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Economic Recycling Methods for Oil Containing Metal Scraps in Automotive Engine Factories

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Abstract: This study aims to explore the economic recycling methods of oily metal shavings in automobile engine factories. By comparing physical, chemical, biological, and comprehensive treatment technologies, the performance of various methods in treatment efficiency, resource recovery rate, and energy consumption was evaluated. The results showed that the highest treatment efficiency of the comprehensive treatment technology could reach 89%; resource recovery rate could reach 41%; resource consumption could reach only 0.68 kilograms of standard coal. The research methods include designing a multi-stage processing flow, optimizing process parameters, and verifying the actual effects of various technologies through experiments. The conclusion indicated that comprehensive treatment technology achieved the highest resource recovery rate while minimizing energy consumption, demonstrating the best economic and environmental benefits. This study provided an efficient and environmentally friendly solution for the reuse of oily metal shavings in automotive engine factories, which is of great significance for promoting the resource utilization of industrial waste.

1. Introduction

Oil containing metal chips is produced during mechanical processing operations, and the oil pollution contained in these metal chips not only poses a threat to the environment, but also reduces the recycling value of the metal. Therefore, developing an economical recycling method that can effectively remove oil pollution and improve metal recovery rate is of great significance for environmental protection and resource conservation. Currently, the treatment technologies for oily metal shavings include physical, chemical, and biological methods, but each of these methods has its own advantages and disadvantages, and may face challenges in efficiency, cost, and environmental impact in practical applications. This article aims to propose a new economic recycling technology by integrating these methods, aiming to improve processing efficiency and resource recovery rate, while reducing energy consumption.

The comprehensive treatment technology proposed in this study combines the advantages of physical, chemical, and biological methods to achieve efficient treatment of oily metal shavings. Through experimental verification, the effectiveness of this technology in improving resource recovery rate and reducing energy consumption has been proven, providing a feasible solution for the reuse of oily metal shavings for automotive engine factories.

The article introduced the research background of the economic recycling methods of oily metal chips, and elaborated on their importance and the necessity of research. Next, the main contributions and research methods of this article were summarized. Then, the specific steps and process parameters of the physical, chemical, biological, and comprehensive treatment technologies used were described in detail, and the experimental design, data collection, and result analysis were presented. The performance of different treatment methods was compared. Finally, the main findings of the study were summarized and its practical application value for the reuse of oily metal shavings in automotive engine factories was discussed.

2. Related Work

The effective utilization of resources and environmental protection are increasingly valued. Many people are committed to researching the recycling, reuse, and management of waste to achieve sustainable development goals. Wang Feng adhered to the concepts of reduction, harmless treatment, resource utilization, and sustainable development, and listed waste iron oil drums and oily metal shavings as hazardous waste exempted from management during the utilization process. In response to some problems in the current standardized management of hazardous waste, feasible suggestions and solutions were discussed and proposed [1]. Chang C Y combined Google's cartographer algorithm with a linear quadratic Gaussian control model, and with the help of cartographers, provided safe navigation with obstacle avoidance capabilities for delivering recycled metal waste [2]. Bae H focused on introducing the technology of recovering lithium compounds from waste lithium-ion batteries based on various stages and methods. These stages were divided into pre-treatment stage and lithium extraction stage, which were further divided into three main methods: pyro metallurgy, hydrometallurgy, and electrochemical extraction [3]. Mao J critically evaluated the progress of recycling automotive waste lithium-ion batteries, emphasizing practical advantages and design, and ranked and compared a series of recycling methods, including the current situation and how to make these methods practical [4]. Du K summarized a series of existing waste library recycling and reuse technologies, such as pretreatment, pyro metallurgy, hydrometallurgy, and direct recycling methods. In addition, the advantages and existing problems of the above methods were analyzed in detail [5].

In addition, Chen H summarized the latest trends and achievements in the chemical recycling and reuse of waste plastics, emphasizing three research topics: depolymerizing plastics into monomers; degradation of plastic into liquid fuel and wax; converting plastics into hydrogen, fine chemical raw materials, and value-added functional materials [6]. Yang B conducted a review and experimental research on the complete recycling and utilization of polyurethane. The combination of glycolysis and hydrolysis resulted in an amine yield of approximately 30% in the model system, demonstrating great potential for further research through optimizing reaction conditions and catalysis in the future [7]. The Pérez-Fonseca A discussed the reprocessing and recycling of polylactic acid as an alternative method for direct biodegradation, in order to explore more economically feasible disposal options [8]. The direct regeneration of waste lithium-ion batteries based on hydrothermal relithiation of positive electrode materials by Xu P was a promising next-generation recycling technology. In order to demonstrate the feasibility of this method on a large scale, process parameters were systematically designed and optimized to minimize energy and raw material costs [9]. Lowe G A introduced the photocatalytic and electrochemical methods for recovering amine and nicotinic acid derivatives, providing a reference for researchers to develop photocatalytic systems with sacrificial electron donors and interested in designing new redox mediators and recyclable electron donor species [10]. The above researchers have made significant progress in waste recycling and reuse technology, but the recycling methods between different wastes are not general and need to be optimized and improved for specific wastes. This article comprehensively considered the technical feasibility, economic cost, and environmental impact of waste treatment, aiming to provide an economical, efficient, and environmentally friendly method for recovering oily metal shavings for automotive engine factories.

3. Methods

3.1 Classification and Characteristics of Oily Metal Shavings

Oil containing metal chips mainly comes from machining processes such as cutting, grinding, drilling, etc., which produce a large amount of metal chips. The classification and characteristic analysis of oily metal shavings are crucial for determining economic recycling methods.

The research on the economic recycling methods of oily metal chips first requires classification and characteristic analysis of oily metal chips [11-12]. Oil containing metal shavings is usually classified by material, including iron shavings, aluminum shavings, copper shavings, and stainless steel shavings, etc. These classifications reflect the original material type of metal shavings. In addition, oily metal chips can also be classified based on their oil content, distinguishing them into low oil and high oil metal chips, which directly affects the difficulty of treatment and the required technology. The degree of pollution is also an important aspect of classification, as clean metal shavings and contaminated metal shavings have different treatment processes and objectives.

Table 1: Oil containing metal shavings data table

Engine Plant	Metal Shavings Type	Annual Oil-Contaminated Shavings Production (tons)	Annual Processing Efficiency (tons)	Energy Consumption (kWh/ton)	Cost (USD/ton)	CO2 Emissions (kg/ton)	Resource Recovery Rate (%)
Plant A	Iron Shavings	5000	4500	50	200	30	90
Plant B	Aluminum Shavings	2000	1800	80	300	20	85
Plant C	Copper Shavings	1000	900	60	400	10	80
Plant D	Stainless Steel Shavings	1500	1350	70	350	15	95
Plant E	Mixed Metal Shavings	3000	2500	65	250	25	75
Plant F	Brass Shavings	800	700	55	300	18	82
Plant G	Titanium Shavings	600	550	70	350	12	90
Plant H	Magnesium Shavings	400	360	45	200	8	85

The particle size distribution and shape of oily metal chips have a significant impact on their treatment and reuse. The particle size and distribution can affect the selection of processing equipment and processing efficiency, while shape diversity may affect subsequent physical or chemical processing processes. In terms of chemical properties, the metal content is the key to evaluating economic value, while the oil content is related to the necessity of degreasing treatment. Environmental characteristic analysis focuses on the degree of pollution and the safety after treatment, evaluating the harmful substances that may be contained in metal shavings, such as heavy metals and organic compounds, as well as whether the treatment meets environmental standards. Finally, economic analysis considers the cost-effectiveness and market demand of different treatment methods, which is crucial for determining the optimal reuse strategy. Through such comprehensive classification and characteristic analysis, suitable economic recycling methods can be provided for automotive engine factories to achieve efficient resource utilization and environmental protection [13-14]. As shown in Table 1, there are data tables for oily metal shavings from 8 engine factories.

Table 1 presents detailed data on the treatment of oily metal shavings by eight automobile engine manufacturers, including various types of metal shavings such as iron shavings, aluminum shavings, copper shavings, stainless steel shavings, mixed metal shavings, brass shavings, titanium shavings, and magnesium shavings. The annual production and processing efficiency of each factory reflect its efficiency in metal chip management. Energy consumption data is measured in kilowatt hours, showing the energy usage during the processing. The cost is measured in US dollars per ton, reflecting the economic cost of processing. In addition, Table 1 also provides the CO2 emissions generated during the processing of each ton of metal chips, which is an important indicator for measuring environmental impact, as well as the resource recovery rate.

3.2 Existing Processing Methods

The existing oil containing metal chip treatment technology involves the selection of multiple technical paths. Physical separation technology is widely used due to its simple operation and relatively low cost. It can quickly separate large metal shavings and oils, but may not be able to completely remove all oils, especially those small particles. In addition, physical methods may require subsequent processing steps to further improve purification efficiency.

Due to its efficient oil removal ability, chemical treatment technology can handle small pollutant particles that are difficult to separate by physical methods. However, chemical treatment involves the use of potentially harmful chemicals, which not only increases treatment costs but may also pose risks to the environment and operator safety.

Using microbial degradation of fats and pollutants as the main method, biological treatment technology provides an environmentally friendly alternative, with low energy consumption and relatively low operating costs. Although the speed of biological treatment may be slower, it provides a sustainable treatment method suitable for long-term applications. It should be noted that the effectiveness of biological treatment is influenced by environmental conditions, such as temperature and pH changes, and typically requires a start-up phase to cultivate effective microbial communities.

The above-mentioned technologies for recovering and treating oily metal shavings have their own characteristics. Physical methods such as screening, magnetic separation, and centrifugal separation are easy to operate and have little impact on the environment, but may not be able to completely remove oil pollution; chemical methods include chemical cleaning and chemical precipitation, which have high treatment efficiency and can effectively remove oil stains, but may generate harmful chemical waste and require additional treatment; biological treatment technologies such as microbial degradation and enzymatic treatment are environmentally friendly and can effectively decompose oil pollution, but the treatment cycle may be longer and the efficiency is relatively limited [15-16].

3.3 Comprehensive Processing Technology

Integrated processing technology can fully utilize the advantages of various processing methods and achieve economic and environmental recycling of oily metal shavings in automotive engine factories [17-18]. The design principle of this technology is based on in-depth analysis of physical separation, chemical treatment, and biological treatment methods. While reducing processing costs and minimizing environmental impact, comprehensive treatment technologies can efficiently remove grease and pollutants from metal shavings. The implementation steps first include using physical methods such as screening and centrifugation for preliminary separation to remove large particles of metal shavings and oil. Next, through chemical pretreatment, specific chemical agents are used to disrupt the adhesion of the oil, preparing for further separation. Subsequently, a microbial treatment process is applied to utilize the biodegradation effect of microorganisms to thoroughly remove residual oils and organic matter. After biological treatment, physical separation is carried out again to ensure that the metal chips reach sufficient purity and meet the requirements for reuse.

The determination of oil content involves technical parameters and key control points, including the determination of initial content and the detection of processed content, to evaluate the treatment effect. The selection and dosage of chemical agents need to be precisely adjusted based on the specific composition of the metal shavings and the type of grease. The selection and cultivation conditions of microbial strains are also crucial to ensure their effective degradation of oils and organic matter. In addition, precise control is required for the parameter settings of physical separation equipment. Finally, the efficiency of wastewater and exhaust gas treatment is also one of the key control points, which must ensure the environmental friendliness of the entire treatment process and meet strict environmental discharge standards. Through this comprehensive processing technology, this study aims to provide an efficient and environmentally friendly solution for the economic reuse of oily metal shavings in automotive engine factories [19-20].

4. Results and Discussion

There are advantages and disadvantages in the performance of different treatment technologies. This study starts from three key indicators: treatment efficiency, resource recovery rate, and energy consumption, and compares the performance of physical technology, chemical technology, biotechnology, and comprehensive treatment technology. Through this comparison, this study aims to reveal the efficiency and feasibility of various technologies in practical operations, as well as their performance in resource recovery and energy utilization. This not only helps this study understand the unique advantages and limitations of each technology, but also guides this study in selecting the most suitable treatment plan in practical applications to achieve efficient and environmentally friendly reuse of oily metal chips, and promote the sustainable development of the automotive engine manufacturing industry.

As this experiment is a comparative experiment, representative oily metal shavings were collected from the engine factory and subjected to pre-treatment such as drying, weighing, and homogenization to ensure consistency in the experiment. The processed oily metal shavings were then divided into eight groups for the experiment. Subsequently, each technology was operated according to the established process flow, and detailed processing steps and parameters were recorded. Physical technology may include steps such as screening magnetic separation and centrifugal separation; chemical technology involves the selection, concentration configuration, and processing time of chemical cleaning agents; biotechnology may include selecting appropriate microbial strains or enzymes and controlling appropriate biological reaction conditions. A multi-stage processing flow was designed by combining comprehensive processing technology with the above methods. During the experiment, the processing efficiency of each technology was measured and recorded, including processing time, processing volume, and efficiency in removing oil pollution. The resource recovery rate, which refers to the quality and quantity of recyclable metal shavings after processing, was evaluated, and energy consumption, including electricity, thermal energy, and other energy usage, was monitored. After the experiment, the collected data was statistically analyzed, and the performance of different technologies in terms of processing efficiency, resource recovery rate, and energy consumption was compared. The advantages and disadvantages of each technology were analyzed.

4.1 Processing Efficiency

High processing efficiency means that more oily metal shavings can be processed per unit of time, and the recovered metal quality is high, with thorough removal of oil pollution. The comparison results of processing efficiency are shown in Figure 1:

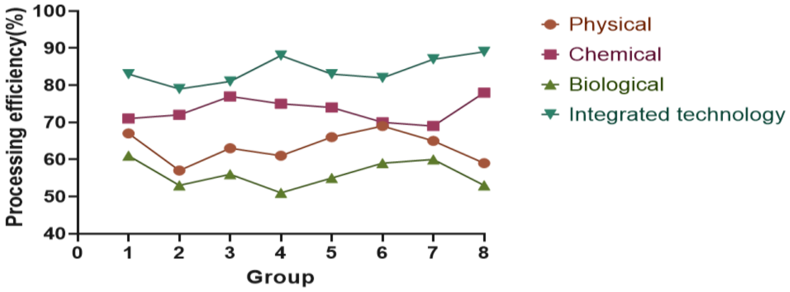

Figure 1: Comparison of processing efficiency

As shown in Figure 1, the maximum processing efficiency of the physical method reached 69%, and the chemical efficiency reached 78%; the processing efficiency of biotechnology was the lowest, with a maximum of only 61%, and the processing efficiency of comprehensive technology was the highest, reaching 89%. Integrated technology significantly improved treatment efficiency by integrating the advantages of physical, chemical, and biological methods, achieving more effective oil pollution removal and metal recovery. Physical methods mainly rely on mechanical action, resulting in relatively low processing efficiency; chemical methods use specific chemical agents, and their processing efficiency is higher than physical and biological methods; biotechnology relies on the action of microorganisms or enzymes, which usually require a longer time to decompose oil pollution, so its treatment efficiency may not be as good as physical and chemical methods.

4.2 Resource Recovery Rate

The resource recovery rate measures the proportion of metal resources recovered and reused from oily metal shavings. The high or low resource recovery rate directly reflects the performance of the treatment method in terms of resource utilization efficiency and environmental sustainability. Resource recycling has significant implications for the extraction of natural resources, prolonging their lifespan, protecting ecological balance, and promoting sustainable development. The comparison of resource recovery rates is shown in Figure 2:

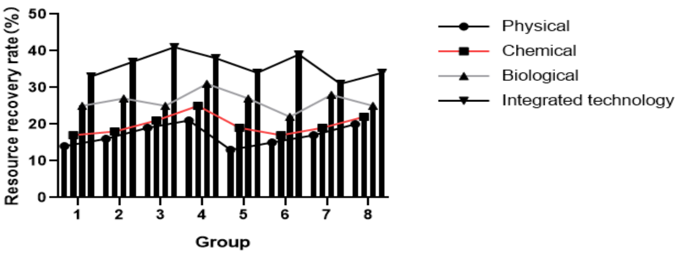

Figure 2: Comparison of resource recovery rates

Figure 2 showed that the resource recovery rate of the physical method for the first group of oily metal shavings was 14%; the resource recovery rate of the chemical method was 17%; the resource recovery rate of the biological method was 25%. The resource recovery rate of the comprehensive method reached 33%, which was higher than that of physical, chemical, and biological resource recovery. Moreover, in other experimental groups, the resource recovery rate of the comprehensive method was the highest, reaching a maximum of 41%. Behind this result, it reflects the scientific and practical application of the integrated method in design. The comprehensive approach integrates the advantages of physical, chemical, and biological treatment technologies to form a multi-stage, multi technology complementary treatment process. This method not only effectively removes oil stains, but also optimizes the characteristics of metal chips at different treatment stages, thereby maximizing the extraction and recovery of valuable metal components.

4.3 Energy Consumption

Energy consumption, as a key indicator for measuring the sustainability of treatment methods, is directly related to the economic and environmental impact of the treatment process. In order to accurately compare the energy efficiency of physical methods, chemical methods, biological methods, and comprehensive treatment technologies, this study designed a series of strictly controlled experiments to record and analyzes in detail the total energy consumption of each technology in treating the same amount of oily metal chips. This study uniformly converted different types and calorific values of energy into the amount of standard coal for statistical and comparative purposes. The results are shown in Figure 3:

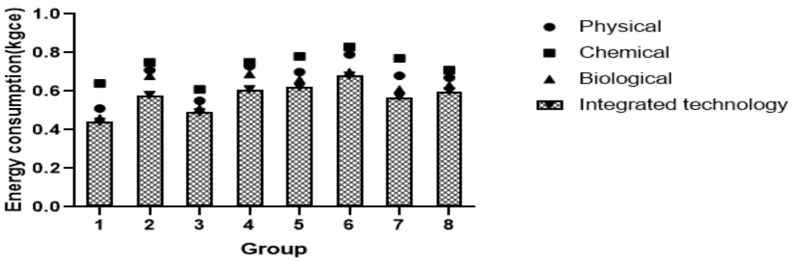

Figure 3: Energy consumption comparison

The maximum energy consumption for physical, chemical, and biological methods was 0.79 kg standard coal, 0.83 kg standard coal, and 0.7 kg standard coal, respectively. The maximum energy consumption of the comprehensive method was only 0.68 kilograms of standard coal. In the process of treating oily metal chips, although physical, chemical, and biological methods each have different energy consumption characteristics, the comprehensive method shows significant advantages in energy efficiency. The process of the comprehensive method can optimize the characteristics of metal chips and the composition of oil pollution, thereby achieving higher efficiency in removing oil pollution and recovering metals, while reducing energy waste.

5. Conclusions

In the process of studying the economic recycling methods of oily metal shavings in automobile engine factories, this study found that physical methods, chemical methods, biological methods, and comprehensive treatment technologies each have their own advantages and limitations. Although physical methods are easy to operate, their energy consumption is relatively high; chemical methods have higher processing efficiency but may come with higher environmental risks; biological methods have shown excellent environmental friendliness, but their processing efficiency and resource recovery may not be as good as other methods; by integrating the advantages of various technologies, comprehensive processing technology not only demonstrates outstanding performance in processing efficiency and resource recovery rate, but also shows significant advantages in energy consumption. Its maximum energy consumption was only 0.68 kilograms of standard coal, lower than other methods. This indicates that comprehensive treatment technology has significant advantages in energy conservation and emission reduction, while considering the importance of environmental protection. Future research should continue to optimize comprehensive processing technologies and explore the potential applications of new technologies to achieve a balance between economic benefits, environmental protection, and sustainable resource utilization in the treatment of oily metal shavings, providing solid technical support for the green development of the automotive manufacturing industry.

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