UDC 621.9-52:621.914:004.89

IZRADA STRATEGIJE ZA OBRADU GLODANJEM NA CNC STROJEVIMA
DESIGN OF MILLING TOOL CUTTING STRATEGY FOR CNC MANUFACTURING OPERATIONS

Jozef NOVÁK-MARCINČIN

Sažetak: *Da bi se postiglo kraće vrijeme obrade i bolja kvaliteta površine, proizvodni inženjer mora primijeniti optimizaciju digitalno kontrolirane proizvodnje strojeva za glodanje kao i koncept točnog dizajna – strategiju gibanja alata za glodanje. Zbog mogućnosti izvođenja velikog broja različitih vrsta površina na različitim proizvodnim strojevima, a korištenjem različitih tehnoloških parametara, teško je izabrati optimalan i učinkovit koncept gibanja alata za glodanje. Novi moderan pristup rješavanju tih problema za sobom povlači primjenu ekspertnog sustava i sustava temeljenog na znanju, kao i klasičnog softvera namijenjenog izradi kontrolnog NC programa.*

Ključne riječi: – strategija obrade glodalom
– NC programiranje

Summary: *In order to obtain better cutting time and better quality of parts surfaces, it is necessary for the manufacturing engineer to implement optimal digitally controlled milling manufacturing machines as well as an accurate design concept—a strategy for milling tool motion. On the grounds of the possibility for realizing a wide array of different type surfaces on different manufacturing devices, and through the exploitation of various technological parameters, it is difficult to choose an optimal and efficient concept for milling tool motion. The new and modern approach to solving these problems constitutes the application of expert and knowledge systems in collaboration with classical software intended for creation by control NC programs.*

Keywords: – milling tool cutting strategy
– NC programming

1. INTRODUCTION

The first benefit offered by all forms of CNC machine tools is improved automation. The operator intervention related to producing workpieces can be reduced or eliminated. Many CNC machines can run unattended during their entire machining cycle, freeing the operator to do other tasks. This gives the CNC user several side benefits including reduced operator fatigue, fewer mistakes caused by human error, and consistent and predictable machining time for each workpiece. Since the machine will be running under program control, the skill level required of the CNC operator (related to basic machining practice) is also reduced as compared to a machinist producing workpieces with conventional machine tools.

The second major benefit of CNC technology is consistent and accurate workpieces. Today's CNC machines boast almost unbelievable accuracy and repeatability specifications. This means that once a program is verified, two, ten, or one thousand identical workpieces can be easily produced with precision and consistency.

A third benefit offered by most forms of CNC machine tools is flexibility. Since these machines are run from programs, running a different workpiece is almost as easy as loading a different program. Once a program has been verified and executed for one production run, it can be easily recalled the next time the workpiece is to be run. This leads to yet another benefit, fast change-overs.

The designer must possess enough knowledge of CNC to perfect dimensioning and tolerancing techniques for workpieces to be machined on CNC machines. The tool engineer must understand CNC in order to design fixtures and cutting tools for use with CNC machines. Quality control people should understand the CNC machine tools used within their company in order to plan quality control and statistical process control accordingly. Production control personnel should be abreast of their company's CNC technology in order to make realistic production schedules. Managers, foremen, and team leaders should understand CNC well enough to communicate intelligently with fellow workers. And it goes without saying that CNC programmers, setup people, operators, and others working directly with the CNC equipment must have an extremely good understanding of this technology [1].

2. TYPES OF CNC PROGRAM REALIZATON

Presented here are three methods of developing CNC programs, manual programming, conversational (shop-floor) programming, and CAM system programming. To this extent, we have exclusively stressed manual programming techniques at the G-code level in order to ensure your understanding of basic CNC features [4].
In this key concept, however, we will explore the various methods of creating CNC programs. We will give applications for each method to determine which is best for a given company. While we do tend to get a little opinionated in this section, you should at least understand the basic criteria for deciding among the programming alternatives. We can discuss three methods of developing CNC programs, manual programming, conversational (shop-floor) programming, and CAM system programming. Keep in mind that no one of these alternatives is right for all companies. Each has its niche in the manufacturing industry.

2.1. Manual Programming

As you have seen, manual programming tends to be somewhat tedious. Admittedly, the words and commands involved in manual programming can be somewhat cryptic. However, all CNC programmers should have a good understanding of manual programming techniques regardless of whether or not they are used.
For the right application, manual programming may be the best programming alternative. There are still a great number of companies who exclusively employ manual programming techniques. If, for example, only a few machine tools are used, and if the work performed by the company is relatively simple, a good manual programmer will probably be able to out-perform even a very good CAM system programmer. Or say a company dedicates the use of their CNC equipment to a limited number of jobs. Once these jobs are programmed, there will never be a need to create more programs. This is another time when manual programming may make the best programming alternative.
Even if a CAM system is used, there will be times when the CNC program (at G-code level) must be changed to correct mistakes during the verification of the program. Also, there will usually be an opportunity to optimize programs after the running of the first few workpieces. If the programmer must use the CAM system to perform these very elementary changes to the CNC program, a great deal of production time can be wasted.

2.2. Shop-floor Programming

Conversational (shop-floor) programming has become quite popular in recent years. With conversational programming, the program is created at the CNC machine. Generally speaking, the conversational program is created using graphic and menu-driven functions. The programmer will be able to visually check whether various inputs are correct as the program is created. When finished, most conversational controls will even show the programmer a tool path plot of what will happen during the machining cycle.
Conversational controls vary substantially from one manufacturer to the next. In most cases, they can essentially be thought of as a single-purpose CAM system, and thus do provide a convenient means to generate part programs for a single machine. Be forewarned, though, that some of these controls, particularly older models, can only be programmed conversationally at the machine, which means you can't utilize other means such as off-line programming with a CAM system. However, most newer models can operate either in a conversational mode or accept externally generated G-code programs.
There has been quite a controversy brewing over the wisdom of employing conversational controls. Some companies use them exclusively and swear by their use. Others consider them wasteful. Everyone involved with CNC seems to have a very strong opinion (pro or con) about them. Generally speaking, companies who employ a limited number of people to utilize their CNC equipment and run a wide variety of different workpieces tend to use and like conversational controls. In this kind of company, one person may be expected to perform many CNC-related tasks. In many job shops, for example, the CNC operator may be expected to set up tooling, make the workholding setup, prepare the program, verify and optimize the program, and actually run production. In this kind of company, anything that can be done to help the operator will streamline production. Conversational controls can dramatically reduce the time it takes the operator to prepare the program as compared to manual programming [6].
In many larger manufacturing companies, the goal is to keep the CNC machine running for as much time as possible. This kind of company employs a staff of support people to keep the CNC machines running. Down time for any reason will be perceived as wasted time. One person may be setting up tools for the next job while the current job is running. Another person may make the workholding setup. Yet another writes and verifies the program. In this case, the operator may only be expected to load and unload workpieces. The support staff minimizes the setup-related work that must be done on-line, while the machine is sitting idle. As you can imagine, this kind of company does not want their programs developed on-line, while the machine is not producing.
There are two other factors that contribute to whether a conversational control is a wise investment. The first has to do with operator incentive. The person running a conversational control must be highly motivated. This person has a great impact on the success of the company.

With motivation, a conversational programmer can outperform a manual programmer by a dramatic margin. This is another reason why conversational controls are so popular among small companies like job shops. In small companies, the person programming conversationally usually has a high interest in the success of the company.
Another factor that affects the wisdom of employing conversational controls is the number of different work-pieces that must be programmed. If only a limited number of different workpieces are required of the CNC machine, conversational programming may not be the best programming alternative.

2.3. CAM System Programming

CAM (Computer Aided Manufacturing) systems are computer systems (software) for preparing the data and the programs for the controlling of numerically controlled production machines for automated production of the mechanical parts, assemblies, electronic circuits, etc. These systems use mainly the geometrical and other data, which has been gained during computer design of the part, respectively produced by the computer aided design (CAD) system. The tools for creating postprocessors, which enable the transfer of the geometrical data defining tool paths into the code acceptable for a control system of an integrated production machine are part of CAM systems. Libraries of postprocessors for mostly used control systems and also modules for simulation enabling animation of production process are often integrated as a part of the CAM systems, too. The user can verify the process of individual operations that are performed on a product and thus he can prevent incidental collisions of the tool with the work-piece or fixtures [3].
With regard to the various histories of individual CAM systems and their development as influenced by many various factors, it is difficult to unite these systems into common groups and to compare them mutually according to their similar functions. In spite of that, by more detailed study, it is possible to find common features which enlist these systems to one of the groups.
As an elementary property, based on which it is possible to enlist the CAM systems to some groups, is considered their completeness and compatibility with other CA (mainly CAD) systems.
Based on this, it is possible to enlist the CAM systems to two groups [5]:

1. CAM systems integrated in the frame of the complex CAD/CAM/CAE systems.

There are enlisted mainly products known as “big” CAD/CAM/CAE systems, for example CATIA (Dassault Systemes), NX (UG PLM Solutions), Pro/Engineer (PTC) and also “medium” CAD/CAM systems, for example Cimatron it (Cimatron) or VisiCAM in this group. The convenience of these systems, with regard to their completeness and integration of individual CAD, CAM and CAE modules, is that there are no existing problems with the transfer of geometrical data among individual parts and modules. The inconvenience, mainly in Unix applications, is the more expensive price of the hardware; this disadvantage can be strongly reduced if these systems are performed under Windows NT on an efficient PC.

2. Specialized CAM, respectively CAD/CAM systems.

This second larger group of the CAM systems is possible to divide into several groups:

a) Complex CAM systems determined for computer support of more technologies - for example SURFCAM (Surfware), SmartCAM (Camax), Mastercam (CNC Software), AlphaCAM (Licom Systems), etc.
b) Specialized CAM systems used for computer support of concrete technology - for example PowerMILL (Delcam) and WorkNC (SESCOI) for milling, ECAM 350 (Advanced CAM Technologies) for production of the circuit boards, etc.
c) CAM superstructures of the specialized CAD systems. The most known is HyperMILL (OPEN MIND), which is a superstructure of CAD systems AutoCAD and Mechanical Desktop (Autodesk) and it is used for computer-aided manufacturing, which is represented by the option of generating NC codes for working machines (drill, CNC mills, CNC wire EDM cutters, CNC branding machines)

The most widely used and the best quality specialized CAM systems have a modular structure enabling the creation of NC programs for 2-5 axis milling machines, lathes, wire cutters, water jet cutting equipment, laser cutting, plasma cutting, etc. They dispose by libraries of postprocessors serving to transfer the generated tool paths into a code that is suitable for the control system of the production machine. Also, they dispose by modules for simulating the production process directly by the computer, which allows for the detection of incidental errors in the NC program. For example, the collision of the model and the tool, intersecting at the material by fast feed speed when the work-piece is not suitably designed, provides an opportunity to see the production process from various views, transparently, or in sections.
The requirements to save or improve the competitive level of products urge producers to use CAM technologies as frequently as possible in relation to their facilities and this trend is expected also in the future. Using only one component of CAD/CAM/CAE systems, for example CAD and the disregarding of or full omission of superstructured parts aimed at computer aided manufacturing may decrease the application effectiveness of these modern tools in an enterprise. Also, the producers of computer aided manufacturing systems have to adapt to this trend and thus permanently upgrade their products in relation to saving and expanding their market positions. Thus, they have to fulfill the requirements of customers as best as possible [4].

3. ADVANCED MILLING TOOL STRATEGY MOTION IN CNC MANUFACTURING

In an optimized system, all the components work up until the limit of their maximal capacity, though none of them has being overstretched. In order to prevent tool damage, turn speed and feed should stay within the boundary of the maximal load for the existing tool path. This way of setting the turn speed and feed leads to the fact that, in the sections with lower load the tool works slower compared to its maximum.

So we try to keep the tool working up to its limit through the whole trajectory, which means that we attempt to reach a constant material withdrawal and steady cutting forces. Unstable cutting force may result in tool damage or slow manufacturing [7].

Optimization of material withdrawal during roughing is the most important step of CAM programming. Cutting depth and tool pitch recommended in tables for tool and material combination assume that we do the constant pitch roughing through the whole trajectory. If the tool path involves entire tool diameter cutting (grooving), or if driving in the corners isn't handled, the tool may withdraw more material than expected. One possibility to keep clear of entire tool diameter irruption into the material in CAM systems is trochoid roughing (Fig.1).

In most cases, finishing of 3D surfaces in Z-layers (also known as "water line" or "constant Z finishing") provides better material breach and more stable withdrawal as when finishing with the operations of trajectory projection. In contour strategies with trajectory projection the tool moves up and down according to the geometry, suffering load peaks during axial irruption into the steep surfaces. In order not to cause tool damage during the load peaks it must work very slowly in the sections with lower precipitousness.

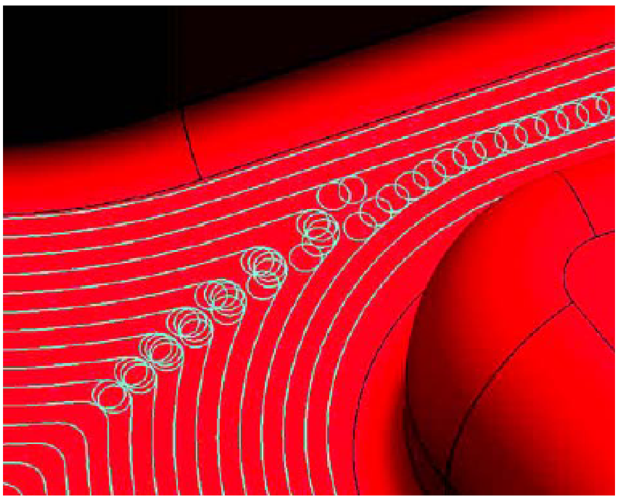

Figure 1. Trochoidal milling in the CAM system

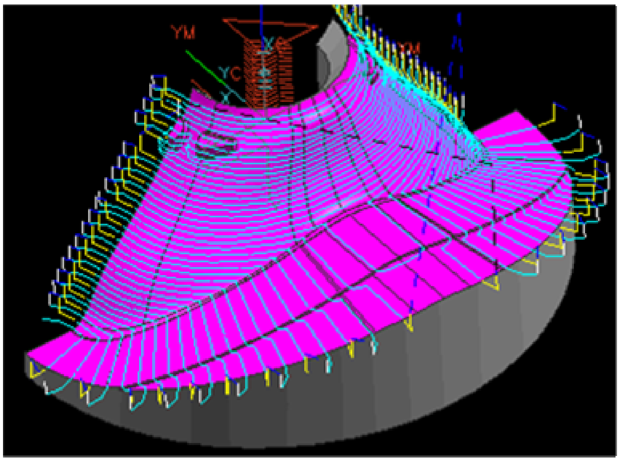

Figure 2. Classical milling with uniform Z-levels

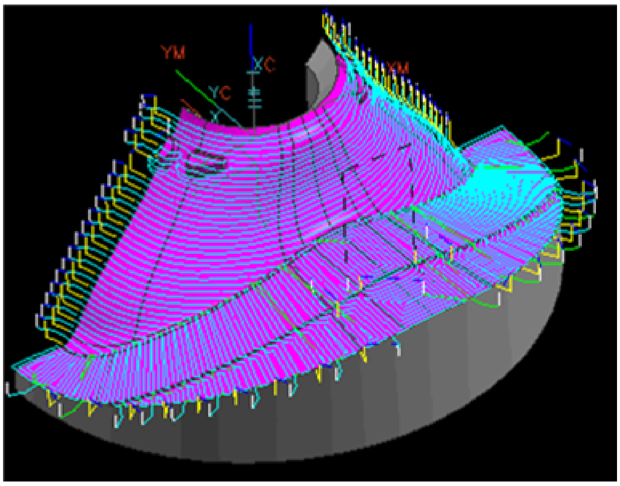

Figure 3. Z-level milling with added levels on non-steep faces in the CAM system

Besides constant Z-layers milling, the CAM system enables the insertion of the trajectories in low-pitched areas so that the depth of the remaining material is constant and the following operations will have steady material withdrawal (Fig. 3).

If there is a need for finishing surfaces by 3-axis contouring instead of Z-layers machining, the peak load is dramatically increased by axial irruption into the steep surfaces (for example chamfered sides of moulds).

4. CONCLUSION

Present and future CAM technologies must be inevitably capable of evolving themselves into an integrated chain of computer support technologies, beginning with model design and its examination in a virtual environment, up to product manufacturing and dispatch to the end user. The most sophisticated CAM Systems will be a part of strong CAD/CAM/CAE Systems, or they will be developed independently, but with maximum possibilities for interconnection with other computer support systems and company information systems.

ACKNOWLEDGEMENTS

Slovak Ministry of Education supported this work, contract VEGA No. 1/3177/06 and contract of applied research No. AV4/0003/07.

REFERENCES

[1] Bedworth, D. D. - Bailey, J. E.: Integrated Production Control Systems. John Wiley & Sons, New York, 1987.

[2] Chang, T. Ch. - Wysk, R. A. - Wang, H. P.: Computer-Aided Manufacturing. Prentice-Hall, New Yersey, 1998, 748 p.

[3] Kalpakjian, S. - Schmid, S. R.: Manufacturing Engineering and Technology. Prentice-Hall, New Yersey, 2001, 1148 p.

[4] Kuric, I.: PLM and CA Systems. In: Proceedings of the conference „Systems-Equipment-Processes SOP2004“. Cracow (Poland), 2004, pp. 23-29.

[5] Lynch, M.: The Key Concepts of Computer Numerical Control. Web page: www.mmsonline.com/articles/cnc98intro.html.

[6] Marcincin, J. N.: New Method for CNC Program Creation. In: Proceedings of the 5th Conference „Advanced Technologies for Developing Countries“. Rijeka, 2006, pp. 137-142.

[7] Necej, P.: Position of CAM System in High Speed Manufacturing Process and the NX System Capability for this Technology. Manufacturing Engineering, Vol. 5., Nr. 4., 2006, pp. 29-31.

Primljeno / Received: 23.2.2008

Prihvaćeno / Accepted: 9.6.2008

Pregledni članak

Subject review

Author address:
Prof. Ing. Jozef Novak-Marcinčin, PhD.
Technical University of Košice
Faculty of Manufacturing Technologies
with a seat in Prešov
Bayerova 1, 08001 Prešov, SLOVAKIA
E-mail: jozef.marcincin@fvt.sk