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NEW METHODS OF PRODUCT CLASSIFICATION FOR COMPUTER AIDED PROCESS PLANNING SYSTEMS

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Summary: *Classification of engineering parts is a very demanding activity especially in process planning. It is one of the important methods utilised in the group technology approach to computer aided process planning. This paper deals with a new method of classification, which extends the possibility of engineering part classification, especially for the process planning of non-cutting processes (forging, casting, etc.)*

Keywords: - *classification*
- *CAPP, group technology*
- *dynamic classification*

1. INTRODUCTION

Humans very often use catalogues and documents with classified and grouped data. A good example is the coding and classification of books in a library catalogue. It is not a problem to find books with an exact and specific word from the book title. Another example is the telephone directory. There is a great deal of other examples of classification systems in real life. Everyone knows that the grouping of similar data into individual groups is an effective and useful activity.

The adequate or corresponding question could be the following: Why is grouping useful in manufacturing?

A company may make hundreds or thousands of different parts. Because the parts are made in a concrete manufacturing environment, many parts are similar in some way. Each part is made according to a process plan. Therefore, many process plans must also be similar. If similar parts are situated in one group (part family) (Fig.1.), their process plans are similar as well. It is possible to create some groups of parts with similar characteristics. If similar parts have similar processes, it follows that utilizing this approach has a very favourable economic benefit [1, 2].

A part family is a group of parts that have either design similarities (geometric shape and size) or manufacturing similarities (machines, tooling, process sequences, etc.). Some parts may look similar to each other, but because of differences in materials, tolerance or other production requirements, they have different manufacturing requirements and thus do not constitute a „manufacturing family of parts" [3].

2. PRODUCT CLASSIFICATION

Classification is the process of identifying and establishing the various classes or divisions that exist for a set of parts based on relevant attributes. However future manufacturing systems will be increasingly more dynamic. They have to be able to rapidly respond to changing conditions by concurrently balancing and optimizing multiple manufacturing constraints. There is an effort to realize automatic classification, which will be more flexible and efficient.

Besides the benefits of classification, there are also some disadvantages. It is possible to state the following advantages of the classification [4]:

- A good coding and classification system provides design engineering with a system that facilitates: efficient retrieval of similar parts; development of a database containing effective product design data; standardization of design; prevention of design duplication; forming of part families; use of producibility tips; and incorporation of engineering design changes into the engineering and manufacturing systems.
- A good coding and classification system provides the manufacturing process with a system that facilitates: development of a CAPP system; retrieval of process plans for part families; development of standard routings for part families; and development of machining cells.
- Standard routings facilitate the development of tooling groups, NC program groups and standard setups for part families.
- Production planning and control can be simplified.
- Because production planning can be simplified, it can be more comprehensive.
- Production scheduling can be simplified.
- Machining cells can reduce in-process inventory, resulting in shorter queues and shorter manufacturing throughput times.
- Improved machine utilization yields shorter setup times and better scheduling.
- Part family data facilitates improving plant layout, which in turn can reduce materials handling costs.

- Purchasing can be more effective. It is easier to choose the proper vendor because the many different parts and materials have been grouped into families, which reduces the complexity of the problem.
- Management can be more effective because the environment has been simplified.

3. CLASSIFICATION IN CAPP SYSTEMS

Current trends in production such as intelligence, automation and flexibility will determine the development tendency of CAPP (Computer Aided Process Planning). CAPP systems often utilise Group Technology (GT) as the basic method for process planning. It is a simple and very efficient method for creating a process plan.
The GT principle is one of the principles used in CAPP methodology [5]. The standard plans are created for a family of similar items. In the GT CAPP systems, a human retrieves the plan for similar components using coding and classifications of parts. The planner edits the retrieved plan to create a variant to suit the specific requirements of the component being planned.
Variant process planning implements a coding and classification scheme by which a process plan for a previously planned part is retrieved.
Variant methods assume that the user is able to determine the appropriate classification codes needed to retrieve appropriate plans and that there are plans that include features that are closely analogous to those of the new part.
The classification is possible to realise according to two methods [6]:

- visual (graphical) classification systems,
- coding.

Manual visual classification is often realized according to graphical classification systems. The planner compares a new part with representative parts drawn in individual cells of the table. The performance of the whole GT CAPP system depends on the implementation effort of the preparatory stage.

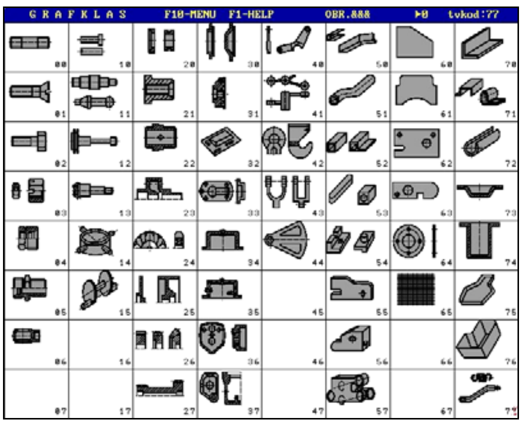

Figure 1. Graphical classification system

The next method used to establish part families is to examine the parts and then classify and code each part into a group with similar attributes. Classification is the process of identifying and establishing the various classes or divisions that exist for a set of parts based on relevant attributes. Classification is realized following the coding process (Fig.2.). Coding is the assigning of symbols to the part properties. Symbols constitute the code that ambiguously describes the properties of a part. Several similar parts may have an equal code.

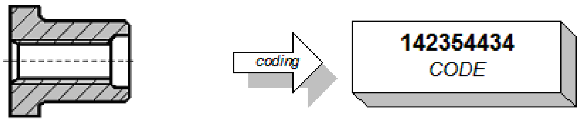

Figure 2. Coding of engineering part

4. STATIC CLASSIFICATION

GT methods are especially utilised in process planning for machining processes. The classification system is a very important part of the CAPP system based on GT. The classification system for machining is of a static character. It is not necessary to change classified parts into individual groups. Oftentimes apart from classification based on geometrical properties (Fig.3.), the classification process continues in classification according non-geometrical properties (Fig.4.) such as weight, tolerances, etc.

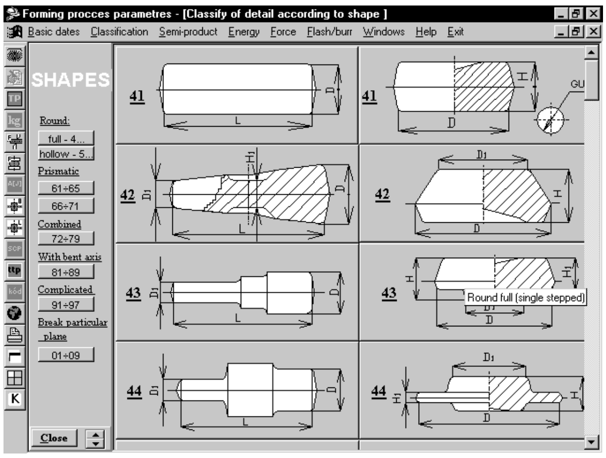

Figure 3. Developed classification based on geometry

The majority of CAPP systems based on GT are intended for manufacture process planning. It is sufficient for the manufacturing process to create a classification system that will be simply fulfilled. There is no need for changing the number of groups, or for changing the localisation of individual engineering parts in individual groups. Therefore, it is possible to consider these classification systems as a static system.

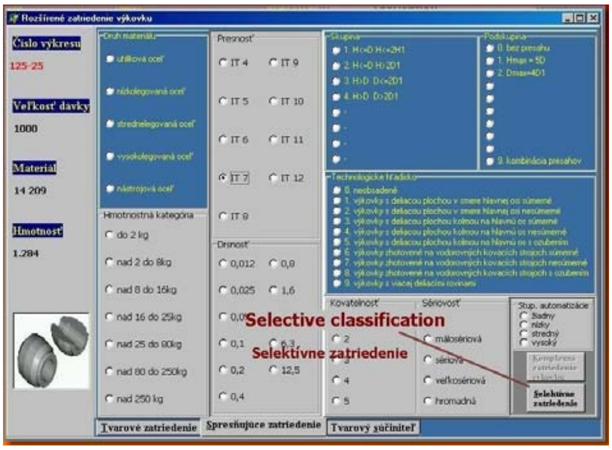

Figure 4. Developed selective classification according to important part properties (non-geometrical properties)

5. DYNAMIC CLASSIFICATION

However there is also a large demand for utilising the GT in other technologies and not only for machining process planning. As the characteristic of non-cutting technologies (such as forging and casting) are different as cutting technologies, there is a need to take other view on the utilisation of GT in this area [7, 8].

As the static classification system is not suitable for the process planning of non-cutting operations, thus there is a concept design of the dynamic classification system oriented especially for non-cutting technologies (Sugar, 2000).

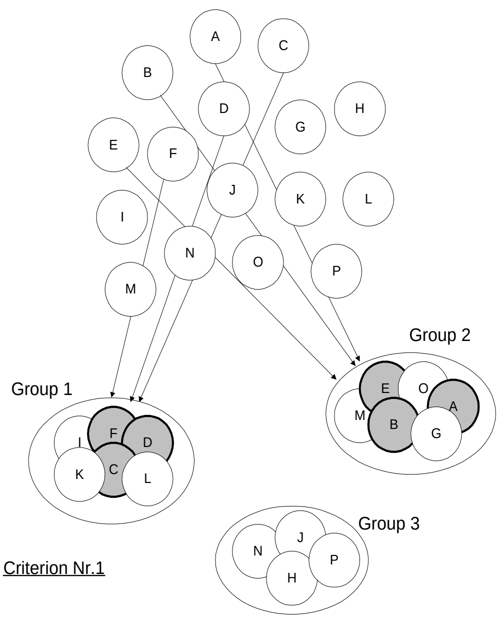

Figure 5. Dynamic classification

Dnamic classification is based on a *flexible classification system* [10]. The engineering parts are *dynamically grouped* to the individual groups according to classification aims. For example, the engineering parts will be dynamically grouped to the family groups according the total costs or operational total times, number of produced parts, series, etc. A mathematical method - *cluster analysis* - seems to be a very good candidate for support of the dynamic classification system concept [11]. *Clustering techniques* have been applied to a wide variety of research problems. The term cluster analysis actually encompasses a number of different classification algorithms.

The principle of dynamic classification is evident in Figures 5 and 6. The parts are flexible and dynamically grouped according selected criterions. It is still appropriate to utilise visual classification as it is a very simple and effective method, however with the flexible option the parts are grouped according to actual demand.

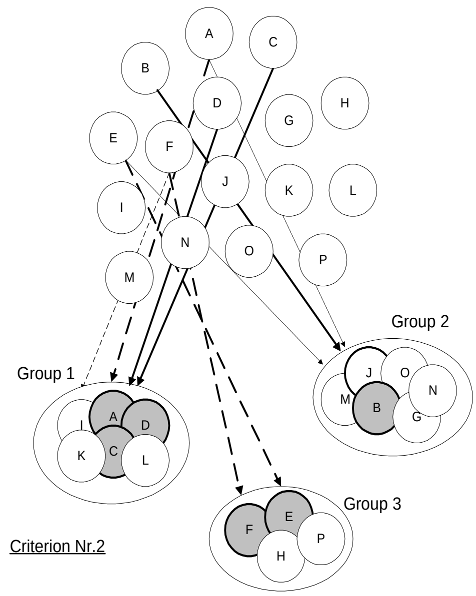

Figure 6. Dynamic classification according different criterion

6. DESIGN OF DYNAMIC CLASSIFICATION

Dynamic classification is systematically elaborated at the Department of Machining and Automation at the University of Žilina. Development of dynamic classification methods is taking place there.

The task consists in the flexible and quick classifying of a set of engineering parts according to determined parameters (e.g. material, tolerances, etc.). This is shown in Figure 7. The other considered parameter causes the consequent reorganizing of all engineering parts and their localising to individual groups. For example, according to the considered parameter tolerance, the selected part will be inserted into the first group, however if the material

will be considered as a classification parameter, the part will be inserted into the other group (Fig.7.).
The classification parameter (*CP*), which is a function of appreciated product parameters, is defined:

$$CP_{\mathrm{k}} = f(x_1, x_2, ..., x_{\mathrm{n}}) \qquad (1)$$

x_1 - geometry
x_2 - material properties
x_3 - tolerance
x_4 - roughness
…
x_{i} - weight
…
x_{n} - level of automation.

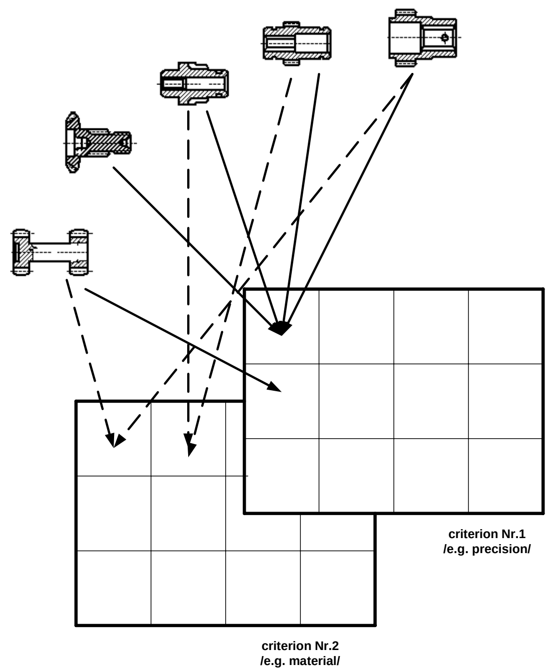

Figure 7. Product grouping according to different parameters

Some parameters are best mathematically expressed (tolerance, roughness, weight, etc.) while others are more problematically expressed (geometry, level of automation, etc.).
The classification parameter can be expressed by a function with only one product property:

$$CP_{\mathrm{k}} = f(\mathrm{Const} * x_{\mathrm{i}}) \qquad (2)$$

or it can evaluate several product properties at the same time:

$$CP_{\mathrm{m}} = f(\mathrm{Const} * x_{\mathrm{i}}, \mathrm{Const} * x_{\mathrm{j}}) \qquad (3)$$

Each parameter of a group has a defined interval of classification parameter:

$$\mathrm{Group}_1 = < CP_1, CP_2)$$
$$\mathrm{Group}_2 = < CP_2, CP_3)$$
$$\dots$$
$$\mathrm{Group}_{\mathrm{k}} = < CP_{\mathrm{k}-1}, CP_{\mathrm{k}})$$

For example, all products with a weight belonging to the same defined interval, will be localised to one group. Products with another weight will be localised to the other group.

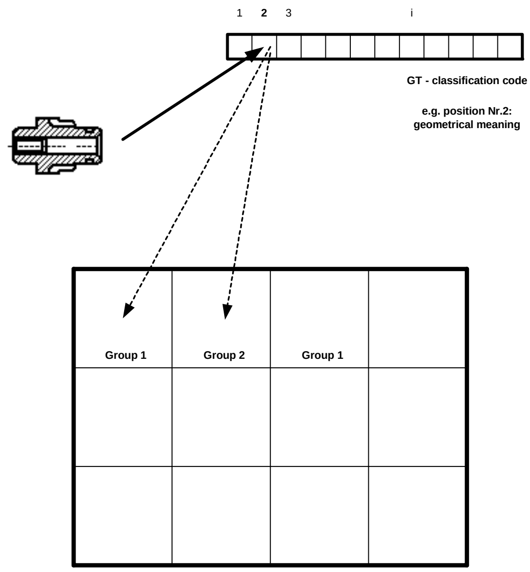

Figure 8. Considered product parameter and its influence on classification

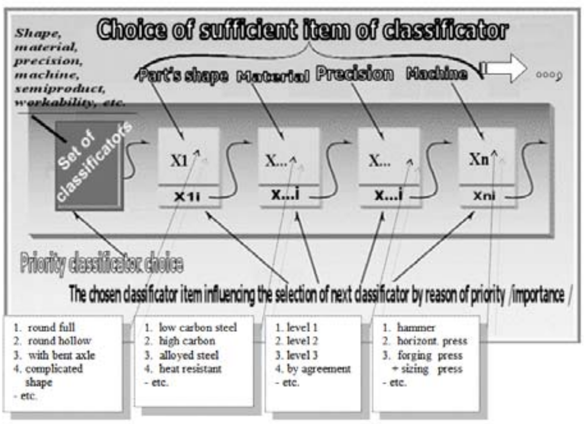

Figure 9. Dynamic classification according to different criterions

The defined classification code has a fixed format and it corresponds with the importance of measuring, the priority of the attribute property factor (Fig. 9, 10). The sequence importance-priority level and the suitable items option of the factors can be changed by affecting other particular classification factors.

The expert system seems to be a good candidate for a useful tool in the analysing and handling of classification factors and their items (sub-factors). Suitably created rules in collaboration with the "inference engine" of the expert system can solve this task with maximal approximation to human (expert) thinking.

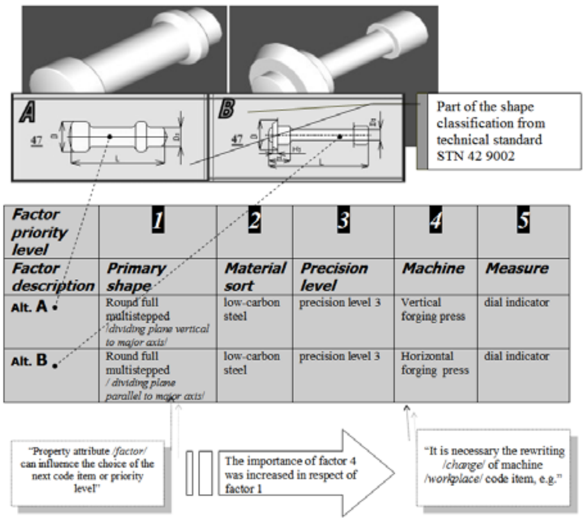

Figure 10. Dynamic classification according to different criterion

7. CONCLUSION

A classification system that more precisely reflects flexible demand is needed. Dynamic classification has been used to categorize product properties according actual demand. During past years, the classification systems in CAPP systems have utilized static classification. The static classification system does not reflect important changes in the factory.

The disadvantages of the current CAPP systems based on GT lie in their static classification systems, which are not suitable for flexible change of GT representatives. There is no support to apply it in these systems. A new approach consists of applying methods, which enable the dynamic grouping of the engineering parts in the individual groups according to selected criterions (e.g. cost, precision, equipment, level of automation, etc.).

The dynamic classification system includes a flexible classification system that generates a detailed and comprehensive knowledge catalogues based on the actual criterions used in the input.

The building of a dynamic classification system utilized in GT CAPP is a time demanding and a very labour-intensive task. The task requires theoretical elaboration, the working out of a serious methodology of process planning and the used of an advanced programming technique. It seems that the dynamic classification method is a very effective and flexible method for part grouping in casting and forging process planning.

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