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FASTENERS AND JOINS SELECTION, TO FACILITATE REUSE, REPAIR, UPGRADE AND RECYCLING

Bârsan Anca, Bârsan Lucian
Transilvania University of Braşov, abarsan@unitbv.ro

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Abstract: Considering the life of a product, from the early stage of raw material extraction, continuing with the production, distribution, use, and the end of life stage, one of the ecodesign principles consists in increasing the duration of its useful life stage. The paper presents some designing options considering the use of fasteners and joins which are meant to lead to products that can be more easily reused, repaired, upgraded or recycled and accordingly, some useful recommendations for engineers regarding the choice of joins and fasteners in product development.

1. THE LIFE CYCLE OF A PRODUCT

In the early 90s, the concepts of sustainability and sustainable development became of a great interest and, related to it, the necessity of evaluating the product and the product effects/impacts over a long period of time. This period of time expends from the early stage of raw material extraction continuing with the production, distribution, use, and disposal stages. This sequence of stages was named "life of a product" and reflects the fact that any product is being born (designed and produced), have a life (use/consumption) and finally ends its life (being disposed).

The possibilities of reusing, reconditioning or upgrading the product and recycling the raw materials from a product's parts created the possibility of extending the life of the product, creating the concept of "life cycle of a product". The options at the end of product's life are presented in Figure 1.

- **Product reuse and upgrading**. At its end of life, a product could be reintroduced in the life cycle, as it is (if it is anymore useful), or after repairing, remanufacturing or upgrading it.
- **Recycling.** If a product cannot be reused, recycling would represent the next alternative. Recycling represents a series of activities that includes collecting of recyclable products and materials (that would otherwise be considered waste), sorting and processing them into raw materials which are used into new products manufacturing.
- **Disposal with energy recovery.** When reuse or recycling of a product is not possible, incineration, preferable with energy recovery, is another end of life option. Incineration is the process of destroying waste material by burning it at very high temperature, producing heat and/or electricity.
- **Land filling.** The products and components which cannot be successfully recycled or treated using the above measures finally go to landfill sites where they are stored.

At the end of life of a product, the success of the recovery and reprocessing of components and materials, both on technical and economical levels, is not only dependent on the applied recycling technology but also on the design of a product. Most manufacturing companies are usually concerned with the products environmental impact, but they are primarily focused on manufacturing operations and the operating life of a product. The development of design for recycling is a waste prevention measure adopted by a company with respect to a product it manufactures. Usually, the designing stage of a product rarely involves a crucial dimension for recycling [5]. To achieve the aims for product design for recycling, the strategies presented bellow could be considered: using of recycled/recyclable materials, designing mono material products, avoiding or minimizing the use of hazardous substances, modular design easy to dismantle, product components identification, development of recycling simulation system, providing all information to assist recycling in documentation.

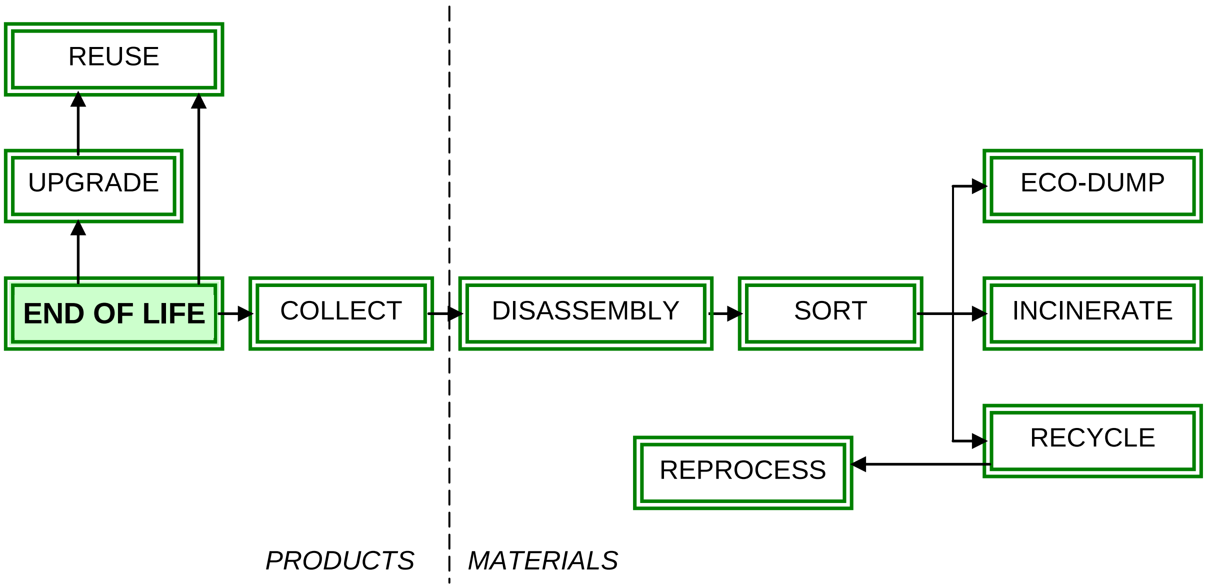


Figure 1. End of life options for a product;

2. JOINS AND FASTENERS FACILITATING DISASSEMBLY

A product designed to be readily taken apart can be repaired or upgraded with ease. At the end of its useful life, the product can also be quickly and economically disassembled for reuse or recycling of parts. Manufacturers are developing new innovative fasteners to meet this need for ease of disassembly. In addition, through the ingenuity of product design teams, new environmentally compatible uses are being found for existing connectors.

Some of these fasteners are easily detached for quick disassembly to allow products to be upgraded or repaired with ease or recycled at the end of life.

Other types of fasteners replace hazardous adhesives that were being used to join parts. Over the longer term, these types of fasteners can make the product an asset and a resource instead of a costly waste at the end of its usefulness.

In addition to the development of new types of fasteners, it is important to consider how existing connectors can be used to enhance the environmental attributes and manufacturing efficiency of a product. There are a number of ways that the parts making up a product can be fastened or connected together. From the disassembly point of view, the joints are classified as: reversible or permanent.

Unlike permanent ones, reversible joints can be removed and re-used without damaging the joint itself. The reversible joints are more convenient for disassembling.

Considering the assembly structure, the connection between two parts of a product can be achieved by using [4]:

- discrete fasteners (separate connector from the part);
- integrated fasteners (molded into the part);
- bonding, or
- other ways of joining parts.

Examples of these connections are presented in Table 1.

The discrete fasteners, threaded or non threaded, have three special characteristics: they do not require heat, they can join dissimilar material, the thickness of joined parts can be different. They are usually metallic, but rigid polymeric materials can be used also.

The integrated fasteners are used, generally, as locators or locks for the assembled parts. They are known also as snap fit fasteners. The mostly used snap fit fasteners, in product development, are presented in Figure 2.

The snap fit fasteners involve no heat, they join dissimilar materials, they are fast and cheap and-if designed to do so- they can be disassembled. It is essential that the snap can tolerate the relatively large elastic deflection required for assembly or disassembly. Polymers, particularly, meet this requirement, though springy metals, too, make good snap fits.

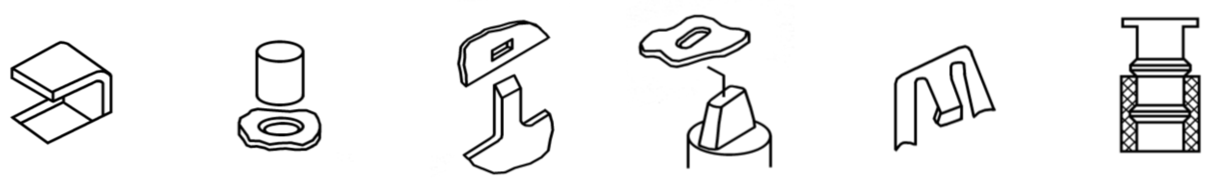
Table 1. Classification of the connections between parts of a product

MECHANICAL FASTENING					BONDING	OTHER
Discrete fasteners *(separate connector from the part)*		**Integrated fasteners** *(molded into the part)*				
threaded screws; nuts & bolts; studs; hooks; bolts; turnbuckles; spring toggle	**non-threaded** nails, tacks; retaining rings; keys; pins; clips, staples; snaps; rivets	**locators** stop; lug; pin in hole; wedge in slot	**locks** cantilever hook; trap; snaps; ball & socket	**compliant** cantilever spring; crush rib feature	energy bonding; welding; brazing; solvent bonding	velcro; crimping; seaming

The most suitable materials to be assembled by snap fit fasteners are those with a large yield strains (yield strain = yield strength/elastic modulus) and with moduli that are high enough to ensure good registration and positive locking [1]. Polymers have much larger values of yield strain than metals. Elastomers have the largest yield strains of all materials, but their low modulus means that the assembly will be too flexible. Among metals, the recommended ones are spring steels, copper beryllium alloys and cold worked brass.

The snap fit fasteners are used, typically, to join small or medium sized polymer parts, metal casing or sheet parts.

Welding and energy bonding represent an alternative to the mechanical fastening, for metals and thermoplastics. If it is intended to reuse, repair, upgrade or recycle the product, the bonding procedure is not one to facilitate the mentioned actions at the end of life product stage and has to be avoided.



a. Lug — b. Pin-in-hole — c. Cantilevered hook — d. Wedge in slot — e. Trap — f. Annular trap

Figure 2. Examples of snap fit fasteners

3. CONCLUSIONS REGARDING THE CHOICE OF FASTNERS AND JOINS IN ORDER TO FACILITATE RECYCLING, UPGRADING AND REPAIRING

The upgrade, repair or recycling of the products are facilitated by an adequate choice of joins and fasteners. These connection systems have to be adopted considering the type of material of the joined components of the product, but also the type and importance of the load on the joint or fastener. The recommendations can be systematized as it follows:

- Reduce the number of fasteners;
- Use the least number of different types of connectors as possible, in order to minimizes the number of tools that are needed when disassembling the product for repair, upgrades, or disassembly;
- Use discrete fasteners for important loads of the joint;
- Use integrated fasteners for connecting components made of polymers;
- Use fasteners that can be removed without tools;
- Use fasteners that can be removed by using common tools (screw driver, wrench) to facilitates ease of repair, upgrade implementation, and disassembly for recycling
- Standardize fasteners;
- If metal bolts are used, they should be of the same head type, magnetic, and have integral washers. Magnetic fasteners of the same head type with washers are easily disconnected, then separated out magnetically during the recycling process;
- For bolt assemblies, use the same dimension of the screw and if possible, hexagon head screw, considered to have the shortest time for disassembly;
- Reduce the number of press fits which do not have “push out” capabilities;
- Use plastic fasteners made from the same polymer type as the part to facilitates recycling of the product;
- If screws are used, use coarse threads versus fine threads. Screws with coarse threads take less time and energy to remove;
- If fasteners require destructive removal, ensure that their removal will not result in damage to the reusable parts, by incorporating breakpoints or appropriate strong lever points [3].

By using these guidelines, the engineers and designers could develop more environmental friendly products which can be easier repaired, upgraded, reused. This way, the durability of product is assured and one of the goals of ecodesign is achieved. For the products or components which cannot be reused, after repairing, refurbishing or upgrading them, the recycling remains the best opportunity to reintroduce the material into the product cycle, directly into the manufacturing or use stage. The disassembly of the product in order to be recycled is facilitated by following the above recommendations.

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