Research on Treatment Technology and Device of Oily Sludge

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Abstract. Oily sludge is a solid oily waste, which is produced during the process of oil exploitation, transportation, refining and treatment of oily sewage. It contains a great number of hazardous substance, and is difficult to handle with. To solve the problem of waste resources of oil sludge with high oil content and usually not easy to aggregate during the preparation of profile control agent, a new oily sludge treatment device was developed. This device consists of heat supply unit, flush and filter unit, oil removal unit and dehydration unit. It can effectively clean and filter out the waste from oily sludge, recycle the oil resources and reduce the water content of the residue. In the process of operation, the water and chemical agent are recycled in the device, eventually producing little sewage. The device is small, easy to move and has high degree of automation control. The experimental application shows that the oil removal rate of the oily sludge is up to 70%, and the higher the oil content rate the better the treatment.

1. Introduction

In the process of development and transportation, oil field will inevitably produce a large amount of oily sludge, which mostly contains petroleum hydrocarbons, if directly emitted without treatment or below the standard, it will cause serious harm [1] to the surrounding. Various ways have been used to combat oil sludge both at home and abroad. These methods include: thermal desorption technology [2], conditioning-mechanical separation technology [3], incineration technology [4] and microbial technology [5, 6] and other technologies. The matching device of oily sludge treatment is mostly used for refinement. The Chemical Equipment Research Institute of China University of Petroleum has developed a skid mounted oily sludge treatment device, which can realize the oil content of oily sludge less than 1%, and then through the deeply pyrolysis can make the mineral oil content less than 0.3% [7]; Qing Li et al developed the thermochemical separation skid mounted oily sludge treatment device, it can reduce the irreducible oil of oily sludge to 0.21% ~ 0.65% [8]; The residues and sewage treated by the oily sludge treatment mobile device developed by Wenya Wang can meet the requirements of the national environmental protection, but the whole process should be carried out under the steam protection [9]. These above oily sludge treatment technologies and devices are inadequate in complex treatment process, low economic efficiency and resources waste.

In recent years, the research on the oily sludge profile control technology has been carried out in major oil fields, and the different formula of profile control agent system for oily sludge has been developed according to the different reservoir characteristics [10,11,12]. Oily sludge as the main
ingredients of profile control agent, to a certain degree, reduce the treatment difficulty and costs of oily sludge. However, most of the current research is to directly add a certain proportion of chemical additives in the oily sludge to make the profile control agent, which will cause serious waste of resources for oily sludge with high oil content. In addition, the polymerization effect of oily sludge with high oil content is not good, and after the oil removal agent, the sludge polymerization is complete, strong and have a good granulation performance [13].

In view of this situation, the focus of this paper is to design a set of oily sludge treatment device, cleaning and filtering the waste and reducing the oil content from oily sludge; Moreover, the water content of the treated oily sludge is low, which is convenient for transportation and storage. So it can be used as the main material for preparation of profile control agent.

2. Technological process

The technological process adopts the procedure of "hot water flushing, medicine demulsification, gravity oil removal and centrifugal dewatering", which is combined with the waste utilization of the oily sludge profile control. The main process is shown in Figure 1.

![Diagram of technological process](image)

**Figure. 1** Technological process of oily sludge

Oily sludge treatment can be used for profile control agent of injection well, it divides the oily sludge treatment system into the four section. In the process, according to the sources and the oil content of oily sludge, under the control of PLC, changing the process conditions and controlling the proportion of chemical agents, to realize the function of the same set of devices to deal with various types of oily sludge.

Impurity removal section: In this section, the method is combined with chemical demulsification, high temperature and high pressure water flushing, using filter drum and filter screen. It is effective for oily sludge, especially for mixture consist of oil and soil. The working principle is: The oily sludge enters into the device through the inlet point, and under high pressure, using more than 80°C water mixed with chemicals to flush oily sludge, while the trommelsieve rotating and then the waste in the oily sludge is filtered.

Gravity separation-Oil removal section: The function of this section depends on gravity, making oil and water stratification, and then recycle oil in oily sludge as much as possible. The working principle is: After flushing and filtering, the oily sludge enters the separation tank, stirred for a certain time to make water and oily sludge mixed evenly and fully reacted. After stirring, holding 50mins to 60mins, and taking the upper layer of oil, the lower water and the silt, the oily sludge through the sludge pump, and then enters the centrifuge for dehydration treatment, in this section, the temperature is controlled at about 60°C.

Chemical flocculation-Centrifugal dehydration section: The main function of this section is to separate the water from the silt in the centrifuge, to reduce the water content of the silt, so as to facilitate the transportation and storage of the oily sludge. The working principle is: When the high
water content of the oily sludge enters the centrifuge, the centrifugal force generated by the high-speed rotation of the centrifuge rotor, speeding up the settling velocity of particles in the liquid, to achieve the purpose of separating water and silt. The separated silt can be transported or stored, and the separated water can be directly reused after heating.

Physical dispersion-Chemical suspension: After the oily sludge treatment, the new condensed "muddy structure" is difficult to disperse evenly under the mixing action of the liquid preparation pool during the transport or storage process. For this, special means are needed for decentralized treatment. It's working principle is similar to the flush and filter section: The injected water disperse mud under the high pressure, and the not up to standard of the solid particles were filtered out. With the filtrate enters the liquid preparation pool, based on a certain ratio, we can add suspension concentrate, dispersant and other additives to make up the profile control agent of oily sludge.

3. Design of device

According to the process sequence of oily sludge pretreatment, the oily sludge treatment device design is shown in Figure 2, based on the sectional functions, it can be divided into flush and filter section, oil section, sludge dehydration section and boiler section. In the working process, the water can be recycled, and the last of a small amounts of residual sewage can be treated in the sewage treatment station; In the whole process, the oily sludge can closed flow in tank and pipeline, which can effectively ensure the cleaning of the working site; In addition, the separated waste oil can be sent back to the joint station for treatment, and the dehydration mud cake can be stored in the destination, which can be used for profile control of water well.

**Figure. 2** Main unit space layout of oily sludge treatment device: 1 Heat supply unit  2 Flush and filter unit  3 Oil removal unit  4 Dehydration unit

The whole device can be divided into four units according to the space layout:

Heat supply unit: Electric heating boiler is the heat supply unit. Three of electric heating pipe, with triangular connection, connected into a group. It is covered with a connecting tube, connected with the external electrical equipment and installed on the flange plate. Each group of electric heating tube is covered with an electric heating shield, and the heating process of oily sludge is completed in the cylinder without arranging the pipeline. Electric heating boiler adopts metal tubular electric heater, so that the electric energy is directly converted into the heat energy. this process does not need air and fuel for combustion, and will not discharge harmful gases and ash in line with environmental requirements.

Flush and filter unit: The flush and filter unit mainly consist of cylindrical filter screen, impeller, high-pressure water nozzle, window, motor, hollow shaft and insulating layer, etc. The high-pressure water nozzle is distributed on the hollow shaft, after material enters the unit, the cylindrical filter screen rotates around the hollow shaft. Hot water flush material by nozzle, and the filtrate produced by flushing and filtering enters the settling tank. It is shown in Figure 3.
Figure. 3 Flush and filter unit layout: 1 Inlet point  2 Envelope  3 Cylindrical filter screen  4 Impeller  
5 Water nozzle  6 Water inlet  7 Residue outlet  8 Liquid hopper  9 Liquid outlet  10 Motor 
Oil removal unit: The oil removal unit mainly includes settling tank, oil collector, agitator, cat 
ladder, window, insulating layer, trace band, the liquid level and the temperature sensor, etc. The 
upper part of the settling tank is a cylinder, the lower part is a conical funnel and the outer layer is 
sequentially fitted with an insulating layer and a trace band. The blade of the agitator has a certain 
angle, which allows the material inside the tank to roll up and down. The effective volume of the tank 
is 2m³. It is shown in Figure 4.

Figure. 4 Oil removal unit layout: 1 Decelerator  2 Base plate  3 Agitator shaft  4 Impeller  5 Tank 
Dehydration unit: The core of the dehydration unit is the centrifuge, which includes the pulley, 
transmission, feeding screw, rotary drum and bearing pedestal, etc. Rotary drum and screw with a 
certain velocity contrast rotating rapidly, while the material continuously enters the feeding screw 
inner from feeding tube and then enters the rotary drum after acceleration. Under the action of 
centrifugal force, the heavier solid components are deposited on the wall of rotary drum, and then the 
sediment layer is formed. The solid component of the deposit is continuously pushed to the end of the 
rotary drum by the feeding screw, and is discharged out from the slag-drip outlets. The lighter liquid 
component forms an inner liquid ring, which is continuously overflowed from the main overflow port 
of the rotary drum and discharged out through the fluid outlets. It is shown in Figure 5.
Fig. 5 Dehydration unit layout: 1 Pulley  2 Transmission  3 Envelope  4 Machine base  5 Outlet  6 Feeding screw  7 Rotary drum  8 Bearing pedestal  9 Feeding tube  10 Clarified liquid outlet  11 Slag-drip outlet

At present, the oily sludge in oil field is mostly stored in woven bags. Because of the high viscosity of oily sludge, it is very laborious and time-consuming to dump and feed. In order to solve this problem, this paper designs unloading device of sacked oily sludge [14] (Fig. 6). The working principle of the device is as follows: The sacked oily sludge is inverted on the transmission belt, and the sludge is discharged from the oily sludge bag under the extrusion of the progressive gyro wheel. Finally, the extrusion of two large pressure gyro wheels complete the dumping of the oily sludge. The whole process is accompanied by washing with the high pressure water to prevent the oily sludge clogging the crack between the gyro wheels. The design can effectively solve the problem of discharging sacked oily sludge and improving the treatment efficiency of oily sludge, which has been granted a Chinese patent certificate.

Fig. 6 An unloading device of sacked oily sludge Oily sludge treatment test: 1 Transmission belt  2 Large diameter gyro wheel  3 Tactic roller  4 Stationary pressure wheel  5 Movable pressure wheel  6 Spring  7 Sludge sump
4. Oily sludge treatment test
During the experiment the manual mode of the oily sludge added to the feed hopper of the filter. Oily sludge into the filter after a certain proportion of chemicals with high pressure hot water washing, the waste was cleaned and removed under the separation of the cylindrical filter screen. From the sludge pump into the settling tank, the filtrate through the stirring and sedimentation for the oil and water separation. After separation, the upper oily sludge was recovered, and the lower mud is dehydrated under the action of the centrifuge. The sludge piled up to the designated place, sewage back to the boiler, and enter the next circulation.

4.1. Experimental conditions
According to the technological conditions of oil removal from oily sludge, the experimental parameters of oily sludge treatment device are set up: The water temperature in the boiler is 100°C; the flushing and filtering time is 15min; the stirring time is 20min; the minimum temperature of the separation tank is 60°C; the holding time is 40min; the solid-liquid ratio is 1:4.

4.2. Sample properties
According to the sources of oily sludge, the natures of the crude oil, the particle size of the silt and the proportion of each component all are not all the same. In view of this situation, the mud samples from different sources are selected to experiment. The specific parameters of oily sludge are shown in Table 1.

| Sample number | Resource                        | Oil content (%) | Water content (%) | Solid content (%) |
|---------------|---------------------------------|-----------------|-------------------|------------------|
| 1             | United station                  | 32.5            | 25.8              | 41.7             |
| 2             | Mixture consist of oil and soil | 10.3            | 21.8              | 67.9             |
| 3             | Workover job                    | 20.3            | 29.5              | 50.2             |

4.3. Treatment effect
The above three different sources of oily sludge were treated by using the oily sludge treatment device. The results showed: that the oil content of the treated oily sludge decreased with the increase of the concentration of the drug. When the concentration of the drug was more than 1.2%, the rangeability in oil content of the treated oily sludge is decreased; When the concentration of the drug is more than 1.6%, the oil content of the treated oily sludge tends to be constant (Figure 7). Consider the water is recycled in the device during the oily sludge treatment process, so the amount of additives can be controlled between 1% and 1.6%.

![Figure 7 Effect of drug concentration on oily sludge treatment](image-url)
5. Conclusions
The oily sludge treatment device designed in this paper is small and easy to move; The parameter setting is simple; High degree of automation; The chemical agents and water are added in the operation process, it will be recycled in device, and produced less residual sewage; In addition, the greater the final oil removal rate, the relative treatment effect is better. There is little oil residue on the surface of the filtered residue, it is better to treat oily sludge with high oil content. The successful development of this device not only realized the small shape and the mobility, but also can be used in combination with the profile control agent. Therefore, it has wide application prospects in oil field.

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