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DESIGN FOR ENVIRONMENT WITH ALUMINIUM EXTRUSIONS

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Extruded aluminium sections have many features that make them suitable for use in environment-friendly products. Still there are much to be done to reduce the variability of section properties and to optimize the processing route from extruded section to finished and assembled component in order to meet cost, quality and performance goals, minimizing adverse environmental impacts and maximizing the conservation of valuable resources. Another important question taken up in this paper, however, is the problem of ensuring that aluminium sections are used in products and technical systems that are contributing to a sustainable development during their total life cycle. In order to ensure this, it is claimed that the it is necessary to carry out a product system diagnosis that combine ecological and competetive considerations. Further one has to promote design for environment that ensures functionality completely fitting into sustainable societies and innovatins based on a multi-disciplinary approach, searching for synthesis of technology, the arts and the humanistic disciplines. The universities should take active part in this process, by creating new areas of competence and establish new alliances with the industry and the society.

INTRODUCTION

Extruded aluminium sections have many features that make them attractive for environmental friendly design:

- there is a short way from raw metal to finished and functional extruded section.
- low cost extrusion dies compared to sheet metal forming dies and injection moulding dies for polymers, makes continuous improvement of section design easy to carry out.
- there is a large variety of creative solutions for mechanical joining of sections, which enhance low cost assembly and disassembly.
- good corrosion resistance, often with no need for surface treatment, ensures low maintenance cost and long product life.
- there is a relative small number of generic aluminium extrusion alloys from which designer makes his selection. This makes alloy selection and the logistics of recycling easy to handle.

- remelting of recycled aluminium alloys needs only about 5% of the energy needed for primary processing.

There are, however, some important challenges for the extruders in improving the competetivenes of aluminium sections compared to other materials:

- Since the extrusion process is a transient process, where the conditions are changing during the press cycle, the control of variability of section shape and dimensions, surface appearance and mechanical properties of the section is of great concern. Design with larger wall-thickness than needed, more scrap produced, and lower productivity may be the results of this variability. Research and development to improve the competence of die design, press design, alloy robustness and process control are an ongoing process. These challenges have been discussed in [1] and [2] and will not be the subject of this paper.

- The processing route from the extruded section to the final component or structural element in the finished product, going from cutting, forming and machining, through surface treatment and finishing, joining and assembly, may often be time consuming and costly, passing many processing steps and experience complex logistics, producing scrap, and not utilizing the inherent properties of the alloy fully. This is a very important area of communication and competence interaction between the aluminium section supplier, the product designer and the manufacturers.

The main question raised in this paper is coming from studies in product design and development for sustainability [3], industrial ecology [4], design for environment [5] and [6]. Even if everything is done for a specific component or product with respect environmental considerations, the consequence of distribution, user-practice during its operational life, and possibly recovery of the material used, may give negative contributions to development towards sustainability. This may be due to the infrastructure in the society, the user practice of the product, or harmful effects to natural ecological systems or the society, which is out of control for the designer and product development team. Ways to approach this problem is the subject of the present paper.

First, sources of information for design for environment as presented in [3] and [7] is discussed. Then the attention is drawn to papers from TU Delft [6] where four steps in design for environment is defined in a fruitful way. Further, some observations made by Altshuller [8] in the development of his Theory of Inventive Problem Solving where he distinguish between the five levels of innovations, is discussed. A measure of eco-efficiency [5], [8] is introduced and conclusions are drawn.

SOURCES OF INFORMATION FOR DESIGN FOR ENVIRONMENT

Fig.1 shows elements from which "Design for Environment" has to draw information:

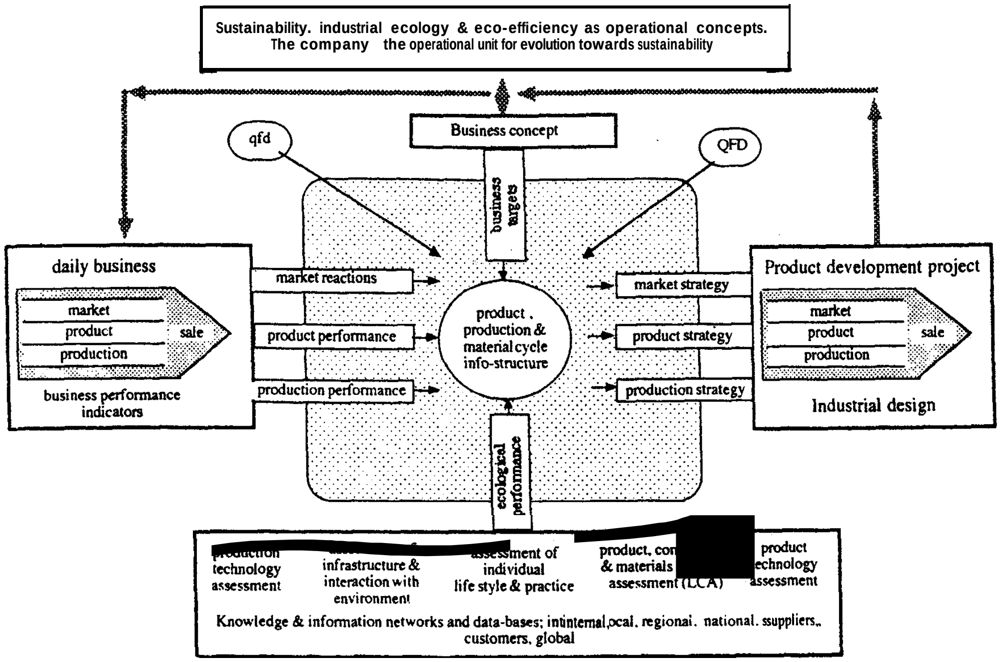

Fig. 1 Sources of information for design for environment [3],[7]

- TO the left of the figure, the daily running of the company is shown, with its market, product, production and sale, in interaction with suppliers and customers. As normal, the business is running on short term performance indicators, and reacts as best as it can to information from the market, product and production performance. The evolution of the company is normally going in incremental steps of improvement of products and processes.
- The company may have decided to improve its competetive position by hiring an industrial designer, indicated on the left of Figure 1. Better adaption to the market need at lower cost improves the situation without any large changes in products or processes.
- If the company has the ambiton to direct its development towards sustainability, it is necessary to make a diagnosis of its ecological performance combined with the assessment of short term competetivness. The centre of figure 1 indicate this diagnostic process. Here all the information about the present competetive position, i.e. the business performance indicators, and the present and future attitudes and preferences of the customers (QFD) and the employees (qfd) are combined with the ecological parameters at the bottom of the figure, and the business concept and targets

at the top of the figure. With this background information, insight and attitude, targets and strategies of the market, product and production can be formulated, and a total design process can be started, having both the short term competetiveness parameters, as well as the ecological performance parameters in mind. It is of outmost importance that the company have all the information needed in a structured and available form. Ways of structuring this information is discussed in [7]. By having this information structured and available, the design team can test the consequences of new ideas, and thus give guidance and directions to the creative processes of finding improved solutions.

There are several important aspects of this “diagnostic part” of the process:
The ecological parameters have many “dimensions”. Five different groups of parameters are given here: (i) life cycle assessment (LCA) of the product, its components and materials. This includes the standard steps in the LCA; inventories, impacts, evaluation and improvement strategies, (ii) assessment of infrastructure of the society and the interaction with the environment that the company and the total product system are a part of [9], (iii) assessment of product technology, (iv) assessment of production technology, (v) tools for suppliers, employees, and customers to assess the ecological profile of their individual life style and practice.Data for this assessments are retrieved from databases and networks as described on the figure 1. Based on the data and the insight gained by such assessments, life cycle cost and eco-efficiency [5] can be applied to check the consequences and feasibility of new ideas.

In order to formulate the business concept and business targets, the concepts of sustainability, industrial ecology and eco-efficiency have to be made operational.

THE FOUR STEPS OF DESIGN FOR ENVIRONMENT

Figure 2 is taken from [6] with a few modifications, and shows the four steps of Design for Environment:

Step 1: Incremental improvement based on common sense and check lists.

Step 2: Complete redesign of existing concept based on some form of eco-indicator and life cycle cost estimator.

Step 3: Alternative fulfillment of functionality based on life cycle assessment (LCA) and life cycle cash flow analysis (LCFA) for alternative product systems, also identifying weaknesses in the infrastructure of society.

Step 4: Functionality completely fitting into sustainable society based on LCA, LCFA and scenarios of alternative infrastructures of the societies.

With reference to Fig.1, it is natural to relate step 1 to the short term actions within the company, step 2 to somewhat longer term projects hiring an industrial designer. In order to carry out step 3 and 4, the need for a full diagnosis as described previously, must be carried out. As shown in Fig.2, this means also that research institutions and universities take part in the long term activities of step 3 and 4.

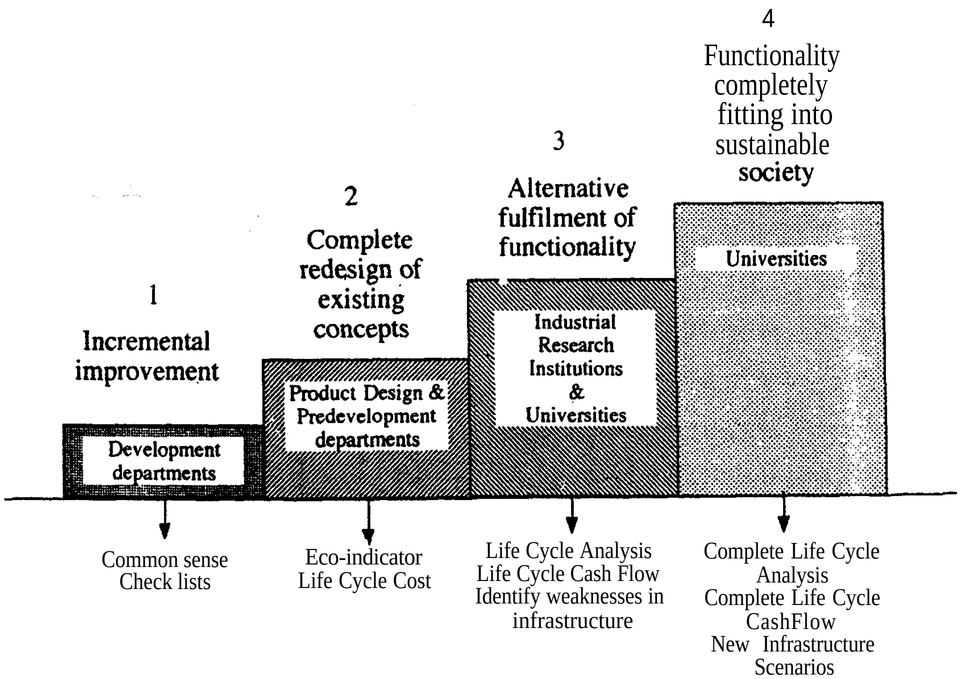

Fig. 2 The four steps of design for environment [6]

THE FIVE LEVELS OF INNOVATION

According to [8], based on studies of patents and scientific discoveries from all areas of technology and natural sciences, technical improvements and innovations can be classified on five levels, Table I.

Level 1: Adaption and incremental improvemnts based on common sense and trial and error.

Level 2: Minor improvements based on conventional problem solving. Here compromises between conflicting design parameters is normal.

Level 3: Major improvements based on inventions that eliminate conflicts between design parameters, utilizing improved problem solving techniques and ideas from all areas of technology.

Level 4: Totally new concepts are created based on a multidisciplinary approach. Here synthesis of technology, the arts and the humanistic sciences are made.

Level 5: The rare cases of discoveries of basic laws and principles of natural as well as social phenomena.

Table I The five levels of innovation [8]

Level	Degree of inventiveness	Share (in % of total number of solutions	Source of knowledge	Approximate number of solutions to consider	Comments
1	Adaption	32	Personal and team knowledge	10	Common sense; trial & error
2	Minor improvement	45	Knowledge within the company	100	Conventional problem solving; compromizing between conflicting designparameters
3	Major improvement	18	Knowledge within the industry :"The technological sphere"	1 000	Inventive problem solving: eliminating conflicts between designparameters
4	New concept	4	Combined knowledge outside and inside the "technology sphere"	100 000	Multidicipilinary approach : synthesis of technology, the arts and the humanistic disciplines
5	Discovery	<1	All that is knowable	1 000 000	Flash of "divine" inspiration ?

Based on the data from Altshuller [8], almost 80% of all innovations are related to level 1 and 2, which seems to be on the same levels as step 1 and 2 in design for environment. It is necessary to bring the result of the design and the product development processes up to level 3 and 4. Again the need for a diagnosis to guide and direct the process of innovations as described on Figure 1 is necessary.

ECO-EFFICIENCY

A performance indicator that reflects the combined efforts of short term competetiveness and long term sustainability is given by the concept "eco-efficiency" [5]: " A product or process that simultaneously meets cost, quality and performance goals, minimizes adverse environmental impacts and maximises conservation of valuable resources".

Guided by the term "Ideality" of evolution of technical systems defined in [8], the following equation of "Eco-efficiency" may be defined:

ECO-EFFICIENCY = (WANTED EFFECTS)/ (COSTS + HARMFUL EFFECTS)

This measure will increase when a change in the total product system give a sum of wanted effects at lower cost and reduced sum of harmful effects. It is, however, important to observe that where as the terms "wanted effects" and "costs" should have well defined system boundaries, the term "harmful effects" should not have any system boundary at all. It is result of a dialog between all involved and concerned parties. An evolution towards sustainability of a technical system, means then an increase in eco-efficiency, using an holistic approach to evaluate the effect of this product system on the society. This certainly requires a variety of competence profiles of the persons engaged in the development of the product system.

The persons that carries out the diagnosis must have other qualities than the creative designer, the research engineer and scientist, the effective production engineer or the manager of the company. It is the competence within these groups, as well as communication between these groups, the suppliers, the customers and the society that is the key issue.

CONCLUSIONS

The suppliers of aluminium extrusions, the extrusion plant, can contribute with the improvements of eco-efficiency by deliever "better,' cleaner, faster and cheaper" products and services [10]. Here, the steps one and two of the design for environment, as well as the level one and two of innovations applies. When it comes to improved eco-efficiency of the total product system, however, during its total life cycle as a part of the infrastructure of the society and the natural ecosystem it belongs to, then the individual plant will be an element in a greater production, distribution, service and retrieve1 system, optimized on many levels. Here, the steps three and four in design for environment and levels three and four of innovation applies.

In the competition between the materials, the knowledge of aluminium as a material for product system concepts adapted to fully sustainable societies, new competences has to be developed and new alliances has to be formed between the industry, the universities, educators and the governmental organisations.

The consequences is that the competition between the material suppliers and producers, will not be so much on the day to day level, it will rather be competition between alternative systems concepts for improving the infrastructure of the society, the functionality of the product and the experiences of the stakeholders, in a way that contributes to increased eco-efficiency for the society.

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