ISSN: 2688-8645

Study on the Separation Effect of Acrylic Acid on Aluminum-Plastic Composites

Lulu Zhang[1, 2, 3, 4, *] and Jianfeng Li[1, 2, 3, 4]

[1]Institute of Land Engineering and Technology, Shaanxi Provincial Land Engineering Construction Group Co., Ltd. Xi'an, 710075, China

[2]Key Laboratory of Degraded and Unused Land Consolidation Engineering, the Ministry of Natural Resources, Xi'an, 710075, China

[3]Shaanxi Provincial Land Consolidation Engineering Technology Research Center, Xi'an, 710075, China

[4]Land Engineering Technology Innovation Center, Ministry of Natural Resources, Xi'an, 710075, China

Abstract

China is one of the countries with the largest consumption of aluminum-plastic composites, but its recovery rate is very low. In this study, the effect of acrylic acid concentration, liquid-solid ratio and separation temperature on the separation efficiency of aluminum-plastic was investigated by using acrylic acid as the separation agent of aluminum-plastic. The research results show that acrylic acid is an excellent separating agent. When the concentration is 6 mol/L, the liquid-solid ratio is 350 L/kg, and the separation temperature is 90 °C, the complete separation time of aluminum-plastic is 124 min, and the loss of aluminum-plastic is 9.2%.

Keywords

Tetra Pak; Separating agent; Acrylic acid; Separation efficiency.

1. Introduction

Aseptic composite paper packaging has been widely used in food, medicine, daily necessities packaging and other fields [1-2]. Taking Tetra Pak as an example, its annual output value accounts for 87% of China's aseptic packaging market. A large number of discarded Tetra Pak packs are discarded, causing environmental pollution and waste of resources [3]. The structure of Tetra Pak mainly includes cardboard layer and aluminum-plastic composite layer. The structure of the aluminum-plastic composite layer from outside to inside is: polyethylene layer (PE), LDPE (adhesive layer), aluminum, EMAA (adhesive layer), polyethylene layer [4-5]. Polyethylene selects low-density polyethylene (LDPE) with no additives, good adhesion and sealing properties, and a relative density of 0.917 to 0.925. The aluminum-plastic composite process is to melt the polyethylene plastic layer by means of high frequency and thermal pressing, and then bond it with the alumina formed on the surface of the aluminum. The composite material prepared by this method has high bonding strength, stable physical properties, and is difficult to separate [6-7].

In recent years, environmental protection and resource recycling have been advocated, and the recycling technology of waste aluminum-plastic composite packaging materials has attracted widespread attention. The current recovery methods include argon gas electrolysis, high-temperature gasification separation, and high-voltage electrostatic separation technology [8-9]. However, this type of technology has higher requirements for equipment. The solution separation method includes acid liquid separation, alkali liquid separation, and organic solvent

ISSN: 2688-8645

separation [10-12]. The lye separation is at the expense of all dissolved aluminium. The organic solvents are mostly separated by chloroform, propyl ether, ethyl ether, toluene, etc., which cause great pollution to the environment. Acid separation has the advantages of high separation efficiency, good separation effect and less environmental pollution. In this paper, acrylic acid was used as a separating agent to investigate its separation effect on aluminum-plastic composites.

2. Experimental

2.1. Separation Method

The aluminum-plastic composite material is cut into square pieces of 1cm × 1cm, mixed with acrylic acid solution according to a certain solid-liquid, heated to a certain temperature, and stirred slightly for a period of time until it is completely separated. Wash the separated aluminum and plastic with washing and dry it for determination.

2.2. Calculation of Aluminum-plastic Loss Rate

The calculation formula of the aluminum-plastic separation loss rate is as follows:

$$T = m_2 / m \tag{1}$$

Where, T is the loss rate of aluminum plastic separation; m is the total mass of all aluminum and plastic before separation.

3. Results and Discussion

3.1. Influence of Separation Agent Temperature on Separation of Aluminum-plastic Composites

In this study, the concentration of acrylic acid was 4mol/L, the liquid-solid ratio was 500 L/kg, and the size of the aluminum-plastic composite was 1cm×1cm. Under the condition of complete separation of aluminum and plastic, the effect of acrylic acid solution temperature on the separation time of aluminum-plastic composite and the loss rate of aluminum was investigated. The test results are shown in Figure 1.

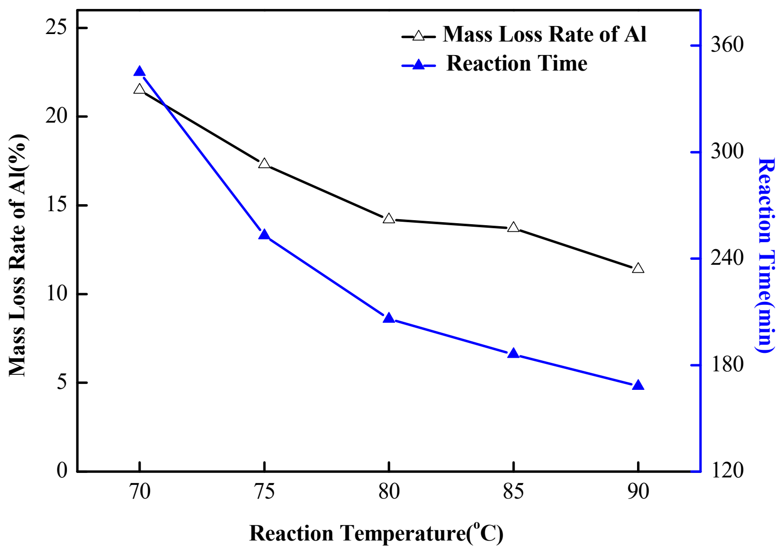

Figure 1. Influence of separation agent temperature on separation of aluminum-plastic composites

It can be seen from Figure 1 that under the condition of complete separation of the aluminum-plastic composite, the loss rate of aluminum and the time required for separation are negatively correlated with the reaction temperature, that is, as the reaction temperature increases, the loss rate of aluminum gradually decreases, The time required for separation is also gradually decreasing. When the temperature is 70 °C, the time required for the separation of the aluminum-plastic composite is longer, and the effect of complete separation can be achieved in 345 minutes. At this time, the loss rate of the aluminum is also relatively large, which is 21.5%. This is because when the separation temperature is low, there are few activated molecules per unit volume, and it takes a long time to completely separate the aluminum. The contact time between the separated aluminum and the acrylic acid solution is long, resulting in the dissolution of the aluminum and a high loss rate of the aluminum. With the increase of temperature, the number of activated molecules per unit volume increases, the effective collision increases, the reaction rate accelerates, and the time required for complete separation gradually shortens. At the same time, the increase of temperature will reduce the viscosity of the solution and accelerate the diffusion of H+ to the interface layer. Therefore, when the temperature is high, the separation rate is fast and the yield of aluminum is high. Since the solvent of the acrylic solution is water, too high a temperature will cause a large amount of volatilization of the solvent. Therefore, the suitable separation temperature is 90°C.

3.2. Effect of Separating Agent Concentration on Separation of Aluminum-plastic Composites

In this study, the temperature was 90°C, the liquid-solid ratio was 500 L/kg, and the size of the aluminum-plastic composite was 1cm×1cm. Under the condition of complete separation of aluminum and plastic, the effect of acrylic acid concentration on the separation time of aluminum-plastic composite and the loss rate of aluminum was investigated. The test results are shown in Figure 2.

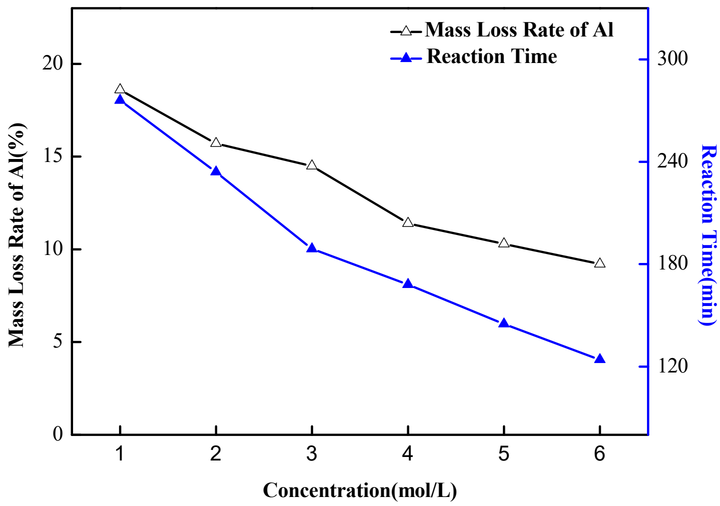

Figure 2. Effect of separating agent concentration on separation of aluminum-plastic composites

It can be seen from Figure 2 that at the same reaction temperature, the time required for complete separation of the aluminum-plastic composite is inversely proportional to the concentration of acrylic acid. In the separation process, the loss rate of aluminum is also negatively correlated with the concentration of acrylic acid, that is, the increase of acrylic acid concentration shortens the separation time of the aluminum-plastic composite, and the loss rate of aluminum also decreases. When the concentration of acrylic acid is 1 mol/L, the complete separation time of the aluminum-plastic composite is longer, which takes 267 minutes. At this time, the loss rate of the aluminum is relatively large, which is 18.6%. Due to the long reaction time, the separated aluminum will continue to react with the acrylic acid solution, so the loss rate of the aluminum is high. As the concentration of acrylic acid increases, the reaction rate increases, and the time required for complete separation is shortened, and reduces the loss rate of the aluminum during the separation process. For example, when the concentration is 6 mol/L, the time required for complete separation of the aluminum-plastic composite is 124 min, and the loss rate of aluminum is 9.2% at this time. Therefore, the more suitable concentration of acrylic acid is 6 mol/L.

3.3. Effect of Liquid-solid Ratio on Separation of Aluminum-plastic Composites

In this study, the temperature was 90°C, the concentration of acrylic acid was 4 mol/L, and the size of the aluminum-plastic composite was 1cm×1cm. Under the condition of complete separation of aluminum and plastic, the effect of liquid-solid ratio on the separation time of aluminum-plastic composite and the loss rate of aluminum was investigated. The test results are shown in Figure 3.

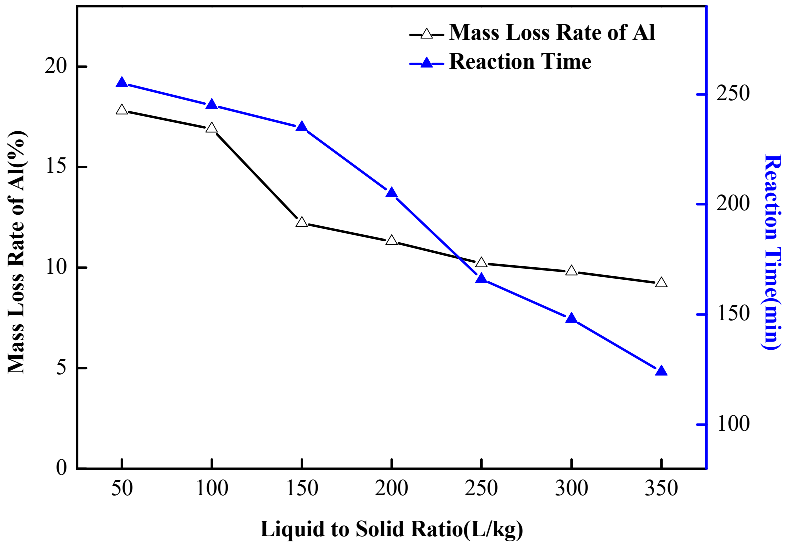

Figure 3. Effect of liquid-solid ratio on separation of aluminum-plastic composites

It can be seen from Figure 3 that with the increase of the amount of acrylic acid solution, the loss rate of aluminum gradually decreases, and the time required for complete separation shortens. When the liquid-solid ratio is less than 50 L/kg, the amount of acrylic acid solution is too small to completely immerse the aluminum-plastic composite. Since part of the aluminum-plastic composite cannot be completely contacted with the acrylic acid solution, the reaction is not complete, and the loss rate of aluminum becomes high. With the gradual increase of the liquid-solid ratio, the acrylic acid solution can gradually immerse the aluminum-plastic composite, the time required for complete separation of the aluminum-plastic composite is shortened, and the loss rate of the aluminum is gradually reduced. When the liquid-solid ratio is greater than 250 L/kg, the loss rate of the aluminum foil is gradually stabilized, and the time required to separate the aluminum-plastic composite changes little. It can be seen from the figure that when the liquid-solid ratio is 350 L/kg, the aluminum loss rate is the smallest, only 9.2%, and the reaction time is the shortest, and the aluminum-plastic composite is completely separated in only 124 minutes.

4. Conclusions

Acrylic acid is selected as the separating agent of the aluminum-plastic composite material, which has the advantages of high separation efficiency and low environmental pollution. The concentration of acrylic acid, liquid-solid ratio and separation temperature are the most important factors affecting the separation time and yield. The concentration of acrylic acid affects the amount of H+ ions, the liquid-solid ratio affects the contact area between the aluminum-plastic and the separating agent, and the temperature affects the activation energy during the separation of the aluminum-plastic. The results showed that the concentration of acrylic acid was 6 mol/L, the liquid-solid ratio was 350 L/kg, the separation temperature was 90 °C, the complete separation time of aluminum-plastic was 124 min, and the loss rate of aluminum-plastic was 9.2%.

Acknowledgments

This work was financially supported by the Shaanxi Provincial Land Engineering Construction Group Research Project (NO. DJNY2021-17; NO. DJNY2022-27; NO. DJNY2022-34)

References

[1] F. J. Fan, Z. P. Yang, F. X. Shi, Discussion on recovery and reuse of Tetra Pak package, Agricultural Mechanization Research. 9 (2007) 221-223.

[2] Z. W. Cui, Reuse of aseptic paper packaging, China Pulp & Paper Industry. 27 (2006) 80-81.

[3] Z. Q. Li, Reuse of aseptic paper packaging in pulp and paper mill, China Pulp & Paper Industry. 29 (2008) 64-67.

[4] A. Korkmaz, J. Yanik, M. Brebu, Pyrolysis of the Tetra Pak, Waste Management. 29 (2009) 2836-2841.

[5] A. K. Kulkarni, S. Daneshvarhosseini, H. Yoshida, Effective recovery of pure aluminum from waste composite laminates by sub- and super-critical water, The Journal of Supercritical Fluids. 32(2010) 1-6.

[6] Z. W. Cui, The research of the recycling of liquid packaging paper box, Shanghai Paper Making. 40 (2009) 62-67.

[7] A. L. M. Cristina, I. F. Maria, Composite of low-density polyethylene and aluminum obtained from the recycling of postconsumer aseptic packaging, Journal of Applied Polymer Science. 5 (2006) 3183-3191.

[8] C. K. Huang, C. H. Shao, Method for separating and recycling aluminum plastic(paper) composite packaging material-comprises using an acid solution containing nitric acid to soak an aluminum plastic (paper) composite packaging material: CH696295A5 [P]. 2007-03.

[9] K. K. Aditya, D. Somayeh, Effective recovery of pure aluminum from waste composite laminates by sub- and super-critical water, The Journal of Supercritical Fluids. 9 (2010) 1-6.

[10] P. Zhang, J. H. Gu, Study on the separtaion between aluminum and plastic in scraps of plastic containing aluminum, Mining and Metallurgical Engineering. 27 (2007) 22-25.

[11] S. F. Zhang, L. L. Zhang, K. Luo, Separation properties of aluminium–plastic laminates in post-consumer Tetra Pak with mixed organic solvent, Waste Management & Research. 6(2014) 1-6.

[12] S. F. Zhang, K. Luo, L. L. Zhang, Interfacial separation and characterization of Al–PE composites during delamination of post-consumer Tetra Pakmaterials, Journal of Chemical Technology and Biotechnology. 90(2015) 1152-1159.