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# The influence of the manufacturing strategy on the production of molds and dies

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**Abstract**

The manufacturing of molds and dies has become more prominent as the world economy advances toward reduced lots, larger diversity of products and more importantly, reduced time for launching new products. Such requirements increased the application of new technologies – on one side looking to improve the digital integration of the process chain CAD/CAM/CNC and on the other side the introduction of the HSC technology in this process chain. However, the introduction of these technologies requires also the gathering of the necessary know-how related to the whole process, for example the application of appropriate cutting strategies, which have a direct effect on the geometrical precision, surface roughness and surface texture of the final part. This paper presents a experimental work about the relation between cutting strategies and the machining time and surface quality of the part. For that was developed a test model representing surfaces found in mold and dies; the material of the part was P20, a typical material for this application. Cutting strategies like Follow Periphery, Follow Part, Parallel Lines and Zig-Zag, were applied in the NC machining of test model and the results considering time and surface quality were compared.


*Keywords:* High speed cutting; Molds and dies; Cutting strategies; CAD/CAM/CNC chain

## 1. Introduction

Increasing demands for industrial designs which provide more harmonic ways of presenting a product, the development of methods and software for modeling and manipulation of complex surfaces as well as the reduction of hardware costs has intensified the use of CAD/CAM Technology in product development [1].

For this reason, the manufacturing of molds and dies has become more prominent as the world economy advances toward reduced lots, larger diversity of products and more importantly, reduced time for launching new products.

However, these technological applications have encountered great difficulties in industry since new factors have emerged as variables in the manufacturing process [2]. Within these variables, the manufacturing strategy is importance for determining the tool path, and therefore responsible for lead time, geometric precision, and surface finishing, which make up the product characteristics for subsequent stages.

Within the CAD/CAM/CNC Technology, product manufacturing is carried out through the creation of a geometric model in the CAD system which is transferred to the CAM system. There the programmer will provide the manufacturing data which will result in the tool paths.

After the generation of the tool path, an internal post-processor of the CAM system creates a NC Program based on all of the tool paths, which is interpreted by the CNC of the tool machine as movements [3].

## 2. Objectives

This study investigates the influence of manufacturing strategies such as surface finishing, lead time and CAM system programming as applied to the development of the product. To do this, the CAD/CAM system is used in the generation of NC Programs for the Discovery 760 Manufacturing Center. Practical knowledge is appropriated on the manufacturing strategies and the programming of the Unigraphics NX2 CAM system for the manufacturing of solids through the use of a model with complex surfaces.

## 3. Material and methods

To reach these objectives the instructional material that accompanies the CAD/CAM system and also materials developed by the Laboratory for Computer Application in Design and Manufacturing (SCPM) were used [4]. In addition, training was carried out for the Discovery 760 CNC Milling Center and the

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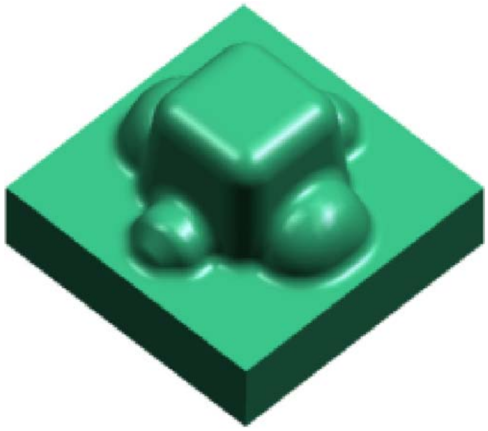

Fig. 1. Test model.

Table 1
Cutting parameters used in the manufacturing operation

| Cutting parameters | Operations | |
|---|---|---|
| | Rough | Semi finish |
| Cutting strategy | Follow Periphery | Follow Periphery |
| Tool | 1 headstock, 50 mm diameter, with interchangeable inserts | Ball nose mill 10 mm of hardened metal |
| Rotation ($n$) | 1180 mim$^{-1}$ | 7960 mim$^{-1}$ |
| Feed rate ($V_f$) | 1130 mm/min | 1590 mm/min |
| Cutting speed ($V_c$) | 185 m/min | 250 m/min |
| Feed rate per tooth ($f$) | 0.11 mm | 0.10 mm |
| Cutting Depth (ap) | 1 mm | 1.5 mm |
| Cutting Edge (quantity) | 4 | 2 |

Siemens 810D Numeric Command was studied using the manufacturer's manual [5].

The practical study of the CAD/CAM system was carried out by creating a test model (100 mm × 100 mm × 70 mm) as illustrated in Fig. 1. The model was manufactured in AISI-SAE 1045 steel at the Discovery Milling Center available at UNIMEP in order to simulate the practical manufacturing conditions. The analysis of results was done by comparing the cutting strategies carried out on the test models according to the following parameters:

- Real manufacturing time;
- CAM programming time;
- surface aspects;
- surface roughness.

In order to make comparisons that would fulfill the proposed objectives of this study, two test models were made. For the first model the Zig–Zag strategy with a 45° angle in relation to the $x$-axis was used. Among the strategies available in the CAM system this strategy was selected in virtue of the quickness with which it can be programmed and the good surface finishing obtained in some cases [6].

Test Model 2 was divided into four manufacturing regions and different strategies were used in each region, such as the *Radial Lines* strategy, consisting in Zig–Zag movements with a central point, which is the starting point for the tool path.

This method was adopted in order to compare the results based on the geometry. For the validation of the results, the same manufacturing parameters were maintained such as the lateral step over and cutting feed rates used in Test Model 1.

### 3.1. Experiment

In the manufacturing of the test models, the operations of roughing, semi finishing and finishing were used.

For all test models the same technological parameters were used in carrying out the operations such as: programmed feed rate, depth, thickness of the cut and feed rate per tooth.

The technological data described in Table 1 was taken from the tool supplier's catalogues in order to be utilized for the roughing and semi finishing operations.

- Test Model 1

  For Test Model 1, the Zig–Zag strategy was used with a 45° angle in relation to the $x$-axis. This strategy was utilized due to its programming quickness and because it has produced a satisfactory surface finishing in some cases [6]. The manufacturing parameters are described in Table 2.
- Test Model 2

  For the analysis of the strategy tool path on Test Model 2, the model was divided into four different regions with different strategies used in each one. However, the same manufacturing parameters of lateral step over and cutting feed rates as Test Model 1 were used.

Table 2
Cutting Parameters used in the finishing operation

| Cutting parameters | Finish operation |
|---|---|
| Cutting strategy | Zig–Zag 45° |
| Tool | Ball nose mill 8 mm of hardened metal. |
| Rotation ($n$) | 8000 mim$^{-1}$ |
| Feedrate ($V_f$) | 1400 mm/min |
| Cutting speed ($V_c$) | 200 m/min |
| Feed rate per tooth ($f$) | 0.08 mm |
| Cutting thickness | 0.1 mm |
| Cutting edge (quantity) | 2 |

Fig. 2 illustrates the regions and cutting strategies that were defined according to the geometry and are identified as:

- Region 1: Radii, Follow Periphery strategy which consists in the tool path based on offsets of the workpiece.
- Region 2: Upper corners, Radial Lines strategy that consists in Zig–Zag movements, with a central point in which the tool path proceeds in the radial direction.
- Region 3: Lateral body of the workpiece, Radial Lines strategy.
- Region 4: Lower spherical geometry, Zig–Zag strategy.

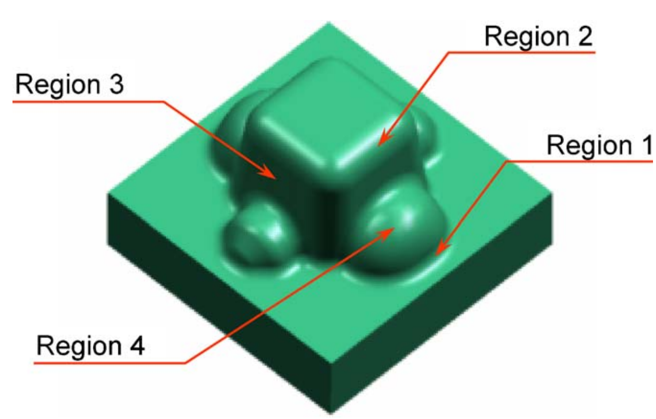


Fig. 2. Manufacturing regions studied.