

Study on Identification Method of Sand Production Type in Unconsolidated Sandstone Reservoir

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Abstract: Sand production refers to the phenomenon in the production process of an oilfield where sand grains from the formation flow into the wellbore and block the flow channels due to excessive production pressure differential, loose cementation of rocks, and other reasons. The sand production from formations is influenced by various factors and exists in multiple forms simultaneously: based on the microstructure of weakly cemented sandstone, the rock particles of sandstone are classified into skeletal sand and loose sand. However, existing research methods can only study the mechanism of sand production from loosely cemented sandstone from a macroscopic perspective. In order to achieve a refined classification of sand production types from loosely cemented sandstone during water flooding processes, this study proposes an experimental method for identifying the types of sand production from loosely cemented sandstone reservoirs. While quantitatively calculating the types of sand production from loosely cemented sandstone reservoirs, this method also fundamentally reveals the microscopic mechanism of sand production from loosely cemented sandstone reservoirs, obtaining accurate analytical results of sand production types.

Keywords: Unconsolidated sandstone; sand production; experimental simulation.

1. Introduction

Sand production refers to the phenomenon during the production phase of an oilfield where sand particles detach and migrate from the formation along with fluids. It is an important factor affecting the productivity of individual wells, thus constraining the efficient development of unconsolidated sandstone reservoirs. Sand production from formations is influenced by various factors and exists in multiple forms simultaneously: firstly, due to the low degree of consolidation of particles within the reservoir, freely moving particles are produced along with fluids, forming "loose sand"; secondly, framework particles reach the failure condition, detach, and fall off, producing "skeletal sand" along with fluids. In order to accurately assess sand production during the production process of unconsolidated sandstone reservoirs and utilize reservoir sand production types for production management, it is particularly important to establish an experimental method for identifying sand production types from unconsolidated sandstone reservoirs through laboratory physical flow simulation experiments. The evaluation results have significant reference value for optimizing reservoir water flooding injection parameters and improving water flooding oil recovery.

In 2010, Shi established a potential energy function for the surrounding rock of oil and gas wells considering seepage conditions based on elastoplastic mechanics theory. They applied the sharp-point mutation model of catastrophe theory to study the physical process of sand production in oil and gas wells, thereby establishing a novel mathematical model for sand production prediction. In 2011, Wei based on their research on the stress distribution in the near-wellbore zone of horizontal wells, proposed the concept of the failure characteristic radius. They determined the location of formation failure and sand production at the characteristic radius and established a corresponding predictive model for the critical production pressure differential of sand production in horizontal wells. They also conducted sensitivity analysis on the calculated results of the critical production pressure

differential for sand production in horizontal wells. In 2012, Fang addressed issues in macroscopic experimental studies of sand production mechanisms by developing a microscopic visualization experimental apparatus for studying the sand production mechanisms in unconsolidated sandstone heavy oil reservoirs. They conducted microscopic visualization experiments to investigate the sand production mechanisms in unconsolidated sandstone heavy oil reservoirs. In 2013, Zhao established a longitudinal wave velocity model incorporating the comprehensive effects of water saturation and dimensionless pore pressure changes using binary quadratic function fitting and optimization principles. Upon this foundation, they introduced factors such as reservoir pressure depletion, water saturation, and lithology influence, and developed a classical combination modulus model. This led to the establishment of a qualitative empirical sand production dynamic prediction model. In 2015, Dong investigated the impact of dynamic factors on sand production conditions. They fitted the variation pattern of rock strength with water saturation based on experimental results and established a predictive method for the dynamic sand production critical conditions in heavy oil thermal recovery reservoirs. In 2019, Li based on the analysis of reservoir dynamic sand production influencing factors and mechanisms, focused on directional perforation wells and horizontal bare-eye wells as their research subjects. Combining analysis of wellbore mechanical stability, they established a predictive method for dynamic sand production in unconsolidated sandstone reservoirs. In 2021, Zhou utilized core simulation methods to characterize sand production patterns under different depositional states, enabling research into reservoir sand production pattern simulation experiments.

Currently, research on sand production types mainly involves the design of devices for sand production in unconsolidated sandstone reservoirs, studies on laboratory experimental testing methods, and analysis of the mechanisms and influencing factors of sand production. The research focus has primarily remained at the macroscopic level, with limited exploration into specific types of sand

production grains in unconsolidated sandstone reservoirs from a microscopic perspective. Additionally, it is unclear how the types of sand production in unconsolidated sandstone reservoirs affect the overall production process during reservoir exploitation.

2. Experimental Part

2.1. Experimental principles

To overcome the shortcomings of existing technologies mentioned above, this paper presents an experimental method for identifying sand production types in unconsolidated sandstone reservoirs. Based on laboratory physical simulation experiments and relying on particle size analysis test results, this method determines displacement velocity. By recording the distribution of sand particle sizes at the outlet end of the same rock core sample under different displacement pressure differentials during displacement and after displacement, precise calculation of the sand gravel particle size distribution interval is achieved. This method fully considers the characteristics of the microstructure of weakly cemented sandstone under displacement, enabling quantitative evaluation of sand production types in unconsolidated sandstone reservoirs.

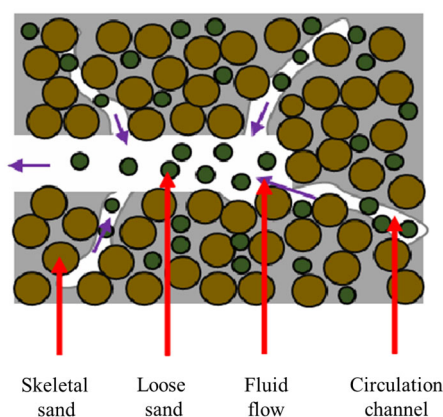


Figure 1. Sand production mechanism of loose sand

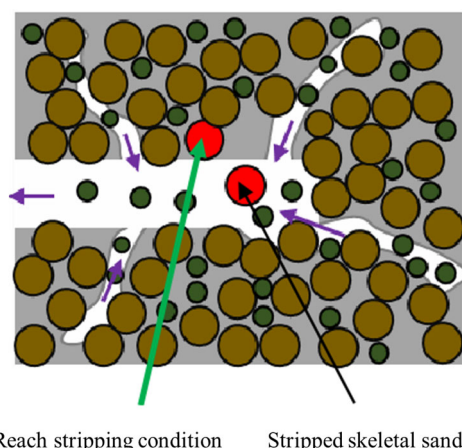


Figure 2. Sand production mechanism of skeletal sand

2.2. Experimental procedure

(1) Before the experiment, the selected natural unconsolidated sandstone core samples are screened, classified, and numbered for particle size testing. Subsequently, the cores undergo deep oil washing with petroleum ether and benzene. The washing is conducted

under conditions of 5 MPa and 80°C continuously for 10 days. After completion of the washing process, the cores are placed in a constant temperature oven for 24 hours at a drying temperature of 100°C.

(2) The experimental cores are then immersed in simulated formation water, with the water level covering the top of the cores. A vacuum pump is used to evacuate for 48 hours to ensure the experimental cores are fully saturated with simulated formation water.

(3) Experimental simulated crude oil is prepared, and it is injected into the cores at a rate of 0.1 mL/min until the oil production at the core outlet reaches 100%, establishing the original oil-water distribution in the formation.

(4) The displacement velocity is set to 0.10 mL/min, and the cores are displaced at constant pressures of 1.0 MPa, 5.0 MPa, 10.0 MPa, 15.0 MPa, and 20.0 MPa, respectively. The displacement process continues until 6 pore volumes (PV) of displacement are injected, upon which the displacement is terminated.

(5) After displacement, the oil and water samples discharged from the outlet end of the cores are collected by filtering the liquid using filter paper. This process allows for the collection of a small amount of sand particles, indicating sand production.

(6) The sand samples obtained from the water flooding experiment are washed with petroleum ether and benzene for 10 days. After the washing process, the sand samples are dried at 80°C for 24 hours.

(7) The cleaned and dried sand samples are subjected to size grading using a vibrating sieve. The sieving process lasts for 1 hour, resulting in the distribution of samples at different particle sizes.

(8) The sand samples are weighed and measured for each particle size category. By analyzing the data, a particle size analysis of the sand samples is conducted, resulting in a particle size distribution graph.

(9) Based on the particle size test results, the lower limit of the main radius is determined. Then, using the particle size analysis results, the sandstone rock particle sand production types are differentiated based on the sample's particle size distribution.

3. Evaluation of Sanding Type

Using the original formation water composition as a reference, synthetic formation water was prepared with a salinity of 15000 mg/L. Subsequently, a single displacement experiment was conducted on the No.1 core sample at a displacement rate of 0.1 mL/min under constant pressures of 1.0 MPa, 5.0 MPa, 10.0 MPa, 15.0 MPa, and 20.0 MPa, respectively. The gravimetric measurements of the gravel at different particle sizes were performed, and through data analysis, particle size analysis of the gravel samples was conducted, resulting in a particle size analysis chart.

Based on the particle size test results, the minimum primary radius of the particle size is determined to be 0.02mm, which is equivalent to 20μm. In this sand particle size analysis, particles larger than 20μm are considered skeletal sand. The particle size analysis of the sand particles reveals a wide distribution range, spanning from 0.79μm to 52.62μm, with a peak appearing near 30.52μm, indicating larger pore throats. The maximum particle size of the sand grains is determined

to be 52.62 μm , with an average particle size of 15.50 μm . The sand is characterized as loose sand, with sand grains predominantly comprising skeletal sand.

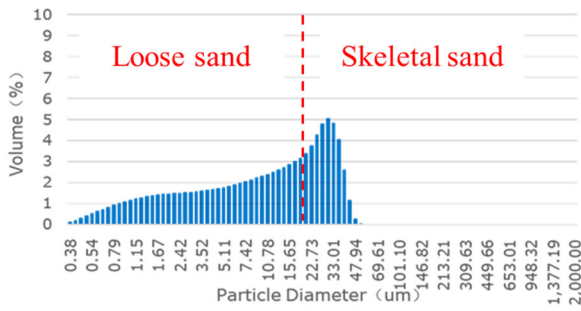


Figure 3. The particle size analysis results of No.1 sample

Based on the original formation water composition from the core location, experimental simulated formation water was prepared with a salinity of 15000 mg/L. Subsequently, the core samples were subjected to single displacement experiments at a displacement rate of 0.1 mL/min, under constant pressures of 1.0 MPa, 5.0 MPa, 10.0 MPa, 15.0 MPa, and 20.0 MPa, respectively. Gravimetric measurements of the gravel at different particle sizes were conducted. Through data analysis, particle size analysis of the gravel samples was performed, resulting in a particle size analysis chart for the samples.

Based on the particle size test results, the minimum primary radius of the particles is determined to be 0.02mm, equivalent to 20 μm . In this sand particle size analysis, particles larger than 20 μm are considered skeletal sand. The analysis of sand particle sizes reveals a narrow distribution range, with particle sizes ranging from 0.38 μm to 7.42 μm . A peak appears near 6.27 μm , indicating smaller pore throats. The maximum particle size of the sand grains is determined to be 7.42 μm , with an average particle size of 3.32 μm . The sand is characterized as loose sand, with no skeletal sand present in the sample.

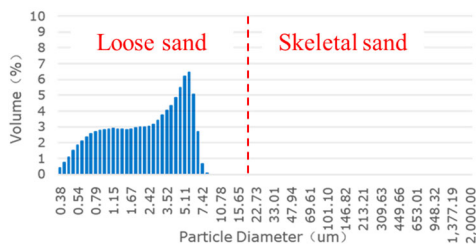


Figure 4. The particle size analysis results of No.2 sample

4. Summary

The paper proposes a quantitative evaluation method to identify the type of sand production in unconsolidated sandstone reservoirs under optimal displacement velocity. This method involves sieving and grading the sand grains after sand production to determine the type of sand production. After establishing the original oil-water distribution in the saturated formation water and crude oil samples, displacement experiments are conducted at the same displacement velocity. Subsequently, samples are collected and cleaned at the outlet end, followed by drying. Particle size selection of the sand grains is performed using a vibrating sieve, yielding particle size analysis results and graphs. By comparing these results with the minimum primary radius of the particle size, the type of sand production can be determined, enabling the quantitative evaluation and identification of sand production types in unconsolidated sandstone reservoirs.

References

- [1] Junfeng Shi, Yunzhang Liu, Xiaodong Wu, et al. A new probe of sand production prediction based on catastrophic theory. *Journal of Southwest Petroleum University (Science & Technology Edition)*. Vol.32(2010) No.02, p.128-132+205-206.
- [2] Yamin Wei, Aiping Wang, Changyin Wang, et al. Prediction model for critical sanding pressure drawdown in horizontal wells based on characteristic break radius. *Journal of China University of Petroleum (Edition of Natural Science)*. Vol.35(2011) No.02, p.85-90.
- [3] Maojun Fang, Xiaolin Zheng, Dan Liang. Microscopic visual experimental study on the sanding mechanism of unconsolidated sandstone reservoirs. *Special Oil & Gas Reservoirs*. Vol.19(2012) No.01, p.98-100+140.
- [4] Yizhong Zhao, Dexu Sun, Wei Liang, et al. Research on qualitative experimental dynamic sanding prediction considering the development performance. *Oil Drilling & Production Technology*. Vol.35(2013) No.05, p.67-70.
- [5] Changyin Dong, Qinghua Zhang, Mingyue Cui, et al. A Dynamic Sanding Prediction Model for Unconsolidated Sandstone Reservoirs with Complicated Production Conditions. *Petroleum Drilling Techniques*. Vol.43(2015) No.06, p.81-86.
- [6] Ning Gong, Jin Li, Jie Xu, et al. Prediction of Dynamic Sanding in Unconsolidated Sandstone Reservoirs of Bohai Oilfield. *Journal of Southwest Petroleum University (Science & Technology Edition)*. Vol.41(2019) No.01, p.119-128.
- [7] Bo Zhou, Changyin Dong, Lizhi Wang. Microscopic simulation experiments on sand production morphology of polymer-bearing unconsolidated sandstone cores. *Fault-Block Oil & Gas Field*. Vol.28(2021) No.06, p.848-853.