

Development of parametric CNC program and decision algorithm into product line made from natural stones

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Abstract: Presently, the group technology algorithms applied to metals have not been applied to granite and marble products yet. As the first step of our research we designed the complex part and we synthesized the manufacturing plans of the complex part. In this paper we optimized the cutting tool paths, we broke the complex part down in order that the NC programming would be easier and more explicit. We made a decision algorithm and a process system to the CNC programming. Then we wrote the manufacture controlling, parametric, modular CNC programs. The CNC machining control programs were also developed to two controls. We wrote the programs partly manually, partly with Edgecam. We developed a software in C# that assists graphically the replenishment of the variables of this program. We added explanatory diagrams, technical drawings and other useful supplementary features to the CNC program in order to create a safe, simple, rapid and flexible the generation of the program. After that we pointed to the necessity of the parametric programming that is based on the group technology philosophy in the case of the products made from natural stones.

Keywords: stone machining, group technology, optimization, CAD/CAM, CNC, C#

1 Introduction

We can include the geometrically and technologically similar parts in groups, and we can manufacture them with group technology. Using group technology for the technology plan of milled parts we invest the small- and medium series with attributes of the high volume production. In this way we can produce a detailed manufacturing plan (with optimized technological parameters) for small and medium series components cost-effectively.

The main purpose of our project was to investigate the advantages and limits of the applicability of group technology adapted to the products made from natural stones. Presently, the group technology algorithms applied to metals have not been applied to granite and marble products yet. We tested the applicability of group technology on a granite worktop product line.

As the first step of our investigation competing product analysis was carried out then after the assessment we designed a granite work top product line of modular elements. We have designed the complex part to apply the group technology techniques. We used the Solid Works 3D design software for the construction design. We synthesized the detailed manufacturing technology, operational succession plan, and operational ordinance of the complex component.

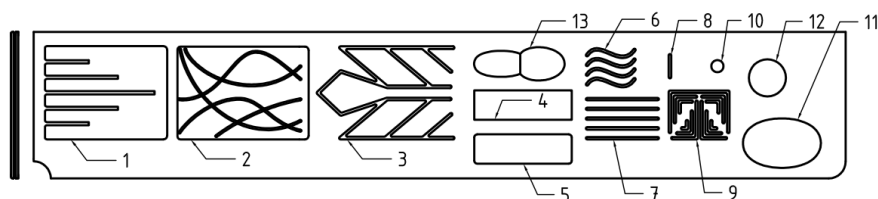


Fig.1. Complex part

The modules seen on Fig.1. are the following: 1), 2), 3) plate dryers, 4) stove, 5) sink, 6), 7), 9) refractory mats, 8) groove, 10) faucet hole, 11), 12), 13) fruit bins. Based on the complex part, the construction of worktops seen frequently in commerce can be put together (Fig.2.).

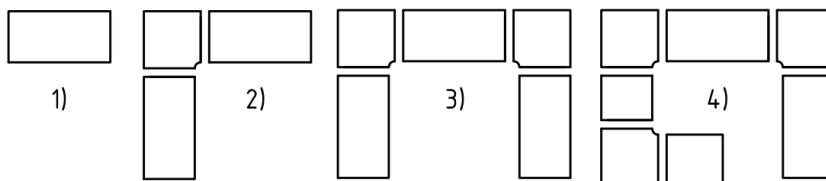


Fig.2. Different construction of worktops

In this paper we wrote the manufacture controlling, parametric, modular CNC programs. The CNC machining control programs were also developed to the FAGOR CNC8070 and the NCT201. We wrote the CNC programs partly manually, partly with EdgeCam. We developed a software in C# that assists graphically the replenishment of the variables of CNC program. We added explanatory diagrams, technical drawings and other useful supplementary features to the CNC program in order to create a safe, simple, rapid and flexible the generation of the program. After all we evaluated the adaptability of group technology technique on different work top constructions.

2 Planning of parametric CNC program

Because of the enormous extension (~450 thousand rows) of the CNC programs belonging to the complex parts it would not be reasonable to write them manually, so that we can create the programs belonging to each part deleting the irrelevant program parts. The solution is the parametric programming, where with the help of the defined variables of the main program the CNC program itself holds a decision algorithm. This algorithm decides which program parts should be considered and which have not.

The CNC programs controlling the machining of the complex part have to include the following:

- Defining of parameters
- General M and G functions
- Technological parameters (feed, speed)
- Decision making algorithm, that can decide based on the global variables which program parts have to run.

2.1 Program structure and decision making algorithm

Part of the structure and decision making algorithm of the CNC programs are seen on Fig.3. As seen on Fig.3., the O1000 main program holds the global variables that have to be filled out by the process engineer. The process when the program decides if a program part should run or not, is called decision making algorithm.

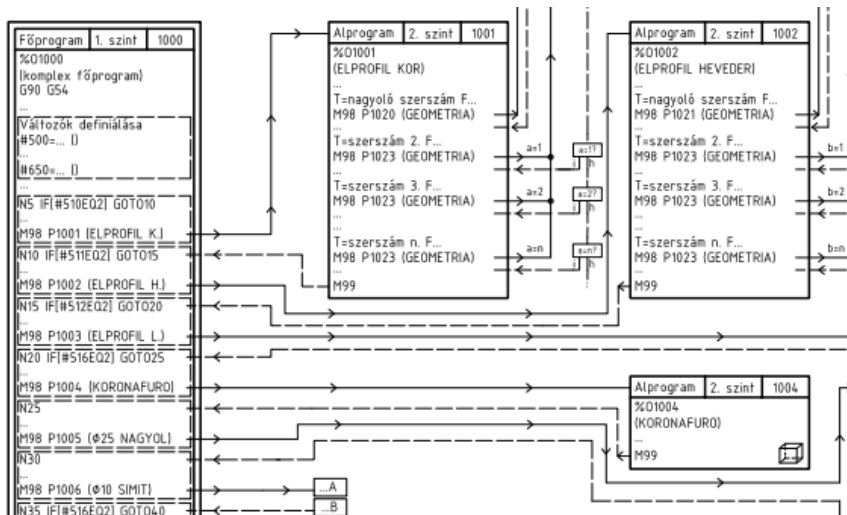


Fig.3. Part of decision making algorithm

The decision making algorithms usually use ‘IF’ and ‘GOTO’ functions. In the arguments of the functions there are global variables defined in the main program. The CNC program part on Fig.4. shows a process like this.

...	
N5 IF[#514EQ2] GOTO10	
G0 Z100	
G0 X100 Y100	
M98 P1030 (CSEPEGTETO MIN. NAGYOLAS)	
G0 Z100	
N10 IF[#513EQ2] GOTO15	
...	

CONSTRUCTION
<u>IF[#514EQ2] GOTO10:</u>
If in the register 514 there is a '2', go to sentence 10, else do the next sentence. Let's say the meaning of '1': yes; '2': no → If #514=1 go ahead and call subprogram #1030, if #514=2, jump over it.

Fig.4. Part of a decision making algorithm

The main program contains 64 variables. This much variables are needed so that the program of the part could be unequivocally defined. These variables need to be uploaded before the making of each worktop. The uploading of the parameters could be done:

- On the keyboard of the machine tool. (*By that time the machine tool is not working →wastage*)
- In word processor. (*slow, danger of typing error*)
- In CNC program Editor. (*slow, expensive*)
- With software support.

The uploading of the variables needs a lot of attention paying, as if we mistype a character, or we delete something from the main program accidentally, it may cause serious consequences. The safest and fastest solution for the uploading of the parameters is if we use a target software. As such program is not available, we developed a software running on Windows operation system. (*See: chapter 4.*)

We called the programs for four subprogram levels. This is shown on Fig.5. On the first level there is only the main program called O1000. This program has to be started at the beginning of the machining of the worktop, only this program contains those variables¹ that are in the arguments of the lower level algorithms. The subprograms containing the geometrical informations also uses local variables², but the local variables also depend on the global variables.

¹ The global variables are not deleted on the shutting down of the machine tool, their values are the same in every program.

² The local variables are deleted on the shutting down of the machine tool, their values are not inherited at the calling of a subprogram.

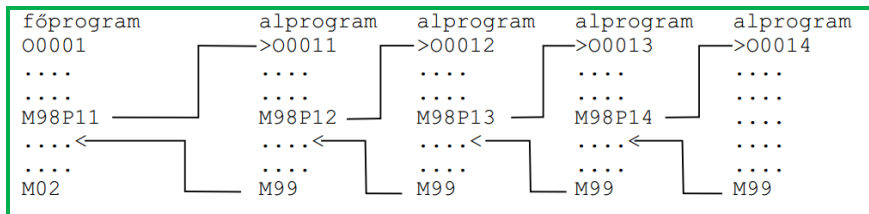


Fig.5. Calling of subprogram levels

With the use of the subprogram we get a well-structured CNC program system that represents well the modular buildup of the worktop and shows the applicability of the group technology.

The programs that also contain geometrical information are signed with a little cube. (Fig.3.). Where the subprogram is not marked (ex. on Fig.3. O1001), there the technical informations, tool changes, decision making algorithms construct the program. We constructed the subprograms which are not marked and the main program manually, with Microsoft Office Word text editor software. From the marked ones the ready machining of the CNC programs with simpler geometry are also made manually, while the more complicated featured ones are made with EdgeCam tool patch software. Then we organized the created CNC programs by program structure.

2.2 CAM programming

The modules held by the complicated surface are unreasonable (*often impossible*) to program, because of this we used the EdgeCam tool patch software.

With the help of the CAD model EdgeCam creates the tool patches. Because of the group technology and the module system we needed to create 3D CAD-models separately for every element of the complex part, so that for each subprogram belongs one work piece zero point and one manufacturing stap. We performed separation on every part element (ex. oval fruit holder), additionally we modeled the different sized twin pieces of every part element. This means at the oval fruit holder for example six different configurations. We made the program for every configuration. As seen on Fig.6. the tool path of the 5 mm deep, medium width oval fruit holder at roughing and finishing. The common characteristic of every tool patch is that the pull strategy helix interpolation is 5°.

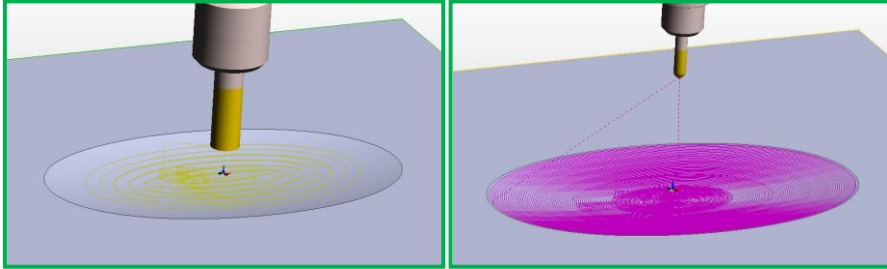


Fig.6. Roughing and finishing tool patch of the oval fruitholder

At CAM programming we had to be really careful so that the coordinate systems axis in the work piece made in the designing module should be unambiguous and the center should be in the same point as regulated in the technical drawing, otherwise the programs made manually and with CAM cannot be joined. On the level of manufacturing step we handled separately the tool patches belonging to one tool because of the modular manufacturing, so that at the linking with the manual programs we did not have to desynthesize the thousands of rows CAM-generated CNC program by manufacturing steps (*tool changing*). As the programs made for NCT 201 controller could be fitted rapidly to FAGOR controlling, the programs generated by CAM has to be the simplest possible. By simplicity we mean that besides the initiative and technological informations it just contains coordinates.

3 Estimation of manufacturing costs

As the next step of manufacture planning, we made an estimation of cost. The technicians of Woldem Kft. estimate the cost of machining by each machine tool's machining time. The machine tool's minute cost contains the following (without exhaustive):

- The cost of energy. (*electric energy, heating, hydraulics, pneumatics*)
- Proportioning the purchase price and amortization of the machine tool.
- Cost of tools. (*Purchase, service, amortization etc.*)
- Wage of operator, process engineer.

If we add the cost of the basic material and the shipping to the cost of the machining, and multiply it by the profit, then we get the base sum of the offer.

At the worktop manufacturing two machine tools and an additional three (manual) process can come into question (depending on the worktop construction). The main production times can be estimated with the help of the CNC programs. I

measured the production time of the manually written programs with the NCT 201 controlling simulation software, while in the case of computer helped method the EdgeCam automatically gives out the main production time. Based on the main production time we can calculate the cost of manufacturing:

$$K_{gy} = t_1 K_{VIZ} + \left(K_{MARÓ} \sum_{i=2}^{30} t_i \right) + t_{31} K_{SAROK} + t_{32} K_{HOMOK} + t_{33} K_{IMP} \quad (1)$$

Where K_{gy} [Ft] is the cost of production, t_i [s] the time of the i . manufacturing step, K_x [Ft/min] minute cost of the x . manufacturing step. The offer can be calculated from this:

$$\hat{AR} = \left(K_{gy} + K_{mdb} + K_{száll} \right) \left(1 + \frac{p}{100} \right) \quad (2)$$

Where $\hat{AR}$ [Ft] is the offer, K_{mdb} [Ft] is the cost of the base material, $K_{száll}$ [Ft] is the shipping cost, p [%] is the gain. The developed software uses the calculation correlation.

4 Software developing for uploading the variables of the CNC main program

We equipped with explanatory figures, technical drawing and other practical complementary functions, so that the CNC program generation will be secure, easy, fast and flexible.

4.1 Requirements

The assignment of the variables defined in the CNC main program has to be treated carefully, as the incorrect assignment or the unneeded accidental intervention (ex. deleting) can cause serious consequences. The occurrence of these kinds of problems can be decreased if the upload of the variables is done with a software equipped with explanatory. At the development of the software we kept in mind the followings:

- Generate the syntactically right CNC main program, upload the registers with the proper values.
- The CNC program can be saved, and has to know easy word process operations.
- Has to provide graphical help.

- The usage has to be easy and fast
- The manufacturing documentation has to be accessible to the complex parts.
- Calculates the estimated production cost, gives opportunity to the making of an offer.
- There should be an easy safety algorithm, which controls the work of the user.

Based on the upper aspects we developed a software in C# language that helps graphically the upload of the variables of the CNC program.

4.2 Demonstration of the software

After the sign in, the window seen on Fig.7. pops up.

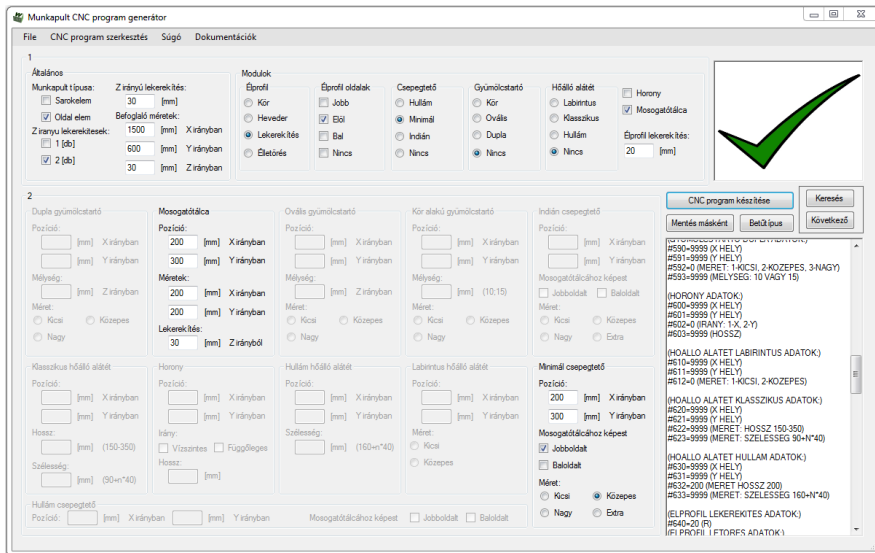


Fig.7. Start window

It can be seen, that the majority on the window (detailed settings) is gray, so it is inactive. As we set which elements do we need, the detailed settings became active. The CNC program can be saved, edited. In the Documentations submenu we can find the part drawings and manufacturing plan. With the pop up window of File menü/ Ár kalkulátor command we can see the need of estimation of the time and manufacturing cost of the set features (Fig.8.). If we want to give an offer, then after giving a profit multiplier calculates it with any of the three eligible currencies.

Munkalap ár kalkulátor

Gyártási költség becslése

Megmunkálási idő /felület	Megmunkálási költség
CNC vizsgás: 0.615384615384615 [min]	389.538461538462 [Ft]
CNC mérés: 1 [min]	300 [Ft]
Sarokcsiszolás: 120 [min]	6000 [Ft]
Homokfúvás: 0.8 [m2]	3200 [Ft]
Impregnálás: 2 [m2]	6000 [Ft]

Kgyártás= 15889,5384615385 [Ft]

Ár= 54,9420384615385 [C]

Árajánlat készítése

Nyereség: 10 [%]

0 0

0% -5% -10%

Kilépés

Kvíz=38 000 Ft/h Kmaró=18 000 Ft/h Kmpr=3 000 Ft/m2 Sűrűség=2600 kg/m³ 1 \$=250 Ft

Khomok=4 000 Ft/m2 Ksarok=3 000 Ft/h Kalapanyag=3000 Ft/kg 1 €=320 Ft

$$K_{gyártás} = K_{VIZ} + \left(K_{MARÓ} \sum_{i=2}^{30} t_i \right) + t_{31} K_{SAROK} + t_{32} K_{HOMOK} + t_{33} K_{IMPR}$$

Fig.8. Price calculator

5 Testing of group technology based construction and manufacturing planning

We tried the documents, programs and algorithms made at the manufacture planning on various worktop constructions, so that we could filter out the potential errors. After detecting and correcting the errors, the construction and manufacturing plans, the algorithms of the CNC programs and the software written in C# developed iteratively. The usability of continuously developed plans was tested on the order sketch seen on Fig.9.

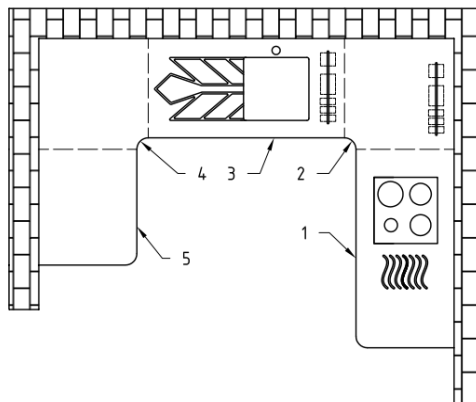


Fig.9. Tested worktop construction

5.1 Testing aspect

The construction and manufacturing plans are considered good if the answer is ‘yes’ to all of the following questions:

- Can we manufacture the tested worktop from the 3D CAD model of the complex part easy and fast?
- Can we manufacture the manufacturing plan of the tested worktop from the manufacturing plan of the complex worktop fast and easy?
- Can we generate machining controlling CNC programs by changing the values of the global valuables of the main program?
- Can the *Woldem CNC* software upload the valuables and estimate the manufacturing costs?

In the case of the tested worktop seen on *Fig.9.* the answers to the questions and their evidence are shown below.

5.2 Testing

5.2.1 Generation of CAD model

The worktop shown on *Fig.9.* can be put together from 5 parts. We can see the worktop parts on *Fig.10.*, here a directions of the coordinate axis are the same as the complex parts coordinate direction.

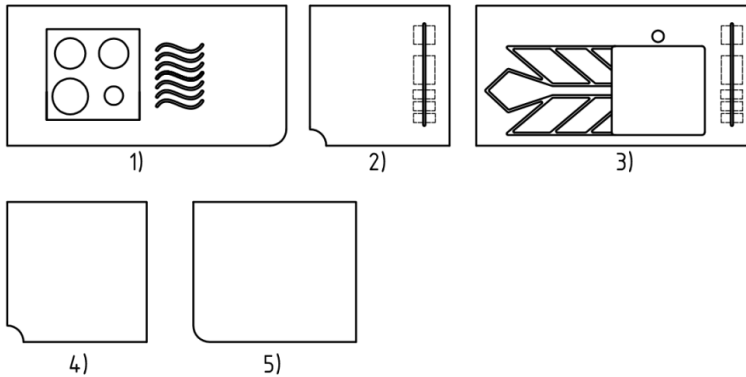


Fig.10. The tested worktops parts

If we combine the complex worktop drawing of parts with the parts seen on *Fig.10.*, it is easy to see that with the deleting of the unnecessary features and changing the geometrical sizes, it is easy and fast to generate every parts 3D CAD model.

5.2.2 Generating the manufacturing plan

Considering, that the tested worktop has five parts, five manufacturing plan are needed. From the manufacturing plan belonging to the complex worktop we can quickly generate the manufacturing plan to each part by deleting the unnecessary manufacturing step belonging to the modules. Three steps are needed for the manufacturing of the part 2) 4) 5): CNC water cutting, CNC milling, and then impregnation. At the parts 1) 3) after the milling the place of the stove and the tap has to be water cutted then impregnated. This way the manufacturing plans can be generated easily and quickly from the manufacturing plan belonging to the complex part.

5.2.3 Generating of CNC programs

The machining CNC programs were made, so that:

- The number of the global variables is enough to describe exactly any worktop construction³.
- Only the main program contains global variables.

It is seen in the main program, to which variables do we need to add value, so that the decision making algorithms in the program jumps over the irrelevant program parts. The five main programs at the manufacturing of the tested worktop are easily generated with the help of the main program belonging to the complex part.

5.2.4 Uploading of the value with software support

At the using of the software it is easily seen that if we choose good values, the variables of the main program can be uploaded. The *Wolden CNC* software designed to the Windows operation system guarantees fast and secure uploading. The CNC main programs and their estimated manufacturing costs can be generated to each of the five worktop parts.

At the testing the answer was 'yes' to all five questions, so as a conclusion the construction and manufacturing plans based on group technology meets the expectations.

Conclusions

In this paper we wrote the manufacture controlling, parametric, modular CNC programs. The CNC machining control programs were also developed to the FAGOR CNC8070 and the NCT201. We wrote the CNC programs partly manually, partly with EdgeCam. We developed a software in C# that assists graphically the replenishment of the variables of CNC program. We added

³ With the optional use of the given modules.

explanatory diagrams, technical drawings and other useful supplementary features to the CNC program in order to create a safe, simple, rapid and flexible the generation of the program.

We tried the documents, programs and algorithms made at the manufacture planning on various worktop constructions. After detecting and correcting the errors, the construction and manufacturing plans, the algorithms of the CNC programs and the software written in C# developed iteratively. After the optimizing, we can say that the documents based on the group technology meets the expectations.

As a result of our research there was made a case study that reflects on the grounds of the usage of group technology in products made from natural stones.

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