressure reaches 30MPa. After a period of rest, observe the change of the confining pressure gauge. If the confining pressure indication remains unchanged or does not decrease significantly, then start vacuuming.

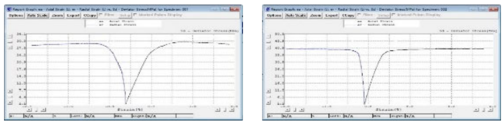
(3) Vacuum: install a vacuum gauge at one end of the core holder, and connect the vacuum pump at the other end. After turning on the vacuum pump, observe the number of vacuum indications. After checking, start vacuuming for 4-6 hours.

(4) Saturated oil: the viscous oil is put into an intermediate container and heated in a thermostat to simulate the real formation oil. The advection pump is started and the flow rate is adjusted to 0.01 ml / min to inject into the core, and the saturation time is 35 days.

(5) Aging oil: after the heavy oil is fully saturated into the core, the core is placed in the thermostat for 1-2 days to fully fit with crude oil or simulated oil.

(6) After the aging is completed, the high-temperature and high-pressure rock comprehensive test system will be used for strength testing.

1.1. Analysis of experimental test results



L3# L4#

Figure 5. Stress-strain curve of outcrop core saturated with high-pressure heavy oil.

Table 3. Physical parameters of outcrop cores saturated with high-pressure heavy oil.

Core number	L3#	L4#
Confining pressure, MPa	10	20
Compressive strength, MPa	28.6	39.5
Shear strength, MPa	4.98	5.6
Young's modulus, GPa	2.326	2.819
Poisson's ratio	0.13	0.15
Maximum principal stress, MPa	26.8	42.8
Minimum principal stress, MPa	10	20
Medium principal stress, MPa	10	20

By comparing tables 2 and 3, it can be seen that the compressive strength, shear strength, Young ' s modulus, Poisson' s ratio and three-dimensional stress of the outcrop core after high-pressure heavy oil saturation treatment decrease significantly under the same confining pressure loading.

By comparing Table 1 and Table 3, it can be seen that the lithology and physical parameters of outcrop core after high-pressure heavy oil saturation treatment are basically consistent with those of producing core. This is due to the outcrop core after high-temperature and high-pressure heavy oil saturation treatment, its structural composition, pore internal crude oil composition and content are close to the field core. Therefore, for the unconsolidated sandstone reservoir which is difficult to obtain the core of the production layer, in the absence of the core of the production layer, the outcrop core after high-pressure heavy oil saturation treatment can be used to replace the core of the production layer to study the lithology, physical parameters and sensitivity of the rock.

5. Conclusion

In this paper, the multi-functional core displacement experimental device and high-temperature and high-pressure rock comprehensive test system were used to compare and analyze the lithology and physical parameters of the rock in the field production layer core, the untreated outcrop core and the outcrop core after high-pressure heavy oil saturation treatment. The following conclusions were reached:

(1) The rock mechanical parameters of outcrop cores without high-pressure heavy oil saturation treatment were large than those of field cores, which cannot directly replace the core for rock physical property analysis.

(2) Rock mechanics parameters of outcrop cores after micro-flow displacement and high-pressure heavy oil saturation treatment were basically consistent with real

cores. And it can be used to replace the core to study the physical parameters of rocks in some special cases.

Acknowledgments

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