Development of 3D CAM system for End mills manufacturing

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ABSTRACT

The development of 3D CAM system for the manufacturing of end mills becomes a key approach to save the time and reduce cost for end mills manufacturing. This paper presents the calculation and simulation of end mill tools CNC machining bases on 5-axes CNC grinding machine tool. In this study describes the process of generation and simulation of grinding point data between the tool and the grinding wheels through the machined time. Depend on input data of end mill geometry, wheels geometry, wheel setting, machine setting the end mill configuration and NC code for machining will be generated and visualized in 3 dimension before machining. The 3D visualizations of end mill manufacturing was generated by using OpenGL in C++. The development software was designed by using Microsoft Visual C++, which has many advantages for users, saving time and reducing manufacturing cost.

Key Words: End mill, CNC grinding machine, helical flute.

1. Introduction

The flat end mills are commonly used in industry for high speed machining. They are characterized by a complex geometry with many geometry parameters, which deals with some complicated processes in machining with grinding CNC machine. Predicting the end mill geometry before manufacturing and generating NC code for machining in CNC grinding machines are necessary to save time, reducing manufacturing cost. Therefore end mills manufacturing have become important research subjects. Ko developed a software for determining grinding wheel geometry and setting condition in end mill manufacturing which predicted the results of helical flute grinding and the configuration of cutting edge [1], Dani Tost et al. presented an approach for the computation of the external shape of the drills through a sequence of coordinated movements of the tool and the wheels on machines of up to 6-axes. The proposed method reduces the 3D problem to 2D dynamic boolean operations followed by a surface tiling [5, 6]. They provided a machining simulation for 6-axes CNC machines using OpenGL for visualization. However they only have shown the fluting and gashing simulations. In the previous studies Sung-Lim Ko and Yong-Hyun Kim presented Development of design and manufacturing technology for end mills in machining hardened steel [2], However the development of system was limited in 2D cross sections of the tools and the results of simulation were restricted to the main fluting operation. They already provided a machining simulation for specific 5-axes machines in 2D. Their simulation algorithm for the helical groove machining is used to develop 3D Simulation CAM system. This paper presents the process of generation and simulation of grinding point data between tool and grinding wheels for all grinding processes in 3D. The program was developed for prediction of configuration of end mills. OpenGL was used to develop end mills grinding CAM system with C++. The simulator does not use any commercial package. The NC code of all processes for end mill manufacturing will be generate automatically in the program and saved in NC code files. These NC code files will be used for machining in CNC grinding machines.

2. Development of 3D CAM system for end mill manufacturing.

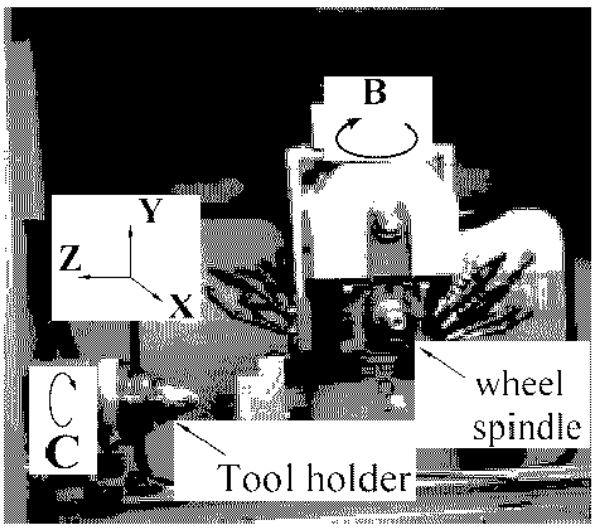

Fig 1 5-axis CNC Grinding machine.

There are difference types of CNC grinding machine tools for end mill manufacturing. In this study, the end mill is machined on CNC grinding machine tool, which has 5 degrees of freedom: three axes in translation (X, Y, Z) and two in rotation (B, C) as shown in Fig.2. Tool is fixed at tool holder, which has two degrees of freedom, rotation (C) and translation (Z). The grinding wheels are arranged at the wheel spindle, which has 3 degrees of freedom two translations (X, Y) and rotation (B).
There are four main machining operations for end mill manufacturing: Fluting, 1st Clearance and 2nd Clearance operations, Gashing, 1st endteeth and 2nd end teeth operations.

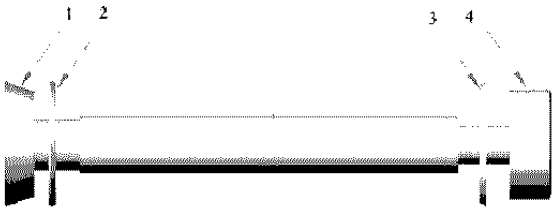

Fig 2 grinding wheels for end mill manufacturing

Four kinds of grinding wheel are used. The figure 2 shows arrangement of grinding wheels for end mill manufacturing. Wheel number 2 and 3 are used for fluting and gashing operations respectively. Wheel number 4 is used for 1st and 2nd clearance operations. The 1st and 2nd end teeth are formed by using wheel number 1. Machining parameters including the machine setting parameter, end mill geometric parameter, wheel setting and wheel geometry must be measured and imported into the program in advance. In each process the end mill geometry will be formed during the relative movement combination between grinding wheel and tool.

2.1 End mill geometry design

End mills are used for machining precision shapes and holes. Therefore end mill geometry design is considered as the most important step. In end mills manufacturing, there are many design factors. The figure 3 shows the design factors for end mills. Diameter (D), Inscribed circle diameter (D_W), Rake angle (γ), Clearance angles (η), helix angle (β), gashing angle (gA), end teeth angles (ε)...
Rake and clearance angles are the most important among the design factors. Rake angle in particular affects stiffness of the cutting edge and rigidity of the tool. An end mill with a positive rake angle improves machining ability, thereby producing lower cutting force and cutting temperature. In general, the positive rake angle is applied to the conventional end mill, In case of a negative rake angle, the stiffness of the cutting edge is increased and chipping suppressed [2].
However, it is not easy to define and determine these parameters because of the curved shape of the helical flute. In this research, rake and clearance angles were defined as the tangential angle at the edge.

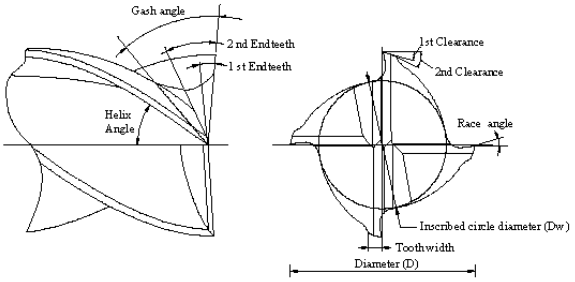

Fig 3 end mill geometry design

The measurement method and influence of the clearance angle on cutting force and surface error in high speed machining was discussed in previous work [2].

2.2 Basic algorithm for the helical flute grinding.

The simulation algorithm for the helical groove machining in this study was based on the assumption that a wheel with finite thickness consists of a finite number of thin disks. The profile of the groove can be calculated uniquely and exactly if an exact wheel profile is used as an input [1,2].

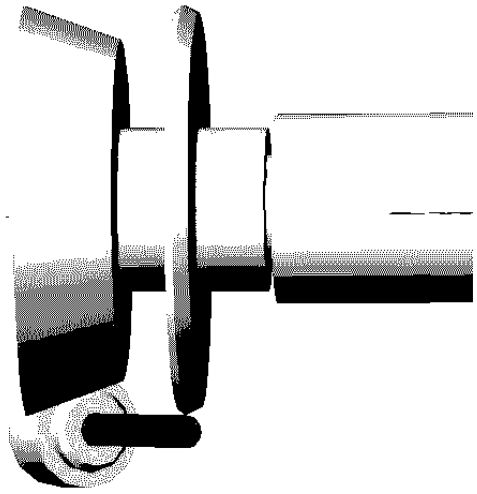

Fig4 the schematic of fluting operation.

The figure 4 shows the initial position setting for flute machining. During the flute operation, the tool is first rotated and next translated along its axis (C, Z). These two movements are not independent.
The end mill configuration is formed by relative movement between wheel and workpiece. The rake face is also formed in this process.

2.3 Simulation for the helical flute grinding.

The end mill shapes are performed by surface modeling using triangles and quads. The visualization implied for construction of end mill shapes depends on the boundary of the model. The figure 5 shows cross session of helical flute in 3D, the end mill configuration of flute face also generated by using triangles and quads between contours.

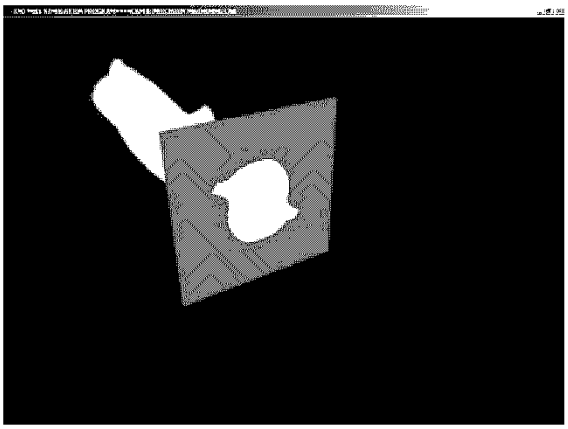

Fig5 cross session of helical flute.

The visualization of end mill shapes implies the construction of the boundary of the surface. It also requires the information on the geometry and the lighting properties of the tool material along with the eventual colors associated to the different operations. Each surface is displayed in different colors.

The comparison of measurement and simulation results in cross session of end mill was presented in previous work [2].

2.4. Simulation results.

The figure (6a) and figure (6b) show input windows for end mill design parameters and grinding wheel geometry parameters

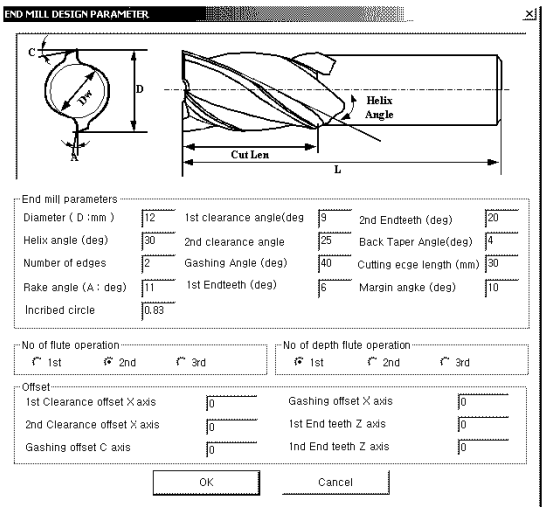

Fig (6a) Input window data for end mill design parameters

Using the input data for end mill geometry and wheel geometry, the computer program will generate the grinding points for clearance faces, endteeth faces, gash face, the intersection between each surface must be generated. The figure 7 shows the simulation of end mill shapes. The visualization of these faces implies the construction of the boundary of the surfaces.

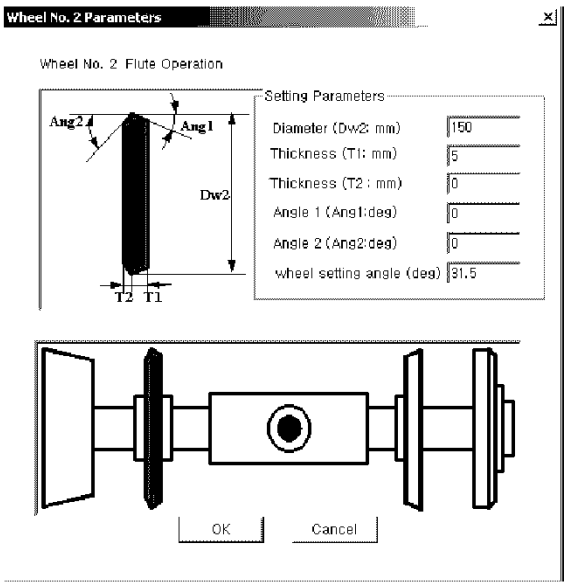

Fig 6b grinding wheel geometry parameter.

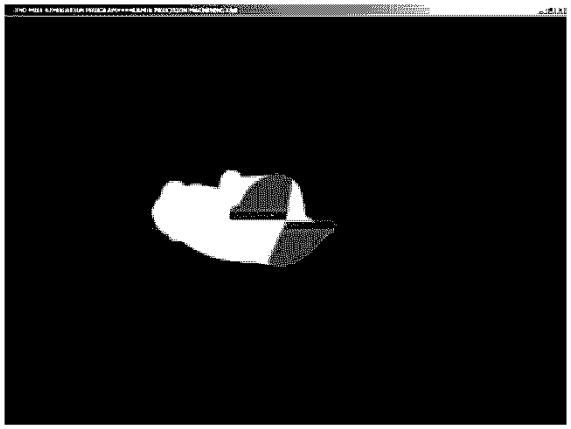

Fig 7 end mill simulation result

The OpenGL graphics system allows creating interactive programs that produce color images of moving three dimension objects. The visualization of end mill relates to lighting conditions surrounding an object, blending, antialiasing, texture mapping, shading, ... In addition, OpenGL related utilities, toolkits, programming and debugging support, widgets, sample, programs and demos available to system are also related. OpenGL was used to exploit the possibilities of The projective Z-Buffer and shading techniques it offer and optimize the visualization delay for whole process.

2.5 Generation of NC codes for end mill machining in CNC grinder machine.

The NC codes for the 5-axis grinding CNC machine are generated, which include position data of each axes (X, Y, Z, B, C). Each machining process is carried out by rotation and translation of the axis of wheel and tool. The initial and final position of all processes was calculated during simulation.

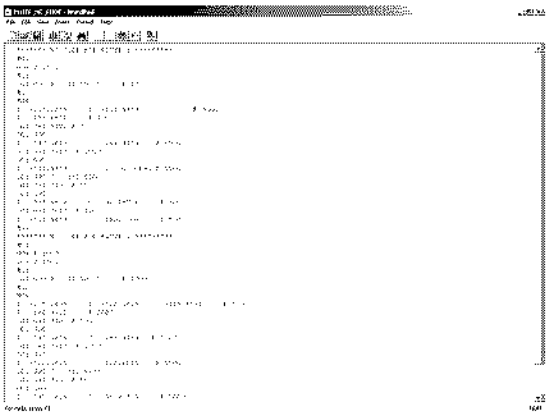

Fig 8 Generation of NC codes for end mill manufacturing.

The figure 8 shows NC code file of flute operation. The NC codes for all processes of end mill manufacturing were generated from the computer program base on machine coordinate and stored in the separate NC code files. These NC code files display the position of the machine axes, the position relative to machining, as well as the rotation speed of the grinding wheel and progress of the machine work.

3. Conclusion.

The paper presents the development of 3D CAM system for End mills manufacturing. The simulating program was developed:

1. The 3D CAM system for end mill manufacturing was developed and applied to design and manufacture end mill for predicting the end mill configuration before machining.
2. The NC codes were generated from the 3D CAM systems used for end mill machining in 5-axis CNC grinding machine.
3. Development of 3D CAM system will be applied for general case of end mills used in industry.

Acknowledgements

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