LOGISTICS WITHIN ECO-DESIGN OF PRODUCTS - SELECTED ISSUES AND CASE STUDY

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Abstract

Logistics is now becoming the key factor of competitiveness for many enterprises. It does not only result from economic reasons but is also the effect of stricter environmental protection requirements. The requirements are increasing with advancements in the development of tools that enable assessment of the environmental impact of products in their full life cycle. This involves the manufacturer's greater environment-wise responsibility for the product in the entire supply chain, which makes it necessary to consider solutions that will lessen the environmental impact at the earliest possible stages of the product design. A constant need arises to support enterprises in eco-design and to conduct research in this field to improve the eco-design methodological and organizational aspects. This paper discusses selected issues and challenges of the logistics process eco-design. In order to put a more practical perspective on the problems under consideration, it also presents a case study of eco-design towards logistics processes optimization using the SimaPro - a tool that assists in the product life cycle assessment. An environmental analysis of three eco-design variants is presented with a comparison of solutions applied to the assembly and disassembly of the turbine stator blades.

Keywords: Eco-design, logistics process, turbine blades, life cycle assessment, environmental analysis

1. INTRODUCTION

The product design is usually created as a result of research and development activities of the manufacturer having appropriate knowledge and specific production potential. However, the knowledge turns out to be insufficient if eco-design is to take account of parameters concerning environmental functions and aspects which are essential from the point of view of suppliers, carriers, customers, retail dealers, waste management enterprises and those involved in the final phase of the product life cycle (the supply chain perspective). Therefore, eco-design assumes such supply chain management that enables effective communication and co-operation between partners in terms of the flow of environmental information, specification and discussion of environmental requirement (e.g. using the supplier's standards or environmental measurement systems), assessment of the suppliers' environmental activity, product re-design based on the customers' environmental preferences, establishment of programmes concerning the recycling of packaging, materials or the product as such, as well as the suppliers' involvement in environmental projects [1]. The importance of these actions increases due to the need to analyse environmental aspects at the earliest possible stages of the product eco-design and development. If done at later stages, inclusion of environmental aspects in the analysis may turn out to be impossible because of prior decisions of technical nature. The outline of problems related to the inclusion of environmental issues in the logistics process design presented herein is enriched with a case study revealing the impact of key decisions made at the design stage on the product assembly and disassembly being under the user's control.

2. ECO-DESIGN OF LOGISTICS PROCESSES - OUTLINE OF PROBLEM

The logistics process requires that the distribution, state and flows of its components, i.e. people, material goods, information and financial means, should be co-ordinated with other processes with respect to the criteria of location, time, costs and efficiency of satisfying desired objectives of the organization [2]. One of the examples of the logistics flow multidimensionality is the environmental impact [3], which depends, *inter alia*, on the kind and amount of used resources and emitted pollution. It is worth noting the comprehensiveness of this impact in the holistic approach to the product life cycle reflected in the logistic supply chain. Due to changes in the customers' purchasing habits and expectations, the supply chain has been expanded in recent years. More and more often now it is a logistics network. The logistics network concept assumes the use of the partners' complementary capabilities not only to reduce transactional costs substantially and adapt to changes occurring in the environment quickly but also to create new technical standards and develop shared technologies [4]. This seems to be a chance for enterprises using eco-design as a tool that enables integration of environmental objectives at the product life cycle individual stages represented by the individual partners in the logistics network (**Figure 1**).

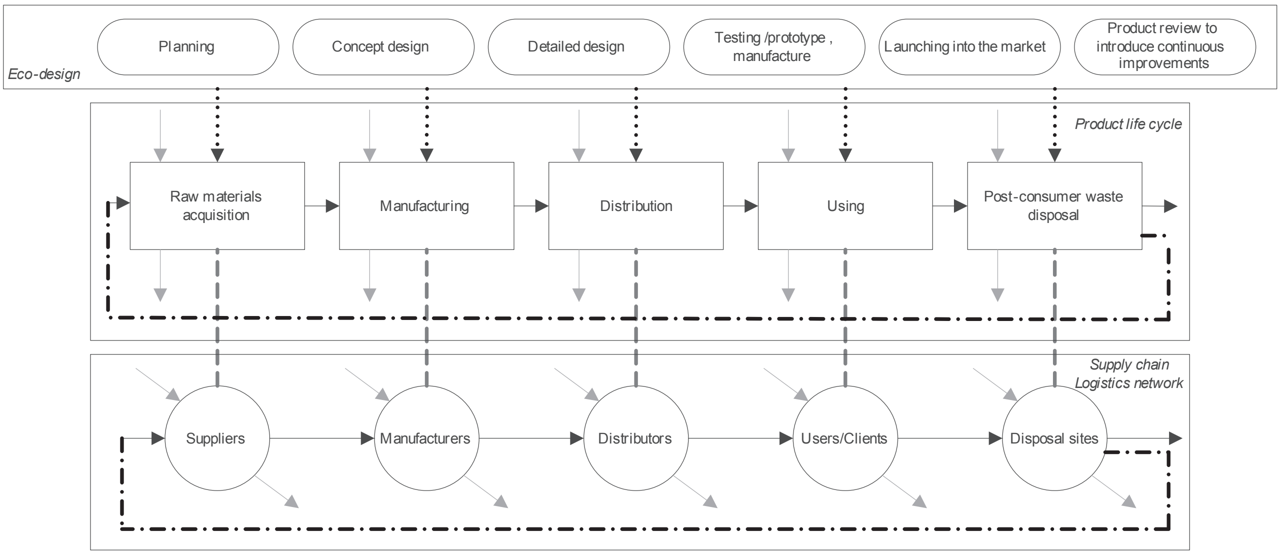

Figure 1 Eco-design in the supply chain perspective

On the one hand, partners in the supply chain or in the logistics network (suppliers, manufacturers, consumers, logistic operators and third parties) are responsible for a certain part of the product environmental impact [3]. On the other, however, achieving a product with the smallest possible environmental impact in the entire life cycle requires synergistic actions taken as early as at the design stage. Owing to the development and implementation of environmentally friendly solutions based on synergistic actions in the supply chain, it is possible to improve environmental parameters in relation to the entire product system, and even to develop and implement eco-innovations [5].

It is not only that early inclusion of environmental aspects in the logistics process design provides a wider range of possible optimal solutions. In fact, it often conditions them. The solutions are the effect of design variants developed with respect to numerous criteria applied in the traditional design concept (such as operating properties, quality, costs, etc.) and additionally taking account of environmental criteria, including those related to the wide range of potential environmental impacts. Competitiveness, implied by the product functionality at different stages of its life cycle, has to be ensured as well. Eco-design also requires a search for compromise solutions within the environmental, technical, economic, societal, qualitative and other aspects under consideration [1]. Section 3 below gives consideration to challenges arising due to the application of these principles in the logistics process eco-design.

3. CHALLENGES OF THE LOGISTICS PROCESS ECO-DESIGN

The complexity of issues related to the eco-design of logistics processes involves the need to face the challenges in the subjective, objective and process dimension.

The eco-design subjects are users and designers [6]. The task of the designer taking account of the logistics process specific parameters is to identify the real needs of users, one of whom will often be the hypothetical user performing the function of the direct user [6]. It should also be remembered that design solutions do not only affect the direct user. They also have an impact on persons whose needs are often opposite, which is of special importance in the case of environmental aspects. For example, if a certain design solution involves polluting the atmosphere, health problems may arise for its other “indirect users”. Thus, the design objectives can be many and they may be perceived differently by different users. In the case of the design of logistics processes it may be necessary to apply participatory design, which assumes direct participation of all users in the design decision-making process [6]. A challenge that has to be faced in this context is the complexity of actions and decisions to be taken and made by the designer. This stands in contrast to the situation when a product is designed without taking account of logistic parameters that are beyond the manufacturer's control. Moreover, due to the present state of the art in the field of the product life cycle environmental impact, decisions made in eco-design are largely intuitive. In many cases designers do not have sufficient knowledge or experience needed to make the product meet environmental requirements at every stage of the product life cycle. It should also be noted that the designers' responsibility for the final effect is now greater - it comprises not only the gate-to-gate analysis but also the wider cradle-to-grave perspective. Another important problem which is often ignored is the designers' position in the structure of the division of labour, especially in the case of designing complex logistics systems that require co-operation along the supply chain links. The challenge in this context is communication between partners in the logistics chain or network and in the team of designers.

The degree of the object design complexity is the premise for the application of systemic modelling in the logistics process design [6]. In it, an analysis can be conducted of the system elements, of the relations between separate systems and of the system-environment relationships. A systematic approach to logistics processes, such as transport, storage, packaging and reverse logistics processes, makes it possible to take account of the entire range of environmental impacts resulting from emissions of pollutants into the atmosphere, water and soil, from fuel, water and electricity consumption and from waste generation and management. The added value produced in the eco-design process is in this case the expansion of the design object by inter-system and system-environment relationships. An analysis of such a wide range of issues related to the object of design, with the multivariance of the solution concepts, is the challenge in eco-design of logistics processes, especially in the context of the need to find compromise solutions including actions taken to improve material and energy efficiency, economic use of land, cleaner production and use, durability of the product, optimized functionality, reuse, recovery and recycling of waste and elimination of hazardous substances and materials [1]. The selection of the design approach / approaches determines the environmental advantages gained throughout the product life cycle.

The main challenge of the eco-design process successful completion is the eco-design paradox, according to which the opportunity to improve a product in terms of its environmental impact decreases as eco-design proceeds. The course of the eco-design process is a function of the enterprise individual approach, within which patterns can be adopted from developed models of the inclusion of environmental aspects in the product design and development. However, it also depends on the complexity of the eco-design tasks. The technical report ISO/TR 14062 includes a general model of the inclusion of environmental aspects in the product design and development process. The model is composed of typical stages of the process of the product design and development - planning, concept design, detailed design, testing / prototype, manufacture, launching into the market and the product review to introduce continuous improvements [1]. In the context of the logistics process eco-design, it should be stated that a possible alternative to sequential design is concurrent engineering. An essential feature of concurrent engineering is team work and simultaneous realization of individual stages of the design process. Concurrent engineering contributes to taking account of later stages of the product development at a possibly early design stage, which is especially valuable in the design of logistics processes. At the same time, however, it is also a great challenge of the eco-design process organization. The effect of the need to focus primarily on specific aspects of products and on the processes taking place in the product design is that the following concept is distinguished in concurrent engineering: the Design for X (Design for Excellence) [7], including for example the design for assembly, the design for disassembly or the design for recyclability - i.e. the approaches directly or indirectly related to logistics processes. The challenges arising from the design process computerization are also worth mentioning. The most important impact in recent years on the design process, and on the activities of designers, has come from computer-based data processing [8]. Computer-aided design (CAD) affects not only the design method, but also the organizational structure, the division of labour and the creativity of individual designers. Moreover, employees performing new functions (e.g. system managers, CAD specialists) get involved in the design process [8]. Consequently, many design tasks are performed using CAD tools, which is also important in the inclusion of environmental aspects in the design process [9]. Eco-design additionally makes use of tools dedicated to the analysis of environmental aspects. Methods, techniques and tools useful in the eco-design process can be divided into: (1) methods and techniques intended specifically for the environmental impact assessment, (2) methods and techniques dedicated to the assessment of eco-design options, the fulfilment the eco-design criteria and comparison of alternative variants and products and (3) software tools supporting the environmental impact assessment and eco-design, as well as tools broadly used in the design process, containing modules which enable to take the environmental aspects into account (e.g. SimaPro) [10]. The difficulty in the application of eco-design assistant tools lies not only in the selection of an appropriate tool from a large number of options but also in the fact that the tools do not have a universal character and specialist expertise is needed to use them. Another problem is that eco-design assistant tools, as instruments intended for a qualitative and quantitative assessment of environmental impacts, are not integrated with tools assisting in design in other areas (e.g. technical, qualitative, safety-related, ergonomic, etc.). Another challenge is the limited access to data gathered on the supply chain individual links. At the same time, it is possible to use databases containing a rich body of data related to logistics processes such as transport, packaging or waste recycling.

4. CASE STUDY

This paper presents an environmental analysis of selected variants of eco-design of the steam turbine stator blades in relation to an eco-design task performed within the design for assembly and the design for disassembly. Selecting the constructive variant within the eco-design affects the processes of assembly and disassembly, including the logistics processes and the related environmental issues. This impact is related, for example, to the transport conditions (taking into account protection of the blades from possible damage), the consumption of energy and materials and the production of waste concerning the packaging process, as well as the energy consumption concerning the logistics operations carried out under the turbine renovation and reverse logistics.

Additionally, adopting the perspective of the user (i.e. of the power plant), important parameters of the assembly and disassembly of blades are the ease of the operations and the time needed to perform them. These two parameters determine the undesirable downtime of turbines, which is eliminated or minimized. Therefore, the analysis of these aspects of the blade life cycle is conducted using many criteria. Consideration of different variants of the blade design offers the chance to select the best solution satisfying both the manufacturer and the other stakeholders in the supply chain.

The analysis of environmental parameters was conducted for three variants of the stator blades:

- B1 - blades with spacers made separately,
- B2 - blades with integrated spacers,
- B3 - blades mounted on the stator ring.

A typical stator blade is composed of the profile and the root. The blade profile is streamlined to guide passing steam. The bottom part of the blade is the root with appropriate fastenings that keep the blade in a groove on the stator perimeter. The spacer is made together with the blade, but it can be made separately (Variant B1) or it can be the blade integral part (Variant B2) [11]. Blades with integrated spacers can also be mounted on the stator ring (Variant B3).

Blades with spacers made separately and those with integrated spacers are mounted in the grooves individually (one by one), and they need proper adjustment during the assembly (additional mechanical working). In the case of the stator ring (Variant B3), it is slid into a groove, prepared in advance, and secured with steady pins.

Blades with spacers made separately and those with integrated spacers are usually removed individually either by knocking or turning them out of the stator groove. In the case of Variant B3, the entire element is disassembled in a single operation, which makes it possible to save time and energy.

The environmental analysis of the variants described above was conducted using the SimaPro 8 Analyst in relation to a functional unit of 100 stator blades ready for assembly in a steam turbine and constituting the turbine stage.

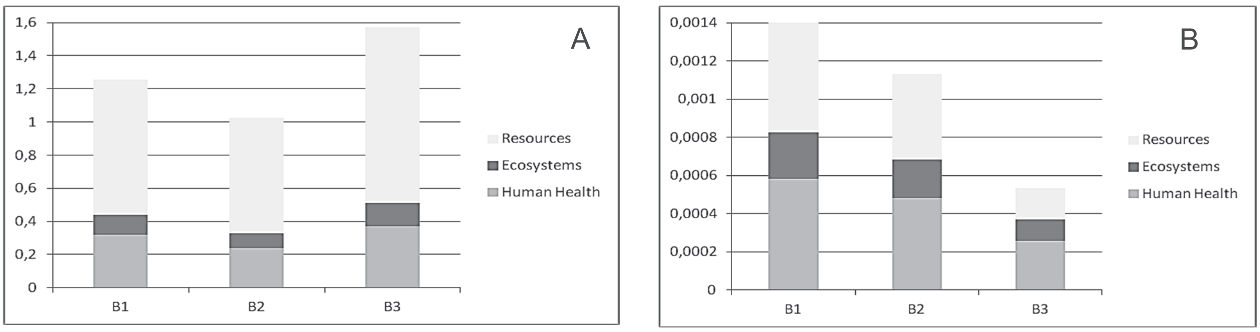

Figure 2 The normalized results of the environmental analysis of Variants B1, B2 and B3 in respect of the damage categories. A - life cycle perspective; B - assembly and disassembly perspective

Taking account of the stage of the sourcing of raw materials, of the manufacture of steel and blades and of the assembly and disassembly of ready blades in the turbine, the obtained results indicate that Variant B2 is the most favourable solution (**Figure 2A**). Variant B3 is the least favourable one in this case, as it involves the need to make an additional element - the ring.

Considering the environmental impact related to the assembly and disassembly operations, the best solution is Variant B3, whereas Variant B1 is the worst (**Figure 2B**). The knowledge concerning the environmental impact of the variants under analysis may be the subject matter of further research and of decisions made in co-operation with partners in the supply chain. It may also stimulate the search for compromise solutions taking account of other criteria, including economic and societal aspects [12].

5. CONCLUSION

The analysis of selected issues related to the logistics process eco-design reveals many problems and challenges. Overcoming them may contribute to the creation of environmentally friendly solutions satisfying the requirements of partners in the supply chain and those resulting from implementation of new systemic solutions. However, satisfactory green solutions cannot be obtained without co-operation of partners in the supply chain. Moreover, organizational problems have to be overcome, too. Environmental aspects are additional essential variables in the design process. This can be seen in the case study concerning the stage of the assembly and disassembly of the turbine stator blades. It is worth seeing in these additional variables not only a chance to reduce the negative impact of products on the environment but also an opportunity to gain economic advantage, stimulate innovation and improve the organization image.

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