Simulation Analysis of Surface Roughness for Milling Process

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ABSTRACT

Surface roughness is one of the most important evaluation indexes in machine cutting. In order to analyze how the tool path affects the roughness of the surface after milling, series of simulations are implemented in MasterCAM. We set up the same processing conditions with same parameters such as speed, material and feed rate etc. in these simulations, but different processing paths are used. We choose three paths: the parallel milling along the X-Y axis direction, the parallel milling along the Z-X or Z-Y axis direction and the streamline processing in the simulations. At the same time, end miller, arc miller and ball miller are respectively selected in the software. So there are totally 9 simulations of the milling process that are performed. Then the experimental cutting processes are performed correspondingly and the surface roughness and the accuracy are measured. The results show that the milling effect of the arc is better and the waste is minimal in the parallel milling along the Z-X or Z-Y axis direction with the end mills.

1. INTRODUCTION

The processing of the injection mold needs milling, grinding, EDM, and light etching process, etc., but the CNC milling process is still the fastest and the most economical way of achieving the main structure and shape of the molds. Lots of papers are focusing on the milling processing of the injection mold, for example, many researches are devoted to studying the relations between the processing quality and the machining speed and feed rate [1-3], and also many studies are devoted to analyzing the difference of the dry milling and wet milling, which can markedly affect the processing quality [4], and many researches are focusing on studying that the different processing path can shorten the processing time and markedly increase the processing efficiency [5]. MasterCAM is an widely used CAD/CAM software which can benefit the design and process the mould and die [6-10], but many studies are always focusing on using the MasterCAM to realize the automatic programming [6, 7]. Also, the technological parameters are studied for finding the most reasonable process parameter setting, so that the processing speed of the part can be improved markedly [8, 9], and one aspect of the process setting is the tool path [10]. But these studies have not performed more comprehensive analysis about the tool path's effect on the mold processing.

This paper focuses on the finish milling of the mold surfaces, the comprehensive analysis and comparison of the surface milling by using different processing paths that are performed to achieve the high precision and the machining quality. Research achievements will be used in the milling of the inner fillet of master mold or the outer arc of the mold heart. The analysis and comparison realized by experimental machining and measurement can prove that the high precision and quality can be obtained in the injection mold milling.

2. ARC CONTOUR MACHINING SIMULATION

2.1. Simulation of the Basic Parameter Settings

In the computer-aided manufacturing software such as Master CAM, the effects of the different processing paths are compared in the same speed, tools, materials and other conditions.

1) Setting the basic operating parameters

The size of workpiece and the coordinate frame are set already which can determine the moving scope of the physical tool; correspondingly, the boundary, NC machining scope and the working scope can be determined by the setting of the original point and corner. The work setting dialog box in Master CAM is shown in Figure 1. Concretely, the size of workpiece is 10 mm, 10 mm and 20 mm respectively in the direction of X, Y and Z; the origin of the workpiece is (0, 0, 0); the option of the tool path planning includes "output the operation comments to NCI", "generate tool paths immediately", "save the tool paths into MC9" and "assign the tool number in sequence"; in the setting of cutter compensation number, the "increase" is chosen and both of the length and radius of cutter are set as 0; in the computation of feed rate, the option "according to the cutter" is chosen, and the maximum speed is 5000 RMP; the material of workpiece is ALUMINUM mm-2024; the post-processors is MPFAN.

2) Parameters setting of surface finish

Surface finish is the final cutting process which can definitively determine the quality. The most important cutting parameters are the tool form, the feed rate, the tool lifting speed, the tool down speed and the spindle speed, etc. In addition, the setting of the finishing parameters consists of the maximum cutting distance and the overall cutting error settings. The tool parameter settings of the surface finishing are shown in Figure 2, and the processing parameter table of this test is shown in Table 1.

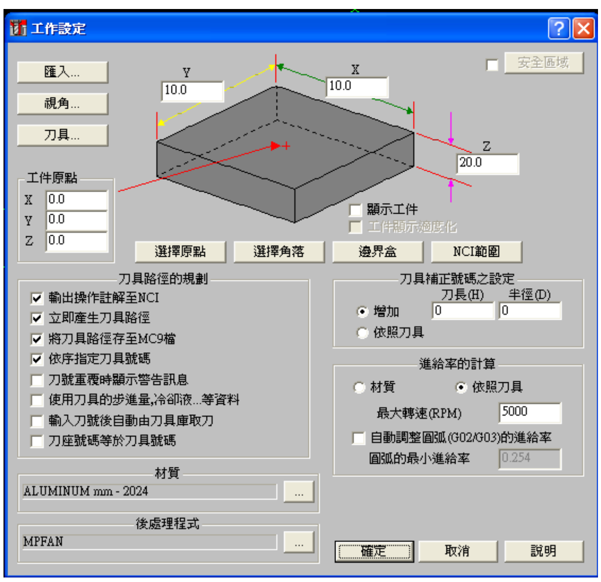


Figure 1. Work setting of MasterCAM.

Figure 2. Tool parameter settings of surface finish.

Table 1. Processing parameters table.

Parameter	Values
Tool size	Φ8 mm
Feed rate	300 mm/min
Down speed	100 mm/min
Lifting speed	600 mm/min
Spindle speed	2500 rpm
Maximum cutting distance	0.1 mm
Overall error	0.02 mm

2.2. Test of Machining Ways

Using the different tools, the simulations are carried out according to various processing paths in Master CAM, such as the parallel milling along the X-Y axis, the parallel milling along the Z-X or Z-Y axis to the milling and the streamline processing. After the processing surfaces and the processing parameters are set, the tool paths are automatically calculated by MasterCAM. The path planning graph is shown in Figure 3. The administrator device can be used to set the plane and the parameters, and finally the solid cutting simulation is carried out to verify the setting.

2.3. Simulation Results

According to the simulation results, the best three methods, the parallel milling along the X-Y axis, the parallel milling along the Z-X or Z-Y axis and the streamline processing are chosen as shown in Figure 4. The simulation results are shown in Figures 5-10. Figure 5 is the result for the parallel milling of the end mill along the Z-X axis and the Z-Y axis, Figure 6 is the result for the streamline processing of the end mill, Figure 7 is the result for the parallel milling of the ball mill along the Z-X axis and the Z-Y axis direction, Figure 8 is the result for the streamline processing of the ball mill, Figure 9 is the result for the parallel milling of the arc mill along the Z-X axis and the Z-Y axis, Figure 10 is the result for the streamline processing of the arc mill.

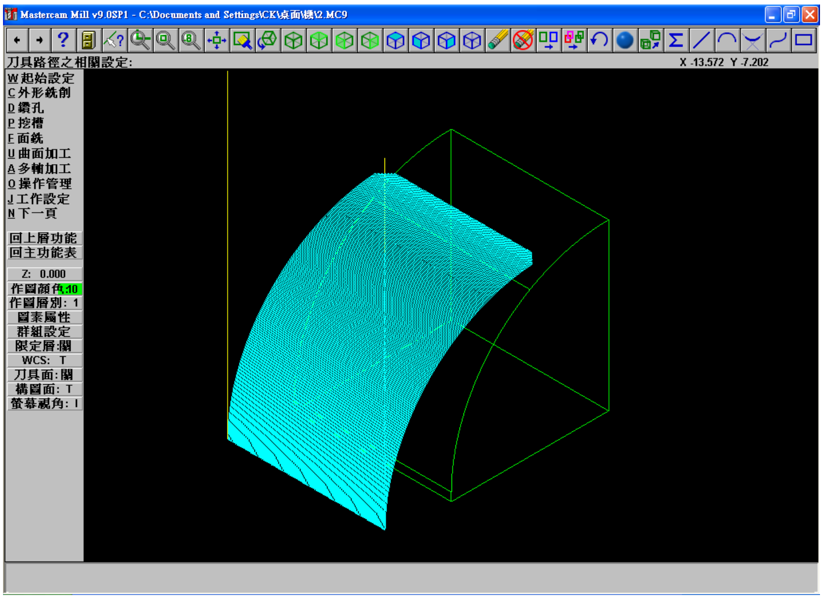


Figure 3. Path planning graph.

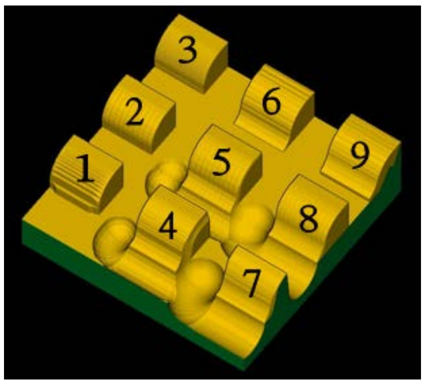
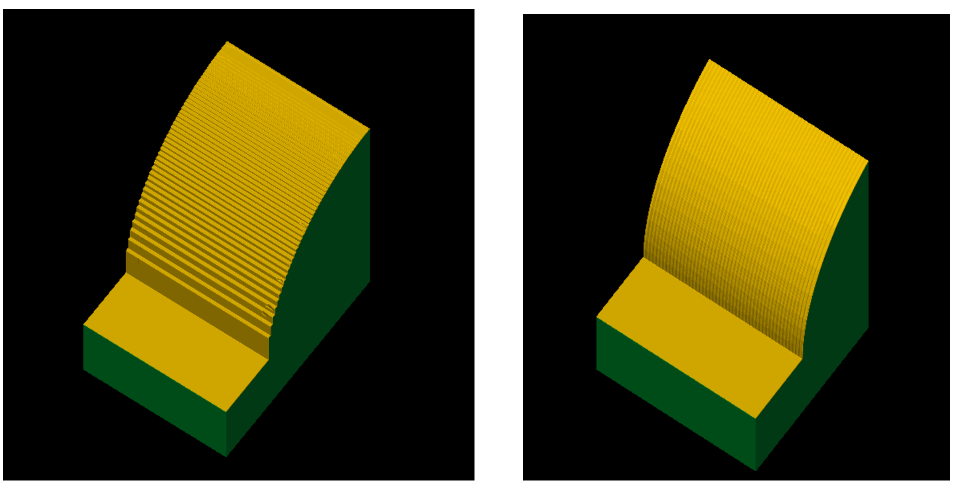


Figure 4. Simulation results.



(a) (b)

Figure 5. Parallel milling for the end mill. (a) Z-X axis; (b) Z-Y axis.

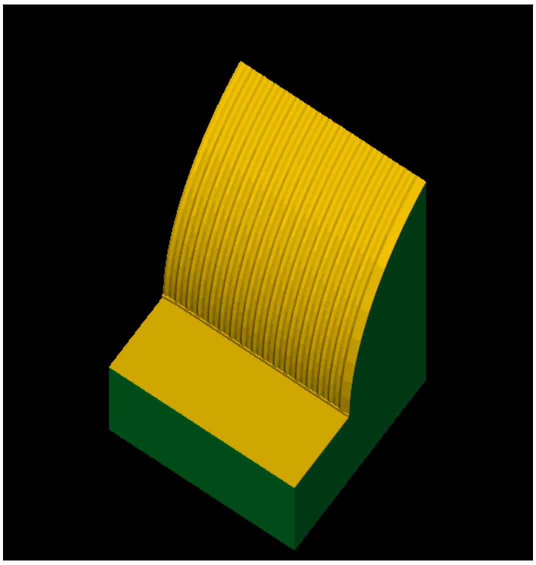


Figure 6. Streamline processing of end mill.

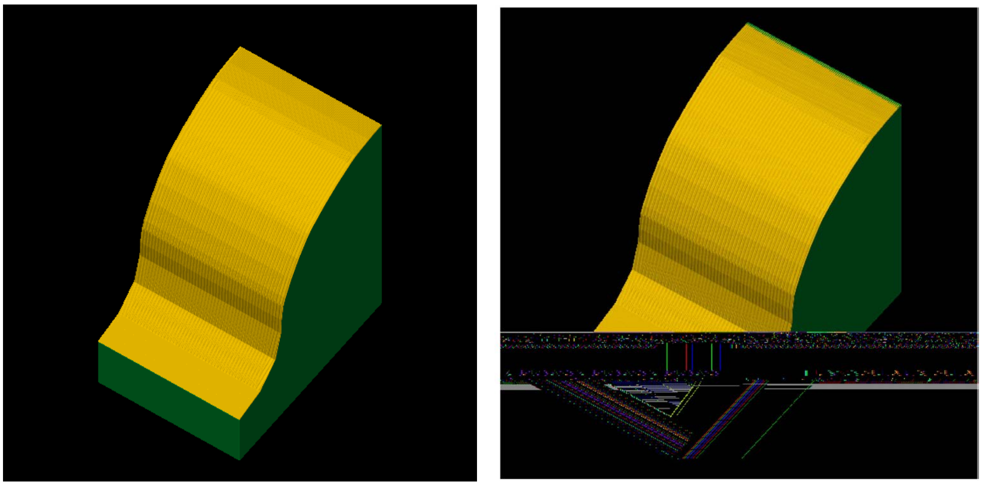


Figure 7. Parallel milling of ball mill along Z-X axis. (a) Z-X axis; (b) Z-Y axis.

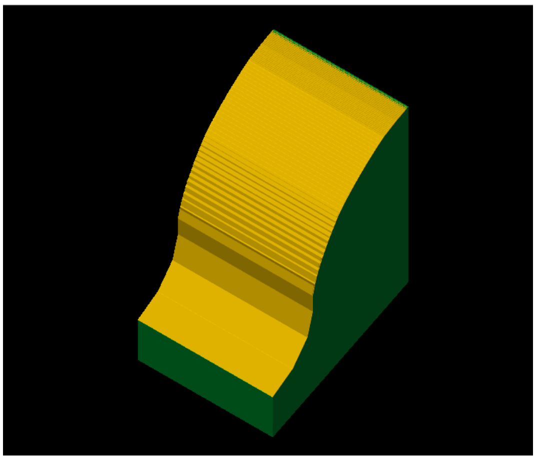
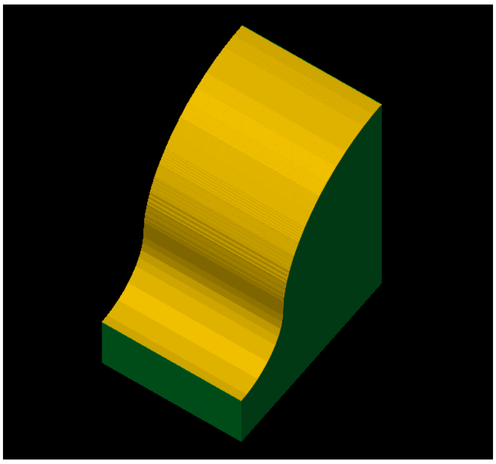
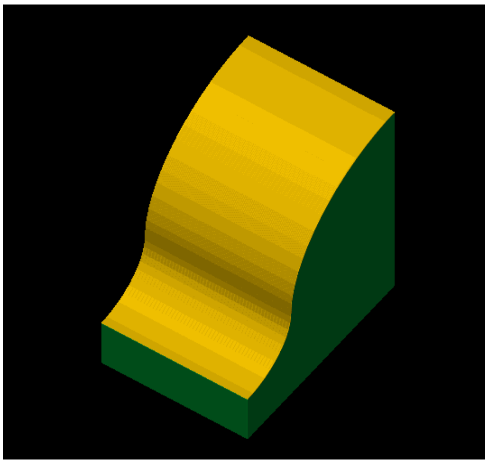


Figure 8. Streamline processing of ball mill.



(a)



(b)

Figure 9. Parallel milling of the arc mill along the Z-X axis. (a) Z-X axis; (b) Z-Y axis.

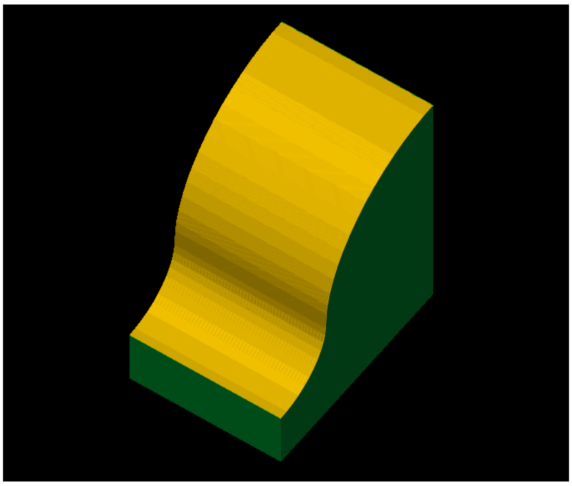


Figure 10. Streamline processing of arc mill.

3. MACHINING EXPERIMENTS OF ARC CONTOURING

All the cutting processes are simulated successfully, so the NC programs can be obtained by using the MasterCAM according to the corresponding parameters set in the simulations. The code generated by MasterCAM is shown in **Figure 11**. After the file conversion has finished, the practical cutting processes are performed by using a CNC milling machine, and totally 9 samples (shown in **Figure 12**) are processed in accordance with the processing conditions in **Table 2**.

4. ROUGHNESS MEASUREMENT OF MILLING SURFACE

By use of a surface profiler, the roughness of the samples obtained from the practical cutting processes is measured. The measurement results are shown in **Table 3**. Obviously, sample 4, sample 3 and sample 7 have better surface roughness than others, and the sample 1 has the worst surface roughness.

5. CONCLUSIONS AND DISCUSSION

According to the measurement results of the surface profiler machined by using the program generated by Master CAM, the path of parallel milling along Z-X axis can obtain the best surface roughness. But

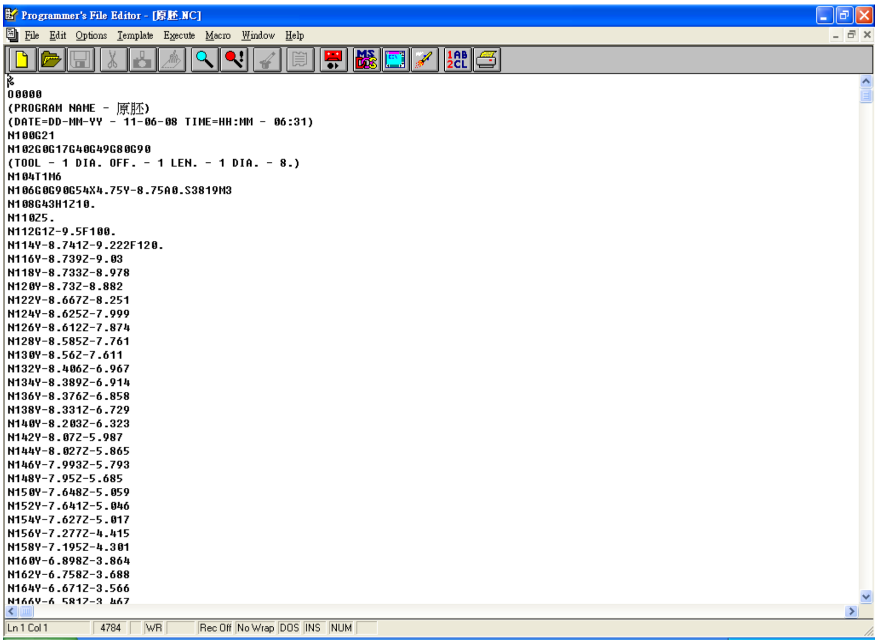


Figure 11. Program code.

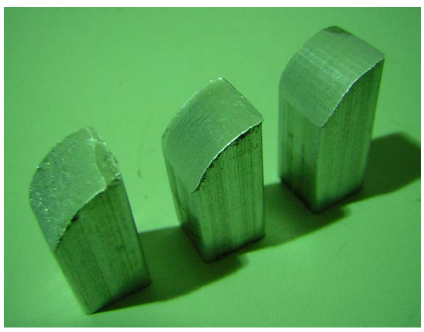


Figure 12. Sample photo.

Table 2. Sample processing conditions.

Sample	Processing conditions
Sample 1	Parallel milling of end mill along Z-X axis
Sample 2	Parallel milling of end mill along Z-Y axis
Sample 3	Streamline processing of end mill
Sample 4	Parallel milling of ball mill along Z-X axis
Sample 5	Parallel milling of the ball mill along Z-Y axis
Sample 6	Streamline processing of ball mill
Sample 7	Parallel milling of arc mill along Z-X axis
Sample 8	Parallel milling of arc mill along Z-Y axis
Sample 9	Streamline processing of arc mill

Table 3. **Value of surface roughness measurement (unit: μm).**

	First measured value	Second measured value	Third measured value	average value
Sample 1	22.617	20.577	23.442	22.212
Sample 2	9.840	9.383	9.924	9.716
Sample 3	1.569	1.801	1.575	1.648
Sample 4	0.587	0.469	0.510	0.522
Sample 5	2.733	2.529	3.132	2.798
Sample 6	5.049	4.742	4.921	4.904
Sample 8	2.269	2.011	2.347	2.209
Sample 8	4.513	4.146	4.318	4.326
Sample 9	5.642	5.881	5.672	5.732

the simulation results show that the machining process will result in over-cutting if the processing condition in Case 4 is selected. Because the Master CAM calculates the processing path without the consideration of the cutter radius of the ball mill, this processing condition is not preferred. Therefore, by use of the parallel milling of the end mill along the Z-X or Z-Y axis, the arc quality is better than others, and the waste is minimal. These research results can guide the practices in milling of the inner fillet of the master mold, the outer arc of the mold heart and the injection mold, which can greatly benefit the precision and quality.

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CONFLICTS OF INTEREST

The authors declare no conflicts of interest regarding the publication of this paper.

REFERENCES

1. Wei, Q.F. and Wang, X.J. (2008) High-Speed Tool Steel Hardened Stainless Steel Milling Process. *Machinery Design & Manufacture*, **2008**, 108-109.
2. Liu, Y.Y., Zhao, P., Wang, Z. and Liu, K.C. (2008) Application of High-Speed Milling Technology in Die & Mold Manufacture. *Die &Mould Manufacture*, **2008**, 71-73.
3. Zhang, Z.P. and Zhang, Z.G. (2006) High-Speed Milling Process and Applied Instances for Die & Mold. *Die & Mould Manufacture*, **2006**, 75-79.
4. Zhou, L. and Lian, L.C. (2008) Application and Key Technologies of Die & Mould High Speed Milling. *Development & Innovation of Machinery & Electrical Products*, **21**, 170, 177-178.
5. Wu, Z.G. and He, Q.G. (2007) The Process of Using HSM in Plastic Bottle Manufacturing. *Mechanical Engineer*, **2007**, 115-116.
6. Zhao, X. (2007) Four-Axle Linkage NC Machining of Lamina Part Based on MasterCAM. *Die and Mould*

Technology, **2015**, 54-57.

7. Lu, H. (2015) NC Machining of Complex Die-Casting Die Based on MasterCAM. *Die & Mould Manufacture*, **2015**, 62-65.
8. Zhang, X.P. and Ma, C.L. (2015) CNC Machining of Phone Convex Model Based on MasterCAM. *Machine Building & Automation*, **2015**, 52-53.
9. Qian, C.H. and Qian, Y.L. (2010) NC Machining Technology of Flow Injection Mold Based on MasterCAM and UG. *Mechanical Engineer*, **2010**, 94-95.
10. Gao, Z.B. and Qin, Y.F. (2011) Research on Integrated Technique of Digital Design and Machining Simulation for Plastics Injection Mould. *Machine Tool & Hydraulics*, **39**, 121-124.