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PART BASED PRODUCT UPGRADE

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1. Introduction

Product upgrade is an important method for prolonging the life of products in the market, since development from scratch is characteristic only of a small percentage of products. Product upgrade discussed in this paper does not only refer to the phase of product use and to an increase in its quality of function fulfillment, but to all phases of product life cycle, because it enables us to reduce the costs of manufacture, assembly, transport, maintenance, recycling and disposal etc. Part based product upgrade means product improvement as a result of improvements to its parts (i.e. changes in the values of part characteristics), whereby these changes have no effect on product architecture. Preservation of product architecture is emphasized here because it enables simple product improvements, while changes in product architecture lead to new connections and interactions between the parts and are therefore more complex.

In spite of the significance of part based product upgrade there are still many companies which upgrade their products using the trial and error approach. This is characteristic primarily of those in which a need for product upgrade occurs rarely due to specific features of the product/market. From literature on product development (e.g. [Andreasen&Hein 2000, Ulrich&Eppinger 2000]) and adaptive design (e.g. [Pahl&Beitz 1993]) one could naturally infer about activities which are necessary for product upgrade, but this is too large an undertaking for such companies. In [Žavbi&Duhovnik 2000], the discussion of product upgrades was not focused on part based product upgrade, and "granularity" of decomposition was not addressed there either. For this reason, the objective of the procedure described in this paper is to enable a more focused, part based product upgrade, which should largely replace the trial and error approach. Special attention is paid to granularity of decomposition enabled by parts, e.g. the simplest building blocks, as one wonders whether such granularity is always useful.

The structure of this paper is as follows: Section 2 describes a procedure for part based product upgrade and the subsections contain a description of individual activities with their results, which serve as the starting point for the next activity. Section 3 discussed the question of granularity of decomposition and Section 4 contains the conclusions.

2. Activities

A procedure for part based product upgrade, which relies on function based decomposition, is proposed. Decomposition should be function based, because functions might be fulfilled by "parts" which are not obvious at first sight (e.g. air cushion in micromechanical accelerometer). A part is defined as a basic element made of a single material without any assembly operations [Mortensen 1999] and described using the following pattern:

Part:

form: *value*
material: *value*
dimensions: *value*
tolerances: *value*

Such elaboration enables a focused approach to part characteristics (i.e. form, material, dimensions and tolerances) and their values which are regarded as sources of possible product improvements. Variation of the values of these characteristics is prime motor for the generation of product improvements.

The proposed procedure for part based product upgrade can most easily be presented with a simplified diagram (Figure 1).

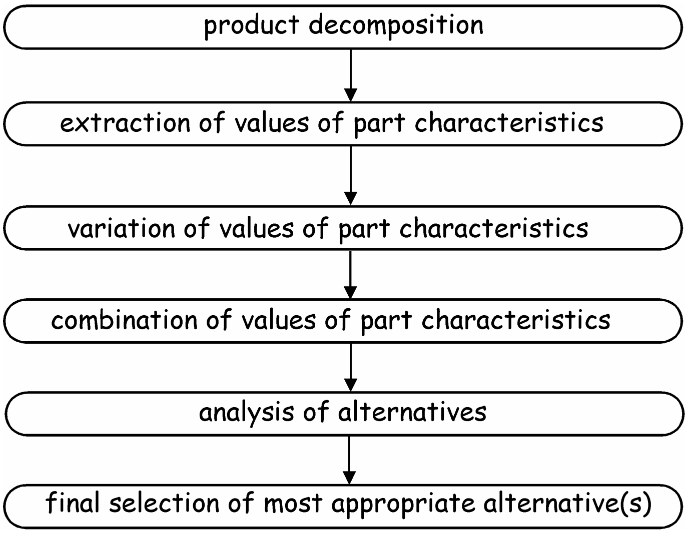

Figure 1. Activities in part based product upgrade

The following subsections briefly describe activities of the procedure presented in [Žavbi 2002]; some are analytical in nature, some synthetic. Some descriptions are also illustrated by short examples.

2.1 Product decomposition

Product decomposition is the basic (analytical in nature) activity of the proposed procedure and enables a clear presentation of the product's parts. Clarity of presentation is important, as the described procedure is intended for part based product upgrade, in which improvement of a few parts or all of the parts serves as the source of product upgrade. It needs to be said that decomposition does not refer only to original products, but also to competitive ones – it is difficult to imagine quality upgrades without analysis of competitive products.

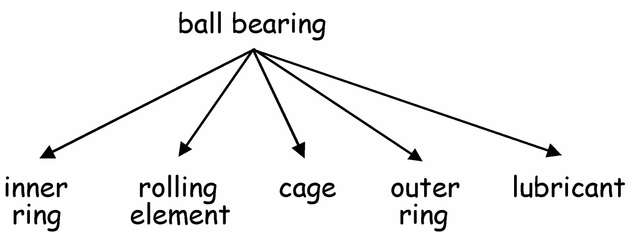

Figure 2. Decomposition of a ball bearing

Let us present decomposition through this short example (Figure 2). A standard ball bearing is decomposed to inner ring, outer ring, cage, rolling element and also lubricant, which at first sight does not even appear to be a part of the bearing, but is very important.

2.2 Extraction of values of part characteristics

As mentioned above, each part has certain characteristics, namely form, material, dimensions and tolerances, and characteristics have values. The extraction of these values is the next activity (analytical in nature) of the procedure and it enables a detailed description of the parts. However, products do not contain only company's own parts, but also supplied parts and building blocks of higher complexity. This raises the question of usefulness of access to details, which is enabled by decomposition down to the level of individual parts. This problem will be discussed further in Section 3.

Bearing parts shown in Figure 2 are described using the pattern presented at the beginning of Section 2, e.g.:

Inner ring:

form: *ring*
material: *steel*
dimensions: …
tolerances: …

Rolling element:

form: *ball*
material: *steel*
dimensions: …
tolerances: …

2.3 Variation of values of part characteristics

The previous activity yields a description of product parts and serves as the starting point for the variation of values of part characteristics (synthetic in nature). By varying the values, one generates alternative values of the characteristics.

Below is an example of the variation of values of some bearing part characteristics:

Inner ring:

form: *ring*
material: stainless steel, ceramics, PTFE, glass, etc.
dimensions: …
tolerances: …

Rolling element:

form: roller, cone, ellipsoid, etc.
material: stainless steel, ceramics, marble, glass, wood, etc.
dimensions: …
tolerances: …

2.4 Combination of values of part characteristics

Combining of values enables us to generate alternative parts, which differ from original ones in that their characteristics have new values. Naturally, combining refers not only to the values of characteristics of individual parts, but also to parts in their entirety. Morphological matrix [Zwicky 1961] is useful graphical tool which supports combining of generated alternative parts.

The example below shows a few combinations of the values of characteristics of some bearing parts:

Inner ring 1:

form: *ring*
material: stainless steel
dimensions: …
tolerances: …

Inner ring 2:
form: *ring*
material: *ceramics*
dimensions: …
tolerances: …

Rolling element 1:
form: *ball*
material: *ceramics*
dimensions: …
tolerances: …

Rolling element 2:
form: *roller*
material: *PTFE*
dimensions: …
tolerances: …

2.5 Analysis of alternatives

The number of possible combinations can prove to be large, but it can be reduced with regard to upgrade requirements. It is clear that the degree of part/product function fulfillment which is enabled by the synthesized alternatives varies and that in many cases it is lower than that of the original product, i.e. the one we are trying to improve. The criteria for assessing the degree of function fulfillment are both qualitative (e.g. level of cultural/social acceptance, ease of maintenance, etc.) and quantitative (e.g. vibration level, electricity consumption, weight, etc.), therefore classification into qualitative analysis and quantitative analysis is appropriate. The use of requirements enables a quick reduction of the number of alternatives which are suitable for further analysis. A requirement can for example stipulate a certain type of material (e.g. biodegradable lubricants), thus eliminating all alternatives which are not compatible with such materials. The number of best assessed alternatives which are to be analyzed quantitatively depends on each individual case.

Qualitative analysis is followed by relevant quantitative analysis of the alternatives. This includes e.g. tribological, noise, thermal and cost analyses, etc. of analytical and/or physical prototypes (i.e. alternatives). One of the reasons for the use of prototypes is to be able to verify product behaviour after changes have been made to the values of part characteristics.

2.6 Final selection of the most appropriate alternative(s)

The final decision should be based on the results of relevant qualitative and quantitative analyses performed using the adopted assessment criteria. The usefulness of these analyses depends primarily on how well the requirements and criteria match the expectations of customers and other stakeholders participating in the product life cycle.

3. Granularity of decomposition

A question which arises here is usefulness of the level of granularity for product upgrades. This problem is encountered during decomposition of final products composed of several building blocks of different complexities, which are designed by part suppliers (e.g. ball bearing as supplied component). It is unreasonable to decompose such building blocks to parts. On the other hand, decomposition to the level of parts is insufficient when a building block is at the same time the final product (e.g. ball bearing as the final product).

The question of granularity of decomposition is therefore justified, as our ability to accurately extract/vary/combine the values of individual part characteristics and the quality of product upgrade both depend on granularity. The following subsections will shed some more light on the problems related to different levels of granularity of decomposition.

3.1 Granularity enabled by parts

The proposed procedure is based on decomposition to the level of parts, which are then described by part characteristics (i.e. form, material, dimensions, tolerances) and their values. A sample part description pattern is given in Section 2. Granularity of decomposition enabled by parts is suitable for parts which are not designed, only installed by the manufacturer of the final product, who is, however, interested in their behaviour. Such parts are for example bolts, rivets, fasteners, steel profiles, etc.

3.2 Granularity enabled by form features

Granularity of decomposition enabled by form features is necessary whenever a company desires to improve a part (and consequentially a product) they have designed themselves, because such granularity enables formal access to form feature characteristics and extraction/variation/combination of their values, which serve as the source of possible product upgrades. The following example of a part description pattern also serves as a pattern for describing form features:

Form feature:
- form: *value*
- material: *value*
- dimensions: *value*
- tolerances: *value*.

For a manufacturer of roller bearings, for example, the final product is a bearing, which is composed of an inner ring, roller, cage and outer ring (i.e. parts). If the manufacturer desires to improve the existing roller bearing design, the existing granularity (enabled by parts) will no longer suffice as it does not enable access to form feature characteristics. Therefore, the inner ring needs to be additionally decomposed to raceway, flanks, etc., which are its form features. Changes in the values of raceway characteristics (i.e. form, material, dimensions, tolerances) affect the quality of function fulfillment of the inner ring and consequentially of the bearing.

3.3 Granularity enabled by composite building blocks

The term composite building blocks is used to denote composite components (e.g. glued, soldered, riveted, screwed together, etc.) from several parts. Such components are for example electrical motor, rolling bearing, clutch, propeller shaft, etc. They are always supplied components, i.e. those which are installed by the manufacturer of the final product, making the manufacturer interested in their behaviour and not in their internal structure. It is not possible to draw up a general pattern for describing such components as is the case with parts, because each supplied component has its own set of characteristics which are relevant to the user. Manufacturer of the final product can therefore improve the product only by replacing the existing components with others. Such granularity therefore suffices for all supplied components in the final product and no further decomposition is necessary.

For example, decomposition of a ball bearing (i.e. supplied component) to parts (i.e. inner/outer ring, cage, rolling element) in a speed reducer makes no sense if the goal is to improve the speed reducer (i.e. product), because the gear manufacturer does not posses detailed knowledge about the influences of individual parts of the bearing on the quality of bearing function fulfillment.

4. Conclusion

The part based approach is typically the least radical one. The procedure is limited to the improvement of parts and consequentially products, with unchanged product architecture. However, part based upgrade is not limited solely to use of the product, but affects all phases of its life cycle. Individual activities of the procedure, especially decomposition of competitive products and extraction of the original values of characteristics, are also useful in benchmarking, which should be an integral part of product upgrade.

Main shortcoming of decomposition is a lack of explicit information on the existing and possible new interactions between the parts which would result from changes in the values of characteristics of individual parts. This shortcoming affects usability of the framework for upgrading complex products.

However, such shortcomings can be eliminated to a large degree by decomposing complex products into sub-assemblies and testing the respective prototypes (analytical/physical).

The paper presents and discusses the problem of granularity of decomposition, which affects the accessibility of part characteristics/form features and extraction/variation/combination of their values, which serve as the source of possible product upgrades. This is because products are usually composed of both supplied and company's own parts/components of different complexities, therefore it is reasonable to use mixed granularity in product decomposition; fine (i.e. level of form features) for one's own parts/components and coarse (i.e. level of parts/assembled building blocks) for supplied parts/components.

The author believes that the proposed procedure provides a useful framework for part based product upgrade and gives sufficient guidance to companies in which product upgrade is a rare occurrence. In addition, it also enables archiving of the entire product upgrade process.

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