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Simulation of VERICUT-based Generating Grinding of Involute Beveloid Gears

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Abstract: Based on the principle of generating grinding, VERICUT is used for generating grinding of involute beveloid gears. Firstly, the tooth surface equation of the involute beveloid gears is derived according to the principle of involute beveloid gears forming and gear meshing theory, and the theoretical model of the involute beveloid gear is established; secondly, the CNC conical gear grinding machine model, grinding wheel tool model and tooth blank are built in UG and imported into VERICUT, and the CNC machining program of the generating grinding is written to carry out the generating grinding simulation; finally, the simulated involute beveloid gear is automatically compared with the design model to verify the accuracy of the generating grinding simulation machining method. This study provides theoretical guidance for the practical machining of involute beveloid gears, reduces costs and shortens machining cycles, thus improving the productivity of involute beveloid gears.

Keywords: Involute beveloid gears, VERICUT, Developing grinding, Machining simulation.

1. Introduction

Involute beveloid gears are a special form of involute gears, which are similar to bevel gears with a certain bevel angle, so they can realize various forms of transmission such as parallel shaft, staggered shaft and staggered shaft, etc. The involute beveloid gears sub-drive also has the advantages of high transmission accuracy, compact structure, and applicability to high-speed transmission fields [1-7]. At this stage, grinding is a way of involute gear processing with high accuracy, but there are many inconveniences in grinding involute beveloid gears by using traditional conical wheel grinding machine. Due to the helix angle of the gear, the left and right tooth surfaces must be re-clamped and grinding must be completed in two times, which will affect the accuracy of the machining of involute beveloid gears [8]. Therefore, the structure of the gear grinding machine must be improved, and the CNC simulation machining technology can check the accuracy of the CNC program and the reasonableness of the machining process before the actual machining [9].

In this paper, we first design the involute beveloid gears model, build an improved CNC conical grinding machine model, then use VERICUT to perform CNC generating grinding on the involute beveloid gears, and finally compare the involute beveloid gears model obtained by generating grinding with the design model automatically to verify the accuracy of the grinding process.

2. Principle of Involute Beveloid Gears Generating Grinding Process and Tooth Surface Equation

2.1. Principle of involute beveloid gears generating grinding process

During the grinding process, the conical grinding wheel is equivalent to the rack tool, and the conical grinding wheel tool moves in accordance with the machining trajectory of the rack tool, as shown in Figure 1. The principle of involute beveloid gears generating grinding is that the grinding wheel tool knuckle plane is tangent to the gear indexing cylinder for pure rolling, i.e. to ensure that the tooth profile of the grinding wheel envelops the tooth profile of the involute beveloid gears.

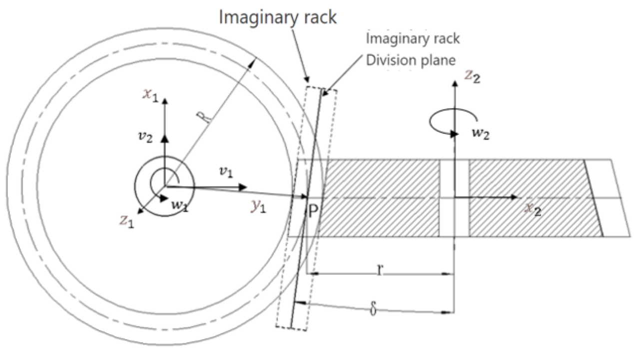


Figure 1. Schematic diagram of grinding process movement

During the involute beveloid gears generating grinding process, the grinding wheel tool and the tooth blank have 5 motions, as shown in Figure 2.

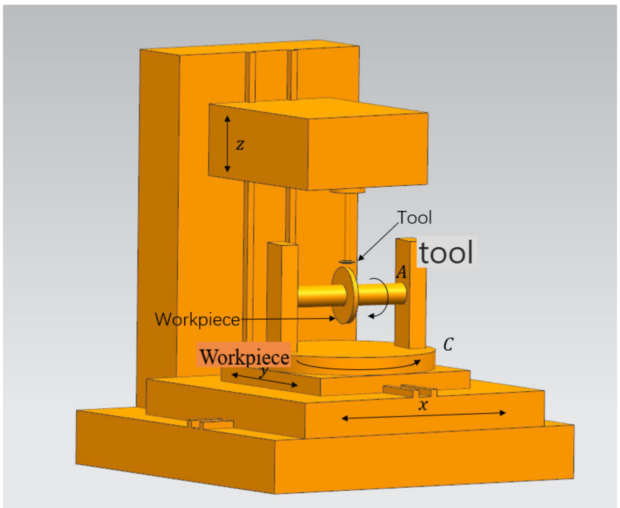


Figure 2. Structure diagram of CNC conical grinding machine

(1) In the main motion of grinding process, the grinding wheel tool makes a reciprocating cutting motion along the y-axis direction;
(2) The grinder makes axial feeding motion along the tooth blank, i.e., linear motion along the z-axis;
(3) The grinder makes radial feeding motion, i.e., linear motion along the x-axis;
(4) The tooth blank does dividing motion, i.e., rotary motion of the tooth blank around the A-axis;
(5) Fulfillment of the pitch angle requirement, i.e. the table drives the tooth blank to rotate around the C-axis.

The linear motion axes x, y and z are coupled with the rotary motion axis A to ensure the involute beveloid gear tooth profile envelope requirements.

2.2. The tooth surface equation of the involute beveloid gears

The tooth shape of the rack tool can envelop the tooth shape of the involute beveloid gears, where AB section is the crest straight section of the rack, corresponding to the envelope of the involute beveloid gears tooth root; CD section is the slant section of the rack, corresponding to the envelope of the involute beveloid gear involute tooth surface part; BC section is the crest arc section of the rack, corresponding to the envelope of the involute beveloid gear tooth root transition circle, the tooth shape of the rack tool is shown in Figure 3.

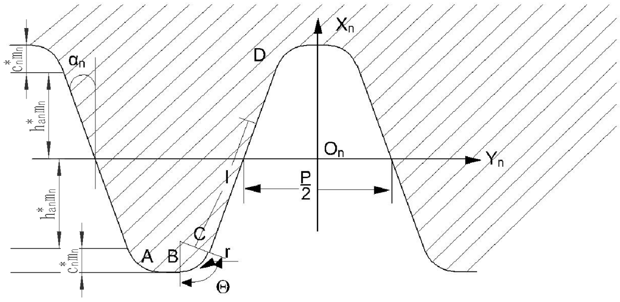


Figure 3. Normal section tooth shape of rack tool

The surface equation of the CD section in the s_n coordinate system is

$$f_n^1(l)=\begin{bmatrix} -h_{am}^* m_n + l\cos\alpha_n \\ \pm(\frac{p}{4}+h_{am}^* m_n \tan\alpha_n - l\sin\alpha_n) \\ 0 \\ 1 \end{bmatrix} \tag{1}$$

Where l is the distance from any point on the linear section to point C, p is a parametric variable; h_{am}^* is the crest height coefficient; α_n is the normal pressure angle; m_n is the normal modulus.

Similarly, the surface equation of the BC section in the s_n coordinate system can be obtained as

$$f_n^1(\theta)=\begin{bmatrix} -(h_{am}^*+c_m^*)m_n + r(1-\cos\theta) \\ \pm(\frac{p}{4}+h_{am}^* m_n \tan\alpha_n + r\cos\alpha_n - r\sin\theta) \\ 0 \\ 1 \end{bmatrix} \tag{2}$$

Where θ is the root transition angle, which is also a parameter variable; c_m^* is the root height factor; r is the root transition radius, whose value is $r=\dfrac{c_m^* m_n}{1-\sin\alpha_n}$

During the engagement of the involute beveloid gears and the rack tool, the positions of the involute beveloid gears and the rack tool are shown in Figure 4.

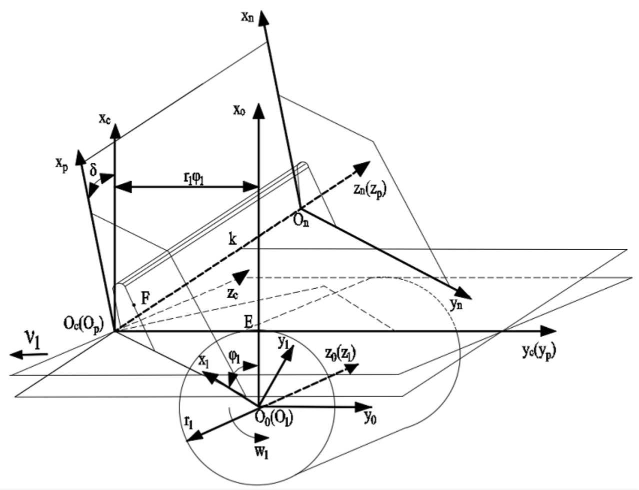


Figure 4. Relative position relationship of rack and pinion

Based on the spatial coordinate transformation theory and gear engagement theory, the tooth surface equation of the involute beveloid gears can be derived as [10]:

$$f_1^1=\begin{bmatrix} r_1(\cos\varphi_1+\varphi_1\sin\varphi_1) - y_c^1\sin\varphi_1 + x_c^1\cos\varphi_1 \\ r_1(\sin\varphi_1-\varphi_1\cos\varphi_1) + y_c^1\cos\varphi_1 + x_c^1\sin\varphi_1 \\ z_c^1 \\ 1 \end{bmatrix} \tag{3}$$

According to the tooth surface equation of the involute beveloid gears, the point cloud of the tooth surface is calculated by using MATLAB programming and imported into UG 3D software to design the involute beveloid gears 3D design model, as shown in Figure 5.

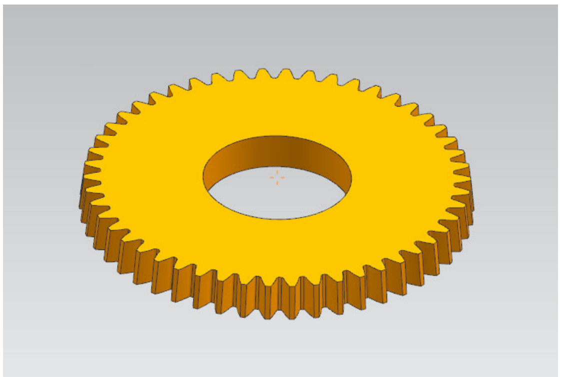


Figure 5. The involute beveloid gears 3D design model

3. Simulation of Generating Grinding of Involute Beveloid Gears

In the paper, firstly, the CNC conical gear grinding machine model is built in VERICUT, followed by the completion of the settings of system parameters, grinding wheel tool, blank and design model, etc. and finally, the G code of generating grinding is imported to simulate the generating grinding process for the involute beveloid gears. The workpiece parameters of the involute beveloid gears are shown in Table 1.

Table 1. Basic parameters of the involute beveloid gears

parameters	Parameter Values
Modulus (m/mm)	3
Number of tooth (z)	50
pitch angle (ρ/°)	6
Tooth width (mm)	15

3.1. Design of grinding wheels and tooth blanks

The grinding profile is designed as a rack tool tooth shape, imported into VERUCUT and set the relevant parameters to generate a grinding wheel tool with a shank, as shown in Figure 6.

The involute beveloid gears tooth blank is theoretically an involute beveloid gears crest curve envelope out of the circular table, using three-dimensional software to design the involute beveloid gears tooth blank, and save as ".stl" format into VERICUT, as shown in Figure 7.

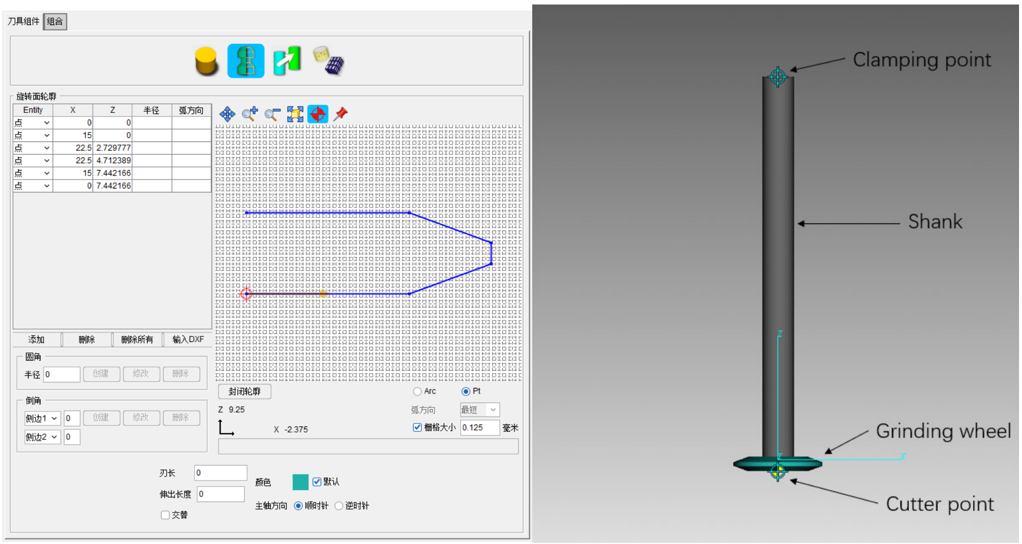


Figure 6. Grinding wheel tool model

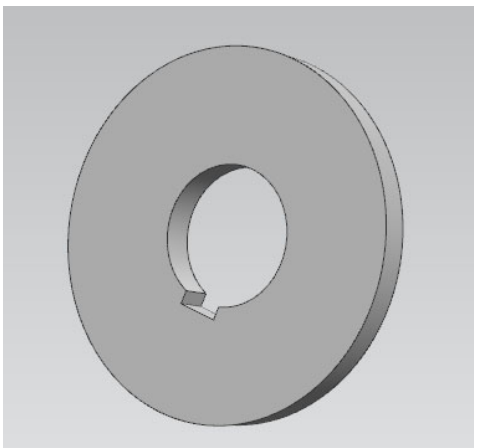


Figure 7. Involute beveloid gears blank model

3.2. The CNC conical gear grinding machine model

According to the above analysis of the motion of the involute beveloid gears generating grinding process and the structure of CNC conical grinding wheel grinding machine, design the 3D model of CNC conical gear grinding machine in UG software, save the parts as ".stl" files, import the parts of the grinding machine in order according to the subordination of the parts in the project tree in VERICUT, and add tools, design models, blanks, etc. to complete the model of CNC conical gear grinding machine. The completed project tree and CNC conical gear grinding machine model are shown in Figure 8.

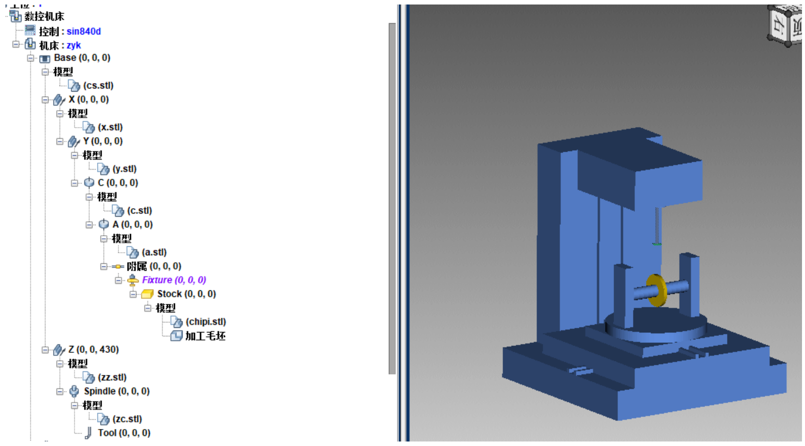
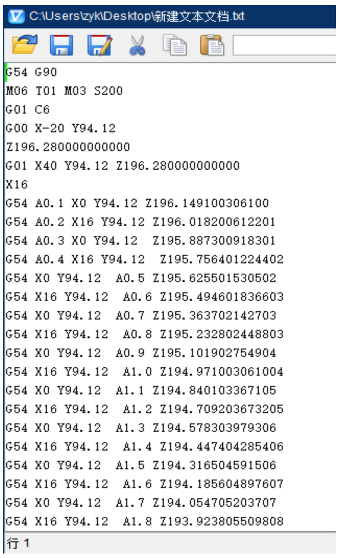


Figure 8. The CNC conical gear grinding machine project tree and model

3.3. Writing of NC program

VERICUT offers multi-brand systems. In this paper, the sin840d (Siemens) system is selected as the control system for the CNC conical gear grinding machine. Based on the machining strategy of machining involute beveloid gears with a standard rack tool, the position coordinates of each motion axis during the generating grinding process are calculated by MATLAB programming with a completed tooth slot as the index, and the angle turned by the tooth blank and the radial depth of cut as variables, so as to complete the machining G-code. Part of the G-code is shown in Figure 9.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G54 G90
M06 T01 M03 S200
G01 C6
G00 X-20 Y94.12
Z196.280000000000
G01 X40 Y94.12 Z196.280000000000
X16
G54 A0.1 X0 Y94.12 Z196.149100306100
G54 A0.2 X16 Y94.12 Z196.018200612201
G54 A0.3 X0 Y94.12  Z195.887300918301
G54 A0.4 X16 Y94.12  Z195.756401224402
G54 X0 Y94.12  A0.5 Z195.625501530502
G54 X16 Y94.12  A0.6 Z195.494601836603
G54 X0 Y94.12  A0.7 Z195.363702142703
G54 X16 Y94.12  A0.8 Z195.232802448803
G54 X0 Y94.12  A0.9 Z195.101902754904
G54 X16 Y94.12  A1.0 Z194.971003061004
G54 X0 Y94.12  A1.1 Z194.840103367105
G54 X16 Y94.12  A1.2 Z194.709203673205
G54 X0 Y94.12  A1.3 Z194.578303979306
G54 X16 Y94.12  A1.4 Z194.447404285406
G54 X0 Y94.12  A1.5 Z194.316504591506
G54 X16 Y94.12  A1.6 Z194.185604897607
G54 X0 Y94.12  A1.7 Z194.054705203707
G54 X16 Y94.12  A1.8 Z193.923805509808
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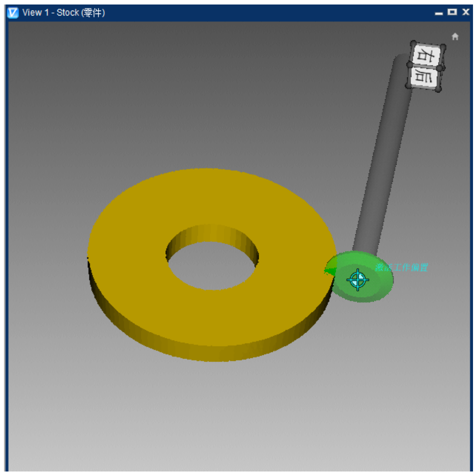
行 1

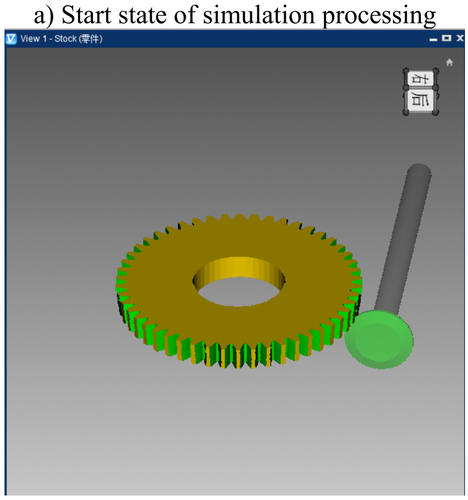
Figure 9. Part of the G-code

3.4. Simulated machining of generating grinding

The machine control and control system parameters were configured in turn, the G-code for grinding processing was imported, and the CNC program was reviewed and checked for syntax, and then the involute variable beveloid gears was simulated and processed as shown in Figure 10.



a) Start state of simulation processing



b) End state of simulation processing

Figure 10. Involute beveloid gears during simulation

As can be seen in the above figure, there are no errors in the simulation process, such as the machine's motion axis exceeds the travel, the machine components collide and interfere with each other.

The involute beveloid gears design model above is transferred back to the ".stl" file and imported into VERICUT as the automatic comparison reference, using the software's own "automatic comparison" function to verify the machining results, with different colors to show the machining results of overcut and residual, and display the error report of the comparison results, as shown in Figure 11.

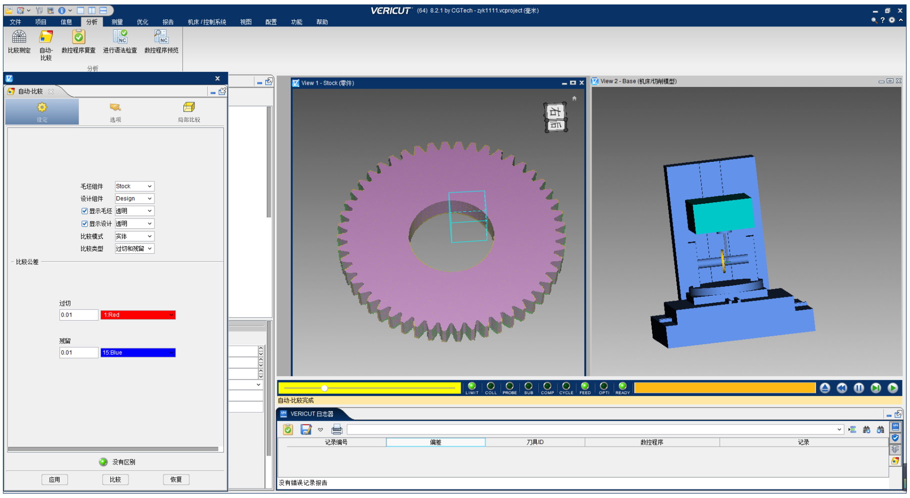


Figure 11. Results of automatic comparison

This paper reports no errors after automatic comparative analysis, which proves that the involute beveloid gears model obtained from simulation machining matches its theoretical model and the machining results are correct.

4. Conclusion

A CNC conical gear grinding machine model was established and VERICUT was used to perform a generating grinding simulation for involute beveloid gears. The simulation results are consistent with the design model, which verifies the accuracy of the proposed involute variable beveloid gears generating grinding simulation machining method. This method can realistically and accurately simulate the spreading grinding process of involute beveloid gears, shorten the cycle time from design to machining, improve the production efficiency of involute beveloid gears, and provide a theoretical basis for the actual generating grinding process of subsequent involute beveloid gears.

References

[1] Pu Lianggui. Mechanical design (7th edition) [M]. Higher Education Press, 1960.

[2] Sapunjang. Design of high speed gear transmission [M]. Machinery Industry Press, 1986.

[3] Senba Masasho. Gear Shifting [M]. Shanghai Science and Technology Press, 1984.

[4] Shen Yichun. Computer-aided design and dynamic simulation of intersecting shaft thickened gears [D]. Harbin Institute of Technology, 2002.

[5] Liu Y. Study of intersecting shaft thickened gears with line contact [D]. Harbin Institute of Technology.

[6] Wen Jianmin. Research on non-involute spatially thickened gear transmission [D]. Harbin Institute of Technology, 2004.

[7] Zhao H, Wu QL, Huang K, Qiu MM, Liu P. Current status and problems of domestic gear research[J]. Journal of Mechanical Engineering,2013,49(19):11-20.

[8] Liu YP, Wu XT, Li HQ. Study on grinding of involute beveloid gears with Conical Wheel Gear Grinding Machine [J]. Journal of Agricultural Machinery, 2006(06): 117-120.

[9] Zhang J, Wang L, Ma LX. Research status of CNC machining simulation system[J]. Machine Tool Electrical,2006(04):5-7.

[10] Huang Jinli. Research on the machining method of spatially thickened gears [D]. Harbin: Harbin Institute of Technology, 2014.