# EXPERT SYSTEM USING FOR GROUP TECHNOLOGY BASED ON NC PROGRAMMING CAPABILITY

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## Abstract

The trend of recent manufacturing is that more requests on the product types with the small-lot quantity. This matter can reduce the possibility of realization of the efficient and low cost production. The problem can be overcome with the application of Group Technology (GT) and the use of CNC machine tool in production system. Group Technology (GT) is a concept to increase production efficiency by grouping various parts and products with similar design and/or manufacturing process. While CNC machine tool is able to make wide-ranging of product flexibly even though the amount of the product become less. To be able to make product close to mass-product production system, CNC machining should be supported with the application of GT. The combination of GT and CNC machine tool is possible if the flexible condition of the NC programming is fulfilled. The program should be used repeatedly for the same or look alike product. The flexible condition is possible, although restricted, with existence of the packet cycle, subprogram, and macro program. Based on the existing part programs, the method of product classification is obtained then continued with product codification. Product classification and codification was proceeding by use of Expert Systems. Result of this codification can be entered into computer to facilitate data and processing information of the product.

## Introduction

Group technology (GT) is a manufacturing philosophy that identifies and exploits the underlying sameness of parts and manufacturing processes [1]. The principle has been applied in many fields including part design retrieval, process planning, machine cell design, facility layout, scheduling, etc. For a company whose product types are variant and production lot size small or medium, the advantages of implementing GT include enhanced ability to adapt to quick market changes, reduced throughput time, reduced production costs, reduced varieties of product design and process planning, and promoted part and process standardization [2].

Parallel to the development of GT concept, CNC machine tool development has improved the machining productivity. CNC machine tool is capable to machine a part in the shorter time than conventional machine tool by reduces the non-cutting time. CNC machine tool has a flexibility to machine the several of product by changing NC programming. It is suitable for a multi-product and small-lot-sized production system or

batch-type manufacturing. But the capability of CNC machine tool is still limited when it applied to increase the machining output level as high as mass-production system. The implementation of GT concept to CNC machine tool has made a possibility to gain such level.

This study is focused on the implementation of GT to the aspect numerical control (NC) programming of turning centers. The GT and NC programming capability will be used to develop a NC program for each part family. The features of NC programming such as canned-cycled and macro programming can be used to realize that combination. The combination of GT and NC programming approaches create the opportunity to generate NC codes and operate CNC machines with greater efficiency [3,4].

After NC program has been created for each part family, the process continues to classify the products. Then the products are codified based on the classification rules that have been created. Nowadays, because of the development of computer science, the need for computer integration of whole creation process has appeared. Computer aided classification which is closely connected with the Expert systems were used as a classifier. The Forward Chaining method was used as a reasoning model. This method involves checking the condition part of a rule to determine whether it is true or false. If the condition is true, then the action part of the rule is also true. This procedure continues until solution is found or a dead end is reached [7].

**Methodology**

The main activity of GT is to group the products. Part family grouping is an important step for successful GT applications. A part family may be grouped with the parts having similar design features such as geometric shape, size, and materials and so on. A part family also may be grouped with respect to production operations: machines, processes, operations, tooling and so on. Grouping is usually related with some criteria:

- Geometric shape,
- Manufacturing technology,
- Used production equipment.

In order to decide whether a product can be entered into any group, geometric similarity is used as the first criteria. Geometric similarity of products includes shape, dimension, and length-to-diameter ratio. In this stage, the products can be grouped mainly into rotational and prismatic (non-rotational) parts. This study will be focused on the rotational parts only.

The next step is grouping based on the manufacturing technology. Because all of the products are rotational parts, therefore the turning process is used as the main process. When the turning process is proceeding in a CNC machine tool, NC programming is needed to operate CNC machine tools. This work studied the programming as the criteria of product grouping.

*Product Group Programming*

There are some ways to prepare NC programming for making a part.

- Manual programming,
- Semi Computer Assisted programming,
- CAD/CAM Integrated System.

Manual programming is the program script arrangement that consist of step-by-step the work process according to the process planned and activation of the supporting function through the certain commands. With the manual program, separate part programs are written for individual parts within a part family. Then the programs are loaded to the controller one-by-one.

While Semi Computer Assisted Programming is the program creation way which part of computing process is assisted with computer. In the program, the user writes the needed parameter in the certain code and finally the computer will turn out in the instruction. Some features where exist in the CNC machine tool are:

- Canned /Multiple Repetitive cycle,
- Parametric/Macro programming,
- Symbolic programming.

Every part is assumed as consist of some features that can be processed with certain cycles such as G70, G71, G90 and so on. If the features have similarity each other, the same cycle can be used together. The cycle was used as one of the grouping criteria.

While in parametric programming, also referred to as macro, in which a part program can be written using variables and parametric expression to represent coordinates (Y and Z), feed and speed functions. This programming allows the user to load a single part for a family of parts to the CNC controller. The part program is then called for machining a similar part or similar feature on different parts by entering the parametric values such as diameter, length and so on. Upon loading the main program, the values of the two parameters are entered, and then these values are transferred to parametric subprograms. This method could minimize the number of program changeovers, reduce redundant codes and shorten the length of the program [4].

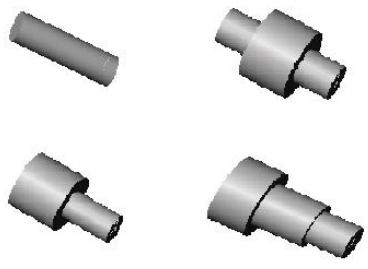

*Fig. 1: A group of part family*

*Table 1: List of CNC Programming for the Part Family (Fig 1.)*

| | |
|---|---|
| O0001;<br>G50X400.Z400.T101S2000;<br>G00G96X45.Z0S150M03;<br>G01G42X0Z0F0.2;<br>G00G97X400.Z400.T100M05;<br>G50X400.Z400.T202S2000;<br>G00G96X45.5Z0S200M03;<br>G90X41.Z-60.F0.1;<br>X39.;<br>X36.;<br>X33.;<br>X30.;<br>X27.;<br>X24.;<br>X21.;<br>X20.;<br>/G65P0002A20.B1.C17.5C-30.J0.15K15.400J400.<br>/G65P0003K21.I0.5J1.K0.15J10.K-20.I15.J-37.5K20.I-40.J2.5<br>G00G97X400.Z400.T200M05;<br>M00;<br>M15;<br>M00;<br>M14;<br>M00;<br>G50X400.Z400.T101S2000;<br>G00G96X45.5Z0S200M03;<br>G01G41X0Z0F0.2;<br>G00G97X400.Z400.T100M05;<br>G50X400.Z400.T202S2000;<br>G00G96X45.5Z0S200M03;<br>/G65P0003K21.I0.5J1.K0.15J10.K-20.I15.J-37.5K20.I-40.J2.5<br>G00X400Z400T100M03;<br>M30; | O0002;<br>G00G96X#1Z#2S200M03;<br>G90X#3Z#4F#5;<br>X#6;<br>G00X#7Z#8;<br>M99<br><br>O003;<br>G00X#9Z#10;<br>G71P1Q5U#1W#10D#11F#12;<br>G00X#13;<br>G01G42Z#14;<br>X#15;<br>Z#16;<br>G70P1Q5;<br>G00X#13;<br>G01G42Z#14;<br>X#15;<br>Z#16;<br>M99; |

*Classification and codification*

According to the definition, classification is the process of categorizing parts into groups on the basis of the proper set of rules and principles. The classification and codification system assigns code to part. Based on these codes, parts can be grouped into part families. Each part family corresponds to a group of machines.

Lot of classification methods has been elaborated. Coding and processing of coded information about classified elements are the main principles of functioning of this method. Different methods of classification used different types of algorithms. The most often used algorithms are among others: hierarchical, iterative and fuzzy ones. This work used hierarchical as method of classification.

Hierarchies of class depend on the complexity of product, but in this study parts are divided into some classes as follow: basic, primary, secondary and so on. Basic class grouped parts into two main groups: rotational and prismatic. Rotational parts generally have cylindrical shape such as shafts, disks. Primary class grouped parts into five groups based on the made macro programming. In the secondary class, the additional information must be given to differentiate among external turning, internal turning and threading. Also the information regard to spindle rotation direction as related to tool orientation (right or left). The classification is continued if the existing class insufficient. The principle should be taken into consideration is the more class the more codes.

The codification is build based on the classification. The structure of the coding scheme, which consists of three classes/levels, has twelve digits coding. The details of the coding scheme description follow here:

(1) The class 1 has only a digit. For example, 1 for rotational and 2 for prismatic.
(2) The class 2 has six digits. A digit is for macro group, four digits are for the used G-code and a digit is for tool path direction.
(3) The class 3 has two digits. A digit is for specific geometrical shape and a digit for spindle direction.

**GT Expert System**

At present, the automation of process planning requires the use of computer systems to perform process planning tasks, such as the selection of the size of raw materials, the machines, the cutting tools, the cutting speed, the feed rate, the depth of cut and the machining sequence. The expert system technique has been implemented in the field of computer aided process planning (CAPP). An expert system is a computer program that simulates human expert(s) in making decisions and solving problems. Expert systems have advantages over the traditional computer systems for the following reasons:

(i) Expert systems organize knowledge in rules and control strategy which allow users to modify a program with ease;
(ii) Expert systems organize knowledge in a way such that they can reason intelligently, thus, expert systems are able to deal with far more complicated problems;
(iii) Expert systems can be designed so that they accumulate knowledge as time passes.

*Knowledge representation*

The knowledge must be organized in an easily accessible format that distinguishes between data, knowledge, and control structures. So that, expert systems are organized in three distinct levels: knowledge base, working memory and inference engine [7]. The knowledge base consists of problem solving rules, procedures, and intrinsic data relevant to the problem domain.

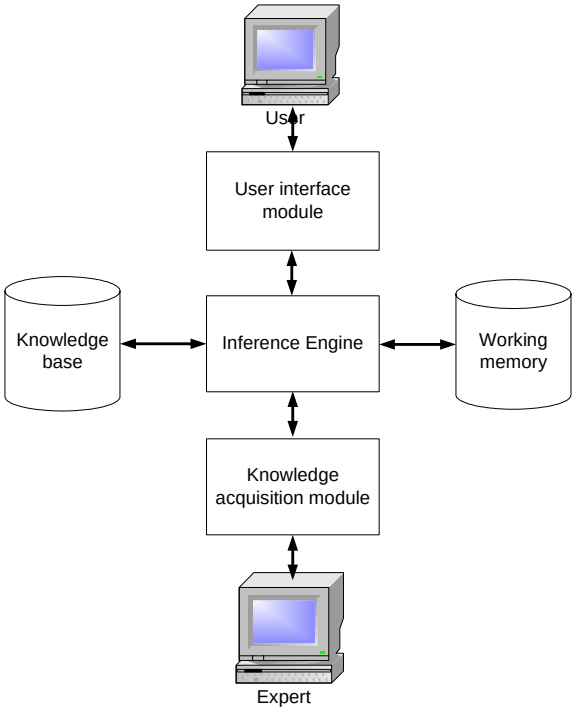


*Fig 2: Components of the GT Expert systems.*

Working memory refers to task specific data for the problem under consideration. While inference engine is a generic control mechanism that applies the axiomatic knowledge in the knowledge base to the task-specific data to arrive at some solution. Figure 1 represents the expert systems structure.

The production rules are used as the knowledge representation schemes. A production rule has the following form: IF(condition)-THEN(conclusion). When the IF portion is satisfied by the conditions, the action specified by the THEN portion is performed. This is called 'fire' situation. A rule interpreter compares the IF portion of each rule with the facts and executes the rules whose IF portions match the facts. For example, the production for the NC programming-based GT as follow:

IF Part X is rotational part
THEN Part X is to be machined in CNC turning
….
IF Part X must be finishing processed
THEN G70 is used as G Code
….

*The inference engine*

The inference engine of an expert system is very important because it controls how to reach a conclusion, i.e. the inference engine determines the sequence in which rules are applied. The inference engine controls the process knowledge in the knowledge base to

solve the problems of the selection of the process, the selection of the G Code and the selection of the cutting parameters and so on.
The inference engine uses Forward-Chaining algorithm to solve problem. It starts with a set of facts or data and to look for those rules in the knowledge base for which the IF portion matches the facts. When such rules are found, one of them is selected based upon an appropriate criterion and fired. After a rule fires, the GT Expert System executes the rule's actions. Now the knowledge base might make some alteration. Then, the rules will be checked again against the facts and criterion in the knowledge base. This generates new facts in the knowledge base, which in turn causes other rules to fire.

*The automatic coding module*
In this work is build the automatic coding module as a part of GT Expert System. The automatic coding module is a computer program written with the Visual Basic 6.0 language. Its objective is to accept the component's design information and store the code in the knowledge base for other modules to generate the process plan. The coding module provides guidance to the users step-by-step as follow:

Step 1 the user push 'Tracing' button and select Rotational in the Product Classification form (see Fig. 3).
Step 2 After Process Type Tracing form is appeared, select one process or more that it will be used to process the part (see Fig 3.).
Step 3 Select the appropriate operation (as represented by G Code) based on the geometric feature of part. The first three-steps is important in code generating process (see Fig 3.).
Step 4 Then, select the additional information such as tool direction, specific shape and spindle rotation direction. The selection matches with part design and machining capability (in fig 4.).
Step 5 Before the information processing, summary of the analyzed data is displayed. Then the information processing is performed and coding module generates a component code (see Fig 5.).

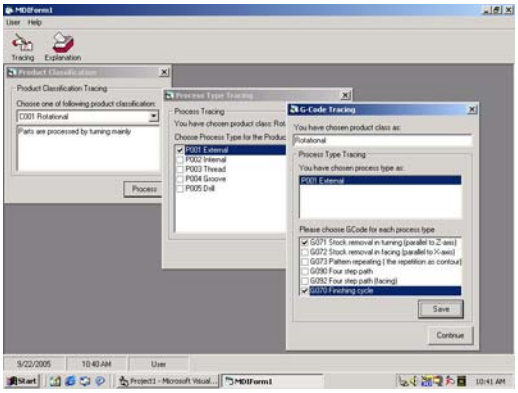

*Fig. 3: The first three-step of GT Expert System*

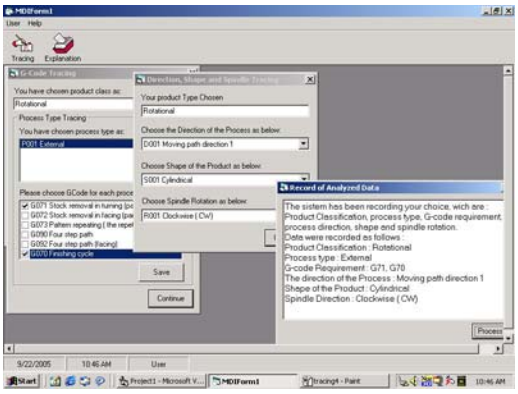

*Fig. 4: The additional information for coding process*

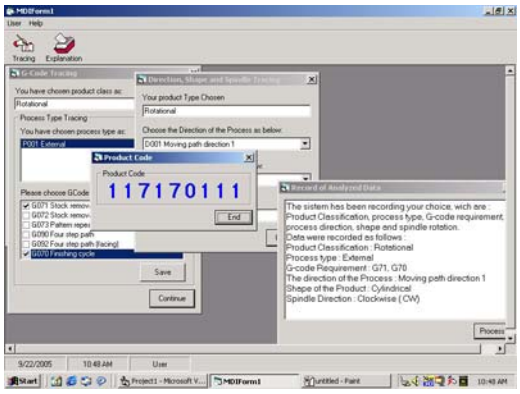


*Fig.5: Coding process result*

## Conclusion

GT concept and CNC machine tool combination are suitable to improve the productivity of small-lot-size manufacturing. GT organized the manufacturing flow so that the manufacturing output can be improved up to the special machine capability. CNC machine have the capability to machine parts flexibly. The implementation of GT concept in CNC machine tool is based on NC programming capability. CNC machine controller provides the features: canned cycle, subprogram and macro program that it can be used as the classification tool. The similar part can be grouped in one family part program. The use of Expert System in codification of parts is to generate part code automatically. The results of parts coding will be used as input for the further process plan.

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