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Separation of Non-ferrous Fractions of Shredded End-of-life Vehicles for Valorising its Alloys

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Abstract **-** Worldwide the end-of-life vehicles (ELV) generate millions of tons of waste, requiring an adequate and efficient management. The non-ferrous fraction contains essentially aluminium, magnesium and copper alloys, being valorised by metallurgical processors to obtain new metals and alloys. However most of the recovered metals are downcycled, as is the case of aluminium where the recycled products are essentially used to produce less purity casting alloys. New or improved separation technologies are therefore necessary in order to allow an accurate separation of alloys or alloy groups, increasing the value of the non-ferrous streams.
In this paper, the composition of the non-ferrous fractions of ELV shredders are assessed with particular relevance for the aluminium and magnesium alloys. Essentially, the main cast and wrought alloys are characterized and their markets and applications are discussed.

Based on waste composition, several physical separation and sorting technologies can be applied to improve the products quality, which are here depicted and discussed. Physical processing includes operations such as eddy current and heavy media separations. For sorting alloys contained in the non-ferrous stream, other sensor-based technologies are being developed, such as electromagnetic sensing and novel laser induced breakdown spectroscopy systems, constituting an important contribution for boosting the non-ferrous metals recycling rates.

Keywords**:** Recycling, End-of-life vehicles, Non-ferrous metals, Aluminium, Sorting technologies.

1. Introduction

The end-of-life vehicles (ELV) generated every year in Europe accounts for more than 10 Mt which should be efficiently managed. Recycling of this waste, essentially metallic, is mandatory for environmental, economic and resource conservation reasons. The European legislation regulates the ELV recycling, defining ambitious recycling rate targets and controlling the use and management of potentially dangerous substances. The ELV recycling business has been an opportunity for many companies, which have created auto-shredder plants mainly focused on the steel recovery.

The shredders are indeed far from be optimized. Concerning the non-ferrous fraction, essentially rich in aluminium but also containing copper and brass, none or incipient separation of alloys is made, and so the recycling involves loss of purity (downcycling). Although some current technologies allow separation of some alloys (like copper and aluminium by colour sorting) the several aluminium and magnesium alloys contained in the non-ferrous stream are not properly valorised. Hence, aluminium is recycled to less purity cast alloys, and unless new technologies enable the recovery of Al in the form of wrought alloys, the aluminium industry will be dependent on the primary extraction with all the well known implications regarding environmental emissions and huge energy consumption. Moreover, Mg recovery in pure forms is also an important goal taking into account the “critical metal” label of this light metal.

The project ShredderSort aims to contribute to the improvement of the recycling of Al and Mg alloys through the development of sorting technologies based on electromagnetic sensing, vision system and novel laser induced breakdown system. The initial research tasks involve the evaluation of alloys present in non-ferrous fraction. Some results of these investigations are presented and discussed in this paper.

2. Results and Discussion

2. 1. Auto-shredder Processes

The recycling of end-of-life vehicles involves a series of operations including depollution, shredding and physical separation. A simplified processing diagram is depicted in figure 1. Although the diagrams can eventually differ in detail from plant to plant, this scheme provides an overview of most of them. After reception, the waste vehicles are depolluted by removing fluids, batteries, tires and other environmentally harmful substances. Simultaneously, other components with valorising potential such as catalysts and large plastic parts are also dismantled. The core of the plant is the shredder, a hammer mill where vehicles are grinded into particles/fragments of less than 200 mm, the main objective being the liberation of materials (ideally, each particles/fragments should be of a single material). The light material (fluff), consisting mainly of textiles, foams, small plastic fragments and metal fines, are removed from the top by ventilation and are collected. The destination of this fraction is usually the landfill, but may be valorised due to its potential energy value. The heavy fraction removed from the bottom is sent to magnetic separation where the ferrous metals are recovered and sent to steelmaking plants, this stream being the most important for the auto-shredder companies from the economic point of view. The other materials are then separated into non-ferrous and non-metal (essentially plastics) fractions, both being also valorised. Technologies of heavy media separation or eddy current separation can be here successfully applied, the later being more common.

Besides the general character of the processing diagram, several other considerations could be referred to. In each main stream, several purification/upgrading steps are normally included: secondary grinding in some streams can provide a better liberation of materials as well as adequate particle size composition for the following physical separations. Secondary magnetic separations are also commonly applied in non-ferrous and non-metal streams to remove remaining ferrous particles that escaped to the main magnetic separation. Particle size classification (generally by using a trommel screen) is also a common operation before the eddy-current separators, in order to optimize the performance of this electromagnetic facility; therefore, about three size fractions of non-ferrous material are normally produced. Hand sorting or picking is also utilized, for example, for removing motor parts and coils, or to separate wires and copper-rich fragments.

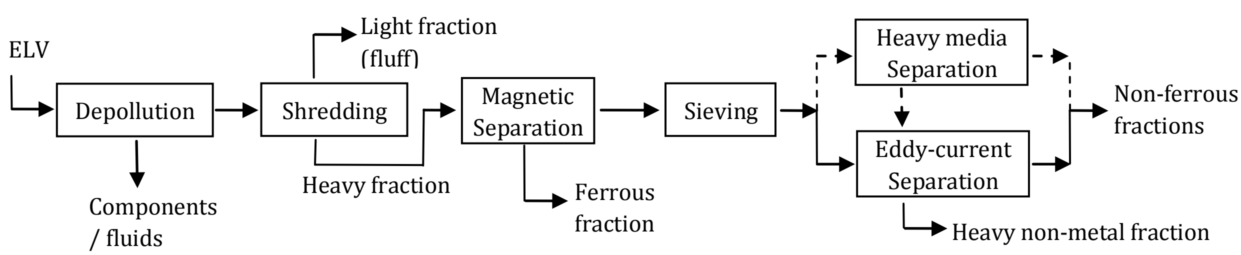

Fig. 1. General processing diagram of an auto-shredder plant.

2. 2. Composition of Non-ferrous Fractions

Figure 2 shows the typical material composition of the ELV (Fig. 2a) and the non-ferrous fraction (Fig. 2b). The percentages presented are average values of the analysis of samples of some auto-shredder plants. Concerning the overall composition, ferrous materials constitute more than 60wt%, but can be even higher in many cases, while non-ferrous material accounts for about 8wt%. Aluminium (and Mg, usually included in the same class) is clearly predominant in non-ferrous metals (about 78 wt%) followed by the copper and brass components (together near 17wt%). The evaluation of experimental results obtained so far showed that the large fragments are commonly composed of wrought Al alloys, since during grinding are easily deformed and winded and less cut. On the contrary, the medium and finer particle sizes have more quantity of cast alloys fragments.

The number of aluminium alloys used in vehicles is very wide (Hirsch, 2004; Luo et al.,2010; Miller et al., 2000; Romhanji et al.,2009). Some of them, considered important is this sector, are depicted in Table 1. Wrought alloys are used in structural parts of vehicles, including inner and outer panels and components. Cast alloys are utilised in car engine parts like cylinders, gear box and brake components. Both wrought and cast alloys are divided in heat-treatable and non heat-treatable. Magnesium alloys usage in vehicles is increasing and are expected to be found in larger quantities in ELV scrap in the forthcoming years. Uses such as gear box, steel wheel, flaps, instrument panel, valve cover and engine parts are nowadays common (Hanko et al., 2002). Some Mg alloys usually found in car components are Mg-Al-Zn (e.g. AZ91), Mg-Al-Mn (e.g. AM50 and AM60) and Mg-Zn-Zr (e.g. ZK30 and ZK60).

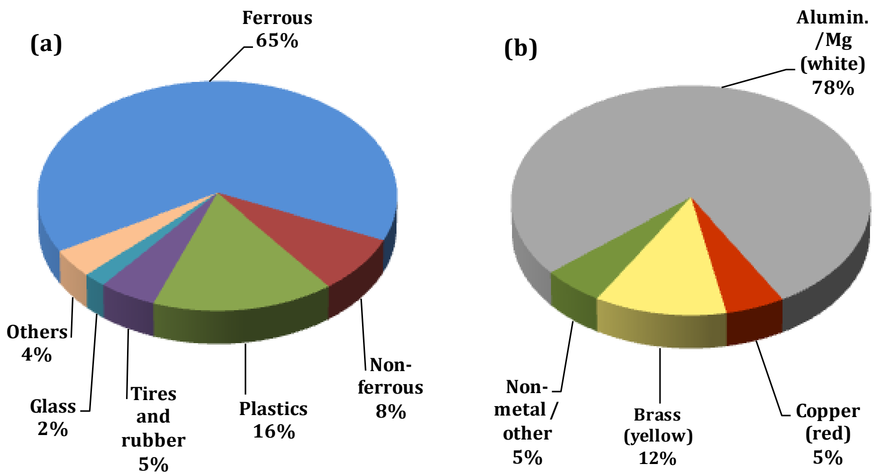

Fig. 2. Typical composition of fractions (wt%) in auto-shredder facilities:
(a) overall composition; (b) composition of non-ferrous fraction.

Table 1. Some important Al alloys used in automotive applications (simplified, not-exhaustive list).

Alloy class	Main elements	Typical wt% range of allowing elements				Examples of applications
		Mg	Si	Cu	Zn	
Wrought						
AA2xxx	Al-Cu-Mg-Si	0.5-15	0-0.8	2-6		Structural components
AA5xxx	Al-Mg	1-5				Inner car body components. Structural sheet
AA5xxx	Al-Mg-Cu	3.5-5		0.5		Outer car body components
AA6xxx	Al-Mg-Si	0.5-1	0.5-1			Outer car body components
AA6xxx	Al-Mg-Si-Cu	0.5-1	0.5-1.5	0.3-1		Inner and outer car body components
AA7xxx	Al-Zn	2.5			4-7	Structural components
Cast						
x2xx.x	Al-Cu-Mg	0.3-1.5		4-5		Car engine parts; cylinder, carburetor, gear box, several machine devices. Vehicle brake handle.
x3xx.x	Al-Si	0-0.5	6-12	0-4		
x5xx.x	Al-Mg	4-10				
x7xx.x	Al-Zn	2-2.5			5-7	

2. 3. Separation and Sorting Technologies for Non-ferrous Metals

Colour sorting technologies have been proposed and industrially used for treatment of non-ferrous fractions. Sensors based on colour recognition can be applied to differentiate copper and brass (red/yellow particles) from aluminium/magnesium (white/grey particles). For sorting the several Al-type alloys these techniques are inappropriate. Nevertheless several methods have been tried for valorising Al alloys from non-ferrous fractions. Shape and size characteristics can be used in hand-sorting of wrought and cast alloys, namely for high dimension particles, but for fine ground material these qualities are hardly distinguished. Since Al alloys with different composition can react differently with selected reagents, a process based on particles tinted by etching can provide colour effects that allow the subsequent use of colour-based sensors (Green, 2007). This alternative has the drawback of introducing a wet chemical step in the non-ferrous valorising process, which can be very disadvantageous for many plants.

Within the project ShredderSort, improved scrap sorting technologies based on electromagnetic and spectroscopic principles are being developed. Firstly, state-of-the art eddy current separators can allow removal of Cu-rich particles from Al/Mg. The former stream is treated by combined Electromagnetic Tensor Spectroscopy (EMTS) and Vision Image Analysis (VIA) which allows separation of copper and brass alloys. The aluminium-rich fraction will be therefore processed by Laser Induced Breakdown Spectroscopy (LIBS), which should allow the sorting of cast and wrought Al and Mg alloys. The technology under development involves two LIBS steps, firstly a high-throughput LIBS for separating the main alloy groups, and secondly, a high-performance LIBS aiming at producing individual alloys.

The previously described technology will contribute to the recovery of high value aluminium and magnesium, improving recycling rates, energy savings and raw materials conservation.

3. Conclusion

Development of new or improved sorting technologies are crucial to promote Al and Mg recycling into high purity alloys, thus avoiding the increase of primary extraction of these metals with all the involved disadvantages for environment and economy, and resources depletion. Advanced sorting technologies under development, based on electromagnetic and spectroscopic alloy properties, can provide an important contribution for improvement of Al and Mg recycling rates.

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