MODERN CHALLENGES IN METAL RECYCLING - PROCESS, TECHNICAL AND ECONOMIC AND LOGISTIC APPROACH

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Abstract

The paper presents the current state of metal recycling. The types of metals subjected to the recycling process and the course of the process are described. Logistic, technological and economic aspects were taken into account. Current technologies of metal recycling and recovery as well as business opportunities in the content of sustainable development were characterized. Challenges for the metal recycling industry were presented. The process of car recycling in the context of opportunities for improvement was analyzed.

Keywords: Metal recycling, recycling process, recycling plant, vehicle

1. INTRODUCTION

The paper presents the problems of contemporary challenges in the recycling of metals in process, technical, economic and logistic approach. The analysis was carried out with reference to recycling of cars, withdrawn from further exploitation. Old cars present a serious health and environmental hazard, especially when they are disposed of without proper processes and technologies. Vehicles contain large quantities of hazardous substances such as waste oil, lubricants, batteries with lead and acid, mercury, lamps, electronics, plastic, air bags. Enough materials are recycled from cars from being used to make new parts. Not only are metals and other materials reused but enough fluids and oils are safely removed from recycled. The problem of recycling end of life automotive vehicles is serious worldwide. The aim of this paper is to analyze the vehicle recycling system, indicate the direction of changes and analyze development perspectives of vehicle recycling in Poland and selected countries of the word. In implementing the topic taken at work, the “desk research” method was used.

2. VEHICLE RECYCLING SYSTEM

Economic development is linked to the use of metals. The growing demand for metals puts permanent pressure on the resources. Metals are high-value resources, and can principle be easily re-used and recycled. Vehicles withdrawn from further exploitation are the source of valuable materials that can live in new products. Many cars parts have a raw material value. It is important, therefore, to recover them effectively. The vehicle recycling system consists of many processes, including: disassembly, preparation of parts for reuse, recycling of materials, use of residues after grinding of scrapped vehicles as a source of energy. So, process management and system analysis, making rational decisions is necessary [1-3].

2.1. Process approach - process participants - logistics forms of the vehicle recycling process

The participants of the recycling system in Poland are: introducers of vehicles, vehicle owners, entrepreneurs running: dismantling stations, vehicle collection points, shredders, recovery/recycling of waste from vehicles, as well as public administration bodies, issuing decisions and inspection services. In Poland, multi - year or post - accident vehicles (passenger cars, lorries, delivery vans, mopeds), unusable, are transported for dismantling. **Figure 1** presents a diagram of the vehicle recycling network.

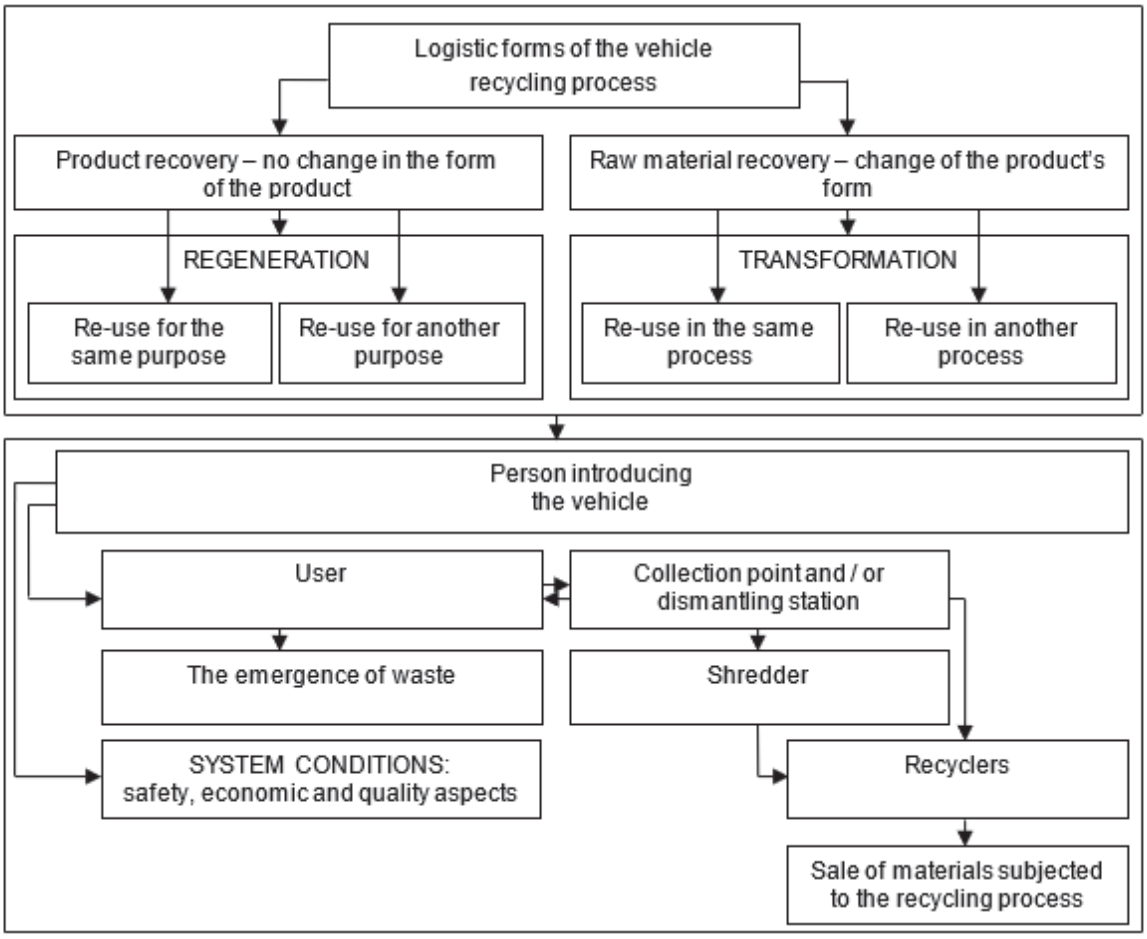

Figure 1 Diagram of the vehicle recycling network, taking into account logistic forms of recycling

2.2. Types of metals subjected to the recycling process - technical and ecological aspects

The vehicles are collected at dismantling stations, where they are dismantled, in accordance with the established procedure, taking into account the order of operations. Everything that can be processed is removed from the vehicle. Steel and other metals are separated from the vehicles as secondary materials. Ferrous and non-ferrous metals together constitute the largest part of the total vehicle weight. Vehicles are constructed of various types of metals: steel, aluminum, palladium, platinum, zinc, cobalt. Certain vehicle components are made of plastics, carbon fiber, rubber and glass. The weight of a typical passenger car consists of over 70 percent of high-quality steel and 5-10 percent of non-ferrous metals [4]. Suitable materials from vehicles, metals and other materials are processed for the production of new parts. All dangerous car fluids are recycled for recycling or disposal. Parts suitable for re-use or recycling are separated from the wreckage of the car, and its body after flattening is transported to the steelworks. In the steelworks is melted. Steel is recovered in the final stage of the process. Plastic, rubber, glass and other materials, after crushing the body of the car by the shredder, are wastes or are remnants of the fragmentation of scrapped vehicles (automobile shredder residua). Up to 10 percent of the vehicle's mass goes to energy recovery [5].

The waste resulting from the dismantling - rugs, rubber, gaskets, headliners, knitted fabrics, polyurethane foam from the seats are used as an alternative fuel in cement plants. Plastics - wheel arches, bumpers are ground on granules and re-used in industry. The glass goes to the glassworks. Aluminum is assembled from the engines. The heads and pistons go to the aluminum smelter. Old tires are ground into rubber (granulates) or pyrolyzed (dry distillation). Granules are also used as an ingredient for road construction. The oils are sent to the refinery. The steel industry processes annually over 14 million tonnes of steel obtained from withdrawn

vehicles [6]. Polish steelworks collect scrap, delivered in packs or cut into small pieces. Most of the smelters buy scrap metal cut into small pieces. From 2015 on vehicle dismantling stations was imposed the standard of the level of recycling and recovery in the amount of 90-95 percent of the vehicle weight [7].

About 2-3 percent of weight of cars is not used. Enterprises do not have the financial means to purchase installations for recycling multi-material waste or brake pads that contain asbestos [8]. Legal regulations do not allow the re-use of catalysts, airbags, seat belts. However, they can be used for creative activities or transported to a plant managing such waste. Parts that no longer drive any vehicle, after thorough cleaning, welding and varnishing can be done with artistic lamps, stands.

Recycling is the beginning of the path of all steel figures, that could get a new life and arise from the ecological attitudes of the customers. In the Polish city of Pruszków is the Gallery of Steel Figures. This is a unique place in the world. An entire museum is devoted to dozens of sculptures built from scrap metal salvaged from a local scrapyard. Their most recent addition is a collection of four iconic cars designed and built by roughly 50 artists over the last five years. The models include a Mercedes-Benz 300 SL, a Bugatti Veyron, a Maserati GranTurismo, and a Lamborghini Aventador. The steel vehicles are built completely to scale and include functional doors and replica interiors. The Gallery of Steel Figures also has wide array of imposing Transformers and other pop culture figures from TV and film, is presented in the **Figure 2** [9].

Figure 2 Steel cars made of recycled elements [9]

In theory, each car sold in the European Union is designed to be almost entirely recyclable. In practice, however car manufacturers do not want to provide instructions for dismantling selected parts or a document provided, from which nothing follows. This is incomprehensible, as the regulations oblige car manufacturers to provide such information to the car recycling companies. Automobile concerns have no interest in processing, retrieving and selling used parts, because they do not earn on them. They prefer to produce and sell new parts. The course of the recycling process is shown in **Figure 3**.

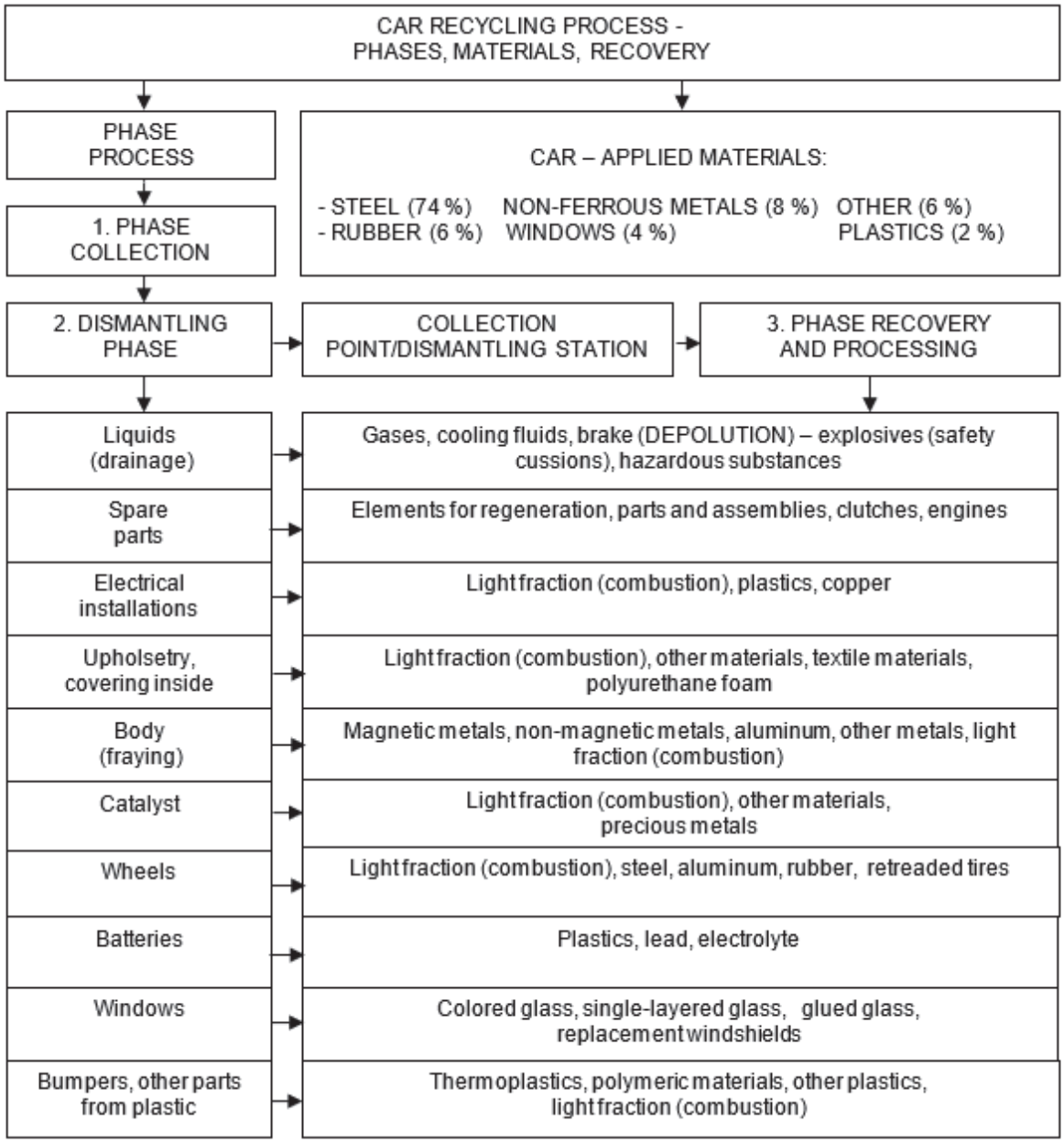

Figure 3 Diagram of the recycling process.

Type of vehicle, parts and assembles to be recovered and quantity of raw materials determines economic efficiency of the process.

3. DEVELOPMENT PERSPECTIVES OF VEHICLES RECYCLING

Recycling end of life automotive vehicles is a serious worldwide problem, also in Poland. Large numbers of second-hand vehicles are being imported to Poland. This situation persists despite the toll taken by such huge imports of old, often more than a decade old vehicle, which in most cases fail to meet safety and environmental protections standards. The upward trend in auto production was maintained in 2016. GUS reveals that 554.600 passenger cars rolled down the assembly lines of all production facilities. Passenger car registrations at end 2016 totaled 416.123. The number of second hand vehicles imported in 2016 exceeded sales of new ones more than two-fold. In the Czech Republic, motor vehicles output reached 1.349.000, the vast majority of which were passenger cars. Production volume, constituting solely passenger cars, significantly increased in

Slovakia, to 1.040.000 units in 2016. Taking into account the number of manufactured motor vehicles, Poland remains on the third place among the central and Eastern Europe countries. In Europe, developing markets, especially western countries, have a higher potential. On Chinese market forecasts expect production to reach a level of about 35 million light vehicles annually. More upward potential is expected also from a large number of emerging markets, such as: Russia, Brazil, Thailand. India in particular seems set for a long-term growth increase [10]. For example, in Japan, Mitsubishi Chemical has revealed its intention to use recycled carbon fibers in the production of car parts in order to cultivate new business prospects [12]. Sorting scrap car parts into just eight classes could increase recycling rates of alloy elements to over 97% in Japan, according to a study by Tohoku University researchers. Optimizing recycling could save Japanese steelmakers 287 million USD on raw materials and cut greenhouse gas emissions associated with obtaining new material by more than 28 percent. The analysis found that between 94 and 99 percent of the alloy elements could be recycled from the scrap car parts and would reduce greenhouse gas emissions associated with the new material by 28.3 percent. Their methodology can be applied globally to other industries helping find the optimal balance between costs and emissions and advance efforts to establish a circular economy. **Table 1** presents: light vehicle, motor vehicles production and regional contribution to growth 2016-2023 (%).

Table 1 Development perspectives in the field of light vehicle assembly and motor vehicles production in the selected countries in the world and regional contribution to growth [10,11]

Light vehicle assembly in the developed markets in the years 2016-2023 (millions)							
2016	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**
41.9	41.8	41.8	42.5	43.1	43.2	43.4	43.3
Light vehicle assembly 2016-2023 in the developing markets in the years 2016-2023 (millions)							
50.9	53.7	58.2	61.9	64.7	66.5	68.0	69.7
Comparison: Motor vehicles production in the selected countries in the world in the year 2017 (thousands)							
2017	**Poland**	**Czech Republic**	**Slovakia**	**Hungary**	**Japan**	**China**	**United States**
Commercial vehicles	175.029	6.112	0.000	3.400	1.345.910	4.208.747	8.156.769
Passenger cars	514.700	1.413.881	1.001.520	502.000	8.347.836	24.806.687	3.033.216
Motor vehicle production	689.729	1.419.993	1.001.520	505.400	9.693.746	29.015.434	11.189.985
Regional contribution to growth (%) in the years 2016-2023							
NORTH AMERICA - 10.2							
SOUTH AMERICA - 5.1							
EUROPE - 6.5							
NEAR EAST - 8.9							
ASIA - 64.1							
PACIFIC - 1.2							

4. CONCLUSION

Vehicle manufacturing is a systematic project and includes tens of thousands of spare parts and related materials. A modern car contains nearly all metals available, as it's a product that integrates a broad range of

other metal - containing products. This is why the focus needs to be on optimizing the recycling of entire products at their end- of life increased of focusing on the individual materials contained in them. The content of iron and heavy metals decreases while the amount of plastics and aluminum is increasing. Raw material that is 100 percent recyclable is steel. Rapid development of automotive industry in recent years in Poland has entailed the introduction of rational management of waste materials from the operation and disposal of vehicles. Rapid increase of the number of cars and the existing age structure of the national fleet, where a significant part is the old and worn vehicles, causes the increase of the total mass of waste vehicles. The age structure of the resident cars in Poland is one of the oldest in Europe. Compared to the standards of the European Union, the car market in Poland is unsatisfactory in terms of quality. It will generate large amounts of solid waste pollution and oil contamination. That is why it becomes urgent to create conditions in both the legal, organizational, technical foundation in the country to collection use and disposal of generated waste from motor vehicles. Technical changes and diverse growth opportunities in developing markets require ongoing investments and organizational change by original equipment manufacturers. Technology development is a key trigger of new technology companies in automotive market. The goal is to introduce autonomous vehicles and ride/car sharing platforms and other transport services providers. Industry can be the resource of driving innovation that maximizes resource efficiency when policy makers draw on their expertise and tools.

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