# DAMAGE-CONTROL TECHNOLOGY OF OIL-BASED DRILLING FLUID FOR SHALE AND TIGHT SANDSTONE: CURRENT SITUATION, CHALLENGE AND SOLUTION

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## Abstract

*In drilling fluid systems, oil-based drilling fluid have advantages of protecting reservoir and keeping borehole stability in traditional recognition, it also have advantages of high temperature resistance, salt and calcium resistance, good lubricity and low damage, these all let oil-based drilling fluid as an important mean of complex formation drilling for high temperature deep well, high angle directional well, horizontal well and so on. But oil-based drilling fluid has the following damage: drilling fluid invade into formation and cause wettability change of rock surface; oil phase enter into formation and cause the reduce of effective flow area; emulsion block formation; migration of oil-wet solid-phase particles, solid-phase particle invasion and so on would also bring many damages to formation. This study analyzed the current situation and challenge of oil-based drilling fluid, put forward solutions, and provided some references for reservoir protection of oil-based drilling fluid.*

***Keywords***: *Oil-Based Drilling Fluid, Reservoir Protection, Wettability, Oil-Phase Trapping*

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## 1. INTRODUCTION

Nowadays, oil-based drilling fluid has large-scale application in the process of drilling for shale and tight sandstone reservoir, and get good effect.[1] However, there are also many problems which restrict the use of oil-based drilling fluid, the main problem is lost circulation which would greatly increase the cost and cause the formation pollution. A series of problems included low drilling fluid caused by high viscosity, hard remove of filtrate invasion and so on put forward higher requirements to reservoir protection. But currently, the research of current reservoir protection is still at the exploration stage[2], research achievement is less, and most of the achievements is carried out by imitating reservoir protection technology of water-based drilling fluid, these don't have pertinence with oil-based drilling fluid. Therefore, the study carefully analyze current situation of reservoir protection technology of oil-based drilling fluid; in view of the actual situation of present drilling engineering, the study sum up the challenge of reservoir protection technology of oil-based drilling fluid; on this basis, the study put forward the thoughts to solve the problems of drilling fluid, and bring forward the proposal to the research of reservoir protection technology.

## 2. CURRENT SITUATION OF TECHNOLOGICAL DEVELOPMENT

### 2.1 Oil-Based Drilling Fluid

The most basic part of the development of reservoir protection technology of oil-based drilling fluid is still the rapid development of oil-based drilling fluid. Over the past 20 years, oil-based drilling fluid and water-based drilling fluid has a great progress, such as oil-based agents, drilling fluid systems.[3-4]

Nowadays, low cost and good performance of environmental protection are the development trend of oil-based drilling fluid. There are many drilling systems which has been developed, such as high temperature and high density oil-based drilling system[5], high performance

and no clay oil-based drilling system, micro-powder oil-based drilling system, constant rheological synthetic-based drilling fluid system[6], reversible emulsion oil-based drilling system[7], BP zero filtration oil-based drilling system[8], low toxicity oil-based drilling system[9], soilless oil-based drilling system, low-solid oil-based drilling system[10].

### 2.2 Change of Wettability

In the process of drilling, the invasion the fluid cause the wettability change of the surface of rock pore or rock cracks, the water wettability was changed into oil wettability, this kind of reverse wettability would cause large damage. Unlike other damages, wettability change would not reduce the absolute permeability of the reservoir rock, the damage is extremely concealed compared to the conventional damage, and it is easy to be ignored in engineering.

Skalli L et al [11] deemed that after oil-based drilling fluid contact with water-wetting rock, great wettability change was not caused by base oil, and primarily caused by mutual effect between some surfactants and oxidized asphalt polarity components of oil-based drilling fluid and rock surface.L Cuiec [12] confirmed that after damage by oil-based drilling fluid, flowback pressure of components was small, permeability recovery value of white oil was highest, this was consistent with the minimum wettability change, and damage caused by white oil was relatively small.DC Thomas et al [13] deemed that organic soil was oil-wetting bentonite which was made from bentonite by surfactant treatment, it could separate as thin solid phase particles which were more easy to enter into pore throat and seepage channel and cause solid-phase blockage.Morrow[14] thought that wetting agent made water-wetting rock surface change into oil-wetting, oil phase and oil-wetting colloid in oil-based drilling fluid were easier to adhere to the surface of oil-wetting channel and pore throat, this would cause the decrease the gas-flow area, and the reservoir permeability would drop, Dingda Xu etc. al [15] thought that components of oil-based drilling fluid would change rock wettability in different degree, components group of the biggest influence were wetting agent, organic soil, asphalt types fluid loss agent, water-in-oil emulsion, emulsifier, white oil; the order of reservoir permeability damage of components was: organic soil, wetting agent, fluid loss agent of asphalt type, water-in-oil emulsion and emulsifier, white oil had the minimal impact.

### 2.3 Oil-Phase Trapping

Oil-phase trapping damage is one of the important damages of oil-based drilling fluid, the research focus on macroscopic damage situation at present, research on microscopic mechanism is less.

Hassan Bahrami etc.al [16] deemed that when using oil-based drilling fluid for drilling, filtrate of oil-based drilling fluid entered into tight formation and formed a kind of immiscible liquid mixtures around the wellbore, and caused the liquid trapping to form an extra damage. Mitchel Tsar etc.al [17] thought that with the increase of invasion of oil-based drilling fluid, reservoir porosity and permeability were decreased, the inlet capillary pressure and index of pore size distribution changes widely, and oil-phase trapping had great damage.Arshad A. Lashari etc.al [18] deemed that on the basis of the result of the interfacial tension, the phase trapping caused by diesel oil was smaller than brine system, permeability damage experiments showed that damage of diesel oil-based drilling fluid is 55%, water-based drilling fluid is 80%.

### 2.4 Solid-Phase Invasion

Oil-based drilling fluid are commonly used in the formation of borehole instability, in this formation, water-based drilling fluid also can’t drilling smoothly. And in such a formation, regardless of oil-based drilling fluid or water-based drilling fluid, solid-phase invasion is a very important damage element.

Solid-phase damage of oil-based drilling fluid is mainly manifested in the migration of oil-wetting solid-phase particles in oil and gas layers, solid-phase particle invasion and so on, all of these mechanism have been widely studied, so the mechanism is no longer described in detail.

### 2.5 Other Damages

Reservoir damage of oil-based drilling fluid also include mud cake damage, internal micro-foam damage and so on, all of these are still studied to the least extent.

Frederick B. Growcock etc. al[19]had carried out a study of reservoir protection ability of microbubble in oil-based drilling fluid. Microbubble existed in the oil-based drilling fluid, and entered into formation with filtrate, its jamin effect would reduce the filtrate loss of oil-based drilling fluid into the reservoir, reduced the degree of filtrate soaking of formation, and also reduced the reservoir damage.

## 3. TECHNOLOGICAL CHALLENGE OF RESERVOIR PROTECTION OF OIL-BASED DRILLING FLUID

The research on reservoir protection of oil-based drilling fluid is still very little, a small amount of literature are mainly focused on wettability experiments and treatment measures. In the practical application of oil-based drilling fluid, the engineers deemed that the damage of oil-based drilling fluid is small in traditional recognition, lacking of the understanding of oil-based drilling fluid.

### 3.1 Lack of Evaluation Methods

Evaluation methods of oil-based drilling fluid and reservoir protection ability mainly include four types of conventional means: porosity/permeability - permeability recovery rate, wettability change, solid-phase jams, emulsification and demulsification, filtration (high temperature). These evaluation technology are mainly aimed at water-based drilling fluid, compared to water, the properties of oil have a big difference, the same evaluation method is not considered whether could be used to oil. Emulsification and demulsification is applicable when evaluate water-based emulsion, and also could be used to evaluation two phase interface of oil and water in oil-based drilling fluid, but whether this evaluation method can be used in gas well cannot be seen. Evaluation method of permeability recovery rate mainly uses the pattern of positive displacement – reverse displacement – positive displacement (**Figure 1**), whether this method can be used in oil-based drilling fluid under high temperature and high pressure is still in doubt.

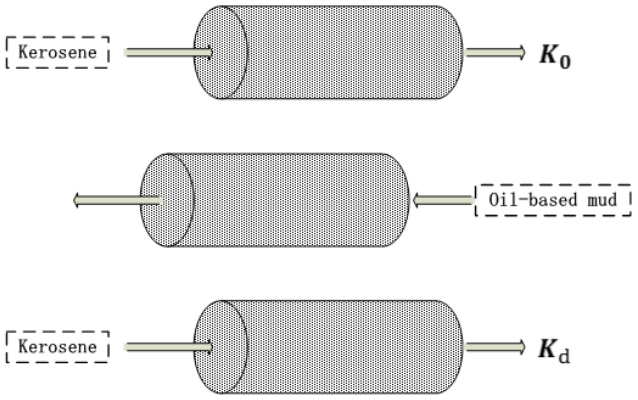


Figure 1. Evaluation method of permeability recovery rate of oil-based drilling fluid

### 3.2 Lack of Consideration Of Multiphase

Existing oil-based drilling fluid research put more emphasis on the pure oil phase, or two phase of oil and water (water-in-oil drilling fluid, meet of oil and water, oil-based drilling fluid which include amount of water). When oil-based drilling fluid is used to drilling, in addition to two phase of oil-water, there are also other multiphase situations, such as oil-oil, oil-gas, oil-gas-water, gas-water, these situations are widely exist. Drilling engineering is not actually consider these situations, and these would cause a lot of complex problems directly. Multiphase situations will bring a relatively serious damage to formation, even more serious than water-based drilling fluid.

### 3.3 Lack of Consideration of Formation Situations

There is a big erroneous zone of using oil-based drilling fluid, some scholars and technicians don't consider the actual situation of formation when they use or study oil-based drilling fluid, they think that there is no problem to use oil-based drilling fluid for drilling when water-based drilling fluid could not meet requirements of drilling, and they deem oil-based drilling fluid as a tiger balm. Based on literature and the project which completed by authors in recent years, we could realize that this view have a lot of misunderstanding, in some cases performance of oil-based drilling fluid is short of water-based drilling fluid. For example, formation in Xinjiang Tazhong Block has multiple pressure systems and narrow safety-density window, in the case of collapsed when used water-based drilling fluid, oil-based drilling fluid also caused collapsed, and the leakage is more serious. But when the performance of

water-based drilling fluid was readjusted, drilling engineering was able to run smoothly.

### 3.4 Lack of Consideration of In-Depth Study

Current research shows that reservoir protection technology of oil-based drilling fluid is still in a stage to imitate water-based drilling fluid. Oil-based drilling fluid is still in solving the problems of suspension stability and rheological stability, reservoir protection is neglected, and protection technology of oil-based drilling fluid has not formed a technology system. Current research focuses on wettability, phase trapping, solid-phase invasion, but there is still no breakthrough, all of these rarely consider seepage media and drilling fluid under formation temperature and pressure. There are a series of other problems, such as less consideration of solid-solid problem, solid-liquid problem caused by emulsification stability of oil-based drilling fluid; internal bubbles of oil-based drilling fluid could cause the change of wettability and capillary force and deepen damage, the phenomenon is put forward by minority literature, and do not do research; chemical changes caused by oil-based drilling fluid have not be considered yet; filter cake and particle size control of oil-based drilling fluid is not be studied. Overall, reservoir protection research is still in its infancy.

## 4. SOLUTION OF RESERVOIR PROTECTION OF OIL-BASED DRILLING FLUID

(1) Reservoir protection of oil-based drilling fluid should be considered when drilling gas layers, and take formation damage into account under two-phase of oil-gas, three-phase of oil-gas-water.

(2) Damage mechanism should be reframed, carry out microscopic mechanism study of wettability, oil-phase trapping, solid-phase damage, establish a mathematical model for solid-phase invasion which is based on the theory of particle kinematics to solve the shortcomings of the mathematical model which based on sedimentary theory; microscopic analysis of wettability and oil-phase trapping should be carried out which based on interface theory.

(3) Physical and chemical change caused by emulsion of oil-based drilling fluid showed be mainly considered, carried out in-depth research of problem caused by emulsion from two aspects of solid-liquid, solid-gas.

(4) Internal microbubbles of oil-based drilling fluid should carry out theory and experimental analysis, on the basis of experimental results to find whether the phenomenon that microbubbles reduce possible damage could transform to a favorable condition to apply to oil-based drilling fluid.

(5) Trying to study on forming a semi-permeable membrane which could effectively reduce the damage of oil-based drilling fluid when oil-based drilling fluid enter into formation.

(6) Existing experimental instruments should be tried to improve and use new technology to form the innovation of reservoir protection measures of oil-based drilling fluid.

## 5. CONCLUSION

With the deepening of the development of shale gas and tight reservoir, oil-based drilling fluid would be used more frequently, reservoir protection technology of oil-based drilling fluid should be synchronized developed. Research of reservoir protection technology of oil-based drilling fluid should stop to imitate water-based drilling fluid gradually, and develop reservoir protection technology based on oil base. A period of time in the future, the research show devote to explain from microscopic damage of oil-based drilling fluid, form a series of reservoir protection technology of oil-based drilling fluid and develop a number of professional instruments of reservoir protection technology to promote the development of reservoir protection of oil-based drilling fluid.

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