THE INFLUENCE OF IMPACT MACHINING OF SCRAPPED STEEL SHEETS OF CANS FOR ACCELERATION OF TIN LEACHING PROCESS

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Abstract

Current tin recovery processes from steel sheets of scrapped cans are mainly based on hydrometallurgical methods using water solutions of acids and bases. Due to the universally binding tendency forcing activities aimed at improving the efficiency of production processes, also in the case of hydrometallurgical methods of metal recovery, it is necessary to look for new economic technological solutions. One of many such activities may be the initial impact machining of sheets of scrapped cans subjected to tin recovery, the result of which may significantly affect the speed of the hydrometallurgical process.

Key words: Cans, tin, recovery, hydrometallurgy

1. INTRODUCTION

Successively exhausting global natural resources, with a simultaneous dynamic increase in the consumption of material goods are the main impulseto search for new methods of recovery and recycling of waste materials. The necessity to ensure stable supplies of raw materials for production, among which metals constitute the largest group, encourages the search for new technological processes aimed at reducing the costs of obtaining them from municipal waste. Most frequently recovered metals packaging waste constituting the fraction of municipal waste is mainly the materials constituting the trunk of these packaging - cans. In this group, the recovery processes carried out mainly concern steel and aluminum sheets, regardless of the possible protective coatings on their surface. In the case of metal recovery from canned tin plates, the applied processes should cover both the steel from which they are made as well as the tin constituting the protective coatings of these sheets. Currently, cans are made from white steel sheets, tinned by electrolytic method [1].The technological process of tinning of steel sheets intended for the production of packaging should be compliant with the resulting standards from the applicable best available technologies BAT [2, 3].The total thickness of the tin layer applied by this method usually ranges from 2 to 5 µm, and therefore the waste of the sheets so coated contains less tin than in the case of fire coating. However, a relatively high share of this waste in the fraction of municipal waste makes recovery of the tin contained in them economically viable. Currently available tin recovery processes from steel surfaces of waste tin cans are mainly based on hydrometallurgical methods using aqueous solutions of acids and bases. The current environmental protection requirements, as the main condition, require the introduction of solutions aimed at improving the energy efficiency of the production processes.This requirement also applies to hydrometallurgical methods for metal recovery [4]. One of many different types of actions that improve the efficiency of these processes may be the initial mechanical treatment of waste tin cans subjected to tin recovery, the effect of which may significantly affect the dynamics of the hydrometallurgical progress. This article describes the results of tests, the effect of which can affect the acceleration of the course of the tin leaching process from steel sheets used to produce cans. The results of these tests can be used as a general process assumption for designing the initial stage of the recovery of tin from this group of waste [5].

2. RESEARCH MATERIAL AND SAMPLE PREPARATION

The tests carried out used steel sheet samples obtained from one of leading industrial manufacturers of cans for food products. The steel sheet tested had a thickness of 0.15 mm and a tin coating on both sides, with the basis weight declared by the manufacturer corresponding to the series: 2.8/2.8 g/m^2. The tests used unpainted steel sheet marked with number 1 and the same plate coated on both sides with layers of protective varnishes marked with number 2. Photographs of sheets were presentedin **Figure 1**.

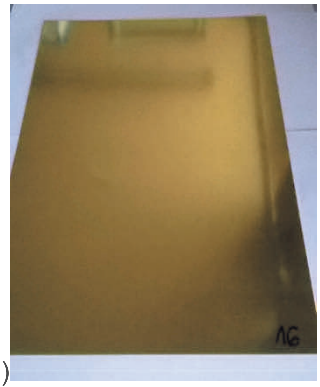

1)

2)

Figure 1 Samples of steel sheets

The varnishes used were commercial products made on the basis of epoxy-phenolic and polyester resins. The list of properties of the tested sheet samples and assigned identification numbers are shown in **Table 1**.

Table 1 List of properties of tested tin-coated steel samples

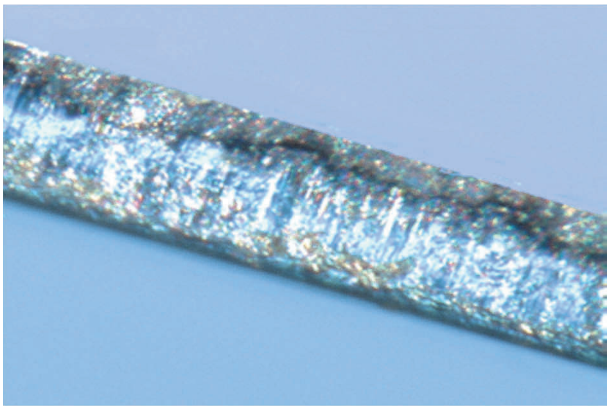
Signature of the tested sheet sample	**Types of applied varnishes**	
	Outer side of the sheet / cans	Inside side of sheet metal / cans
1	unpainted sheet	unpainted sheet
2	unpainted sheet	white enamel (polyester varnish)

The research began with microscopic observation of the surface of the plate samples and measuring the thickness of the applied protective layers of the varnish. Observations were made using a NIKON SMZ 1500 type microscope, using a 100x magnification of the image. The results of microscopic examination in the range of the thickness of varnish layers are presented in **Table 2**.

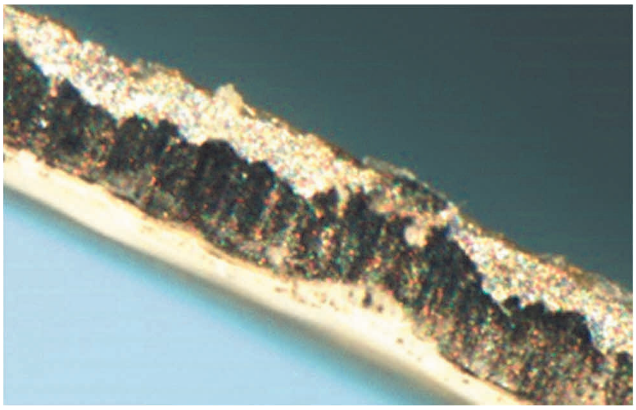
Table 2 List of results of thickness measurement of varnish layers on the tested plate samples

Signature of the tested sheet sample	**Thicknesses of varnish layers** (µm)									
	Outer side					Inside side				
	Measurement			Mean	Standard deviation	Measurement			Mean	Standard deviation
	1	2	3			1	2	3		
1	unpainted sheet			-	-	unpainted sheet			-	-
2	3.74	3.83	3.93	3.83	+/- 0.095	7.00	7.12	7.33	7.15	+/- 0.167

During the microscopic tests, also photos of cross-sections of sheet samples were taken. Photographs of samples are shown in **Figure 2**.



a) Sheet metal sample 1 - 100x magnification



b) Sheet metal sample 2 - 100x magnification

Figure 2 Photographs of sheet samples

Next, the thickness of tin coatings was measured on the surface of the plate sample 1, which was a standard for comparison of results obtained in the further part of the research. The measurement was carried out using the Fischerscope® XRAY XDL X-ray fluorescence analyzer. The measured mean of the three measurements of the tin h_1 shell thickness on the outside of the sheet 1 was 0.521 µm, while on the inside the coating thickness h_2 of the tin was 0.520 µm. The thickness of the tin coatings found were equivalent to the basis weight on the outer and inner side of 3.8/3.8 g/m^2, which in accordance with the PN-EN 10202/2003 standard allows qualify the sheet metal for the 2.8/2.8 g/m^2 series. In the next stage of the research, the sheets of metal shown in **Figure 1** were cut by pneumatic press for disks with a diameter of 6 mm. The size of the samples prepared in this way enabled further processing of the tested material for tin recovery in laboratory-scale processes simulated in the laboratory. An example of the appearance of a plate sample (in the form of discs) prepared for further research is shown in **Figure 3**.

Figure 3 Sample view of a sheet sample in the form of cut discs

Then, a sample of a mass of 50g coated double-side plate was treated in a laboratory impact mill for 15 minutes. The view of the laboratory impact mill and the inside of its drum are shown in **Figure 4**. The arrangement has the following parameters: drum diameter 200 mm, drum width 75 mm, roll diameter 65 mm, 50 mm, 30 mm, speed 150 min^{-1}, electric motor power 1 kW.

Figure 4 Interior view of the laboratory drum of the impact mill

A view of a double-side varnished sheet metal sample subjected to a 15-minute impact treatment is shown in **Figure 5**. The sheet sample after impact machining was given the number 3.

Figure 5 View of the sample 3 - coated sheet on both sides after impact machining

A sample of the double-sided varnished sheet after the impact machining was subjected to microscopic observation using a NIKON SMZ 1500 microscope and a 100-fold magnification of the image. The results of microscopic examination in the range of the thickness of varnish layers are presented in **Table 2**. The organoleptic tests carried out on the sample of the sheet treated with impact proved that from 65 to 75% of the original surface of protective coatings was separated from the surface of the sheets.

3. TESTS OF HYDROMETALLURGIC TIN RECOVERY

In the next stage of the research, tin leaching was carried out from the sheet surface 3 - after impact machining and from the surface of the uncoated sheet, in order to make a comparison. First, the tested samples was given a fixed surface S = 25 cm^2, and then weighed. In the case of uncoated steel, the sample weight was m_p = 3.0 g. In contrast, in the case of varnished sheet metal (including sheet metals before impact machining), the sample weight was 3.07 g. Subsequently, the tin mass in the test sheet samples was determined to be m_{pSn} = 0.019 g, using the formula (1) [5]:

$$m_{pSn} = [(h_1 + h_2)\cdot 10^{-4}]\ S\ \rho_{Sn} \quad (1)$$

where

m_{pSn} - mass of tin in the sample (g)

h_1 - thickness of the tin coating on the external surface of the plate sample (μm)

h_2 - the thickness of the tin coating on the inside surface of the plate sample (μm)

S - area of the test sample, amounting to 1 (cm^2)

ρ_{Sn}- specific gravity of tin at a temperature above 13.2 °C, amounting to 7.3 g/cm^3

The samples thus prepared were subjected to tin recovery tests using hydrometallurgical methods. The experiments were carried out in a glass vessel filled with a leaching solution with a volume of V_{R1} = 0.03 dm^3 (guaranteeing the ratio s / l = 1/10) at 20 °C and constant rotational speed of the stirrer 300 rpm. The duration of the test process was 3 hours. Samples of the leaching solution were collected at 15, 30, 60, 120, 180 minutes of the process, without interruption. As a leaching agent, the solution 1M NaOH was used. Samples taken during the process were diluted and analyzed for tin concentrations. The tests were performed using the Agilent MP-AES 4200 emission spectrophotometer. The results obtained are shown in **Figure 6**.

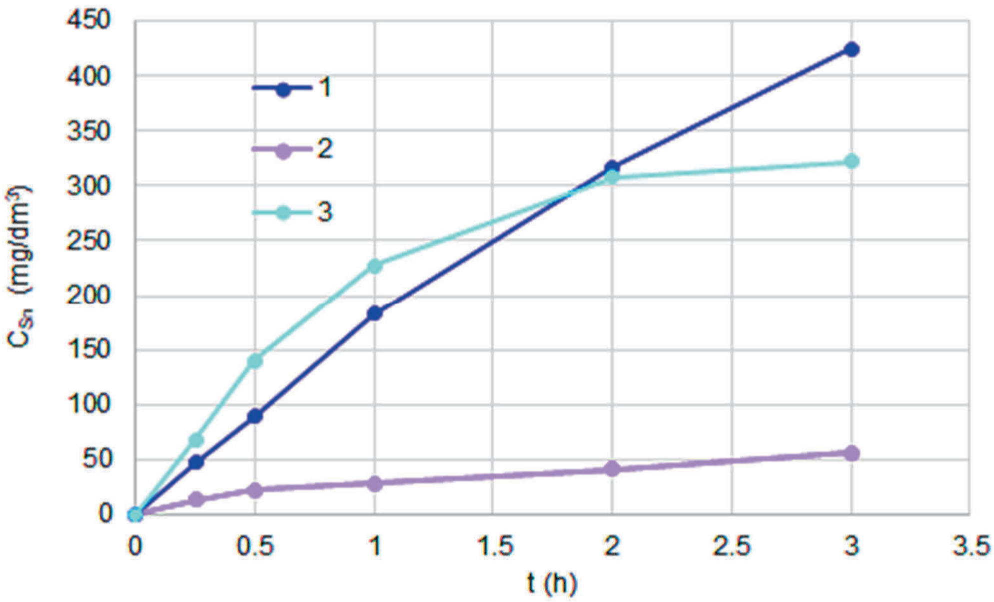


Figure 6 Dependence of tin concentrations in 1M NaOH solution since sample leaching:
1 - unpainted, 2 - double-sided varnished, 3-double-sided varnished, impact-treated

The above test results show that the layers of protective varnishes on the surface of the tested samples (have not been subjected to any treatment), constitute the essence of an obstacle in the process of tin leaching from the tin coatings underneath. A graphical comparison of the concentration of tin from leaching is shown in **Figure 6**. The graphic dependence of the obtained tin concentrations shows that in the case of sample leaching after impact treatment in the first 15 minutes of the process, a 45% increase in tin concentrations was obtained in relation to the values obtained for the reference sample - uncoated sheet. After 30 minutes of the process, however, the highest 57% increase in tin concentration was obtained - in the case of a sheet sample after impact machining, in relation to the uncoated sheet. After 60 minutes, a decrease in the upward trend was found,at which the difference in the concentration of tin was 24%. However, after 120 minutes, the compared samples obtained similar concentrations of tin in leaching solutions. The experiment was completed after 180 minutes, resulting in a tin concentration value of 24% lower in the case of the sample after impact treatment in relation to the tin concentration obtained for the standard sample.Probable causes of this state of affairs are tin losses caused by mechanical treatment of the lacquered sample and insufficient removal of varnish layers from its surface as a result of mechanical machining.

5. SUMMARY AND CONCLUSIONS

The tests and the results obtained allow specify the following conclusions:

1) Varnishes on the surface of the tested samples showed resistance to 1 M NaOH solution. The low efficiency of the tin leaching process from the surface of the tin samples coated with the top layer of varnish, prompts to looking for new methods that enable their initial removal.

2) Mechanical impact of the test sheet sample 2, led to an increase in the dynamics of the tin leaching process in 1 M NaOH solution in the first 120 minutes from its start. This effect should be applied in the form of a designed technological arrangement, constituting the initial element of the string for hydrometallurgical recovery of tin from the surface of waste cans, also taking into account the elimination of tin losses caused by mechanical machining of sheets.

3) Bearing in mind the increased dynamics of the tin leaching process from the surface of the sheets after the mechanical removal of layers of varnish in a roller mill, it seems correct to continue research on improving this process.

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