Agronomy Research **18**(S1), 923–930, 2020
https://doi.org/10.15159/AR.20.141

New approach for recycling spare parts, components and assemblies

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Abstract. Recycling and disposal are one of the most complicated topics in the lifecycle of a mechanism, especially in case of previous generations of machines that were designed without taking any care of post exploitation period. In the current work, the 'feasibility points' of recycling units, methods of recycling as well as pricing formation for recycling materials, reviewed and proposed by several world universities and scientific bureaus and applied by major world brands have been analysed. The general principles that should be rated as a basis when designing and creating new mechanisms, as well as the actions which we consider as a necessary supplement to the existing rules of the lifecycle of assemblies and which should be applied in practice, were introduced by authors in the 'Management of parts and components for units and assemblies in mechanical engineering industry and its impact on the environment'. It was discovered that even modern assemblies, not to mention previous generations, are being designed without taking into consideration any possibilities of easy recycling the used materials. The number of components of mechanisms, which are being repaired as assemblies, is continuously increasing, while maintainability and repairability of separate parts is decreasing. Taking into account the state of the art in the field, the new approach for promoting the reusing natural resources and decreasing the harmful effects of obsolete components of mechanisms on the environment is proposed.
Thus, using the fast-moving parts that in post operational period can be easily detailed by type of a material will ensure more efficient consumption of natural resources. Our research and developments significantly reduce the costs of recycling and these materials become competitive comparing to the new ones.
Taking into account the state of the art in the field, the new approach for promoting the reusing natural resources and decreasing the harmful effects of obsolete components of mechanisms on the environment is proposed.

Key words: management of parts and components, impact on the environment, parts recycling.

INTRODUCTION

Any modern manufacturer of mechanisms and components has the only goal – making profit. All designs and technological processes are subjected to the cost reduction of producing finished products.

Attention should be drawn to the fact that today none of the component manufacturers include into their technological process or take into consideration

recycling and disposal methodologies of their own products. Well-known methods for the development, production, operation and disposal of machine components are presented in the considerable amount of the scientific papers as well as in educational literature with the references to the current legislation, particularly in the European Union, for instance in (Duales System Holding, 2012; Driessen et al., 2015; Sanden et al., 2016; Schweitzer et al., 2017).

According to the traditional approach, the main accent is on the green manufacturing and maintenance of the products. Herewith, the utilization and reusing of the scrap are stated as a separate block of the Product life-cycle management (PLM) and considered only after a product is presented to the market. For instance, one of the well-known 3Rs ('reduce, reuse, recycle') – reuse – promoted by environmental agencies in many countries, covers a range of activities from informal product exchanges between acquaintances to industrial reuse of products and components (Cooper & Gutowski, 2015). However despite of efforts there is still minimal effect of the declared strategy to the reality. For example, European Commission statistics claim that currently in Europe 16 tonnes of materials per person per year are used and 6 tonnes of that becomes waste. Due to faulty waste management a significant amount of secondary raw materials, like metals, glass and plastics still get lost from the material stream (Karavida & Nommik, 2015).

On the other hand, in (Cooper & Gutowski, 2015) it is pointed out, that researches determine the theoretical maximum steel reuse rates for different product categories, none of which are above 30%. Moreover, the underlying assumption that reused products perfectly displace new items may often be incorrect. Threreby in the previous works of the authors, in particular, 'Management of parts and components for units and assemblies in mechanical engineering industry and its impact on the environment', the discussion about the necessity to introduce changes to the regulations and legislation that would force manufacturers to develop methods of recycling the used materials already during the design phase of the product was initiated.

A key thesis of the previous work (Mitrofanovs et al., 2019) was to introduce changes into the product life cycle by taking into account the influence of all factors on setting up the technical specifications for product design and implementing the ECO solutions being developed by authors (Fig. 1). On the Figure 1 the bright fields indicate the changes we bring into the already known pattern of the Product life-cycle. According to the proposed new approach, designers should include the reusing technology of the materials/components used in the project during the initial stages of the design. Implementation of the new model of the PLM (together with the actualization of the EU legislation), which provides the synergy between design and regeneration of the machine components, will reduce the utilization of the materials and increase it reusing.

Thus, the main point which could be changed is the 'Technical specification with new ECO solutions' (Fig. 1) contains the following elements (supported and regulated by the legislative framework, i.e. Ecological law):

- Technical requirement;
- Design and engineering;
- Economic evaluation;
- Production technology;
- Production engineering;
- Maintenance and repair equipment;

- Technology of recycling;
- Economic feasibility.

Each of the new points proposed, requires new methods of preliminary analysis and modelling, which are undoubtedly should be based on the practices of the available studies and researches in the world.

It is crucially important that the legislation (Ecological law) would indicate to the product manufacturers the processes which can reduce the negative impact of the Product life-cycle on the environment in general (Sanden et al., 2016).

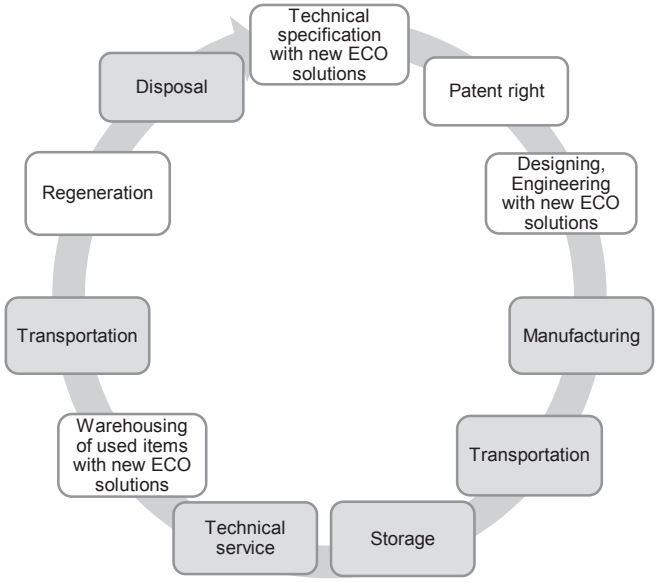

Figure 1. New vision of Product life-cycle.

Within further research authors consider possible scenarios for solving the tasks described above and possibilities of introducing these solutions into production, which would save logistics time, reduce inventory, deadstock, disposal of used and obsolete assembly units and components. The solution of each task will significantly reduce the consumption of natural resources, energy and negative impact of disposal on the environment.

However, our latest studies have shown that there are some more factors having influence on the result of the regeneration of the used materials and using recycled materials. As can be seen on the diagram of the production cost (Fig. 2), the basis is technological cost, which consists of raw materials, fuel and energy. All these components are independent of the manufacturer and their price is defined by exchange quotations and conditionally can be considered as Germanized for the region.

Unfortunately, it was revealed that manufacturers do not take into account the costs of recycling materials (see on the Fig. 3), so the manufacturer is not interested in the processes of sorting and regenerating used products. Currently, sorting and disposal of the components which life-cycle has been finished is carried out by specialized companies focused on this or that type of processing materials (Grafov, 2011). The full cost of the secondary raw materials is shown on the Fig. 3.

The more complex and accordingly more expensive way of used materials till processable secondary raw materials we have, the less expedient is the detailed processing of the used materials (Fig. 2). The feasibility of the entire technological process of material regeneration is in the interval between the sorting of the recycling materials and the exchange prices of the secondary raw materials.

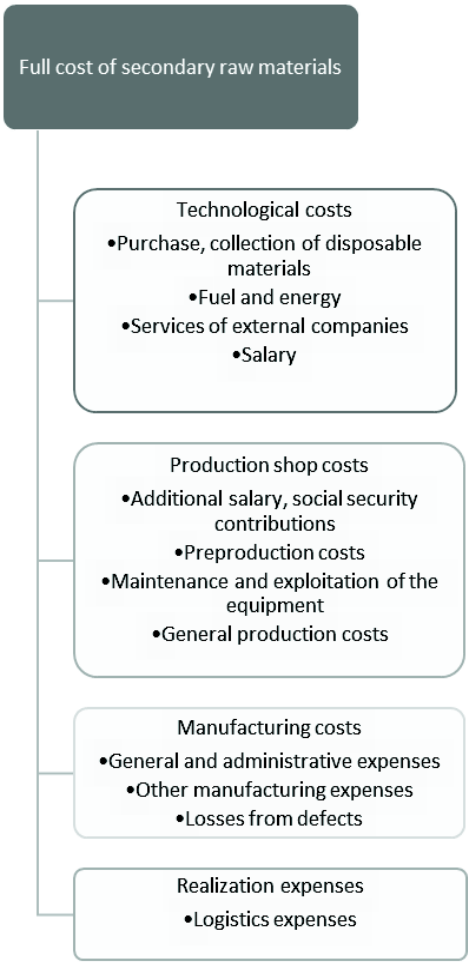

Figure 2. Diagram of the production cost.

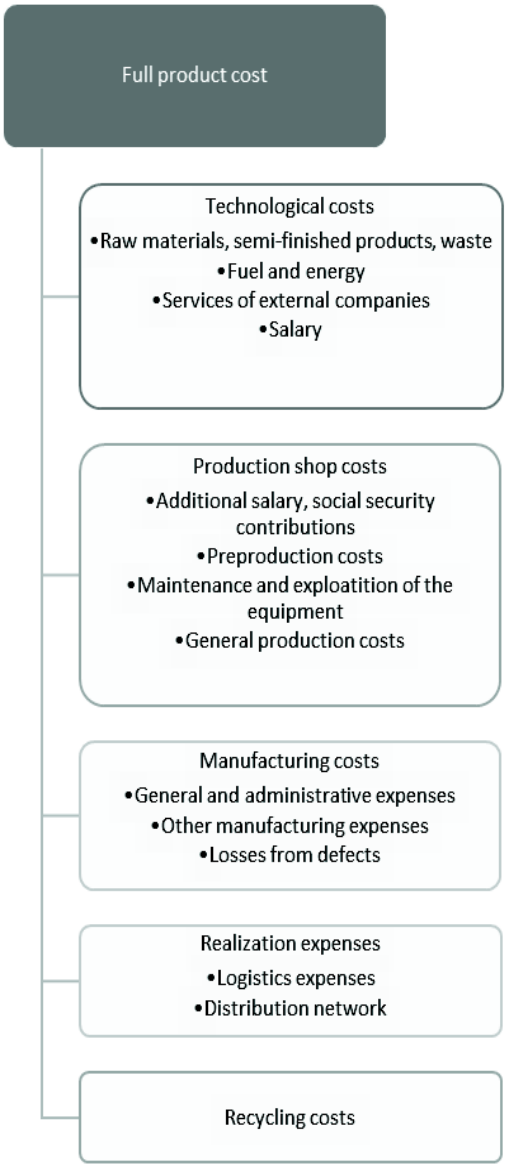

Figure 3. Diagram of full cost of the secondary raw materials.

In mass production, recyclers of the secondary raw materials cannot be 100% sure of the chemical composition of the materials, which implies a wider range of chemical composition tolerance, so as a result these products made of these materials can be only used for less critical structures.

Studies done by M. Orzolek (Orzolek, 2019), as well as studies of Recycling Research Institute (Recycling Research Institute, 2019) and others (Watkins & McAleer, 2004), show that the more complex the combination of composite materials, the less economic feasibility of recycling them (Fig. 4).

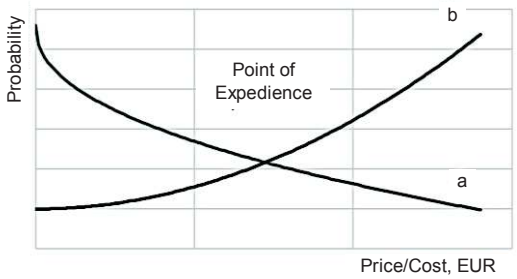

Figure 4. Probability of recycling: (a) price of recycled material and (b) cost of recycling the complexity of the material.

As a rule, complex materials are being cut into pieces and disposed in the ground or burned in furnaces. It might sound shocking, but in some countries, where environmental law does not apply, the burning of waste materials occurs in an open way (Fig. 5). According to the research of Recycling Research Institute only 7% of tires are being recycled and new products are being produced from the obtained materials.

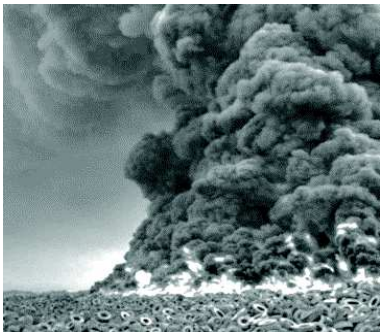

Figure 5. Burning tires.

Figure 6. Cars rest is grinding without dismantling.

In authors' opinion it is extremely important that the materials of quick wear assemblies, within reasonable limits, would be regulated by the legislative framework, and the manufacturer, already at the time of construction, would develop and provide the public with methods of maintainability, dismantling and recycling. The aim of this work is to develop a new approach for promoting the reusing natural resources and decreasing the harmful effects of obsolete components of mechanisms on the environment.

According to the Grüne Punkt the actual amount of recyclable materials from automotive industry is only 10%, while the rest is grinding without dismantling and disposal (Squintani, 2013). Avrashkov L.Y. also points out this problem in his works (Fig. 6) (Avrashkov, 2015).

NEW APPROACH

In fact, manufacturers of assemblies can regulate several factors that make their recycling cheaper:

Ease of the dismantling of the assembly.

2. Standardization of the used materials.

3. Standardization of the collection of the used assemblies.

Acceptable correction in the country of the cost of raw materials, fuel and energy is possible only on the part of the government, which is able to provide subsidies for production, introduce tax preferences, introduce or cancel excise taxes (Fig. 7).

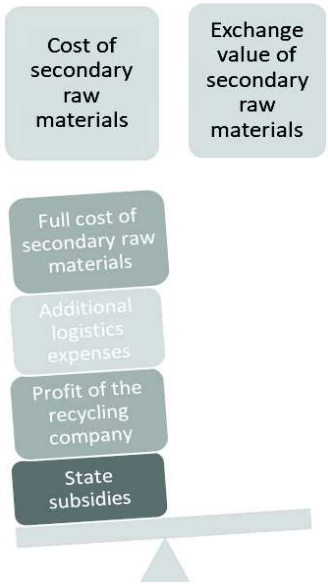

Figure 7. Prices model of secondary materials.

In countries with high labour costs and high excise taxes on energy, materials processing is extremely expensive. Therefore, in most cases, the entire technological cycle of processing is limited to the collection and optimization of the volume of worn assemblies. 'Raw materials' are sold, or sometimes delivered to countries with costs for low energy-intensive production, or to countries with 'sparing' environmental laws that allow waste to be disposed without separation and without environmental standards.

RESULTS AND DISCUSSION

Taking into account the state of the art in the field, the new approach for promoting the reusing natural resources and decreasing the harmful effects of obsolete components of mechanisms on the environment is proposed. Thus, using the fast-moving parts, that in post operational period can be easily detailed by type of a material, will ensure more efficient consumption of natural resources. Research and developments done significantly reduce the costs of recycling and these materials become competitive comparing to the new ones.

It is necessary to change environmental legislation and, as we consider, to supplement the previously proposed Technical specification with new ECO solutions with the new points:

1. At the phase of product design, the manufacturer must propose a regeneration methodology.

2. The manufacturer must agree with the regenerating organizations on the labelling of the assemblies in order to ensure easy sorting of the used materials.

3. The manufacturer must agree on the methodology for collecting waste materials and assemblies with utilizing organizations.

4. In the development of new assemblies, the manufacturer is obliged to develop a methodology for producing easily dismantlable assemblies, while ensuring the ability to sort materials by their type.

5. The manufacturer is obliged to use environmental standards for fast moving parts.

Including of the mentioned points will significantly reduce production costs for storage, disassembly and sorting. This will increase the level of identification of recycled material.

As a result, it will significantly reduce the cost of secondary raw materials and increase its quality (Fig. 8), which in turn will become attractive from an economic point of view for use in new products, reduce the burden on the use of new materials and will significantly affect the environmental situation in general.

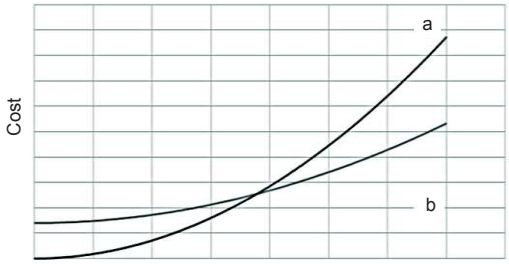

Figure 8. The complexity of the material: a) cost of new material; b) cost of recycled material.

CONCLUSIONS

The new approach for recycling spare parts, components, and assemblies, which is a substantial part of a new vision for Product Life-Cycle management (PLM) is proposed. The necessity to promote the new vision for PLM is the fact, that the number of components of mechanisms, which are being repaired as assemblies, is continuously increasing, while maintainability and repairability of separate parts is decreasing.

According to the proposed new approach, designers should include the reusing technology of the materials/components used in the project during the initial stages of the design. Thus, using the fast-moving parts, that in post operational period can be easily detailed by type of a material, will ensure more efficient consumption of natural resources. Implementation of the new model of the PLM (together with the actualization of the EU legislation) significantly reduce the costs of recycling and these materials become competitive comparing to the new ones.

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