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CHARACTERISATION OF AUTOMOTIVE SHREDDER RESIDUE

F. Margarido [1], C.A. Nogueira [2]
1 Dep. Engenharia Mecânica, Instituto Superior Técnico (TU Lisbon), Av. Rovisco Pais, 1049-001 Lisboa, Portugal, fernanda.margarido@ist.utl.pt
2 Laboratório Nacional de Energia e Geologia, I.P., UPCS, Estrada do Paço do Lumiar, 1649-038 Lisboa, Portugal, carlos.nogueira@lneg.pt

ABSTRACT

The autofluff residue of a Portuguese shredding facility was characterised aiming at identifying the presence of heavy metals in several constituents of these residues, in order to propose possible valorising solutions. Particle size analysis showed that average characteristic diameter (d_{50}) was 6.5 mm, the coarser fractions (> 11 mm, representing 40% of weight) being essentially composed of plastic pieces, rubber, foams and textiles, particles in the range 2-11 mm being composed of mixed materials, while in particles below 2 mm (referred as fines) the presence of glass, ceramics and other inorganic materials became very frequent, in spite of a very fine foam was also detected in the very fine fractions. XRD analysis of fines allowed detecting the crystalline phases quartz, calcite, rutile and magnetite. Elemental analysis by EDXRF was carried out on several fractions in the particle size range 0.02-2.0 mm, showing the presence of practically all the elements detected in all fractions, namely Fe, Zn, Cu, Pb, Ba, Sn, and also traces of Cd, Sb, Mo and Sr. Some of these metals are hazardous and can be problematic in what concerns the possible valorisation of the residue.

Keywords: Automotive shredder residue; characterisation; heavy metals; recycling.

INTRODUCTION

End-of-life vehicles (ELV's) require adequate and efficient management due to environmental and economic reasons [1-3]. Recycling of ELV's is usually carried out in auto-shredding facilities [4], where vehicles are decontaminated, shredded and subsequently several fractions are obtained by means of combined physical processes involving air classification, magnetic, eddy current and size separation. The main material stream is a ferrous fraction (about 70-75% of total feed weight) sent to steel manufacturers, a non-ferrous and heavy (polymer-rich) fractions, also potentially recoverable, and a light fraction (also called fluff or autofluff) designated as automotive shredder residue (ASR), representing 20-25% of initial weight, to be sent to disposal.

A typical diagram of an automotive shredder process is presented in Fig. 1. The ELV's transported to an authorised facility are received and stored appropriately. After recording the vehicle data, it is sent to a depollution process where hazardous components such as batteries, tires, mercury switches and fluids (including remaining fuel, waste oil, shock absorbing oil, brake fluids and cooling liquids) are removed. Other components for dumping or recycling are also removed at this stage, including wheels, glass, plastic bumpers and catalytic converters. The depolluted vehicle is then sent to the shredder, usually a hammer mill, where size reduction is carried out allowing liberation of different materials. In the shredding chamber, the first separation occurs, the light materials (foams, cloths) being drawn away by suction and the heavy fraction containing metals and some plastics being discharged in the bottom of the shredder. The light fraction passes by a magnetic separator to recover some remaining steel, resulting the ARS as waste stream. The heavy fraction is processed through a series of physical separation steps to produce the main stream of the process: the steel rich fraction. The separation starts with a magnetic operation where the ferrous materials are selectively collected and afterwards passes by a picking shed where some mixed materials are removed and the steel fraction is finally produced and sent to melting in electric steelmaking facilities. The non-magnetic materials are sieved into homogeneous particle size fractions and processed in an eddy current separator to extract the metals (essentially copper and aluminium) from the non-metallic materials (mainly heavy plastic fragments). Finally this fraction is manually picked to remove some non-ferrous pieces that inadvertently passed through. Both streams, the non-ferrous and the heavy non-metals, are sent to other facilities for recycling the contained materials.

ASR constitutes the most important environmental problem for all shredding facilities [5]. European legislation imposes exigent recycling targets for the next years, which is originating high pressure over the recyclers. ASR has great energy potential since most part of its components is combustible (plastics, elastomers, textiles, accounting 60-70% of fluff). The remaining materials are essentially inorganic, namely glass, ceramics, electric wire and paints (Fig. 2). However, in spite of depolluting operation, fluff residues still contain traces of several potentially hazardous substances such as organic fluids and heavy metals, which inhibit valorising options. So, it is actually very difficult to reduce the landfilled materials to values less than 20%.

A research is being carried out for the characterisation of ASR samples from a Portuguese automotive shredder plant. The main objective is to characterise several fractions of this residue and to identify the distribution of heavy metals in order to assess possible valorising options. The initial results of this research are here reported.

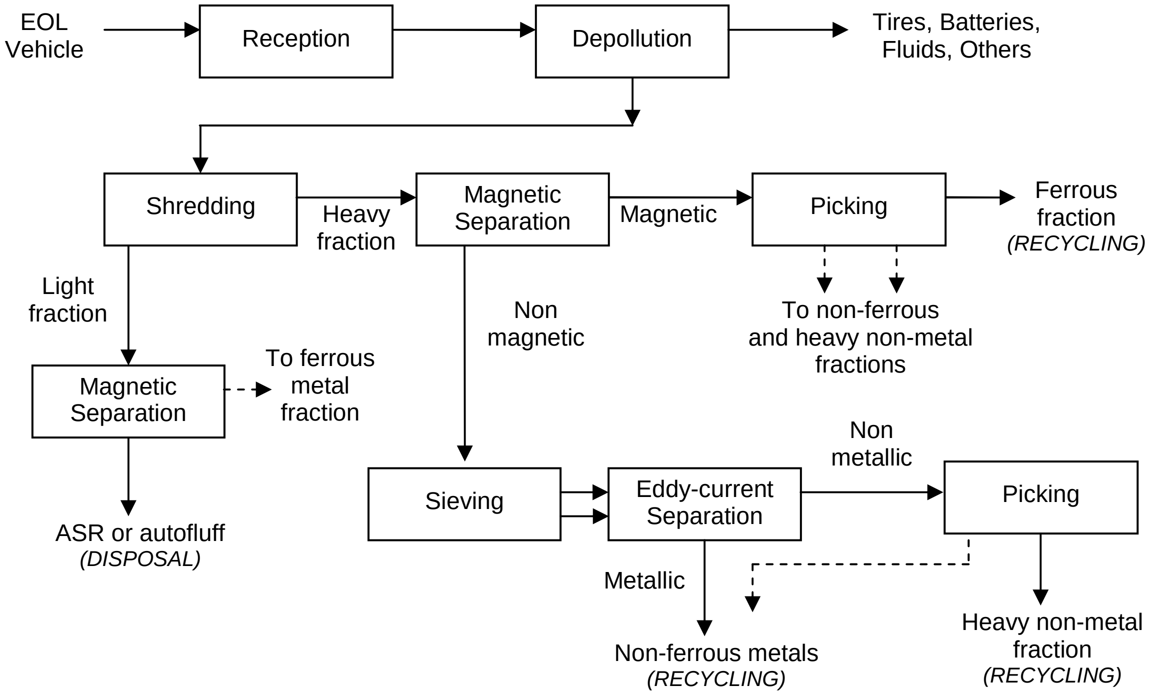

Fig. 1 – Simplified diagram of the process of an automotive shredder plant.

EXPERIMENTAL

The initial ASR sample was kindly provided by a Portuguese auto-shredder company (Ecometais, Seixal). The sample was manually homogenised and sorted using a Jones divisor into several samples of about 1 kg. The particle size was assessed by sieving with a magnetic stirrer (Fritsch Analysett 3) using standard sieves of several apertures, from 50 mm to 0.020 mm. Chemical analysis of fine fractions was carried out by a Energy Dispersive X-ray Fluorescence (EDXRF) spectrometer (TN Spectrace Quanx) with a rhodium source. The X-ray diffraction experiments was performed by a diffractometer (Philips PW 1830), with a Cu Kα source using acquisition values of 40 kV and 30 mA and a scanning speed of 1º(2θ)/min.

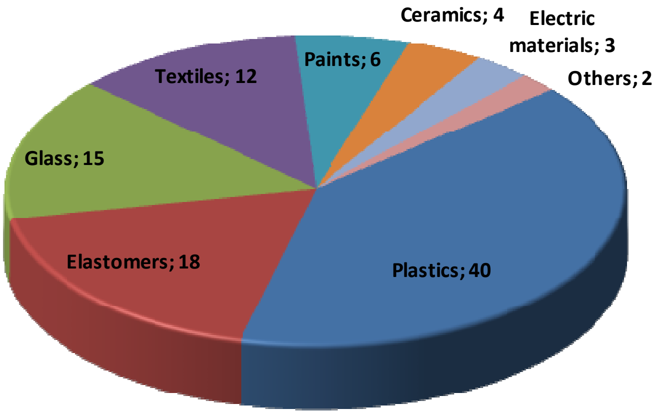

Fig. 2 – Typical composition (wt%) of main materials of ASR.

RESULTS AND DISCUSSION

After reception and sorting/homogenising, the particle size distribution of the ASR sample was determined by sieving. The results obtained (Fig. 3), showed that this waste is essentially composed of large fragments. Average particle size (d_{50}) is 6.5 mm. More than 40% of weight has dimensions higher than 11 mm. Visual analyses combined with microscope observation allowed to conclude that this coarse fraction is very rich in plastics, rubber, foams and textiles, but is contaminated by small particles and powder. The intermediate fraction, between 2-11 mm, weighting about 30%, is composed by mixed materials. Below 2 mm, the ASR is essentially rich on inorganic materials such as glass, ceramics and small metallic and plastic particles. A very fine foam also appears in small particle size fractions.

It seems that a sieving operation can remove substantial part of inorganic materials, such as hazardous metals, contained in the fines (20-30% from ASR weight), allowing to increase its potential energy content. In order to identify the presence of metals in the ASR, several fractions of different particle sizes (from 2 mm to 0.02 mm) were analysed by EDXRF technique, which allows a qualitative and also semi-quantitative elemental determination according with the respective peak areas. Note that the conditions used were optimised for transition metals and not allowed detection of light elements such as Al and Si. An example of spectra obtained is presented in Fig. 4, revealing the presence of several metallic elements. In all fractions analysed, substantial quantities of iron were found, and some non-ferrous metals like copper, zinc and lead also appeared as secondary elements. These can be present as metallic phases from steel, copper, and other alloys, or even metal oxides. These elements are used in electric/electronic equipment. Barium is another element clearly identified in all fractions analysed of ASR, probably coming from plastic components or from electronic devices. Minor or trace elements found were tin, antimony, molybdenum, strontium and cadmium.

These results prove that some metallic hazardous elements are present in the fine fractions of ASR. However, the larger fragments also contain contamination of aggregated fine powders, essentially the textiles which have high absorption characteristics, but its content is much lower than in fines. In order to decrease the powders content in larger pieces and to allow its energy valorisation, these contaminants shall be removed as well as possible. Two techniques are proposed to allow aggregated particles to liberate from gross materials: (1) wet sieving or water washing followed by sieving; (2) Mechanical treatment by grinding. Some preliminary tests using these two alternatives were already carried out, showing that fine powders are disaggregated from the gross ASR fraction, thus decreasing its contamination. Research shall proceed to optimize these operations.

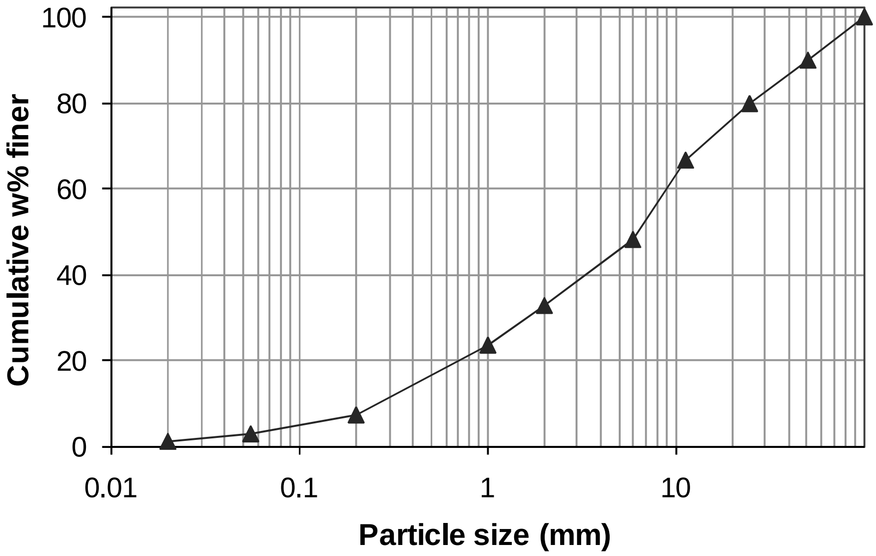

Fig. 3 – Particle size cumulative distribution curve of ASR sample (average of 7 trials).

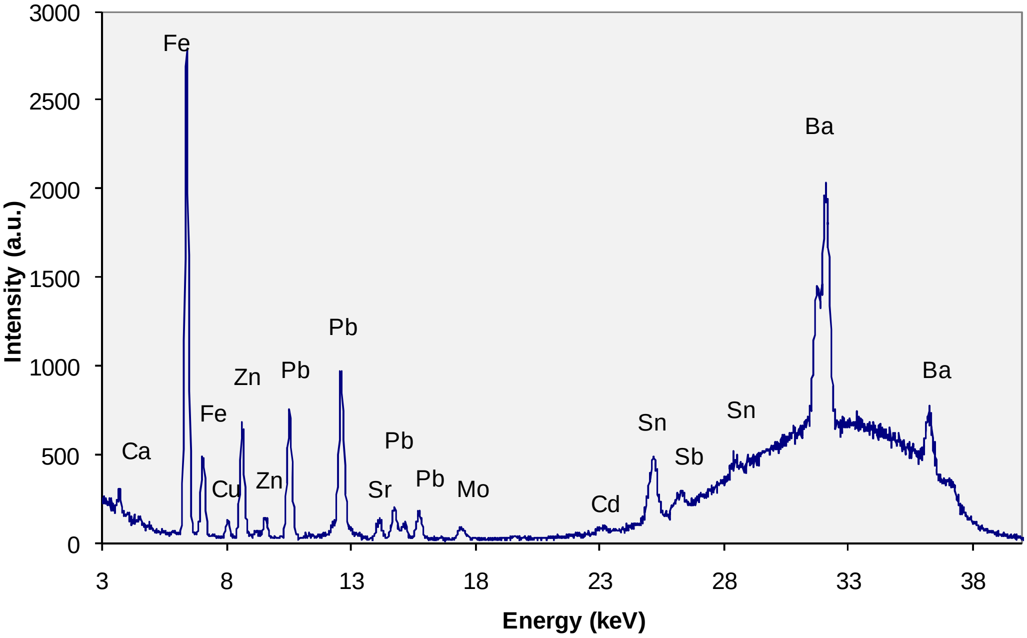

Fig. 4 – EDXRF spectra of ASR fractions (particle size 1-2 mm).

The analysis of the particles by X-ray diffraction allowed identifying the main crystalline phases present in the residue (Fig. 5). All the samples analysed contained SiO_2 (quartz) and $CaCO_3$ (calcite), most of them also contained TiO_2 (rutile) and some of them Fe_3O_4 (magnetite). Glass which is a major component of fine materials, is not detectable by this technique because is amorphous. The same applies to plastic particles. Phases containing heavy metals (like Cu, Zn, Pb, Sn) were not detected by XRD probably due to their low content.

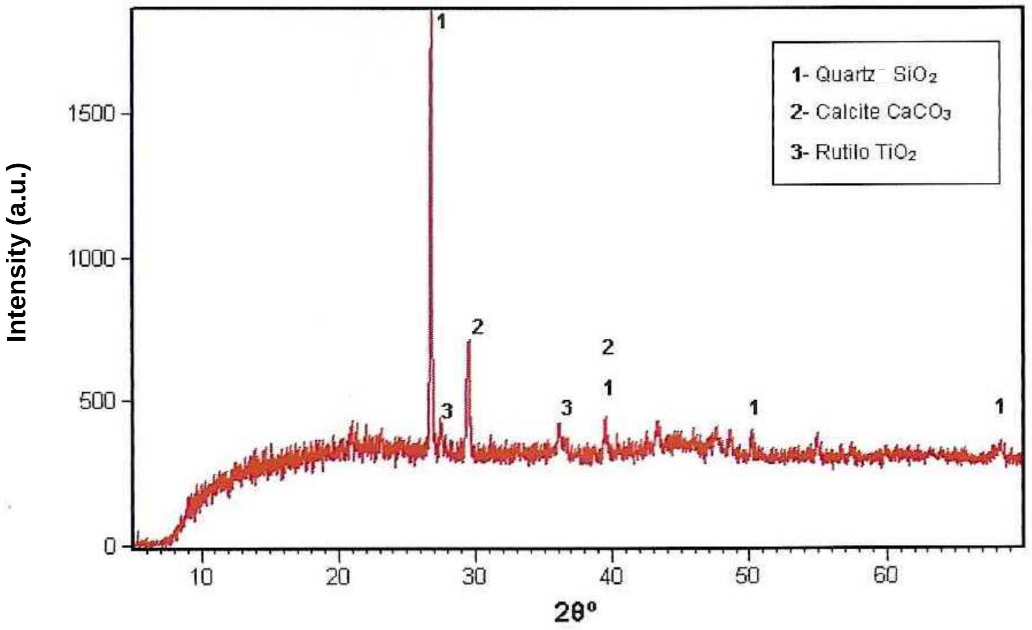

Fig. 5 – X-ray diffractogram of ASR sample with particle size range 0.1-0.2 mm (Cu Kα source).

CONCLUSION

The characterisation of an ASR sample from an auto shredder facility was carried out aiming at identifying the presence of heavy metals in several parts of this waste which are harmful concerning its possible energy valorisation. ASR contains large fragments of organic materials with energy value such as plastics, elastomers and textiles, but also fine particles essentially composed of inorganic materials like glass, ceramics and metals. Several heavy metals were identified in fines and powder, including Fe, Cu, Zn, Pb, Sn, among others, mainly in fractions bellow 2 mm, but large fragments also contained these aggregated particles. In order to reduce contamination of ASR, these fine particles must be removed by sieving, mechanical treatment or washing methods.

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