Fókuszban a hazai felszín alatti természeti erőforrások - nyersanyagok, energia és technológiák nexusa, ISBN 978-963-358-277-0, oldal: 121-128.

Investigation of the mechanical preparation and separation of driving support systems for recovery of secondary raw materials

B. Gyürék[1], R. Romenda[2], S. Nagy*[3]

[1] Miskolci Egyetem, Nyersanyagelőkészítési és Környezeti Eljárástechnikai Intézet, barbara.gyurek@gmail.com

[2] Miskolci Egyetem, Nyersanyagelőkészítési és Környezeti Eljárástechnikai Intézet, roland.romenda@uni-miskolc.hu

[3] Miskolci Egyetem, Nyersanyagelőkészítési és Környezeti Eljárástechnikai Intézet, sandor.nagy@uni-miskolc.hu

Abstract

Passenger vehicles have more and more driver support systems to increase the safety of road traffic, so the number of electronic devices in them is also increasing. The shortage of raw materials experienced in the past period drew attention to the fact that it is not only necessary to deal more with municipal solid waste, but also to recover the previously used valuable raw materials from electronic and other types of waste as much as possible, promoting the circular economy. During the research, the aim was to utilize the driving support systems of passenger cars, during which, in addition to the enrichment of the individual main components, it also covered the determination of the gold content found in them. The study proposes the utilization of these tools by completing individual mechanical procedures.

1 Introduction

Vehicles are one of the keys to our rapidly developing world, as over the years it has become the primary land transportation of our modern age. New technologies are revolutionizing the automotive industry, and innovation gives new meaning to what it means to drive. [1]

As the number of cars on the roads increases, unfortunately, the number of accidents also grows. As a result, the researchers performed further developments called advanced driving assistance systems. Nowadays, more and more vehicles are equipped with these different systems. The main goal of them and making driving easier is to drastically reduce the number of accidents on the roads and other car accidents that come with it by helping drivers. These systems respond faster than any person to each situation and are constantly alert. They have already been introduced today and are currently being installed in various car segments, from premium to economic models. Moreover, it is expected to become mandatory in cars soon. Such systems include, for example, lane departure warning, automatic parking assist or adaptive cruise control. [1][2]

With the growth of the automotive industry, the amount of passenger car waste generated has also increased. One of the most significant environmental problems of our time is collecting generated waste and its proper management. However, thanks to the actions taken to benefit our environment, less and less waste is being carried out every year by landfills in the European Union.[3][4]

Concerning waste vehicles, the EU has drawn up a directive describing the mandatory treatment of car waste. The directive also covers material recycling, re-use, energy consumption, the treatment of harmful substances to our environment, and waste going to landfills. Nevertheless, it does not include any restrictions on the advanced driving assistant systems mentioned above. As new technologies will be installed in more and more cars, it is worth considering waste management.

2 Materials and Methods

2.1 Materials

During the research, 3 different electronic driving support system units were examined. The sample materials (Table 1, Figure 1) were provided by Auto Mandy Car Ltd. (Budapest) as a partner of the University of Miskolc.

Table 1. Samples and properties

Sample	*Manufacturer*	*Product number*	*Mass [g]*
Adaptive Cruise Controller	*Bosch*	*A 000 905 30 11*	*206,52*
Electronic Control	*Bosch*	*A 167 905 02 00*	*40,13*
Car electronics plug	*-*	*-*	*3.24*

(a) (b) (c)

Figure 1. Samples: (a) Adaptive Cruise Controller, (b) Electronic Control, (c) Car electronics plug

As a first step, before the samples are subjected to any physical process, they must be disassembled to separate and know the different parts. After examining the ACC and ECM samples, the simplest method was manual disassembly. In the case of PS, it was vice, but since the sample was assembled and the materials inside were bonded with a strong adhesive, its exploration proved unsuccessful. After each part was sufficiently separated, the parts were measured by using digital scales. After the disassembly of the components, the testing of the PCBs could be performed in two ways. For both studies, the material composition was examined.

2.2 Methods

2.2.1 Material analyses and mechanical preparation

The three sample types that were the subject of the investigation were first examined with an Olympus Vanta XRF Analyzer hand-held X-ray spectrometer, and then with a Phenomen ProX Desktop SEM electron microscope to find the gold-containing components. The gold content of these components was later determined by the analytical laboratory of Metal Shredder Hungary Ltd. after wet chemical preparation using the FAAS method with a Perkin Elmer AAnalyst 400 device. The XRF analytical method is used to determine the elemental composition of substances. An X-ray portion of the XRF was placed at a point on the selected material during the measurement. After completing the test process, the result appeared on the device's display. The measurements were performed in order to know the composition of the different separated materials. To determine the material components more accurately, a scanning electron microscope was used. The measurement required flat surface specimens smaller than 10 mm, which were cut out from the PCBs. These specimens were fixed to a circular pin and placed in the SEM analysis chamber. During the measurement, it was necessary to select the points at which the studies were performed. The requirements for the research were to find materials that could be recovered both economically and environmentally.

The choice of equipment for crushing the ACC and ECM samples had to consider the material composition, that the components would fall sufficiently into pieces during breakage, and that the PCBs would not be damaged. In experimentation, the first choice fell on the impact crusher. The equipment was operated at different circumferential velocities during the breakage experiments. Dispatch was aided by a cellular feeder. In the samples, upon arrival in the crusher, they came into contact with moving parts of a rotor, which generated tension and, as a result, fracture began in them. The so-called blow bars then threw the samples onto the crusher plates, causing further fractures in them by the impact stress. Eventually, the sample leaving the equipment arrived in a bowl. The breaker appeared to be sufficient, so no further breakage attempts were required.

The Electronic plugs were much smaller or less rigid material; the samples were sent to a hammer crusher. After feeding, the samples encountered articulated percussion devices of a rapidly rotating rotor. These percussion devices shredded the samples by hitting the sheet steel wall of the housing. The material left the machine when it reached the size of the sieve placed in it.

2.2.2 Separation process

The samples were subjected to further separation experiments after comminution. The purpose of the separation process was to separate the various materials of the samples, most notably the PCBs and the metal parts of the plug, which contain gold, from the other materials.

After crushing process in most cases involves screening. Thus, the ACC and ECM materials coming out of the crushers were sieved by predetermined fractures. The main goal was to separate the PCB and Al case (in ACC) from the other materials. The materials obtained from their comminution were measured and selected for fractions with a square sieve of different sizes.

In order to separate the PCBs, it can also be done by using an eddy current separator (ECS). These kinds of separators are widely used sorting equipment. The ECS is a dual-belt conveyor system, and the right-hand side features a separate, rotating, high-speed magnetic rotor. The device is based on the phenomenon that the Lorentz force pushes the charge into a field in a magnetically induced space in a conductor moving at a given speed. The magnetic field of the generated eddy current has the exact opposite effect to the magnetic field that creates it, causing the guide piece to move (deflect) perpendicular to the plane defined by the magnetic field and velocity. All this does not affect the movement of the particles and pieces of the non-conductive material, so the PCB has been separated from the other materials. Separations were made by varying belt speed and rotor speed.

For separating the smallest (under 5 millimeters) metallic parts from the non-conductive materials the suggested equipment is the electrodynamic separator. The separation is based on differences in magnetic properties and/or electrical conductivity. The advantage is that the individual components can be effectively separated under dry conditions, avoiding compaction, dewatering, hydro transport, or additional drying operations. Samples are fed to the coronal zone, where they are negatively charged and led to the surface of the drum. Low-resistance particles are positively charged by throwing them into an electric force. In contrast, strongly conductive particles retain their charge in the coronal zone, adhering to the drum and then falling off or scraping off with a brush.

3 Results

When presenting the result of the particle size distribution on the ACC unit (Table 2), it can be seen that thanks to the preliminary, gentle shredding, the PCB boards were enriched in one particle size fraction.

Table 2. Size and material distribution of the ACC unit after comminution

particle size [mm]	mass ratio [%]	PCB [g]	Plastic [g]	Ferrous metals [g]	Non-ferrous metals [g]
0 - 4	3.38		14.04	4.5	
4 - 8	1.48		8.12		
8 - 16	8.72		26.31	21.48	
16 - 32	5.44		27.20	2.61	
32 - 45	20.65	80.09	33.08		
45 - 56	8.67		47.50		
56 - 60	51.66				283.09

The separation of the PCB boards was carried out with the Eriez eddy current separator. Since the amount of sample material was limited, the number of tests was increased by sending them multiple times with the same settings. Table 3 shows the output of the ECM PCB boards.

Table 3. The yield of PCB panels using an eddy current separator (belt speed 1 m/s)

1.

Magnetic drum rotation speed [Hz]	Successful yield [pcs]	Unsuccessful yield [pcs]
30	14	6
35	17	3
40	16	4
45	18	2
50	20	0

The results of the gold content were shown in Tables 4. to 6. what the Metal Shredder Hungary Ltd.exemined.

Table 4. Gold content of the ACC unit

Main part	Mass [g]	Gold content [g/t]
Plastic cover (2 pieces)	53.94	50.4
Aluminum case	107.89	0
PCBs	35.89	81.3
metal clips	8.80	0
Total	206.52	27.3

Table 5. Gold content of the ECM unit

Main part	Mass [g]	Gold content [g/t]
Plastic cover	21.54	0
PCBs	8.93	264.6
Plugs	9.66	0
Total	40.13	58.9

Table 6. Gold content of the Car electronic plugs

Main part	Mass [g]	Gold content [g/t]
Plastic cover	2.42	0
Metal pins	0.82	2186.0
Total	40.13	554.7

The tests reveal that after removing the electronic parts and dismantling the cars by hand, they can be revealed by gentle pre-shredding to eliminate the cohesion of the corresponding parts and to improve the efficiency of the further separation steps in order to extract the valuable raw materials.

After pre-shredding, the required sieving of the fraction is used to separate the appropriate grain-size fraction, on the one hand, in the interest of reducing the material flow to the machines, and on the other hand, in order to ensure the optimal operation of the equipment.

With the help of magnetic, eddy current and electrodynamic separators, the separation of grains with a high gold content can be solved, so they can be returned to the production processes.

The flowcharts of the test and processing technology flowcharts of the ECM and ACC were presented in Figures 2. and 3.

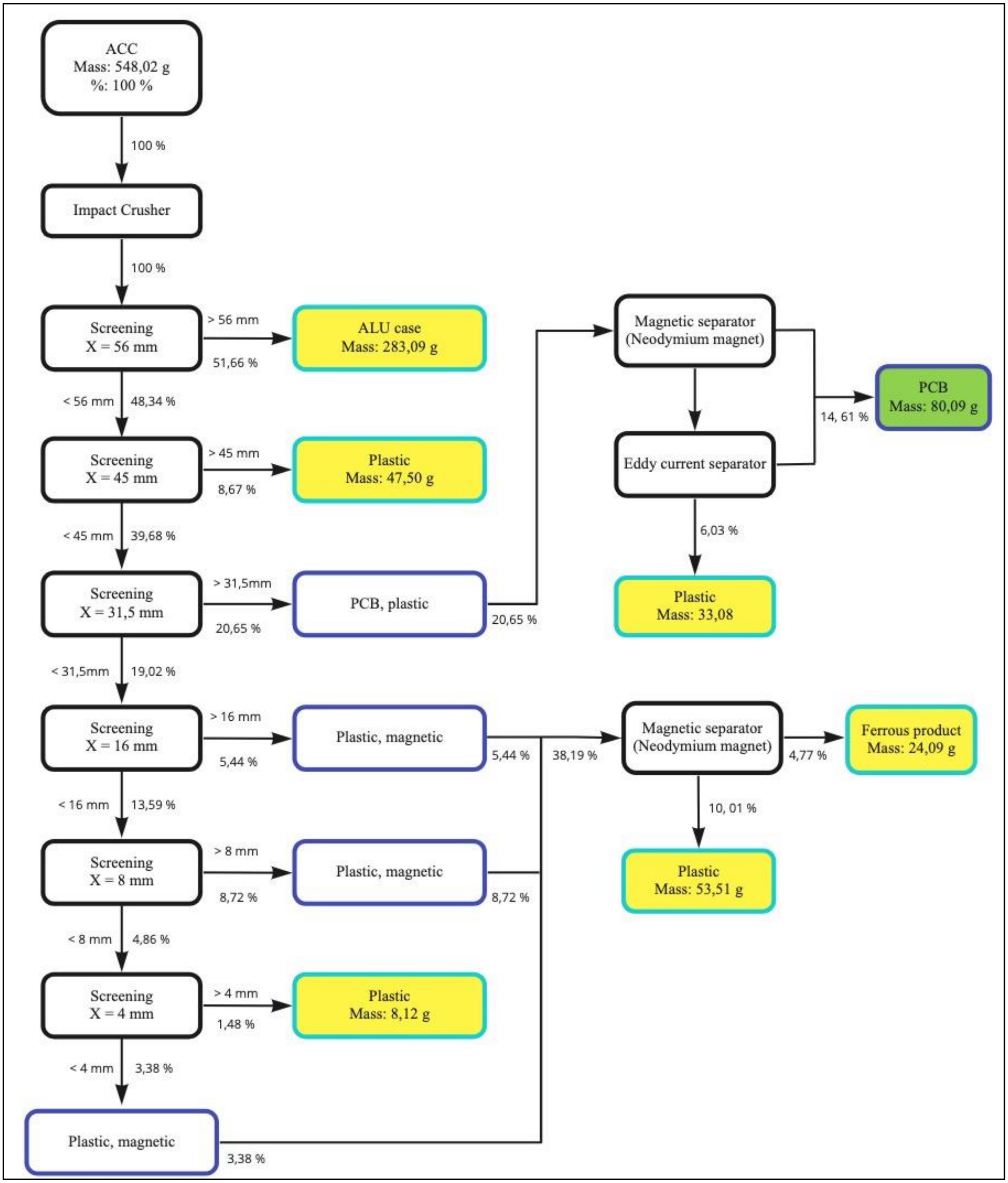

Figure 2. Flowchart for ACC test and processing technology

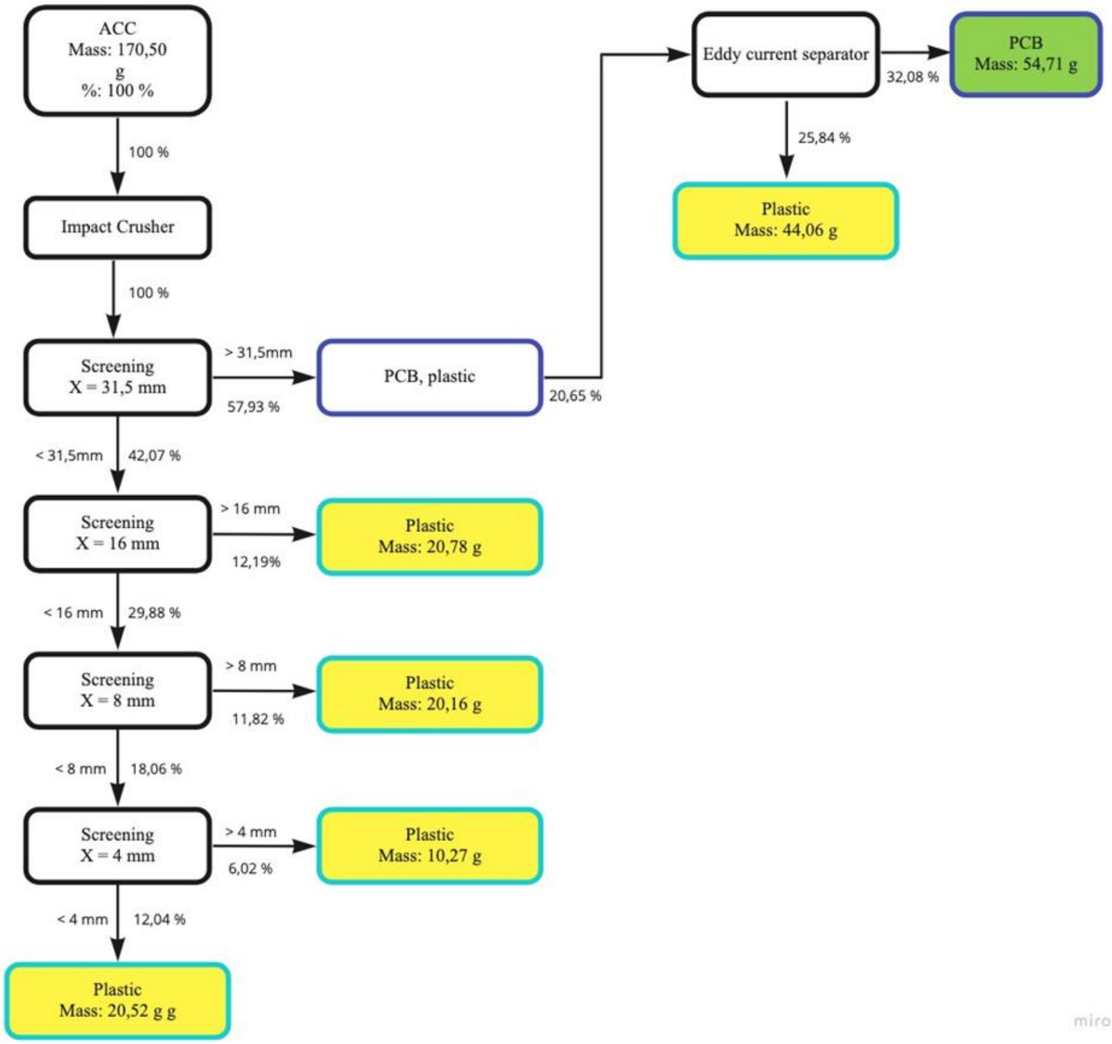

Figure 3. Flowchart for ECM test and processing technology

4 Conclusions

During the research, two advanced driving systems samples and a car electronics plug were tested. In all three cases, it was necessary to explore each sample to find out what it contained.

Studies with ACC have shown that the approximate fractions recoverable from the material stream are (1) plastic - 25 w%, (2) PCB – 16 w%, (3) Al case - 51 w%, and (4) Fe metals - 8 w%. Examination of the material composition of the samples revealed the precious metal content (gold - Au) on the surface of each measurement point of the PCB. The comminution equipment used was the impact crusher, which successfully separated the individual components of the sample from each other.

In the research with ECM, the approximate fractions recoverable from the material stream form two groups, (1) PCB - 32 w% and (2) plastic - 68 w%. In this case, too, the material composition test revealed the precious metal content (gold - Au) on the surface of each measuring point of the PCB. The comminution equipment used was the impact crusher, which successfully separated the individual components of the sample from each other.

5 Acknowledgement

The research was conducted at the University of Miskolc as part of the „Developments aimed at increasing social benefits deriving from more efficient exploitation and utilization of domestic subsurface natural resources" project supported by the Ministry of Innovation and Technology from the National Research, Development and Innovation Fund according to the Grant Contract issued by the National Research, Development and Innovation Office (Grant Contract reg. nr.: TKP-17-1/PALY-2020).

6 References

[1] Földessy, J. (2014). Basic research of the strategic raw materials in Hungary. CriticEL Monography. vol. Milagrossa Kft.. no. 10. 2014.

[2] Wautelet, T. (2018). Exploring the role of independent retailers in the circular economy: a case study approach. Vol. Master of Business Administration: eufom European University for Economics & Management A.s.b.l. Study centre Luxembourg.

[3] EMF. Ellen MacArthur Foundation. (2017). https://www.ellenmacarthur-foundation.org/circular-economy

[4] Directive 2000/53/EC of the European Parliament and of the Council of 18 September 2000 on end-of life vehicles.