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MECHANISM UPGRADE USING PRESCRIPTIVE MODEL OF PART BASED PRODUCT UPGRADE

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1. Introduction

Penetrating the market with a new product is a far more demanding task than marketing a fully developed product. Therefore, it is easier for companies to upgrade their products than develop brand new ones. Two additional reasons for upgrading a product are technology and knowledge possessed by a company.

The product, mechanism M75 (Figure 1), is produced by NIKO d.d. company from Železniki, Slovenia. Our mechanism has a European market share of 25 %. The product falls into the category of smaller and less demanding products. The perfection of the product has reached such a level that the producers of mechanisms improve the manufacturing technology only and corresponding changes of shape, dimensions and material of individual parts. The consumers' demands also have an important influence on changing the product. But roughly speaking, the mechanism has not changed considerably for 125 years.

Improving the mechanism at Niko d.d. company is usually a matter of trial-and-error process (in cases when improvements are initiated within the company). Therefore, our company has decided to take a more systematic approach to improving the binding mechanism for sheets of paper, which is expected to generate changes faster. However, we are aware of the fact that the generation of changes is only the first step towards the improvement and it does not guarantee economic suitability of alternatives. Only the analysis of alternative solutions can show whether the changes are economically justifiable or not.

The process of using the prescriptive model has shown some weak points, particularly in the area of product decomposition into individual parts as well as in the areas of selecting the part characteristics [Žavbi, 2002] and selecting the assessment criteria for the ideas. The need to set the criteria specifically for individual characteristics and parts has arisen. Based on weak points, found in the process of using the prescriptive model, some improvements in both areas have been proposed.

Figure 1. Mechanism M75

Many good ideas emerged, however, additional development brings problems, related to the consumers' demands (the analysed mechanisms are semi manufactures) and restriction in the production process (large-scale production).
The article presents individual activities within the prescriptive model and its use on a real industrial product. Chapter 2 deals with the applied method and chapter 3 describes the use of the prescriptive model on the mechanism M75. The last chapter focuses on the observations during the course of work and the application value of the model for our case.

2. Part based product upgrade approach

The prescriptive model defines the activities, used in search of improvements on products. The activities need to be carried out in a fixed order (Figure 2). It ensures that the method can be repeated and the user's focus is on the steps leading to the solution. Despite dividing the process into individual activities the user can still show his or her creativity within the activities.

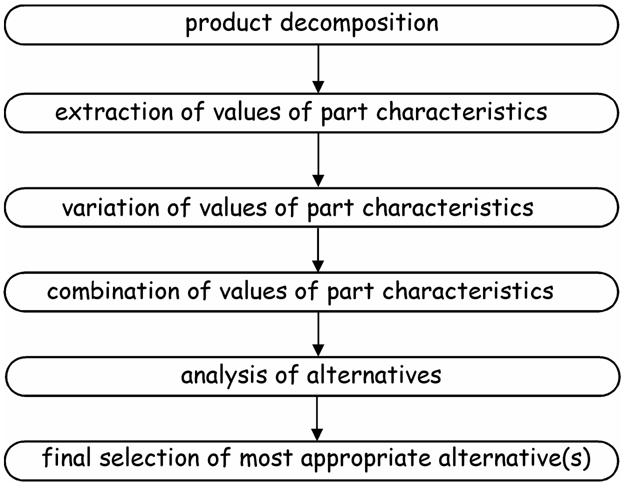


Figure 2. Activities, provided by the model [Žavbi, 2002]

2.1 Decomposition

Product decomposition is the basic (analytical in nature) activity of the proposed procedure and enables a clear presentation of the product's parts. In this way, the product's nature is much clearer, which leads to a faster and more effective focus on individual parts. It is important to decompose the product into individual independent parts [Žavbi, 2001], which are assembled in the manufacturing process (Figure 3). The particular part is made of a single material without assembly operations and only performs a function within an assembly rather than the function of an assembly [Žavbi, 2002]. It can also perform supplementary and linking functions with the adjacent parts. It has been mentioned that the prescriptive model does not impede creativity in the process of searching for new solutions. Even more, it is possible to say that it stimulates creativity. Focusing on one particular part is a clear sign of the priority that requires alternative solutions.

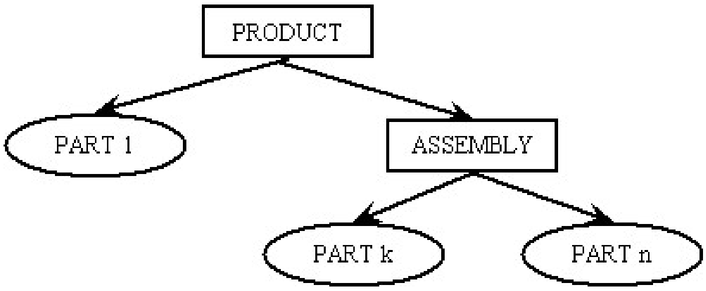


Figure 3. The tree structure of decomposition

2.2 Extraction of values of part characteristics

Each part is further defined by its characteristics. The values of these characteristics precisely define the part in the material and geometric sense. These characteristics are the shape, material, dimension and tolerance [Hubka, 1988], [Žavbi, 2001], [Žavbi, 2002]. Geometric position has been added to the said characteristics and therefore, each part had five characteristics: material, dimension, shape, geometric position and tolerance. Some characteristics have a more prominent role when it comes to the parts that are easy to manufacture and have a bigger visual effect (e.g. shape – car), while other characteristics are more important for the parts that influence the manufacturing technology rather than perform a function (e.g. tolerance – sliding bearing). Using the prescriptive model in search of changes on the mechanism, the same characteristics for all parts have been used.

2.3 Variation of values of characteristics

Part decomposition and part characteristics have channelled the focus on a specific area where alternative solutions were sought. Using a preliminary analysis of individual parts, the current values for individual characteristics have been found.

Seeking alternatives is one of the more important steps of the design process. Good ideas can lead to a good product. There is a positive correlation between the number of alternatives and their quality [Andreasen & Hein, 2000]. It is therefore important to stimulate and provide the highest possible level of creativity [Pečjak, 2001] during the process of seeking alternative values of characteristics. It is also important to avoid fixation of ideas among the members of the team, seeking the alternatives, as the constant contact with the product impairs the thinking process. There are several methods, stimulating creativity during the idea generation process. The method of idea writing [Pečjak, 2001] was used in our case. From the viewpoint of the techniques of creative thinking, the focusing method [de Bono, 1992] was also used. First, the focus is on a specific part and afterwards also on individual characteristics of this part. In this way, the changes are treated comprehensively and systematically.

2.4 Combination of values of part characteristics

Due to the abundance of proposed changes, several combinations of alternative values of individual characteristics to the alternatives of the work process are set up. For the purpose of creating the alternatives, the alternative values of individual characteristics can be used several times. The most closely related ideas, according to a member's personal opinion, are combined.

2.5 Analysis of alternatives

For the purpose of making the final selection, the ideas need to be closely analysed. The idea, generated during the process of variation of values of characteristics, should comply with the requirements and criteria. The ideas are assessed. The assessment process is an iterative one (Figure 4) as it is impossible to make a quality assessment of the ideas that have not been precisely defined in the material and dimensional sense. Nearly all ideas, generated during the process of searching for alternatives, are of this nature.

Assessment takes place on several levels. Each loop, shown on figure 4, within the iterative process contributes to the development of the idea and shifts it to level of higher concreteness. The ideas on the first level are still very abstract (Figure 5). With each level, ideas become more and more developed and sophisticated. The requirements and criteria for each level of idea – product design also need to be well defined and analysed. If requirements on lower levels are too strict the number of lost alternative solutions is too big, which means that good solutions are lost, too. If the requirements are too loose, the load of work on the following levels is bigger than necessary. Combination of requirements and criteria has been used for the assessment purposes.

The final result of this activity is the ideas, whose sophistication permits making decisions on further detailed economical and technological analyses, followed by the final selection of the most appropriate alternatives.

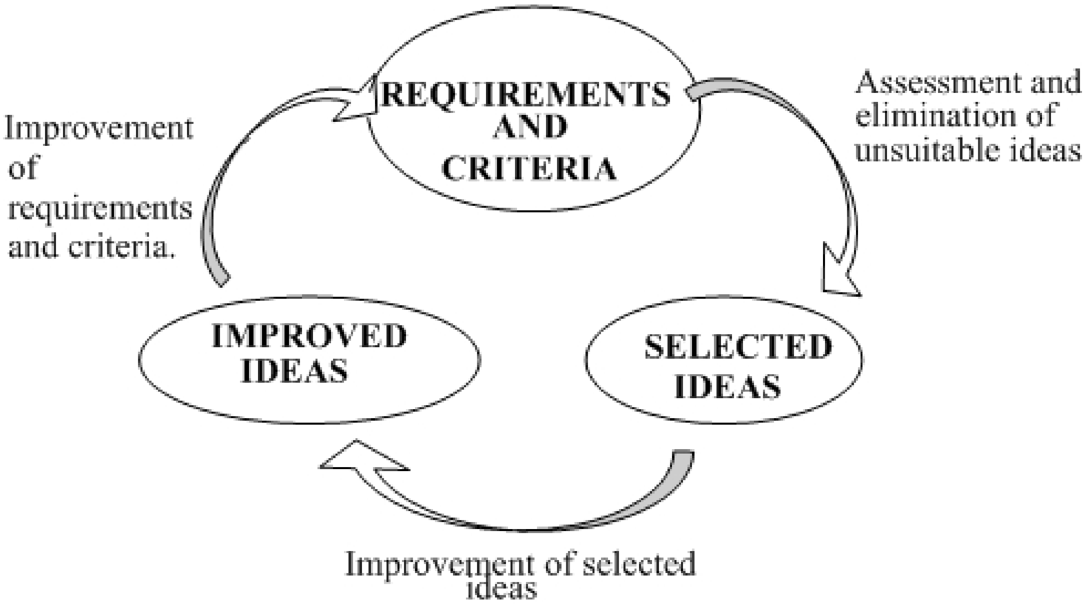


Figure 4. Iterative analysis of ideas

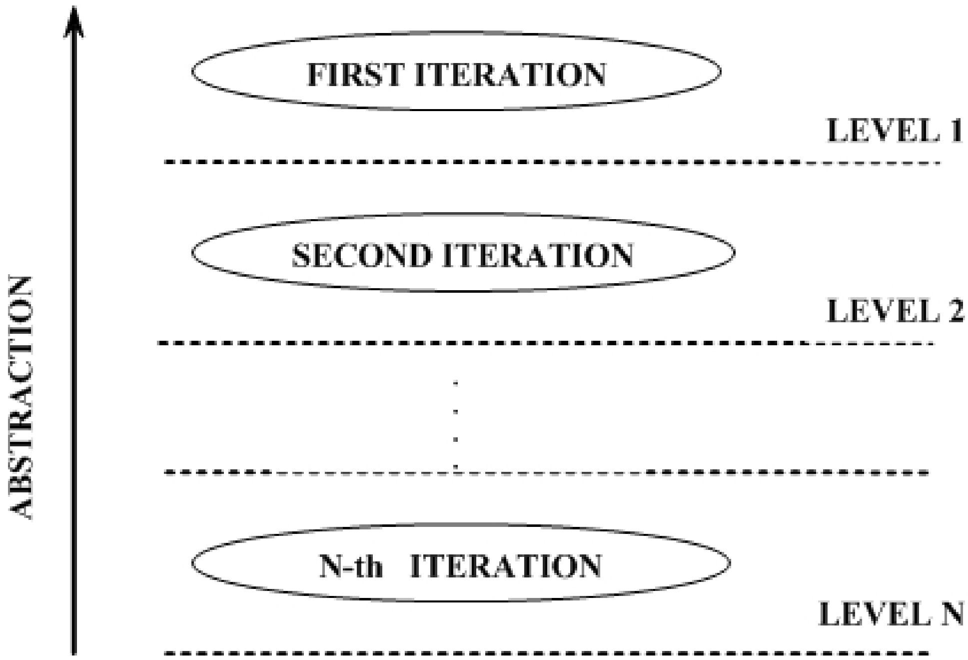


Figure 5. Levels of assessment

3. Mechanism M75 upgrade by means of the prescriptive model

Using of the prescriptive model in the process of searching for improvements on the mechanism M75, we tried to verify the application value on a large-scale production and technically relatively sophisticated product. The conclusion was that it is valuable especially in cases when minor modifications of individual activities are taken into account. A more detailed account of the course of activities and the mode of application in the company will be shown on concrete examples

3.1 The history of changes

Each product has a history of its own development and improvements. All changes for the past 10 years have been examined. In our case, the changes on parts were significant. Changes that took place in the past were helpful in getting familiar with the product. It is even more important when it comes to forming teams, composed of members of the company and different consulting institutions. A look into the history of changes reveals the areas of the biggest and the smallest number of changes. The R&D department can therefore make a choice to work more intensively on the parts that have been subject to the smallest number of changes – it is presumed that such parts offer a better opportunity for economically justifiable changes [Rihtaršič et al., 2004]. The analysis of the past helped our team to get familiar with the product and to establish what product and what part has been the most or the least problematic. It is reflected by the number of changes. Changes for each part were divided into changes of material, dimensions, shape, geometric position and tolerances. 76 changes of this type occurred in ten years.

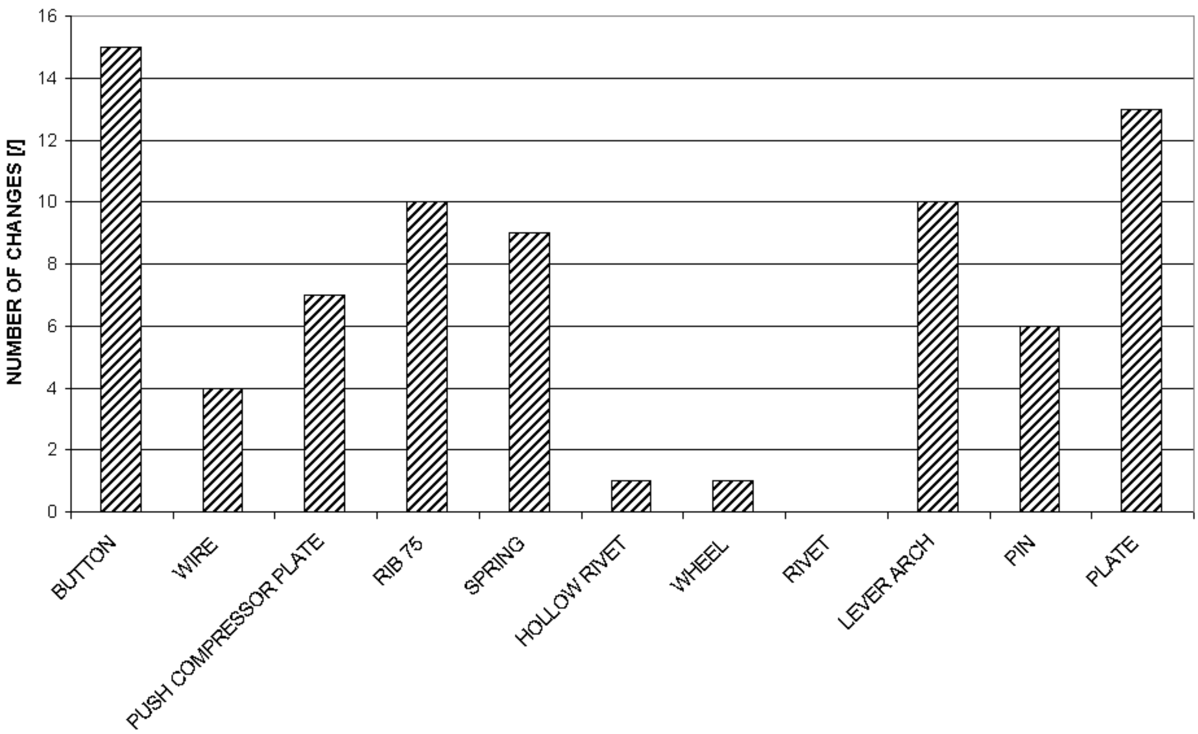


Figure 6. The number of changes on individual parts

Figure 6 shows the proportion of changes on individual parts. The button and the plate have been subject to the greatest number of changes, while rivet, wheel and hollow rivet have been subject to the smallest number of changes. Rivet has not been subject to any changes in the past 10 years. It was interesting to find out that the dimensions had been the most frequent subject to changes (Figure 7). Usually, the thickness of the material and dimensions of some details on the part were changed. Tolerances were also changed often. The changes of tolerances are required by the production process. As this is a large-scale production product, a constant remedy of deficiencies throughout the production process was necessary. It was reflected by the changes of some tolerances and also dimensions. The dimensions of the button are very small, which means that the changes of the dimension or changes of the tolerance took place in the same proportion. Along with searching and changing the materials, optimum materials for the production of parts were searched for. The shape and geometrical position has stayed practically the same while the working principle of individual assemblies has not changed at all during the period in question.

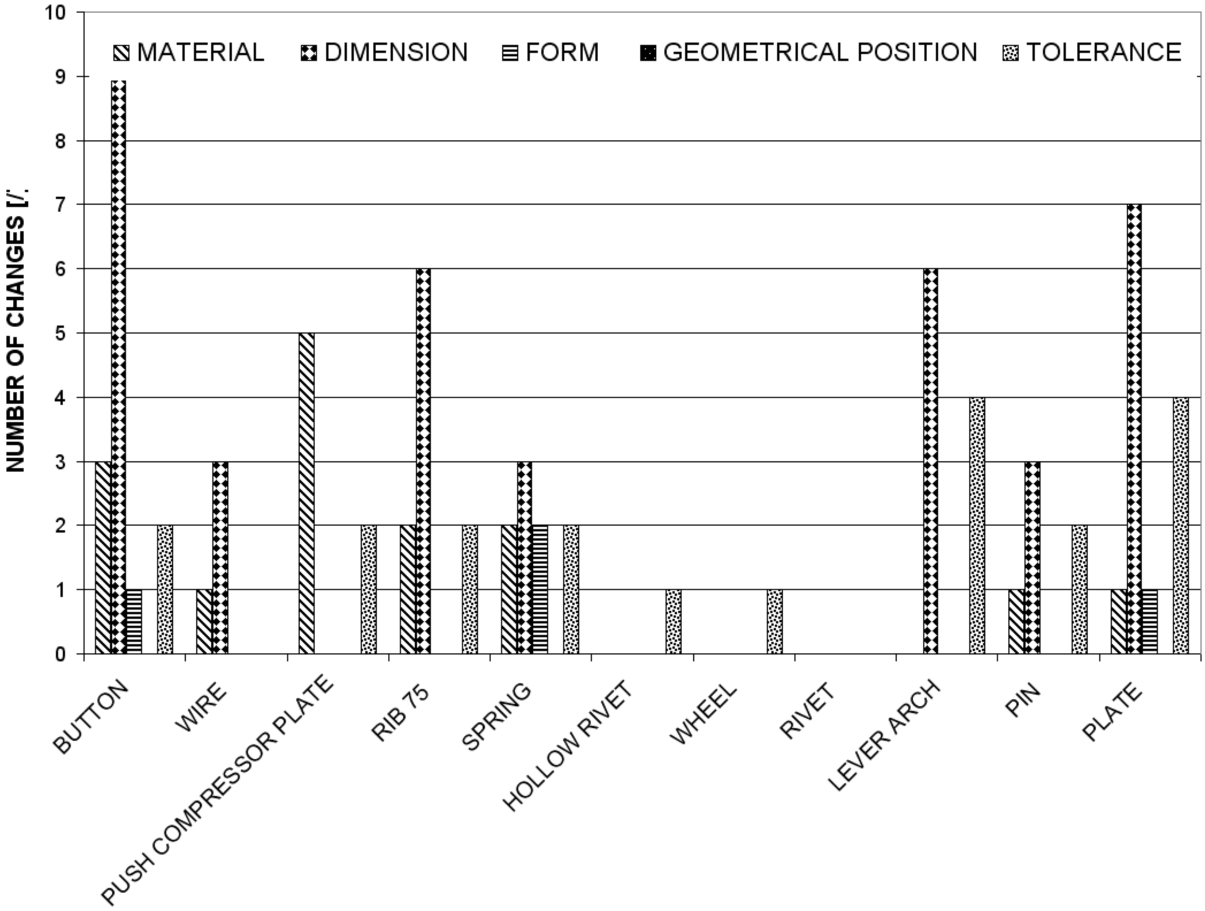


Figure 7. The number of changes of individual characteristics

3.2 Decomposition

The product has been decomposed into elements, made of a single material without any assembly operations [Žavbi, 2002]. The mechanism M75 was decomposed into individual assemblies and further on into individual parts (Figure 8).

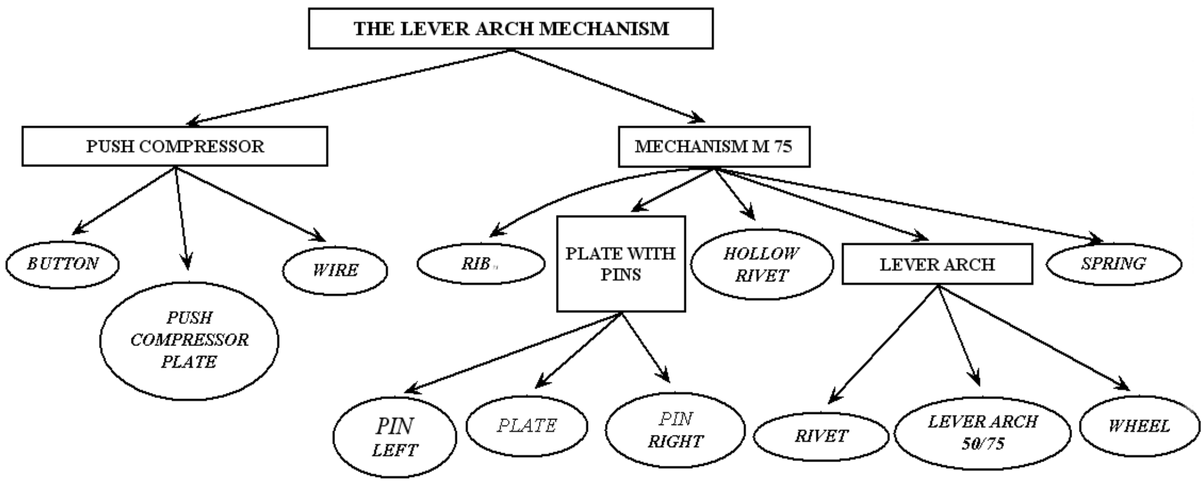


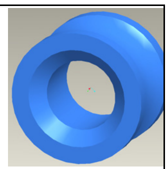
Figure 8. Mechanism M75 decomposition

The problem of showing the relationship between individual parts emerged. Namely, the decomposition, shown in the prescriptive model does not show the relationship between individual parts. Attention should be paid to this problem during the process of making alternatives as a change of one part can require a change on the part that it is associated with. After the decomposition, the mechanism was disassembled into 12 parts on three levels. The rectangle shows an assembly and the ellipse shows a part (Figure 8). Figure 8 shows two assemblies and no parts on the first level, assemblies and parts on the second one and parts only on the third level. The number of levels should be sufficient to allow parts only on the lowest level. In the follow-up, the equivalent parts were considered only once.

3.3 Extraction of values of part characteristics

Values of characteristics are extracted for each part. The wheel in table 1 is shown as an example.

Table 1. Values of the wheel characteristics

MATERIAL	DIMENSION [mm]	SHAPE	GEOMETRICAL POSITION	TOLERANCE	
Polymer	ϕ3.7 x ϕ7 x 4.8	Cylinder, engineering drawing – annex 5	Position on the lever and rib	Clearance-fit for rotation	

It has been established that in the case of parts with many dimensions the characteristics *dimension* and *shape* cannot be adequately described without the engineering drawing. Gauge measures only are entered into the table. More detailed information on the shape and dimension is obtained from the engineering drawing, attached in the form of an annex.

3.4 Variation of values of characteristic

A team of three people was set up for the purpose of *looking for alternatives*. The members of the team have been employed at the company for different periods and are of different educations. The management, design, technologic and economic skills as well as creative thinking techniques were represented in the team. The goal of the team was to produce the greatest possible number of different ideas. The method of idea writing was used [Pečjak, 2001]. The method proved suitable for the initial phase. First, each member analysed the problem and produced some ideas on his or her own. New ideas emerged through mutual interaction. However, members need to be very careful not to become blinded by his or her own ideas and comment and criticize the colleague’s ideas. In order to stimulate the team creativity, the team had the entire product, its assemblies and parts at its disposal. The team produced 189 ideas in five hours.

The biggest number of ideas was produced for the characteristics of *shape*, *dimension* and *material*, while the smallest number of ideas was produced for *geometric position* and *tolerance* (Table 2). Comparing the results on Figure 6, a similar pattern of characteristics can be noticed. Such a small number of ideas for geometric position and tolerance was caused by the indirect influence of decomposition without any representation any relationship between the parts. Due to the said deficiency in decomposition, each member was given a sheet of paper during the idea generation and used it for writing the ideas, related to the changes of assemblies. There were 27 of such ideas.

Table 2 shows an example of some ideas, produced for the wheel. Each member wrote and drew his or her ideas on a sheet of paper in the form that required no further explanations.

During the process of idea generation it has been noticed that technologists usually present their ideas in the written form while designers almost always use also a drawing when they explain their ideas.

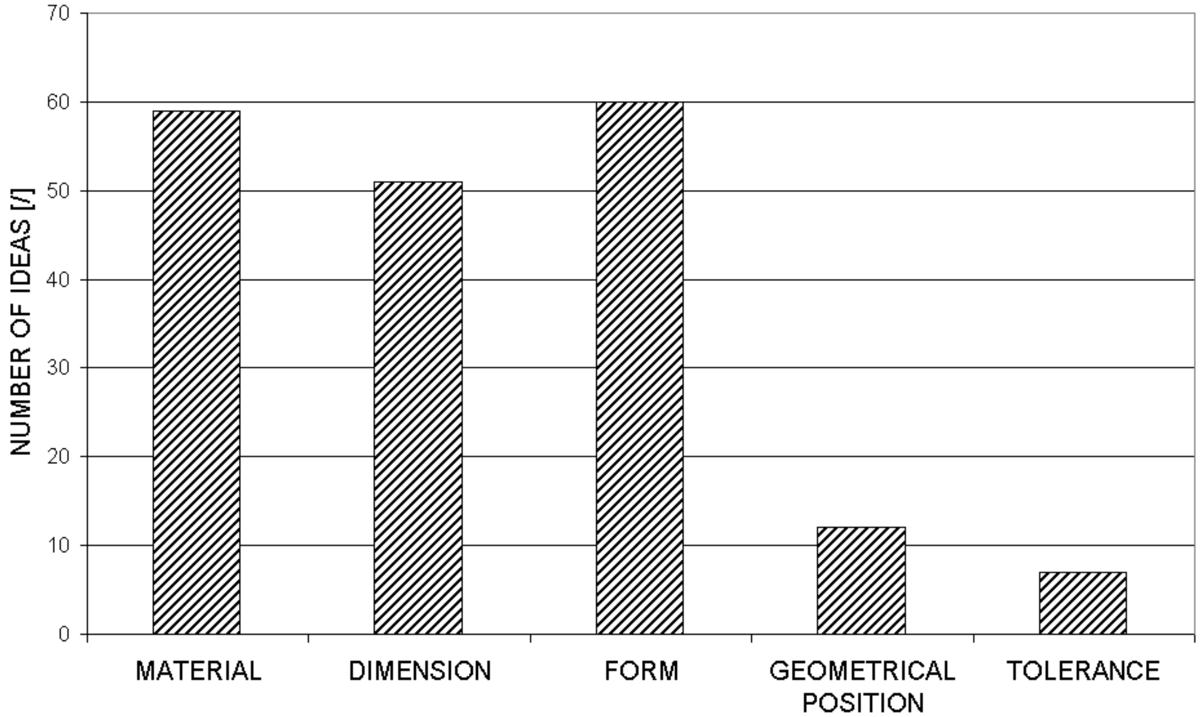
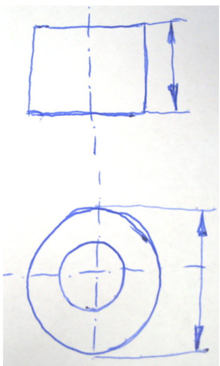
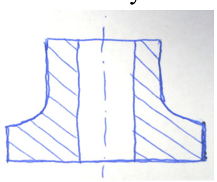


Figure 9. Total number of proposals for changes of values of individual characteristics on all parts

Table 2. An example of the ideas, produced for the wheel (the current state is shown in table 1)

MATERIAL	DIMENSION [mm]	SHAPE	GEOMETRICAL POSITION	TOLERANCE
Aluminium	Thinner, wider 	Round on one side only. 	Lower on the rib	Clearance-fit with smaller clearance

3.5 Combination of values of part characteristics

The planned activity *combination of values of part characteristics* was not carried out. The main reason was the nature of ideas. Alternative proposals for changing values of individual characteristics were independent. Therefore, any change of one value of a characteristic could be combined with any other change of value of another characteristic. In this way, a very big number of combinations would emerge. On the other hand, a good idea in combination with a false one can be overlooked if all combinations are not carried out. The second reason is lack of concreteness of ideas on the lower levels, which makes them less suitable for good combinations. For this reason, we opted for assessing values of individual characteristics instead of their combinations.

3.6 Analysis of alternatives

We approached the selection of ideas iteratively, with assessment on several levels. All ideas, not matching the basic criteria and therefore not having any realistic chances of coming into real life, were eliminated on the first level. Other ideas were assessed on the next level (Figure 5). Ideas were improved in the meantime. Assessment on the first level was very complicated, as the ideas had not been analysed enough, which made setting any requirements impossible. On the basis of technological, marketing and design requirements, six to seven criteria were selected. The financial criteria are not possible yet on this level. The assessment of each criterion was given in relation to the comparison with the existing product. The assessment was carried out by the members of the team. Each member was required to make 1323 comparisons. It came out that comparison between the new idea and the old part on the first level was worthless when account of technological criteria was taken. The existing technology is adapted for manufacturing the existing parts and its direct use for manufacturing modified parts is more complicated. By gradually dropping the number of ideas, the selected ideas were further developed. The following two levels included the marketing and technological requirements since the ideas were already better developed. Financial requirements were also included, which is of key importance with regard to the question whether the changes are justifiable or not. When the criteria were being set we encountered the fact that the mechanism is a semimanufacture. Consumers demand that the mechanisms are compatible, which means that our mechanism and another company's push compressor can be used on one production line or vice versa. It imposes a major limitation, as it is not possible to make any significant changes. The final selection of alternatives has not been carried out yet.

4. Findings

Practical application of the model showed its advantages and disadvantages. The advantage lies in the fact that it leads to a specific part and its characteristic that is the subject of the production of a substantial number of changes. Search for solutions is better focused in this way. The use of prescriptive model is also possible in companies with limited R&D resources.

Decomposition revealed that relations between the parts should be shown. Parts, forming an assembly, perform the function of the assembly and the function within the assembly. Changing a part of the assembly can lead to a change of its function, which, in turn, can lead to a change of the function of the assembly, which should not be changed. It means that adjacent parts should be changed in the way that the function of the assembly remains the same. When it comes to very complicated parts, division into levels was insufficient, which required decomposition down to individual *wirk elements* (Problem of granularity [Žavbi, 2002]). It has been found out that tolerances on our products have no significant role and are far more linked to the technology of the product than its design. The problem of distinction can be encountered in the case of products where changes of the dimensions and tolerances are of the same order of magnitude. Beside the said example, the tolerance has the most important role on the level where concreteness of the changes of work is very high.

It would also be necessary to define precisely activities within the process of assessing alternative proposals for changes.

5. Conclusion

A step forward has been made when a systematic approach to the search of changes was taken again after 20 years. The prescriptive model could be used regardless of the fact that our company has limited R&D human resources, which is a clear advantage. Searching for solutions was focused on a particular part and its characteristics (i.e., material, dimension, shape, geometric position and tolerance), which means a more comprehensive solution. The proposed changes were analysed and assessed by the iterative process. Quality solutions should be justifiable from the economic and marketing point of view and need to be technologically feasible. Ideas on the level of assemblies were generated as a side product, which can lead to the change of the working principle of a product. It opens space for completely new solutions.

The process of using the prescriptive model has shown some weak points, especially in the area of product decomposition into individual parts: granularity is sometimes not fine enough (in case when parts are multi-functional) and dependency between parts is shown only implicitly.

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