COMPUTER AIDED SELECTION OF SUITABLE MANUFACTURING STRATEGIES

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Abstract: Goal of this paper is to describe manufacturing strategies used in 3D milling and possibilities to simplify the choice of manufacturing strategy, which would be most suitable from the aspect of manufacturing efficiency as well as from the machined surface quality consideration. Main attention is directed to computer aid of this choice process. It describes program created for optimization of suitable milling strategy selection, functional principles of this program and conditions related to its creation.

Keywords: computer aid, milling strategies, software application, Delphi

1. INTRODUCTION

Currently in the field of CAD/CAM systems there is need of using these systems to more definite improving of production’s efficiency, of production time shortening, simplification of production, saving of energies and materials and that also in implicated form of better exploitation of production devices and lesser tools consumption. This request of productivity improving concerns all the participants from the field of tool, automobile and aero-industry, producers of moulds and different parts of variable shapes in various usage areas.

One possibility of production’s efficiency improvement is dedication to innovations in the field of application of chip machining technology with relatively great efficiency and good machining quality – milling. It is technology of miscellaneous exploitation for machining of planar, 3D shaped and rotary surfaces, for machining of slots, threads and gearing. One of attributes related to better use of milling is milling strategy, which means the way of tool motion down the machined surface. Wrong strategy selection can negatively affect production time and costs in roughing as well as in finishing strategies. Question of suitable strategy choice is therefore still actual even in new vintage CAM systems.

Optimization of suitable manufacturing strategy selection is important matter mainly for new and inexperienced users of CNC technics, for the acquirement of knowledge about strategies and their importance and utilization of new software tools would present barrier from economical and time aspect. Simple but helpful software product should assist in faster decision about strategy fitness and produce positive impacts of this decision correctness. Further chapters consist briefing of computer aid of manufacturing strategies and creation method of software which mitigates the selection of milling strategy.
2. COMPUTER AID OF MANUFACTURING STRATEGIES

Currently there is a huge number of products offering computer aid in different production spheres including manufacturing strategies area. Uniform effort of this CAM systems is to simplify the work of NC programmer and to ensure the correctness of his decisions or even to substitute his own decision by software process and by that to secure best possible milling efficiency. To most common CAD/CAM systems solving the problems of manufacturing strategies currently belong (latest versions of software are listed in brackets):

- EdgeCAM (version 12)
- ProENGINEER (Wildfire 4)
- ProTOOLMAKER
- CADDS (version 5)
- CAM-TOOL (V3)
- Catia (V5R18)
- FeatureCAM (2008)
- SurfCAM (Velocity)
- Unigraphics (NX5)
- MasterCAM (X5)
- PowerMILL (version 8)
- ESPRIT (SolidMILL)
- VX CAD/CAM (version 13)

These software systems get in the scope of 2 – 5 axis machining also to milling. They contain sections for roughing, which is machining with goal of cutting the most material volume possible considering additional material for further operations and finishing, which means the process of removing residual material left on workpiece after some previous technology. To main roughing strategies supported in CAD/CAM systems belongs:

- raster milling – tool path is parallel with coordinate system axis, tool is moving upright with minimal steps
- contour milling – tool path copies the contour of machined element
- profiling – tool path copies the contour of machined element while keeps moving with defined steps
- raster and profiling – combination of two previous strategies

![Fig.1. Computer aid of milling strategies in Canadian system CAM-TOOL](image)

To finishing strategies offered in CAD/CAM systems usually belongs:

- projection milling – means projection of 2D predefined motion to the model

![Fig.2. Most common roughing strategies](image)
- constant Z-hight milling – mill moves in certain height while copying model’s contours
- corner milling – for removing the residual material after previous tool or in between two intersected surfaces
- nib milling – mill moves down the model continuously like a pen
- rotary milling – tool moves linear, workpiece rotates around its axis

Fig. 3. Projection strategies of finishing

In most software concerning manufacturing strategies NC programmer has an option to choose suitable strategy, which would allow surface machining in shortest possible time while preserving requested quality. However only few programs select optimal strategy without choice process of its user.

3. DECISIVE PARAMETERS OF MILLING STRATEGY SUITABILITY

While judging strategy fitness for certain shape (surface or element) it is necessary to come out with concrete criteria, based on which the decision will be made. These criteria should be universal from different points of view:
- usable for various elements
- usable and available in different CAM software
- independent from exploitation of man neither of computer

To most considered criteria for optimal milling strategy selection belongs machining time, tool wear and roughness extent shown as acquired quality. Of course in all three cases desirable result gives the strategy with minimal criteria value.

3.1 Machining time parameter

Production efficiency relates to productivity, which is determined by number of parts manufactured in time unit, for example a shift. Way of enumeration is defined by equation

\[ P = \frac{\tau_{sm}}{\tau_k} \]

where \( \tau_{sm} \) is shift time and \( \tau_k \) is part time needed for manufacturing of one part.

Part time consists out of three components:

\[ \tau_k = \tau_s + \tau_v + \tau_p \]

where \( \tau_s \) is machining time, \( \tau_v \) is secondary time and \( \tau_p \) is addition time.

From the sight of chip machining technology, most important is machining time, defined by following equation:
\[ \tau_s = \frac{l_{vn} \cdot i}{f_m}, \]
where \( l_{vn} \) is tool path length, \( i \) is number of transitions, \( f_m \) feed per minute.

Value \( l_{vn} \) presents length of tool trajectory that is defined by machining strategy. Machining time parameter therefore presents most important criteria in efficiency judging process since real time value affects duration of every part production.

### 3.2 Surface quality parameter

This parameter reflects surface condition obtained at the end of milling by used strategy. It is about extent of roughness on surface. That recalls necessity of further machining with thinner tool or different strategy. Higher need of further technological actions results in more time needed for manufacturing and higher production costs. Therefore the extent of residual material should be concerning as another criteria for optimal strategy selection.

### 3.3 Tool wear parameter

Tool wear parameter is observed especially for tendency of optimal use of cutting tools (mills), which belongs to technical-material resources directly affecting production costs.

Mill wear arises from interaction between tool and workpiece material and depends mostly on cutting conditions. Often it’s about combination of these four factors:

- **Mechanical factor** – static and dynamic loads resulting from chip creation process.
- **Thermal factor** – heat coming from machining strains material of cutting tool especially during discontinuous cutting.
- **Chemical factor** – comes out from creation of very metallic surface inclined to chemical reactions and diffusion process.
- **Abrasive factor** – most machined material contains hard grains causing abrasive effect.

Combination of these four factors negatively affects cutting material and interrupts it. Troubles related to discontinuous cutting can be avoided also by suitable strategy choice.

### 4. CREATION OF APPLICATION FOR SUITABLE MILLING STRATEGY SELECTION

For creation of application program language Object Pascal was used including its visual implementation called Delphi. Every application created in Delphi is based on components. They generate its design and executive kernel. Most of necessary components are implied with an installation pack of Delphi, other can be created by user. These attributes decided about using Delphi for creation of application for suitable milling strategy selection.

Application terminates optimal strategy after considering decision criteria. To do so it compares the output values of computations for each strategy (length of absolved trajectory, number of contours, etc). To perform these computations program needs input data given by user corresponding with cutting conditions. That concern tool diameter, feed rate, side motion and sizes of machined surface.

User’s environment consists out of 4 main parts:

- **Geometry selection section** – buttons for choice of machined surface type according to its geometrical characteristics.
- **Input information section** – space for writing of cutting parameters related to suitable strategy selection.
c) **Graphical information section** – visual information giving user a view of planned strategy and dimensions

d) **Output information section** – space for quoting the results of computations and final strategy selection. For comparison, numerical values of results are shown for each strategy. Optimal variant would be highlighted.

*Fig. 4. User’s environment of created application – a) geometry selection section, b) input information section, c) graphical information section, d) output information section*

Program for its computation uses mathematical operations summarizing length of tool trajectory. When entering input data into the editable labels, it assigns them to relevant variables. Numerical dimensions of machined surface and tool diameter serves as limit borders decisive about stopping of tool motion. After pressing the COMPUTATION button program starts the procedures that calculate the length of tool path for each strategy according to input data received from user. Optimal solution presents the variant with lowest value of machining time criteria.

From programmer point of view, application uses events control of particular visual components – panels, edit fields, labeled edit fields, buttons, images. From the aspect of computation, main part of program code consists of cycles, that ensure computing determination in case of reaching the borders of machined surface. Final border contouring of machined element is added to result in order to make the final faces and edges smooth.

*Fig. 5. Source code sample – cycle determining computation of trajectory absolved by tool and providing results outcomes*
5. CONCLUSION

Computer aid of optimal manufacturing strategy selection and proposition has important role in improvement process of production efficiency and productivity. This fact is confirmed by experiences of many companies operating in different industrial spheres. Therefore it is mission of software creators to provide users with better and more accessible possibilities of usage of computer aided selection process related to manufacturing strategies. Current CAD/CAM systems dispose with great tools in the field of suitable strategy selection and proposition. Many users though would appreciate simple program that would not be fixed to any other software able to pre-select optimal manufacturing strategy.

Paper describes the way of such program’s creation, briefly describes programmer environment and methods used for determining of suitable strategy. In future the program should be enriched of computations concerning third dimension, what would make it applicable for non-planar surfaces. Huge addition would be the possibility of working with surfaces imported from other software and combination of mathematical computing methods with 3D graphical robot. This software tool of Delphi environment uses vector-declared commands for fictive graphic pen motion in the area with predefined borders.

6. REFERENCES

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