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METHOD OF RECYCLABILITY ASSESSMENT ON THE EXAMPLE OF FORKLIFT TRUCK

Summary. While using and after withdrawing from service technical objects, the technical objects causing ecological risk. In order to minimize the negative impact the technical object on the environment and achieve high level of recyclability, the specific steps should be undertaken in the design phase. The legal aspects of recycling process in case of vehicle were discussed. The disassembly process was discussed in case of fork lift truck. Two main characteristics influencing recyclability and a few categories were chosen for their evaluation. With using two main characteristics and their categories the parts susceptible and not susceptible for recycling can be found out.

PROPOZYCJA METODY OCENY PODATNOŚCI NA RECYKLING NA PRZYKŁADZIE WÓZKA JEZDNIOWEGO

Streszczenie. Obiekty techniczne w trakcie ich eksploatacji jak i po zakończeniu cyklu życia niosą ze sobą zagrożenie ekologiczne. W celu minimalizacji negatywnego wpływu obiektów technicznych na środowisko, już na etapie ich projektowania powinno podejmować się działania umożliwiające osiągnięcie wysokiego poziomu podatności recyklingowej. W artykule omówiono aspekt prawny recyklingu urządzeń i pojazdów transportowych oraz charakterystykę procesu demontażu wózka widłowego. Zaproponowano dwie główne cechy wpływające na podatność recyklingową i dobrano kategorie ich oceny. Przy wykorzystaniu dwóch głównych cech i kategorii ich oceny, można po selekcjonować części na podatne i nie podatne na recykling.

1. INTRODUCTION

The final stage of the life cycle of the transport device is its liquidation. It based on the final disposal it by removing the device and its items from the company. Transport facilities as all other devices have their life cycle consisting of several stages. The most important step in the recyclability assessment is designing phase. According to the approach used in design phase depends, whether the facility will be able disposable or not. An important phase in the life cycle of facilities is the end of life. In this moment the most important question is, whether the facilities will be given to recycling or recovery processes or whether its proper parts will be reused.

Internal transport equipment [ITE] usually is withdrawn when its values reach a specific degree of wear. Wear is evaluated in terms of the impossibility of further use of the object (technical aspects), or its operation in terms of profitability (economic aspect). When the end of life facilities will start, the utilization problem of various tapes of waste arises. For instance, three different tapes of waste can be found:

- Disposed parts that are impossible to reuse.
- Parts which are suitable to reuse.
- Operational waste, including fluids from disposed object.

It should be remembered that withdrawal of facility should cause the least environmental problems [3]. The best solution in this area is the application of recycling, reuse or recovery, which also very often provide a positive economic effect of taken actions. The main objective of these processes is to reduce the negative environmental impact of waste, generated after the end of life facility. An important element is also declining amount of raw materials and the progressive overflow of landfilling. Another objective is the recovery of energy and obtaining the greatest number of parts and amount of materials that can be reused in the production process or for reuse as a spare part.

The best way to reduce waste in this area, is the re-using an individual elements of the object (if it is possible). However, in some cases, the re-use of parts is not cost effective or is associated with low quality of its operating characteristics. Re-use is not technically and economically justified in marginal cases due to the total wear of parts.

Therefore, effective application in this case has recycling. The high recycling level is feasible, if at the design stage included:

- construction characteristics of the device,
- ease of disassembly its components,
- replacement parts,
- or material composition was taken into account.

An approach that takes into account such action is called "Design for Recycling" [DFR]. Therefore, various devices are susceptible to recycling after the end of their life [5,6,10,11].

The issue of recyclability allows specifying the level of negative environmental impact, which has a technical object after its end of life. It also provides guidance for designers and constructors that allow evaluating the effectiveness DFR approach. At this point, a feedback is created, linking the beginning and end of product life cycle. Therefore, the problem of assessing and analyzing the recyclability of different groups of devices should be widely discussed.

In the case of MHE, there are regulations which partly indicate the direction of it designing in the context of recycling. This issue is covered partly in Machinery Directive [4]. It determines the possibility of giving the CE mark to a device, if the manufacturer in designing phase includes the need to prevent hazard to human health and safety, which may be caused by a technical facility throughout its life cycle. Unfortunately these regulations do not apply the negative environmental impact of technical facilities after its end of life.

This issue has been resolved in the vehicles cases by the so-called voluntary agreements. Which results in vehicle manufacturer’s collaboration, seeking to reduce operational waste and waste generated after the end of vehicle life [14]. That should be achieved, inter alia, through appropriate design of equipment, so that it would be susceptible to recycling, and until 2015 that its recycling will have been 100%.

In the case of internal transport equipment such directives do not exist. However, due to its common use in various industries, it can be determined that ITE quantity results in large amount of waste emerging after its EoL.

It should be pointed that several ITE have substantial structural similarity to the vehicles (for example forklift trucks). Due to the similarity of motor vehicle [MV] to ITH and taking into account the fact of diminishing natural resources and increasing the amount of waste, the ITH should be subjected to the same provisions of MV . Nowadays, about 85% of passenger vehicles are possible to recycling, despite the fact that their diversity of materials is very large. Fig. 1 depicts the proportions of the content of each material in the ordinary European passenger vehicle [8].

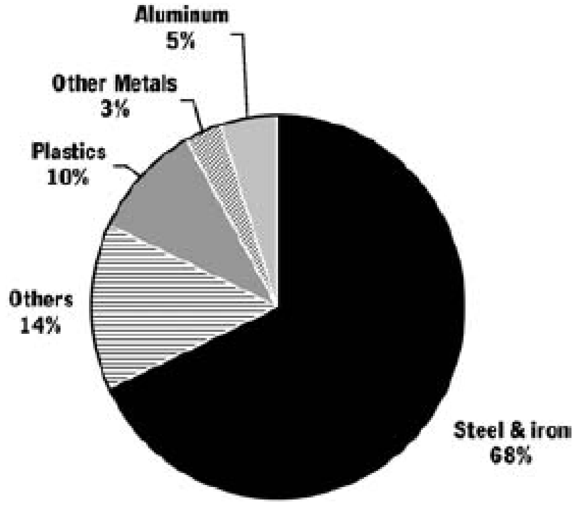

Fig. 1. The percentage of specific materials in ordinary European passenger vehicle
Rys. 1. Procentowy udział poszczególnych materiałów w przeciętnym europejskim samochodzie osobowym

Many similar studies about the material composition of vehicles and their impact on the environment were found in the literature [2,9]. Such information was not found in the context of the ITH. Taking into account the possibility of having large negative impact on the environment by ITH, its recyclability must be examined. Analysis of recyclability helps to draw conclusion and optimize the design stage in the ITH life cycle. Moreover it responds to the question if there is a possibility to recycle, reuse or recover the ITH after its completion

There are no considerations for ITH recycling system or determination impact of ITH on the environment in the literature. Therefore, there is a need to examine these objects in terms of recyclability. In the literature there are many studies of:

- vehicles recycling [5],
- electrical and electronic devices [13,1],
- and agricultural machinery [12].

In order to eliminate this gap, the recyclability assessment will be evaluated on the example of forklift truck.

2. METHOD OF RECYCLABILITY ASSESMENT

Recyclability is calculated as the weight of parts which are susceptible to recycling in relation to the total weight of the machine parts and presented in the literature [1,7,12]. Method is depicted in equation 1:

$$W_{rl} = \frac{\sum_{i=1}^{n} m_{ri}}{m} \times 100 \tag{1}$$

where:

W_{rl} – weight indicator of facilities recyclability [%];
m_{ri} – weight of parts susceptible to recycling [kg];
m – total weight of devices [kg].

The recyclability assessment was carried out based on example of forklift truck with:

- a combustion engine,
- a capacity of 1,5 tons,
- a “duplex” lift mast.

It is the most popular type of forklift trucks.

In order to calculate the forklift truck recyclability it is necessary to collect information about:

- components of forklift truck,
- how to dismantle the components,
- number of repeated components,
- weight of parts,
- material of which they are composed.

The basic components of forklift truck according to an order of its disassembly are:

- disassembly of starter battery,
- disassembly of LPG cylinders.
- draining systems including: hydraulic system, lubrication oil system of an engine and a gearbox, engine cooling system, braking system,
- disassembly of a counterweight,
- disassembly of the lift mast, including: forks, overhead and foot guard, load apron, lifting frame, lift chains, lifting cylinders, mast tilt cylinder, pressure pipes,
- disassembly a drive unit with accessories, including seats, engine cover, fuel system, engine wires equipment, hydraulic system, motor engine with gearbox,
- disassembly of braking system, including: steel wires, brake master cylinder,
- disassembly chassis (running gear), including wheels, braking system components integrated with the drive wheels, drive train's of driving wheels (axles), suspension and steering system,
- disassembly of elements such as: side covers, masking elements, elements of the dashboard,
- disassembly of an electrical installation,
- disassembly of other elements integrated with engine and suspension system.

In order to calculate recyclability the assessment of ease of disassembly and separation of materials (if necessary), and the degree of possibility that the material will be recycled, was prepared. The categories of possibility that material will be recycled are contained in Table 1.

Table 1

Categories of possibility that material will be recycled

Categories	1	2	3	4	5	6
	Part can be easily regenerated (single type of material)	Parts that can be recycled - there is infrastructure and technology that allows this type of process (low complexity of the material)	Recycling is technically feasible, but the infrastructure is not available	Recycling is technically feasible, the technology exists, but is complicated and often unprofitable	Parts is made from material suitable for energy recovery, but that cannot be recycled	Part is made from a material for which the technology of recycling is not exist

Categories 1-3 are considered to be susceptible for recycling.

In case of the ease of disassembly and separation of materials (if necessary), five categories can be found. The categories are shown in table 2.

Table 2

Categories of the ease of disassembly and separation on materials (if necessary)

Categories	1	2	3	4	5
	Components can be quickly and effortlessly removed by hand (no need to make the separation)	Components can be disassembled by hand, using light tools (low complexity, a simple separation process)	Components must be removed using manual disassembly and force, using light tools and requires partial manual or mechanical separation (or shredding of separate materials and parts)	Dismantling is carried out manually with the use of large equipment and requires mechanical separation or/and shredding of separate materials and parts	Components cannot be disassembled. There is no separation technology

Categories 1-3 are considered to be susceptible for recycling.

4. CONCLUSIONS

Taking into account the variety and widespread use of forklift trucks, it can be assumed that the forklift trucks have a significant market share in transportation equipment market. Therefore, there is a chance that their production, use and its end of life carry environmental risks.

In order to eliminate factors, which have negative influence on the environment after the completion of product life cycle, it is necessary to verify if the forklift trucks can be recycled and to what extent. Useful in this regard is the analysis of recyclability.

The calculations should take into account the liquid used in a forklift (ordinary forklift truck with duplex mast has about 45 liters of fluids - at one time) and the surface treatment of used materials. These two factors have a significant impact on the recyclability. To evaluate the recyclability, suggested characteristics and categories can be used. Based on this information, it can be assessed whether in the design phase, DFR approach was being applied and to what extent.

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