

Study on the effect of innovative leaching solvent on the oil removal for oily drilling cuttings

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Abstract. A new type of leaching solvent for oily drilling cuttings was developed, and the effect of leaching solvent on the oil removal for oily cuttings was investigated. The results indicated that the leaching solvent had good capacity of oil removal for oily cuttings, and the oil content of treated cuttings is less than 0.6%. The leaching solvent could be separated from the oil phase through distillation, and the recyclable solvent could be reused to treat other cuttings. Moreover, oil resources adsorbed on the oily cuttings could be recycled and reused to prepare new drilling fluids, so the drilling cost could be reduced greatly. As a result, the leaching solvent could treat the oily cuttings effectively, and recycle and reuse oil resources, and thus produce great economic benefits. It can play an essential role in safe drilling jobs and improvement of drilling efficiency in the future.

1. Introduction

Due to high temperature, high pressure, ultra-thick composite gypsum-salt formations, high-density oil-based drilling fluids have been used in the process of drilling operation of the salt-gypsum formations and fractured pay zones in the past year [1-3]. Oil-based drilling fluid system has excellent comprehensive properties, and it could solve the contradiction between safety drilling of ultra-deep wells and formation complexity [4-8]. Until now oil-based drilling fluid has been used in the drilling engineering of about 80 wells.

However, a large number of drilling cuttings contaminated by oil-based drilling fluids are produced in the process of drilling operation [9-13]. These oily cuttings contain large amounts of harmful substances, such as petroleum hydrocarbons, surfactants, heavy metals, and so on, which are toxic and difficult to be biodegradable, so the discharge of oily cuttings without any treatment will lead to serious environment contamination [14-16].

Recently, China legislation has set the limits of total petroleum hydrocarbon (TPH) of permitted oil associated with discharged drilling cuttings to 2%, with a view to reducing this limit further in the near future. Hence, oily drilling cuttings should be treated to remove oil phase prior to discharge into the environment.

In order to meet the requirement of harmless treatment for oily cuttings, a new type of solvent is developed for treating oily cuttings, and it can dissolve base oil and surfactants in oily cuttings effectively. The effect of leaching solvent on the oil removal for oily cuttings is tested in details. The experimental results indicate that the leaching solvent could treat the oily cuttings efficiently. In addition, it can be separated from base oil rapidly by distillation. The recyclable solvent can be reused to treat oily cuttings, so the cost of leaching solvent could be reduced.



The oil content of treated cuttings is less than 0.6%, and the treated cuttings could be used to pave the road, or used as raw material for cement or plaster production. The recyclable oil phase could meet the requirement of reuse, so it can be used to prepare new oil-based drilling fluids.

2. Experiment

2.1. The concept of leaching solvent

The leaching solvent works neither as a kind of surfactant solution nor an emulsifier but by cleaning. It preferentially dissolves the surface of oil contaminated cuttings, so oil phase is removed from the surface of cuttings. The treated cuttings and liquid phase can be separated by centrifugal force into two distinct phases. Since the boiling point of leaching solvent is lower than the diesel oil, it could be separated from the liquid phase through distillation.

Once the recovered oil has been separated from the surface of the cuttings, the solvent and the recovered oil can be separated under high temperature condition. This allows recycling of the oil back to the active mud pit, and the recyclable solvent can be reused to treat further oily cuttings.

2.2. The research of leaching solvent

Based on the similarity-intermiscibility theory, the leaching solvent consists of three kinds of organic solvents, including glycol ether compound (A), methoxy ether compound (B) and petroleum ether (C). The same quality of oily cuttings is treated by various proportions of solvent components, and the oil content of treated cuttings is tested, as shown in table 1.

The experimental results indicate that these leaching solvents have good oil removal capacity. When A:B:C is chosen as 2:2:3, the treated cuttings has the minimum oil content, so this proportion of solvent component has the best oil removal ability. In order to evaluate the efficiency of the solvent and its recyclability, a series of laboratory tests have been undertaken.

Table 1. The oil content of cuttings treated by different proportions of solvent components.

A:B:C	m ₁ /g	m ₂ /g	Δm/g	TPH/%
1:1:1	30.005	28.199	1.806	6.02
1:2:1	30.013	28.059	1.954	6.51
1:3:1	30.009	28.130	1.879	6.26
2:2:1	29.988	28.000	1.988	6.63
2:2:3	30.002	28.358	1.644	5.48
2:3:2	29.979	28.213	1.766	5.89

3. Results and discussion

3.1. The effect of dosage of leaching solvent on oil removal

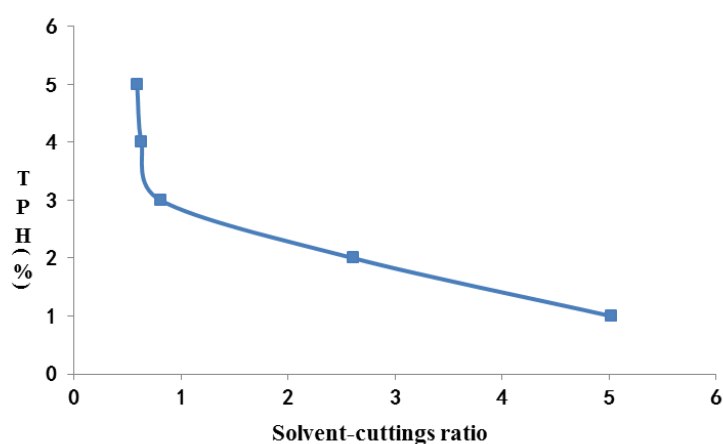
Different proportions of oily cuttings and leaching solvent are mixed at 60 °C. After mixed in 30 min, the cuttings are separated by centrifugation. The oil content of cuttings could be calculated by the mass difference of cuttings before and after leaching treatment.

The oil content of cuttings before and after leaching treatment is shown in table 2 and Figure 1. With the increase of cuttings-solvent ratio, the oil content of treated cuttings reduces greatly. When the ratio of oily cuttings and solvent is above 1:3, the oil content of treated cuttings can be reduced below 2%, so this dosage of leaching solvent could meet the requirement of leaching treatment. Considering the high cost of solvent, the cuttings-solvent ratio is chosen as 1:3.

Moreover, the leaching solvent can be separated from oil phase through distillation at high temperature, and the remaining liquid phase is merely oil composition. The recyclable solvent can be reused to treat oily cuttings. Therefore, the cost of leaching solvent could be reduced.

Table 2. The oil content of cuttings treated by various cuttings-solvent ratios.

Cuttings-solvent ratio	m_1/g	m_2/g	$\Delta m/g$	TPH/%
1:1	30.003	28.503	1.500	5.02
1:2	30.010	29.230	0.780	2.61
1:3	30.011	29.771	0.240	0.80
1:4	30.008	29.819	0.189	0.63
1:5	30.012	29.834	0.178	0.59

**Figure 1.** The effect of solvent-cuttings ratios on the oil content of cuttings.

3.2. The effect of leaching time on the leaching efficiency

As the cuttings-solvent ratio is 1:3, six copies of the same mass of oily cuttings are added by the same amount of leaching solvent. After mixed in different times, the cuttings are separated by centrifugation. The oil content of treated cuttings could be calculated by the mass difference of cuttings before and after leaching treatment at different times.

The oil content of cuttings before and after leaching treatment at different times is shown in table 3 and Figure 2. With the increase of leaching time, the oil content of cuttings reduces significantly. When the leaching time is above 20 min, the oil content of cuttings can be reduced below 2%. Given the leaching efficiency and energy consumption, the leaching time can be chosen as 20-30 min.

Table 3. The oil content of cuttings treated by different times.

Leaching time/min	m_1/g	m_2/g	$\Delta m/g$	TPH/%
5	30.011	27.940	2.071	6.90
10	30.109	28.875	1.234	4.11
20	30.006	29.648	0.358	1.19
30	29.988	29.814	0.174	0.58
40	30.014	29.852	0.162	0.54
50	30.002	29.852	0.150	0.50

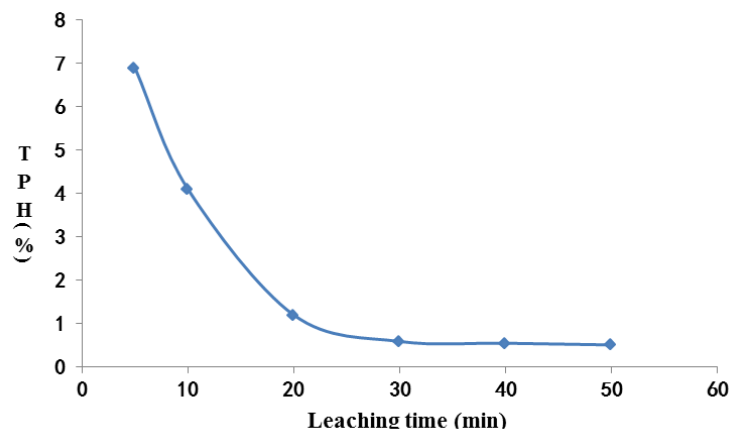


Figure 2. The effect of leaching time on the oil content of cuttings.

3.3. The effect of leaching temperature on the leaching efficiency

When the cuttings-solvent ratio is 1:3, six copies of the same mass of cuttings are mixed by the same amount of solvent in 30 min. After treated at different temperatures, the cuttings are separated by centrifugation. The oil content of cuttings could be calculated by the mass difference of cuttings before and after leaching treatment at different temperatures.

The oil content of cuttings before and after leaching treatment at different temperatures is shown in table 4 and Figure 3. With the increase of leaching temperature, the oil content of cuttings reduces greatly. When the leaching temperature is above 60 °C, the oil content of cuttings can be reduced below 2%. Given the leaching efficiency and energy consumption, the leaching time can be chosen as 60-70 °C.

Table 4. The oil content of cuttings treated by different temperatures.

Leaching temperature/°C	m_1/g	m_2/g	$\Delta m/g$	TPH/%
30	30.006	28.212	1.794	5.98
40	30.019	28.629	1.390	4.63
50	30.016	29.316	0.699	2.33
60	29.998	29.782	0.216	0.72
70	30.011	29.843	0.168	0.56
80	30.003	29.856	0.147	0.49

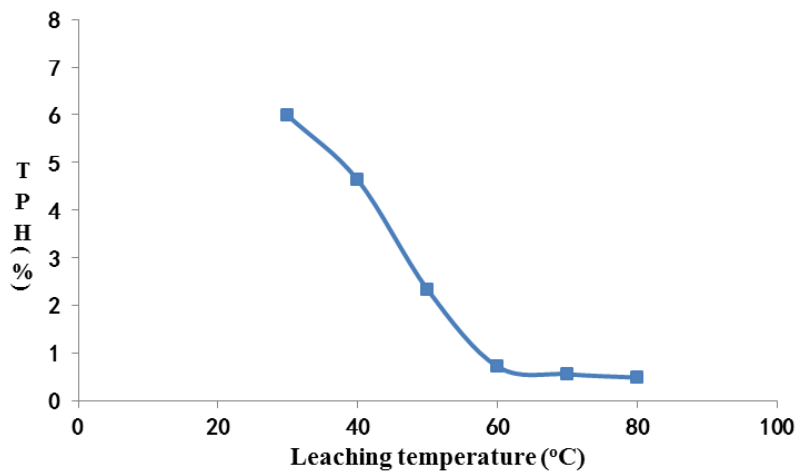


Figure 3. The effect of leaching temperature on the oil content of cuttings.

3.4. The leaching effect of leaching solvent

When the cuttings-solvent ratio is chosen as 1:3, the leaching time is chosen as 30 min, the leaching temperature is above 60 °C, the oily cuttings are treated very efficiently. The cuttings before and after leaching treatment are shown in Figure 4. The treated cuttings could be used to pave the road, or used as raw material for cement or plaster production.

The liquid phase before and after leaching treatment, including the solvent containing oil, the recyclable solvent, the recyclable oil, are shown in Figure 5. The recyclable solvent could be reused to treat oily cuttings, so the cost of leaching solvent could be reduced.

The oil resources (oil-based drilling fluids) adsorbed on the cuttings could be recycled. The rheological properties of recyclable oil-based drilling fluids are shown in table 5. The result indicates that the recyclable oil resources could be reused to prepare new oil-based drilling fluids. Due to recyclable exorbitant drilling fluids, the drilling cost could be reduced. The leaching treatment method could recycle and reuse oil resources, and thus produce great economic and environmental benefits.



Figure 4. The cuttings before and after leaching treatment.



(a) The solvent containing oil



(b) The recyclable solvent



(c) The recyclable oil

Figure 5. The liquid phase before and after leaching treatment.**Table 5.** The properties of recyclable oil-based drilling fluids.

Performance	Unit	Parameter
density	g/cm^3	1.30
oil-water ratio	-	88/12
apparent viscosity	$\text{MPa}\cdot\text{s}$	99
plastic viscosity	$\text{MPa}\cdot\text{s}$	88
yield value	Pa	11
initial gel/final gel	Pa	3.5/2.5
electrical stability	V	340

4. Conclusions

1) This new leaching solvent is characterized by high efficiency for oily cuttings, no secondary pollution, and it can meet the requirement of the harmless treatment of oily cuttings produced in the drilling operation.

2) The oil content of cuttings treated by leaching treatment is less than 1%. The obtained cuttings can be used to pave the road, or used as raw material for cement or plaster production.

3) A large amount of valuable oil resources could be recycled by the leaching treatment method, and the recyclable drilling fluids could be reused to prepare new drilling fluids. So the drilling cost could be reduced greatly. It can bring great economic and social benefits, and provide a strong technical support for cleaning production of drilling operation of oil-based drilling fluids.

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