



INNOVATIVE ECONOMY
NATIONAL COHESION STRATEGY



**INSTITUTE
FOR SUSTAINABLE
TECHNOLOGIES**
NATIONAL RESEARCH INSTITUTE IN RADOM

EUROPEAN UNION
EUROPEAN REGIONAL
DEVELOPMENT FUND



Project co-financed by the European Union from the European Regional Development Fund

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A DEVICE AND A METHOD FOR RECYCLING EMULSION CUTTING FLUIDS

Key words

Waste cutting fluids, recycling, coagulation, post-emulsion water.

Abstract

Environmental requirements, increasing costs, and water usage are generating the need for closed water cycles in the production processes and for reclaiming water from sewage. Activities in this regard also include the emulsion fluids used in subtractive machining processes used as mixtures with 90–98 percent water. This article presents a method for recycling waste cutting fluids consisting in separating of the oil/water emulsion and treating the water to the level that will allow its reusing for technical purposes. The waste emulsion fluids that had been used in subtractive steel machining were subjected to testing after coagulation, barrier filtration, adsorption, and aeration. The subsequent processes were carried out using the developed device. The changes between the physicochemical properties of the cutting fluid and the reclaimed water phase were determined to reflect the effectiveness of the processes. The reclaimed water was subjected to a detailed analysis of its physicochemical properties, which would consequently determine its suitability for reuse for the manufacturing of cutting fluid. It was found that, as a result of destabilization

processes and wastewater treatment, the reclaimed water properties that allow its reuse for technological purposes were restored. The method and the device can be used in the metal industry.

Introduction

In Poland, the annual consumption of the concentrates for metal machining is at about 8.7 thousand tonnes. These are concentrates, intended to be used as 2–10% emulsions or water solutions [1, 2]. Therefore, the amount of generated waste fluids can reach as much as 87–435 thousand tonnes. In view of the complex chemical composition and the presence of ecologically harmful components, the European Commission Decision 2000/532/EC of May 3, 2000, and in the Waste Act from April 27, 2001, deemed waste cutting fluids hazardous waste [3, 4]. In contrast to other wastes, they must be treated separately in regards to the disposal and they must be rendered harmless [5, 6]. The most effective technique for the disposal of waste cutting fluids is the separation of oil/water emulsions and the maximum recovery of the resultant ingredients. Due to more than 90% water content, an important step in the recycling of cutting fluid is the separation of emulsion into a water phase and an oil phase. Subsequently, the treatment of the obtained water phase must be rendered to a state allowing its reuse for technical purposes or safe introduction into the wastewater system, and the maximum density of separated sludge must be reached. As a result, this leads to minimizing the amount of produced sewage of hazardous waste and protecting water resources [7–9].

For separating waste water-oil emulsion, chemical, physicochemical, electrochemical, and physical methods are used. Chemical methods are based on the destabilisation effects of selected chemical compounds on the Stern ion layer surrounding individual droplets of oil, then their coalescing and the production of emulsion. Physicochemical methods include the small droplet process of aeration, the evaporation of the water phase, flocculation, and the destruction of the oil phase by special strains of bacteria. Electrochemical methods are based on a process of the destabilization of emulsions in an electrostatic field and electrocoagulation. Modern physical methods include filtration, using membranes working in the micro- and ultrafiltration. Especially effective is the de-emulsifying method using specially introduced components. They are inorganic salts of metals and inorganic acids or polymeric organic compounds. In addition, carbon dioxide and hydrogen peroxide can be used. [10–14].

The article presents a method and a device for destabilising waste cutting fluids by chemical methods and a multi-step wastewater treatment of the water phase.

1. Characteristics of the method and the device for recycling of waste cutting fluids

Waste cutting fluid recycling occurs in two basic stages – destabilisation of the fluid and the treatment of the separated water phase. The diagram for this method is presented in Fig. 1.

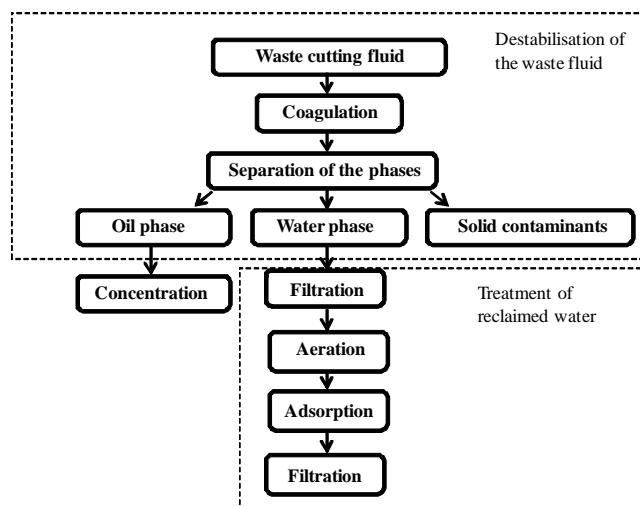


Fig. 1. Diagram of the recycling method for cutting fluid

The destabilisation of the fluid is achieved by the process of coagulation. Prior to the process, the Chemical Oxygen Demand is evaluated. The COD assessment allows a preliminary estimation of the concentration of coagulant required to effectively destabilize the fluid. Since waste cutting fluids are characterized by very diverse chemical composition, a suitable type of coagulant is selected at this stage. The process utilises organic polymer coagulants and sulphates of aluminium and iron. The coagulation process runs in the processing Tank I, at room temperature. In order to carry out destabilizing of the fluid, small portions of the coagulant are introduced during mixing. Contact of components is maintained for 30 min during continuous stirring. This is followed by a process of settling and sedimentation. After a clear separation of the water and oil phase (20–24 h), the oil phase is drained from the tank. It is transferred to the filtration press, where it is subjected to a process of filtration and concentration. Meanwhile, the water phase is subjected to a process of treatment by the barrier filtration method. The process lasts for 30 minutes, and after this time, the water is pumped to processing Tank II, where the water is subjected to adsorption and aeration or just aeration. The quantity of the adsorbent necessary to carry out the process depends on the rate of the COD

indicator of the reclaimed water phase. In order to carry out the process of adsorption during mixing, the absorbent is introduced into the water. The mixing lasts 30 minutes. After this time, the water is subjected to a filtration process, while aeration may be conducted before or after the adsorption process. Optionally, instead of aeration, a deep oxidation reaction can be applied. The treatment is carried out until the required parameters are obtained (Tab. 1). The quality of the water described by the parameters is sufficient for reusing it in the manufacturing of cutting fluid [15].

Table 1. Critical values of recycled post-emulsion water

Parameter	Critical value	Research method
COD, O ₂ mg/dm ³	< 1000	PN ISO 6060: 2006
Total organic carbon, mg/dm ³	< 200	PN-EN 1484:1999
pH	6.5–9.0	PN-EN ISO 0523:2012
Dissolved substances content, mg/dm ³	< 500	PN-C-04541:1978
Organic compounds content, ppm	< 10	Infra-Cal analyser

The processes of the destabilization of waste cutting fluids and the treatment of the separated water phase are carried out using the developed and manufactured device shown in Fig. 2.



Fig. 2. A device for the recycling of waste cutting fluid

Technical specifications of the device are as follows:

- Destabilizing output – 200 dm³/24h
- Filtration output – 100 dm³/h
- Aeration output – 120–150 dm³/min,
- Oil fraction separation output – 30 dm³/10 min
- Filtration size – 5–15 μm
- Processing tank volume – 200 dm³
- Electrical supply – 380 V, 50 Hz
- Semi-automatic control.

The basic technological modules are the following:

- The destabilisation module for waste cutting fluid, which is used to separate oil and water phase in the fluid;
- A module for sludge separation and thickening, which aims to isolate the separated oil phase and to concentrate it by separating out the remaining water;
- The barrier filtration module, which is used to remove solid pollutants from the separated water phase; and,
- The post-emulsion water treatment module, which is designed to remove dissolved organic and inorganic components from the water.

The modular construction of the device allows any configuration according to the technological needs.

2. An example of the recycling process of waste cutting fluids

Using the constructed device, the recycling of used cutting fluids was performed. There were two types of emulsion fluids. In the first stage, the type and amount of coagulant was selected, which is required to carry out the process of the destabilisation of the fluid. In both cases, it was the hydrated aluminium sulphate. The coagulant concentration was 0.25% for Fluid I, and 0.28% for Fluid II. The water separated after the destabilisation both for Fluid I and II was subjected to barrier filtration by a set of three filters with a filtering size of 5 μm. Next, the purified water from Fluid I was aerated and subjected to adsorption using solid adsorbents. The adsorbent was bleaching earth with a maximum grit size 0.2 mm and specific surface area of 75 m²/g. The aeration supported intensive growth of bacteria and biological treatment of water. The aeration process lasted 10 days at room temperature. Adsorption was performed at 5% concentration of bleaching earth, also at room temperature. Tab. 2 shows the change of physicochemical properties of waste cutting Fluid I subjected to the process of coagulation and of the separated water after aeration process and adsorption.

Table 2. Changes of physicochemical and microbiological properties of waste emulsion cutting Fluid I after subsequent treatment processes

	Research method	Waste Fluid I	Reclaimed water phase	Water after aeration	Water after adsorption
COD, O ₂ mg/dm ³	PN ISO 6060: 2006	45 000	5 100	2 300	800
Oil content, ppm	Infra-Cal analyser	29 000	70	50	15
pH	PN –EN ISO 10523:2012	6.8	6.6	6.3	6.0
Bacterial content	dip slide	10 ⁷	10 ⁷	10 ⁷	10 ⁷
Fungus content	dip slide	medium	medium	medium	medium
Conductivity mS/cm	PN-EN 27888:1999	–	–	1.06	1.10
The content of dissolved substances, g/l	PN-C-04541:1978	–	–	0.5	0.4
Total organic carbon, mg/dm ³	PN-EN 1484:1999	–	–	650	120

Waste cutting Fluid I was characterised by a high content of oxidating organic and some inorganic biodegradable components, which is indicated by the high value of the COD. It contained many oil components and was contaminated with bacteria at a high level and with fungus at a medium level. After destabilising, the separated water phase had a 9-fold lower value of COD and 400-fold less oil content. Microbiological contamination did not change, but there was a slight change in pH towards an increase in acidity. After the subsequent processes of aeration and adsorption, a further reduction in the content of organics and oils occurred in the fluid and a slight increase in acidity. After the adsorption, the fluid conductivity, which reflects the presence of ions (cations and anions), increased slightly, which could be a result the introduction of ions from the bleaching earth in the acid used as an activator. The value of total organic carbon decreased more than 5-fold. The microbiological contamination of the fluid remained unchanged. It was necessary to disinfect the water phase with UV radiation, which reduced contamination of bacteria to a level of 10³. The fungi content was not found. As a result, the treated water, separated from the waste cutting liquid reached the level of properties that allowed its re-use as a thinner for cutting fluid concentrates.

Because waste cutting Fluid II did not contain bacteria or fungi, in the process of treatment of the separated water phase, aeration was replaced by deep oxidation. The basic reaction reagents were hydrogen peroxide and ferrous sulphate. The process was carried out at a temperature of about 70°C, in the presence of a catalyst. After oxidation, the water was subjected to the adsorption process using bleaching earth at 3%. Tab. 3 shows the changes in the

physicochemical and microbiological properties of waste cutting Fluid II subjected to the process of coagulation and treatment of the separated water phase.

Table 3. Changes of physicochemical and microbiological properties of waste emulsion cutting Fluid II after subsequent treatment processes

	Research method	Waste Fluid II	Reclaimed water phase	Water after oxidation	Water after adsorption
COD, O ₂ mg/dm ³	PN ISO 6060: 2006	66 000	8 100	2 900	750
Oil content, ppm	Infra-Cal analyser	37 000	90	60	8
pH	PN –EN ISO 10523:2012	7.3	7.0	6.9	6.6
Bacterial content	dip slide	none	none	none	none
Fungus content	dip slide	none	none	none	none
Conductivity mS/cm	PN-EN 27888:1999	-	-	1.11	1.11
The content of dissolved substances, g/l	PN-C-04541:1978	-	-	0.8	0.8
Total organic carbon, mg/dm ³	PN-EN 1484:1999	-	-	700	100

Compared to Fluid I, waste cutting Fluid II contained a larger amount of organic and inorganic pollutants, susceptible to the action of oxygen (higher COD) and oil ingredients. However, they did not contain bacteria or fungi. After the coagulation, the separated water phase was characterised by the COD value that was 8-fold lower than the fluids and oil content of 400-fold lower. Subjecting the water to subsequent treatment processes resulted in further improving its quality. As a result, the process of adsorption and deep oxidation applied in the separated water phase resulted in obtaining high-quality water. The treated water had a low COD value, practically contained no oil, was not contaminated with bacteria or fungi, and the contents of the soluble substances and substances present in organic compounds was low. The high level of assessed properties allowed its re-use in technology.

Conclusions

The results of research showed that the described method for recycling waste emulsion cutting fluids, implemented using the constructed device, provides the means to reclaim the water used for the preparation of these fluids and to give it a quality suitable for its reuse in technological processes. The treated water was characterised by low values of indicators reflecting the

presence of compounds dissolved and suspended in water, organic and inorganic, oil ingredients, and cations and anions. This indicated an effective destabilisation of waste fluids, a separation of the water phase, and the removal of the remains of the cutting fluid and coagulant components. Using the developed methods and the designed device provides the means to use it on-site of the waste cutting fluid.

Taking into consideration the amount of cutting fluid used quid per year (over 400 thousand tonnes), containing more than 90% water, even a one-time reclamation treatment and returning part of it to service brings a quantifiable economic effect and an incalculable but a very important ecological effect embracing the global trends in the protection of water resources.

Scientific work executed within the Strategic Programme “Innovative Systems of Technical Support for Sustainable Development of Economy” within Innovative Economy Operational Programme.

References

1. Ciecze do obróbki metali, Część III, Mechanik, 2005 (5–6), s. 507–510.
2. Ciecze do obróbki metali, Część IV, Mechanik, 2005 (7), s. 621–624.
3. Decyzja Komisji 2000/532/WE z 3 maja 2000 r.
4. Ustawa z 27 kwietnia 2001 r. Prawo Ochrony Środowiska.
5. Steinmec F. i inni, Uwarunkowania ekologiczna stosowania emulsji olejowo-wodnych w obróbce wiórowej metali. Nafta-Gaz, 2000 (10), s. 605–615.
6. Chaaban Moustafa A., Hazardous waste source reduction in materials and processing technologies, Materials Processing Technology, 2001 (119), pp. 336–343.
7. Ostrikov V.V. i inni, Waste-free technology for processing used lubricating oil, Chemical and Petroleum Engineering, 2003 (39), pp. 292–297.
8. Podniadło A., Paliwa, oleje i smary w ekologicznej eksploatacji, WNT, Warszawa 2002.
9. Listwan A. i inni, Podstawy gospodarki odpadami niebezpiecznymi, Politechnika Radomska, 2009.
10. Włodarczyk A., Warchoń A., Ginalski J., Ultrafiltracja jako sposób rozdzielania emulsji olejowo-wodnych, Nafta-Gaz, 2002 (1), s. 45–49.
11. Cheng Ch., Phipps D., Alkhaddar R.M., Reviw. Treatment of spent metalworking fluids. Water Research, 2005 (39), pp. 4051–4063.
12. Cambiella A. i inni, Treatment of oil-in-water emulsions: Performance of a sawdust bed filter, Journal of Hazardous Materials, 2006 (B131), pp. 195–199.

13. Hilal N. i inni, Treatment of waste coolants by coagulation and membrane filtration, *Chemical Engineering and Processing*, 2004 (43), pp. 811–821.
14. Nadarajah N., Singh A., Ward O., De-emulsification of petroleum oil emulsion by a mixed bacterial culture, *Process biochemistry*, 2002 (37), pp. 1135–1141.
15. Sprawozdanie z realizacji projektu badawczego pt. „Opracowanie metody destabilizacji emulsji wodno-olejowych dla celów utylizacji cieczy obróbkowych”, ITeE – PIB, Radom 2009.

Metoda i urządzenie do utylizacji emulsyjnych cieczy obróbkowych

Słowa kluczowe

Zużyte ciecze obróbkowe, utylizacja, koagulacja, wody poemulsyjne.

Streszczenie

Wymagania środowiskowe oraz rosnące koszty i zużycie wody generują potrzebę zamykania obiegów wodnych w procesach produkcyjnych oraz odzysku wody ze ścieków. Działania w tym zakresie obejmują także emulsyjne ciecze obróbkowe stosowane w procesach ubytkowej obróbki metali jako 90–98-procentowe mieszaniny z wodą. W artykule przedstawiono metodę zagospodarowania zużytych cieczy obróbkowych polegającą na rozdzieleniu emulsji olej/woda oraz uzdatnieniu wydzielonej fazy wodnej do postaci umożliwiającej ponowne wykorzystanie jej w celach technicznych. Badano zużyte ciecze emulsyjne stosowane podczas ubytkowej obróbki elementów stalowych poddane procesom: koagulacji, filtracji przegrodowej, adsorpcji i napowietrzaniu. Kolejne procesy realizowano za pomocą opracowanego urządzenia. Wyznaczono zmianę fizykochemicznych właściwości cieczy obróbkowych oraz odzyskanej fazy wodnej odzwierciedlające skuteczność stosowanych procesów. Odzyskane wody poddano szczegółowym badaniom fizykochemicznym decydującym o możliwości ich ponownego wykorzystania do wytwarzania cieczy obróbkowych. Stwierdzono, że w wyniku zastosowanych procesów destabilizacji i uzdatniania ze zużytych cieczy obróbkowych odzyskuje się wody o właściwościach pozwalających na ponowne ich wykorzystanie w celach technologicznych. Metoda i urządzenie mogą znaleźć zastosowanie w przedsiębiorstwach przemysłu metalowego.

