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RECYCLING OF END OF LIFE VEHICLES IN SERBIA AS RESOURCE OF SECONDARY ALUMINUM

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Abstract

In this paper estimation of the potential amount of Aluminum in End of Life Vehicles (ELV´s) in Serbia are shown. Also, we approve recyclability of Aluminum scrap in lab conditions as well as his impact on environmental quality. High efficiency of Aluminum from scrap was obtained with significant emission reduction in the environment. The importance of recycling of Aluminum as the driving force in the automotive recycling industry has been shown which is very important for countries where recycling of vehicles is in a development stage.

Keywords: secondary aluminum, recycling, ELV, emission

INTRODUCTION

At the end of their useful lives, automobiles are usually sold to automotive dismantlers who remove the still useable parts for reuse or remanufacture, and dispose of the hazardous materials (usually consisting of vehicle fluids) in an appropriate manner. The remaining hulks, often flattened to facilitate transportation, are sent to automobile shredders, who use hammer-mills to break them into fist-sized fragments. Most of the ferrous metals are recovered by magnetic separation, while the lightweight waste material or "fluff" (ASR), comprised mainly of foam, textiles, plastics and dirt, is removed by air cyclone separation. The ferrous metal scrap is sent to steel mills for recycling, and the fluff is land-filled.

The remaining mixture of high density, non-magnetic materials is rich in nonferrous metals. It is usually sent to nonferrous metal separators for the recovery of metals such as aluminum, zinc, copper, brass, magnesium, and stainless steel. The processes employed by the nonferrous separators are water elutriation, eddy current separation, and heavy media separation. The waste material that remains, consisting mainly of dirt and fines, is land-filled [1].

All the ferrous metals are recovered for recycling, while the subsequent non-ferrous metal separation processes result in the recovery of the following constituent weight fractions [1]:

Aluminum: 70.0%,

Zinc: 18.5%,

Copper and Brass: 10.0%,

Stainless Steel: 1.5%.

There are strong predictions for aluminum applications in hoods, trunk lids and doors hanging on a steel frame. With this respect significant increase in sheet aluminum consumption will be expected for automotive industry in Europe. For casting aluminum a key trend has been the switching the use of cast iron for engine blocks to aluminum, resulting in significant weight reduction. It was expected that more than 50% of motor engines change to aluminum blocks in 2000.This must be noted that although aluminum has a realistic chance to capture a grater share in car body and motor applications, but, its penetration in automotive industry has been limited up to now due to factors like, raw material cost, manufacturing cost, industrial structure, recycling, regulations, etc [6].

Increasing share of aluminum has positive impact on the viability of dismantlers. It means that if more parts are made from aluminum the dismantling rate will be significantly higher than the today's 15%. The profitability will increase to 50% or even more by 55% aluminum substitution. Shredders will also experience an improved profitability due to lower hulk weight and increased revenue from aluminum. With 15% aluminum substitution, the profitability of shredders will increase by 40%. However, the effect of non-ferrous separators is positive but not as high as shredders and dismantlers. By considering the current technology used for non-ferrous separation, it is assumed that the aluminum scrap is sold as a mixed scrap. However, if the separation of different aluminum products is achievable the profitability will be considerably enhanced. Today the recycling rate of automotive aluminum is estimated to be between 85 and 90%, and the product of recycling secondary foundry alloy casting constitutes fully 60-70% of the aluminum used on current vehicles. The sheet and extrusion scraps which form the minority portion of the total weight measured are recycled into casting alloys because secondary castings in general have a greater tolerance for alloying elements and impurities than sheet or extrusion products. With increasing growth in the use of sheet and extrusion there will be a need to separate sheet, extrusions and casting during the recycling process. Then sorting is needed for separating different aluminum alloys [6].

Recycling of ELV's in Serbia

In Serbia, in 2008 there were about 2,2 million vehicles with an average age between 18 and 19 years. It is estimated that more than one million of old vehicles, in various states of completeness, waiting to be recycled, and about 100,000 to 120,000 vehicles drop out of exploitation due to deterioration of each year.

In Table 1 there are data on the number of registered domestic and imported vehicles for the period since 1998 by 2008 year [3]. Table 1 shows that in the previous period in Serbian motor pool the domestic motor vehicle production was dominated, while in the last decade there has been a turnaround, and in 2008 there was significantly larger number of imported vehicles.

Table 1: Registration of motor vehicles in the Republic of Serbia (brand - domestic, imported)

Year	1998.	2000.	2002.	2004.	2006.	2008.
Domestic	1022295 57.8%	994185 55.3%	940160 48.6%	931430 44.8%	915254 42.6%	870995 38.3%
Imported	745629 42.2%	803726 44.7%	995265 51.4%	1149730 55.2%	1232038 57.4%	1403775 61.7%
Summ	**1,767,924**	**1,797,911**	**1,935,425**	**2,081,160**	**2,147,292**	**2,274,770**
Brand: „Zastava“	706,163 40.0%	676,725 37.6%	637,129 32.9%	620,915 29.8%	584,096 27.2%	535,442 23.5%

Source: Ministry of Internal Affairs of Serbia, 2009 year

Table 2 shows that dominant share of passenger cars in Serbia has three brands: Fiat, Opel and Volkswagen [3]. These relationships are very important because the structure of the materials in vehicles. In European automotive industries the use of lightweight materials, including aluminum, has a rising trend. Therefore, we conclude that a relatively large amount of aluminum will be accumulated in the Serbian territory.

Table 2: Registered passenger cars by brands in 2008 in Serbia

Brand of the passenger car	Registered in 2008	**%** Share
„Zastava“	535442	34.89
„Opel“	187820	12.24
“Volkswagen”	187138	12.19
„Fiat“	92961	6.06
„Ford“	80852	5.27
„Mercedes-benz“	76842	5.01
„Reno“	54960	3.58
„Škoda“	30840	2.01
Rest	287789	18.75
Summ:	1534658	100.00

Source: Ministry of Internal Affairs of Serbia, 2009 year

Regarding the situation of waste motor vehicles it is essential to consider two periods: before 2006 year period after 2006 year. In the first period in the Serbian territory there are over one million vehicles at the end of life cycle scattered all over illegal waste dumps or the natural environment (forests, ravines, streams, rivers, lakes, green areas). These vehicles were mostly "fringed" - removed vital parts, and generally with a high degree of corrosion. With the arrival of U.S. Steel in Serbia begins intensively recycling of steel scrap including waste motor vehicles. During that time dispose of all non-ferrous materials and fluids according to the natural environment occurs up. In the second period, after 2006, we can talk about relatively complete motor vehicles at the end of life cycle. Vehicles dropped from exploitation in the last three years have a significantly lower corrosion of metals.

Taking into consideration the average composition of the material in vehicles and the number of used motor vehicles which are withdrawn from exploitation, quantities of waste materials in a year that are available for recycling were calculated. These results are shown in Table 3 [2].

Table 3: The total quantity of waste material passenger vehicles in Serbia, per year

Material	**30,000 waste vehicles, per year (in tons)**	**120.000 waste vehicles, per year (in tons)**	**Dispose of used components and fluids (exploited)**
Steel / iron	18,780	75,120	unknown
Other metals	1,467	5,868	unknown
Plastic	1,251	5,004	unknown
Tires	777	3,108	12,950
Glass	927	3,708	unknown
Fluids	452	1,848	18,425
Rubber	249	996	unknown
Rest	1,137	4,548	unknown
Summ	25,040	100,200	

If we take into account the assessment of the share of Aluminum in to the non-ferrous output stream [1-3], amount of aluminum ranges from 1026 to 4107 tons per year. In the coming years, this amount will have a growing trend, primarily due to the import of European automobile brands.

Aluminum is a very important strategic material both for the automotive recycling industry and automotive manufacture industry, especially in countries where such industries are in the developing stage. Relatively high market value of aluminum and high recyclability rate will improve productivity of dismantlers and shredders.

Recyclability of Aluminum form scrap

Samples, used in further analysis, were taken from the shredder plant and represent post consumer aluminum scrap from the unclean construction waste and from automotive shredding process.

Samples AA 1.1L, AA 1.2L and AA 4.2L are low alloyed Aluminum scrap. Samples AA 2.1H, AA 2.2H and AA 4.1H are high alloyed Aluminum scrap (higher share of Silica). Samples AA 3.1Z and AA 3.2Z are Aluminum scrap so called “Zorba” (with Cu, Zn and Fe). Samples AA 5.1HL and AA 5.2HL are Aluminum scrap with mixed low and high alloyed Aluminum scrap.

The impurities, dust, non-metallic fractions (polymers, plastics, rubber, textile), and metallic parts made of tin, brass, zinc, copper, steel, etc. are removed manually from the samples. After classification, each batch (samples AA 1.1L to AA 3.2Z) has a weight of 10-13 kg and batch of samples AA 4.1H to AA 5.2HL has weight of about 640-740 kg. Batch with weight of 10-13 kg (samples AA 1.1L to AA 3.2Z) was melted in induction furnace, under the following operating conditions: plumbago crucible with and without salt as liquefier, open bath, mechanical removal of slag with intensive combustion. Batch with weight of 640-740 kg (AA 4.1H to AA 5.2HL) was melted into furnace with gas burners with adding salt: “ALUXAL 108”, Sodium Fluosilicate. Temperature in the furnace was maintained above 690^{o} C. After melting the samples were cast into molds and cooled at room temperature. Utilization of aluminum, percent of slag, burnt and magnetic fractions was measured and results are shown in Table 4.

Before the melting of waste, manual removal of visible impurity was preformed, but some of the oil, grease and paint remain on the aluminum filings. This affects directly to extract of aluminum from the waste, which indicates that utilization of aluminum from the sample AA 1.1L, which is very oiled and painted, is 84 % and utilization of same sort of sample AA 1.2L is over 87 %, which are much cleaner and less painted.

On utilization of aluminum from the waste also affects the compactness of sample pieces. Greater compactness and increased thickness of the pieces lead to a larger excerpt of aluminum from waste.

Removing the slag was carried out mechanically and batch melting was done in relatively small quantities (the average weight of the charge was around 13 kg) which led to a high percentage of slag. Thus obtained slag is very rich in metals so the further treatment is necessary.

Table 4: Utilization of aluminum from aluminum waste, share of slag, loss and magnetic fractions

Sample	Input, kg	Out, kg	Utilization, %	Slag, %	Loss, %	Magnetic fractions, %
AA 1.1L	44.00	37.27	84.71	13.21	2.09	
AA 1.2L	33.90	29.71	87.59	9.62	3.04	0.35
AA 2.1H	50.68	47.70	94.12	3.72	1.69	0.47
AA 2.2H	41.50	37.98	91.50	7.52	0.96	0.00
AA 3.1Z	39.94	35.06	87.78	10.41	1.80	0.90
AA 3.2Z	32.60	27.39	84.15	10.25	4.16	1.43
AA 4.1H	643	589	91.6	7.46	0.94	
AA 4.2L	731	612	83.72	11.49	4.79	
AA 5.1HL	738	634	85.9	11.78	2.32	
AA 5.2HL	695	630	90.64	7.48	1.18	

Based on these results we conclude that, in the industrial conditions, this type of waste is necessary to pre-treated (removal of dirt, oil, paint, dust, rubber, polymers, pressing of pieces etc.) to get as much utilization of aluminum. Also, larger batch quantities are required as well as better treatment of slag.

According to these data, it is estimated that in the industry conditions, utilization of Aluminum is possible up to 98% with corresponding improvements in process.

Conclusion

As the automotive industry is one of the largest consumer of many materials, it follow that the automotive recycling industrial is a very important source of secondary raw materials. In recent decades, with technological development, customer demand is increasing so that the complexity of the vehicle is inevitable. The complexity of the vehicles is reflected in the variety of materials, which require special treatment after the end of life cycle of vehicles.

Replacement of steel parts in a car with aluminum parts is inevitable, hereby necessary special treatment of such waste in the automotive recycling industry is essential.

In this paper we shown that amount of aluminum in the ELV´s in Serbia is not negligible and it can be important row material for Aluminum recycling plant. Also, in consideration of the linear growth of the amount of Aluminum in the ELV’s in Serbia it can be predict significant increase of secondary Aluminum in recycling industry.

Aluminum is a very important strategic material both for the automotive recycling industry and automotive manufacture industry, especially in countries where such industries are in the developing stage. Relatively high market value of aluminum and high recyclability rate will improve productivity of dismantlers and shredders.

Besides economic benefits, recycling and increased use of aluminum in the automotive industry strongly influences on the ecology.Traffic sector is the most significant emission source primarily due to large number of old vehicles and the use of low quality fuel [4].

A large number of cars in urban areas lead to a major environmental problem, which is reflected primarily in the exhaust gases. This amount of exhaust gas can be significantly reduced by introducing lighter materials in automobiles, first of all aluminum alloys, which will reduce weight of vehicle, decrease energy consumption and after all emission of gases. Influence of vehicles powered by alternative energy sources, to reduce environmental pollution in environment, is a great.

Despite this, a problem caused by inappropriate and inefficient procedure of recycling materials from vehicles or consumer goods is significant. The PCDD/PCDF (polychlorinated dibenzo-*p*-dioxins, polychlorinated dibenzofurans) and PCB (polychlorinated biphenyls) released from shredder plants are from industrial, intentional production and have been introduced with oils, dielectric fluids, and other materials contained in these vehicles or consumer goods and which are simply set free through this mechanical process. Sources of dioxin precursors that may result in the formation of PCDD/PCDF when burnt include PCB-containing condensers, PCB- or chlorobenzenecontaminated waste oils or textiles, and polymers containing brominated flame retardants (formation of polybrominated dibenzo-p-dioxins (PBDD) and polybrominated dibenzofurans (PBDF) as contaminants) [5].

In our experiments by removing of non-metallic materials (primarily polymers, rubber, oil and dust), from this types of waste, emissions of harmful compounds (PCB, PCDD/PCDF, etc.) in the environment are significantly reduced.

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