Research on Application of Hydrocyclone Microbubbles Generator in Flotation of Oil-Water Emulsion

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Abstract—With the improvement of environmental protection requirements, economical and efficient oily wastewater treatment methods have become a research hotspot. At the same time, the characteristics of microbubbles (large specific surface area, high zeta potential, rises slowly) make it very widely used in various fields, including the treatment of oily wastewater. There are many methods to generate microbubbles, and each method has its own applicable fields. In order to better apply microbubbles to the separation of emulsified, the experiment used a hydrocyclone to produce microbubbles. The ability of microbubbles to separate oil-water emulsions verified by the method of combining visual processing with oil content testing. The experiment shows that the hydrocyclone can generate a large number of small-sized microbubbles, and the microbubbles are stable in the emulsion for more than 30 minutes. In addition, the microbubbles can better float the emulsified oil and concentrate it on the water surface. After the treatment of microbubbles, the oily wastewater can be easily separated from oil.

1. Introduction
At present, the petrochemical industry produces a large amount of oily wastewater. With the increasingly serious environmental problems and stricter regulations, the purification of oily wastewater have become research hotspots. Among them, because of its special properties, microbubbles have become a good carrier for flotation of emulsified oil, and provide a good solution for oily wastewater treatment.

Microbubbles refer to bubbles with a diameter of 1-100μm. Compared with traditional bubbles, microbubbles have the characteristics of small diameter, slow rise, large specific surface area, high surface energy, and higher zeta potential\cite{1}. Based on these characteristics, microbubbles can achieve the effects of self-pressurization, adsorption of small particles, and promotion of free radical generation. Therefore, microbubbles have a very wide range of applications in materials\cite{2}, biomass energy\cite{3,4}, medical medicine\cite{5,6}, organic matter degradation\cite{7,8}, separation\cite{9-14} and other fields. Its broad application fields have made it attract more and more scholars' attention in recent years. At present, there are also preliminary research and application of microbubbles in the flotation of emulsified oil droplets\cite{13,14}. The emulsified oil is relatively stable in water, and the addition of microbubbles can drive the oil to float together and concentrate on the water surface.

The surface energy of microbubbles is much higher than that of ordinary bubbles. They are generally obtained by shearing larger bubbles in a high-speed turbulent liquid flow. At present, the research and application of microbubble generating devices are relatively mature, but they have their own shortcomings because they are based on different principles. For example, the Venturi type microbubble generator is a relatively common one. In the Venturi microbubble generator, bubbles are only generated...
near the wall at the junction of the throat and the expansion section, which limits its expanded application\cite{16,17}. Membrane production method\cite{18,19} and the electrolysis method\cite{20,21} can produce stable microbubbles, but the cost and energy consumption are high. The hydrocyclone microbubble generator can better make up for the above shortcomings. The research on the hydrocyclone microbubble generator can make it better used in industrial production, and treat wastewater with lower cost and higher efficiency. Therefore, we researched and manufactured a small hydrocyclone microbubble generator, and investigated the effect of microbubbles on the flotation of emulsified oil.

2. Methods and Materials
The microbubbles are produced by the hydrocyclone, the air inlet diameter is 1 mm and the bilateral inlet diameter is 6 mm, the internal diameter is 16 mm, the gas-liquid outlet diameter is 10 mm, and the copper mesh is wrapped at the outlet to increase turbulence to promote gas-liquid mixture. Fig. 1 shows the hydrocyclone microbubble generator used in the experiment. The water inlet on both sides of the hydrocyclone is connected to the pump and enters the water with 600 L/h flow. The liquid flow rotates at a high speed in the interior of the generator and produces a negative pressure in the center to inhale the gas. Therefore, the hydrocyclone microbubble generator does not need to be connected to the air pump.

![Fig.1 Hydrocyclone microbubble generator](image)

Emulsified oil is made of tap water and diesel oil. In order to realize the visualization of flotation, Sudan I (oil-soluble dye) is used to dye the oil. In order to ensure that the diesel oil is fully emulsified, it is slowly added from the inlet of the pump. After that, let the oil-water emulsions stand for 10 minutes to ensure that the emulsion is stable before proceeding to the next step.

To facilitate observation, the flotation experiment was carried out in a transparent PMMA container, and a control group without microbubbles was set. Pass water (600L/h) and air (100ml/min) into the hydrocyclone to generate microbubbles, and then pass the microbubbles into the prepared oil-water emulsions for 30 seconds. And oil content was measured by infrared spectrophotometer (JLBG-126, Jilin Jiguang Technology Co., Ltd.).

3. Results and Discussion

3.1 Visualization
In order to facilitate observation, microbubble flotation is carried out in a transparent container, which is divided into two parts: for flotation (A) and for control (B). Put the dyed emulsion into the container A and let it stand. At the same time, the microbubbles and oil-water emulsions are injection into container B through the hydrocyclone, then let it stand when the liquid level reaches the same height.

Figure 2 shows the surface layer of the oil-water emulsions in A and B after standing for 5 minutes. It can be clearly observed that there are flakes of oil floating on the surface in A, while B is still in a relatively stable state. Figure 3 shows the comparison of the surface layers of the oil-water emulsions in
the containers A and B after standing for 10 minutes. The surface oil slick in A increases significantly, but there is almost no change in B. This shows that the flotation effect of microbubbles on emulsified oil in water is obvious, and because of the stability of microbubbles, there is still flotation ability after 10 minutes.

3.2 Oil content

Curve A in fig. 4 shows the oil concentration in water decreases significantly at 0-10min and 20-30min, while the oil content in water changes little within 10-20min. In the first 10 minutes, the oil concentration decreased from 313.28mg/L to 246.63mg/L, and the treatment efficiency was 21.27%. And in 10-20 minutes, the oil concentration dropped to 239.37mg/L, the treatment efficiency was only 2.9%. In the next 10min, the concentration of oil dropped significantly, the treatment efficiency was increased to 36.84%. This may be due to uneven distribution of bubble sizes. Larger bubbles and tiny bubbles are more frequent, while the middle size bubbles are less frequent. In the early stage of flotation, larger bubbles carry oil droplets to float to the liquid level, and in the later stage, oil droplets are carried and float by the tiny bubbles. And curve B shows that in the absence of microbubbles, the oil-water emulsion is relatively stable, the oil content of the emulsion will not decrease.

4. Conclusions

1) Hydrocyclone can be used to produce microbubbles suitable for the flotation of oil-water emulsions.
2) The tiny bubbles can be kept in the emulsion for at least 30min.
3) Microbubbles can be used for the flotation of emulsified oil, which can concentrate the tiny oil droplets dispersed in water on the water surface.
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