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Study on recycling of waste water from spent water-soluble coolant †

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Abstract

We propose a recycling system that can recover the useful water from the spent water soluble coolant by using a surfactant and powdered activated carbon. The processing of about 70 liters of actual spent water soluble coolant yielded about 60 liters of clear water with 6.7 of pH and 0.0 of Brix value. About 120 liters of recycle water-soluble coolant was prepared by diluting an emulsion type cutting fluid 20 times with the recycle water. The recycle coolant has been showing the very similar Brix value and pH changes as those of virgin coolant until 100 days usage. The recycle coolant also showed the same potential to inhibit the progress of flank wear as that of virgin coolant. These facts indicate that the recycled water can be utilized as a dilutor of renewal water-soluble coolant.

Keywords: Recycling; Water-soluble coolant; Emulsion type cutting coolant; Brix value; pH; Flank wear

1. Introduction

A water-soluble coolant has been widely used as a cutting fluid in various machining process. The main problem with water-soluble coolants is that they become contaminated with use and have to be replaced with new ones, thus yielding waste coolant. The water soluble coolant contains over 300 kinds of substances and the waste coolant must be treated properly before disposal. The methods used in the treatment are based on the separation of the oily phase from the aqueous phase. Traditional treatment methods require high energy consumption or the application of a variety of chemicals, which decreases the processing efficiency and increases the cost of the process: 30 to 100 yen/L in Japan. In addition, the treated water phase often has high BOD and COD levels [1].

To reduce the management cost and environmental load of water-soluble coolant, we have been studying a recycling system for water-soluble coolant [2, 3]. In this paper, we propose a recycling system that can recover the useful water from the spent water soluble coolant by using a surfactant and powdered activated carbon. Then we show the system performance of recycling system obtained from the processing of actual spent water-soluble coolant on a 70 liter scale. Finally, we examined the fluid ability of recycle coolant through a drilling experiments.

2. Experimental

2.1 Description of recycle system

Fig. 1 shows the basic idea of recycle system for water-soluble coolant. The water-soluble coolant is usually deteriorated due to the oxidation of oily additives and contamination of tramp oils, chips and microorganisms. Although most of the contaminants can respond to well established processing techniques such as chemical processing and ultrafiltration, some components are difficult to separate. So the recovered water is not always drainable as an industrial waste water. In the proposed system, we considered that the recovered water is utilized as a dilutor of renewal coolant together with the difficult-to-separate components.

2.2 Water-soluble coolant

The spent water-soluble coolant had been used as a cutting fluid for about 6 months in a machining center of Yonago National College of Technology in Tottori. The original water-soluble coolant (virgin coolant) was prepared by diluting an emulsion type water-soluble cutting coolant, 20 times with tap water in Yonago city, Japan.

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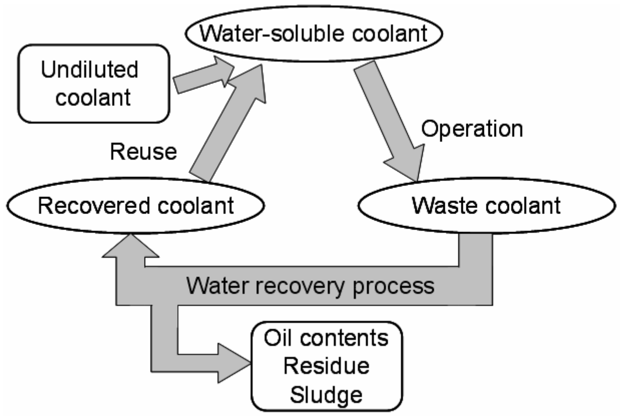

Fig. 1. Basic idea of recycle system for water-soluble coolant.

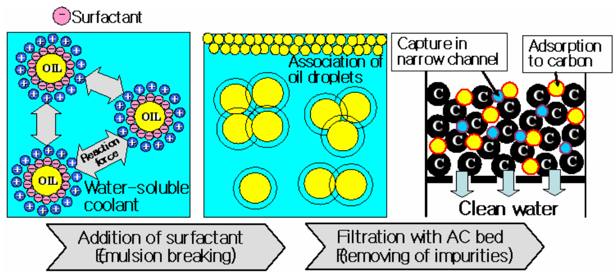

Fig. 2. Process of how to treat water-soluble coolant.

2.3 Processing of spent water-soluble coolant

About 70 liters of spent water-soluble coolant was processed by using a trial apparatus. Fig. 2 shows the process of how to recover the water from spent coolant. The water recovery process consists of three major steps. At the first step, the tramp oil, mostly lubricating oil, is removed by using a gravity flow with high frequency vibration. In the second step, the emulsified oil is separated from the coolant by adding a surfactant. Addition of surfactant gets rid of the stability of emulsion through reacting with the emulsifier already existing in the coolant. The water/oil separation leaves an aqueous solution containing some organic and inorganic substances. Finally, to recover the recycle water, the residual substances are separated from the aqueous solution by filtrating with powdered activated carbon bed.

2.4 Reusing of Recycle Water-soluble coolant

The recycle coolant was prepared by diluting the emulsion type water-soluble cutting coolant 20 times with recycle water. Before preparing the recycle coolant, the recycle water was heated up to 373K for 30 minutes to sterilize, because some pieces of microorganisms, which often promote the deterioration of water-soluble coolant, were retained in the recycle water. To observe the fluid ability change of virgin and recycle coolants in operation, we measured the Brix value, pH and anti-corrosion performance every two weeks. The Brix value is proportional to the concentration of effective components in the water-soluble coolant. To evaluate the fluid ability of recycle coolant, drilling tests were conducting intermittently ranging over the total of 100 days. The cutting conditions are summarized in Table 1.

Table 1. Cutting conditions in drilling test.

Tool	High-speed steel Parallel shank solid drill (without oil hole) Diameter 8 mm
Cutting speed	40 m/min
Feed	0.15 mm/rev
Work piece	Material : S50C Thickness : 25 mm (through hole)

3. Results and discussions

3.1 Performance of oil separating system

Before processing the actual spent water-soluble coolant with trial apparatus, the basic performance of the oil separating system was experimentally examined by using a small-scale (1L/batch) apparatus. The surfactant treatment and filtration with powdered activated carbon (AC) bed play the most important role in the water/oil separation. Fig. 3 shows the Brix value change against the dosage of surfactant, when an cationic surfactant was added into the virgin and spent water-soluble coolants. The Brix value maintained the initial value, around 6.0, until the dosage came up to about 1.0wt% and then descended suddenly down to around 0. At the moment when the Brix value was down to around 0, most of the oil phase was isolated in the upper layer. The Brix value started to increase gradually by dosing an excess surfactant.

The surfactant treatment left an aqueous solution containing some pieces of inorganic and organic substances. To separate these residues, the aqueous solution was filtered with powdered AC bed. In the powdered activated carbon bed, a large number of narrow channels were formed by consolidating the activated carbon powders under reduced pressure (320hPa). When the aqueous solution is passing trough the powdered AC bed, most inorganic and organic substances are absorbed on the activated carbon. The volume of filtrate increased in proportion to the filtration time and the virgin and spent coolants showed the same rate of filtration, about 0.03 $cm^3/cm^2 \cdot s$.

3.2 Water recovery from water-soluble coolant

About 70 liters of spent water-soluble coolant was processed by using a trial apparatus. Fig. 4 shows external appearances of coolant in the removal step of tramp oils, emulsion breaking step and powdered activated carbon filtration step. The material balance through the processing is summarized in Table 2.

The gravity flow with high frequency vibration can separate tramp oils continuously from the coolant and leave lubricating oil free coolant. In the emulsion breaking step, a cationic surfactant was mixed into the lubricating oil free coolant at about 10g per 1kg of coolant. The added surfactant obstructed the action of surfactants. As a consequence, the emulsified oil was separated as a floating matter. In this experiment, about 120g of floating oily content was generated per 1kg of lubricating oil free coolant. Removing the floating oily content left a yellowish brown aqueous solution containing some pieces of inorganic and organic substances. To eliminate these substances, the yellowish brown aqueous solution was filtered with powdered AC bed. The filtration of aqueous solution yielded about 60 liters of clear water with 6.7 of pH and 0.0 of Brix%.

Finally, the clear water was heated up to 373K for 30 minutes to sterilize because some pieces of microorganisms, which often promote the deterioration of water-soluble coolant, were retained in the water. To estimate microbial population in the recovered water, colony growth was examined by readymade culture plates. No colony growth of colon bacillus, staphylococcus and fungus was found as shown in Fig.5.

3.3 Fluid ability of recycle coolant

About 120 liters of recycle water-soluble coolant was prepared by diluting an emulsion type cutting fluid 20 times with a water mixture of 60 liters of recycle water and 60 liters of tap water. Fig. 6 shows the external appearance of recycle water and recycle coolant. No water/oil separation and the 3rd phase formation were found both in the recycle and virgin coolants. To keep a fluid's ability to perform its role in machining, the cutting fluid has its own optimum range in oil concentration, pH Level, microbial contamination and corrosion inhibition. Table 3 shows the essential characteristics of virgin and recycle coolants right after preparation. Both virgin and recycle coolants show the same characteristics and have the proper fluid properties as the cutting fluid.

To examine the aged deterioration of recycle coolant, the recycle coolant has been used as the cutting fluid in a machining center of Yonago National College of Technology since April 7th, 2008. The aged deterioration test of virgin coolant had also been done from July 7th, 2007 to March 21, 2008 by using the same machining center. Even after about 100 days usage, no breaking down or deterioration of emulsion was found in both virgin and recycle coolants. Fig. 7 shows the Brix value and pH changes of virgin and recycle coolants during the long time usage. The recycle coolant showed very similar Brix value and pH changes as those of virgin coolant until 100 days usage. Namely, the recycle coolant had the same service life as that of virgin coolant.

To examine the ability change of recycle coolant in the machining process, a drilling test was conducted intermittently for over 100 days. Fig. 8 shows the relation between the number of machine holes and tool wear. In the dry cutting condition, the drill was broken at the 36th hole drilling due to the adhesion. On the contrary, the recycle coolant showed the potential to inhibit the progress of flank wear as well as the virgin coolant. The flank wear was around 200 μm even after 100 holes drilling and there was no breaking down of drill. The long time usage, over 100 days, of recycle coolant also showed no effect on the flank wear; the recycling coolant kept its ability in drilling process at least for 100 days of usage.

Table. 2. Materials balance through processing of spent coolant.

Input	Spent water-soluble coolant	70 L
	Surfactant	0.7 kg
	Powdered activated carbon	1.05 kg
	Others River sand (Reusable)	
	Electric power	
Output	Recycle water	60 L
	Lubricating oil	4.0 kg
	Floating oily content	9.5 kg
	Activated carbon (Regenerative)	1.1 kg

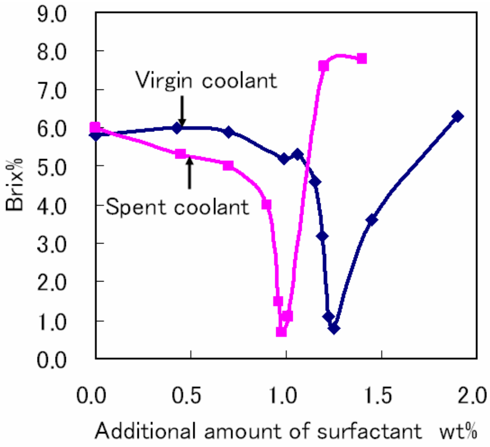

Fig. 3. Relation between dosage of surfactant and Brix value.

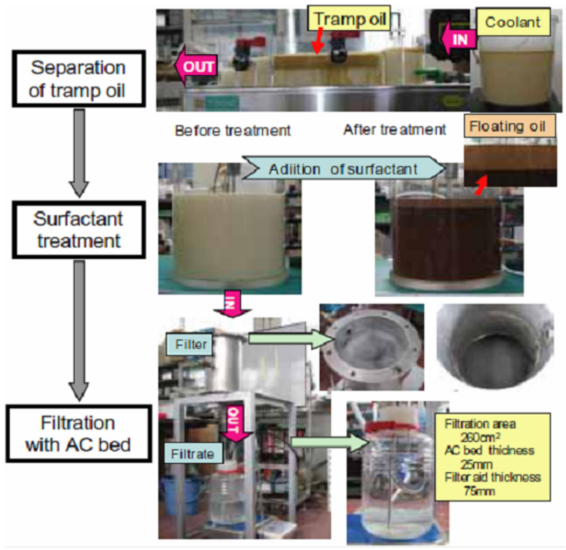

Fig. 4. External appearance change of actual spent coolant through the processing.

Table. 3. Characteristics of virgin and recycle coolants.

	Brix% (Oil content)	pH	Population of microorganisms	Corrosion inhibition
Virgin coolant	5.3	9.4	none	Good
Recycle coolant	5.4	9.3	<10^2 (count)	Good

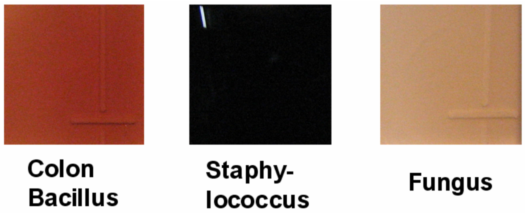

Fig. 5. Colony growth in recycle water.

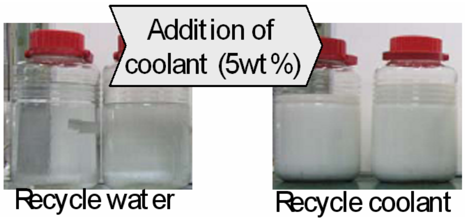

Fig. 6. External appearance of recycle water and coolant.

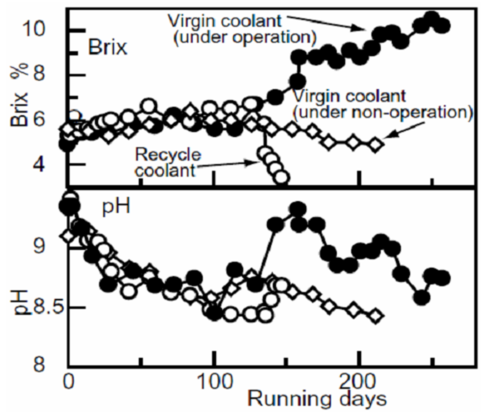

Fig. 7. Brix value and pH changes during long time usage.

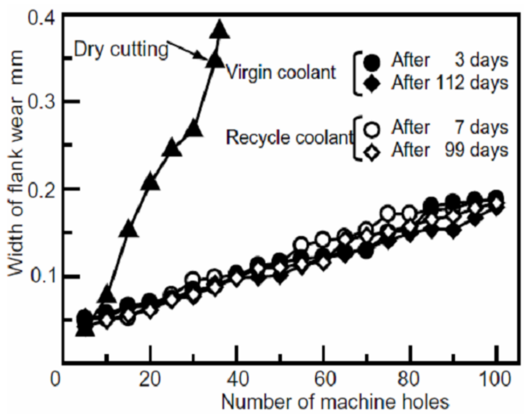

Fig. 8. Relation between number of holes and tool wear.

4. Conclusions

We propose a recycling system that can recover the useful water from the spent water soluble coolant by using a surfactant and powdered activated carbon. The processing of about 70 liters of actual spent water-soluble coolant yielded about 60 liters of clear water with 6.7 of pH and 0.0 of Brix value. No colony growth of colon bacillus, staphylococcus and fungus was found in the recycled water.

About 120 liters of recycle water-soluble coolant was prepared by diluting an emulsion type cutting fluid 20 times with a water mixture of 60 liters of recovered water and 60 liters of tap water. The recycled coolant had been used as the cutting fluid in a machining center since April 7th, 2008. The recycled coolant showed a very similar Brix value and pH changes as those of virgin coolant until 100 days usage. Namely, the recycle coolant had the same service life as that of virgin coolant. The recycle coolant also showed the potential to inhibit the progress of flank wear as well as the virgin coolant. In addition, the long time usage, over 100 days, of recycle coolant showed no effect on the flank wear. This means that the recycled water can be utilized as a dilutor of renewal coolant.

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