Research on 3D Complex Surface Construction and NC Machining Based on MasterCAM

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Abstract

Automation level of complex surface NC program is the key to the companies. As NC manufacturing technology moves forward rapidly, the NC program depending on CAD/CAM becomes more critical. MasterCAM is one of the most commonly used CAD/CAM softwares worldwide and has some comprehensive surface milling functions with a simplified, customizable interface, and abundant powerful, fast toolpath. Based on MasterCAM, the NC technology characters and CAD/CAM NC machining process are introduced. According to the basic surface frame, the construction methods of loft surface and coons surface are deeply studied by examples, the construction conditions of complex surfaces are researched, the construction skills in 3D complex surfaces are represented. A 3D craft model is built by MasterCAM, machining technology is planned, proper process methods, tool type, toolpaths and technology parameters are selected. The workpiece is well machined by NC method, and the NC code is automatically obtained at last. The machining process is correct by analyzing the computer simulation. Complex surface construction and NC program are deeply studied.

Keywords: Surface Construction, NC Machining, MasterCAM.

1. Introduction

For manufacturers to remain competitive in a world market, they must increase the automation level in NC program because the market competition depends on production speed, product quality, and innovative process concepts [1-2]. NC machining is one of the most important parts of CAD/CAM system. NC machining system has obvious advantages on shortening designing periods, reducing manufacturing time, especially in some die products with the characters of small batch, rapid diversification, complexity and accuracy [3-4]. Program efficiency can be obviously improved by CAD/CAM, and some NC machining codes of complex surface can be programmed. NC machining is popular to manufacturers. Figure 1 is the general NC process chart in the CAD/CAM systems [3].

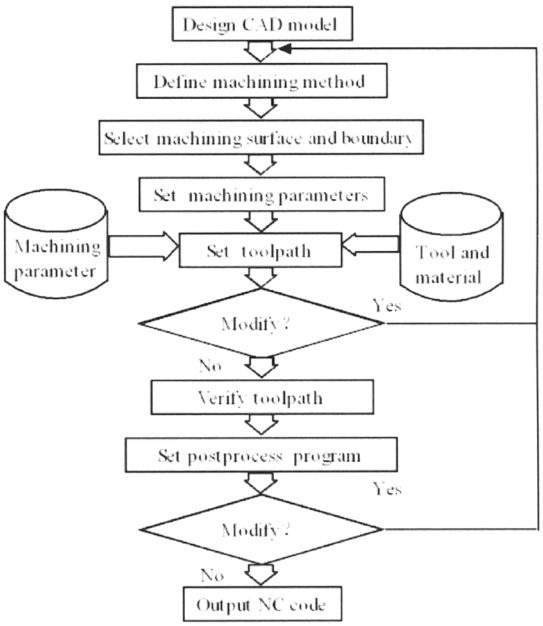

Figure 1. NC process chart in CAD/CAM

2. Loft surface construction

MasterCAM has many powerful functions on constructing complex surfaces. Loft surface is one of complex surfaces. It can be constructed by smoothly linking a serial of different sections by sequence. Figure 2-5 are a serial of loft surfaces based on frame by different methods. Figure a) is the basic frame, the number represents selected sequence of the closed curve chains, and the arrow represents curve chain direction. Figure b) shows the constructed surface.

In figure 2a), three closed curve chains are selected by sequence, and the start point and the curve direction are same. Figure 2b) is the constructed surface which links the frame smoothly.

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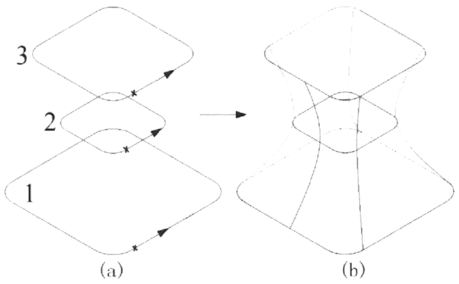


Figure 2. Loft surface

The start point position and the curve direction are important to construct the loft surface. Different start point position and curve direction will cause different surfaces.

(1) Different sections should keep "same start point" rule, a twisted surface will be constructed else.

Compared figure 2a) with figure 3a), the start point position of the third curve is changed, a twisted surface is obtained.

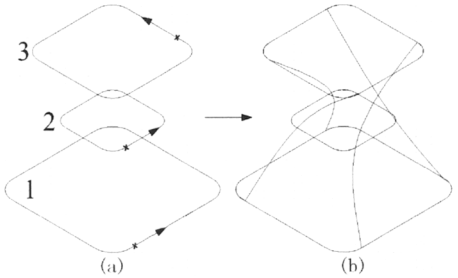


Figure 3. Different start point

(2) Different sections should keep "same curve direction" rule, a twisted surface will be constructed else.

Compared figure 2a) with figure 4a), the second curve direction is reversed, and then a twisted surface is built, especially in the middle.

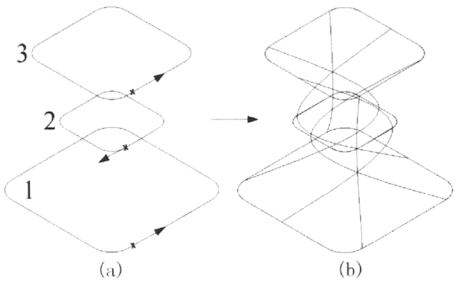


Figure 4. Different curve direction

(3) Surface shape is related with the selected section sequence.

Compared figure 2a) with figure 5a), the sequence of curve 2 with 3 is changed, the last constructed surface has an obvious concave character.

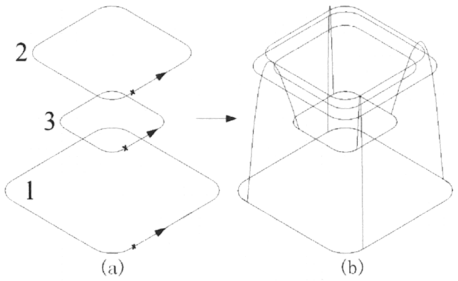


Figure 5. Different section sequence

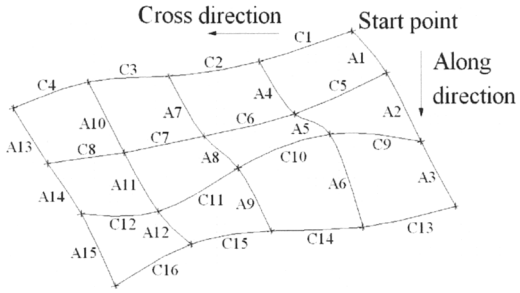
3. Coons surface construction

A coons surface can be constructed by four random space curves which are linked each other. A coons surface can also be constructed by three space curves, but the surface characters will be different according to the selected sequence of the boundary curves [5-7].

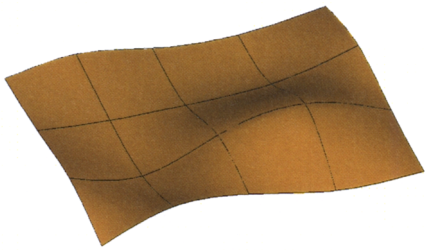
Many complex coons surfaces should be constructed by manual-link method. How to define the coons surface shape is a very complex process and requires skills.

3.1 Open boundary

In constructing coons surface, a random corner is defined as start point shown in figure 6a). If the vertical direction is defined as along direction, the horizontal direction is the cross direction else. The symbol "*A*" represents the along direction, and the symbol "*C*" represents the cross direction. Small surface number in the along direction is 3, and that in the cross direction is 4. In constructing whole coons surface, curves A1-A15 are selected firstly, and curves C1-C16 are selected later by sequence. The figure 6b) is the last coons surface.



(a) Frame geometry

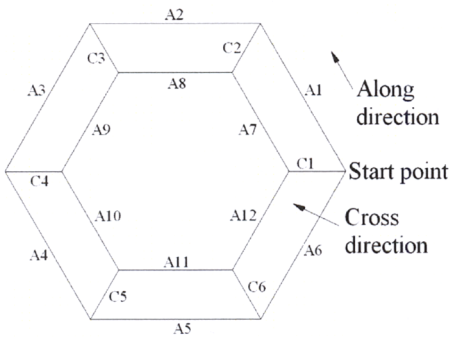


(b) Open boundary coons surface

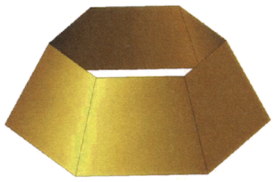
Figure 6. Open boundary

3.2 Closed boundary

Figure 7a) is a closed boundary geometry. A random point is defined as start point, and the along direction, the cross direction, the curve segments are labeled. Small surface number in the along direction is 6, that in the cross direction is 1. Curves A1-A12 are selected by sequence in defining along direction, and curves C1-C6 are selected later in defining across direction. Finally, the curve C1 should be selected again. Figure 7b) shows the last constructed coons surface.



(a) Frame geometry



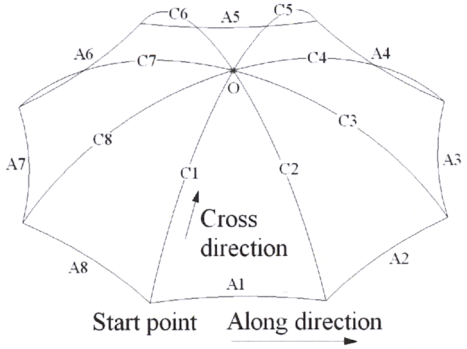
(b) Closed boundary coons surface

Figure 7. Closed boundary

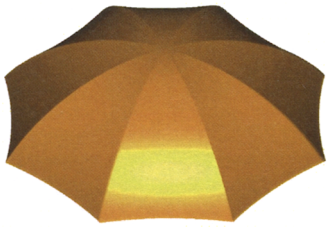
In defining the cross direction, the curve C1 must be selected again after selecting all curves C1-C6. This process is the obvious construction difference between closed boundary with open boundary coons surface.

3.3 Closed boundary with mixed point

Figure 8a) is a special coons surface, the top of the surface is a point "O". In constructing surface, the point "O" can be thought as a closed curve chain whose diameter is 0 mm, and another closed curve chain is A1-A8. The surface number in the along direction is 8, that in the cross direction is 1. In defining the geometry boundary in along direction, curves A1-A8 are selected by sequence. But in defining the boundary in cross direction, because the point "O" is thought as a mixed point, it is selected eight times. After selecting all curves C1-C8 in cross direction, the curve C1 should be selected again. Figure 8b) shows the constructed umbrella surface.



(a) Frame geometry



(b) Closed boundary coons surface with mixed point

Figure 8. Closed boundary with mixed point

In defining the along direction, the mixed point "O" is thought as a closed chain which is composed by eight curves, and it should be selected eight times; In defining the cross direction, after selecting all curves C1-C8, the unfolded curve C1 should be selected again. All above are the obvious construction difference between open boundary with mixed-point closed boundary.

4. Complex surface NC machining

After designing a 3D model, the manufactures should properly plan the whole NC machining process. Good technology should consider the geometric shape, the surface roughness, the precision, the rigid and the workpiece deformation [8-10].

Figure 9 is a craft model designed by MasterCAM. According to the geometric dimension, a 180×110×35 mm workpiece is selected, and it is manufactured by a vertical miller.

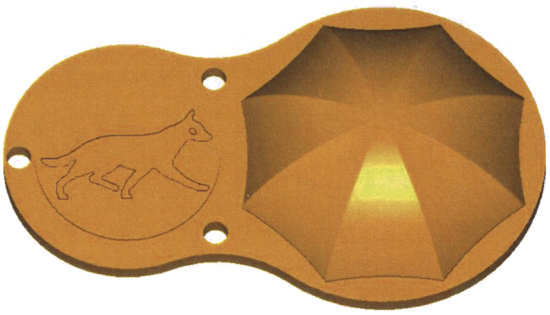


Figure 9. Craft model

4.1 Parallel roughing

Fast bulk material removal is essential to efficient NC programming. Select a Φ16 Endmill3 bull tool, and the "Surface parameters" dialog box is set as follows: Retract: 50 mm, Absolute; Feed plane: 5 mm, Incremental, Rapid retract; Tip comp: Tip; Stock to leave in "Drive surface/solid": 1 mm; Stock to leave in "Check surface/solid": 0 mm; Compensate in "Tool containment": Center.

The "Rough parallel parameters" dialog box is set as follows: Total tolerance: 0.025 mm; Cutting method: Zigzag; Max stepdown: 3 mm; Max. Stepover: 6 mm; Machining angle: 0°; Plunge control: Cut from both sides; Pick up "Allow positive Z motion along surface".

Figure 10 shows the result after the parallel roughing.

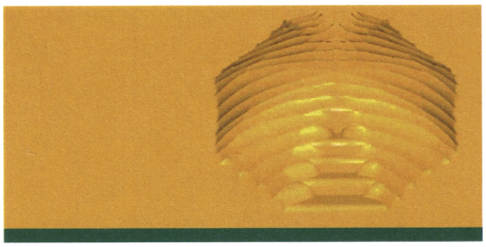


Figure 10. Result after parallel roughing

4.2 Contour semi-finishing

After roughing, semi-finishing is used to manufacture the model surfaces. Pick up Toolpaths-Surface-Finish-Contour-All-Surface, select a Φ8 endmill sphere tool, and the "Surface parameters" dialog box is set as follows: Retract: 50 mm, Absolute; Feed plane: 5 mm, Incremental, Rapid retract; Tip comp: Tip; Stock to leave in "Drive surface/solid": 0.2 mm; Stock to leave in "Check surface/solid": 0 mm; Compensate in "Tool containment": Center.

The "Finish Contour parameters" dialog box is set as follows: Total tolerance: 0.025 mm; Maximum stepdown: 1 mm; Direction of closes contours: Climb; Direction of open contours: One way; Translation: Broken.

Figure 11 shows the contour semi-finishing toolpath.

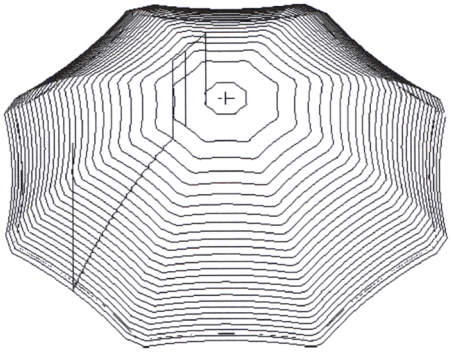


Figure 11. Toolpath in semi-finishing

4.3 Flowline finishing

Pick up Toolpaths-Surface-Finish-Flowline-All-Surfaces, select a Φ4 endmill sphere tool, and the "Surface parameters" dialog box is set as follows: Retract: 50 mm, Absolute; Feed plane: 5 mm, Incremental, Rapid retract; Tip comp: Tip; Stock to leave in "Drive surface/solid": 0 mm; Stock to leave in "Check surface/solid": 0 mm.

The "Finish flowline parameters" dialog box is set as follows: Total tolerance: 0.01mm; Scallop height in "Stepover control": 0.1; Cutting: One way.

Figure 12 shows the result after flowline finishing.

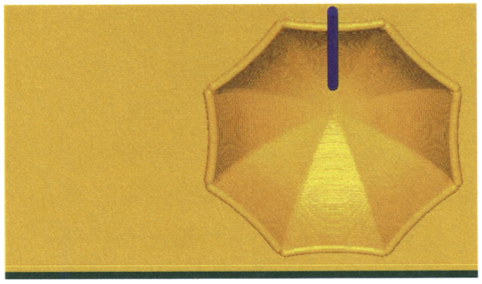


Figure 12. Flowline finishing

4.4 Pocket-finishing

Pick up Toolpaths-Pocket-Chain, select the closed chains and a Φ8 endmill flat tool, the "Pocketing parameters" dialog box is set as follows: Retract: 50 mm, Absolute; Feed plane: 10 mm, Incremental, Rapid retract; Top of stock: 30 mm, Absolute; Depth:-1 mm, Absolute; Machining direction: Climb; Tip comp: Tip; Roll cutter around: None; XY stock to leave: 0 mm, Z stock to: 0 mm. Pocket type: Facing.

The "Roughing/Finishing parameters" dialog box is set as follows: Stepover: 75%; Stepover distance: 6 mm; Passes: 1, Spacing: 0.25, Spring: 0, Cutter compensation: computer in "Finish" box; Select "Morph

Spiral" in "Rough"; Pick up "Spiral inside to out" and "Finish outer boundary".

Figure 13 is the pocket-finishing toolpath.

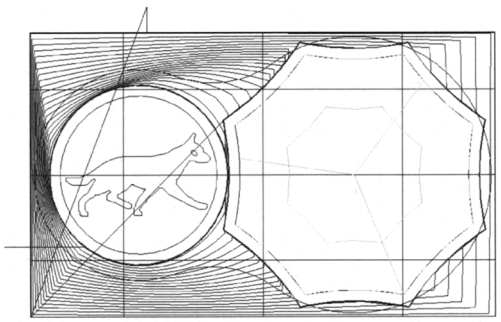


Figure 13. Toolpath in pocket-finishing

4.5 Pocketing

Pick up Toolpaths-Pocket-Windows, select the closed dog chains and a Φ2 endmill flat tool. The "Pocketing parameters" dialog box is set as follows: Retract: 50 mm, Absolute; Feed plane: 10 mm, Incremental, Rapid retract; Top of stock: 30 mm, Absolute; Depth:-0.5 mm, Absolute; Machining direction: Climb; Tip comp: Tip; Roll cutter around: None; Linearization tolerance: 0.001; XY stock to leave: 0 mm, Z stock to: 0 mm; Pocket type: Standard.

The "Roughing/Finishing parameters" dialog box is set as follows: Stepover: 75%; Stepover distance: 1.5 mm; Passes: 1, Spacing: 0.25, Spring: 0, Cutter compensation: computer in "Finish" box; Select "Morph Spiral" in "Rough"; Pick up "Spiral inside to out" and "Finish outer boundary".

Figure 14 is the toolpath in pocket-finishing the dog.

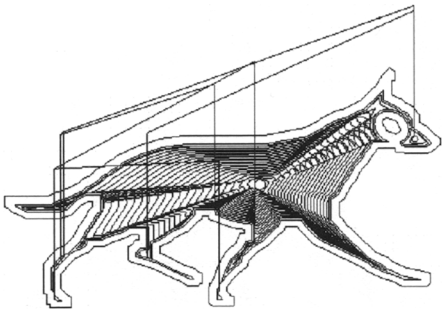


Figure 14. Toolpath in pocket-finishing dog

4.6 Drill and 2D contour machining

Pick up Toolpaths-Drill-Manual, select the Φ8 center drill tool, the "Simple drill-no peck" dialog box is set as follows: Retract: 10 mm, Absolute; Top of stock: 30mm, Absolute; Depth: -17mm, Absolute.

Pick up Toolpaths-Contour-Chain, select a closed chains and a Φ10 endmill flat tool, and "Contour parameters" dialog box is set as follows: Retract: 50 mm, Absolute; Feed plane: 10 mm, Incremental, Rapid retract; Top of stock: 30 mm, Absolute; Depth:-7 mm, Absolute; Compensation type: Computer; Compensation direction: Right; Tip comp: Tip; Roll cutter around: All; XY stock to leave: 0 mm, Z stock to: 0 mm. Contour: 2D. The parameters in "Depth cuts" dialog box is set as follows: Max rough step: 5.0 mm; # Finish cuts: 1; Finish step: 0.1 mm; Depth cut order: By contour.

Figure 15 shows the machining process simulation. The final NC codes of the craft model are as follows:

```
%
O0000
N100G21
N102G0G17G40G49G80G90
N104T1M6
N106G0G90G54X-89.Y-54.A0.S1432M3
N108G43H1Z50.
N110Z35.093
N112G1Z27.093F6.7
N114X89.F429.6
N116G0Z32.093
N118Z50.
N120X-89.Y-48.
N122Z35.093
N124G1Z27.093F6.7
N126X89.F429.6
N128G0Z32.093
N130Z50.
N132X-89.Y-42.
N134Z35.093
N136G1Z27.093F6.7
N138X89.F429.6
N140G0Z32.093
N142Z50.
N144X-89.Y-36.
N146Z35.093
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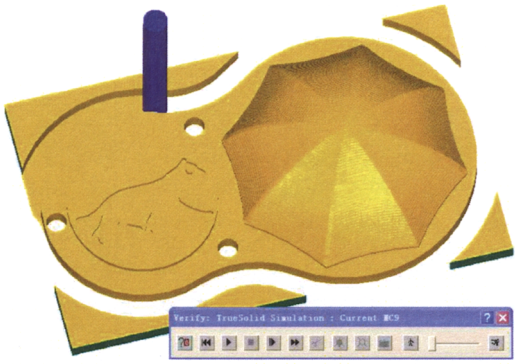

Figure 15. Milling simulation

5. Conclusion

(1) The construction of loft surface should obey "same start point, same direction" rule, else a twisted surface will be built. The constructed loft surface shape is related with the selected section sequence.

(2) In constructing coons surface, curve selection method in along and cross direction has obvious influence on the surface shape.

(3) MasterCAM has comprehensive surface milling functions with a simplified, customizable interface, and abundant powerful, fast toolpaths. It has obvious advantages on shortening designing periods, reducing manufacturing time.

Acknowledgement

The project is supported by Doctor Foundation of Guangdong University of Technology (053049).

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