INVESTIGATION INTO THE RECOVERY OF TIN FROM SCRAPPED STEEL CANS WITH A PROTECTIVE COATING

GAJDA Bernadeta, RETERSKI Jarosław, SIWKA Jerzy

Czestochowa University of Technology, Department of Metal Extraction and Recirculation, Czestochowa, Poland, EU

Abstract

The sustained constant increase in the manufacture of packaging, among which tin-containing steel cans constitute a numerous group, requires searching for and implementing new methods enabling the recovery of tin from packaging scraps making up a large fraction of the generated municipal waste stream. In order to determine the preliminary assumptions for newly designed methods for tin recovery from waste steel cans, it becomes necessary to establish the basic parameters of chemical processes that might constitute a principal or additional part of an effectively operating technological line. The investigation results described in this paper relate to basic parameters of the process of leaching tin from waste can steel sheets - as input data necessary for establishing the scope and run of the tin recovery process. The testing material were steel sheet samples originating from the manufacturer of food product cans covered with a tin coating and one-sidedly and double-sidedly covered with a lacquer layer. The samples were subjected to preliminary mechanical processing in a roller mill, followed by leaching in a 1.0 M NaOH solution. The essential part of the investigation was the analysis of the possibility of removing tin from waste steel sheets that may form charge for the metallurgical process as an iron-bearing source. At the same time, the world's dwindling natural resources of tin, qualifying it for the group of critical metals, indicate the need for conducting research on the recovery of tin from waste raw materials. The presented investigation results indicate the need for undertaking further activities to determine the standard technological requirements necessary for designing and supervising the correct course of the process of recovering tin from waste steel sheets.

Keywords: Tin, recovery, leaching, waste can steel sheets

1. INTRODUCTION

Depending on the applied technology, the tin content of waste steel packaging ranges usually from 0.3 to 2 %, which makes the use of pyrometallurgical methods for tin recovery practically infeasible and uneconomic. It is therefore necessary to search for other methods for tin recovery, an example of which might be hydrometallurgical methods. In spite of their numerous advantages (including especially relatively low costs of their industrial application), these methods encounter a number of obstacles that make the effective running of the process of tin recovery from the steel scrap surface difficult. The most important obstacle is the presence of layers of lacquers protecting the waste can steel sheets surfaces. The use of the chemical methods of stripping lacquer layers without preliminarily establishing the hydrometallurgical process parameters may hamper its further progress and pose a serious challenge to the design of an environmentally safe method of handling the generated waste sludges and solutions and the atmospheric emissions of gases. So, in the case of processing wastes containing large amounts of tin plated steel cans, a crucial operation is the appropriate preparation of the scrap and establishing the initial parameters of the hydrometallurgical process that will guarantee its correct running, while considering the currently applicable trend for reducing the basis weight of tin on manufactured can steel sheet surface. On the other hand, steel sheet can packaging which were put into circulation a few years ago and have been in the market ever since, exhibit a variable tin content; therefore, they require a material homogeneous in terms of tin content to be generated. This fact means an additional need for reducing the tin content of the metallurgical change material, as the presence of tin, as a non-ferrous metal, in steels produced in electric arc furnaces with a large fraction of steel scrap is the cause of numerous

material defects in the products. The adverse effect of tin on the steel properties results not only from its precipitation at grain boundaries or forming low-melting intermetallic compounds during solidification of continuous steel ingots, but also from interaction with other harmful elements originating from the scrap - especially copper. The maximum allowable tin content of constructional steels is generally around 0.015%.

The investigation results described in this paper relate to basic parameters of the process of leaching tin from waste can steel sheets - as input data necessary for establishing the scope and run of the tin recovery process. The testing material were steel sheet samples originating from the manufacturer of food product cans covered with a tin coating and one-sidedly and double-sidedly covered with a lacquer layer. The samples were subjected to preliminary chemical and mechanical treatment, followed by leaching in the NaOH solution. The essential part of the investigation was the analysis of the possibility of removing tin from waste steel sheets that may form charge for the metallurgical process as an iron-bearing source.

2. THE USE OF TIN FOR PRODUCING TINNED SHEETS

The most common way of the commercial use of tin is its application as an anticorrosive coating on steel sheets intended for the manufacture of metal packagings. These packagings are made from tinned steel sheets (of low-carbon cold rolled steel) coated with a tin coating of a basis weight ranging from 1 to 15.10 g Sn/m^2, depending on the tin plating method [1]. The gauge of the sheets used is dependent primarily on the purpose of the manufactured cans and ranges, depending on the application, from 0.15 mm (for cans intended for packing foodstuffs) to 0.25 mm [2] (for cans to be used for packing other products).Until recently, tin coatings on objects in contact with food (food tins, cans, pans, pots) have been produced by the hot-dip coating method with either single or multiple dipping (2 or 3 times) in metal baths at a temperature of 240 - 250 °C. The overall thickness of the tin coating is 5 - 40 μm [3]. Nowadays, steel sheets tin plated by the electrolytic method are commonly used. The overall thickness of the tin coating applied by this method does not exceed 2 μm. The main purpose of applying a tin coating on the can sheet surface is to protect it against the corrosive effect of products packed into the cans. The large quantity and variety of manufactured packagings available in the market in the form of cans make their manufacturers undertake actions aimed at minimizing the production costs, which often involves the use of ever thinner sheets with reduced tin coating thicknesses. The tendency to minimizing the tin coating applied on the can surface, observed in recent years, has resulted in the actual double-sided sheet tin plating thickness (the thickness ratio of the outer coating to the inner coating), which still a few years ago was 5.6/5.6 g Sn/m^2, amounting now to 2.8/2.8 g Sn/m^2. Due to the reduced tin coating thickness and the need for meeting the preset parameters of the sheet related to its resistance to the corrosive influence by the packed product, additional lacquer (epoxy-phenyl or polyester) coats are now applied to enhance the anticorrosive protection of the sheet.

The metallic fraction of waste can steel sheets is now recovered most often from the stream of municipal wastes subjected to the processes of segregation in waste treatment plants. To select waste steel sheets, a line of technological plants is used, which operate based on mechanical and electromagnetic separation processes along with the processes of mechanical removal of parts of labels, paints and lacquers. Thus obtained metallic waste in the form of steel cans, prior to determining the method of its further processing and establishing the recovery method, is subjected to analytical examination to determine the tin content. After determining the tin content based on the performed examination (and depending on the specific tin level in the examined material), the obtained metallic fraction can be handed over, as a charge material, to further metallurgical processing or to subject to processes aimed at the recovery/removal of tin. The process of tin recovery/removal from waste steel sheet can be carried out using either leaching methods or electrolysis. However, either of the methods requires pure and homogeneous wastes. Thus recovered tin constitutes a good raw material for industrial reuse. However, the efficiency and cost of these methods depend chiefly on the origin and type of steel wastes, as well as on the degree of their purity, i.e. the contents of undesirable admixtures in the form of metals other than steel, as well as paper and plastics [4], and especially protective

coatings of lacquers applied on the surface of sheets intended for can production. Therefore, the selection of the tin recovery method envisaged for industrial application and the determination of the technological process parameters require the preliminary examination of the charge material to be made. This examination should encompass the tin content level in the material to be processed and the level of material contamination with other substances. The choice of the correct project assumptions for the process requires also the analysis of the economy of the entire project and the prospects for its functioning and development in the aspect of meeting the environmental protection standards to be carried out.

3. INVESTIGATION METHODOLOGY AND THE ANALYSIS OF THE RESULTS

The main objective of the undertaken investigation was to determine the basic parameters of the processes of preliminary preparation of tin plated steel sheets for the tin removal process by leaching in a 1M NaOH solution.

Steel sheet samples obtained from a leading industrial manufacturer of cans intended to be used for packing foodstuffs were used for testing. 0.15 mm-gauge steel sheet double-sidedly plated with 2.8 g/2.8 g (out./inn.) tin coatings and either one- or double-sidedly covered with epoxy-phenyl and polyester lacquer coats was tested. The samples were assigned the numbers 1, 2 and 3, depending on the type of lacquer coating applied. Sample no. 1 was double-sidedly tin plated, non lacquered, steel sheet. Sample no. 2 was one-sidedly tin plated steel sheet with an one-sidedly applied lacquer coat in the form of a "white lining" (the type of coating most often used inside cans). Sample no. 3 was double-sidedly tinned steel sheet with a lacquer coat in the form of "white lining" applied on one side, and a lacquer coat in the form of "golden lining" (the type of coating most often used inside cans) on the other side. The steel sheets were cut into 6 mm-diameter discs using a pneumatic press. Thus prepared material is illustrated in **Figure 1**. Then, sample no. 2 was subjected to the mechanical working process to remove the lacquer layer in a roller mill. The sample subjected to 15 minutes' treatment in the roller mill was assigned the number 2M after that process. A view of the roller mill is shown in **Figure 2.**

Figure 1 The test material

Figure 2 The laboratory roller mill

Next, sample no. 3 was subjected to the process of chemical top layer stripping in a mixture of a 10 % NaOH solution and a 10 % ethyl glycol mixture at a temperature of 100 °C (for a duration of $t = 25$ min), assigning it the number 3-Ch after this process. The both samples were washed with distilled water and dried. So prepared samples with the numbers 1, 2, 2-M, 3 and 3-Ch were leached in a 1.0 M NaOH solution. The purpose of this operation was to examine the effectiveness of tin dissolution from the sheet sample surfaces. The analysis of tin concentrations in the examined solution was made by the atomic emission spectroscopy method (with an Agilent MP-AES 4200 spectrometer). **Table 1** summarizes the basic parameters of the samples subjected to leaching.

Table 1 A summary of the basic parameters of the leached steel sheet samples

Specimen No.	Sheet lacquer coat type (outer side / inner side)	Test sheet sample preliminary treatment process	Sample mass (g)
1	lacquered / not lacquered	Untreated	3.040
2	not lacquered / white lining	Untreated	3.016
2-M	not lacquered / white lining	Hammering for t = 15 min	3.002
3	golden lining / white lining	Untreated	3.050
3-Ch	golden lining / white lining	Chemical lacquer removal in a mixture of 10 % NaOH and 10 % ethyl glycol, t = 25 min	3.050

A summary of the test results for the process of tin removal from all samples is presented in **Figures 3** to **5**.

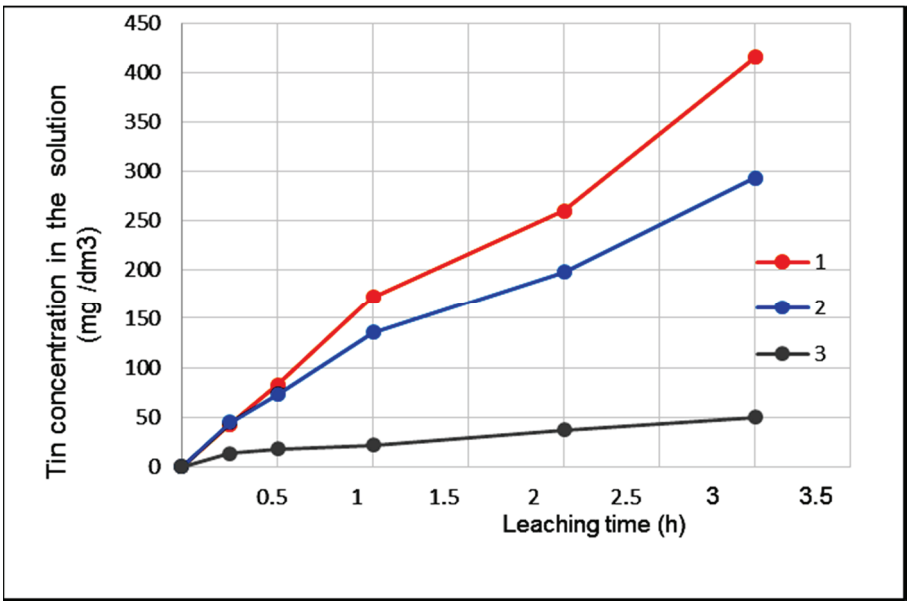

Figure 3 The kinetics of tin leaching from samples nos. 1, 2 and 3 using a 1.0 M NaOH solution

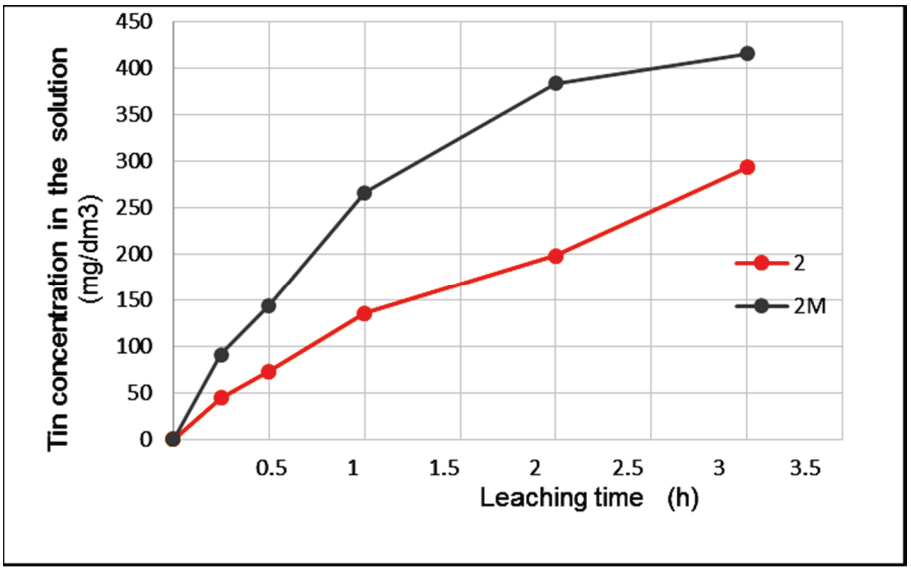

Figure 4 The kinetics of tin leaching from samples nos. 2 and 2-M using a 1.0 M NaOH solution

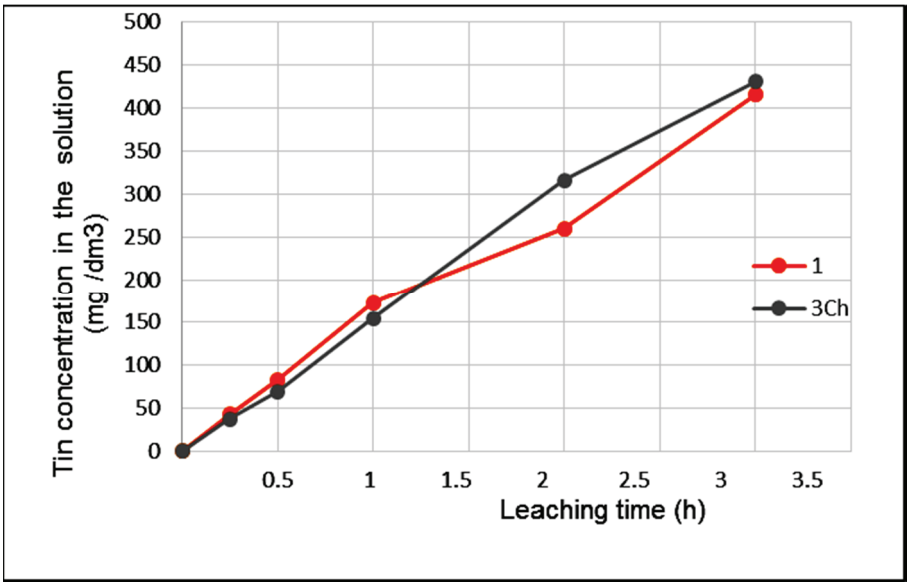

Figure 5 The kinetics of tin leaching from samples nos. 1 and 3-Ch using a 1.0 M NaOH solution

As can be seen in **Figure 3**, the lacquered top surfaces effectively inhibit the passing of tin to the solution. It is indicated by **Figure 4** that the sheet hammering process to remove the lacquer coat has resulted in an increase in tin leaching efficiency. **Figure 5** shows that the chemical removal of the lacquer from the sample surface enables tin leaching efficiency to be achieved, which is comparable to that for not lacquered sheet (sample no.1). **Table 2** summarizes the values of tin concentrations in the solution after 3 hours of leaching process duration for all the samples tested (nos. 1, 2, 2-M, 3 and 3-Ch).

Table 2 Tin concentration in the 1.0 M NaOH leaching solution for the samples tested for a duration of t = 3h

Sample No.	Tin concentration (mg/dm^3)
1	415
2	293
2-M	415
3	50
3-Ch	430

4. CONCLUSIONS

The investigation carried out and the obtained investigation results allow the following conclusions to be drawn:

1. The mechanical or chemical preparation of test sheet samples nos. 2-M and 3-Ch aimed at removing the top protective lacquer coats - as activities preceding the process of leaching in the 1 M NaOH solution - have the favourable effect of enhancing the tin leaching efficiency. This fact can be of assistance to a considerable extent in developing a method for the preparation of waste tin-containing steel sheets for the hydrometallurgical tin recovery process.
2. A low efficiency of the process of tin leaching from sheet samples covered with a top lacquer coat (samples nos. 2 and 3), which had not been prior subjected to mechanical or chemical treatment aimed at its stripping, was found. Further investigations into the possibility of using the hydrometallurgical tin recovery process, preceded by a coupled chemical top lacquer coat stripping method, need to be carried out for this type of material.

REFERENCES

[1] Standard PN-EN 10202/2003: Cold rolled products intended for packagings - Tin electroplated or specially chromium plated steel, p. 1.

[2] SIWKA, J., GAJDA, B., RETERSKI, J. Standardization of steel sheets samples coming derived from tin-coated steel waste cans. *Ore and non-ferrous metals - Recycling*, 2016, vol. 61, no 3, pp. 126 -131.

[3] SUROWSKA,B.*Selected problems of corrosion and corrosion protection.* Lublin University of Technology, 2002, p.111

[4] ŻAKOWSKA, H.Recycling and recovery of waste metal packagings. *Opakowanie,* 2007, no. 4, pp.19 -25.