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OPTIMIZATION OF CUTTING TOOL MOTION STRATEGY FOR CNC MILLING TECHNOLOGICAL PROCESSES

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Abstract: *Optimal motions of cutting toll in milling processes are very impotent for short time of cutting and for finish quality of surface. For needs of optimal concept machining implementation at digital controlled manufacturing machines is important accurate to design concept - strategy of tool motion by manufacturing engineer. On the ground of possibility realisation of great number different types surfaces at different manufacturing devices and after exploitation of different from a lot of technological parameters is strenuous to choose of optimal and efficient concept of tool motion. In paper is presented outputs of scientific project realisation on Faculty of Manufacturing Technologies oriented to area of optimal cutting strategy realisation.*

Key words: *NC machines, CNC milling machines, cutting strategy.*

1. INTRODUCTION

The design engineer, for example, must possess enough knowledge of CNC (Computer Numerical Control) to perfect dimensioning and tolerance 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.

2. CNC PROGRAMS CREATION

Presented here are three methods of developing CNC programs, manual programming, conversational (shop-floor) programming, and CAM system programming. To this point, we have exclusively stressed manual programming techniques at G-code level in order to ensure your understanding of basic CNC features [7].

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 will 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 with 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.

We relate this to performing arithmetic calculations longhand as opposed to on an electronic calculator. Math teachers unanimously agree that students must understand how to perform arithmetic calculations manually. Once the student possesses a firm understanding of how to perform calculations manually, a calculator can be used to expedite the calculation procedure.

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 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. Conversational (shopfloor) programming

This form of 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 [8].

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 workpieces 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 systems programming

CAM (Computer Aided Manufacturing) systems are computer systems (software) for preparing the data and the programs for 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 product by the computer aided design (CAD) system. The tools for creating postprocessors, which enable the transfer of the geometrical data defining tool paths to code acceptable for control system of belonging 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. User can verify the process of individual operations which are performed on product and thus he can prevent the incidental collisions of the tool with work-piece or fixtures [9].

In regard to various histories of individual CAM systems and their development influenced by many various factors, it is difficult to unite these systems to common groups and to compare them mutually by 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 group.

As elementary property, based on which is possible to enlist the CAM systems to some groups, is considered their completeness and compactibility with other CA (mainly CAD) systems.

Based on this, it is possible to enlist the CAM systems to two groups [11]:

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

There are enlisted mainly products known as „big“ CAD/CAM/CAE systems, for example CADDS 5 (Computervision), CATIA (Dassault Systemes), Unigraphics (Unigraphics Solutions), Euclid (Matra Datavision), Pro/Engineer (PTC), I-DEAS (SDRC) and also „medium“ CAD/CAM systems, for example Cimatron it (Cimatron) or VisiCAM into this group.

The convenience of these systems, in regard to their completeness and integration of individual CAD, CAM and CAE modules, is that there are not existing the problems with transfer of geometrical data among individual parts and modules. The inconvenience, mainly in Unix applications, is more expensive price of hardware; this disadvantage can be strongly reduced if these systems are performed under Windows NT on 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 supporting of more technologies - for example SURFCAM (Surfware), SmartCAM (Camax), Mastercam (CNC Software), AlphaCAM (Licom Systems), etc.

b) Specialized CAM systems used for computer supporting 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. Most known is HyperMILL (OPEN MIND), which is superstructure of CAD systems AutoCAD and Mechanical Desktop (Autodesk) and it is used for computer aided manufacturing which is represented by options of generating NC codes for working machines (drill, CNC mills, CNC wire EDM cutters, CNC branding machines)

The above CAM systems are characterized especially by their maximal orientation to the computer aided manufacturing and thus their modules used for creating the solid models of products are at low level (enable to create wire-frame and 2D models, but not solid models). In many cases, they do not support CAD area and models are transferred from specialized CAD systems (for example Solid Edge, Solid Works, Cadkey, etc.).

Mostly used and the best quality specialized CAM systems have modular structure enabling to create 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 for transfer of the generated tool paths to code which is suitable for control system of the production machine. Also, they dispose by modules for simulating the production process directly by computer, which allow to find incidental errors in NC program. For example collision of the model and tool, intersecting to material by fast feed speed when the work-piece is not suitable designed, option to see production process from various views, transparently, or in section.

The requirements to save or improve the competitive level of products urge the 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 disregarding or full omission of superstructured parts aimed to computer aided manufacturing may decrease the application effect of these modern tools in 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 good as possible [6].

3. OPTIMIZATION OF CUTTING STRATEGY

In optimized system all the components work until the limit of their maximal capacity, though none of them is being overstretched. In order to prevent the tool damage, turn speed and feed should stay in the boundary of maximal load for 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.

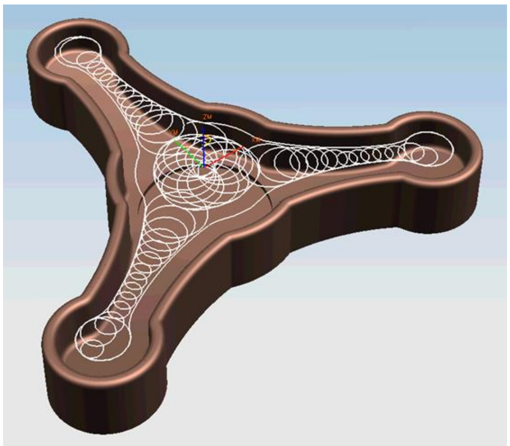

Fig. 1. Trochoidal milling in CAM system.

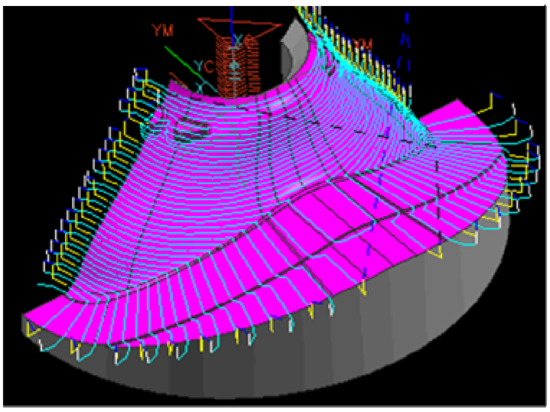

Fig. 2. Milling with uniform Z-levels.

So we try to keep the tool working up to its limit through the whole trajectory, which means that we attempt to reach constant material withdrawal and steady cutting forces. Unstable cutting force may result to tool damage or slow manufacturing [10].

Optimization of material withdrawal during the 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 the driving in 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 finishing with the operations of trajectory projection (Fig. 2). 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 the tool damage during the load peaks it must work really slow in the sections with lower precipitousness.

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

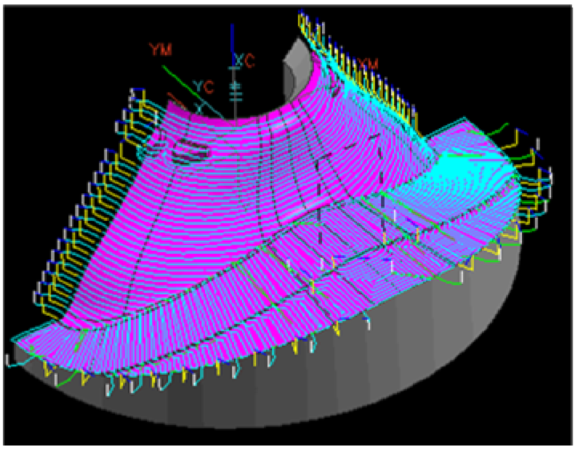

Fig. 3. Z-level milling with added levels on non-steep faces.

If there is a need of finishing surfaces by 3-axis contouring instead of Z-layers machining, peak load is dramatically increased by axial irruption into the steep surfaces (for example chamfered sides of moulds). There are two ways of lowering the peak loads while penetrating steep surfaces. One of them is to modify the angle of overriding so that tool goes through the steep sides under 45°. This decreases real precipitousness of trajectory and overloading of tool. Minor effect of this solution is that the tool doesn't longer remain in lengthwise corners. The other method of avoiding the tool overload on steep surfaces is to use first machining using Z-layers operations.

4. CONCLUSIONS

The demands for keeping and increasing of a level of competitive abilities of a company products force the producers to use CAM technologies in the highest degree and this trend can be also expected in the next future. In order to use the most sophisticated CAM systems in the manufacturing companies it is necessary to analyse, compare and evaluate the abilities of the above mentioned systems. To appreciate which of the systems offered in a software market are the most advantageous was also a task of the present essay.

In CAM Systems field it is possible to expect in future the trends of development as follows:

- working in of the newest research results from a turning, milling, grinding technology theory into the single modules (computer support of new technologies; namely HSC, hard and curve machining - NURBS),
- further feature of modules for CA support of machining with possibilities of CA support of progressive technologies (water-jet, laser, plasma);
- modules generation for manufacturing support in other technological fields, e.g. cupping and bending mould, welding, assembly, etc.);
- working in of expert systems into manufacturing computer support field with aim to use more effectively before solved tasks and problems;
- creation of finished postprocessors databases with a possibility to use them as a whole, or to use the parts of a postprocessor for another postprocessor creation;
- transition from CAD/CAM to CAPE (Concurrent Art to Product Environment) Environment allowing, by a control, to solve completely all stages of a new product realization from a virtual design up to practical realization in a manufacturing process;
- using of STEP (Standard for the Exchange of Product Model Data) Standard for taking over of a model from CAD Systems by specialized CAM Systems.

The present and future CAM technologies must be inevitably able to involve themselves into an integrated chain of computer support technologies, beginning with a model design and its examination in a virtual environment up to a product manufacturing and its dispatching to an 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 to be interconnected with other computer support systems and company information systems.

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