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RESEARCHES ON IDENTIFYING SOLUTIONS, DESIGNING AND IMPLEMENTING INNOVATIVE TECHNOLOGIES FOR RECYCLING AND REUSE OF NON–FERROUS METAL BASED RAW MATERIALS

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Abstract: Secondary materials are essential to the industry's survival because even new metals often require the combined use of recycled materials. The recovered materials are melted down in a furnace, poured into casters and shaped into ingots. These ingots are either used in the foundry industry or they can be transformed into flat sheets and other wrought products, which are then used to manufacture new products. Aluminium offers intelligent and practical solutions to recovering for recycling. The main activities described in this article are carried out during the experimental phase of the research and they are oriented towards the recovering aluminium for recycling. The objective of the research is to develop some recycling facilities for re–smelt and re–cast of aluminium by using charcoal briquettes into a mini metal foundry, designed and manufactured in laboratory. In this research we experimented a reusable backyard foundry that melts aluminium cans (soda and beer) easily and safely.
Keywords: secondary materials, recycling & reuse, non–ferrous metal based raw materials, aluminium cans (soda and beer)

INTRODUCTION

Recycling is a modern concept in the waste management, emerged as one of the possibilities to limit waste and to use resources more efficiently.[1–3] It has become increasingly clear that the industrialization and the sustained growth of the population have led to the consumption of increasingly large amounts of resources. An economic development without metal resources is inconceivable in the 21st Century and it is not possible to be in the global competition, with about 75–85% of the world economy depending on these resources. Recovery and reusing of recyclable resources are means of solving the contradiction between the requirements of the economic growing process and the restrictive nature of natural resources.[1–5] In this broad context, non–ferrous metals and their alloys are in the centre of modern life and in many developments of high technology, especially in high–top industries.

At least 42 non–ferrous and rare metals are produced in the European Union being used in a variety of industrial applications. Non–ferrous metals are produced from a wide range of raw, primary and secondary materials. Primary raw materials are derived from ores (from deposits) and then treated before they are introduced into metallurgical processes for the production of raw metal. The secondary materials are indigenous waste and residues or residues, which may also undergo the same treatment. The production of secondary non–ferrous metals includes the production of metal from secondary raw materials (including wastes) and the rewinding and alloying processes. There are many similarities in the production of primary and secondary non–ferrous metals in some cases being impossible to distinguish between the techniques used. There have been identified 10 groups of metals with similar production methods, one being aluminium and its alloys.

In Europe, ores deposits containing metals in high concentrations have been progressively emptied only some specific sources being remained. Recycling is an important component when replacing raw materials for a number of metals, which are recyclable and which can always be recycled without losing any of their properties. In general, recycling prevents the loss of potentially useful materials and reduces the consumption of raw materials. Thus, recycling can make a significant contribution to sustain development; at the same time the introduction of secondary raw materials in a large proportion in the production process leads to a reduction in raw material consumption. Non–ferrous metals (including aluminium) can be recovered from their waste and can be reintroduced into the production cycle by recycling without losing their qualities.

Researches on identifying solutions, designing and implementing innovative technologies for recycling and reuse of non–ferrous metal based raw materials are numerous.[1–3] The specific strategic objective of capitalizing recyclable metal resources – including the non–ferrous metal raw materials area – is the implementation of new concepts and new technologies for sustainable processes in the non–ferrous metals industry and environmental protection (standards and best practices in the non–ferrous metals industry) through new technologies and innovative solutions on: [1,2]

- the efficient use of natural resources;
- improving metal recovery by recycling and reuse of raw materials;
- substitution of critical metals;

- replacing raw materials with attractive commercial alternatives with low impact on the environment;
- the development of new materials through material capitalization;
- techniques for the manufacture of metallic materials;
- prevention and minimization of metal waste;
- rehabilitation of polluted areas through metallurgical and / or mining activities;

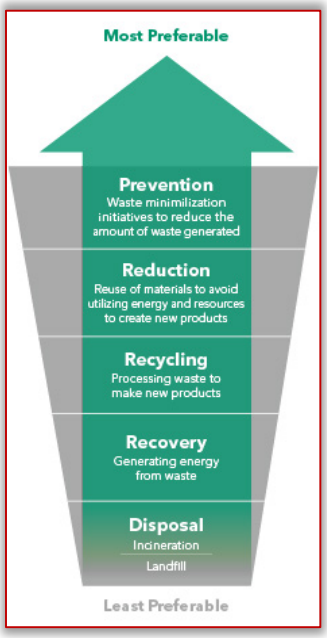


Figure 1. Different materials waste management approaches

With the worldwide volume of wastes processed increasingly sourced from consumer and light industrial waste streams, the percentage of valuable nonferrous metals has dramatically increased. This trend, coupled with environment protection legislation and ever increasing waste minimization, has driven the need for complicated, integrated nonferrous recovery plants. Millions of tonnes of nonferrous scrap are recovered annually and used by smelters, refiners, ingot makers, foundries, and other manufacturers. Secondary materials are essential to the industry's survival because even new metals often require the combined use of recycled materials.

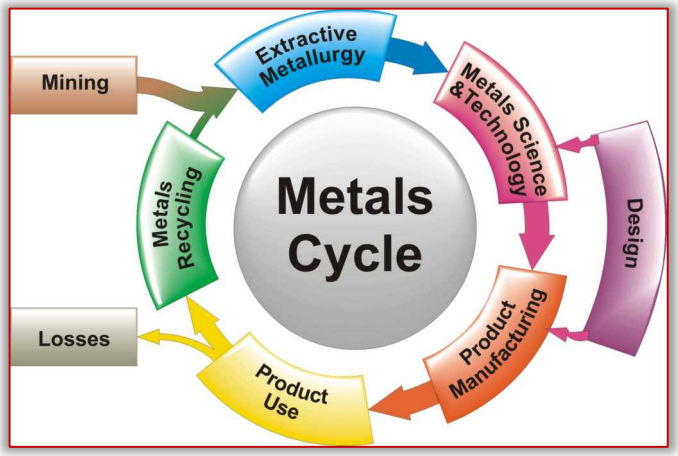


Figure 2. The metal's life cycle

All metals can be recycled with minimal or no loss of their original physical properties. They are such versatile materials that the possible applications for each metal and their combinations are endless. The most commonly used non–ferrous metals are Aluminium, Copper, Lead, Zinc, Nickel, Titanium, Cobalt, Chromium and precious metals. Non–ferrous metals, including aluminium, do not degrade during the recycling process and thus can be recycled an infinite number of times. Aluminium has (great recycling potential) and is often re–used for the same application for which it was originally manufactured. Its strength, flexibility and light weight, make it ideal for large applications.

Figure 3. Non–ferrous metals with great recycling potential

Thus, the non–ferrous metals recovery and any recycling process has become increasingly important – both domestically and globally. The trends are continually increasing resource recovery rates with a particular focus on the reduction of metal losses to and diversion from landfills relatively low cost and isotropic properties especially in those applications not requiring extreme loading or thermal. The general trend is for improvements to be sought in every area possible – new ways of applying existing technologies are sought to gain improvements along with the development of new technologies for solutions to existing and emerging applications. The beverage cans metal recyclers are also focusing on increasing both their material recovery rates and the quality of the recovered material.

In this sense, aluminium is readily recycled without any loss of quality and hence scrap aluminium has significant value. Therefore, the recycling of Aluminium is extremely important due to several economic and environmental reasons. Among all the aluminium scraps, the beverage cans is the most recycled packaging material because of the high value of the scrap and ease of collection. The recycling of aluminium beverage cans eliminate waste. It saves energy reduce emissions, reduce use of city landfills and provides added revenue for recyclers. Moreover, Aluminium is a vital material in the construction, packaging, and transportation industries. Structural components made from Aluminium and its alloys are vital to the all industries.

KEY TRENDS IN THE METAL INDUSTRY

Materials substitution and efficient use of materials are strongly interrelated factors.[1–5] The threat of materials substitution has encouraged all producers to apply new technologies aimed at reducing the amount of material (and hence lowering the cost) required to meet consumer needs.[1–3,6–9] Materials substitution significantly affects the trend toward more efficient use of monolithic materials.[1–3,7–8] The increasing use of alternative materials in aircraft, automotive and construction applications has motivated the metal industry to provide lighter weight aluminium alloys and metal matrix composites.

The motivation for this substitution has mainly been the opportunity to achieve weight savings.[1–3,6–9] As the properties of these materials improve, their level of performance, and hence substitution, should also increase.[1–3,6–9] More important, as more experience is gained with these materials, their associated costs could decrease, providing the major motivation for their use, especially in above–mentioned advanced industries.[1–3,6–9] To develop these advanced materials, the metal industry has undergone some actions:

- efficient use of materials in technological processes, devoting significant research resources to develop lighter weight alloys and metal matrix composites products and increased process technologies that require less metal to satisfy a particular market need.
- materials substitution, knowing that when a new material can offer a cost or performance advantage over the current material in an established industrial or commercial application, the new material will begin to displace the old in that application.

Development of lightweight aluminium–based composites can be considered as one of the promising solutions to address this issue. At present, the development of metal matrix composites with light metal matrices are gaining increasing attention due to their enhanced properties coupled with weight savings. These unique properties make them attractive for automotive and aircraft industries in which the weight reduction is the critical factor. So far, extensive studies have been done for the production of aluminium matrix composites and now these are being manufactured commercially for numerous industrial applications. In light metal matrix composites, aluminium is mostly used as a base metal matrix phase.

Aluminium alloy matrix (aluminium matrix composites) constitute an important category of design and weight–efficient materials and their processing has the vast development in the various research on advanced materials to overtake the need of low cost, light–weight and high–technological properties. Their relatively low cost and properties especially in those applications not requiring extreme loading or thermal conditions. Also, the processing problems and commercial difficulties associated with continuously reinforced aluminium matrix composites are contributory to the recent interest in their particulate composites (commonly ceramic particles such as SiC).

RECYCLING METAL RECIPIENTS

Owing to increased urbanization and modern lifestyle, demand for use of metal packaging has tremendously increased. Metal packaging is safest form of packaging so it is the basic preference of consumers. Metal is the most recycled material than any other waste packaging materials. About 80% or more metal packaging are recycled and used again without any loss in quantity and causing any loss in nutrients of Food and beverages.

Figure 4. Recycling metal recipients

Aluminium is the most precious metal that is used in packaging, because this package has many advantages for both beverage and a consumer manufacturer, which neither PET nor glass has. [1–3] For example, the aluminium can for beverages is a lightweight, unbreakable package, cools quickly in the refrigerator, protects the content of factors such as light and air, has long life, maintains the effervescence and freshness of beverages, requires no labelling, and not last it is easy to recycle. [4,5,8,9] Aluminium cans are recycled in a closed circuit after the recycling process, and aluminium can be re–injected again or can be used for other products. Recyclable aluminium can come from a wide range of sources, including industries and private households. They also include metal containers used as packaging by large beverage manufacturers (juice and beer). [1–5,8,9]

Figure 5. Metal containers used as packaging by large beverage manufacturers (juice and beer)

Aluminium beverage cans are, like PETs, omnipresent, but similarities stop here. Unlike plastic, aluminium can be recycled to infinity without degrading at all. The recycling process is relative simple: the beverage cans are sorted, then washed to remove the contaminants and then melted. The molten metal is converted into ingots which are then transferred to another processing unit and pulled into thin sheets, which can then take the form of beverage cans. On the whole, the process is very fast, a beer can deposited at a waste collector is recycled and reaches the market again. [4,5,8,9]

There are many initiatives involved in improving the return of aluminium waste and the industry is an active player in this area. Recycling empty beverage cans is only an example. Aluminium dosages are an important and extremely valuable resource, representing an important source of secondary aluminium. Once the beer or juice is consumed, if the empty can is properly collected and subsequently recycled, it can be revalued indefinitely without losing anything. Thus, aluminium cans can become raw material.

Aluminium packaging has an intrinsic quality and cannot be said about it as a waste, but as a resource, being 100% recyclable.[1–9] Thus, out of all recyclable packaging, aluminium cans have become the most innovative and durable packaging. Aluminium can be recycled indefinitely without losing its properties unlike other recyclable materials such as plastic, paper or glass, which can be recycled for a limited number of times. The aluminium industry has all the interest to promote recycling as part of the industrial strategy. In Europe, about 50% of the total aluminium used to produce new beverage cans and other aluminium packaging products comes from recycled aluminium. [1–3]

However, a large proportion of packaging waste is generated in households, which requires a separate waste collection infrastructure from metallic cans which are mixed with other household waste or separately through locally developed networks. [1–3,7–9] The volume / weight ratio for aluminium metal dosages is quite high: one aluminium box has 13–15 grams, the boxes are made of 0.17 mm aluminium sheet. Thus, a pound of aluminium cans consists of approx. 60–70 pieces, which can be collected, flattened or even perforated. That is why the sustainable solution for fulfilling the recycling obligations and, implicitly, increasing the recycled quantities is the further extension of the population's access to the selective waste collection services. Creating and promoting the market for recycling and developing recycled materials from these packaging are fundamental. Thus, aluminium cans are an important resource that is also extremely valuable.

The aluminium can is the most recycled beverage packaging. [1–5,8,9] Obviously, this is only possible if they are collected and (re)introduced into the recycling circuit. If a can is left in nature, obviously it cannot fulfil its recycling potential. All the cans are 100% recyclable once they have been collected and reached a recycling point, even the smallest piece of aluminium is not lost. There are several forms to recycle beer or soft drinks cans. [1–3,6] As a rule, they can be melted and reused by an infinite number of times without losing quality.

Figure 6. Recycling aluminium cans by melting

In the European Union the recovery rate of these wastes varies between 40–70%, the latest statistical data indicating that the rate of recycling of aluminium cans reaches approx. 65%. [1,2] Worldwide, two out of three cans are recycled, but only one in three is recycled in Romania, or about 30–35%. [1,2] In 2007, the Recycling Standard for Romania required recycling at least half of aluminium waste by 2020. The recycling rate was then 3%, then rose to 5% and only in 2010 the growth was more significant, reaching 10%. [1–3]

Nowadays a recycling rate of approx. 35% of the quantity placed on the market due to the sustained increase of the industry's contribution to a coherent and efficient system of selective collection of packaging waste, capable of meeting these obligations through the development of waste management services for recycling purposes. This is due to the efficiency of the partnership with over 200 management companies that carry out waste collection, sorting and transport services for recycling purposes. [1–3]

In Romania there are only small collection centers for aluminium cans, but there are also small units processing them. [1–3] Our country is lacking in recycling facilities, so the 33 or 50 centiliters cans are taking the road to Europe, to European recyclers that actually do the recycling of can bales, the aluminium being melted in factories with special technologies. This raw material is brought back in the form of an aluminium sheet and is transformed into another can. [1–4,8,9]

RECYCLING THE ALUMINIUM CANS

Aluminium is the most expensive recycled product and recycling of aluminium is economic: it uses less energy and recycling is self–sustained due to the high value of the aluminium used. In other words, it is worth recycling it from all points of view: it is easy to carry, recyclable, infinitely reusable, it does not rust. For this reason, aluminium is rarely lost.

Recycling is the reprocessing of materials in new products [1]. Thus, in order to carry out the recycling process of collected non–ferrous metal waste, aluminium waste melting facilities are required. This enables cost efficiency and faster recycling of waste from aluminium [1]. Many of the drink products we buy are packaged in cans made from aluminium and this material can be recycled after we have finished with them to make either new cans or other products.

Figure 7. Recycling metal recipients

In this direction we propose a micro station for melting of aluminium wastes from the beverage cans (Figure 8). Research refers to a process for obtaining secondary aluminium from waste, by directly melting it into an experimental aggregate. All the soda cans came from a local recycling depot.

A lot of charcoal briquettes are placed around the crucible until they are filled. The charcoal is ignited and when the crucible is hot, the aluminium cans are introduced. Melting takes place at a temperature of 680–750°C. Thus, small ingots or secondary aluminium chips are obtained.

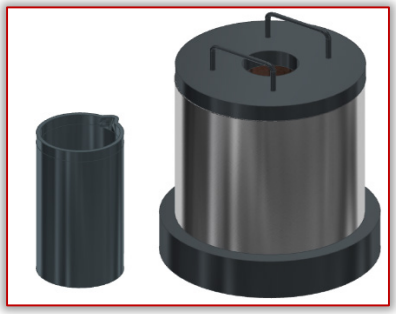
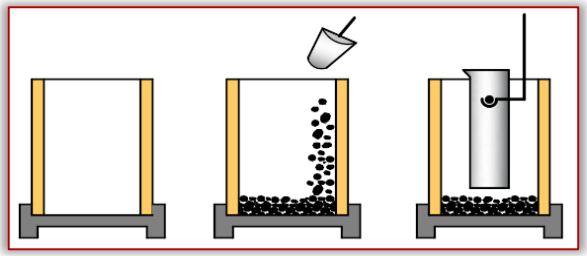


Figure 8. Designing technologies for recycling wastes from the beverage cans

(a)

(b)

Figure 9. Micro station for melting of aluminium wastes from the beverage cans: (a) the melting aggregate; (b) the crucible



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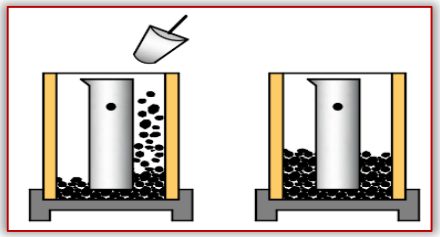
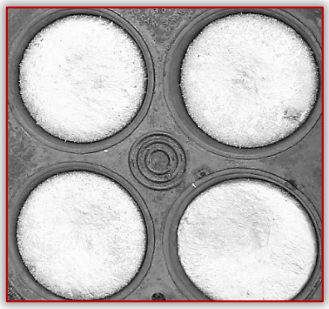


(b)

Figure 10. Micro station for melting of aluminium wastes from the beverage cans: (a) preparing the micro–station; (b) preparing for melting;



(a)

(b)

Figure 11. Casting of recovered aluminium wastes from the beverage cans: (a) ingots casting; (b) aluminium ingots

CONCLUSIONS

Many products are designed so that they can be recycled, at the end of their useful lifetime. This was not always the case. In the past, products were manufactured largely from new raw materials, mined from the earth's crust. When they ceased to work, they were 'dumped' in a landfill sites, often causing pollution and environmental damage. Aluminium drinks cans are usually recycled into ingots at a special "closed–loop" plant. This is the ultimate recycling process for environmental efficiency and used cans are often recycled. Aluminium cans (soda or beer) are easy to recycle and there are huge environmental benefits for doing this – yet many cans still go to landfill. If we recycle more cans we can reduce the amount of raw materials needed to produce new products.

All the Aluminium drinks cans can be melted down and used again and again. For this reason, recycling is part of the normal lifecycle for large industrial products – around 75% of all the aluminium ever made is still in circulation. The metal can be recycled time and time again without loss of properties, so getting the aluminium recycling habit is one of the best things we can do for the environment. Moreover, many of the drink products we buy are packaged in cans made from aluminium and this material can be recycled after we have finished with them to make either new cans or other products.

References

[1] Centrul Național pentru Dezvoltare Durabilă / National Centre for Sustainable Development 2007 Strategia Națională pentru Dezvoltare Durabilă a României: Orizonturi 2013–2020–2030 / National Sustainable Development Strategy for Romania: Horizons 2013–2020–2030 Bucuresti http://www.mmediu.ro

[2] Capră G S and Stan A–C 2013 Strategia Națională de Gestionare a Deşeurilor 2014–2020 / National Waste Strategy 2014–2020, Bucuresti http://www.mmediu.ro

[3] Ganea O, Simionescu A, Boța I and Popa M 2011 Reciclarea deșeurilor, o piață emergentă – Raport privid piața muncii în domeniul gestiunii deșeurilor în România București www.eco–social.ro

[4] Niero M and Olsen S I 2016 Circular economy: To be or not to be in a closed product loop? A Life Cycle Assessment of aluminium cans with inclusion of alloying elements Resources, Conservation & Recycling 114, 18–31

[5] Wernick I K and Themelis N J 1998 Recycling metals for the environment Annual Review of Energy and the Environment 23(1), 465–497

[6] Verran G O and Kurzawa U 2008 An experimental study of aluminium can recycling using fusion in induction furnace, Resources, Conservation and Recycling 52(5), 731–736

[7] Thomas M P and Wirtz A H 1994 The ecological demand and practice for recycling of aluminium, Resources, Conservation and Recycling 10(1–2) pp 193–204

[8] Das S K and Yin W 2007 The worldwide aluminium economy: The current state of the industry, JOM, 59(11), 57–63

[9] Millbank P 2004 Aluminium recycling vital to global supply chain, Aluminium International Today 16(5), 44–49

[10] Bulei C, Todor MP and Kiss I (2018) Metal matrix composites processing techniques using recycled aluminium alloy IOP Conference Series: Materials Science and Engineering 393 1–6

[11] Bulei C, Todor MP, Heput T and Kiss I (2018) Recovering aluminium for recycling in reusable backyard foundry that melts aluminium cans, The 7th International Conference on Advanced Materials and Structures (AMS 2018), 28–31 March 2018, Timisoara, Romania

[12] Bulei C, Todor MP, Kiss I and Alexa V (2018) Aluminium matrix composites: Processing of matrix from re–melted aluminium wastes in micro–melting station, International Conference on Applied Sciences (ICAS 2018), 9–10 May 2018, Hunedoara, Romania

[13] Gabrielle Gaustad, Elsa Olivetti, Randolph Kirchain, Improving aluminum recycling: A survey of sorting and impurity removal technologies, Resources, Conservation and Recycling, 58, 2012, 79–87

[14] G.O. Verran, U. Kurzawa, An experimental study of aluminum can recycling using fusion in induction furnace, Resources, Conservation and Recycling, 52(5), 2008, 731–736

[15] Stategia Națională pentru Dezvoltare Durabilă a României: Orizonturi 2013–2020–2030 (National Sustainable Development Strategy for Romania: Horizons 2013–2020–2030), Centrul Național pentru Dezvoltare Durabilă (National Centre for Sustainable Development), Bucuresti, 2007

[16] Oana Ganea, Adriana Simionescu, Irina Boța, Maria Popa, Reciclarea deșeurilor, o piață emergentă – Raport privid piața muncii în domeniul gestiunii deșeurilor în România, București 2011, www.eco–social.ro

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