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Vehicles optimization regarding to requirements of recycling

Example: Bus dashboard

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Abstract. It is very important during production to take into account the requirements regarding to recycling of vehicles. On this manner it is possible reuse of consisting materials and optimization of End-of-Life Vehicles. In European Union has defined targets to be achieved in the future for the recycling rate of vehicles at the end of their service cycle. Directive of the European Parliament and of the Council 2000/53/EC regulate waste management in the vehicle sector. This manuscript presents in global the international legislative in this field, regarding to the situation in Republic of Serbia. As contribution, during production of domestic city bus running on natural gas, performed the replace of material for bus dashboard on the basis of plastic and polyurethane foam, with ecological material with carbon inserts. The requirements for dismantling, reuse and recycling are integrated in the design of new bus.

1. Introduction

In 2016, more than 22.5 million of trucks and busses (approx. 7.5 million in U.S.) and approx. 72.1 million of personal cars (approx. 4.2 million in U.S.) were produced globally. According to prognosis, a total of around 107 million vehicles will be manufactured worldwide in 2020 [1]. Worldwide, some 79 million automobiles are expected to be sold by the end 2019. From the second side, in 2017, some 26 million vehicles were sold globally, and U.S. is the largest market for commercial vehicles.

Parallel the number of end-of-life vehicles (ELV) arising constantly, and there are gaps between the numbers of deregistered and ELV in many countries. There is no detailed information available because of a certain number of de-registered vehicles are commercially exported to the underdeveloped countries as second hand. Also, it is important to reduce illegal shipments of ELV; because inspections of transports within and out of the EU should be intensified.

If current trends continue and no relevant legislation from design to disposal vehicles, The Globe can become overloaded vehicles at the end of the service cycle. Vehicle recycling and reuse of materials incorporated is very important from that point of view and presents a solution the problem.

1.1. Problems with the dismantling of the vehicle at end-of-life

Regarding dismantling (consisting of collection, depollution and crushing) of ELV in Europe, two main aspects have to be considered.



First, there is evidence suggesting that ELV are treated illegally in some cases. However measures which make the disposal of an old vehicle in the country of de-registration more attractive, such as refunds obtained in a deposit-refund system, would help reduce illegal shipments of ELV.

Second, there is evidence suggesting that even in authorized treatment facilities dismantling (specifically depollution) is not in full compliance with the relevant requirements of the existing ELV Directive.

Liquids seem to be removed to a certain extent. Certain types of fluids or components such as brake fluids, windscreen washer fluid, oil filters or shock absorbers, however, are not always removed or depolluted.

Usually little effort is put into the removal of components containing heavy metals, such as Hg, containing display backlights or switches.

Lead-Acid Batteries are generally removed from ELV because lead may be used as a source of income and because of constraints for the shredder process if not removed. Gas tanks and air bags are usually removed because of the well-known risks for shredder plants.

Shredder means any device used for tearing into pieces or fragmenting ELV, including for the purpose of obtaining directly reusable metal scrap.

In order to improve depollution of ELV, measures should be taken against illegal waste car dismantlers and unauthorized treatment facilities.

Depollution of ELVs should lead to shredder residues with low contents of hazardous substances. According to some available information on the composition of shredder residues, it is in particular the content of hydrocarbons that indicates that the depollution of ELV is not always sufficient.

1.2. Legislation in domain of recycling and recovery of the vehicle

Every year ELV in the Community generate between 8 and 9 million tons of waste, which must be managed correctly. EU regulation for the automotive sector regarding to ELV is Directive (2000/53/EC) [2].

The requirements for dismantling reuse and recycling of ELV and their components should be integrated in the design and production of new vehicles.

According to ELV Directive demands, the reuse/recyclable target for components of a vehicle must constitute a minimum of 85 wt. % (weight percentage) and the recoverable parts a minimum of 95 wt. % per vehicle.

ELV Directive requires the number of improvements on the vehicle and equipment as it is: engine efficiency, the use of biofuels and other alternative fuels, weight reduction by application of new materials etc. Responsibility and awareness of vehicle manufacturers is very important here.

However, recycling and recovery rates are different and overestimated due to differ between States, and different national interpretations. There exist the need for improvement regarding the recycling and recovery of ELV materials.

Dismantling and subsequent material recycling of glass and plastics for instance takes place in minor quantities in several States. Recovery of glass after shredding, however, prevents glass recycling because of the bad quality of the glass. Recovery of plastics from shredder residues is still limited. Whereas in some States post shredder technology has been installed and landfilling of shredder residues prohibited or made very expensive, several States still deposit shredder residues on landfills. Overall, in this area is very important and necessary to establish harmonization.

The job is complex and due to the intensive application of new propulsion technologies. Current issues are solving the problem for recycling of electric vehicles with recovery their parts, such as permanent magnets etc. [3].

The recycling of all plastics from ELV should be continuously improved. The Commission is currently examining the environmental impacts of PVC.

There are several other legislations dealing indirectly with plastics and plastic waste, be it safety or emissions related. The second most important problem is in domain of recycling and recovery of polyurethane (PU) foams from vehicles [4].

Polyurethanes are dominant also in transport sector, in passenger cars, as well as in trucks and buses, not only in construction sector, inside buildings and for furniture.

Average plastic content is approx. 150 to 120 (kg/car), of which PU constitutes a rather large, but widely varying share. On avg. polyurethane represent around 10 to 15%, depending on manufacturing technology.

PU materials reduce the fuel consumption directly through lightweight design, either in conventional models or in new hybrid metal or plastics designs. PU bonding capabilities enable new manufacturing technologies, such as replacing welding, and improved design, lightweight metals technology etc.

There are many different types of PU used in vehicles given the broad performance standards requiring reduced weight, increased fuel economy and comfort and improved resistance, insulation and sound absorption. The variety of applications is equally broad, including items such as seating cushions, steering wheels, sound and energy absorbing elements, ceilings and dashboards.

Dashboards protect the mechanics of the vehicle against moisture, impact, abrasion, excessive heat, and harmful UV rays. For several decades, plastics have been playing an increasingly vital role in the performance and design of these panels. Acrylonitrile-Butadiene-Styrene (ABS), polycarbonate alloys, polycarbonates, polyester, and polypropylene are the most common materials associated with these important applications.

The numerous and varied PU automotive applications leads to a rather broad product mix being utilized in vehicles. The product properties vary from light foam, as used for seating, to very rigid and tough thermoset plastic materials, as in steering wheels, instead of thermoplastics.

In this area there is also a problem because that dismantling of seat cushions or larger parts containing PU, such as the instrument panel, is not eco-efficiency.

Shredder treatment technology and the further refinement by companies such as Salyp or Sicon, and new post shredder technologies have shown the bigger cost and limits [4].

2. Proper experience in the field of buses designing regarding to ELV recycling requirements

Domestic recycling industry is in this moment in the stage of development. The problem is the design of the vehicles, which does not allow an adequate and rapid implementation of the process of dismantling, and the lack of unified system.

Due to existence of several domestic bus manufacturer in the market solution to the problem of recycling these vehicles is very important. Designing regarding to recycling demands inside ELV Directive allow not only to meet domestic ecological requirements, but also to contribute to the increase in the export potential of the vehicle trademark.

As an example, Figure 1 shows the structure of redesigned local city bus running on natural gas. Dismantling information for the correct and environmentally sound treatment of ELV formed, too.

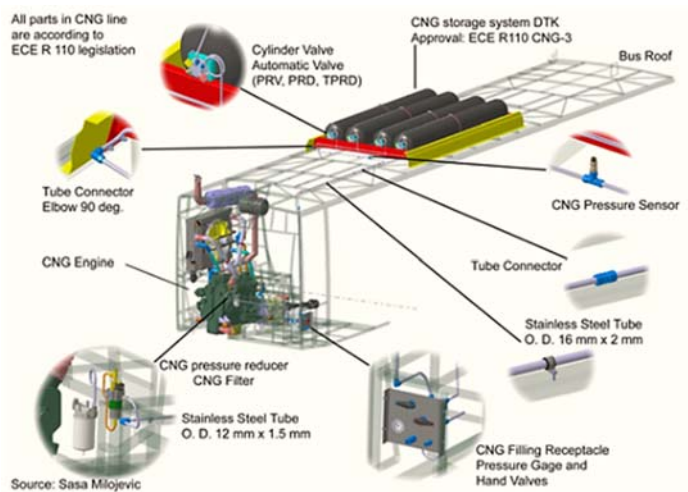


Figure 1. Redesigned domestic city bus, running on natural gas.

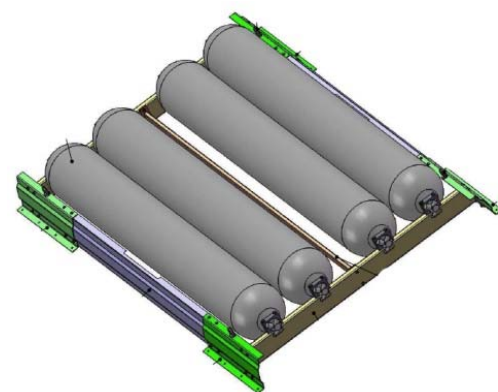


Figure 2. Module with aluminum gas tanks for alternative fuels.

Of light composite materials are also produced and tanks on vehicles running on conventional and alternative fuels, such as hydrogen and natural gas. Under such conditions of application, the material of the tank must sustain the high pressures and other impacts such as corrosive effects of fuel etc. Figure 2 shows a module with aluminum tanks for alternative fuels [5-8].

Applying the light materials for tanks, is achieving a weight reduction of vehicles to alternative drive which contributes to the reducing fuel consumption and preserving the environment.

Based on the results of the analysis, the buses are very complex system regarding to their compatibility for recycling and reuse.

Inside recycling factories, is very difficult to organize recycling process, starting from complex process for dismantling of parts, sorting of materials, etc.

To increase bus recycling rates, the complex interconnected material cycles originating from recycled buses have to be optimized from a technological as well as economical point of view. The optimization of the resource cycle of buses involves the interaction of various disciplines, as shown in Figure 3 [9].

To links the recycling of buses from a material and energy perspective as depicted by that figure's golden circle; recycling technology and design as represented by the grey circle; and cognizance of economy, environmental impact, and legislation as shown by the blue circle.

Fundamental knowledge of recycling processes, such as shredding, mechanical separation processes and metallurgy, and material characteristics of recycling (intermediate) products, such as material type and liberation, have to be combined with that of the design of the product (material combinations and connections). In order to optimize the resource cycle and maximize the recycling rate of future buses, the parameters determining the recovery rate for each of the materials present in the multilateral ultralight bus of the future, as well as the dynamics and statistically distributed nature of the resource cycle system have to be fully understood.



Figure 3. The diverse and distributed properties of recycling materials (clockwise: steel approximately 650 t. from 1,153 ELVs; copper fraction; Al/Mg/Cu/Zn fraction; plastic fraction; Al/Mg/Cu/Zn fraction; steel fraction).

Generally, during buses production according to international and domestic requirements in domain of ELV recycling adopted is the following concept:

- Bus concept according to characteristics requested by the market and customer exceptions. Optimization of the bus design with minimization of energy and material consumption during service cycle and design with easy disassembly;
- Use of ecological materials suitable for reuse, with minimal percentage of included hazardous materials;

- Mass reduction contributes to lowering fuel consumption in the traffic, as well as logistics costs during production process;
- Optimization of production technology (technological process with minimal energy consumption and toxic emission); and
- Design according to ELV Directive to allow disassembly and separation of materials and possibility to reuse components. Materials must be labeled (specifically elastomers and polymers).

3. Recyclability and recoverability; Calculation method

The International Standard (ISO 22628:2002) specifies a method for calculating the recyclability rate and the recoverability rate of a new road vehicle, each expressed as a mass fraction of the vehicle. Under this procedure, performed by the vehicle manufacturer when a new road vehicle is put on the market, potentially, the vehicle can be recycled, reused or both (recyclability rate), or recovered, reused or both (recoverability rate) [10].

Recyclability rate of the bus is determined by the recovery by each of the materials present in the bus. Indicators of recyclability and recoverability rates are determined by the calculation of the masses of materials of bus components identified in the technical documentation of the bus maker with subsequent monitoring of actual deviations in production.

Recyclability rate (R_{cyc}), or (recyclability indicator for reuse) of the bus, is calculated as a percentage by mass (mass fraction in percent), using the following equation (1):

$$R_{cyc} = \frac{m_p + m_D + m_M + m_{Tr}}{m_V} \cdot 100 \geq 85\% \quad (1)$$

Recoverability rate (R_{cov}), or (recovery indicator) is calculated using the equation (2):

$$R_{cov} = \frac{m_p + m_D + m_M + m_{Tr} + m_{Te}}{m_V} \cdot 100 \geq 95\% \quad (2)$$

where is:

- m_p - Mass of materials taken into account at the preliminary process (pretreatment); (all liquids, battery, oil filters, tires, catalytic converters, gas tanks etc.);
- m_D - Mass of materials taken into account at the dismantling (large, easily removable parts from polymers, elastomers, as it is bumper, lining, dashboard etc.);
- m_M - Mass of metals taken into account during Shredder processing at the metal separation process;
- m_{Tr} - Mass of nonmetallic materials for recycling taken into account during Shredder processing etc.; and
- m_{Te} - Mass of materials taken into account at the nonmetallic residue treatment step and which can be considered for energy recovery (polymers and elastomers difficult to dismantle or less than 100 and 200 g, respectively) and other combustible materials (leather, wood, cardboard, etc.).

Time for dismantling the bus is determinate by the features of its design, the elements of fastening the units and parts, the availability of technical instructions for dismantling etc. The bus recycling costs at ELV is very dependent upon dismantling time. Many manufacturers are investing time and resources to shorten the time required for dismantling the bus at ELV.

4. New design and development of buses podium dashboard

In order to minimize the time and financial costs for the dismantling of buses, special solutions and limitations are being put at the design stage, simplifying disassembly. Using the computer-aided design (CAD) to aid in the creation, modification, analysis, or optimization of a design system, helps to simplifying dismantling.

An example of modeling the dismantling of plastic parts of the city bus type (203 CNG-S) podium dashboard is shown in Figure 4 and 5.

The result is the catalog for the dismantling of city bus, which meets the requirements of the EU regulations on the suitability of vehicles for disposal.

Podium is an integrated platform, a generic dashboard solution (ISO16121) compliant, including mainly:

- A main console with adjustable steering column, steering wheel (with optional integrated commands) and stalk switches;
- MultiBUS modules like MultiC cluster in the center and Switch Packs in the left and right part can be adapted: number of CAN buses (1 to 3) and number of gauges (2, 4 or 6 gauges);
- A slot for Public transport system, a gearbox selector, up to 4 push buttons for doors and a rotary switch for exterior lighting (different number and type of switches; low current switches, door buttons...); and
- A harness interface for the chassis.

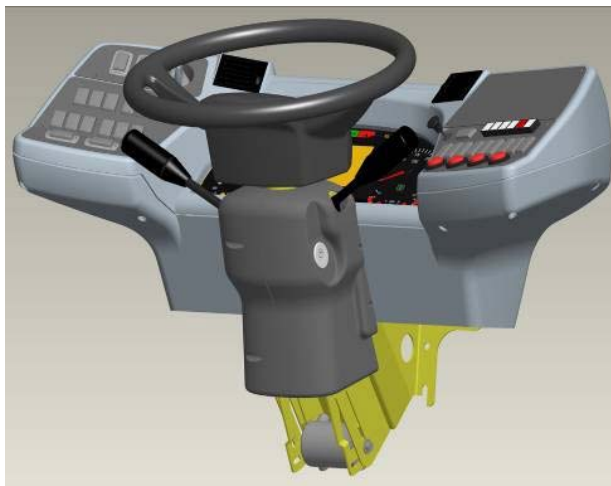


Figure 4. Integrated platform with new design of podium dashboard for city bus.



Figure 5. Internal design of podium dashboard for easy dismantling.

In order to be as close as possible to Bus and Coach Market requirements, podium is a flexible and modular unit which can integrate several options. Dedicated catalogues centralize the available options.

The main Podium advantages compared to competitors' solutions are:

- A modern style and design compatible with the latest Bus and Coach developments;
- Better Man Machine Interface (cluster with large color TFT display, backlit switches...);
- An empty space dedicated to public transport system on the right part of the console; and
- Improved ergonomics (more space for driver legs, centralized commands etc.).

5. Conclusions

If current trends continue and no relevant legislation from design to disposal vehicles, The Globe can become overloaded vehicles at the end of the service cycle. Vehicle recycling and reuse of materials incorporated is very important from that point of view and presents a solution the problem.

EU regulation for the automotive sector regarding to ELV is Directive (2000/53/EC). The requirements for dismantling reuse and recycling of ELV and their components should be integrated in the design and production of new vehicles.

Domestic recycling industry is in this moment in the stage of development. The problem is the design of the vehicles, which does not allow an adequate and rapid implementation of the process of dismantling, and the lack of unified system.

The recycling of all plastics from ELV should be continuously improved. The Commission is currently examining the environmental impacts of PVC. The variety of applications is equally broad, including items such as seating cushions, steering wheels, sound/energy absorbing elements, ceilings and dashboards.

As contribution, during production of domestic city bus running on natural gas, performed the replace of material for bus dashboard on the basis of plastic and polyurethane foam, with ecological material with carbon inserts. The result is also the catalog for the dismantling of city bus, which meets the requirements of the EU regulations on the suitability of vehicles for disposal.

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