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Filtration and Optimization for the Recovery of Powder Soap Used in Wire Drawing Process

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Tel Çekme İşleminde Kullanılan Toz Sabunun Geri Kazanımı İçin Filtreleme ve Optimizasyon

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Abstract

Today, the amount of production and production-related waste has increased in order to meet the rapidly increasing consumption. Recycling processes have become inevitable in order to dispose of the resulting wastes without harming the environment and human health and to bring them into the economy. In this study, the recovery of sodium-based waste powder soap used in wire drawing processes was carried out. The ion solution method, which is a physical separation method, was used. With this method, the recovery rate was found to be 98%. Thermal and chemical analyzes were carried out with thermogravimetric and differential thermal analyzes device (TGA/DTA), X-ray fluorescence spectrometer device (XRF) and Fourier transform infrared spectroscopy (FTIR) to determine if there is any change in the structure of the material obtained after recovery.

Keywords: *Wire Drawing, Die Soap, Recovery, Ion Solution.*

Öz

Günümüzde hızla artan tüketimi karşılamak için üretim ve üretime bağlı atık miktarı artmıştır. Ortaya çıkan atıkların çevreye ve insan sağlığına zarar vermeden bertaraf edilmesi ve ekonomiye kazandırılması için geri dönüşüm süreçleri kaçınılmaz hale gelmiştir. Bu çalışmada, tel çekme işlemlerinde kullanılan sodyum bazlı atık toz sabunun geri kazanımı gerçekleştirilmiştir. Fiziksel ayırma yöntemi olan iyon çözelti yöntemi kullanılmıştır. Bu yöntemle iyileşme oranı %98 olarak bulunmuştur. Termogravimetrik ve diferansiyel termal analiz cihazı (TGA/DTA), X-ışını floresan spektroskopisi cihazı (XRF) ve Fourier transform kızılötesi spektroskopisi (FTIR) ile geri kazanım sonrası elde edilen malzemenin yapısında herhangi bir değişiklik olup olmadığını belirlemek için termal ve kimyasal analizler yapılmıştır.

Anahtar Kelimeler: *Tel Çekme, Hadde Sabunu, Geri Kazanım, İyon Çözeltisi*

1. Introduction

Wire drawing process is a metalworking method based on the plastic deformation of the thick-section material by the pulling force applied towards the die exit by passing it through conical dies called rolling (wire drawing die) (Joong-Ki and Young-Chul 2023, Sun-Ho et al. 2014). Rolling is also categorized as wet and dry spinning (Murakawa et al. 2004). The basic logic of wet and dry spinning is the same and differs in terms of the lubricant used. While special liquid emissions are used in rolling boxes in wet drawing, aluminum, calcium or sodium-based powder lubricant (soap) is used in rolling boxes in dry drawing. Powder lubricants are generally preferred in wire drawing processes.

Powder lubricants are produced with different chemical characteristics in order to show proper working performance at different stages of the process. Powder lubricants are divided into three main groups as calcium-based, sodium-based and aluminum-based soaps (Felder et al. 2011, Özer and Yurci 1997).

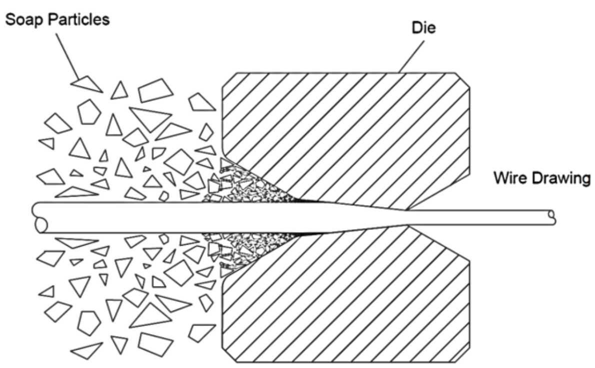

Figure 1. Wire Drawing Principle.

Metals show various deformation behaviors depending on the processing temperature during wire drawing, because the underlying mechanism of strengthening and ductility of metals is different based on temperature

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(Joong-Ki and Young-Chul 2023, Kubota et al. 2021, Liu et al. 2020, Hwang 2020, Wei et al. 2020, Kauffmann et al. 2015, Strzepek et al. 2019, Hillery and McCabe 1995).

Calcium-based soaps are insoluble in water. Pure softening temperatures range from 145 °C to 165 °C. They are especially used in the first chambers of low wire drawing speeds in the process. Sodium-based soaps are soluble in water. Pure softening temperatures are between 140 °C and 160 °C. Aluminum-based soaps are insoluble in water. Pure softening temperatures are between 140 °C and 160 °C. Generally, calcium and sodium-based soaps are used at high wire drawing speeds and in wire drawing processes where surface conditions are important, while aluminum-based soaps are generally used in the processing of thick-section materials (Jeimin et al. 2023, Sarma and Vinu 2022, Wright 2011, McNulty 2006, Tripp 1998, Eickemeyer et al. 1996, Brard 1991).

Lubricating soaps are put into the rolling box, and before the wire enters the rolling mill, the soap powders placed in the rolling box pass through it. The reason for the use of powder lubricants is to minimize the friction forces in contact with the wire and the roller, to facilitate shaping and to prevent the formation of scratches on the wire surface. Powder lubricants used in wire drawing processes become a waste that needs to be disposed of by mixing with the metal parts scraped from the wire surface during the reduction process. The resulting wastes cannot be reused as lubricants.

The European Union has the world's largest wire manufacturing industry, followed by Japan and North America. Millions of wires are produced every year. In each of these productions, the soaps mentioned in the subject are used (European Commission 2019).

The aim of this article is to realize the recovery of waste soap. So that it can be used in wire drawing repeated times, and this contributes both financially and environmentally in terms of the process. In the study, a physical method, not a chemical method was used to separate the metal particles found in a wide spectrum of lubricating waste powder soaps. Since not involving chemical methods in proposed recovery process, there is no different by-products were generated. When the metal particles are physically separated by using ion solution from the contaminated soap particles, powdered lubricating soap is left. This approach strongly approves that it has low energy consumption, and will find a good place for itself in the wire drawing soaps recovery processes.

2. Recycle Process

2.1. Optimization of Parameters for Ion Solution

2.1.1. Ion Solution Optimizations to Sodium-Based Original Soaps

After the wire drawing process, powder particles called waste but containing soap were separated using the ion solution method. Ion solution optimizations were made for the sodium-based original soaps used in the wire drawing process. The reason for optimizing the ion solution to the original soaps is to determine the amount of soap that comes to the surface in the solution. The yield % value obtained will be applied for waste soaps at the same rate. Salts selected for use in solution; They are salts of sodium chloride (NaCl), magnesium chloride (MgCl2), potassium chloride (KCl), calcium chloride (CaCl2).

Separately, salts and solutions were prepared, mixed at certain times and subjected to a waiting period, and then observations were made. It is the solution prepared with sodium chloride salt, which yields as a result of the observations. In the solutions prepared with other salts between 5-25% values, the original soap settled to the bottom and no accumulation occurred on the surface. Therefore, no results were obtained.

In the prepared solutions, 100 ml of water and 5 g of sodium-based original soap were used. In addition, flotation optimizations with %5-10-12,5-15-20-22,5-25 were made by using NaCl salt into the solution and are given in Table 1. In Figure 2, the solution images of the original sodium-based soaps prepared in different ratios are given by numbering according to Table 1.

Table 1. Solutions prepared for sodium-based original soaps at different values

Sample No	1	2	3	4	5	6	7
Concentration (%)	5	10	12,5	15	20	22,5	25
NaCl (gr)	5	10	12,5	15	20	22,5	25
Water (gr)	100	100	100	100	100	100	100
Soap (gr)	5	5	5	5	5	5	5

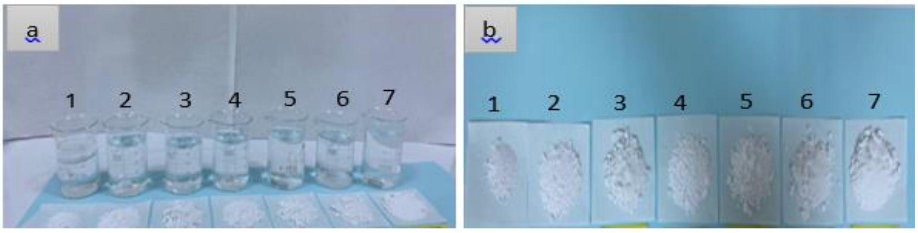

Figure 2. (A) Solution images prepared at different ratios, (B) Soap images after solution

2.1.2. Ion Solution Optimizations for Sodium Based Waste Soaps

The ideal result was found in the ion solution study for the original soap, and the same value was applied to the waste powder particles, which are called waste after the wire drawing process, but contain soap. Optimum efficiency was obtained with 20% NaCl ratio in solutions prepared for sodium-based original soap. A solution was prepared at the same rate for the waste containing sodium-based used soap.

In the prepared solution, 100 ml of water, 5 g of sodium-based waste soap, and 20% NaCl salt were used. After the solution was mixed in the mixer for 10-30 minutes in the range of 300-500 rpm, the soap that came to the surface was collected and taken into another beaker and dried. After the recovered soaps were dried in the oven, they were washed several times to remove the NaCl salt. Afterwards, drying was performed again and the recovered soap was weighed. Figure 3 shows the image of the solution prepared with 20% NaCl salt of sodium-based waste soap.

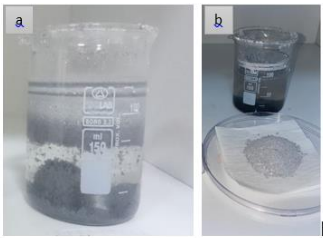

Figure 3. (a) The image of the prepared waste solution, (b) The image of the soap obtained from the waste after the oven.

3. Results

3.1. Elemental Analysis

3.1.1. X-Ray Fluorescence Spectrometer (XRF)

Panalytical Axios Advanced model XRF device was used in the studies. XRF has a wide wavelength. Organic groups such as loss of fire, carbon, hydrogen, nitrogen, free sulfur, are burned at 1000 °C for 1 hour. Thus, the part called organic group is removed by burning. As a result, it is determined how much mass is lost or not.

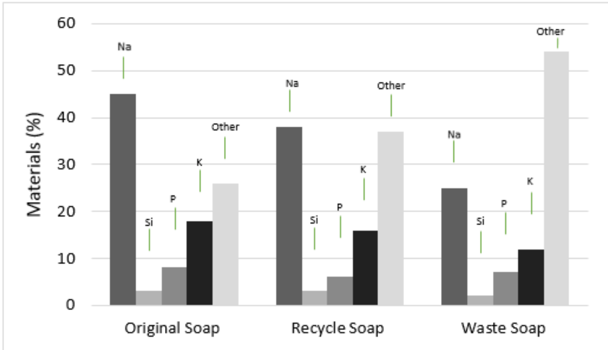

Figure 4. XRF analysis of original, recycled and waste soaps.

According to the results obtained, the sodium (Na) ratio in the recycled soap was taken as a basis. The sodium content in the soap is in parallel with the sodium content in the original soap. Silicon (Si), Potassium (K) and Phosphorus (P) ratios have almost the same % values compared to the original soap. While there was a decrease in the sodium rate due to metal pollution in the wastes, an increase was observed in the rate of other elements.

3.1.2. Fourier Transform Infrared Spectroscopy Analysis (FT-IR)

Perkin Elmer 400 FT-IR/FT-FIR Spectrometer Spotlight model FTIR device was used in the studies. In the 3000-2700 cm^{-1} range, the -C-H peaks occurring in both A sample and B sample are common. Likewise, C=C peaks occurring in the 1600-1400 range, C-O peaks occurring in the 1310-1085 cm^{-1} range and C-H peaks occurring in the 1250-600 cm^{-1} range are common in the original soap and reclaimed soap evaluated.

3.2. Thermal Analysis

3.2.1. Thermogravimetric and Differential Thermal Analysis (TG/DTA)

Thermal behaviors between original soap and reclaimed soap were investigated with Perkin Elmer Diamond model TG/DTA device. According to the analysis result, it is seen that the mass change starts after 350 °C in sample. As a result of the studies and trials, the characterization was supported by elemental - thermal analyzes and the recovered soap was compared with the original soap.

In this study, ion solution method was used for the recovery of waste powder soap used in wire drawing process. Four different salts were used in the prepared solutions. Sodium-based original soap images prepared with NaCl salt in different proportions are given in figure 2. The amounts of soap obtained from the solutions are given in Table 2. After the solution prepared with 20% NaCl salt, it was washed several times in order to get rid of the NaCl salt. Afterwards, the drying process was carried out again and the recovered soap was weighed. The amount of soap obtained as a result of weighing is 4.90 gr.

As a result of the studies, it was seen that the recovery rate was 98%. Whether there is any change in the structure of the material obtained after the recovery was examined by thermogravimetric and differential thermal analysis (TG/DTA) device, X-ray fluorescence spectrometer (XRF) device, Fourier transform infrared spectroscopy (FTIR) device and thermal and chemical analyzes.

4. Discussion

In the developed method, the optimum conditions in the process can be determined without any difference between the recovered soap and the original soap. In addition, it is advantageous that it can be applied to wires with different contents, such as steel wire, aluminum wire, compared to other recycling methods, the method is a simple method, and the materials to be used are easily accessible. However, it is seen as a result of the prepared solution results that there is non-recoverable soap in the waste. In this context, this efficiency rate can be increased with other methods. Especially in the recovery studies in the literature, there is information that the recovery of waste soap is difficult. For this reason, many countries create relevant policies, regulations and recovery systems to reduce the damage to the environment.

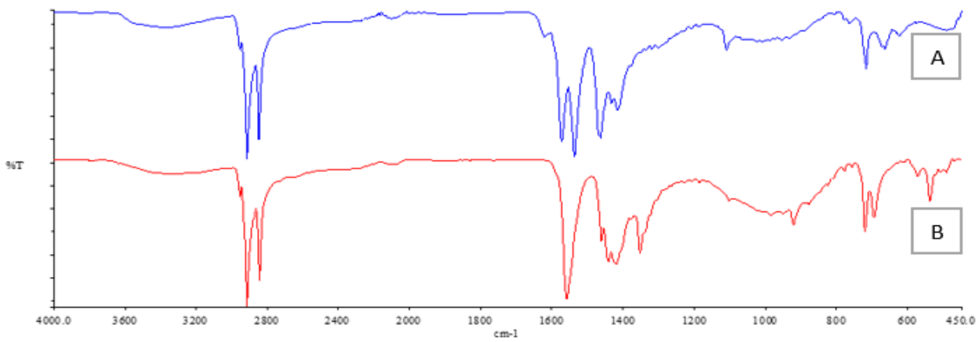

Figure 5. (A) Recycled soap and (B) original soap FT-IR graph.

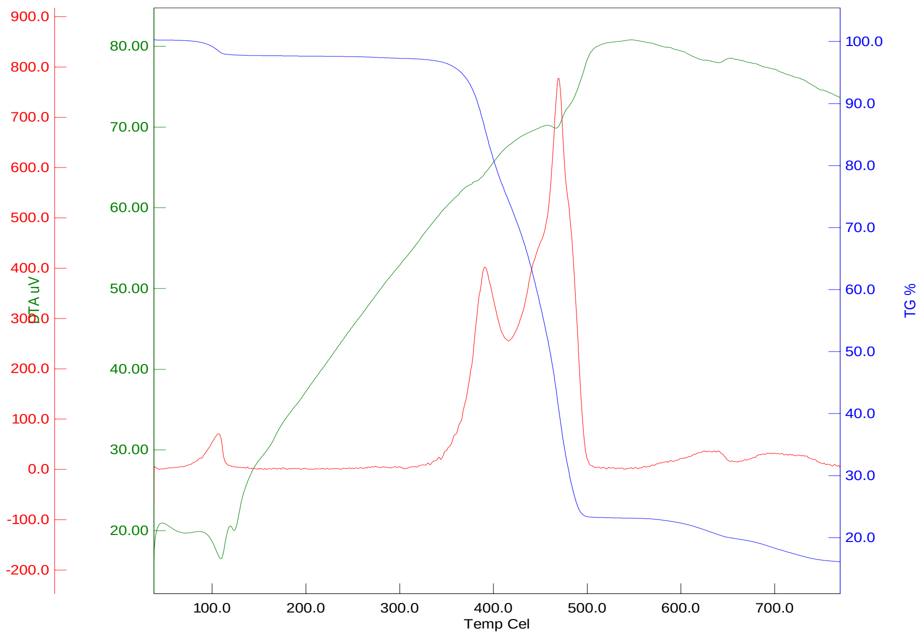

Figure 6. Recovered soap TG/DTA analysis graph.

Table 2. Result values obtained from solutions prepared from sodium-based original soaps

Sample No	1	3	4	5	6	7
Concentration of NaCl (%)	5	12,5	15	20	22,5	25
Amount of Soap in Solution (gr)	5	5	5	5	5	5
Amount of Soap Obtaned (gr)	1,25	4,6	7,48	4,90	4,81	4,67

5. Conclusion

It is known that the use of powder lubricants in wire drawing will never end. In this sense, making improvements for the recovery of the waste powder soap will provide significant benefits to the facilities in the sector.

In this study, ion solution method was used for the recovery of waste powder soap. In the proposed method, solutions were prepared using four different salts. Optimizations with %5-10-12,5-15-20-22,5-25 ratios were made by using 100 ml of water, 5 gr sodium-based waste soap and salts at different rates in the solution.

It was determined that the most efficient salt in the prepared solutions was the NaCl salt with 20%, and the most ineffective salt was the $CaCl_2$ salt with 5%. After determining that the efficient salt is sodium chloride salt, the amount of soap that can be obtained from the waste was determined. It has been washed several times to remove salt. As a result of the studies, it was determined that the amount of soap obtained from 5 g sodium-based waste was 4.90 g. In addition, as a result of the analysis, the reuse of recycled soap was found appropriate. In the studies, it was observed that the recycled soap exhibited the same lubricating properties as the original soap.

As a result of the ion solution method used, the recovery rate of the waste powder soap was 98%, which was supported by the results.

Declaration of Ethical Standards

The authors declare that they comply with all ethical standards.

Conflict of Interest

The authors do not have financial and personal relationships with other people or organizations that could inappropriately influence their work.

Credit Authorship Contribution Statement

Author-1: Study design, Formal analysis, Investigation, Resources, Writing – original draft, Writing – review and editing, Project administration, Project administration.

Author-2: Study design, Formal analysis, Investigation, Resources, Writing – original draft, Writing – review and editing, Project administration.

Author-3: Study design, Supervision, Study design, Formal analysis, Investigation, Resources, Writing – review and editing.

Author-4: Study design supervision, Study design, Formal analysis, Investigation, Resources, Writing – review and editing.

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