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ECO DESIGN: MAKE IT HAPPEN BY AN ENVIRONMENTAL INNOVATIVE PRODUCT DESIGN

B. Rosemann. and H. Meerkamm

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1. Objectives

What is done at state of the art eco-design to improve the eco-profile of products is: Take the products, perform a weak point analysis (i.e. an LCA) and redesign the existing products focusing the found weak points, resulting in a product which differs very less from the starting point. That means a small change in design by an investment of a huge time effort to perform the LCA and neglecting essential procedural needs to find complex problem solutions like the design of environmental innovative products.

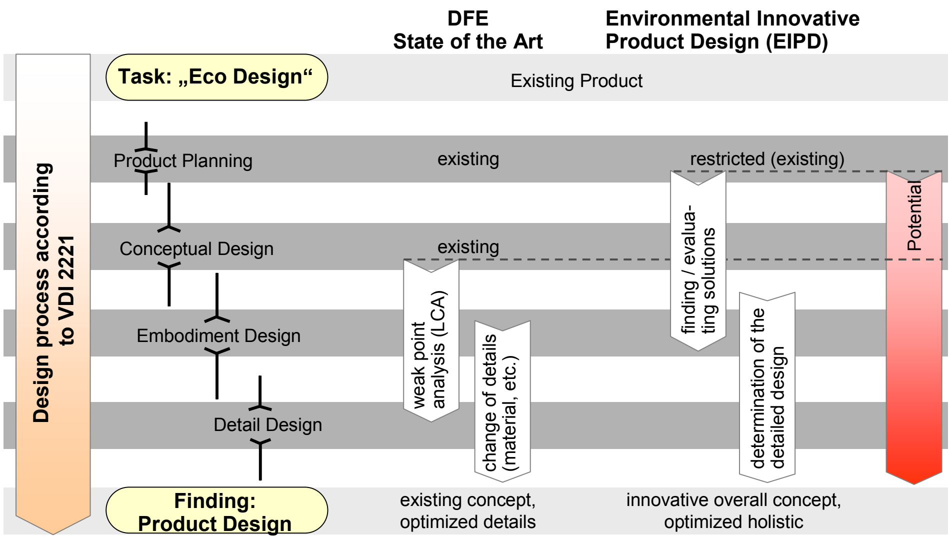

Figure 1. Comparison between state of the art eco design tasks and an environmental innovative product design referencing to the framework of the VDI-Guideline 2221

In contrary a approach with an holistic view starting at the former conceptual level allows the improvement of products which seems to be squeezed out in their development, because the consideration of the conceptual design offers further potential for stepping forward at the improvement (figure 1).

It is not unusual to reach innovative solutions found by the detailed consideration of alternative solution at a conceptual level because it is necessary to leave known solution paths (figure 2).

A holistic “Eco Design” is an extremely complex approach which asks for the fulfillment of a great quantity of restrictions. Therefore the development of sustainable products leads nearly automatically to market oriented products [Rosemann 2002].

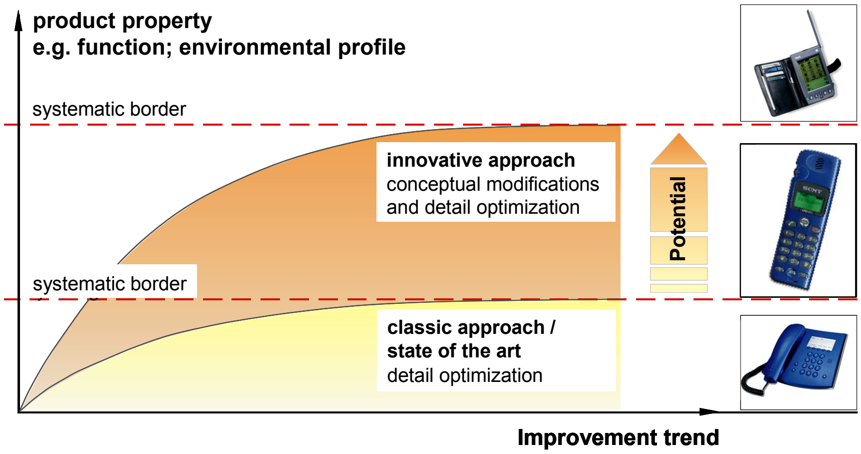

Figure 2. Connection between design approach and improvement level of product properties

2. Essential Design Process Requirements for an Environmental Innovative Design

Focusing at a competitive design process for designing eco products, it is necessary to minimize the additional time amount to consider the additional environmental product requirement.
In spite of the holistic redesign of products, which is essential for an Environmental Innovative Product Design (EIPD) in comparison with the state of the art Design for Environment shown on figure 1, it is essential for reducing the time to market to focus mainly on the essential product requirements. These is expressed by the concentration on customer requirements (function, ergonomics, and so on), on cost requirements and last but no least on environmental requirements. That is in the mentioned order, because products will be sold in the first instance because of functional and cost arguments.
If we have a detailed view at the conventional design for environment, it is remarkable, that the main focus of the time exposure is required for the weak point analysis. Only the minor time is used for the finding of design advancements. Further on these advancements can only include small changes, because the concept and the solution principles used are not changed. Therefore the improvement level is very small. That means the changing are for example the change of materials or the change of connection technologies.
On the opposite the EIPD process the eco design task without an initially performed weak point analysis. The EIPD focuses mainly on generating alternative solutions on a conceptual level based of the main functions by consideration of the mentioned product requirements. After that the found solutions has to be evaluated on the base of a multicritera evaluation regarding the formulated requirements. A significant reduction of the time effort is reached for the environmental evaluation by the use of a life-cycle-impact-assessment (screening) or the use of simple specific impact criteria’s. Because partial solutions are compared, the time effort is also reduced in comparison to perform a LCA for the weak point analysis of a whole product in the conventional Design for Environment process. The selected solutions were detailed and optimized in the next stage of the development process (see figure 1).

3. Methods

Generally, the broad range of necessary methods is well known to perform an environmental innovative product design. In core, it is the process of an Integrated Product Development (IPD), which is defined as an interdisciplinary, process oriented approach with a view on the total life cycle [Meerkamm 2002]. It has to be seen as a combination of the use of design methods, tools based on information technology, a well adapted organization and the acting people in the centre of all. Inherent there is a complex view in the interference between product (design solution) and the following processes [Meerkamm, 2002]. It focuses at:

- Interdisciplinary, methodological approach
- Life-cycle orientation by focusing on main aspects
- Predictive Engineering based on a IT-tool support

3.1 Interdisciplinary, methodological Approach

Because of the high complexity of the problem (Design for sustainability means to fulfill at the same time the challenge of Design for X) and the demand for finding innovative solutions a design-method oriented approach was realized. Based on the requirement list a function structure was created. The main functions defines the main modules of the product, which has to developed by interdisciplinary working groups, because the historic development of innovation processes shows, that base innovation are reached interdisciplinary. Innovating today at complex technical products is not practicable by single developers. The working groups were declared responsible for the different main modules. According to the predominating physical base principles the members of the teams were recruited from the engineering design-, material-, analysis-, production and assembly-, and environmental field. The methodical frame was defined by the VDI 2221 (see figure 3).

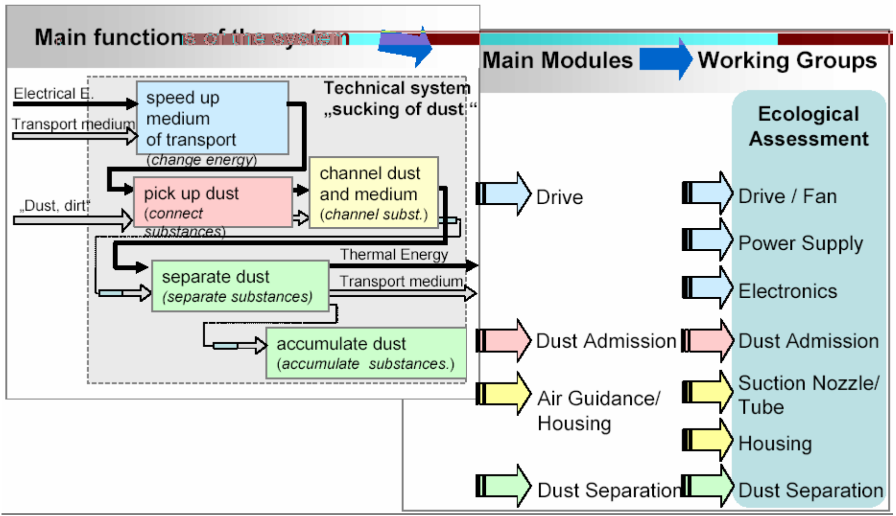

Figure 3. Interdisciplinary, method based approach at the development of an sustainable vacuum cleaner (connection between functions, modules and interdisciplinary working groups)

3.2 Life-Cyle Orientation

Extensive investigations of a broad range of environmental products evaluations on the base of life cycle assessments and investigations of environmental oriented product innovations shows:

- Production phase: The environmental burdens of passive products are preliminary determinated by the production phase. These phase is also essential for active products.
- Active products, with a high portion of electronics possess a higher impact at the production than non electronic products.
- Transport processes between production or recycling locations and internal transport processes can be disregarded.
- Use phase: Most energy consuming products (active products) possesses the dominant impact at the environment at the use phase from a nominal power less than 1 kW. The impact mainly is defined by the energy consumption.
- Recycling phase: The environmental burdens of the end of life are negligible in respect to the production and use phase.

Because of the elucidated main impacts on the on hand and the during the design substantial influenceable life cycle phase production on the other hand it is coherent to draw the conclusions:

- To minimize the influence of the production the selection of the used materials is to be accomplished with the help of an ecological evaluation of possible alternatives. The evaluation has to include the production processes. That mean focusing on a material level.
- For relevant reduction of the energy consumption at the use, the energetic effect chain, which obtains the function realization, has to be analyzed to identify and improve the most important sub functions. That means focusing on a energetic level.

For the establishment of closed substance cycles a material homogenization and a feasible modularization in the products structure as far as possible should be acquired to enable a fast separation of recyclable material fractions or independent function modules.
The mentioned activities can only be attained by starting at the conceptual design [Rosemann, 2003].

3.3 Predictive and Rapid Engineering based on a IT-tool Support

In combination to the methodical approach it is essential to exhaust the potential of state of the art simulation tools. Therefore the working teams have to use actual IT-based tools for their development work. For example for:

- finding of alternative solution principles, physical effects and "Wirkprinzipien"
- investigations/optimizations in the field of mechanical, electrical, fluid dynamical behavior
- production simulation
- product structure optimization
- disassembly simulation
- life cycle impact evaluation

In addition to these simulation activities, the simulation results have to be checked by experimental investigations. Material analytic with special laboratory equipment, optimization of the electrical and fluid dynamical behavior are some important activities for the vacuum cleaner example. The 3-dimensional solid modeling with CAD allows a rapid prototyping for manufacturing real and well operating prototypes. The combination of all IT-based activities, experimental work allows the approach of predictive engineering [Rosemann, Meerkamm 2003].

4. Example pilot-project results

The developing and realizing a prototype of a vacuum cleaner shows, that the philosophy and the suggested procedure is powerful enough for innovation and for improvements even in the field of well developed products. Working in an interdisciplinary team combined with a methodical and IT-tool based approach allows the creation of successful solutions for sustainable at the objective section. How successful the concentration on substantial aspects of an environmental innovative product development can be, was impressively demonstrated in the IPP (Integrated Product Policy) pilot project Bavarian development net for innovative technologies (BEnefiT) promoted by the Bavarian State Ministry for State Development and Environmental Affairs. This network built of university and industrial authorities is led responsible by the Institute for Engineering Design (Prof. Meerkamm) at the University of Erlangen-Nuremberg and pursues the approach of an integrated product policy (IPP).
Based on the described approach the implementation in several examples of use is visualized. This demonstrates the possibility to attain even on output-provoked products the improvements for each product life phase and the benefits for all participants in the life cycle by use of a methodical, system-oriented procedure according to an Integrated Product Policy (IPP) and to reach product innovation due to environmental requirements.
The extensive improvements are quantitatively measurable, by setting the degree of fulfillment of different product-related environmental criteria of IPP fair products or services in relation to conventional kinds of fulfillment. These criteria, however, are partially product specific and are therefore difficult to be specified for adoptions accordingly in each case. Such a simple benchmark permits the representation of the improvements transparently compared with established ecological evaluation models. The comparatively simple system of evaluation permits the application in the early concept

phases, where a life-cycle-assessment is not meaningfully applicable due to the lack of available information. Further on, with this approach we obtain a benchmark which declares the degrees of the improvement to the final customer in an understandable form.
Transferred to the redesigned BEnefiT vacuum cleaner prototype, a set of advantages can be shown. Compared with reference, the prototype thus reaches an improvement from 1.6 to 2. It consumes only half of the electricity during the use phase like conventional devices while delivering the same suction power. With a total weight of only little more than 4 kilograms, it is over 1 kilogram more lightweight than comparable devices, which means an improvement factor of approx. 1.25.

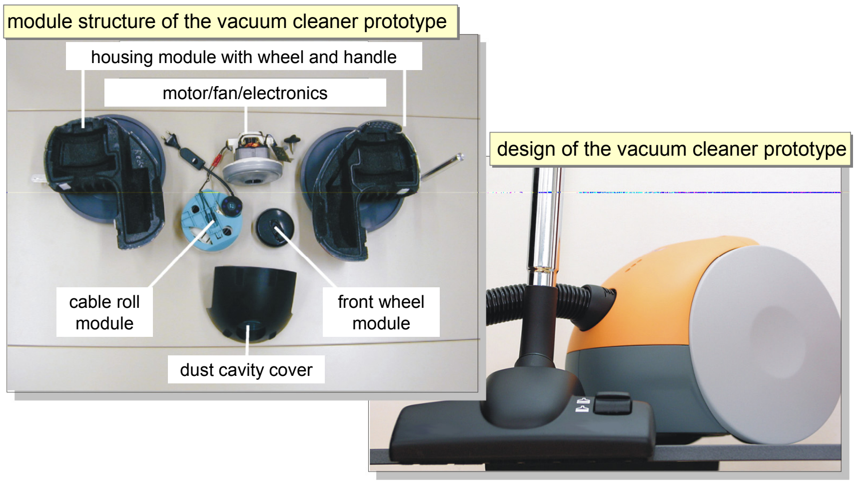

Figure 4. Design and simplified structure of the consequent environmental aware redesigned vacuum cleaner

Through the reduced material usage and the extremely reduced and coordinated material variety - 13 instead of 26 different materials - an improvement of about 50% is reached. The simple construction structure of the device, which gets by with only one connecting element, makes a disassembly time of 13 seconds possible for the achievement of sort-pure material fractions. The reference device, which was the best one available on the market, needs a disassembly expenditure of 182 seconds - an improvement around 14. Therefore a clear proceed can be gained within the recycling in place of costs. The vacuum cleaner housing consists of only two construction materials, polypropylene and polycarbonate. That is, in contrast to approximately nine different materials in comparison devices, an improvement around the factor 4.5. The polycarbonate portion is, in fact, so small that the complete housing can be regarded with the recycling as a high-quality PP material fraction.
The extensive improvements, which were obtained in the context of the project by the example of a vacuum cleaner, referred to the environment are readable from the LCA, which is accomplished project-accompanying.
The mentioned environmental referred progress is recognized in figure 5 and figure 6.
For potential customers however it might be of stronger importance that the equipment with improved environmental profile has the further following advantages during same suction power:

- Less Weight (better handling)
- Decreased device size (less storage volume, better handling)
- Approximately 40-50% less energy usage
- Simply to disassemble (repair, service)

A more detailed representation of the developed prototype and its advantages you will find in [Rosemann 2003].

Impact Category	Device	Value	Improvement [%]
CO2-Äquivalent [kg]	*Reference*	718,25	42
	Prototype	413,95	
Energy consumption [kWh]	*Reference*	845,00	42
	Prototype	487,00	

Figure 5. Improvements in the use phase of an environmental oriented redesigned vacuum cleaner exemplified pictured in essential impact categories

Impact Category	Device	Value	Improvement [%]
Renewable energy sources	*Reference*	0,0357	97
	Prototype	0,0010	
Energy Sources (non renewable)	*Reference*	19,3155	75
	Prototype	4,8360	
Eutrophication (NO3)	*Reference*	0,0000	0
	Prototype	0,0000	
Eutrophication(PO4)	*Reference*	0,0165	45
	Prototype	0,0090	
Human toxicity	*Reference*	1,19E-04	100
	Prototyp	0,0000	
Ozone depletion (CFC11)	*Reference*	9,79E-06	100
	Prototype	0,0000	
Resources	*Reference*	368,3840	93
	Prototype	56,2920	
Oxygen	*Reference*	32,0116	82
	Prototype	5,8670	
Heavy metal to air	*Reference*	0,0008	100
	Prototype	0,0000	
Heavy metal to water	*Reference*	0,0002	100
	Prototype	0,0000	
Summer smog (C2H4)	*Reference*	0,0215	-20
	Prototype	0,0270	
Greenhouse effect (CO2)	*Reference*	58,9813	74
	Prototype	15,3880	
Acidification (SO2)	*Reference*	0,2780	2
	Prototype	0,1370	

Figure 6. Improvements in the production phase of an environmental oriented redesigned vacuum cleaner exemplified pictured in different impact categories

5. Key Conclusions

The main aspects of a design for environment can be focused without performing the known approach with performing a weak point analysis by the use of an LCA. Instead it is possible to focus on energetic and material efficiency, which allows a time saving approach applicable in the early phases of the product development. Bound by an IPD products innovation are probable, approved in the case of a vacuum cleaner project.

References

Meerkamm, H.: "Integrated Products Development as a Key to Sustainable Products", In: Proceedings ICED 2003, Stockholm, August 2003.

Pahl, G.; Beitz, W.: Engineering Design, 2nd Edition, Springer Verlag, 1996.

Rosemann, B.: "Hidden Pattern of Environmental Innovative Products" In: Proceedings ICED 2003, Stockholm, August 2003.

Rosemann, B.: Engineering for Sustainable Development - Design Patterns of Environmental Sound Products -. In: Seminar Proceedings CIRP Seminar on Life Cycle Engineering, Copenhagen, Mai 2003.

Rosemann, B., Meerkamm, H.: Methodological framework and examples of an environmental innovative product development. 9th CIRP International Seminar on Life Cycle Engineering; Erlangen, 09./10. April 2002.

Bernd Rosemann, Dipl.-Ing.
Chair of Manufacturing and Remanufacturing Technology
Bayreuth University, Universitätsstraße 30, 95447 Bayreuth, Germany
Telephone: +49 (0) 921 55 7304, Telefax: +49 (0) 921 55 7305
E-mail: bernd.rosemann@uni-bayreuth.de