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Recycling Methods for Cutting Medium in Automotive Engine Factories

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Abstract: During the production process, a large amount of cutting medium is required for cooling, and these medium will be contaminated and aged over time, leading to a decrease in their performance. In order to reduce the generation of waste and resource consumption, recycling cutting medium has become the main solution. This study uses regeneration methods such as filtration, centrifugal separation, chemical treatment, and adsorption to regenerate and reuse cutting medium from automotive engine factories. This study evaluated the effectiveness and feasibility of the regeneration treatment method through comparative experiments and analytical tests. The experimental results show that the cleanliness of the cutting oil before regeneration is between 30% -35%, and after regeneration treatment, its cleanliness reaches 85% -93%. The regeneration treatment method can effectively remove suspended solids and dissolved impurities in the cutting medium, significantly improving its cleanliness.

1. Introduction

If we want to maintain the normal operation of the engine and ensure machining quality, the traditional practice of frequent replacement of cutting medium not only leads to resource waste, but also generates a large amount of waste, which has a negative impact on the environment. Therefore, developing a feasible regeneration and reuse method for effective treatment and purification of cutting medium has important practical significance. This article uses regeneration methods such as filtration, centrifugal separation, chemical treatment, and adsorption to purify and restore cutting medium. The significance of this research method lies in solving the problem of traditional replacement of cutting medium, achieving resource conservation and recycling. By regenerating and reusing cutting medium, not only can production costs be reduced, but also the generation of waste can be reduced, reducing the negative impact on the environment and achieving the goal of sustainable development.

This article first introduces the background and research significance of cutting medium regeneration and reuse, and then provides a detailed introduction to the regeneration treatment methods used, including filtration, centrifugal separation, chemical treatment, and adsorption processes. Next, this article evaluates the effectiveness and feasibility of the regeneration treatment method through experiments and analytical testing. Finally, the research results are summarized and the advantages and potential challenges of regenerating and reusing cutting medium are discussed.

2. Related Work

Many scholars have conducted research on the regeneration of cutting oil. Zhao Yan introduced a design technology for a cutting fluid filtration device, which achieved precision filtration and self-cleaning filtration of cutting fluid through hydraulic systems and control methods. The high-precision filtered cutting fluid will be used in various functional links of the machine tool, avoiding problems such as clogging of the filter element in the filter tank and frequent shutdown and replacement in conventional filtering methods, or complex and expensive design of separate filtering units [1]. Li Liang used coolant oil pressure as a single factor variable to analyze Φ CFD simulation and experimental research were conducted on the flow field of a 17 mm standard gun drill, exploring the influence of coolant oil pressure on cutting forming and fracture. The results indicated that the flow of coolant in the early stage of cutting forming would strengthen the lateral curling of cutting, thereby affecting the radius of cutting spiral curling and the number of cutting spiral coils [2]. Wu Mingyang theoretically analyzed geometric characterization models such as the degree of sawtooth, sawtooth frequency, and sawtooth step distance. He conducted experiments on cutting GH4169 nickel based high-temperature alloy with polycrystalline cubic boron nitride (PCBN) tools under high-pressure cooling conditions, and prepared and polished samples for cutting under different cutting amounts and coolant pressures to analyze the morphology and characterization of serrated cutting [3]. Liu Yaowei proposed a laser displacement measurement error compensation method for residual cutting fluid surfaces based on multi wavelength collaboration. The results showed that the absolute value of measurement error after compensation was less than 0.01 mm, and compared with the uncompensated measurement data, the error decreased by at least 92% [4]. Liu Qinglun designed a magnetic enhanced high-pressure cutting fluid cutting system to address the issues of high filtration accuracy, large filtration volume, and the need for manual replacement of filter elements in the cutting fluid circulation system of high-speed machining CNC machine tools. The rapid replacement of multiple modules designed through magnetic enhancement can improve the solid-liquid separation ability of magnetic cutting and increase the filtration effect [5]. Wu X elucidated the key scientific issues in the research on eco-friendly cutting fluids and waste liquid treatment [6]. Li H analyzed the film-forming mechanism of inorganic corrosion inhibitor oxides and precipitation films [7]. Katna R introduced readers to the current application status of non edible vegetable oils and their applications in mechanical processing [8]. Anand R aimed to investigate the synergistic effect of TiO_2 and GnP nano additives on the rheological and processing properties of biodegradable vegetable oils [9]. Mardonov U investigated the differences in permanent effects between magnetic fields and pulsating electromagnetic fields on cutting fluids [10]. These studies have provided great help for this article, which will further explore the regeneration methods of cutting fluid.

3. Method

3.1 Cutting Medium

In the manufacturing process of automotive engines, cutting is an important machining process used to manufacture various components of the engine. During the cutting process, a large amount of cutting will be generated. If these cuts are not discharged in time, they will interfere with the cutting process, reduce machining efficiency and quality [11-12]. However, cutting medium can effectively flush and remove the cutting, ensuring the smooth progress of the cutting process. Its selection and application can also have an impact on the quality of the workpiece surface. The appropriate cutting medium can improve the smoothness and roughness of the cutting surface, reduce burrs and surface defects during the cutting process, and improve the machining accuracy and surface quality of the workpiece. By providing cooling and lubrication effects, cutting medium can reduce friction and heat accumulation between tools and workpieces, effectively reduce tool wear speed, improve cutting efficiency and economy [13-14].

3.2 Cutting Oil Regeneration

The cutting medium will mix with the cutting fluid to form a suspension containing particles, grease, and other solid impurities. Through the principle of screening and separation, membrane filtration can remove these solid particles and impurities from the cutting fluid, reduce their concentration, improve the quality and reusability of the cutting fluid. Selecting appropriate membrane materials and types for filtration based on the characteristics of the cutting medium. The commonly used membranes are microfiltration membranes or ultrafiltration membranes [15-16], whose pore size can effectively filter out solid particles and macromolecules in the cutting fluid. The pre treated cutting fluid is fed into a membrane filtration system, which usually consists of a membrane module, filter element, and filtration equipment. The cutting fluid passes through the filter element in the membrane module, and solid particles and impurities are blocked by the membrane. Pure cutting fluid flows out through the membrane pores, and the filtration effect and processing capacity are controlled by adjusting the pressure and flow rate during the filtration process [17-18]. As filtration progresses, solid particles and impurities accumulate on the membrane surface, leading to membrane blockage and reduced filtration efficiency. Therefore, regular cleaning and maintenance are necessary as they can remove dirt and sediment from the membrane surface and restore the filtration performance of the membrane.

3.3 Emulsion and Cleaning Agent Regeneration

The viscosity of emulsions and cleaning agents is relatively small, and impurities in the medium are relatively easy to filter, so the difficulty of reuse is relatively small. The same thing as cutting oil is that the emulsion and cleaning agent also come with a vibrating filter membrane during the recycling process. The filtration accuracy of the emulsion is 70 microns, and the filtration accuracy of the cleaning agent is 10 microns. Unlike cutting oil, the surface of the vibrating membrane does not need to be coated with bamboo fibers, so there is no oil sludge generated, and the system does not require built-in pressure filtration equipment. The emulsion needs to be updated after 1 year of cyclic use, and the update cycle for cleaning agents is 3 months. The replaced waste liquid is filtered through a regeneration system through a vibrating membrane with a filtration accuracy of 0.45 microns. Finally, 5% of the concentrated liquid is disposed of as hazardous waste, and 95% of the emulsion and cleaning agent are tested and evaluated as qualified before entering the circulation system for continued use [19-20].

3.4 Cutting Medium Detection and Evaluation

The evaluation parameters of cutting oil mainly include kinematic viscosity (40 ℃), total acid value, water content, cleanliness, and appearance. Kinematic viscosity is an important indicator for measuring its viscosity and flowability, which can be measured at 40 degrees using a viscometer. The total acid value measures the content of acidic components in cutting oil, and excessive total acid value may increase the corrosiveness of cutting oil. The moisture content in cutting oil has a significant impact on its performance and stability, and is usually measured by a water analyzer. The cleanliness of cutting oil indicates the presence of impurities, solid particles, or precipitates inside, and the appearance evaluation can observe its transparency and color changes. The important parameters that need to be tested and evaluated for emulsions are concentration (titration method), defoaming performance, rust prevention performance, bacteria (24 hours), pH value, floating/impurities, conductivity, chloride ion content, and lubrication performance. The important parameters that need to be tested and evaluated for cleaning agents are concentration (titration method), rust prevention performance, bacteria (24 hours), and pH value. Table 1 shows the detection results of a cutting medium:

Table 1: Testing Results

Parameter	Cutting Oil	Emulsion	Cleaning Agent
Kinematic Viscosity (40℃)	15.2 cSt		
Total Acid Value	0.12 mg KOH/g		
Water Content	0.05%		
Cleanliness and Appearance	Pass		
Concentration (Titration Method)		5.2%	3.8%
Defoaming Performance		Excellent	
Rust Protection Performance		Pass	Pass
Bacteria (24 hours)		8.5	9.2
Suspended Solids/Impurities		Moderate	
Conductivity		650 μS/cm	
Chloride Ion Content		15 ppm	
Lubrication Performance		Good	
Bacteria (24 hours)		<10 CFU/mL	<10 CFU/mL

4. Results and Discussion

4.1 Process

Collecting cutting oil that needs to be recycled and make it into 20 cutting oil samples. 20 samples were filtered using vibrating and non-vibrating filter membranes, and the blockage time of these samples during filtration was tested. After filtration, the pH value and cleanliness of the samples before and after filtration were measured, which were used as evaluation indicators in this study?

4.2 Results

The blockage time can well reflect the performance of vibrating and non-vibrating filter membranes in the regeneration and utilization of cutting oil. The shorter the time required for blockage to occur, the less ideal the filtration effect is, and the filter membrane needs to be replaced frequently. If the blockage occurs for a long time, it indicates that the filtration performance of the membrane is good, which can avoid the problem of frequent membrane replacement in a short period of time. Figure 1 shows the blockage time test:

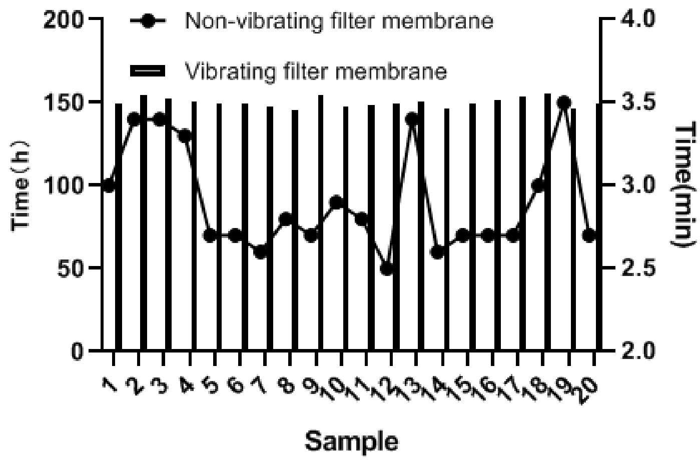

Figure 1: Blockage time

During the recycling process of cutting oil, it comes with a built-in filtration device. Firstly, we chose a vibrating filtration membrane with a filtration accuracy of 70 microns. Compared with non-vibrating filtration membranes, vibrating filtration membranes maintain the boundary between the solid and the membrane during the vibration process, ensuring that the filtration process is not easily blocked. The experiment shows that in a specific cutting fluid medium, the average time for the first blockage of the non-vibrating filter membrane is 3 minutes, and the average time for the first blockage of the vibrating filter membrane is 150 hours. Secondly, in order to prevent blockage during the filtration process, a bamboo fiber coating is added around the filter membrane. The function of the coating is to adsorb solid small particles in the cutting fluid, provide a boundary between the solid and the filter membrane, and prevent particles from blocking the filter membrane. When the adsorption of bamboo fibers has reached saturation, a pressure difference is formed, which triggers the equipment to perform backwashing. The bamboo fibers that are filled with oil stains after flushing are a one-time oil sludge. The primary oil sludge contains a large amount of cutting oil. After being pressed by the equipment's built-in press, the cutting oil directly enters the circulation system for continued use. The pressed secondary oil sludge is discharged through pipelines. Before the regeneration and reuse of cutting oil, the secondary oil sludge is disposed of as hazardous waste, which not only wastes cutting oil raw materials but also increases the cost of hazardous waste disposal. After the introduction of secondary pressure filtration equipment, the secondary oil sludge is subjected to deep pressure filtration and filtered through filter cloth to obtain 35% mass ratio of crude oil. The remaining 65% mass ratio of tertiary sludge is ultimately disposed of as hazardous waste. 35% of the crude oil is filtered through a vibrating membrane with a filtration accuracy of 0.2 microns. Finally, 5% of the concentrated waste oil is disposed of as hazardous waste, and 30% of the cutting oil is tested and evaluated as qualified before entering the circulation system for continued use.

The change in pH value after cutting oil regeneration treatment can provide clues about the treatment effect. If the regeneration treatment is effective, the pH value of the cutting oil may return to the normal range. This indicates that the regeneration process has successfully removed acidic or alkaline substances, restoring a good acid-base balance to the cutting oil. Figure 2 shows the pH changes before and after cutting oil regeneration:

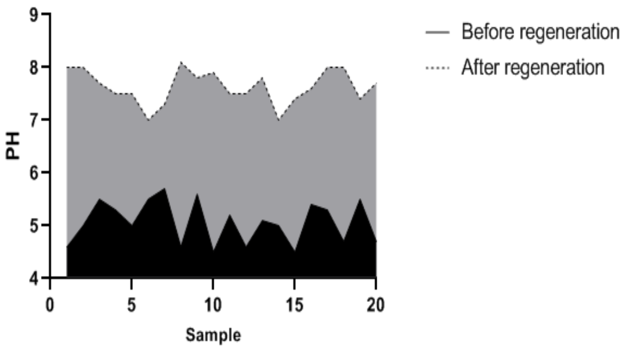

Figure 2: Changes in pH

After testing and comparing the pH values, it was found that the pH value of cutting oil significantly increased after regeneration treatment. The pH values of 20 initial samples ranged from 4.5 to 5.7, and after regeneration treatment, their pH values increased to 7 to 8.1. There may be excessive alkaline substances in cutting oil, and during regeneration treatment, acidic substances or acidic treatment methods may be used to neutralize or remove these alkaline substances. The neutralization of alkaline substances can also lead to an increase in the pH value of cutting oil.

Cleanliness can reflect the content of suspended solids in cutting oil. The regenerated cutting oil has a higher cleanliness, indicating that the treatment process effectively removes these suspended solids and restores the cutting oil to a clean state. Figure 3 shows a comparison of cleanliness:

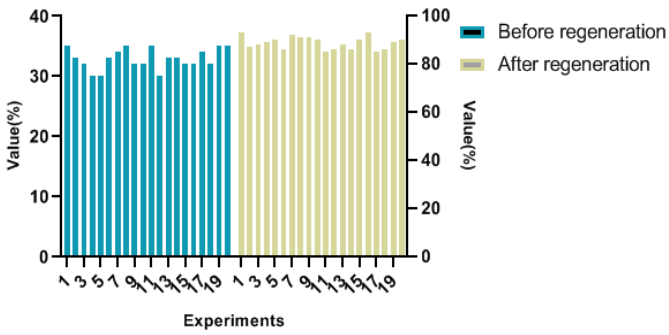

Figure 3: Cleanliness

It can be seen that the cleanliness of the cutting oil before regeneration is between 30% -35%, and after regeneration treatment, its cleanliness reaches 85% -93%. The regeneration process may use filtration to effectively remove suspended solids in the cutting oil, such as metal shavings, wear particles, and other solid impurities. Therefore, an increase in the cleanliness of cutting oil can indicate a decrease in the content of suspended solids.

5. Conclusion

The regeneration treatment of cutting medium can remove pollutants, impurities, and aging products, restore their cleanliness and performance. The regeneration treatment methods include filtration, centrifugal separation, chemical treatment, and adsorption processes, which can effectively remove suspended solids and dissolved impurities, and improve the purification effect of cutting medium. Regenerative treatment can not only reduce the generation of waste and its negative impact on the environment, but also lower production costs and resource consumption. However, in the process of regeneration and reuse, it is necessary to ensure the reliability, effectiveness, and consistency of regeneration equipment and processes to ensure that the regeneration treatment effect meets the expected requirements. In summary, the regeneration and reuse method of cutting medium in automotive engine factories is a feasible environmental solution that can achieve resource conservation and recycling, while improving the quality and performance of cutting medium.

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