Coupling Unit of Demulsification Device and Structural Optimization

Haifeng Gong, Bao Yu and Fei Dai

ABSTRACT

The demulsification dehydration of emulsified lubricating oil is very important in the resource recycling process of industrial waste oil. At present, it is difficult for traditional dehydration processes and devices to accomplish the demulsification dehydration treatment of waste oil with water quickly and efficiently. The coupling of high-voltage pulsed electric field and jet centrifugal field is put forward to accomplish the dehydration of emulsified oil rapidly. By the design of technological process and the use of FLUENT software, the optimal structure parameters of coupling unit, which is applied on the demulsification dehydration treatment of waste oil, are obtained. The double-field coupling demulsification device is designed and manufactured. The performance test results show that, the experimental results are basically consistent with the numerical simulation results, the double-field coupling demulsification dehydration device has a stable working performance and can achieve the oil-water separation of emulsified oil effectively and rapidly.

INTRODUCTION

Due to physical, chemical or human factors, lubricating oil can be easily emulsified. After a period of using, it becomes waste oil that the property degrades so that it cannot be used [1]. The resource recycling of waste oil has important
significance for solving the problem of energy shortage, environmental pollution and etc. [2]. The demulsification dehydration of emulsified oil is the first link in many resource recycling of waste oil process. But it is very difficult to deal the waste oil, which has generally high water content, complex impurity composition and so on [3]. The demulsification devices, such as gravity settlement tank, electric dehydrator and vacuum oil filter, are widely used. However, for waste oil with high water content, they have some limitations in the aspects of the treatment efficiency and energy consumption [4-6]. The coupling of high-voltage pulsed electric field and jet centrifugal field is emphatically discussed. It is use to accomplish the dehydration of waste oil rapidly. The design of double-field coupling demulsification device and the optimization design of associative architecture are accomplished.

TECHNOLOGICAL PROGRESS OF DEVICE

At present, using the vacuum oil filter in the dehydration treatment of waste oil is the most common way to finish oil-water separation [7]. As for the emulsion of waste oil, which has complicated structure and high water content, it is difficult for single physical means to accomplish the demulsification quickly and efficiently. Coupling two or more than two kinds of operation technology to complete the dehydration of waste oil is the mainstream of technology development in the future[8]. The process design conception of the double-field coupling dehydration is as follows: the accumulation and amplification of the minimal water drop in the waste oil is accomplished by using high-voltage pulsed electric field. Due to traditional gravity field is substituted by jet centrifugal field, the transfer of the water drop in the oil under the stronger centrifugal force has formed the outside helical flow with downward movement. The settlement process is accelerated. At last, the oil-water separation is accomplished quickly and efficiently.

According to the conception of process design, the practicality and maneuverability of the process are considered. The technological process of the double-field coupling demulsification dehydration device is designed, shown as figure 1.

In figure 1, to reduce the fragmentation of the water drop in oil, single screw pump is selected as the power source of device [9]. The emulsion of waste oil, which is from induction valve into coarse filter under the effect of the pump, removes part of solid impurity, such as metal particles, sand particles and etc. The high speed fluid is formed in the outlet of oil. It has been divided into two paths to enter the double-field coupling demulsification device. On the one hand, the water phase of separation enters the small oil tank; on the other, the oil phase of separation enters the large oil tank. Meanwhile, considering that a little amount of water with oil enters the small oil tank, a delivery valve is set on the bottom of oil tank to make oil-water mixture into pump and the coupling device again. The cyclic dehydration has been realized.
STRUCTURAL OPTIMIZATION

Coupling Unit Structure

The double-field coupling unit is integrated by the high-voltage pulsed electric field and jet centrifugal field. Coalescence of emulsion water droplet is completed in a short time by using high-voltage pulsed electric field. Jet centrifugal field can realize settling separation of the coalescence droplet in short time. In general, the
efficiency of demulsification dehydration of emulsified oil is improved, and the dehydration is realized quickly and efficiently [10]. The structural diagram of the double-field coupling unit is shown in figure 2.

**Optimization**

In the process of oil-water separation, more attention is at the purifying degree of output liquid, which is the dehydration rate of overflow port [11]. Therefore, this paper will use the formulation of clarification rate or net separation efficiency to assess that each structure parameter has influence on separation rate. The formula is shown as the following:

\[
E_c = 1 - \frac{\varphi}{\varphi_i}
\]  

(1)

When the dehydration rate is calculated, \(\varphi\) is used as the volume fraction of water in the overflow port. \(\varphi_i\) is used as the volume fraction of water in the inlet. When deoiling rate is calculated, \(\varphi\) is used as the volume fraction of oil in the overflow port. \(\varphi_i\) is used as the volume fraction of oil in the inlet.

By FLUENT software, the numerical simulations of oil-water separation of double-field coupling unit are conducted, the effects of different structure parameters on the oil-water separation efficiency are analyzed, and thereby the optimal structural parameters of coupling dehydration device are obtained, which is shown in TABLE I.

<table>
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<th>D</th>
<th>D_i</th>
<th>α</th>
<th>β</th>
<th>D_u</th>
<th>L_u</th>
<th>D</th>
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<th>L_0</th>
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<td>45mm</td>
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</table>

Figure 3. Dehydration device of double field coupling for wasted oil.

**DEVICE AND TESTING**

Based on the optimal structure parameters, the demulsification dehydration device of double field coupling for wasted oil is designed and manufactured. It is shown in figure 3.
To test the working performance of device, the experiment of device is conducted. In the experiment, the mixture of No.5 engine oil and water, which the volume fractions of water is 10%, is adopted. Stirred adequately and allocated to three groups, the oil, which the flow velocity is 9 m/s, is injected into coupling dehydration unit from two oil inlets by using screw pump. After the processing is completed, the sampling and testing of overflow and underflow discharge liquor. The results of three groups are shown in TABLE II.

From TABLE II, it is appearance that the test results of three times are fairly close. It shows that the coupling dehydration device has a stable working performance. The average value of three times test results is 90.8% and 66.6%. In the range of the errors permitted, the reliability of simulation results is fully verified. The dehydration rate of overflow, in three times tests, has more than 90%. It shows that the dehydration effect of double-field coupling dehydration device to emulsified is very good and it is highly efficient.

CONCLUSION

The coupling of high-voltage pulsed electric field and jet centrifugal field can accomplish the dehydration of emulsified oil rapidly. The double-field coupling demulsification device that has been designed and manufactured has a stable working performance and can achieve the oil-water separation of emulsified oil effectively and reliably.

The relative structure parameters in the double-field coupling device have a great influence on the efficiency of oil-water separation. Optimal design of structure parameters can be conducted by numerical simulation.

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| TABLE II. THE RESULTS OF SIMULATION AND TEST. |
|-----------------|------|------|------|------|
| index           | simulation | first | second | third |
| dehydration rate of overflow | 93.1% | 90.6% | 91.5% | 90.3% |
| deoiling rate of underflow | 68.2% | 66.5% | 67.4% | 65.9% |
REFERENCES