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Recycling as an important element of engineering design

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Cleaner production and biotechnology

ABSTRACT

Purpose: In this article an attention to environmental aspects, especially the necessity of recycling usage in the engineering design was paid.
Design/methodology/approach: In the paper characteristic of engineering design and individual stages of this process, tools which designer uses to its realization were presented. Moreover, the factors which should be consider in the designing process were described.
Findings: In this article, on the basis of engineering design methodology the ecodesign algorithm in which the principles of recycling were considered was proposed.
Research limitations/implications: Design for recycling helps protect the environment and creates a sustainable means for conserving our resources. Recycling it is not only the usage of the secondary resources. It should be the system of materials circulation, consciously usage in the process of products designing which can be many times processed.
Practical implications: Ecodesign is a new approach to designing and it depends on identification of the environmental aspects connected with product and consideration them to the designing process already on the early stage of product development.
Originality/value: The worked out ecodesign algorithm systematizes workings performed during designing process and shows the meaning of the ecological aspect (necessity of recycling in it) in this process.
Keywords: Industrial application of cleaner production methods; Engineering design; Ecodesign algorithm; Recycling

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1. Introduction

At present, all workings aiming at the intentional aim achievement are called designing. The word „design" has the wide meaning. It has already a little common with plans in drafts form. This concept is employed in the reference to the most various undertakings which aim is realization of specific plan.

However engineering design relates to technical problems invariably. This is a very complex process which consists of material, constructional and technological designing. The engineering design requires of consideration of many factors: functional, economic, marketing, ergonomic and ecological. Every one of them is equally important, because they are related with themselves closely. However minimization of negative influence of the product on the environment becomes more and

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more often the main aspiration of designers, apart from care of the suitable quality of the product and its safety. The designing of product which is under every consideration good i.e. adapted to the optimum conditions of production, exploitation and sufficiently close to the ideal solution, and near fully satisfying the consumers needs and the environment friendly requires of proper designing process organizing. It is necessary accurate planning of the individual stages of the process, engaging of competent persons and taking care about the proper tools of designing. The complexity and diversification in one design is so large that many experts from various fields should be engaged. The proper coordination of works is necessary also and designing is closely connected with management in this place, so we can hear about design management or designing management.

There is no universal method which makes possible every engineering design process carrying out according to one scheme. This results from variety of realized designs, and also from specific of work organization in enterprises.

2. Engineering design

The engineering design of the product consists of three essential elements: constructional designing, material designing and technological designing (Fig. 1). They are interdependent, inseparable and they influence on themselves [1].

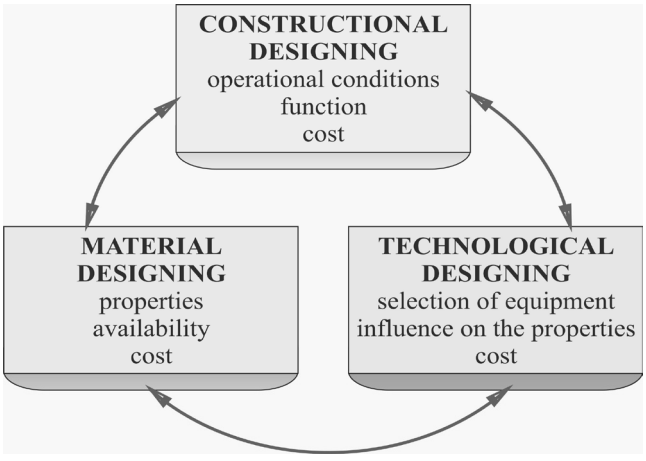

Fig. 1. Schema of interrelation between components of engineering design of product [1]

The aim of the constructional designing (also called constructing) is formulation of the shape and geometrical characteristics of products designed with the thought about satisfying of human needs. You should always follow a principle, according to this the simplest construction is the best construction.

Beyond the shape and geometrical characteristics, determination of tolerances dimension which will make possible the later assembly is also the phase of constructional designing [2].

All stages of the engineering design process require decisions concerning of materials from which product will be made. The choice of material is often dictated requirements of the design. The proper selection of material about required physical, chemical and technological properties guarantees the suitable safe life of product.

The number of available by engineers materials is great. Although the standardization tends towards decrease of this number, new materials about better properties still appear, widening possibilities of the choice.

Selection of proper technological process makes possible the conferment of required geometrical features and properties of individual elements of product, it shapes required structure of material, also. The proper structure assures obtainment of expected mechanical, physical and chemical properties of product. The well-chosen technological process also guarantees correct contribution of product elements after assemble. The essential matter on the technological designing stage is consideration of production size and automation level of factory.

Technological designing on the conceptional and general designing takes into account following factors: material factors, shape factors and technological factors.

Selection of material usually decides about the choice of specified way of production. Selection of technological process is conditioned by material properties.

3. Engineering tools and materials data

To engineering design process proceeded correctly, the designers have to dispose certain designing tools. The basic and the most important tool of every designer is open mind and the will of all possibilities consideration, and then – engineering knowledge and information from the range of material engineering. Information concerning material is necessary on every designing stage, however in diversified range and about various details.

The computer aided design (CAD) and the possibility of databases using including information about standard parts and theirs assemblies make easy routine actions of designers in more and more large degree (Fig. 2) [3].

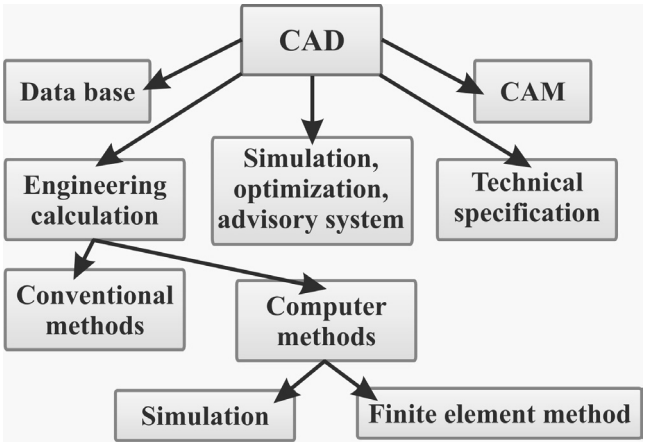

Fig. 2. Range of computer aided design [4]

Thanks to CAD usage the engineers have the easier access to knowledge sources, libraries, normative studies, legal regulations and valid directives in the concrete branch of industry. This is possible thanks to databases and work in network environments usage in the engineering design process. Computer aided design makes possible whole design record, and then it is facilitated modifying of technical documentation in computer memory. CAD structure was presented in Figure 3.

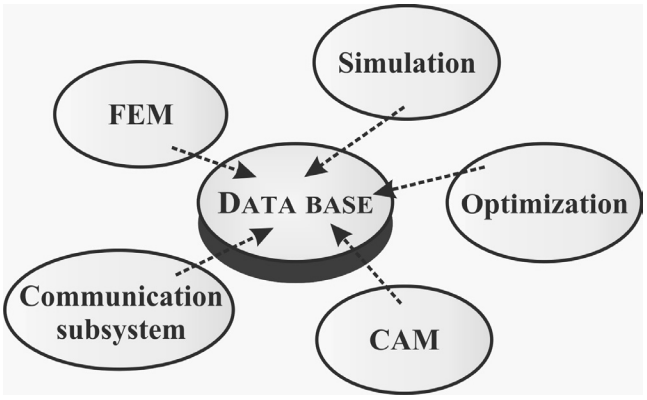

Fig. 3. Structure of CAD system [5]

4. Ecological factors during engineering design

The engineering design is a very difficult process. On every stage of work we should take varied factors into consideration:

- functional,
- marketing,
- sociological,
- economic,
- qualitative,
- ecological, etc.

Larger requirements about the environment protection caused that on the stage of designing the special attention is put on the environmental aspects. This initial phase of life cycle of product plays the decisive part in quality assurance of its functioning in the next stages of usage (production, exploitation and liquidation) with reference to relation with the environment, also. Knowing problems relating to designing it is easier understand ecodesign concept. It was created in the aim of emphasis of environmental and economic problems in the present designing.

Ecodesign is a new approach to designing and it depends on identification of the environmental aspects connected with the product and consideration them to the designing process already on the early stage of product development [6,7]. Ecodesign is also defined as designing for environment or designing according to sustainable development principles.

In the foreign literature there function different definitions usage in relation to ecodesign [8,9]:

- green design,
- environmental design,
- ecological design,
- life cycle design,
- sustainable product design.

The ecological design depends on implementation of ecological aspects in the area of traditional products designing in the aim of improvement of their environmental aspects, without principal change of the product conception.

Despite of individual features of every organization, designing processes are similarly realized. Each of them begins from the qualification of needs and the product functions. Next, one defines requirements, conception of design, detailed design and on the end productive assumptions. On every stage of designing designer analyses alternative solutions. Implementation of ecodesign principles requires of good organization and connection requirements relating to the environment protection with designing process. It requires of suitable tools usage which are the source of actual information from the range of the environment protection, also [8].

4.1. Methodology of ecodesign

Implementation of the environmental aspects in the product designing process can be realized on many ways. This process depends on specific of product and kind of enterprise. ISO 14062 standard systematizes the matter of integration of the environmental aspects with designing process (Fig. 4) [9]. The results of every stage and information connected with its should be conveyed to the next phases of designing process. This makes possible systematic improvement of the product both in relation to technical and ecological matters.

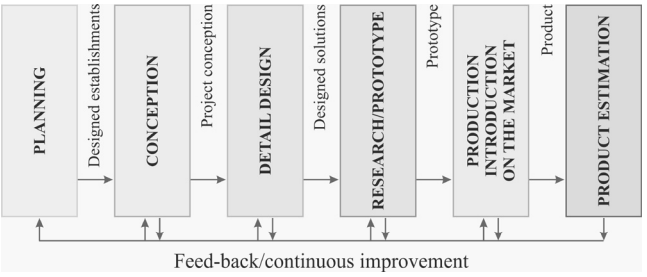

Fig. 4. Designing and development process of product [9]

You should take this into consideration that the possibility of usage of standard procedure does not exist in every case. Enterprises apply various approaches and tools to their products designing.

The ecodesign methodology elaborated by CEEE (Centre of Excellence Electronics & Environmental) was described below. This is practical and simple method enabling the accurate and quick ecological valuation of product, identifying weak points, settlement of improvement strategy and generating concrete implementation ideas (Fig. 5).

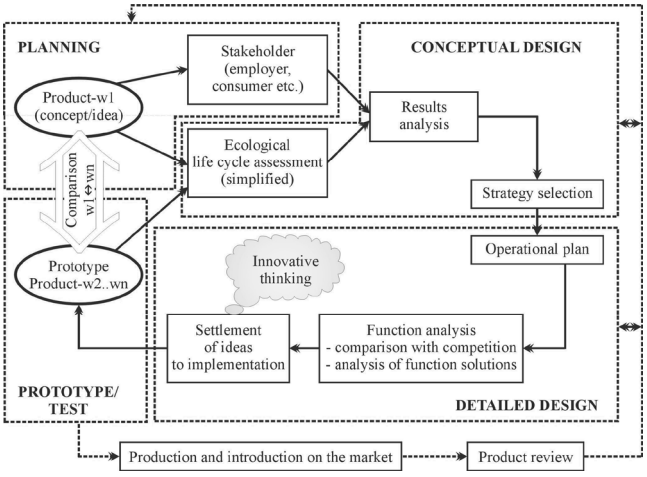

Fig. 5. Systematic procedure for an ecodesign [10]

Conception

The very important element of ecodesign is working conception elaboration. The object of designing workings can be improvement of product existing on the market in relation to ecological aspects or elaboration of completely new conception. It is important to begin implementation of environmental aspects as earliest [10].

Settlement of interested parties requirements

The potential buyer has a certain requirements which should fulfils the designing product. Manufacturer and salesman have their expectation. The legal matters imposed by legislators can't be omitted, also. The designers have to carry out the designing process considering all requirements and create the product which will satisfy all needs [10].

Simplified life cycle assessment

The degree of product influence on the environment on every stage of its life cycle is very diversified. That is why every phase of investigation should be under consideration separately. The analysis can be carried out with eco-indicators (coefficients) usage, representing in the numerical form the degree of negative influence of product (or process) on the environment. Reduction of the environmental estimation to only one eco-indicator is large simplification and omit many environmental aspects in the contrast to complex LCA analysis. The environmental estimation with eco-indicators usage is made using coefficient of energy consumption (expressed in [MJ]). The analyses showed that in case of energy consumption coefficient we can get a sustainable relation among the work expenditure and results which are sufficiently precise to recognize the main ecological problems. The identification of all mistakes and defects which have the negative influence on the environment is the most important thing in this eco-design phase [10].

Strategies of product improvement

On the basis of the environmental analysis and requirements from the potential buyers, manufacturers, salesmen and legislators parties, the strategies of product improvement in the reference to the phase of life cycle in which the given problem occurs are formulated. In the production phase, for example, we can aim at [10]:

- minimization of materials used,
- usage of ecological materials and components,
- reduction of ecological unfavourable materials.

However, in the exploitation phase the improvement strategy concerns:

- increase of energetic efficiency of product,
- limitation of product function to indispensable from the consumer point of view.

In the phase of the end of product life one can aim at its improvement with regard to recycling.

Settlement of the working plan

The aim of this eco-design stage is the settlement of the plan according to which the realization of principles contained in the improvement strategies will take place. The working plan contains concrete aims and steps of action. It is to every product worked out individually, taking its specific under consideration, because there is no possibility of universal scheme creation [10].

Ideas to implementation

It is the most creative part of the eco-design process, which aiming to elaboration of the ideas of settled plan implementation. The starting point can be e.g. analysis of competitive products existing on the market. The central point of solutions search is the function analysis which product has to fulfil. The settlement of these functions allows to investigation of possibility of their realization. Recapitulation of the analysis results can be presented in morphological box form which contains the settled product functions and possible ways of their implementation. The combinations of individual solutions lead to the various conceptions of the product.

The „brain-storming" in which the whole designing team takes part is the another form of the settled ideas elaboration. One requires innovative thinking, spontaneity and creative inventiveness from its participants [10].

Comparison of the input product (or the original conception) with the ecological version

The results of workings aiming to product improvement in relation to ecological should be analysed and referenced to starting product. The results of achieved changes, formulated in numerical eco-indicator form, can be easily interpret graphically.

Process recapitulation

The aim of recapitulation of designing process is inclusion of the environmental aspects on every stage of the life cycle of product. Preparation of suitable documentations, individual stages of ecological improvement of the products properties are important, also. The eco-design is not the single process, but continuous pursuit of perfection. In this process workers of all enterprise sections should participate [10].

The entrance to designing of every product should be customer and his needs, because every enterprise can't make risk production of the product, which the potential purchasers needs does not fulfil (Fig. 6).

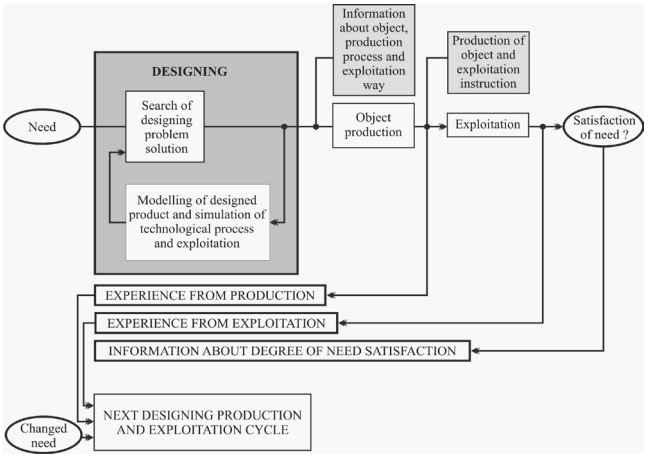

Fig. 6. Schema of designing process against the background of needs satisfaction [11]

The proposal of the algorithm procedure during engineering design taking the environmental aspects and the necessity of recycling usage under consideration was presented in Figure 7.

Planning

The planning phase should be started from the exact analysis of market which gives necessary information to decisions making connected with the product. The subject of research are: competitive products existing on the market, demand on new products, absorptivity of the market, expectations and customer requirements. In the aim of got these information different analysis and investigations methods are used. The questionnaire method can be one of them. It depends on obtainment from respondents answers for questions which are included in questionary.

The designing team creation is the next stage. The person responsible for design should takes care of the commitment of suitable persons – it is the design manager. The design team should consists of: engineers, constructors, experts from the field of materials selection and production processes and experts from the field of the environment protection (especially experts from recycling methods) and the environmental management, too. The employment of experts from so many fields is necessary because of the interdisciplinary character of the work. It gives a great possibilities and makes possible many mistakes avoid.

The effective communication it is the key, or the most important factor of success. It influences on every aspect of design management and its efficiency. The communication inside design does not include information about changes or works progresses only. This is continually relaying information about gained knowledge also [12].

The members of the team have to work together beyond individual work over the particular part of design, especially during decisions making, search of new, better, more the environment friendly solutions. The team meetings are important element in the range of internal communication. They are a form of team integration, but they give possibility of knowledge interchange.

Heuristic methods (from Greek - heuriska - discover making) are significant in problems solving and search of new ideas. The brain-storming and morphological analysis belong to the most often applied techniques.

Conceptual design

The aim of conceptual design creating is elaboration of conception connected with general specification of materials and processes. The designers should consider in it product requirements which were already analysed in the planning phase. All created conceptions have to take into consideration the environmental aspects on this stage. Formulation of general brief foredesigns make the designers do analysing of all available technological solutions and materials data. They usage many tools in this aim. To them belong: data bases, experts systems, and also systems of computer aided design CAD/CAM (Computer Aided Manufacturing) or connected with the environmental aspects - analytic tools of LCA (Life Cycle Assessment) [7,13]:

- check list/card concerning of material, assembly, disassembly and recycling,
- eco-indicator methods,
- MIPS indicator - Material Input Per Service Unit,
- MIT indicator - Material Intensity.

They make possible estimation, in what degree the product which is the object of designing will loaded the environment and influenced on its during the whole life cycle.

The limitation of quantity of materials, resources and energy is the one of more important assumptions in the conceptual design. This leads to decrease of production costs, but to minimization of quantity of waste and easier recycling first of all.

The results analysis is the essential element of this stage. The designers should choose this variant, among all created conceptions and ideas, which in the largest degree fulfils requirements, it is possible to implementation and optimum with regard to accepted criteria. The solutions analysis the designers should carried out using existing techniques of decision making.

General design

The aim of the stage of general design creation is extension of the conception. From general considerations, ideas during design works product form is presented. The constructors have to create draft documentation, determine parameters, dimensions. The designers should make specification of available materials and technological processes, from which the product can be produced (taking into consideration ecological aspects, recycling possibility, recycling technologies [14,15]). They have serious task to carried out. The subject of their considerations should be these materials and technologies, which are safe and the environment friendly only [16].

The influence of products on the environment is subject to changes in individual periods of life cycle, that is why analysis carrying out in the next stages is necessary. One can do this with eco-indicators (coefficients) usage, representing degree of negative influence of product on the environment in the numerical form. This leads to indication which from the stages of life cycle of product is the most burdensome for the environment and it makes possible effective counteraction of these threats.

Economic factors play very important role in the designing process. The financial analysis is equally important, because the design has to be profitable. The Cost-Benefit Analysis (CBA) is extraordinarily helpful tool to this analysis carried out.

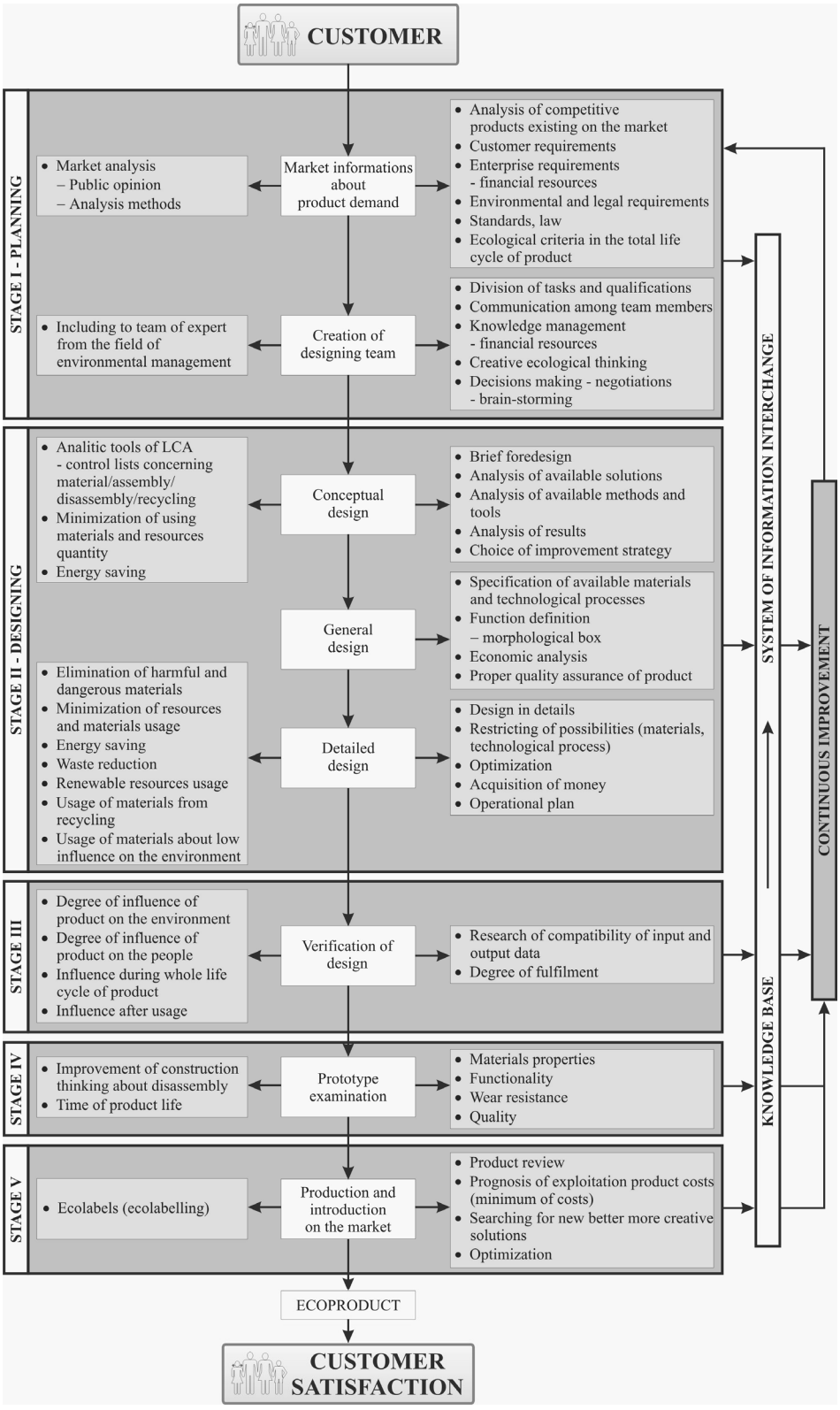

Fig. 7. Algorithm of ecodesign [own elaboration]

The necessary element of the engineering design of product is proper quality assurance. The quality has the greatest meaning in this phase of product formation, because the best technological process carried out will not assured of high quality, if it is not considered in the design.

Detailed design

On this stage of designing the designers should limit possibilities of materials and technological processes usage to one, alternatively several. They should using databases make their precise specification.

The designers should answer on the following questions: is it possible to usage of renewable materials? Which from applied conventional materials could be substituted by renewable equivalents? Are proposed materials usage in recycling? How many various kinds of materials could be used in the product? What is the cause of such diversification? Is possible simplification of design (construction) to reduce quantity of kinds of materials? These questions have to inform that the designers should usage materials from recycling and materials about the smallest influence on the environment first of all [13]. Designing for recycling the designers should usage a principle of limitation of quantity and the variety of applied materials, avoidance of composite, many-layered materials and making difficult the recycling. Ecodesigner should take into consideration conditions of final waste management in place of usage and liquidation of products e.g. how many waste will be managed.

The other important element of this designing stage is multicriteria optimization carried out (however, optimization it is usage in every stage of designing process, in different form) [17].

Verification of design and prototype examination

After the end of designing stage the designers should make the product verification. The penetrating analysis of technical documentation makes possible finding potential mistakes and shortcomings, especially if its carried out a person who did not participate in the design. The lack of commitment in the design makes possible the objective opinion. The compatibility of input and output data should be examined. The design should fulfil all requirements (in this ecological first of all), both these defined by customer, and defined by law.

When the design is positively verified the designers make a prototype of product. Next, the investigations on its are carried out until its destruction. During these investigations verified: does the product fulfil constructional, qualitative requirements, does it fulfil assumed functions, etc.

Production and introduction on the market

This stage includes product production, its introduction on the market, and all actions connected with promotion, advertising and marketing also. The main aim of this phase is acquaintance of potential purchasers with information concerning of the product and advantages resulting from its purchase.

In this phase of design the designers should prognosis of exploitation costs carried out, that is all liabilities connected with the product functioning, certainly this costs should be the smallest.

The good and effective way of product promotion is ecological labelling, also called ecolabelling. After certification on the product are placed ecological sign which testifies that manufacturer adapted product or processes applied during its production to requirements connected with the environment protection.

5. Conclusions

The engineering design of the product is extremely complex process which is difficult to definition. It begins in the moment of appearance of proper need and decision making about the test of its satisfaction, and ends in the moment, when one disposes information, resources and methods making possible its realization.

The decision making about designing of the environment friendly product is not a problem, it is important to realize the design in due time, with predetermined budget, and this requires the perfect organization of designing process. In this moment very useful can be the algorithm worked out. It systematizes workings performed during designing process and shows the meaning of the ecological aspect (necessity of recycling in it) in this process.

Additional information

Selected issues related to this paper are planned to be presented at the 16th International Scientific Conference on Contemporary Achievements in Mechanics, Manufacturing and Materials Science CAM3S'2010 celebrating 65 years of the tradition of Materials Engineering in Silesia, Poland and the 13th International Symposium Materials IMSP'2010, Denizli, Turkey.

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