Applied Ecotechnological Issues For Recycling Cars

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Abstract: - The paper shows the need for recycling cars. Recycling operation is particularly complicated because after dismantling and split a wide range of material resulting in a proportion different and difficult to separate. There are presented two recycling technologies: Schreder and Hammer Mill Technology and some of their advantages and disadvantages. Comparative results obtained after applying the two technologies are also presented.

Key-Words: - shrreder technology, hammer mill technology, end-of-life-vehicle recycling

1 Introduction
Every year about 18 million new passenger cars are registered in the European Union. From the current total of about 230 million registered passenger cars in the member states of the EU, about 14,5 million have been de-registered in 2009, according to the EU’s automobile industry’s Association (ACEA). However, only about 9,5 million cars have been recycled by the EU’s automobile recycling industry in 2009. The difference between the 14,5 million cars de-registered and the 9,5 million cars recycled in the EU is explained with treatment paths unknown to ACEA, i.e. shredding without pre-treatment, illegal treatment, abandoned vehicles and last but not least exports to third countries /3/.

Over the next 10 years, more than 140 million end-of-life vehicles (ELVs) in the EU will have to be recycled. For this purpose the European car recycling economy provides capacities for processing a number of end-of-life vehicles equaling 70% of the annual turn-out of new cars. A task of remarkable dimension in both technological and economical terms. Thanks to automobile recycling approximately 82 million tons of ferrous metals will be recovered from 140 million cars in the European Union within the next 10 years. These figures are just one example for scrap metal recycling as a perfect model for waste reduction working worldwide.

Traditionally, Germany is one of the leading exporters of industrial products. Another leading position, however, has been much less than satisfactory for some years now. Germany is also the biggest exporter of ELVs in the European Union. While waste exports are illegal, ELVs are considered economic goods when exported. But in fact, apart from the recyclable material, they contain up to 30% of waste, mainly in plastics, the disposal of which is very expensive in Germany. This has led to a sharp rise in exports. They have grown, by now, to about 1 million cars annually. This is not due to a lack of sufficient domestic recycling capacities. There is a widespread network of car recycling businesses all over the country with an annual processing capacity of more than 3 million ELVs. But their future perspectives are insecure as, for the cost of waste disposal, they can’t compete with exporters who offer to remove ELVs free of charge /3/.

In Eastern European countries, where a large percentage of the cars are shipped to, environmental protection, up to now, is not a priority in the ELV business. Neighboring EU countries are affected, too, by the growing stream of ELVs from Germany. It has led to some irritations that Germany sets high environmental standards but fails to provide regulations for financing their implementation, thereby fostering exports.

2 Composition of ELVs - Material and Functional Elements
Raising standards of comfort, safety and performance have, in two steps, substantially changed motor cars since the 50’s. Until the early 70’s, average cars continuously grew in size and performance over the years, while their materials remained almost the same.
With a 76% share of steel and iron and 2% plastics in its overall weight, a 1965 model was not too different from one that had left works 15 years earlier.

This changed following the OPEC oil embargoes: the balance of the materials was altered (fig. 1). In 1975 an average car contained 45 kg. (5% of its weight) of plastics. Today, plastics amount to a mean 135 kg. in a new car, equaling 14.1% of its overall weight. At the same time, the percentage of steel and iron fell to now 60% and a further reduction to 50% by the year of 2015 is foreseeable. While fuel consumption was kept low by improved engine technology, plastics were found to lower production costs. Their share will, therefore, keep growing. By the year of 2015, 200 kg. of plastics in a car will be the second largest share after steel with iron in third place. The amount of light metal is bound to rise beyond 100 kg. within the same period of time.

Iron and Steel - The following materials are found in end-of-life vehicles: car body, engine block, engine parts, gear box, driving shafts and half shafts, axles, wheel suspension, springs, suspension strut, brake parts, wheels, exhaust system, door and side window mechanism, seat structure, ball bearings, fastening elements, fuel tank.

Ferrous scrap, as recovered from end-of-life vehicles, is a secondary raw material substituting raw iron. Scrap is a feed material for steel production that can be brought straight into steel mills, while raw iron must first be smelted from iron ore in an energy-consuming process. Steel production requires less raw iron if more scrap metal is available as a feed material. Ferrous scrap can reduce the energy consumption of steel smelting by as much as 70%, resulting in substantially lower production costs. Graded ferrous scrap is a commodity which is traded in large amounts internationally. Recycled Steel: 74% energy saved compared to primary production.

Aluminium - e.g. engine block, cylinder head, gearbox casing, other engine parts, wheels.

Aluminium is employed in automotive engineering mostly for engine and chassis components. Aluminium body parts, up to now, are rather unusual but used by Audi for example. Presently, the material’s weight in end-of-life vehicles amounts to about 50 kilograms. Aluminium manufacturers predict an increase to more than 150 kilograms in new cars over next few years. More than 90% of the aluminium in end-of-life vehicles is recycled. Non-ferrous metal separators reliably recover the aluminium fraction after shredding. Metallurgical technology permits the production of secondary aluminium from aluminium scrap without a loss of quality. Smelting primary aluminium from minerals like bauxite takes a very high energy input of about 15,000 kWh per ton. Producing a similar amount of secondary aluminium requires just 20% of that input. Saving energy makes aluminium recycling viable. It also saves natural resources and helps reduce environmental pollution. Recycled Aluminium: 95% energy saved compared to primary production.

Copper - e.g. wiring, negative terminal connection, starter motor, alternator, ignition coil, heater fan motor, cooling fan motor, windscreen wiper motor, electric window winders, switches, auxiliary motors.

An average end-of-life vehicle contains about 9 kilograms of this smooth metal applied mostly in generators, starter motors, several auxiliary electric motors, ignition coils and wiring. Because of the material’s thermo-conductive properties, radiators are frequently made of cooper alloys, too. Like the other metals used in automotive engineering, copper can be recycled by resmelting without suffering a loss of quality. Copper fragments are recovered from shredded material by Non-Ferrous Metal Separators. Copper coils which have not come apart from their iron cores during the shredding process are sorted out manually. Recycled Copper: 85% energy saved compared to primary production.

Zinc- e.g. engine parts casings, intake manifold, door handles, window winder handles.

The most commonly known application of zinc in automobiles are galvanized body panels for corrosion protection. A far larger amount of zinc, however, is used for more than a hundred cast components such as, for instance, fuel pump casings or window winder handles. Altogether, an average motorcar contains about 5 kilograms of zinc. Like aluminium or copper, zinc can be recycled in specialized metallurgical plants. Today, as with other non-ferrous metals, the sorting is usually done with Non-Ferrous Metal Separators.
Brass-ex. radiator, coolant pump, heating radiator, heater valves, bolts, fittings, bushes.
Presently, the total weight of Brass in end-of-life vehicles amounts to about 3 kilograms.

Lead-ex. battery, balancing weights. Recycled Lead: 65% energy saved compared to primary production

Rubber-ex. tires, tubes, silent blocks, seals, floor mats, pedal rubber linings, fan and timing belts, bumper trims.

Plastics-ex. seat covers, imitation leather, interior linings, dashboard, interior trim panels, carpets, bumpers, radiator grilles, side panels, wheel covers, inner wing covers, mirror casings, fuel tank, liquid containers, rear lights, bumper shields, electric insulations, ventilation grids, spoilers.

Glass and Ceramics-ex. front, rear and side windows, sunroof, rear-view and outside mirrors, head-lights, catalytic monolith, ceramic insulations.

Textiles-ex. seat covers, carpets, interior trim panels, insulating material.

Liquids-ex. engine lubricants, gearbox oil, automatic transmission fluid, break fluid, hydraulic fluid, coolant fluid, air conditioner fluid, windscreen cleaning fluid, battery fluid, fuel.

3 Waste Materials from Automobiles

About 30% of a car's weight turns out as rejects after shredding. They are a material mix of 30-40 types of plastic, glass, rubber, cellulose, textiles, chips of paint, ceramics, mud and small particles of metal (fig. 2). This fraction, called Automotive Shredder Residue (ASR), is the main problem in end-of-life vehicle recycling today. Since up to now there was no technology for processing the material on a larger industrial scale, in most European countries it must legally be landfilled or incinerated.

ASR-conditioning, a newly developed process by Scholz AG in Espenhain near Leipzig (Germany), now makes it technically feasible to avoid disposal and reuse shredder residues. Like mineral oil, its large share of plastics is composed of hydrocarbon molecules. The material can, therefore, in principle partly substitute fossil fuels in plants with combustion temperatures above 1,200º Celsius. This temperature level ensures the destruction of dioxins which may evolve from insufficient combustion of material containing PVC or contaminated with polychlorinated biphenyls (PCB).

If using shredder residues as a fuel material is to make sense in economical and ecological terms, it must be employed where fossil fuels can be substituted on a larger scale. This applies, for example, in cement production or iron smelting in cupola furnaces. For industrial applications the fluffy, heterogeneous automotive shredder residue must be conditioned to obtain a dry, uniform material of sufficient density and good combustion behavior /5/. Grain, density and combustion behavior can be adjusted as needed at the Scholz process in Espenhain (Germany). A modular system allows for these steps to be combined, enabling shredder plants to offer industrial partners a constant product quality suited to their technological demands.

Experts on environmental issues have unanimously greeted the conditioning of automotive shredder residues (CAR) as a progress. It helps economizing on natural resources and offers a chance of getting the upper hand of a formerly uncontrollable cost factor in ELV recycling. The improved behavior of CAR in landfills is another advantage that helps reduce the problem of automotive shredder residues. Due to the high combustion temperatures, only vitreous slag remains of CAR when it is used as a fuel material. Vitreous slag, like all blast furnace slags, can be landfilled or used as an addition in road surfaces or other building materials.

There are two main types of residue: the airborne dust ('fluff') caught by the shredder dust collection system (consisting of upholstery fibers, dirt, rust, paint etc.) and the non-metallic residues separated from the recovered metals material streams by the media separation plant (consisting of unusable rubbers, plastics, stones etc.). The aspirated dust and the separated residues together represent about 17 to 25% of the average vehicle weight. This has been land filled so far, representing no more than 0.2% of total landfill waste in the EU. Progress in media separation technology is continuing, enabling recovery of further materials.

Fig. 2. Material analysis for the ASR-fraction.
4. Recycling Techniques for Materials of Automobile Construction

When we say "recycling" we differentiate between re-using complete components (product recycling) and recycling of materials. Product recycling has always been the domain of the dismantling companies and is already well developed. Even so, a great deal of material derived from car wrecks remains to be disposed of even after product recycling. Hence the emphasis needs to be placed on the material recycling.

Modern end-of-life vehicle recycling not only is supposed to help protect the environment and natural resources, but is also expected to work economically, keeping costs at bay for its clients. Costs economy requires rationalized procedures. An improved eco-balance, on the other hand, needs individual decisions about the extent of dismantling each vehicle will sensibly have to undergo. A two-step processing system accounts for both these requirements. As a compulsory first step, though, all fluids are extracted from vehicles to avoid environmental risks from spillage. Only then spare parts and those components bound for separate recycling are removed (product recycling). Central shredding plants process the stripped car bodies on an industrial scale acting as production plants for metallic secondary raw materials (material recycling) - fig. 3.

4.1. Shredding techniques

At first glance, shredding whole car bodies into pieces the size of 5-15 cm seems like simple destruction by use of enormous powers. Looking more closely, though, it turns out to be a both complex and fascinating technology. Shredding facilitates the recycling of the various types of metal which altogether amount to approximately 70% of the overall weight of an end-of-life vehicle.

4.2 Hammer mills

Hammer mills are not so common in comparison to shredders, which is due to the fact that from the big shredder producers only Thyssen-Henschel Recycling Technik GmbH (in short HRT) from Kassel, Germany, is offering this type of “shredder”.

The mills can be compared to very large coffee grinders, with the axle rotating vertically. The scrap to be shredded drops from the top to the bottom, and is then ejected. There is no grate in these mills. The rotor is slightly conical. There are three or four discs on the vertical shaft to which the axles of the “hammers” are attached. But, as with turnings crushers, these “hammers” are alloy steel toothed impact rings with an internal diameter larger than the axle around which they can rotate freely. These impact rings therefore leave space for passing scrap. The further the scrap drops, the smaller the space between the ring hammers and the liners or wear-resistant walls becomes.

A number of fixed “wings” are attached to the rotor shaft at the top of the rotor housing, smaller in diameter than the discs with rings. The raw material is torn apart by these wings to prepare it for the grinding action of the rings below. Dedusting takes place at the bottom of the mill, its kick-out door is situated at the top. A secondary dust collection unit is nowadays placed on the zigzag air classification unit through which the scarp falls (fig. 5.).
Variation of Cast Aluminium Alloy in spot samples

5 Method of Evaluating the Analysis Results
In preparation for the computer-based evaluation of the analysis results, the results from manual sorting of the individual lump size classes were listed in two tables for each spot sample. First, a computer-based calculation was made of the contents and degrees of dissociation of all components, separately for each lump size class and summarily for the entire lump size class range > 4 mm of all spot samples, which had been analyzed by manual picking. Subsequent sorting of the values on the basis of the components revealed the immense variations of the individual values (fig. 6.).

6 Results of the Analysis
As already mentioned before, the analyses of the samples from the non-ferrous fraction in regard to the distribution by piece size and the extent of disintegration of each piece did reveal that the halved values of the piece sizes are at the installation shredder about 30 mm and at the installation hammer mill about 45 mm.

This fact, connected with the reduced disintegration extent of the samples from the non-ferrous fraction from the hammer mill installation indicates that the hammer mill has a smaller shredding effect than the shredder installation.

The composition analyses is showing that the magnetic sorting of the hammer mill installation is not operating sufficient enough because in the large-sized fractions are a lot of magnetic pieces, which are “spoiling” the non-ferrous metal fraction. In the waste fractions of both installations, i.e. shredder and mill, are over 50% of all pieces with a size smaller than 4 mm.

For a metallurgical utilization only the iron content could be taken into consideration, but the enriching of the iron content to metallurgical interesting values seems at least problematic from the economical point of view.

Figures 7 and 8 show the lump size distribution functions determined for the two non-ferrous metal pre-concentrates, which show the half-value lump sizes for the shredder amounting to 30 mm and for the hammer mill of 45 mm.

Fig. 5. Diagram of a Hammer mills plant

Fig. 6. Variations of the content of cast aluminum alloys in the spot samples (non-ferrous metal pre-concentrate from shredder).

Fig. 7. Lump size distribution function for shredder.
The generally more flat course of the size distribution function of the hammer mill is presumably mainly due to insufficient shredding of the non-ferrous metal containing parts of the feedstock.

This shows, on the one hand, by the extremely high non-metal contents – as compared with the non-ferrous metal pre-concentrate from the shredder – in the lump size classes from approx. 2 to 32 mm (and thus by the non-ferrous metal recovery in this range) and, on the other hand, by the lower degree of disintegration of the non-ferrous metals.

6 Conclusion
There are some important conclusions of this study, that are mentioned next.

1° Based on the assumption that the shredder yields the product masses per year are as follows: 100,000 tons/year – steel finished product, 5480 tons/year – non-ferrous metal pre-concentrated and 31500 tons/year – waste product.

2° Based on the assumption that the hammer mill yields, the product masses per year as follows: 25000 tons/year steel finished product, 3080 tons/year non-ferrous metal pre-concentrated and 14,400 tons/year – waste product;

3° The analysis of the samples from the non-ferrous fraction in regard to the distribution by piece size and the extend of disintegration of each piece shown that non-ferrous fraction from the hammer mill installation has a smaller shredding effect than the shredder installation.

References:

Fig. 8 Lump size distribution function of the non-ferrous metal pre-concentrate from hammer mill