INTERNATIONAL DESIGN CONFERENCE - DESIGN 2004
Dubrovnik, May 18 - 21, 2004.

DESIGN 2004

PART BASED UPGRADE OF A VACUUM CLEANER MOTOR

J. Rihtaršič, R. Žavbi and J. Duhovnik

Keywords: product upgrade, product decomposition, product characteristics

1. Introduction

In order to maintain or increase their market share, companies usually opt for upgrading their existing products, while designs from scratch are limited to a small number of cases only. Since the upgrading is still often based on the trial-and-error principle, it has been decided to take a more systematic approach in search of improvements. Mainly due to its simplicity, Domel d.d. decided to test the prescriptive model of part based product upgrade [Žavbi&Duhovnik 2001, Žavbi 2002] in search of improvements. Therefore, a detailed analysis of the changes, introduced to the vacuum cleaner motor 496 family, will follow.
The whole vacuum cleaner motor (thereinafter VCM) will be divided into individual sub-assemblies as they occur during its assembly process. Afterwards, all changes that occurred within the sub-assembly will be collected. Changes for each sub-assembly will be further classified into characteristic classes of changes: changes of the working principle, dimensions, shape, topology and materials. In relation to the number of changes that occurred within an individual sub-assembly, conclusions will be made, regarding its technical sophistication. Attention will be paid to the sub-assemblies that have been subject to changes to a lesser degree. Parts of these sub-assemblies will be then proposed as the subject of changes as it is presumed that these parts have the greatest potential for economically justifiable changes.

a) b) c)

Figure 1. Vacuum cleaner motor from the a) 493, b) 496 and c) 462 family, produced by Domel,d.d

A VCM (figure 1) will serve as an example of the importance and influence of upgrading a VCM on its “attractiveness“ on the market. The correlation between the “attractiveness“ and upgrading will be shown by means of the comparison between the number of orders or, in other words, the production of VCM, and the number of changes in a year (Figure 3 and Figure 4).

2. Part based product upgrade approach

The selected model is particularly suitable for products that have been on the market for a longer period and have been subject to a number of changes. On the basis of these changes, we can take a systematic approach to the search of solutions on the parts that were to some extent not in the focus of attention (they were therefore subject to a lesser degree of changes). The use of the descriptive statistics and focusing on the parts that have been subject to the smallest number of changes are particularly desirable in case of products whose functional description is difficult (in the mathematical sense) due to a vast number of variables. In these cases, the correlation between a change of a part and an improvement of the product properties is not direct. Therefore, an improvement of the VCM correlates to its efficiency, noise, vibrations, heating and also its price. An improvement of a property that causes too serious deterioration of one or more other properties is therefore unacceptable. The decomposition is followed by the analysis of the changes that the parts of the product have been subject to. This activity was not planned in the original model (figure 2). Using the descriptive statistics, it is our aim to eliminate subjectivity from the process of defining changes. Namely, it is in the human nature to give preference to those changes of characteristics whose consequences (i.e. changed properties) can be predicted and to avoid the less known areas. The remaining steps will be illustrated on the sub-assembly that will prove to be the least technically sophisticated. Details follow in [Žavbi&Duhovnik 2001, Žavbi 2002].

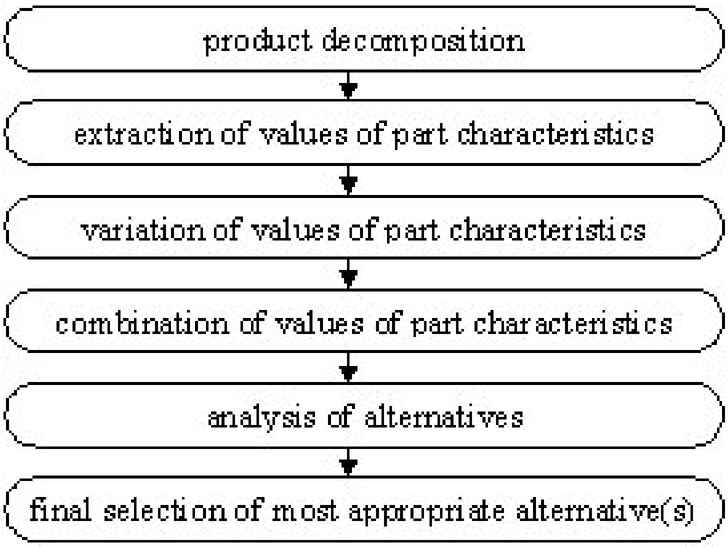

Figure 2. Activities in part based product upgrade-original model [2]

3. Upgrading VCM

The production of VCM at Domel d.d. company began in 1976. With our own development we reached a market share of 35%, which places us among top VCM producers in Europe (Figure 3). VCM consists of a commutator electric motor and a fan stage. The VCM 496 family, which includes those VCMs where the majority of the basic constituent parts is the same, will be presented in the follow-up.

The VCM 496 family was originally designed in 1985. It was subject to its first changes in 1986 (Figure 4). The changes do not only reflect a better functionality and higher efficiency, initiated by Domel d.d., but are mainly the result of adapting to the needs of customer. A change that occurred on one VCM from the 496 family and was then introduced to another VCM from the same family, was recorded only once.

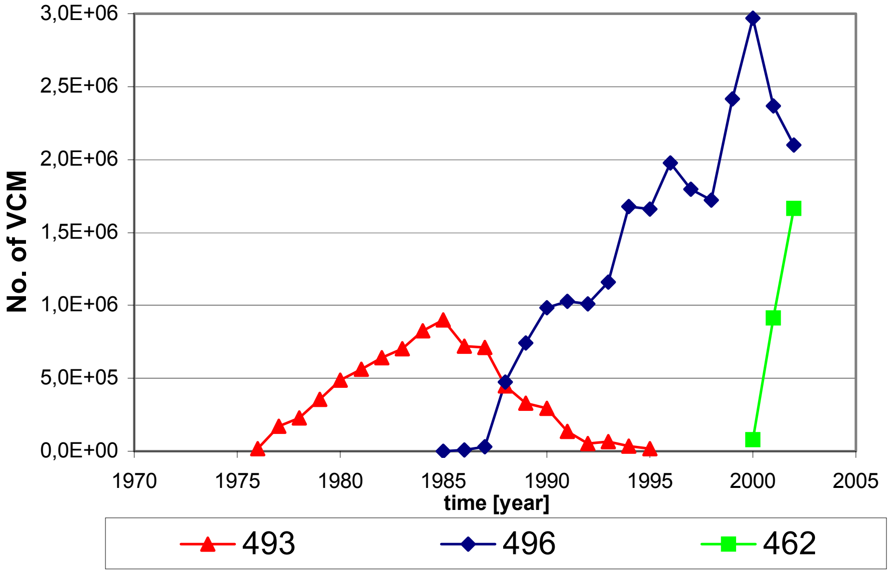

Figure 3. The number of annually produced VCM

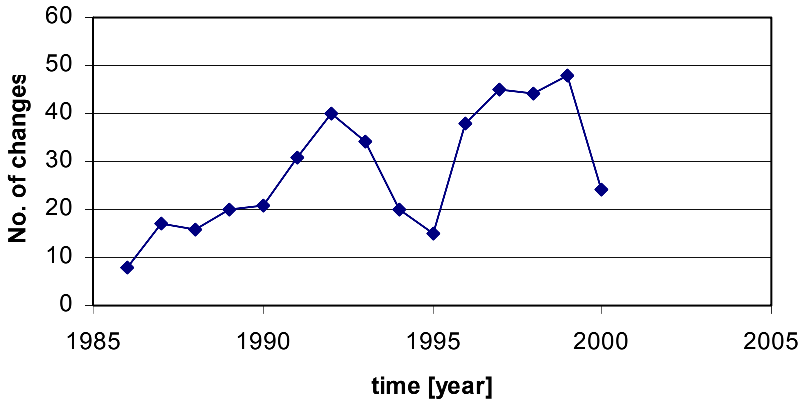

Figure 4. The number of all changes of the VCM 496 family in each year

Comparison between the graphs, showing the number of changes and the number of produced (sold) VCM in a year reveals that the increase or decrease of the number of changes does not correlate directly to the increase, decrease or stagnation of sales. It happens after one or more years' delay. It can be noticed that the number of changes dropped significantly between 1992 and 1995, however, the sales were rising. On the other hand, the number of changes grew between 1995 and 1998 while the sales stagnated. The last major decrease of changes in 1999 is reflected by the decrease of VCM sales in 2000.

3.1 Product decomposition

The majority of changes, occurring on the basic constituent parts is qualified as the change of the *working principle, dimension, shape, topology* and *material.* However, a group of unclassifiable changes remains. They cannot be classified into any of the above-mentioned classes. Most often they mean the substitution of an individual part with an equivalent part by another producer with the purpose of improving functionality, reduction of costs, extending the life cycle or the original part was simply not supplied in sufficient quantities and a substitute had to be introduced.

The total number of changes, recorded in the VCM 496 family between 1986 and 2001 equals 428. Figure 5 shows that the greatest number of changes occurred in the dimension class, followed by the changes of shape. The lowest number of changes occurred in the class of working principles, where only one such change occurred - load transfer by means of friction replaced the shape load transfer. A relatively big number of alternative spare parts, listed under the heading other changes is a result of large-scale production with many constituent parts. In the case of small-scale production or individual products the number of these changes is smaller or they are non-existent.

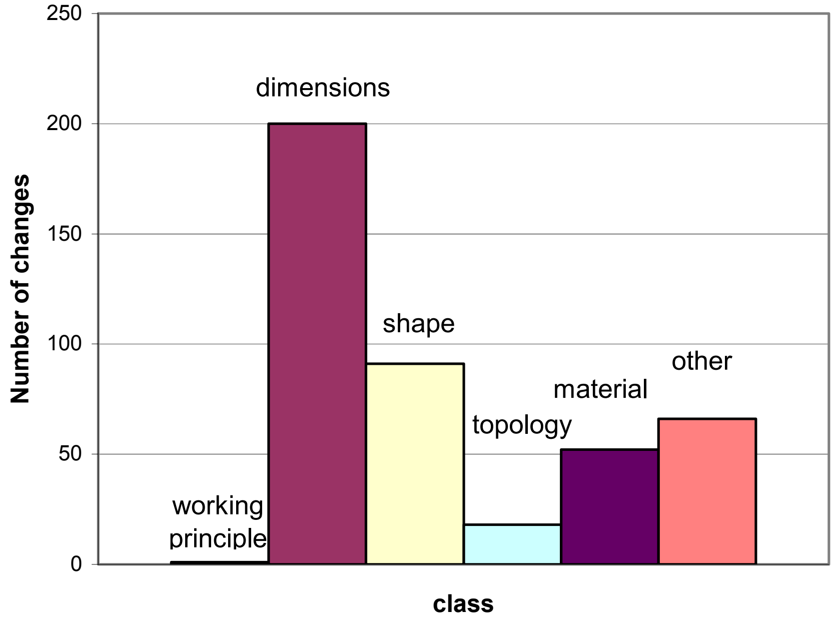

Figure 5. The number of changes within the classes

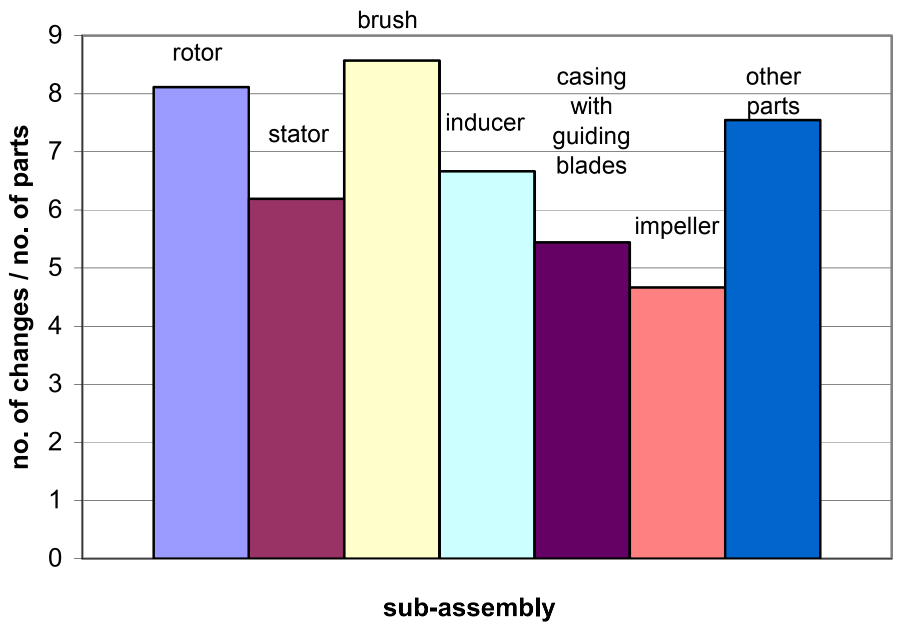

Figure 6. The number of all changes in relation to the number of parts for each sub-assembly

Although the greatest number of changes are made on individual parts, all changes cannot be attributed to individual parts as some of them occurred as a result of the assembly of parts. This type of changes occurred in the area of design tolerances and technical changes. We tried to take account of these changes by putting individual parts into sub-assemblies as they occur during the assembly of a VCM. The parts, occurring individually and not within a sub-assemblies during the assembly process, have been put into the group other parts.

Figure 6 shows the number of changes in relation to the number of parts, forming a sub-assembly. Based on the initial hypothesis, regarding the correlation between the number of changes and the sophistication, it is possible to make a conclusion that the brush reached the highest level of sophistication. The lowest level of sophistication and also the highest potential for improvement is therefore possible in the impeller sub-assembly.

Once an assembly or constituent parts with potentially the highest possibility of economically justifiable changes have been selected, the classes with the lowest number of changes should be looked into (Figure 7).

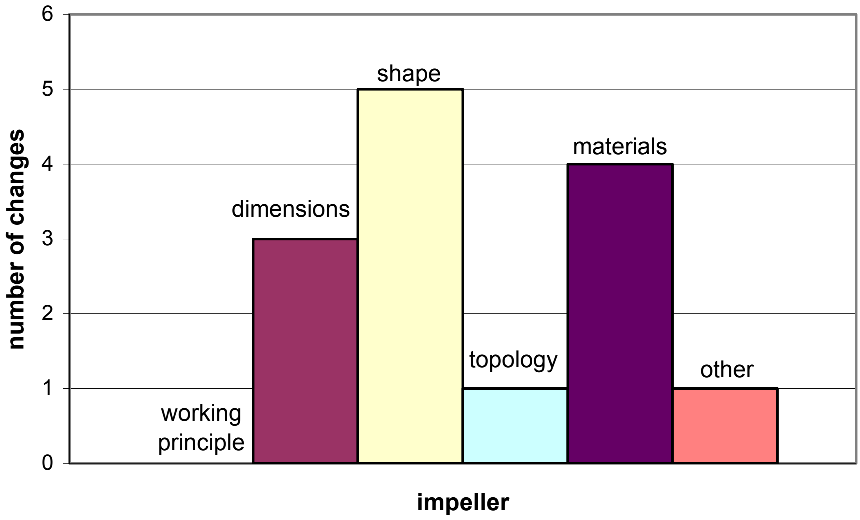

Figure 7. The number of changes within the classes for the impeller sub-assembly

The impeller sub-assembly shows that no change occurred in the category of working principles and only one in the topology class. Class other includes one technological change, which was made for the balancing purpose of the VCM.

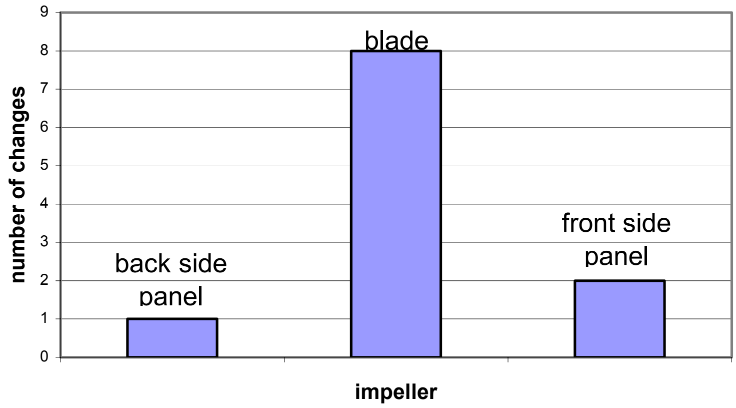

Figure 8. The number of changes on basic parts of the impeller assembly

Therefore, the most radical changes are expected in the field of working principles and topology, however, it is often necessary to look closely at the changes in other categories, too. For example, the

material itself was changed only twice, when the mechanical properties were improved, while in two other cases it was a matter of changing the dimensions of the input raw material.
When an assembly is to be broken down into individual parts it needs to be borne in mind that all parts within an assembly are not of the same importance in terms of fulfilling the main functions of the product (their function can be of the linking nature or they can be there only as a temporary solution). The impeller sub-assembly shows that the number of changes of the blade sticks out, while the number of changes of the back and frontside panels was much lower (Figure 8). When the sub-assembly is further broken down into individual parts, we lose changes which result from assembly process.

3.2 Defining characteristics of the parts of the impeller assembly

Characteristic are attributed to the parts of the impeller sub-assembly, following the latest changes.

Backside panel:
- dimension: …
- shape: flat plate
- topology: …
- material: steel

Blade:
- dimension: …
- shape: curved plate
- topology: …
- material: steel

Front side panel:
- dimension: …
- shape: curved plate
- topology: …
- material: steel

3.3 Varying the values of characteristics of individual parts

Figure 8 shows that the impeller sub-assembly has not been subject to changes of the working principle as this type of change has the greatest impact on the architecture of the existing product. It is associated with a number of design as well as production changes, which can in case of highly automated production, result in high costs and eventually do not justify the change. Therefore, in the case of VCM, it has been decided not to change the working principle, which in turn does not appear as a variable, whose characteristic values could be a subject of varying.

Backside panel:
- dimension: 0...130, etc.
- shape: flat plate, curved plate, etc.
- topology: …
- material: steel, aluminium, plastic, composite material, etc.

Blade:
- dimension: …
- shape: curved, flat, profiled, with constant width, with variable width, polished etc.
- topology: …
- material: steel, aluminium, plastic, composite material, etc.

Front side panel:
- dimension: 0...130, etc.
- shape: flat plate, curved plate, etc.
- topology: extended blades, etc.
- material: steel, aluminium, plastic, composite material, etc.

Impeller on figure 9 features a curved front side panel and variable blade width. The back side panel is flat.

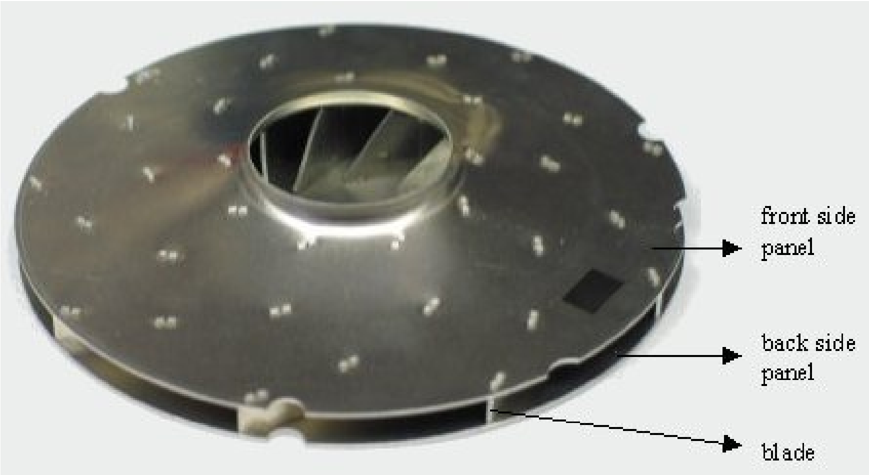

Figure 9. Impeller with a curved front panel and variable blade width

3.4 Combining values of characteristic of individual parts

By combining values of characteristic [Žavbi 2002], new parts are generated and individual values can be grouped, as shown in the example below.

Backside panel:
dimension: …
shape: flat plate
topology: …
material: composite material

Blade:
dimension: …
shape: curved and profiled with variable width
topology: …
material: composite material

Front side panel:
dimension: …
shape: …
topology: extended blades
material: composite material

3.5 Analysis and the final choice of the most suitable alternative

By combining values of individual characteristics, a vast number of possible alternatives to the existing parts are generated. In order to remove the alternatives with no application value it is necessary to define the criteria and use them in order to assess individual alternatives. Defining the importance of individual assessment criteria has proved problematic. In this case, the customer can be of a great assistance, as it is him or her who ranks the criteria in order of importance. Once the criteria have been set it is fairly easy to isolate a small number of alternative improvements with a practical value. Experts from different fields can now assess the remaining alternatives. They choose the best alternative independently of each other. If the assessment is produced by those who also proposed the ideas it is recommended to make the final choice by means of a method with the highest possible level of objectiveness of the assessment. In these cases the Analytic Hierarchical Process (AHP) [Saaty 1988, Saaty 1992] method is often used. These two final steps are subject to current work.

4. Conclusion

The method is very suitable for products with some tradition behind them as it forces seeking improvements in the areas that have not been subject to appropriate attention in the past, due to shortage of qualified personnel or the necessary equipment or improvements in a particular area were simply not necessary. Despite the objective nature of the approach to upgrading, it should be taken in account the fact that all changes are not equally important. Changes, such as longer or shorter cables

do not reflect technical sophistication of a product and do not lead directly to better functioning of a product. They only lead to better adaptability to the customers. If the number of such changes becomes too big they can blur the real picture about the sophistication of a product.
The values of individual characteristics have been varied. The result of combining the values of characteristics (i.e., dimension, shape, topology and material) is a vast number of alternatives. The assessment of alternatives has proved to be the biggest problem at this moment. The problem lays in defining the importance of assessment criteria. These criteria are not universal as they change together with time as well as with social characteristics of people and places. The method has proved successful when it comes to focusing on less sophisticated parts and further on to upgrading these parts.
Our company has had experiences with optimizing products, based on genetic algorithms [Papa et al. 2003], however, this method is only successful with analytically or numerically well defined parts with the number of optimization variables, which is neither too big nor too small. Our know-how and experiences have been supplemented with the use of the prescriptive model for upgrading. It is a positive experience as it provides a systematic generation of a vast number of changes.
The findings from this article are based on the use of the model for upgrading one type of products only and due to lack of data it is premature to make any general assessments.

References

Papa, G., Koroušić-Seljak, B., Benedičič, B., Kmecl, T., "Universal Motor Efficiency Improvement Using Evolutionary Optimization", IEEE Transaction on industrial electronics, Vol. 50, 2003, p. 602-611.

Saaty, T.L., "Multicriteria Decision Making - The Analytic Hierarchy Process", University of Pittsburgh, (Second Edition), Pittsburgh, 1988.

Saaty, T.L., "How to make a decision: The Analytic Hierarchy Process", European Journal of Operational Research 48, 1992, pp 9-26.

Žavbi, R.., Duhovnik, J., "Designing a cutter using prescriptive model of conceptual design", Proc. of the ICED 2001 Conference, Glasgow, 2001, pp 53-60.

Žavbi, R.., "Part based product upgrade", Design 2002, Dubrovnik, 2002, Vol. 1, pp 585-590.

Janez Rihtaršič, Ph.D. student
DOMEL, d.d., Otoki 21, SI-4228 Železniki, Slovenia
temporary address: University of Ljubljana, Faculty of Mechanical Engineering, Laboratory for Engineering Design – LECAD, Aškerčeva 6, SI-1000 Ljubljana, Slovenia
Telephone: 00 386 1 4771 740, Telefax: 00 386 1 4771 156
Email: janez.rihtarsic@lecad.uni-lj.si