Technical application of waste oil treatment in compound field

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Abstract.—This paper introduces the technology of treating waste oil by using composite fields such as gravity field, electric field and ultrasonic. Improper treatment of waste engine oil will seriously pollute the environment, and it can be put into industrial production after appropriate pretreatment. The device pretreats and recycles the waste oil, the equipment operates stably, which can not only save the cost, but also reduce the pollution to the environment, and has good social and economic benefits.

1. Introduction
With the rapid development of economy and society, the use of various lubricants in industry is also increasing, and the output of waste engine oil is also increasing day by day. According to statistics, the output of China’s waste mineral oil industry was about 6.24 million tons in 2013, reaching 7.317 million tons by 2018, [1] with a growth rate of 17.2%, of which 80% of the waste engine oil can be recovered through regeneration process. Compared with the huge amount of waste engine oil, China’s waste engine oil treatment and regeneration industry started late, and the corresponding technology development is relatively slow. Only some large oil refining enterprises will have special facilities for waste oil recovery and treatment. In some small and medium-sized enterprises, there is no or serious lack of corresponding waste oil treatment facilities, which seriously restricts the sustainable development of green environmental protection in the industry.

2. Introduction to waste engine oil

2.1. Definition of waste oil
Waste oil usually refers to the oil extracted or synthesized from crude oil and polluted by physical or chemical impurities in the process of use. The service life of various lubricating oils is different, and they must be replaced within a certain time limit. It varies according to the type of oil and the mechanical equipment used. Although the total amount of waste oil is large, it is difficult to collect and recycle it completely because the amount of waste oil discharged from each equipment, vehicle and ship is not too large and the locations are scattered. According to GB/T 7631.1-2008 classification of lubricants, industrial oils and related products (class L), it can be divided into four categories: Waste internal combustion engine oil, waste gear oil, waste pressure oil and waste special oil. It is mainly composed of organic hydrocarbons, such as aging oil, paraffin, asphalt, etc; There are many kinds of impurities in waste oil. First, solid impurities are generated due to the reaction between additives in oil
products and oxygen in the air or aging and deterioration due to long service time. Such as suspended flocculation impurities, mechanical impurities, etc; Second, it contains a certain amount of water. Its main source is that the water in the air is dissolved in the oil, or due to poor sealing performance, the external water vapor enters the equipment and dissolves in the oil. The washing oil for cleaning equipment and parts belongs to waste oil, which also contains a lot of water. According to its existence form, it can be divided into: ① Suspended water, also known as free water, is insoluble in hydrocarbon liquids and is suspended in liquids. ② Emulsified water, that is, water that forms an emulsion with water and oil. It is usually water in oil (O / W type) and a very small amount of oil in water (w / O type). This kind of water is extremely stable and cannot be removed by simple gravity sedimentation method. ③ Dissolved water, i.e. water slightly dissolved in waste engine oil.

2.2. Hazards of waste engine oil

As a country with the whole industrial chain, China has a high degree of mechanization and a large amount of waste oil. According to the national list of hazardous wastes (2021), waste oil belongs to hazardous waste and the waste category is HW08. If the waste oil is treated at will without removing water and solid impurities, it will not only cause huge economic losses, but also cause serious environmental pollution.[2]

In fact, waste engine oil is a neglected "waste", which has the dual attributes of resources and waste. It is a misplaced resource. There are relatively few enterprises with waste oil recovery qualification in China, less than 1000 nationwide. Waste oil also includes waste oil, kitchen waste oil and other types of waste oil. The treatment processes of different types of waste oil are also different, which leads to fewer enterprises qualified to treat waste oil. Many small and medium-sized enterprises treat waste engine oil as follows: 1. At the same time, the transportation of waste engine oil can not be the same as that of ordinary engine oil. Because it contains many substances different from oil products such as mechanical impurities and moisture, it must be transported to the treatment enterprise by special vehicles, which will not only pay a lot of treatment costs, but also add a lot of burden to the production and operation of the enterprise. 2. Illegal discharge. For some small auto repair enterprises, the replaced waste engine oil is difficult to be handed over to qualified enterprises for treatment. In addition to the reasons mentioned above, there are also factors such as fewer treatment outlets and long transportation distance. Many enterprises risk illegal discharge, or sell waste oil to other unqualified companies or personnel for treatment. This is likely to bring huge environmental and social problems.[3] Hooman [4] and others used microwave-assisted acidification to convert calcium bentonite into porous adsorbent for the removal of waste engine oil pollutants in batch system, and determined the optimal preparation conditions of adsorbent based on multiple groups of experiments. S. Darwish et al. [5] prepared porous nanocomposites from zebrafish bone biological waste for the field of waste oil recovery. Experiments show that the material can achieve nearly 100% removal efficiency in 6 Adsorption cycles. It is an ideal material for decolorizing adsorbent and waste oil regenerator. He Xiong et al. [6] designed a device for recycling waste oil by gravity sedimentation, which was applied to the water pump maintenance workshop of the enterprise. The device integrates oil-water separation and storage. The waste oil and wastewater mixture leaked during the disassembly of the water pump is filtered and separated by the device, and can be recovered for centralized treatment.

To sum up, waste engine oil must be properly regenerated before it can be turned into treasure and put back into process production and life.

3. Waste oil treatment process in compound field

3.1. Electric field treatment of waste oil

Because there is a certain amount of water in the waste lubricating oil, the above simple regeneration process can only remove the mechanical impurities and oil sludge in the waste lubricating oil, but can not remove the water of the waste lubricating oil. At present, various waste oil treatment stations
generally adopt dehydration, impurity removal and demulsification devices based on electric dehydration technology, and some are supplemented by other physical fields for joint treatment. According to different application characteristics of electric field, it can be divided into AC electric field, DC electric field, AC / DC electric field and pulse electric field.

![Diagram of working area of electric dehydration tank](image)

1-Upper plate, 2-Lower plate, 3-Oil inlet, 4-water outlet, 5-Oil outlet
I-Clean water layer, II-Water layer, III-Weak electric field region, IV-Strong electric field region, V-oil

Fig. 1 Schematic diagram of working area of electric dehydration tank

3.2. Treatment of waste oil in compound field

3.2.1. Principle of compound field processing

The three methods of gravity sedimentation, electric dehydration and ultrasonic cavitation are organically combined to make full use of the advantages of the three methods to effectively separate and remove the water and impurities in the waste oil.

In the gravity field, due to the density difference between oil and water, the gravity settlement phenomenon of oil floating and water sinking occurs. Moreover, the larger the particle size of oil droplets, the faster the floating speed, and the better the effect of gravity sedimentation. In the pretreatment process of oil-water separation of crude oil, 0.008% ~ 0.2% NaCl (weight) will be added to increase the density difference between water and oil, and have a certain demulsification effect on water in oil.

In the electric field, the waste oil is affected by the electric field, resulting in dipole coalescence, which polarizes the water in the waste oil. The water droplets with heterogeneous charges attract each other and condense into large droplets, which settle to the bottom of the tank under the action of gravity; Waste oil is also affected by the change of electric field intensity. The oil film vibrates due to the change of electric field strength, tears the oil film, separates the water wrapped in it, collides with other water droplets, and settles to the tank bottom by gravity.

In the ultrasonic field, the waste oil is subjected to the action of ultrasonic. Under the action of overpressure cavitation in a very short time, the instantaneous local high temperature and high pressure conditions are formed, accompanied by strong shock wave and micro jet oscillation, which impact the water in oil and suspended mechanical impurities in the liquid and break its interface. Under the action of strong electric field, it intensifies the condensation into large particles. Ultrasonic efficiency can accelerate the aggregation and sedimentation of mechanical impurities, flocs and water.
4. Introduction of waste oil treatment unit in compound field

4.1. Equipment composition

The utility model relates to a device for impurity removal and dehydration of waste oil by using composite field force. The overall structure is a horizontal steel reaction tank, and the pipe orifice is provided with liquid inlet, drainage outlet, liquid outlet and other connections. Auxiliary equipment includes: automatic frequency conversion voltage regulator, high-voltage connecting bellows, high-voltage inlet pipe, electrode plate, liquid distributor, ultrasonic generating rod, etc. The drainage pipe is arranged at the bottom of the reactor, and the stainless steel pipe is provided with small holes to facilitate the discharge of separated water; The liquid inlet pipe is introduced from the tank bottom and arranged above the drainage pipe at the bottom of the reactor. The liquid enters the reactor from the inlet pipe. After passing through the liquid distributor, the liquid is broken and dispersed into large droplets; The electrode plate is hung in the middle and upper part of the reaction tank by insulation, and the external high voltage is introduced to the electrode plate by automatic frequency conversion regulator and high-voltage connecting bellows to provide a gravity settlement environment for liquid impurity removal in the reaction pipe; The ultrasonic generating rod is arranged radially around the reaction tank to provide ultrasonic input for the tank.

Insulating sealing flanges shall be set for liquid inlet, liquid outlet and high-voltage lead-in pipe. The outer layer of pole plate hanging and high-voltage electric lead-in wire shall be provided with insulating layer. Anti corrosion measures shall be taken for the inside and outside of the reaction tank according to the specifications, and phase electric protection measures shall be taken. The equipment is shown in Figure 2.

As shown in Figure 3. The ultrasonic generation pipe 10 is evenly distributed around the reaction tank along the radial direction of the tank body. The ultrasonic generation tube 10 emits ultrasonic waves with different frequencies and powers into the tank, so that large droplets of waste oil liquid sprayed through the liquid distributor are broken into small droplets under the cavitation effect of ultrasonic waves; At the same time, the large droplets of "water in oil" in the liquid are broken to separate the internal water from the oil package.

![Fig. 2 Schematic diagram of reaction tank for waste oil treatment in compound plant](image)

1: liquid distributors, 2: Outfall, 3: Liquid inlet, 4: Insulated suspension plate, 5: Electrode plate, 6: High pressure inlet pipe, 7: High pressure connecting bellows, 8: Automatic frequency conversion voltage regulator, 9: Liquid outlet pipe, 10: Ultrasonic generating tube, 11: reaction tank, 12: Seepage hole.
4.2. Operation implementation process

The main implementation process is as follows: the waste oil enters the bottom of the reaction tank through the liquid inlet 3 and is sprayed to the electrode plate 5 by the liquid distributor 1. The waste oil is sprayed into large droplets through the liquid distributor, and large droplets with different sizes and diameters are broken into small droplets under the action of ultrasonic cavitation sent out by the ultrasonic generation pipe. The electric field generated by the electrode plate 5 provides a gravity sedimentation environment to spray and refine the waste oil droplets, water droplets and mechanical impurities in the electric field, which are separated to different positions in the tank due to different properties. The water droplets settle at the bottom of the tank and are discharged from the drain port 2 below the tank bottom through the small hole of the drain pipe; Mechanical impurities are adsorbed on the electrode plate; The oil floats up to the tank top and is discharged from the upper liquid outlet 9 of the tank top through the outlet pipe. The automatic frequency conversion voltage regulator 8 transforms the industrial power (380V) into the voltage used for separation. The electric field is connected through the high-voltage bellows 7 and introduced into the electrode plate 5 in the tank through the high-voltage inlet pipe 6, providing an electric field environment for the separation of waste oil liquid impurities.

The waste oil with the temperature of about 80 ℃ is pumped into the reaction tank at the speed of 2m / s, and the valves of other pipelines in the tank except the incoming pipeline are closed. When the waste oil is filled with about 30% of the capacity of the reaction tank, that is, the oil level does not cross the lower electrode plate, the electrode plate starts to be powered on and the ultrasonic generating rod starts to work. The waste oil began to be impacted by ultrasonic cavitation, and the wrapped water droplets and mechanical impurities began to separate. The separated water settles to the tank bottom due to the action of electric field and is discharged through the drainage pipe; The mechanical impurities are adsorbed by the electrode plate, and the waste oil clear liquid treated by the composite field floats on the upper layer of the liquid surface. The liquid level continues to rise until it does not pass through the liquid output pipe, and the treated oil on the upper layer is pumped out by the vacuum pump. The whole unit realizes the continuous treatment of waste oil compound field.

In terms of the effect of the specific implementation process, this equipment can better dehydrate and remove impurities from the waste oil. Around a horizontal 50m3 pretreatment device, 60 ultrasonic oscillators are set, with ultrasonic frequency of 32kHz, power in the range of 4~22W / cm2 and section of 800mm × Continuous action for 70s at sound intensity of 15W / cm2 at 100000mm; Under the same electric field, the sedimentation rate of mechanical impurities and water in waste oil
liquid is 60% higher than that of waste oil without ultrasonic action. The water content of waste oil shall not be greater than 0.2% (m) and the mechanical impurities shall not be greater than 1.0% (m).

4.3. Operation implementation process
(1) The dehydration and impurity removal of waste oil by composite field has achieved good results. For waste oil with different physicochemical properties, it can effectively separate water and mechanical impurities. In one reaction tank, the technical requirements for dehydration of waste oil and removal of suspended mechanical impurities can be met at the same time;

(2) At the same time, this equipment can be equipped with Beidou Positioning System and other systems and devices convenient for the supervision of government functional departments, so as to standardize the field of waste oil recovery in China and better guide small and medium-sized enterprises to dispose of waste oil through legal channels.

(3) The electric field intensity in the equipment can be adjusted by frequency regulator or according to the waste oil treatment capacity. The ultrasonic field intensity can be adjusted by the ultrasonic generator. The ultrasonic generator rod can provide the field strength of different ultrasonic power, break and refine the droplets in the waste oil, increase the volume of suspended impurities and speed up the separation speed;

5. Conclusion
The treatment of waste engine oil has become an important challenge for major enterprises in the world. The device can carry out efficient and rapid pretreatment of waste oil, and provides a new way for the treatment of subsequent processes and the reuse of waste oil. It can not only save a lot of oil purchase and treatment costs for enterprises, but also reduce the environmental pollution caused by improper oil treatment, and bring economic, environmental and social benefits to enterprises. It is believed that more and more such waste engine oil treatment devices will be put into use in the future production and life, so as to achieve a new breakthrough in the field of renewable resources in China.

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