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Modelling and Optimization of the Cutting Tool Trajectory

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ABSTRACT

The trajectory of the cutting tool has an important influence on the quality of the piece, especially on the cost of production.

The objective of this work is to find a solution to reduce errors trips, and develop a mathematical model. To achieve this goal, an experimental study was developed to quantify the errors due to the trajectory of the cutting tool. We used the finite differences method for the modeling and optimization these errors.

INTRODUCTION

The realization of complex shapes by machining through trajectory generation in software Computer Aided Manufacturing (CAM), based on a geometric model of reference, a machining strategy, information technology and machine tool control digital data. To ensure the best possible performance in terms of quality and productivity, it is necessary to integrate a maximum of constraints when generating the machining path.

Several studies have been made in this context. Rahou et al [1] present a strategy for optimizing the cutting tool in real time based on the systematic dispersion (wear of the cutting tool). Mojtaba [2] proposed solving methods associated with the simulation method (MMP Model of Manufactured Part) developed by Vignat and Villeneuve. The MMP is a 3D geometrical defects caused generic model of the parts manufactured by a given manufacturing process. Romulus [3] proposed a method for calculating the three-dimensional tolerance analysis by considering the main dispersion processes and errors due to the machine tool. It has developed a range of processes involving dispersions, errors of machine tools and functional tolerances. Bai [4] analyzed a dependent relationship of operational dimensions to estimate machining errors in terms of linear and angular dimensions of a workpiece. Cai et al. [5] proposed a method to conduct a robust fixture design to minimize workpiece positional errors as a result of workpiece surface and fixture setup errors. Djurdjanovic and Ni [6] developed procedures for determining the influence of errors in fixtures, locating datum features and measurement datum features on dimensional errors in machining. These studies were conducted when a static case was assumed.

Kim and Kim [7] have developed a volumetric error model based on 4x4 homogenous transformations for generalized geometric error. Eman and Wu [8] have developed error model accounts for error due to inaccuracies in the geometry and mutual relationships of the machine structural elements as well as error resulting from the relative motion between these elements. Kakino et al. [9] have measured positioning errors of multi-axis machine tools in a volumetric sense by Double Ball Bar (DBB) device. Takeuchi and Watanabe [10] have shown five-axis control collision free tool path and post processing for NCdata. In the work of [11] a study was presented on the influence of the position of the cutting tool on dynamic behavior in milling of thin walls, and in work of [12,13,14], authors thus illustrate the influence of the trajectory of the cutting tool on the surface quality tolerances of manufacture for machining on the machine tool has numerical control.

EXPERIMENTAL STUDY

The goal is studied the influence of the tool path on the dimension of the part. To achieve this, we used the following test conditions:

- Machine: CNC), Denford D13511 CYCLONE, FANUC language ;
- Tool: Roughing tool SDJCR 1212 F11 TIZIT 220217/001;
- Measuring device: Compare 1:100;
- Test: 25;
- Move vacuum;

The objective of this step is to determine the tool path errors. To achieve this goal, we conducted a series of 25 tests measuring tool empty runs, varying the distance between the tool and the meter of length L = 20,30,50 , 80,100, as shown in Figure 1.

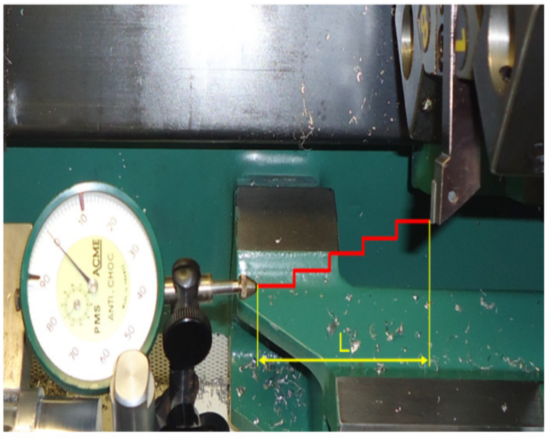

Figure 1: Test Example

Figures 2, 3, 4, 5 and 6 show the errors variation for the handling of 20mm, 30 mm, 50 mm, 80 mm and 100mm. We observe that the length of tool movement is not constant, the errors are significantly different, and vary between -0.011 mm and 0.01 mm.

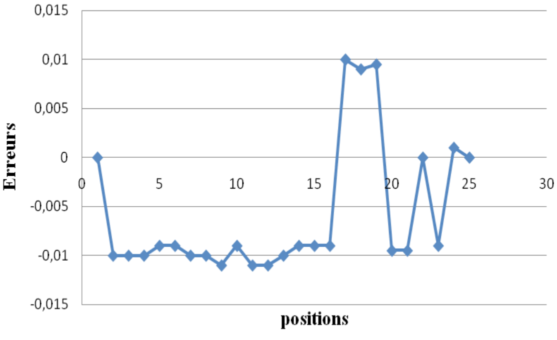

Figure 2: Handling 20mm.

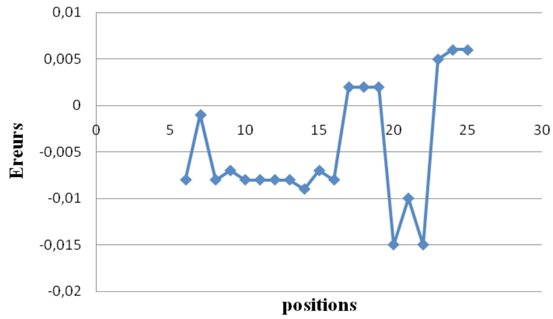

Figure 3: Handling 30mm.

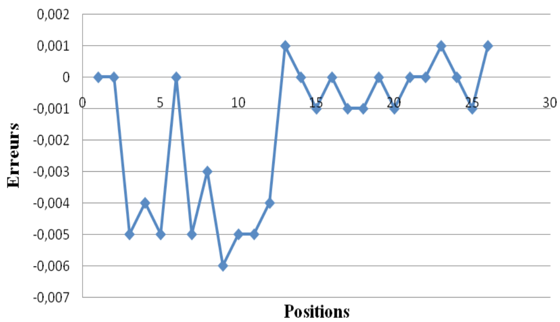

Figure 4: Handling 50mm.

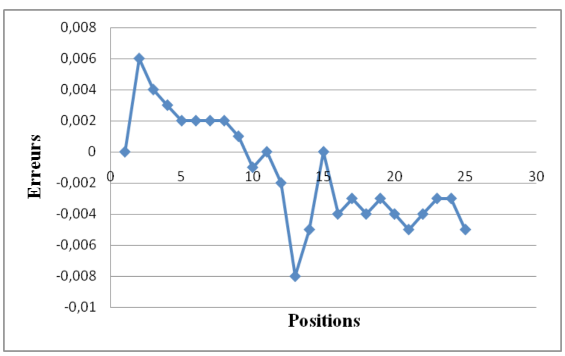

Figure 5: Handling 80mm.

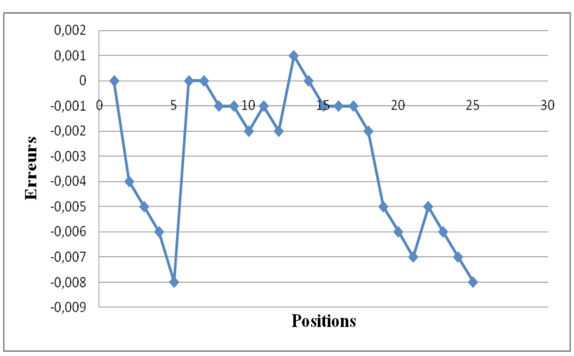

Figure 6: Handling 100mm.

TABLE -1.
STATISTICAL Results

Distance	Average	Standard deviation	TI
20	-0,582 E-2	0, 687 E-2	0,0412
30	-0,527 E-2	0, 629 E-2	0,0377
50	-0,183 E-2	0, 237 E-2	0,0142
80	-0,148 E-2	0, 377 E-2	0,0227
100	-0,312 E-2	0, 289 E-2	0,0173

MODELING

In this section, the results of the experimental study on the influence of tool path on IT were used as database modeling. The aim is to adjust these errors by a function E = F (x). This transformation can be modeled by several methods such as the method of Lagrange, Newton's method and the fixed point method, the method of least squares. In this paper we used the finite differences method.

The general form of interpolation is given by the (1)

$$f_{n-1}(x) = a_1 + (x - x_1)a_2 + (x - x_1)(x - x_2)a_3 + \cdots + (x - x_1)(x - x_2)$$

$$+ \cdots (x - x_{n-1})a_n$$

Finite differences are given by the relations (2)

$$(\nabla f(x))_i \approx \frac{f(x + te_i) - f(x)}{t}$$

$$f(x + h) \approx f(x) + \nabla f(x)h + \frac{1}{2}h^T H_f(x)h$$

$$x_{K+1} = x_K - H_f^{-1}(x_K)\nabla f(x_K)$$

$$H_f(x_K)s_K = -\nabla f(x_k)$$

The polynomial equations for the five manipulations are given by (3),(4),(5),(6) and (7)

$$P1(X) = -1{,}297X + 6{,}989.10^{-2}X^2 + 1{,}987.10^{-3}X^3$$

$$P2(X) = -9{,}571.10^{-1}X + 5{,}012.10^{-2}X^2 + 1{,}254.10^{-3}X^3$$

$$P3(X) = -5{,}325.10^{-2}X + 2{,}812.10^{-3}X^2 + 7{,}791.10^{-5}X^3 \quad (5)$$

$$P4(X) = -2{,}315X + 1{,}254.10^{-1}X^2 + 3{,}394.10^{-3}X^3 \quad (6)$$

$$P5(X) = -3{,}304X + 1{,}845.10^{-1}X^2 + 5{,}052.10^{-3}X^3 \quad (7)$$

CONCLUSION

In this study, we found that moving with less error is the par-axial shift. The change of speed on the shift has an important influence on manufacturing tolerances.

Developed by the finite difference model has been to compensate for errors in the tool path for machining. This compensation can be given by three methods.

1. Inject the models developed in the function of the tool offset T represented by D. numeric address
2. Programming models developed in the machining program.
3. Develop an interface (assembler) between the control unit and the operative part.

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