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TOOL RADIUS SELECTION IN MILLING PROCESS

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Abstract: The milling process nowadays is assisted designed by CAM applications. Selection of the tools for the milling process is not CAM main purpose, and normally is accomplish by the designer of the process. As a result, the CAM designer selects the tools many times in an improper way, taking consideration on milling strategy, milling parameters, material to cut, surfaces finish and the number of operations. All these parameters are optimized by the human designer, based on his own experience. Application software to assist the human operator it seems to come into view for many CAM systems.

1. Introduction

The selection of tool for milling process is a standard procedure for all tool manufacturers. First, the selection take account of machining conditions: good machining conditions, moderate machining conditions, or unfavorable machining conditions. After that, the next step is to determine the code of workpiece material group (i.e. steel, stainless steel and cast steel, cast iron, NF metals, difficult cutting materials as titanium alloys, and hardened steel). Also, the machine stability, clamping system and workpiece can by subdivided in very good, good or moderate conditions. The next step is to define the recommended geometry by means of the workpiece material code of a certain tool manufacturer depending on the existing machining conditions.

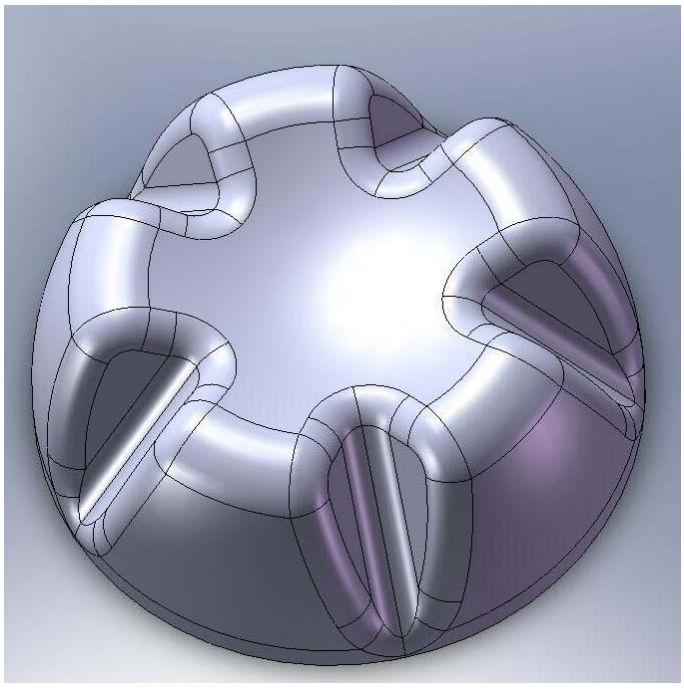

Figure 1

For roughing operations, the correct tool is chosen by means of the parameters defined in terms of workpiece material group, machining conditions and geometry. For semi-finishing and finishing components the correct tool is chosen by means of the parameters defined in terms of workpiece material group, machining conditions and geometry.

In this stage, the appropriate carbide grade and the suitable geometry have already been selected. The next step is to select the appropriate value for cutting speed v_C. The selection of cutting speed depends on the workpiece material, the cutting material grade and the ratio:

$$\frac{a_e}{D_c} = \frac{\text{width\_of\_cut}}{\text{diamter\_of\_cutter}} \qquad (1)$$

From calculus or from the charts the user can select the type of inserts (coated grades, uncoated grades, CBN, Cermet etc). The next step is to select the starting value for feed per tooth. The selection of feed rate depends on the workpiece material, and the type of cutter. Usually, the feed per tooth value f_{Z0} shown in the charts is based on maximum width of cut are to be reduced accordingly (i.e. that means a_e = diameter of the tool D_c) and the maximum depth of cut a_p which can be run by the cutter. If the width / depth of cut differs from the maximum value, the appropriate correction factors of the corresponding cutting process conditions should be applied:

$$f_Z = f_{Z0} \cdot Ka_e \cdot Ka_p \qquad (2)$$

These values are to be reduced accordingly if the machining conditions are unstable, also considering the driving power available on the machine tool and the rigidity of the machine. This procedure is typical for surface milling, all the rest operations such as plunging into inclined surfaces, circular interpolations into solid material, vertical plunging, up milling of steep surfaces, line-by-line milling etc must be calculated with specific formulas.

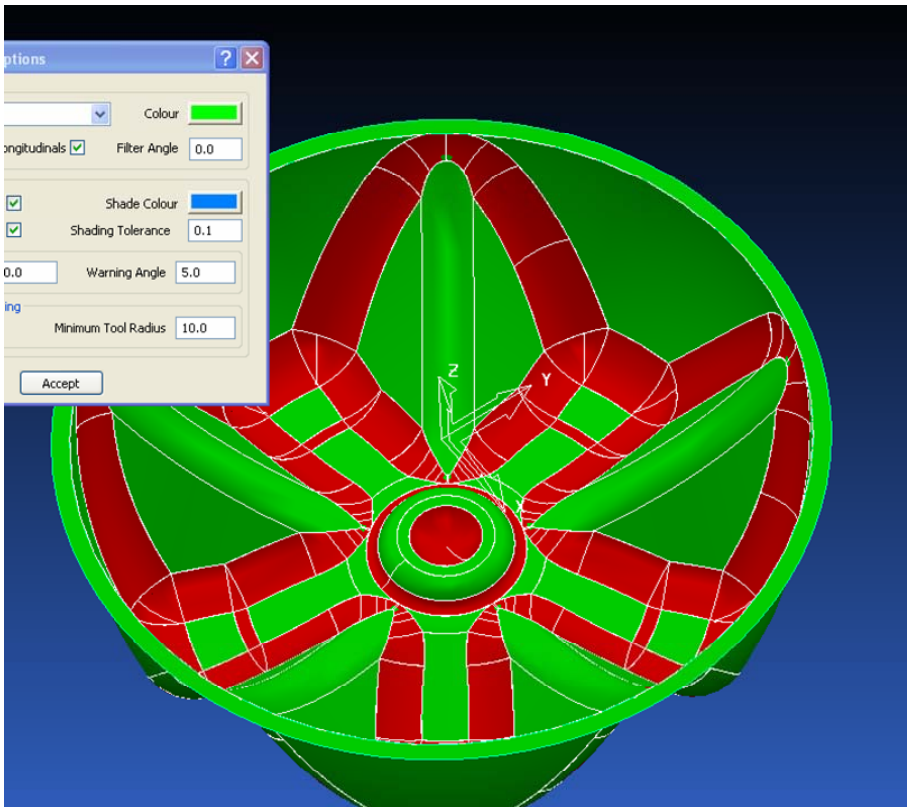

Figure 2

In case of finishing operations for complex surfaces tool selection is more complicated assignment, because the tool radius can be selected from a large range of dimensions, and the results depends by many parameters. It cannot set up general rules in all milling processes since the manufactured parts are infinite number in terms of shapes.

2. Tool radius selection in milling process

Let's take in considerations a complex set of surfaces like in figure 1. To machine the mold for this kind of parts we need milling tools for roughing and finishing. The number of tools for finishing (in fact: semi-finishing and finishing) depends by many parameters: surface quality, feature radius, and not the last the time of cutting process (metal removal rate [cm^3/min]).

To set up the number of tools and accurate selection of tools dimensions the engineer will determine at the beginning the maximum radius capable to fit into features

radius. This characteristic is common for the majority of CAM systems, and is shown in figure 2 for specific commercial CAM software.

CAM engineer is tempted to use always the maximum radius possible to fit in feature radius. As a rule, the CAM engineer decides on tool radius as in (3) because of CNC machine tool kinematics.

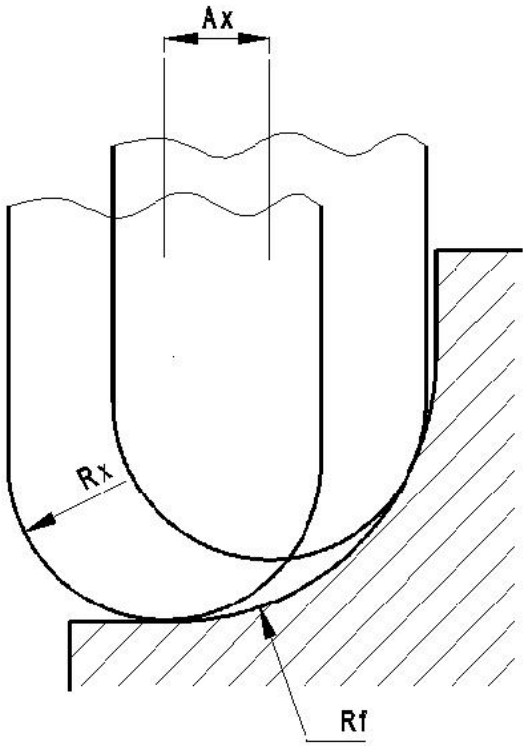

Figure 3

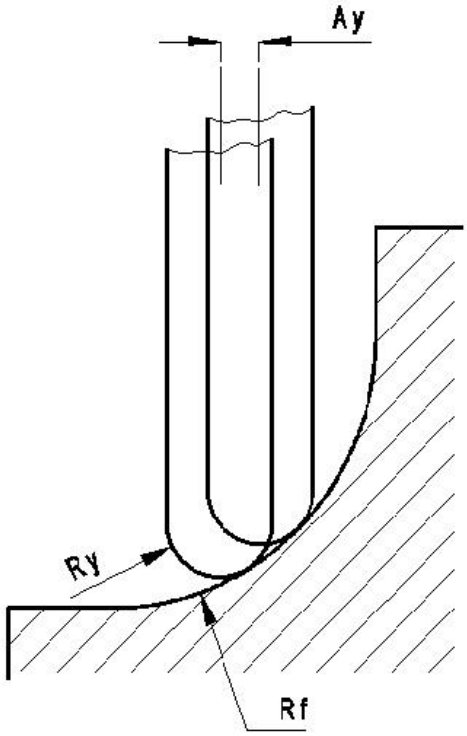

Figure 4

$$R_X = (0{,}9...0{,}95) \cdot R_f \qquad (3)$$

Because the surface finishing depends primarily by tool radius, the CAM engineer will select the tool from figure 3 and not the tool from figure 4. The surface finishing R_{max} depends on:

R_{max} = f (Tool radius; workpiece material; cutting parameters)

If the manufactured part has only one feature radius – like in figure 3 or 4 R_f, the tool radius selection is a very simple choosing procedure, using formula (3). If not – meaning the piece has different R_f radius for many features, we will use numerous tool size, with all these parameters:

$N = \{ N_{Rx} ; N_{RY} ; N_{AX} ; N_{AY} ; N_{RF} \}$

In this situation, tool selection must be calculated by application software. This software has to pass to the CAM system all parameters of tools. The CAM system will simulate the operations with all tools and based on volume of metal removal and surface finishing. The modus operandi is exposed in figure 5.

Figure 5 revealed our solutions for any CAM system. In fact, our application for cutting tool selection is platform independent, because is a stand alone application. At this moment, we work to integrate in the most popular CAM systems – see references – as a plug-in or as a developer tool.

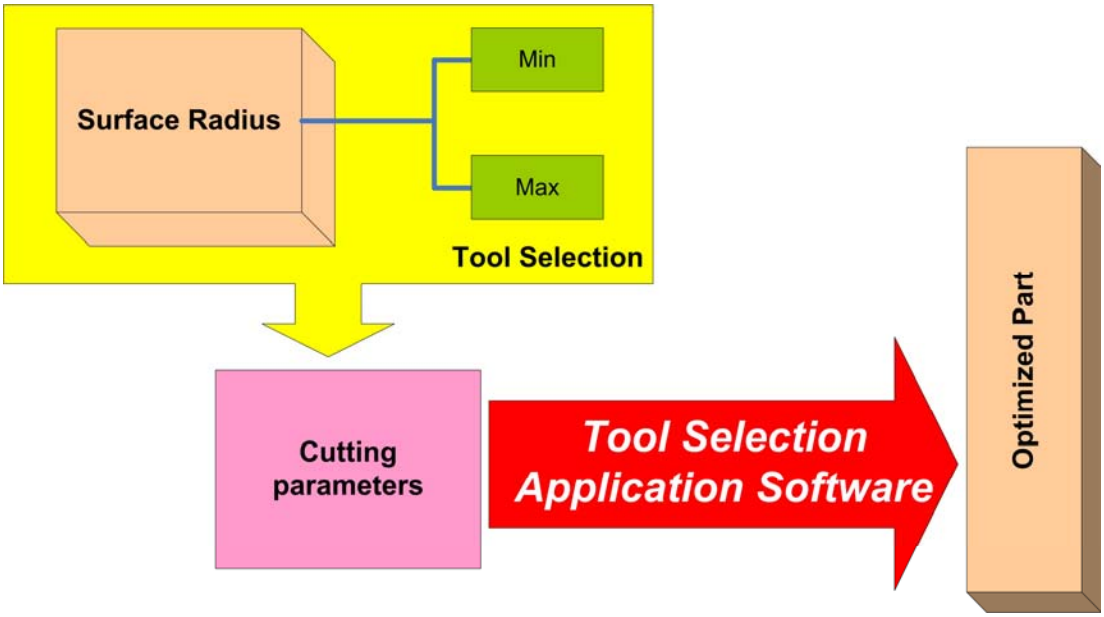

Figure 5

3. Conclusions

At this point of the research we developed "Tool selection application software" based on traditional programming. No artificial intelligence or expert system approach was used. We experienced difficulties to connect our module with commercial CAM applications such as [1], [2], [3] or [4].

A number of commercial CAM applications already include elements of expert systems for tool selection in large modules to perform the entire CAM process automatically, however today results are far from expectations.

We will develop our application taking in consideration the results of the significant CAM producers, as well the tools makers and machine tools companies' outcomes. Now available to work, our results introduce significant new capabilities, including tool selection for high speed machining.

A good tool selection for finishing operations lets CAM engineer choose the best method for a specific project: finish machine multiple surfaces, solid models, or a combination of both; unlimited Pencil Finishing machines the part in logical segments; parallel finishing; 3D project machining; constant scallop machining maintains a consistent finish on sloped and flat surfaces; flowline machining cuts single or multiple surfaces using their natural shape to define the cutter path, delivering a smoother finish.

References:

[1] http://www.delcam.com , May 2007
[2] http://www.mastercam.com , May 2007
[3] http://www.solidcam.com , May 2007
[4] http://www.ptc.com , May 2007