Aluminium matrix composites: Processing of matrix from re-melted aluminium wastes in micro-melting station

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Abstract. This assessment focuses on the composites with metal matrix, the development of these composites having an important innovation in area of materials engineering over the last years, having in view that these type of composites offer several attractive advantages over the traditional engineering materials due to their superior properties. Therefore, the metal matrix composite become economical alternatives to the monolithic alloys due to their improved specific strength, stiffness and wear resistance combined with better physical properties such as low density and low coefficient of thermal expansion. Even though the specific strength of composites is not up to the mark, advantages like low processing cost and ease of processing make them as potential candidates for various innovative applications. In the meantime, the recycling of any waste is as such a worldwide phenomenon. In this context application of aluminium wastes for development of some value added product has been thought of in this work. This paper presents an overview of aluminium matrix composite systems on aspects relating to processing of matrix from re–melted aluminium wastes.

1. Introduction
The efficient use of materials and the materials substitution are strongly interrelated factors.\textsuperscript{[1–5]} The threat of materials substitution has encouraged all producers to apply new technologies aimed at reducing the amount of material required to meet consumer needs.\textsuperscript{[1–3], [6–9]} Therefore, materials substitution significantly affects the trend toward more efficient use of the monolithic materials.\textsuperscript{[1–3], [7–8]} The increasing use of alternative materials in many technological applications has motivated the industry to provide metal matrix composites. The motivation for materials substitution has mainly been the opportunity to achieve weight savings.\textsuperscript{[1–3], [6–9]} To develop these materials, the metallurgy has undergone some actions:
— the efficient use of materials in technological processes, devoting significant research resources to develop lighter weight alloys and metal matrix composites and increased process technologies that require less metal.
— the materials substitution, knowing that when a new material can offer a cost (or performance) advantage over the current material in an established industrial application, will begin to displace the old in that application.

Reducing the weight of the vehicle increases the fuel efficiency, which results in lower life–cycle costs.\textsuperscript{[1–3], [6–9], [13–15]} Significant reductions in weight and increases in strength are desired to meet fuel efficiency needs. Moreover, the industry experts have projected that substantial weight
savings could be achieved along with the property improvements.[1–3], [6–8] The many applications of these materials do not all have the same cost and performance requirements.[1–5], [8], [13–15] Accordingly, the investment criteria of user companies specializing in different product areas are different and the barriers to investment are highest in cost–sensitive areas, wherein expensive new materials must compete with cheap, well–established conventional materials. The relatively high cost of these composites will probably prevent their extensive use in some commercial applications. However, they may well be used in specific mechanical components such as pumps, bearings, gears, springs and suspensions.[10–15]

2. Development of metal matrix composites
Metal matrix composites with ceramic particulates – having a high volume fraction of the hard, brittle and elastically deforming ceramic reinforcement in the soft and plastically deforming metal matrix – have in recent years grown in use in various applications. In particular, these composites are noted for their high strength and wear resistance, coupled with enhanced high temperature properties.[15–20]

Discontinuously–reinforced aluminium alloy–based metal matrix composites (MMCs) containing particulate, whisker or short fibre reinforcements in an aluminium alloy metal matrix have in the time period spanning the last decades, engendered considerable scientific and technological interest for use in a spectrum of high performance markets.[15–20] Besides, the discontinuously–reinforced aluminium alloy–based metal matrix composites based on particulate reinforcements are attractive primarily because they can be made to have properties that are isotropic in three dimensions, or in a plane, when compared one–on–one with the continuously–reinforced metal matrices.[16–20]

In order to make metal matrix composites more attractive, several research priorities should receive attention in automotive sector. The priorities relative to the metal matrix composites are grouped in several categories of descending priority, which reflect the special needs to be done in order to promote the development of these materials in advanced sectors, including the automotive industry:[13–15]

— research in the area of development of lower cost manufacturing technologies, first in importance being the need for the low–cost and the highly–reliable manufacturing processes.
— research in the area of development of lower cost materials, including the search for all–type fibers or particulates and better matrices and continued development activities on existing materials is important to lower costs as well.
— implementing a rigorous control over the matrix, the reinforcement and reinforcement–matrix interphase in the metal matrix composites, which is critical to both the performance and cost of the composites.

In area of research and development of lower cost manufacturing technologies, the actions are oriented to develop high efficient manufacturing processes, research should concentrate on optimizing the industrial and laboratory processes, while in area of research and development of new and cheaper materials all actions need to increase the metal matrix composites production experience with present reinforcements and matrices, in the best route to lower costs, development of cheaper materials (reinforcements and matrices) being a major need.[1–4], [13–15]
Last, but not least, the priorities for implementing a rigorous control over the matrix, the reinforcement and reinforcement–matrix interphase in metal matrix composites can optimize the reinforcement–matrix interface and can prevent deleterious chemical reactions between the reinforcement and the matrix which weaken these composite.[4], [13–15], [20] Therefore, perhaps the most important element in the development of metal matrix composites will be an understanding of the relationships among the constituent properties (reinforcements and matrices), microstructure, and the macroscopic properties of the composite’s structure.

Metal matrix composites generally consist of lightweight metal as matrix (alloys of aluminium, magnesium or titanium), reinforced with ceramic particulate, whiskers, or fibres.[3–5], [16–20] In this sense, the reinforcement is very important because it determines the mechanical properties, cost, and performance of a new engineered material.[13–20] Reinforcements for metal matrix composites have a dual demand profile, which is determined by the composites processing and by the matrix system of the material, which can be achieved only by using non–metal inorganic reinforcement components.[15–20]

Aluminium metal matrix composites consist of aluminium alloy as the main constituent, which serves as matrix phase. The second constituent is embedded in the matrix and serves as reinforcement, which is usually non–metallic and generally ceramic such as silicon carbide, graphite and aluminium oxide. Sometimes boron carbide, aluminium nitride, silicon nitride, titanium carbide and boron nitride can also be considered.

Properties of these composites can be modified by varying the nature of constituents and their volume fractions. Generally, based on the type of the reinforcement, aluminium metal matrix composites are classified as fibre reinforced, whisker (short fibre) reinforced and particulate reinforced and illustrated in Figure 2. The imbedded phase is most frequently one of the shapes illustrated in Figure 2: fibers, particles, or flakes.

![Figure 2. Possible shapes of the reinforced phases in a composite materials:](image)

- (a) long fiber (aligned continuous, aligned discontinuous, random),
- (b) particle (spherical, cubic or platelets), and (c) short fiber (whiskers) or flake

3. Recycling the aluminium beverage cans

Aluminium is not surprisingly one of the most recycled materials today.[4], [5], [8], [10], [12,] Also, it is also the only packaging material that completely covers the cost of its own collection and processing by recycling. [4], [5] It is widely recognized that the recovering aluminium for recycling is not only economically viable, but energy efficient and ecologically sound,[1–5], [8], [10–12] The cost of recycling aluminium, which can be used an infinite amount of times, is less than producing new aluminium with raw materials.[1–5], [8], [10–12] The aluminium is one of the few materials – along with the copper and the steel – for which recycling costs are exceeded by the sales price of the recycled product. Aluminium is worth recycling it from all points of view: it is easy to carry, recyclable, infinitely reusable, it does not rust. Therefore, aluminium is rarely lost.[1–7], [10–12] In this sense, aluminium have a great potential, it is often re–used for various applications and could offer practical solutions to recycling. The use of synthetic composite materials like metal matrix composites allows to create components with certain mechanical, physical, chemical properties, imposed from the
design stage, making it possible to reduce material consumption, respectively to reduce the quantity of waste resulting from the manufacturing procedures.[13–20].

Recycling is the reprocessing of materials in new products being a modern concept in the waste management, emerged as one of the possibilities to limit waste and to use resources more efficiently.[1], [2], [4], [6–8], [10–12] Moreover, the importance of recycling is increasing and the secondary materials are essential to the industry’s survival.[1], [2], [6–12] Generally, the recovered metal are melted down in a furnace, cast into ingots, which are either used in the foundries.[1], [2], [6–8], [10–12] Thus, in order to carry out the recycling process of collected aluminium waste, melting facilities are required. This enables cost efficiency and faster recycling of waste from aluminium.[4], [5], [10–12]

Aluminium cans are an important and extremely 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 a very important raw material (Figure 3). 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 juice and beer beverage manufacturers.[4], [5], [9]

We propose a micro–station for melting of aluminium wastes from the beverage cans (Figure 4). The objective of the research is to develop some recycling facilities for melting of aluminium wastes by using charcoal briquettes into a micro–station, designed and manufactured in laboratory. The main activities described here are carried out during the experimental phase of the research and they are oriented towards the recovering aluminium for recycling. [4], [5] In this research we experimented a reusable backyard foundry that melts aluminium soda and beer cans, easily and safely.

Figure 3. Aluminium cans recyclability by melting

Figure 4. Melting of aluminium beverage cans: (a) preparing the micro–furnace (b) the melting micro–furnace with the feeder and the crucible; (c) the assembled melting aggregate;
A lot of charcoal briquettes are placed around the crucible until they are filled.[4], [5] 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.

Depending on the end use, aluminium can be simply cast into the finished part, or cast into an intermediate form, such as an ingot, which can be re-used in industry for different utilities, depending on the market demand. Also, this ingots can be used as matrix for a large diversity of metal matrix composites.

4. Concluding remarks

In a world which is increasingly demanding sustainability, recycling of the non–ferrous metal has become a very important practice. Opting for recycling processes does not only mean being responsible towards the environment, it is also a very reasonable industrial process that rely on using non–renewable resources. Also, materials substitution and efficient use of materials are, as we mentioned above, priorities of the several industries.

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. Non–ferrous metals, including aluminium do not degrade during the recycling process and thus can be recycled an infinite number of times. 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.

The aluminium can is the most recycled beverage packaging. Obviously, this is only possible if they are collected and (re)introduced into the recycling circuit. An aluminium can goes through various processes before it is fully recycled and in combination with other recycled aluminium cans turned into a melt aluminium which is then made into aluminium matrix for metal matrix composites. 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 matrix composites constitute an important category of 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).
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