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POSSIBILITY OF A QUICK CHECK ON MILLING STRATEGY SUITABILITY

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Preliminary notes
The area of computer aided manufacturing in the field of chip machining still provides space for improvements in matters of selection of a suitable manufacturing strategy during creation of NC sequences. The paper analyzes current situation in solutions for milling strategies and importance of the selection of a suitable strategy from the viewpoint of several parameters. It also provides information about a newly created software application that presents the tool of computer aid to a milling strategy selection based on the criterion of necessary milling time. It describes functional and programming aspects of the program and offers the results obtained from the realized experiments. It also mentions the possibilities for further development of the application.

Keywords: *manufacturing strategies, milling, software application*

Mogućnosti brze provjere odgovarajuće strategije glodanja

Prethodno priopćenje
Područje računalne potpore u proizvodnji u području strojne obrade još uvijek pruža prostor za poboljšanja u pitanjima odabira odgovarajuće proizvodne strategije tijekom stvaranja NC sekvenci. Rad analizira trenutnu situaciju rješenja za strategiju glodanja i važnosti odabira odgovarajuće strategije sa stajališta nekoliko parametara. Također donosi podatke o novoj softverskoj aplikaciji koja predstavlja alat za računalnu pomoć pri odabiru strategije glodanja na temelju kriterija potrebnog vremena za glodanje. Softver se opisuje sa aspekta programiranja i funkcionalnosti, te daje rezultate ostvarenih eksperimenata. Također se spominju mogućnosti daljnjeg razvoja aplikacije.

Ključne riječi: *proizvodna strategija, glodanje, primjena softvera*

1 Introduction

Many current software products from the CAM area deal with problems of milling. Beside the possibility of working with parametric data obtained from own CAD environment included in native module or imported from other software they offer many settings and options that lead their users to a definition of the manufacturing milling sequences. There are though few typical ways of tool motion over the machined surface. These characteristic projections of common geometrical shapes to the surface of the milled area are called manufacturing strategies. The paper deals with the importance of selecting a suitable milling strategy, it investigates the possibilities to improve the assumptions for a right selection and thus it comes to the optimization of milling strategies in the creation process of sequences and NC programs [1, 11].

The importance of the milling strategies area lies in revealing the gap and taking the opportunity for making the milling process more technologically effective and economic. The selection of a milling strategy can affect final roughness of the milled surface. From the viewpoint of additional technological operations there is also chance to affect the level of undersurface residual stresses. Nevertheless the greatest and most logical change can be achieved in the value of the time that is necessary for machining of the milled surface. This paper deals with a concrete idea of a simple but effective form of software support for a suitable milling strategy selection while considering machining time as its evaluation criterion. It brings the information on creating user and hardware undemanding program that realizes the calculations of the length of tool trajectories for milling with the use of different strategies and selects the best one from the viewpoint of manufacturing time. It describes basic input and output characteristics of the program that was created in programming environment Borland Delphi. In the end it also deals with the program application possibilities demonstrated on a series of examples produced in the laboratory of the Faculty of Manufacturing Technologies. It considers further improvements and reserves in the area of developing the applicability of the program in the preparation phase for milling of complex surfaces and shapes [2, 8].

2 CAM support of milling strategies

Modern software products from the field of computer aided manufacturing include in their CAM modules a lot of effective tools for optimization of creation procedures of manufacturing sequences. For many years the systems like Pro/Engineer, Unigraphics or Catia belong to the best known and most used in their area. They present high-class solutions of concurrent engineering philosophy concentrating on working tasks of all stages involved, from converting the product idea into a model through manufacturing and all the way up to "ready for sale" completion. Beside that software there are special CAM systems used in many companies. These programs find their substantiates as they meet the requirements of users while keeping their expectations satisfied mainly because of lower price. Their group grew rapidly in the last few years. Examples can be seen in SurfCAM, EdgeCAM, PowerMill etc. Matters and features impacting milling efficiency, including milling strategies, are the subjects of study in many institutes and organizations which provide CAM producers with progressive information obtained from the research. One of them is Corrosion and Metals Research Institute in Stockholm, Sweden.

All mentioned programs provide the creator of manufacturing sequences with the possibility to affect milling strategy, although only few of them give (mostly partially) the reasons for the realized selection. In the area of milling strategies different software products use different names. Geometrical references of particular trajectories are still very similar or even the same. Among commonly most used milling strategies there are three with their usual names indicated as Raster, Box and Spiral [3, 4, 10].

In the strategy of raster type the tool moves along parallels in lengthwise direction while these parallels are connected with transverse value of side step. With box strategy the tool copies the contour of the milled surface in successive miniatures connected with the trajectory of side step. Spiral Strategy represents a set of uncrossing lines or a curve that in spiral way directs from the border of contour to its centre or contrariwise. Character of all three basic milling strategies is shown in Fig. 1.

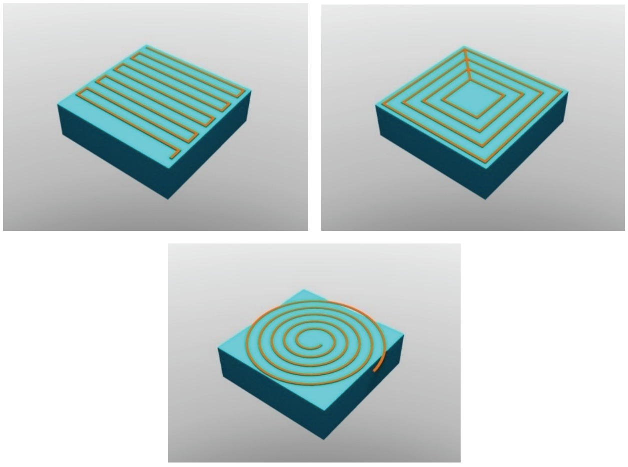


Figure 1 Most common strategies used in CAM software products (raster, box, spiral strategy)

To think about these strategies and to make appropriate considerations means to include their diversities into preparation phase of milling strategies. This step is usually placed in selecting of manufacturing parameters. Besides setting the values of feed rates, spindle speeds and many others there is also chance to choose the manufacturing strategy that can be also called scan type in the table of parameters. When it comes to the selection of a right strategy, the user is about to make a decision on suitability of different strategies. He should be able to see behind this selection and understand the impact of the realized choice. If he can afford to trust his intuition based on years of experience he can simply do the task and move to another phase. But from software point of view he has no other chance to make sure that the selection is right than check every possible outcome by changing the strategy type and running the milling simulation again. Then he can compare the results according to the appointed criteria. Such proceeding can be work or time demanding. Program can offer too many types of strategies that are slightly different or its working environment can be intricate enough to make it fast. Therefore the NC sequences creators and programmers could use simple additional application that would select a suitable way of tool motion prior to the strategy selection on the basis of main dimensional parameters of machined surface.

3
Possible solution on selection of suitable milling strategy

For making our solution reasonable first we need to find the main parameter that determines the suitability of milling strategy. One way is to consider the economical aspects of manufacturing. Efficiency of production is closely related to its productivity. That can be determined as the number of parts produced in a specific time unit, for example one shift. Calculation of productivity is realized according to the equation.

$$p = \frac{t_{sm}}{t_k}, \text{pcs} \tag{1}$$

where t_{sm} is shift period and t_k is piece time necessary for machining of a single part.

Piece time consists of three elements:

$$t_k = t_s + t_v + t_p, \text{min} \tag{2}$$

where t_s is machine time, t_v is subsidiary time and t_p is instrumental time.

From the viewpoint of technology of chip machining most important is machine time necessary for change of dimensions and shape of part. This time can be expressed with equation

$$t_s = \frac{l_{vn} \cdot i}{f_m}, \text{min} \tag{3}$$

where l_{vn} means tool trajectory, i is number of passes, f_m is feed rate per one minute.

Value l_{vn} represents the length of trajectory of tool motion, the way of this motion is set by manufacturing strategy. Of course after milling the surface with different strategies we achieve different length values of tool trajectories.

Therefore the machining time parameter of the given component is the most important criterion considered for evaluation of efficiency of production as it directly and with real value affects the manufacturing of each part and in a larger sense of the whole production. Creating the new software application for selection of a suitable manufacturing strategy we decided to put this parameter of machining time to the first place. For computation of milling time of a surface with defined dimensions it is only necessary to determine the length of tool trajectory [6].

4
Software application created for strategies evaluation

Working name of the program is MISTRA, the abbreviation of milling strategies. It was created in the programming environment Delphi from Borland Company. It is a software building tool that uses the syntax of original Pascal language in environment with classical object programming. On the form that represents the window of future application there are objects allocated (buttons, images, edit fields) between which there are action relations or calculations defined. After receiving the input data from user the program is able to realize computations and to gain the geometrical characteristics of the part surface shape. Based on this the length of tool trajectories can be drawn and computed with subsequent calculations realized for getting relevant machining times. User interface of operational version of the program can be seen in Fig. 2.

Figure 2 Software application MISTRA – trajectories and results for milling of rectangular pocket

After starting the program and passing first screen the user may choose one of four buttons on the left side so the shape character of machined surface is set. So far the application works with basic geometrical shapes – circle, rectangular, L shape and T shape. Next the user moves to the editable fields for input values of the program. Inputs are split into categories in two screens:

- Dimension of machined surface,
- Tool diameter and parameters of cutting process (feed rate, step over).

Together with the dimensions of machined surface the user can also select whether it is machining of pocket or straight machining of planar surface. Set difference then starts or stops keeping the characteristic circle of tool inside the contour of machined shape. After clicking on the last button the computation is realized for the lengths of tool trajectories and corresponding time values. In the same time the trajectories are graphically displayed on output panel in the form of three different strategies. User is provided with a quick chance to check the suitability of existing strategy from the viewpoint of time that is needed for milling.

Situation in Fig. 2 with the use of dimensional scale presents a surface with dimensions 180 × 130 mm. Tool diameter was 12 mm, feed rate was 250 mm/min, side step over was 10 mm. Final time difference after using spiral and raster strategies is almost 2 minutes. Let us say that we want to mill out the metal layer with thickness of 6 mm. By setting the parameter of maximal thickness of material removed after one pass to the value of 2 mm this time difference would be over 5 minutes. With large numbers of manufactured elements/parts better strategy could provide great time savings and influence economical efficiency of production.

5 Programming and computation of MISTRA application

Basic condition for good application running is the definition of objects and their properties and the creation of right relations between particular elements allocated on the programming form. These factors affect the look of application and its chronological functionality.

Most important part of creation of computing application from the viewpoint of content is assuring the problem free run of program – prevention from possibility of unwanted failure or cycling freeze down while preserving utilization of proper calculation methods.

Calculation and displaying of tool trajectories are achieved by the combination of programming cycles with the aim to determine the level of repeating of certain geometrical shape in the frame of projected strategy and consecutively to stop the trajectory generation after reaching that repeating level.

```
while (YH+rfz+i*cfz)<(YD-rfz) do
                    begin
                     LineTo(X,Y+cfz);
                     X:=X;
                     Y:=Y+cfz;
                     if odd(i) then
                              begin
                               LineTo(XL+rfz,Y);
                               X:=XL+rfz;
                               Y:=Y;
                              end
```

Figure 3 Example of source code of application - combination of cycles

On the basis of running these cycles in necessary number there is also the final output value of tool trajectory cumulated, while particular geometrical segments of that trajectory are calculated thanks to the known geometrical equations. Example of using the combination of cycle is given in Fig. 3 where there is part of cycle realizing drawing of tool trajectory for milling with raster strategy. After good input setting of i value, that represents the number of repetitions, and after its changing until meeting the critical condition of reaching relevant geometrical border the cycle stops with the defined surface being machined. There are basically two ways of handling the computations of trajectory length. We can process the computations and displaying of trajectories as two different activities realized in two different sections of source code. The other solution is to have the computations running simultaneously with the sketching of trajectory and thus to make sure that the displayed lines exactly correspond with machining time [5].

6 Practical application and verification of software solution

The created software application was primarily tested from user point of view. After it was found resistant to user mistake in the form of wrong geometrical data input or wrong definition of milling parameters it was also verified from the functional point of view. We prepared manufacturing sequences for many samples while determining the best (fastest) strategy using the new program. For comparison and physical verification we machined several surfaces with the application of three different strategies. Measured times were put in tables and results compared with the ones obtained from the MISTRA.

Manufacturing sequences were created in Pro/Engineer, version Wildfire 5. As we wanted to compare the impact of strategy type and keep other conditions equal in all cases, the milling trajectories of all samples were generated in roughing style. Sequences provided us with CL data that were transferred to NC programs using postprocessor built in G-post unit of Pro/Engineer.

All manufacturing tasks were carried out in the laboratory of the Faculty of Manufacturing Technologies in Prešov, Slovakia, that belongs to the Technical University of Košice. We used milling device ConceptMill 55 from Austrian producer EMCO. To suit the tool equipment of the mentioned laboratory the samples were made of duralumin. Each sample surface was achieved after milling with the use of different kind of scan type parameter [7, 9].

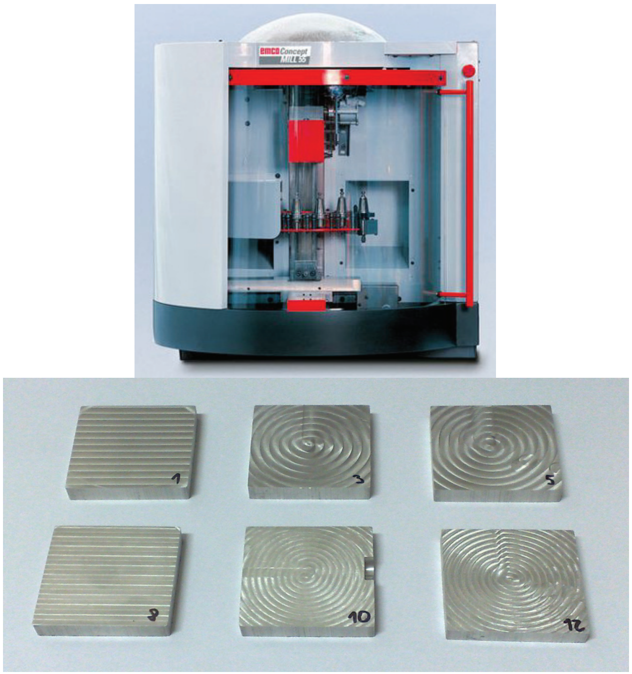
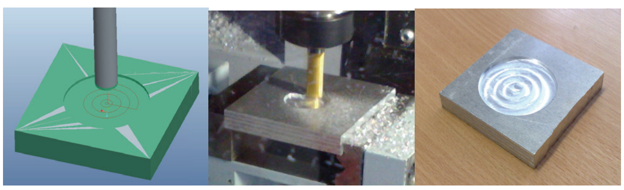


Figure 4 Emco ConceptMill 55 and one series of samples created after milling with the use of different strategies

For the CAM equivalent of different milling strategies we used the following SCAN_TYPE parameter indexes included in the CAM module of Pro/Engineer:
- SCAN TYPE 1 (MISTRA application raster strategy),
- SCAN TYPE SPIRAL (MISTRA application box strategy),
- SCAN TYPE FOLLOW HARDWALL (MISTRA application spiral strategy).



a) b) c)

Figure 5 Sample creation proceeding – a) Pro/Engineer CAM sequence, b) Emco ConceptMill 55 manufacturing, c) sample with surface created with the use of box strategy for circular shape

After machining of sufficient number of samples the measured machining times were put together into a small database. They were taken as time differences between the first point of material cutting and reaching the retract surface at the end of the sequence again.

First check was oriented to the verification of the fact that the application created in Delphi computes manufacturing times that are comparable with real time periods measured at the machine. The following table shows that the divergence between the MISTRA and Pro/Engineer results was less than 10 % for each geometrical shape. That provides us with solid assumption that the program can be used for practical estimations about necessary production times.

Table 1 Comparison of output machining times – values from new program and known CAM software

Shape	Strategy	*t* (min) Pro/E	*t* (min) MISTRA	div. (+/-)
Rectangle	Raster	18,28	19,97	8,46 %
	Box	18,01	18,25	1,32 %
	Spiral	17,43	17,89	2,57 %
Circle	Raster	10,4	10,6	1,89 %
	Box	16,31	17,05	4,34 %
	Spiral	17,65	17,48	0,97 %
L shape	Raster	49,62	48,72	1,85 %
	Box	54,17	55,61	2,59 %
	Spiral	45,96	43,19	6,41 %
T shape	Raster	13,98	14,72	5,03 %
	Box	14,06	14,9	5,64 %
	Spiral	12,74	13,43	5,14 %

Other comparisons were made for showing the dependency of the time necessary for milling on type of the selected manufacturing strategy. Curves that characterize the course of values of machining times according to strategy types were put together by two categories: values relevant to milling of pockets (tool kept inside of section borders) and values relevant to milling of whole surface (tool moving all over the section). Results of that comparison are obvious in Fig. 7.

Time values between three displayed samples (colours) vary, as they respond to the samples of different sizes with milling of different depths. After consideration of obtained results it is obvious that milling time depends on used strategy. When evaluating the time results for rectangle surfaces, it is necessary to understand that the spiral gets the characteristic look of a rectangle. For milling of pockets the most suitable strategies seem to be spiral for a rectangle pocket and box for a circle pocket. For milling of the whole surface the most suitable are raster for rectangles and spiral strategy for circles. Wider generalization of results would though demand utilization of outputs taken from large numbers of planned experimental measurements.

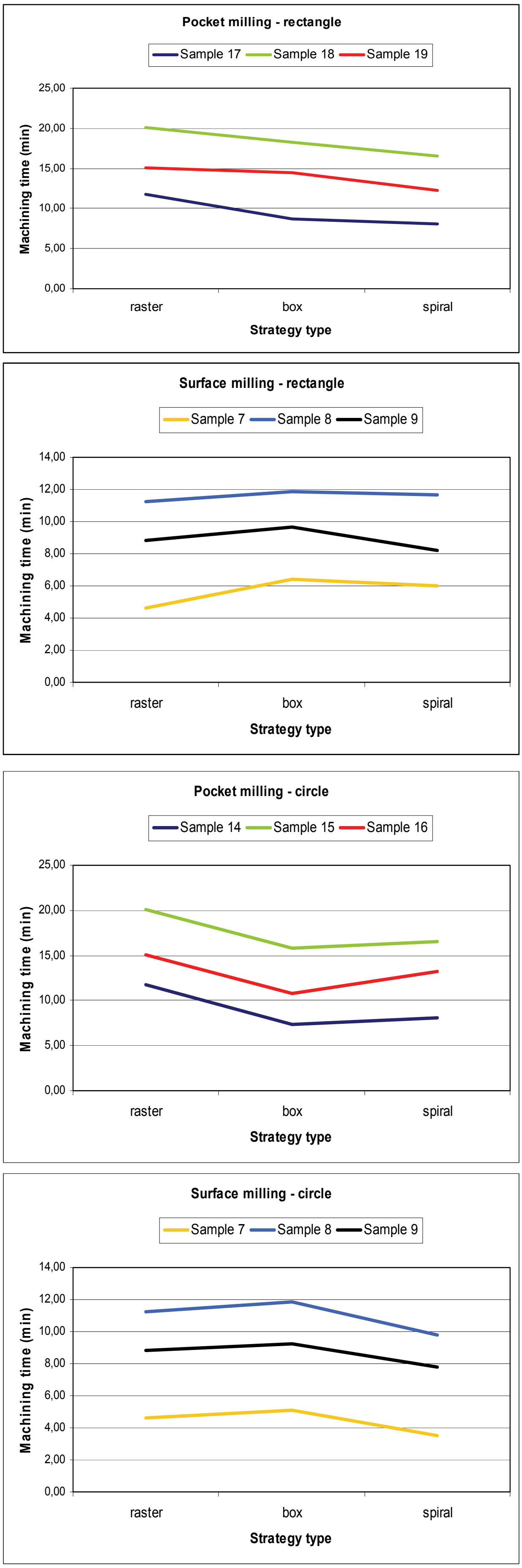


Figure 7 Graphical courses of time values – milling inside the borders, milling over the whole surface

7 Conclusion

Possibility of a quick check on the suitability of a milling strategy belongs to tools for increasing production efficiency from the viewpoint of time and therefore also from the economical saving in manufacturing. This paper describes one attitude to software solution of these problems via a newly created software application. User of CAM product can use it as handy additional software for selection between available milling strategies. This application should be helpful also for users that still realize workshop floor-programming. The space for improving the functional attributes of the MISTRA program is in the area of more complex surfaces and shapes created for example after joining 4 basic types included in the operational version of program. There could be also some external graphical environment imported with capability to display the part model and designed strategy in 3D view. Matter that needs to be solved is then assuring of working connection between Delphi structure and one of open source graphical environments. Another possibility of innovation lies in a future database of the values of residual stresses that are assumed after milling with different strategies. Involvement of this factor though supposes wide series of tests so results can be used for building such program database. Manufacturing strategies and their righteous choice represent the areas with the necessity of further development. Better solution in that area contributes to ensuring higher productivity of manufacturing.

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