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Advanced CA Methods for Increasing the Productivity of Engineering Activities

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Abstract: **The paper deals with aspect of computer support in engineering activities. Computer support and Computer Aided (CA) systems present tools for improving of productivity and efficiency in engineering enterprises. It is necessary to know methods and approaches leading to an implantation of the modern CA systems and technologies. Special attention is given to design and process planning activities. The paper also deals with a new method of classification, which extends the possibility of engineering part classification. The presented methods were developed and elaborated by author's team.**

Keywords: **CA systems and technologies, CAPP, productivity**

I. INTRODUCTION

Economic pressures urge manufacturers to make more customised products of high quality, in smaller series, with shorter lead time and of course, without increased costs. Time is becoming rapidly the most strategic topic of companies. Costs are also important, more important are competitive price and the most significant are marketability of manufactured products. Resource cost and job cost have essential influence on direct product cost. The outline strategic business goals can be achieved by increased flexibility and well organised information flows.

Engineering activities realised before manufacturing are very important in term of influencing of total production cost. The engineering drawing and especially the process planning such as the main engineering activities are critical production cost factors. Therefore there is meaning to deal and interest with advanced methods implemented in Computer Aided (CA) systems. Especially attention is give to developed methods in area of process planning activities.

II. TOOLS AND METHODS FOR CA SYSTEMS

New conditions on global market, globalization of market, globalization of competition and globalization of trade urge that enterprises look for new methods and approaches which increase productivity and efficiency of all factory processes. The following items are very important reserve areas for increasing economic factory indicators:

- New constructional and tool material,
- New progressive production technologies,
- Automation of production,
- Rationalization and computer support of engineering activities,
- Implementation of modern information technologies,
- Mew methods of planning, production control and factory organization.

The following methods seem to be very good candidates for increasing efficiency and productivity of engineering activities in the production enterprise [5]:

- Concurrent Engineering /Simultaneous Engineering/ - this method enables parallelism of several processes during design process. The main advantage consists in possible problem prediction for production and assembly just during design process. The method is especially based on DFx /DFM, DFA, DFMA, DFE, DFC, etc../ technique.
- DFC /Design For Cost/ - methods belonging to CE/SE however has special meaning in the enterprise. It is design method taking care of connection between design process and cost.
- PDM /Product Data Management/, PDMII /Product Development Management/, PLM /Product Lifecycle Management/ - systems and methods for managing the enterprise documentation, processes and business activities.
- DOE /Design of Experiments/ - set of methods and recommendation for design process.
- FMEA /Failure mode and effects analysis / - prediction of potential product errors.
- VA-VE /Value Analysis-Value Engineering/,
- QFD /Quality function deployment / - determination of critical location in the production processes.
- CAE /Computer Aided Engineering/ - set of methods for simulation and analysis. It is possible to meet with them especially in CAD/CAM systems or as individual special CA systems.
- Integration STEP – Powerful tool for integration of CA systems in framework of product life cycle. It is standardized by ISO norm 10303.
- Cross Enterprise Engineering – horizontal and vertical enterprise integration. It is view on integration solving in framework of the whole factory.
- Dynamic process planning – dynamic process planning according actual capacity and conditions in the factory workshop.
- Non-linear process plans – creation of process plan variants /in tree structure/ corresponding with various situation in the factory workshop.
- JIT in process planning – process planning according actual state in the factory workshop.
- Expert process planning – expert support for creation of process plan.
- Evolution and genetic algorithms – utilised especially for solving of optimisation tasks.

- Utilisation of complex CA system such as DELMIA. The SW is enables solve all important activities /development, design, process planning, ergonomics, quality, layout, robotics, etc./ in framework of enterprise.

However these methods are not panacea for problem enterprise solving. It is necessary to realise very serious analyse the factory conditions before their implementation. An inexpert implementation could have opposite effects. It happens oftentimes.

III. COMPUTER SUPPORT FOR PROCESS PLANNING

The process planning activities are significant means for flexibility, time to market and competitive advantage of enterprise. The process planning systems are therefore important tools for increasing of efficiency and profit. One question is very relevant – is possible to achieve by current methods and means of the process planning the flexibility and time performance? Accordingly it is needful to find new tools and advanced methods for solving of the process planning task in the modern enterprise.

Computer support can markedly help to solve some planning activities. Computer aided process planning (CAPP) is a tool for the automated design of route sheet. The CAPP represents the implemented methodology of process planning in the software package. The CAPP includes all process planning activities needful to realise of the design of the process plan. The CAPP system has to solve the planning activities such as selection of machining operations, selection of machine and cutting tools etc.

There are two basic approaches for creation and processing of process plan based on computer support and advanced planning methods [3]:

- variant process planning based on Group Technology (GT) utilizing,
- generative process planning based on exact mathematical principle utilised modelling of part, manufacturing knowledge and process planning.

There are two scientific areas for methodical elaborating of process planning:

- Theory of Group Technology for variant process planning,
- Expert process planning for generative process planning.

There is necessary to elaborate methodology for variant and generative process planning. Concrete CAPP system will be designed and made according process planning methodology. As the two planning approaches are different, as well the CAPP methodology for variant and generative methods will be unequal.

The methodology for generative approach consists of the following main activities and tasks:

- Modelling of engineering parts (feature modelling, B-REP, CSG method, etc.),
- Modelling of process planning (selection of machine tools, cutting tools, fixturing, sequence of manufacturing operations, etc.),
- Modelling of manufacturing operations (feature modelling),
- Modelling of manufacturing operation parameters (selection and optimisation of cutting conditions),
- Modelling of engineering knowledge (manufacturing knowledge, heat treatment knowledge, knowledge of process structure, etc.).

The methodology for generative approach is influenced by the following methods of individual modelling tasks:

- Process planning: forward or backward planning strategy,
- Engineering knowledge: forward or backward chaining of knowledge,
- Micro and macro planning strategy,
- Optimisation of manufacturing operation: one or multi-criterion optimisation.

The methodology for variant approach consists of the following main activities and tasks:

- Design and statement of group representative for engineering parts,
- Identification of engineering properties,
- Statement of similarity of engineering properties,
- Design of classification systems,
- Coding of engineering parts,
- Retrieval of similar engineering parts,
- Classifying the engineering parts to the groups.

IV. DEVELOPMENT OF METHODS FOR PROCESS PLANNING

The CAPP methodology has been elaborated during several years on the Department of Automation and Production Systems, University of Žilina. Especially PhD thesis are oriented to the solving of the automated process planning. In the following text will be described the topics of CAPP methodology based on utilising of Group Technology which are in process.

4.1 Static classification

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), 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].

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.

GT principle is one of principle used in CAPP methodology [5]. The standard plans are created for a family of similar items. In the GT CAPP systems 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 plans exist and include features which are closely analogous to those of the new part.

The classification is possible to realise according two methods [6]:

- visual (graphical) classification systems (Fig.1.),
- coding.

Manual visual classification is often realized according to graphical classification systems (Fig.1). 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 implementation effort of the preparatory stage.

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

Majority of CAPP systems based on GT is intended for manufacturing process planning. It is sufficient for the manufacturing process to create classification system which will be only fill up. There is no need for changing the number of groups, change localisation of individual engineering parts in individual groups. Therefore it is possible to consider these classification systems as static system.

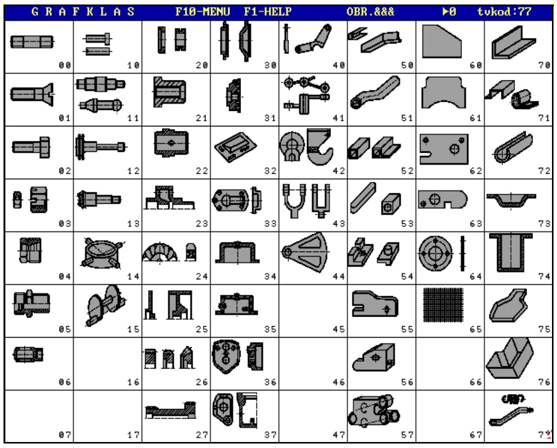

Fig.1. Graphical classification system

4.2 Group technology for non-cutting technologies

CAPP systems based on the Group Technology are very good elaborated especially for cutting technologies. The non-cutting technology area (welding, casting, forming) is not so supported by the current GT CAPP systems. Utilising of cutting tools and other equipment are different in non-cutting technologies as in the cutting technologies. According the comparison of CAPP systems for cutting and non-cutting areas is possible to state that automation of machining process planning is on the greatest quality level. The basic idea of the GT is possible to utilise for non-cutting technologies however by other way. The similar engineering parts (produced by non-cutting technologies) belonging to family, will have the similar technological conditions and similar utilised instruments and equipment. The order of process operations is not important. The GT CAPP system for forging and casting was elaborated on the University of Žilina. The basis is in graphical classification system /Fig.1 and Fig.2/, finding of similarity of new and produced parts, retrieving of process documentation and modifying of technological parameters. The modification and calculation of technological parameters are the most important in area of GT utilisation in non-cutting technologies.

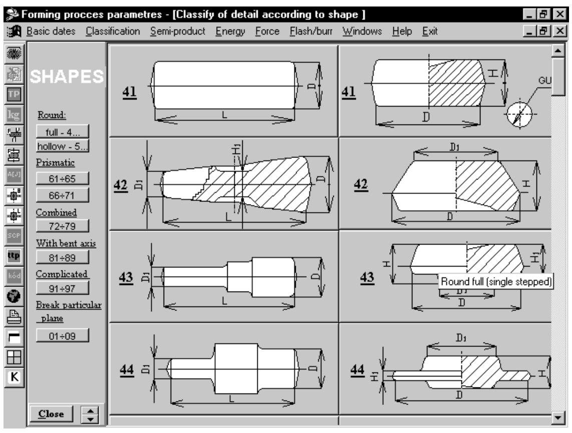

Fig.2. Developed visual classification according the geometry

4.3 Selective classification

Sometimes it is problem to determine and classify new engineering part to some groups. It doesn't mean that there is no similarity between new part and some group. Question is the following: What is similarity and how to determine the similarity among parts?

Important are defined criterions which determine the properties of individual groups. The process for selective classification of new engineering part is the following:

- Finding the most similar group for new engineering part,
- If there is no similarity between new part and GT representative, it is possible to extend individual properties (e.g. tolerances) characterizing the group, till the similarity is finding,
- If the group is determined, it is necessary to valuate whether the similarity has still technological meaning. For example the circle and square could be similar according edges, however there is no technological meaning (other tools for hole process).

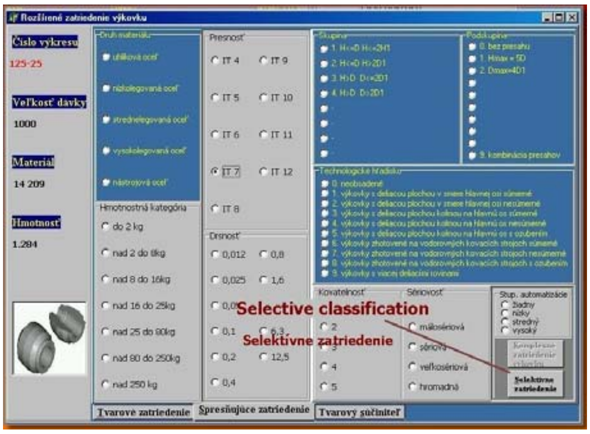

Fig.3. Developed selective classification according important part properties

The process for finding the similarity between new engineering part and individual groups based on extended properties of groups with respect on technological meaning is titled as selective classification. The process planner in the system (Fig.3) determine some property (tolerance, dimension, roughness, etc.) and he watches at its extension if there is some similarity. Then he must valuate the technological meaning of similarity.

4.4 Dynamic classification

However there is a big demand to utilise the GT also for 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 need to take other view on utilisation of GT in this area [6, 7].

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

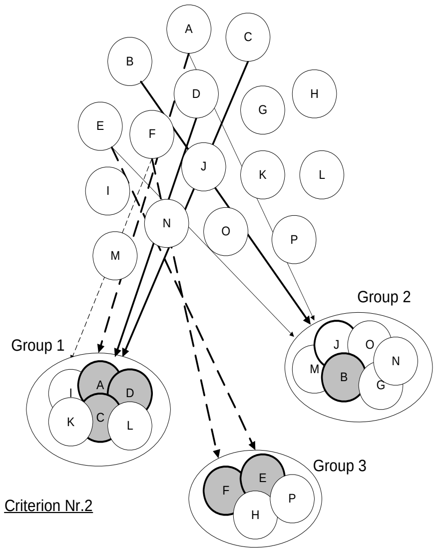

Fig.4. Dynamic classification according different criterion

The dynamic classification is based on *flexible classification system* [10]. The engineering parts are *dynamic grouped* to the individual groups according to classification aims (Fig.4). For example the engineering parts will be dynamic grouped to the family groups according the total costs or operational total times, number of produced parts, series, etc.. There is a mathematical method - *cluster analysis* - which seems to be a very good candidate for support of dynamic classification system creation [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.

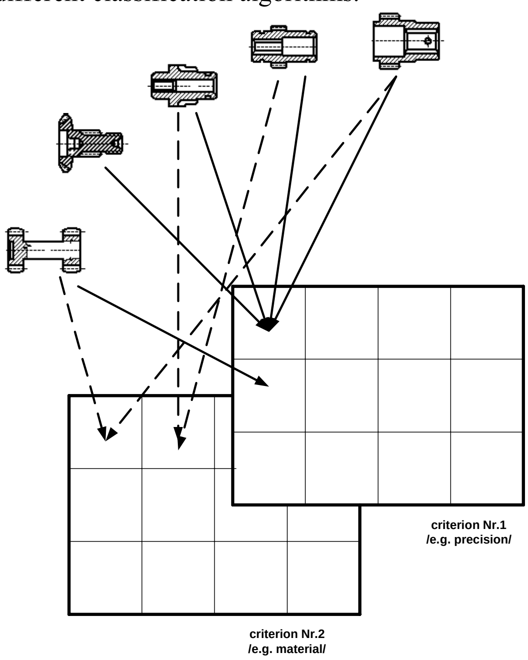

Fig.5. Product grouping according different parameters

The principle of dynamic classification is evident on Fig.4 a Fig.5. The parts are flexible and dynamic grouped according selected criterions. It is still appropriate to utilise the visual classification as it is very simple and effective method however with flexible possibility the grouping the parts according actual demands.

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.

4.5 Parametrisation and association

New approach base on parametrisation and association /Fig.6 and Fig.7/ is new method of GT utilising in process planning. The developed approach consists of parametrisation of process plan and making of association with part features. The association is realised between part feature and process operations. Association between part features and process operations creates the link between design features and manufacturing features located in process plan /Fig.7/.

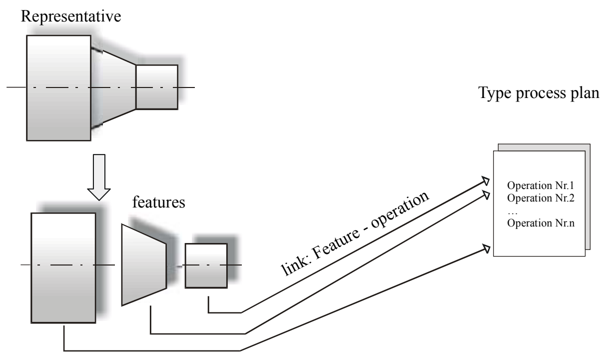

Fig.6. Association - links between parametrised design features and process operations

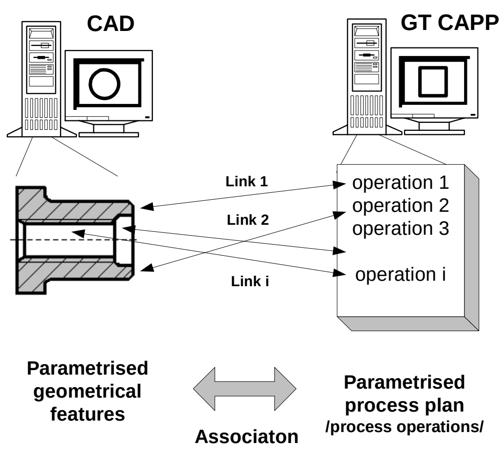

Fig.7. Principle of parametrisation and association in GT CAPP

V. CONCLUSION

The Department of Automation and Production Systems, University of Žilina systematically engages in research into CAPP methodology and its application in factories. The building of CAPP system is time demanding and very labour task. The CAPP tasks require the theoretical elaborating, working out the serious methodology of process planning and used advanced programming technique. The above mentioned topics are elaborated as PhD thesis.

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