Study on separation of aluminum-plastic composites with benzene ethanol-water method

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Abstract: The efficient separation and recycling of aluminum-plastic composite materials in Tetra Pak was studied. Using the benzene ethanol-water mixed solution as the separating agent, the separation mechanism of aluminum and plastic was studied. Benzene ethanol-water is mixed according to a certain volume ratio, and the volume ratio of each component of the separating agent, separation temperature and other parameters are optimized. The results show: when the volume ratio of the components in the separating agent is V (benzene): V (ethanol absolute): V (water) =30:20:50, and the separation temperature is 60°C, the separation effect is the best. The total yield of plastic can reach 97%. The waste liquid treatment is simple, and the environmental pollution is little.

1. Introduction

The liquid packaging box represented by Tetra Pak is a high humidity packing box composed of natural wood pulp paper, high-quality aluminum foil and high-quality low-density polyethylene plastic (LDPE). It has low cost, light and convenient, which is widely used in the packaging of milk, juice, soy milk, coffee, wine and other liquid foods. The packaging generally has 6 layers, which can effectively block the factors that affect the deterioration of milk and beverages. The contents of cardboard, LDPE and aluminum foil are 73%, 20% and 5% respectively [1, 2]. The output of this type of composite packaging waste is increasing year by year, but the recycling rate is low. A large number of paper-plastic-aluminum composite packaging materials are incinerated or landfilled, which wastes resources and pollutes the environment.

In recent years, with the coordinated development of circular economy and low-carbon economy, the recycling technology of waste paper-plastic-aluminum composite packaging materials has attracted wide attention from Germany, Finland, Brazil, Denmark, Sweden, Japan, China and other countries [3]. Among the existing reuse technologies, "hydraulic crushing and extraction of pulp for recycling papermaking" supplemented by "aluminum-plastic separation" is the most economical and effective method for recycling this composite packaging material at present [4, 5]. However, the plastic layer and the aluminum foil are formed by hot pressing or bonding, and the bonding strength is relatively high. The efficient separation between the layers has always been a difficult point in this field [6, 7].

At present, the separation methods of this type of aluminum-plastic composite materials mainly include the following: (1) Using the different melting points of aluminum and plastic to pyrolyze and gasify the plastic, recover the aluminum foil, and use the gasified plastic for power generation [8]. (2)

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Using pure water under high temperature and high pressure to separate aluminum and plastic, this method has a large loss rate of plastic, and requires high equipment, and it is difficult to realize industrialization [9]. (3) Utilizing the property of aluminum and aluminum oxides to dissolve in acid and alkali, use hydrochloric acid or sodium hydroxide to dissolve aluminum to recycle plastics [10]. However, this method has problems such as long reaction time, difficulty in achieving complete separation, and the need to extract aluminum from the solution. (4) Using inorganic acid such as nitric acid to dissolve the aluminum oxide on the bonding surface to separate aluminum and plastic [11]. Nitric acid pollutes the environment and corrodes equipment seriously, and the reaction speed of nitric acid is too fast, and more aluminum foil is dissolved. (5) Using some acidic organic solvents to penetrate LDPE to reach the aluminum-plastic bonding surface, dissolve the aluminum oxide on the bonding surface, and achieve the effect of aluminum-plastic separation [12]. In this paper, a mixture of benzene-ethanol-water is used for aluminum-plastic separation, and the separation process of the mixture was mainly studied.

2. Experimental

2.1 Separation method

Cut the aluminum-plastic composite materials into 3cm×3cm square slices and the separating agent according to a certain solid-liquid ratio, place them in a constant temperature container, heat to a certain temperature, gently stir for a certain period of time, and then completely separate. The separated aluminum and plastic were washed with water and ethanol. The separating agent can also be recovered by standing and layering.

2.2 Calculation of aluminum-plastic separation rate and loss rate

The formula for calculating the separation rate of aluminum and plastic is as follows:

$$S = m_1 / m_2 \tag{1}$$

Where, S is the aluminum-plastic separation rate; m_1 is the total mass of s eparated aluminum and plastic; m_2 is the total mass of separated aluminum and plastic and unseparated aluminum and plastic.

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

$$T = m_2 / m \tag{2}$$

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 Separation effect analysis

Use benzene ethanol-water as the separating agent to investigate its separation effect on aluminum-plastic. When V (benzene): V (absolute ethanol) <3:1, aluminum-plastic cannot be separated; when V (benzene): V (absolute ethanol) ≥3:1, one side of aluminum-plastic can be separated while the other side cannot be separated. After adding a small amount of water to benzene and absolute ethanol, both sides of the aluminum and plastic are easily separated. Therefore, the benzene alcohol water as the aluminum-plastic separation agent has high separation efficiency and high yield, and the waste liquid is easily recovered and has little environmental pollution. The separated product of aluminum-plastic composite is shown in figure 1.

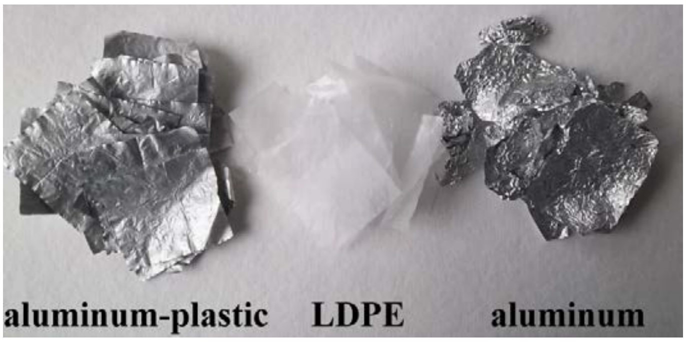

Fig 1. Comparison photos before and after aluminum-plastic separation.

3.2 Mechanism analysis

The aluminum-plastic composite materials are composed of two low-density polyethylene plastic film layers and an aluminum foil layer. The aluminum foil layer is composed of elemental aluminum and aluminum oxide formed on the surface due to oxidation. The aluminum foil and the polyethylene film on both sides are bonded in different ways. One side uses molten polyethylene as an adhesive, and the other side uses a high-strength organic adhesive to bond.

Benzene can swell plastics and can also dissolve plastics at a certain concentration. Control the concentration of benzene to swell the plastic within the swelling range of the plastic and reduce the bonding force of the aluminum-plastic interface, thereby separating one side of the LDPE adhesive; the plastic on the side of the organic adhesive is also swelled, but the benzene and ethanol cannot dissolve the organic adhesive. After adding water, the water penetrates into the aluminum-plastic interface to dissolve the organic adhesive. Ethanol function is to make water and benzene mix well in a short time and it can easily control the concentration of benzene.

3.3 Mechanism analysis

Make the volume ratio of benzene ethanol-water in the separating agent benzene: absolute ethanol: water = 30: 20: 50, and the liquid-solid ratio of the separating agent to aluminum plastic is 100 ml: 0.98 g. Stir slightly to separate at different temperatures. The aluminum-plastic separation efficiency was tested, and the results are shown in figure 2A and figure 2B.When the separation temperature is 50℃ and below, even if the separating agent is in contact with the aluminum-plastic for 1 hour, the aluminum-plastic is not separated. When the temperature is 60-65℃, the separation rate quickly reaches 100%, and the time used is only 3-5min. At this time, most of the adhesive and a very small amount of plastic are dissolved in the separating agent, and as the temperature rises, the dissolution rate of adhesives and plastics increases, and the total yield of aluminum-plastics decreases. When the temperature is greater than 65°C, the boiling point of the separating agent is reached, and the separating agent volatilizes more severely.

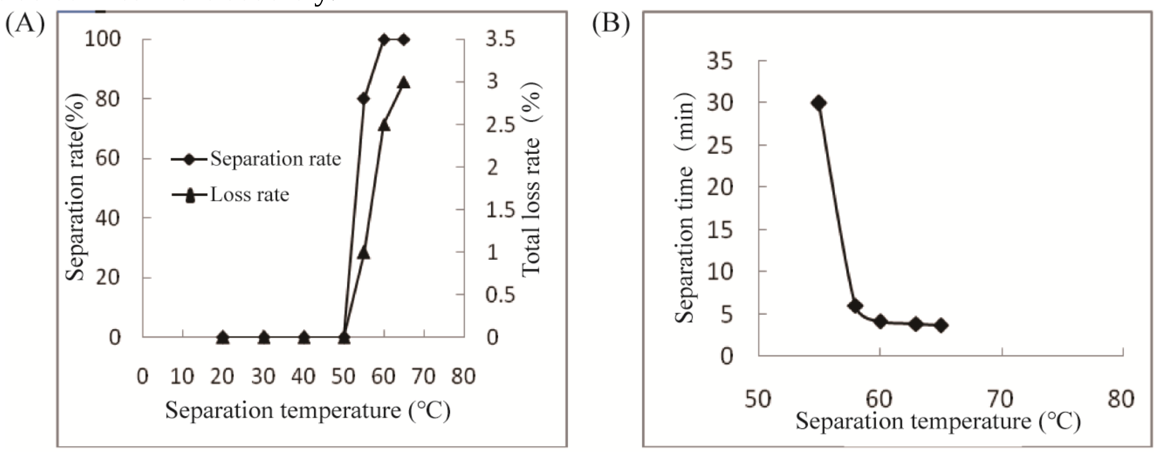

Fig 2. The effect of separating temperature on (A) the separation rate and loss rate, (B) separation time of aluminum-plastic.

3.4 Influence of the volume ratio of benzene-alcohol water in the separating agent on the separation of aluminum-plastic composite

3.4.1. The effect of benzene volume ratio on the separation of aluminum-plastic composite materials

The liquid-solid ratio of the separating agent and the aluminum-plastic is maintained at 100ml: 0.98 g, the reaction temperature is 60°C, and the reaction time is 5min. The volume of ethanol absolute in the fixed separating agent is 20 mL, and the volume of water is 30 mL, and the volume fraction of benzene in the separating agent is changed according to the liquid-solid ratio. The measurement results of separation rate and loss rate are shown in figure 3A and figure 3B.

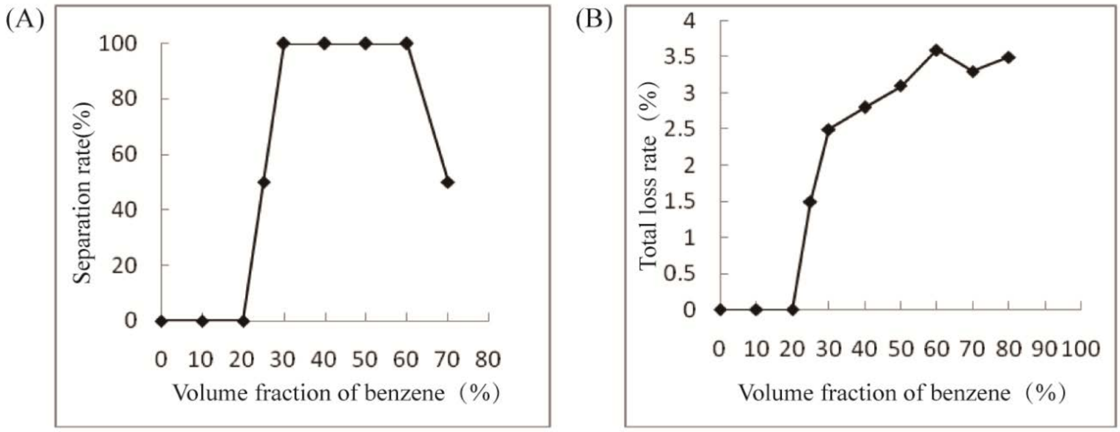

Fig 3. The effect of volume ratio of benzene in separating agent on the (A) separation rate and (B) total loss rate of aluminum-plastic.

When the volume ratio of benzene in the separating agent is less than 20%, the aluminum-plastic materials does not separate at all. When the volume ratio of benzene is increased to 25%, one side of the aluminum-plastic materials is completely separated, and no separation occurs on the other side. It is found through observation that the side with polyethylene as the adhesive is easier to separate, while the side with organic adhesive is more difficult to separate. When the volume ratio of benzene is greater than 30% and less than 60%, the separation effect on both sides is better. When the volume ratio of benzene is greater than 60%, the volume ratio of water becomes smaller, and the side where the organic adhesive is bonded cannot be separated.

It can be seen from figure 3B that when the volume ratio of benzene is between 30% and 60%, the total loss rate of the aluminum-plastic composite materials is proportional to the volume fraction of benzene. When the volume ratio of benzene is 70% to 80%, only one side of the aluminum-plastic separation occurs, and the side bonded with the adhesive does not separate.

3.4.2. The effect of water volume ratio on the separation of aluminum-plastic composite materials

In the same case, the volume of ethanol absolute in the fixed separating agent is 20 mL, and the volume of benzene is 30 mL. The volume fraction of water in the separating agent is changed, and the results of the determination of separation rate and loss rate are shown in figure 4A and figure 4B.

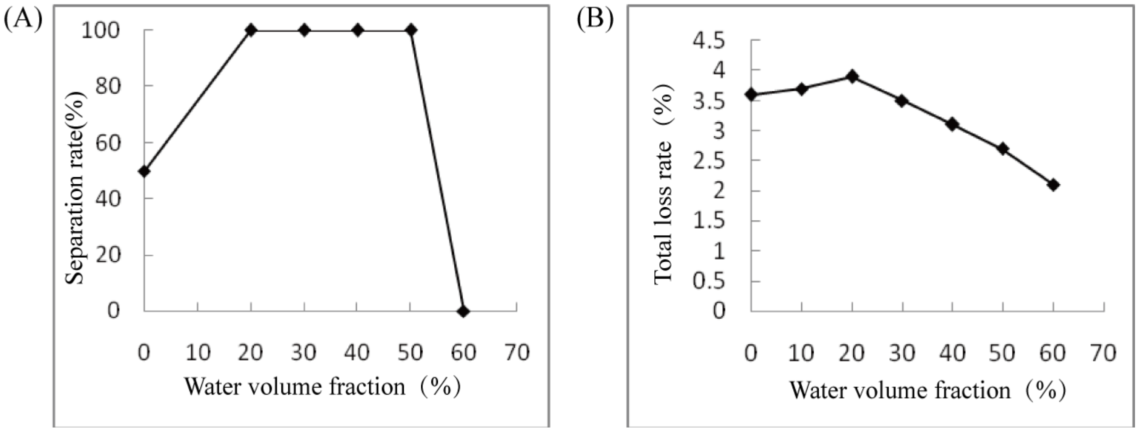

Fig 4. The effect of volume ratio of water in separating agent on the (A) separation rate and (B) total loss rate of aluminum-plastic.

It can be seen from figure 4A that when there is no water in the separating agent, one side of the aluminum-plastic materials with the adhesive cannot be separated, while the plastic on the other side can be completely separated. As the volume fraction of water in the separating agent increases, when it reaches 20%, the aluminum-plastic materials can be completely separated. When the volume ratio is greater than 50%, the separation rate will decrease until it reaches zero. This is because the volume ratio of benzene in the separating agent is reduced, resulting in cannot be separated.

It can be seen from figure 4B that when the volume ratio of water is between 0 and 20%, the loss rate of the aluminum-plastic materials is proportional to it. This is because as the volume ratio of water increases, although the dissolution of benzene to the plastic decreases, the dissolution of the adhesive increases, and therefore the loss rate increases. When the volume ratio of water is between 20% and 50%, the loss rate is inversely proportional to the volume ratio. This is because as the volume ratio of benzene decreases, the loss rate of plastics also decreases, and the dissolved amount of adhesive remains basically unchanged.

4. Conclusions

The separation temperature of aluminum and plastic plays a very important role in the separation of aluminum and plastic by the benzene ethanol-water method. The optimal reaction temperature is 60°C. When the volume fraction of benzene and water in the separating agent is lower than a certain value, the aluminum-plastic does not separate or only separates on one side; when the volume fraction of benzene is too large, it will increase the dissolution of the plastic and reduce the total yield of aluminum-plastic; the volume fraction of anhydrous ethanol when it is too low, benzene and water will separate instantly, and the effect of mixing in a short time cannot be achieved. The best volume ratio of phenyl alcohol to water is V (benzene): V (ethanol absolute): V (water) =30:20:50.

Acknowledgments

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