Circular Economy in Industrial Bearing Production

LIMBĂŞAN Ileana Georgiana
Transilvania University of Brasov, Romania, limbasan.g@unitbv.ro

Abstract
Circular economy is a new form of approach to the development of productive economic processes, arising from the aggressive resource consumption. The traditional approach for products in the field of environmental protection targets pollution prevention and waste management. These strategies aim only at preventing or minimizing the potential environmental impact, without considering the product design. Eco-design addresses the first stage in the product life-cycle, namely the stage of development. The new concept aims at eliminating the environmental impact from both product and manufacturing process. This paper presents the concept of circular economy, as well as the situation of the application of the circular economic model in the bearing companies with business units in Romania. Moreover, it intends to justify the need to pass to the circular model in the industrial bearing production, presenting the results obtained with respect to the consumption of resources, implicitly the emissions of substances detrimental to the environment (CO_2 emissions) with a view to manufacturing and assembling bearings as products. The instrument used for this purpose was the Life-Cycle Inventory Analysis.

Keywords
Circular economy, bearing, LCIA

1. Introduction

Circular economy emerged as a response to and a prevention measure against the resource waste, and it is a concept which refers to the possibility of designing and manufacturing products with zero waste. Whereas the linear economic model involves succession: raw-materials extraction – product processing / manufacture– use – waste disposal, the circular model (Figure 1) requires that even from the design stage, all product components be biodegradable or have 100% recycling potential [1]. Recycling is the stage which can link the beginning to the end of the process, by reintegrating the materials in the production processes. In this manner, the approach becomes advantageous for the economy, by minimizing the consumption of natural resources, by optimizing costs, and by developing business opportunities.

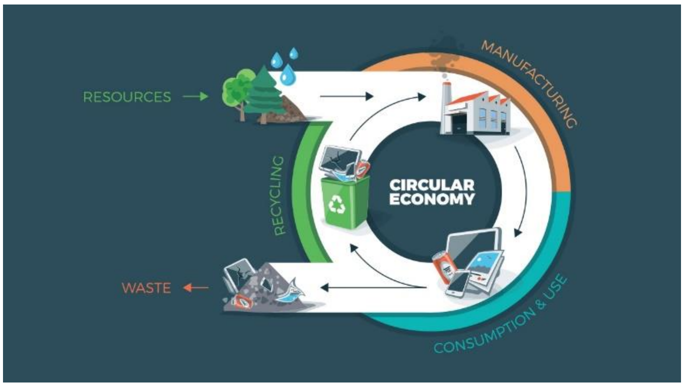

Fig. 1. Concept of circular economy (Source: [2])

Simply said, the goods manufacturing companies should rethink their economic development strategies, by designing and developing structures that favour the reuse, repair, reconditioning and recycling of the existing materials and products.

Basically, the adoption of the eco-design by the goods production companies will allow embedding circularity into the products from their first stages of existence. The conditions are thereby created for achieving efficiency in terms of the use of resources, low carbon emissions, as well as a better waste management, when the products reach the end of their effective exploitation period [2].

2. The Current Stage of Applying the Circular Economic Model in the Bearings Manufacturing Companies with Business Units in Romania

Currently, the companies in the industrial field, and especially the bearing manufacturing companies with business units in Romania, are at an early stage of the transition to the circular model. In the bearing industry, the passage to the circular model might involve a concern for: reducing the consumption of raw and other materials; using more efficient machinery, equipment (low energy consumption), assimilating more efficient technologies with a lower impact on the environment, or generalizing the interest in the repair of bearings.

In terms of the concerns for the reconditioning or repair of bearings – as a prerequisite for the transition to the circular model, there are few companies oriented towards such processes. Most of them offer services such as: computer calculations and simulations, information on how to choose among the types of bearings, and technical support for the maintenance of manufactured products: assembly / disassembly, lubrication, aligning) [3].

The situation presented below proves this aspect.

Rulmenti SA Barlad (held with 90.7 % of its capital by the Turkish holding Kombassan) produces a wide range of bearings (roller bearings, ball bearings) in over 13000 constructive variants, under the brand URB. The subsidiary Compas SRL provides reconditioning services for large-size or special bearings: radial-axial bearings, with cross-shaped conical rollers, used for boring-and-turning mills, and special bearings, with internal/external gearing, used for civil-engineering equipment [4].

Schaeffler Romania develops and manufactures various types of bearings and other types of industrial products, under the product brands INA, FAG and LuK, catalogue products manufactured in series and destined for the approximately 60 industrial branches, as well as for other automotive applications. The company has in Germany a specialized department for reconditioning bearings with internal gearing larger than 500 mm, the costs of reconditioning being by 30% - 40% lower than the costs of manufacturing a new bearing [5].

Timken Romania is another important competitor on the market of large-size bearings, components and accessories, rolled rings, being a leader in the field of conical-roller bearings manufacture. The range of offered industrial services includes the repair/ reconditioning of bearings (the internal diameter between 12 inches and 18 inches, for bearings from their own catalogue) and over 500 mm internal diameter, for bearings from different types of industries, manufactured by other companies, in particular for the aeronautical industry. The information provided by the company implies that the time spent on inspecting the bearing is five days, whereas the reconditioning lasts 15 days [6].

The experts in bearing design and maintenance claim that repairing/reconditioning bearings is an effective way of prolonging their sustainability, in heavy industrial applications. It is stated that less than 10% of the used bearings reach L10 designed nominal durability. Furthermore, it is stated that a repaired bearing can perform its functions with the same technical performance as before the repair [7]. In this context, the advantages of bearings reconditioning are:

- Prolonging the life time of the bearing (by redesigning its component parts, the progress in the development of new materials) [7];
- Reducing the maintenance costs [8];
- Repair time approximatively 1/3 of the manufacturing-cycle duration for a new bearing [7];
- Cost of repair /reconditioning up to 60% lower than the manufacturing cost for a new bearing [7];
- Reduction up to 90% of the energy consumption necessary for manufacturing a new one [9].

The types of repairs that may be performed on the bearing components are different. The decision to resort to one thereof is based on a thorough analysis of the bearing by the experts, and mainly refers to the eligibility of the bearing to be repaired or not.

The term of repair is generically used, and it may cover any type of operation performed on the bearing components, depending on the type of damage or fault. In practice, there is about recertification, reconditioning, remanufacturing [7]:

- Recertification refers to the process of certifying a bearing for operation, when the product has not been used for a longer period of time. The specific activities to the recertification process are: cleaning, examining, verifying internal games, preserving, and packaging;

- Rectification supposes grinding the surfaces of the bearing elements, resorting to a process of vibrating grinder. Recertification and rectification are operations which, according to experts [9], define the repairs of Type I - low complexity level;
- Reconditioning supposes operations of polishing, buffing, honing or drum cleaning of the bearing components, with a view to removing the traces of rust or corrosion, on order to prevent more serious damage to the surfaces. These are repairs of Type II - medium complexity level [9];
- Remanufacturing is applied to bearings with major surface damage of the bearing components. It supposes rectification operations of the bearing races, or, if the repair is not economically efficient, one may replace the rollers, the cage components, or even the rings. Remanufacturing falls under the category of the operations with a high level of complexity, Type III, according to experts [9].

3. Need to Pass to the Circular Economy in Industrial Bearing Production

The traditional approach for products in the field of environmental protection targets pollution prevention and waste management. These strategies aim only at preventing or minimizing the potential environmental impact, without considering the product design. Eco-design addresses the first stage of the lifecycle, namely the development stage of the product. The new concept aims at eliminating the environmental impact from the product and from the manufacturing process. Although the design is a "clean" process in itself, this is the stage which determines most environmental impact elements of the product. Once the design ended, and the manufacturing technologies established, a very little margin of manoeuvre remains, so as to increase the efficiency of the processes and to minimize their emissions. Moreover, the most advanced recycling technologies should comply with the requirements defined in the design phase. The eco-design can contribute to the prevention of waste generation, yet it is not limited to this aspect, in as much as it aims at preventing other environmental impacts: reduction of the energy consumption, of the air and water pollution.

One of the decisively important tools for elaborating an eco-design strategy is the Analysis of the Life Cycle Inventory (LCI). According to the recommendations [10] the analysis can take place at all stages of the lifecycle, starting with conception-design, and ending with the transformation of the product in waste. For each phase of the life cycle, the input and output flows are identified, the sources of impact are identified, the impact of these flows on the environment to be subsequently evaluated. The evaluation is made according to all forms of impact: in terms of resource use and pollution [10, 11]. According to [10], the inventory refers to the synthetic situation of the consumptions of materials, energy and emissions, necessary and generated throughout the lifetime of the product. LCI supposes collecting and analysing the input/output data referring to the system under study, but it does not also involve assessing the environmental impacts associated to the collected data, that is the interpretation of the obtained results cannot be the basis for obtaining the conclusions about the corresponding environmental impacts.

In this context, the results obtained from the use of the Life-Cycle Inventory Analysis (LCIA) within a case study for the product conical-roller bearing (ID = 431.8 mm) are presented below [11].

The objective of the study was to identify those components which have the largest share of resource consumption, of waste and emission generation, these aspects showing the interaction of the product with the environment, and the orientation of the designers' activity so as to allow the further improvement of the product by redesign (for some component parts) or the reconditioning of the product.

The bearing under consideration belongs to the two-row conical-roller bearing group, with the components: inner ring, outer rings, outer spacer ring, two semi-cages and 78 conical rollers. The outer diameter of the bearing is 571.5 mm, the inner diameter is 431.8 mm, and the width is 133.35 mm. The entire bearing (except the cage which is acquired as a finished component), is made of steel and weighs 89.2 kg.

In order to make the LCIA, only the stages corresponding to the processing carried out in the company, afferent to the bearing components (Figure 2) were taken into account. All product components are acquired in the semi-finished stage, being subsequently processed up to the stage of finished components.

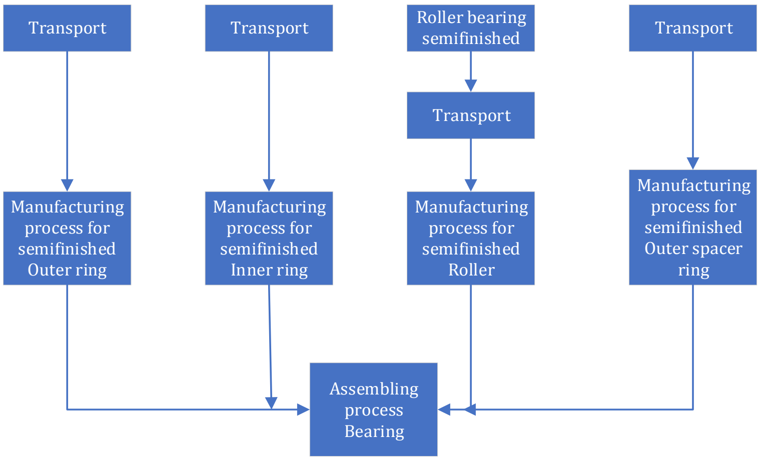

Fig. 2. Flow chart of the life cycle for the product under study

For each product component, flow charts were made in which the inputs (energy, water, compressed air, other substances necessary to the processing) and outputs (recoverable/irrecoverable waste) were identified. Figure 3 shows the charts afferent to the processing for the rings and roller.

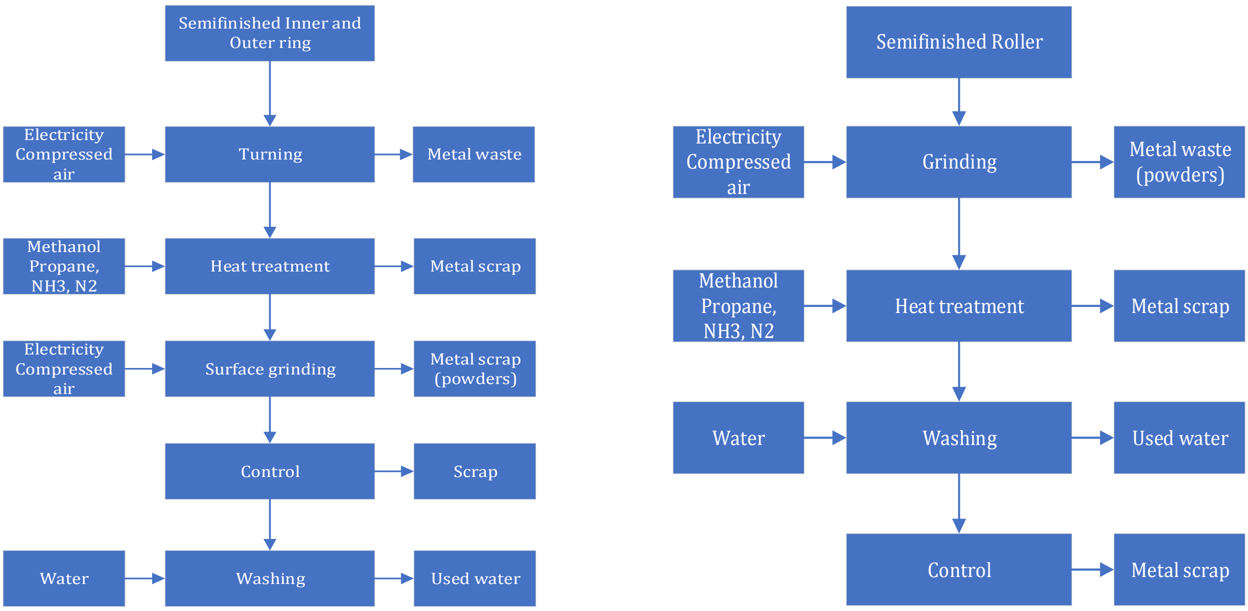

Fig. 3. Flowchart of the manufacturing process for inner/outer ring and roller of bearing

In the case study, the situation of the resource consumption (inputs in the processing afferent to each component and to the assembling), of the waste generation (outputs from the processing afferent to each component and to the assembling) and of the air emissions (CO_2 emissions), for the product under consideration was highlighted. The graphs below illustrate the situation of the electricity consumption (Figure 4a) and CO_2 emissions (Figure 4b).

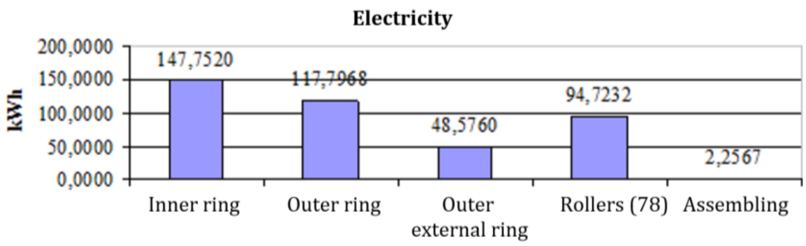

Fig. 4a. Global situation of the electricity consumption for manufacturing and assembling the product

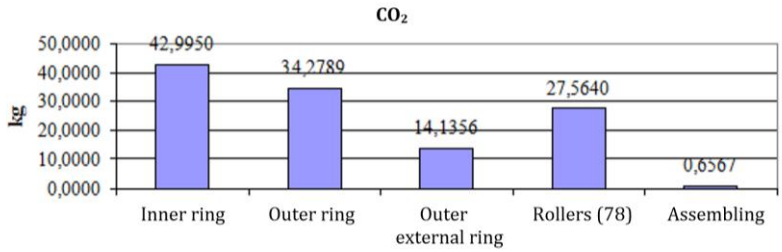

Fig. 4b. Quantity of CO_2 emitted in the air

The environmental balance afferent to the product under consideration (Table 1) resulted from the study [11] reflects all non – elementary inputs, emissions to air and outputs as waste for the processes afferent to bearing components and assembling process. In PhD thesis [11] the results of the Life-Cycle Inventory, by categories inputs/outputs, are presented in detail.

Table 1. Environmental balance for the studied product

Inventory results	Substance	Total	Unit of measure
Non-elementary inputs	ELECTRICITY	411.105	kWh
	METHANOL (CH_3OH)	3.434	kg
	PROPANE (C_3H_9)	0.2121	kg
	AMMONIA (NH_3)	0.0162	kg
	AZOTE (N_2)	0.0263	m^3
	COMPRESSED AIR	325.39	m^3
	METHANE GAS	24.644	m^3
Non-elementary outputs	METAL WASTE (TURNINGS)	99.55	kg
	METAL WASTE (SCRAP)	4.08	kg
	POWDERS	5.373	kg
	WASTE EMULSIONS	1.616	kg
Emissions to air	CO_2	119.63	kg

The Life-Cycle Inventory for the studied bearing led to the following results:
- for the inner ring component, the highest consumption of resources (electricity, propane, methanol, ammonia, azote, compressed air), resulting from the mechanical processing by cutting and heat treatment was recorded;
- for the outer ring component, the highest consumption of methane gas, necessary for the heat treatment, was recorded;
- for the inner ring component, the largest quantity of waste emulsions, metal waste as turnings, powders, resulted from the mechanical processing, was recorded;
- for the roller component, the largest quantity of metallic waste as scrap was recorded, due to the fact that the functional unit considered is the total of 78 rollers which are part of a finished product;
- for the outer ring component, the highest quantity of CO_2 emitted in the air was recorded, coming from the fact that the electricity used within the processing results from non-renewable processes.

The analysis of the environmental balance achieved within this case study shows that, out of all components of the studied product, the rings (inner, outer) hold the largest share in terms of resource consumption, implicitly emissions of substances which affect the environment (CO_2 emissions). These consumptions are mainly due to the necessity to perform the precise mechanical-processing operations and the heat treatment, processes which ensure the durability and dimensional-constructive precision of the product.

4. Conclusions

The analysis of the Life-Cycle Inventory (component part of the Life-Cycle Evaluation) allows establishing a baseline of the environmental performance for a certain product, by quantifying the use of the flows of raw materials, energy, emissions to air, water and soil, associated to that system, for all processes afferent to achieving the product (throughout its life cycle).

Due to this kind of analysis, the company can make the best choices at the product design stage, with a view to minimizing the impacts of the product on the environment. Each design option supposes certain potential impacts; their comparison helps the decision-maker choose the optimal solution, avoiding the transfer of environmental impacts from one stage to another of the lifecycle.

In this context, integrating the Product Life-Cycle Assessment into the actions specific to the design and redesign of industrial products is a prerequisite for the transition to the circular economy of the manufacturing companies.

References

1. www.ecotic.ro/welcome-change/economie-circulara//. Accessed: 2017-05-22
2. http://environ.ro/index.php/ro/economie-circulara/. Accessed: 2017-05-22
3. www.schaeffler.ro/content.schaeffler.ro/ro//. Accessed: 2017-05-21
4. www.rulmenti-compas.ro/. Accessed: 2017-05-21
5. www.rulmentigermania.ro/servicii/reconditionare-rulmenti. Accessed: 2017-05-21
6. www.timken.com/ro/products/servicii-industriale/. Accessed: 2017-05-21
7. Jay, A. (2016): *Repararea rulmenţilor oferă o alternative economică la înlocuirea acestora, în industria grea (I)* (*Bearings repair provides an economic alternative to replacing them, in heavy industry (I)*). Available at: http://www.ttonline.ro/sectiuni/transmisii-mecanice/articole/13533-repararea-rulmentilor-ofera-o-alternativa-economica-la-inlocuirea-acestora-i. Accessed: 2017-06-10 (in Romanian)
8. http://rulexim.ro/servicii/reconditionari-si-reparatii-rulmenti. Accessed: 2017-05-21
9. Jay, A. (2016): *Repararea rulmenţilor oferă o alternativă economică la înlocuirea acestora, în industria grea (II)* (*Bearings repair provides an economic alternative to replacing them, in heavy industry (II)*). Available at: http://www.ttonline.ro/sectiuni/transmisii-mecanice/articole/13629-repararea-rulmentilor-ofera-o-alternativa-economica-la-inlocuirea-acestora-i. Accessed: 2017-06-10 (in Romanian)
10. ISO 14041 (1998): *Manangement de mediu – Analiza Ciclului de Viaţă – Definirea scopului, domeniului de aplicare şi analiza de inventor* (*Environment management – Life Cycle Analyses – Definition of purpose and inventory analyses*). (in Romanian)
11. Geroşanu (Limbăşan), I.G. (2011): *Studii şi cercetări de analiza valorii asupra unor grupe de produse din industria de rulmenţi* (*Value analyses studies and research on some product groups in the bearings industry*). PhD thesis. Transilvania University of Brasov, Romania (in Romanian)

Received in October 2017