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A new model to select fasteners in design for disassembly

Thomas Jeandin*, Christian Mascle *

Department of Mechanical Engineering, Ecole Polytechnique de Montréal, C.P. 6079, succ. Centre-ville Montréal (Québec) H3C1J4, Canada

* Corresponding author. Tel.: +1-438-397-4865. *E-mail address:* thomas.jeandin@polymtl.ca

Abstract

Product disassembly will only take place if there is enough generated profit. But as the end-of-life is often overlooked during the design process it makes the disassembly hard to perform and therefore the profitability is especially reduced. Design for disassembly is one of proposed solutions and fasteners are one of the points that have most impact on the disassembly of products. The aim of the proposed model is to determine among several alternatives which one allows to meet the requirements in assembly, in-use, services and disassembly. The model takes into account the semi-destructive disassembly (deteriorate a part of a sub-assembly to recover valuable components or materials and while reducing the disassembly time without important value loss). The model developed in this paper is mainly based on the Analytic Network Process (ANP) to define the best alternative and make the fastener selection during the design process easily. An example is presented for a better comprehension.

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1. Introduction

Having to take into account disassembly has become a necessity for manufacturers. Indeed, respect of the environment is a point more and more important and products cannot be developed without taking their environmental impact into account. So manufacturers have had to adapt to these new constraints. One possibility is to facilitate the revival of products at the end of their life to minimize their impact. For this it is necessary to design products taking into account disassembly that will be performed at the end of the life cycle in order to recover the parts or materials as efficiently as possible. Some manufacturers have well understood that end of life products are not only wastes and that they can derive many benefits from the disassembly. We can for example quote Fuji Film Co. Ltd, which produces single-use cameras [1]. A very thoughtful design allows efficient disassembly through an automated factory. By reusing parts and recycling materials, about 95% of the products weight is recycled. Moreover, the recovery of parts that are used in the manufacture of new products, allows reducing the time and the production cost.

Different methods have been developed to facilitate the work of designers, they are a part of the Design for Disassembly, DfD. Different approaches are possible as the optimization of disassembly strategy or techniques [2], the aspect that interests us more specifically is the choice of fasteners. They have a strong influence on disassembly and a poor choice of fasteners can cause a long and difficult disassembly and therefore significantly reduce profitability. The main problem that arises in the selection of fasteners is the consideration of all aspects of the different phases of the life cycle. An attachment must both, ease as much as possible the assembly, withstand stresses during use of the product and enable an efficient disassembly. The designer must therefore succeed in finding the best compromise.

Different methods of choice for fasteners have already been developed; we can first mention the method developed by Güngör [3]. This method relies on the Analytic Network Process (ANP). The different phases of the life cycle are taken into account with parameters representing the difficulties of assembly, number of fasteners, the required space, tools ..., others representing the constraints related to product use such as reliability or appearance and finally parameters representing the problems encountered during disassembly. The evaluation of alternatives is based on comparisons

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between parameters and cannot be enough accurate, moreover the method is long to set up and may lengthen the duration of the product development phase. Another method that we can quote was developed by Ghazilla et al. [4]. It uses the decision making method PROMETHEE with different qualitative and quantitative parameters which primarily represent problems related to the disassembly. Parameters related to the costs and physical properties of attachments are also taken into account.

The results obtained through these methods are interesting, but some aspects are not taken into account consequently the use of these methods is limited to certain cases. A very important aspect of the disassembly which is not considered is the possibility of a semi-destructive disassembly of the product. This involves destroying a fastener or a part to recover easily a more valuable part. The time saving is often important without losing many values compared to a non-destructive disassembly. The presented method addresses this disassembly aspect in order to offer a more complete method.

2. The ANP method

To assess the possible fastener alternatives to assemble a product we decided to use the ANP method developed by Saaty [5] which is a decision making method. This method has proven itself in various fields and allows evaluating different possibilities taking into account a large number of parameters. This method uses a system of pairwise comparison between the parameters related. We must determine which parameter is the most important and how many more important. A comparison scale was developed, ranging between equal importance of parameters until absolute importance of a parameter on another. Before performing these comparisons it is necessary to create the network that represents the problem studied by defining all the parameters taken into account and the links between them.

We tried to represent the majority of the problems encountered when selecting fasteners that are related to assembly problems, to the product use and to the disassembly process. The network that we used includes 4 groups, a group that includes the proposed fastener alternatives and a group for each of the product life cycle phases. The parameters included in these groups are detailed in the following sections.

2.1. Alternatives group

Before using this method it is necessary to define several alternative fasteners. These alternatives are included in this first group. The fasteners can be classified into different families according to their characteristics. Sonnenberg [6] proposes in his PhD thesis a separation into 5 main families:

- *Discrete fasteners*. These attachments are independent parts such as screws or rivets.
- *Integral attachments*. The attachments are integrated into parts and generally allow assembly without additional parts such as snap-fits.
- *Adhesive bonding.* The parts are linked with adhesive materials such as glues.
- *Energy bonding.* With an input of energy it is possible to create a link between parts. This is the case for the welding or soldering.
- *Other fasteners.* This family includes various types of fasteners like crimping or zippers.

2.2. Assembly group

This group includes the parameters that reflect the problems encountered during the product assembly. A literature review has allowed us to determine the useful parameters that are:

- *Number of fastener elements*. Depending on the type of fasteners used the number of parts will be more or less important. A small number of parts generally facilitates the assembly.
- *Space required.* Each type of fastener requires a minimum space to be installed which must be as small as possible.
- *Number of assembly steps*. This parameter affects directly the assembly time and therefore the profitability.
- *Probability of damage*. The assembly of the product can cause damage to the parts or the fasteners and thus reduce the quality of the product or force a replacement.
- *Cost of changes*. If a change of fasteners is chosen, the design of the parts must be changed. Depending on the type of attachment selected at the beginning the modifications will be more or less important.
- *Test difficulty*. To validate a design, tests are often necessary. Some types of attachments make these tests difficult.
- *Assembly complexity*. This parameter is actually a global parameter involving several other parameters and is calculated differently. We will detail the calculation in the next section.

2.3. Use of the product group

When using the product, several constraints must be respected. The parameters we chose are the following:

- *Ability to support different environments*. To ensure product reliability, fasteners must be able to withstand different conditions. Some attachments are more effective on this point and more resistant when there are problems with moisture or temperature variations.
- *Fastener reliability*. Ensure a reliable connection is a vital aspect to ensure product quality.
- *Effect on appearance*. The appearance of a product is important and depending on the type of fasteners selected the result will be different. This can lead the user to discard a product because he is no longer satisfied with the appearance of the product. An attractive appearance is a good marketing aspect but it also ensures a longer use of the product before its replacement.

2.4. Disassembly group

Choosing a type of fastener greatly influences the disassembly of the product. To represent the problems related to the disassembly we use the following parameters: