ISSN : 0974 - 7435 Volume 10 Issue 23

2014

BioTechnology

An Indian Journal

FULL PAPER

BTAIJ, 10(23), 2014 [14789-14794]

Research on the simulation processing of the rake face of the ball end mill

Lishuai
College of Mechanical &Electrical Engineering, Zaozhuang UniversityShandong province, 277160, (CHINA)

ABSTRACT

The ball end mill, as an important tool to process the complex three-dimensional curved surface, is helpful to achieve high efficiency and high precision machining when was used with nc machine tool, which is highly demanded in the manufacturing factory. This paper further analyze the processing theory and method of the ball end mill, and establishes a grinding simulation system of the rake face on the Solid Works platform based on Visual Basic as the secondary development tool; verifies the validity of the theory though analyzing the simulation results and provides a basis for optimizing the grinding parameters in the practical processing process.

KEYWORDS

Ball end mill; Cutter grinding simulation; Rake angle; Visual basic; Rake face.

INTRODUCTION

The development of numerical control machine tool and mold industry raisesa higher requirement for the performance and reliabilityof the ball end mill. Cutter grinding is critical in the manufacturing processof the ball end mill, whose spiral groove was formed by high-rate grinding of the grinding wheel, butthat was processed by multi-axis linkage grinding machinewith more adjust parameters, more complex operation and higher cost in our country. Therefore, it's significant for the manufacturer and users of the ball end mill to further optimize the grinding parameters in the manufacture process through the analysis of the mathematical model of the ball end mill.

GRINDINGMOVEMENT OF THE RAKEFACE OF THE BALLBLADE

To implement the cutter grinding of the ball end mill, grinding wheel and the ball end mill have to realize translational movement towardthree directions,X, Y, Z, and rotate around the axis of the ball end mill. $\sigma = [O; X, Y, Z]$ 、 $\sigma_0 = [O_0; X_0, Y_0, Z_0]$ 、 $\sigma_S = [O_S; X_S, Y_S, Z_S]$ respectively indicate the coordinate systemofthe ball end mill, machine tool and grinding wheel. For aconvenientcalculation, we assume that the initial position of the coordinate system of machine tool $\sigma_0 = [O_0; X_0, Y_0, Z_0]$ is overlapped with that of workpiece, $\sigma = [O; X, Y, Z]$ and the coordinateoriginis in the position O, the center of the ball head. The posture of grinding wheel and the spatial relationship of the ball end mill in the grinding process of the rake face of the ball end mill are shown in Figure 1.

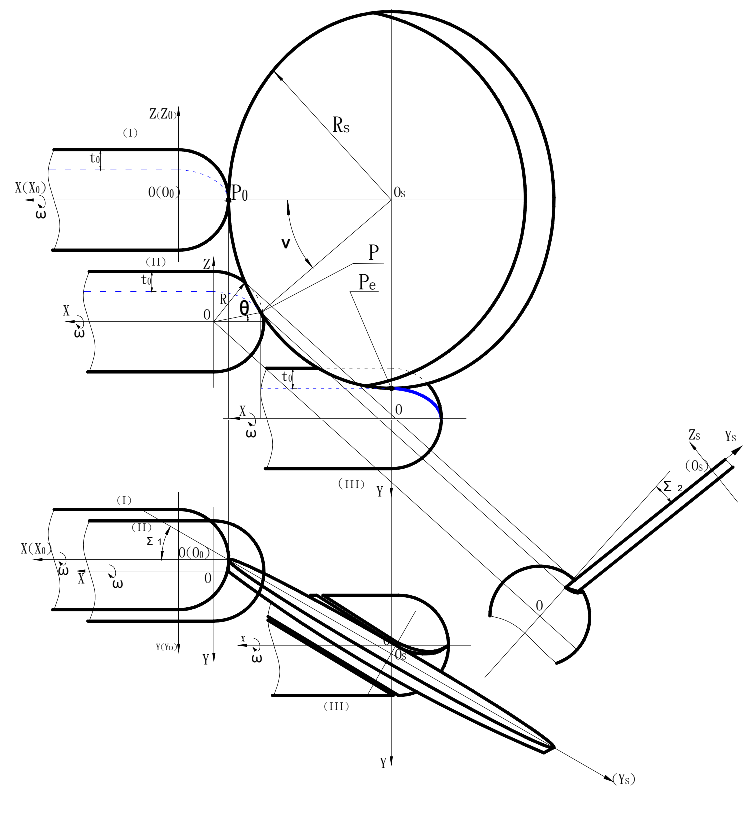


Figure 1 : Theprocessing and motion relationship of the rake face of theball end mill[1]

BBe, as the bottom curve of the rake face of the ball end mill, is always tangentwithPoPPe, the large-endcircumference of the grinding wheelin the manufacturingprocess, forming the spiral groove of the rake face. In the grinding process of the rake face, the large-endcircumference of the grinding wheel is tangent with point B on the bottom curve first, then Pe, the lowest point on the grinding wheelis tangent with Be, the end of the bottom curve. In order to avoid the interference and over-tangency between the grinding wheel and the spiral groove of the ball end mill, installation Angle Σ 1 should be 2 °larger than the spiral Angle, and takingspiral Angle as β, so Σβ+ 1 = 2 °. The circumference surface of the grinding wheel rotates around the horizontal axis of large circle Σ 2 angles is beneficial to make this grinding method more general and common in usage.

The equation ofthe tangent point P betweenPoPPe, the main aspect circumferenceand BBe, the bottom curve of the ball end mill is:

$$\begin{cases} \dfrac{R_s(\cos\Sigma_1\cos\nu - \sin\Sigma_1\cos\Sigma_2\sin\nu)}{(R-t_0)^2\sin\theta\cos\theta} - \dfrac{R_s(\sin\Sigma_1\cos\nu + \cos\Sigma_1\cos\Sigma_2\sin\nu)}{(R-t_0)R\sin^2\theta\cos\omega} = 0 \\ \dfrac{R_s\sin\Sigma_2\sin\nu}{(R-t_0)R\sin^2\theta\sin\omega} - \dfrac{R_s(\sin\Sigma_1\cos\nu + \cos\Sigma_1\cos\Sigma_2\sin\nu)}{(R-t_0)R\sin^2\theta\cos\omega} = 0 \end{cases} \quad (1)$$

(1)

When θtakes a fixed value, it always corresponded with a set ofωandνin the equation set (1). According to a series of calculatedtangent point P, the tangent point was converted at the bottomcurve in $\sigma_0 = [O_0; X_0, Y_0, Z_0]$ and the large-end circumference of the grinding wheel, so as to get the following formula of the motion curve of the ball end mill and the grinding wheel in the manufacturing process:

$$\begin{pmatrix} \Delta X \\ \Delta Y \\ \Delta Z \end{pmatrix} = \begin{pmatrix} R(1-\cos\theta) + R_s(\cos\Sigma_1 + \sin\Sigma_1\sin\Sigma_2\sin\nu - \cos\Sigma_1\cos\nu \\ R_s(\cos\Sigma_2\sin\nu - \sin\Sigma_1) - (R-t_0)\sin\theta\sin\omega \\ (R-t_0)\sin\theta\cos\omega + R_s(\sin\Sigma_1\cos\nu + \cos\Sigma_1\sin\Sigma_2\sin\nu) \end{pmatrix}$$

(2)

GRINDING MOVEMENT OF RAKE FACE OF THE CIRCUMFERENCE BLADE

The forming of the rake face of the circumferenceBlade is same with the forming principle of the spiral groove on the drill, and the relative movement relationship and position relationship between the grinding wheel and the ball end mill in processingare shown in Figure 2.

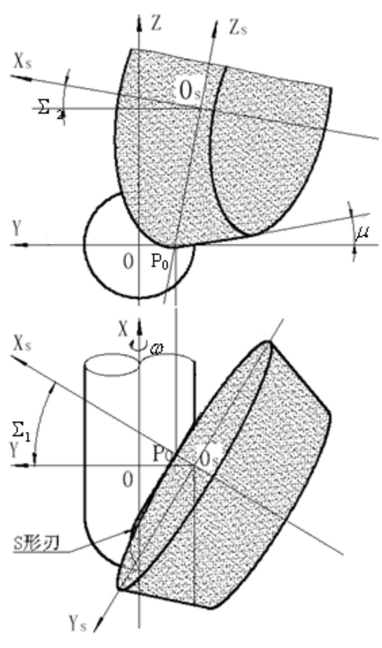


Figure 2 : The position relationship between the grinding wheel and the ball end mill

If the rake face of circumference blade is orthogonal helical surface, then its equation can berepresented as:

$$\begin{cases} X = R_X\cos\omega \\ Y = R_X\sin\omega \\ Z = \dfrac{P_z}{2\pi}\omega \end{cases}$$

(3)

In this type: R_x is the radius of any point on the rake face of circumference blade, so its calculation formula is: $R_x = \sqrt{X^2 + (X-R)^2 \tan^2 \mu}$, μ is the included angle between the generatrix and axis of the grinding wheel,which is the half taper of the grinding wheel of the circular cone[2].

ESTABLISHMENT OF SIMULATION MACHINING SYSTEM BASED ON THE SOLIDWORKSPLATFORM

For the purpose of verifying the correctness of the mathematical model and processing movement, a lot of different sizes of the ball end mill blank, and different types and sizes of grinding wheel are needed for trial cutting, and for the convenient measurement of the related parameters and avoiding the waste of materials, a set of grinding simulation and machining system of the rake face was founded on the SolidWorks platform with Visual Basic language as the secondary development tools. First of all, begin with parametric design for the ball end mill and grinding wheel, that means opening the macro recording to create physical model in SolidWorkswith theparameter size marked by variables, so macro recording gets entity established code base, then parameterized modeling of the ball end mill blank and grinding wheel could be realized in the way of controlling the variables on the bases of the objects and methods of macro file organized reasonably, modified a little and variables used to replace the specific parameters[3] in its own application. After that, the rake face was formed by means of Boolean difference calculation between the entities to make the grinding wheel to realize the simulated grinding processfor the milling blank after using the milling blank entity generated by parametric modeling and the grinding wheel entity, the simulation results are shown in Figure 2.

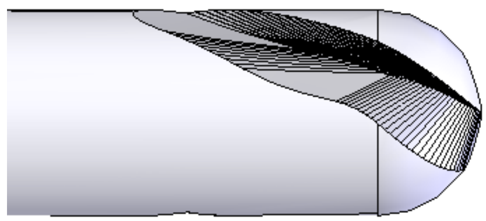
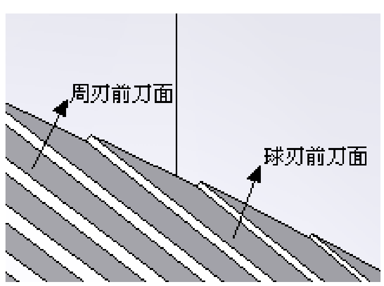


Figure 2 : The grinding simulation processing results of the rake face

ANALYSIS AND EVALUATION ON THE GRINDING SIMULATION RESULTS OF THE RAKE FACE OF THE BALL BLADE

Analysis of blade

In the process of grinding and machining for the rake face of the ball blade, the big circle of the grinding wheel is tangent with the curve at the bottom of spiral groove in the rake face of the ball blade, and the circular spiral groove on the milling cutter handle is grinded according to the way of normal spiral groove. The simulation results in Figure 3 shows that, the rake face of circular blade connected smoothly with the rake face of the ball blade, which improves the stability of the ball end mill in the cutting process. As it’s shown in Figure 4, the ball blade is the reasonable s-shaped curve, crossing the central axis of the milling cutter with a smooth transition, so as to ensure good machining quality, cutting performance and chip removal ability of the milling cutter[5].



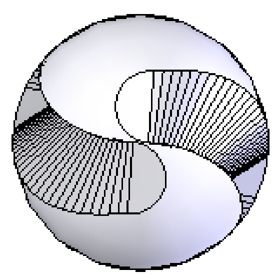


Figure 3 : The connection betweencircular blade and the ball **Figure 4 : S-shaped ball milling**

Rake angle distribution of the rake face of the ball blade

Rake Angle, the important parameters for the cutting tool, whose size determines the sharpness and strengths of the cutting edge[6], has a significant influence on the cutting process. The ball blade curve can be achieved when the rake face of the ball blade crossing with hemispherical surface, and the reference surface is changed due to the changes of normal vector of each point on the ball blade. We define θas theincluded angle between the connection line from any point to the ball center and X axis Angle (as shown in Figure 5), the distribution range of θis 0 ° ~ 90 ° from the top of ball to the ball blade and circumference blade; ∂ is the included angle between the connection line from any point on the ball blade to the center of the ball and Z axis (see Figure 6).

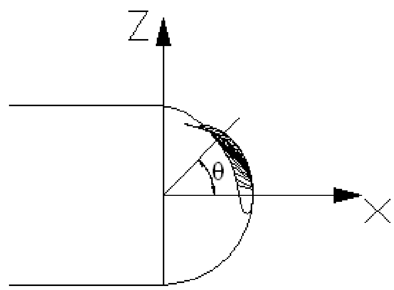


Figure 5 : Angleθofthe ball blade

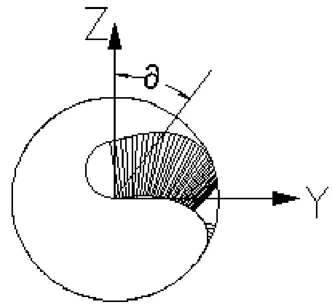


Figure 6 : Corner∂

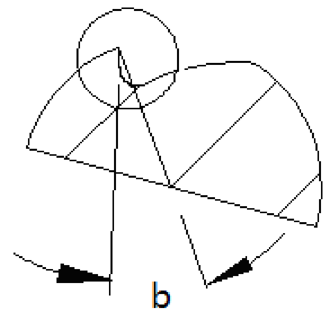


Figure 7 : Rake angle b

The sectionwhich has one point on the ball blade, keeping vertical with its ball blade curve and passing the center of the ball head, needed to be measured. On the section, the included angle between the connection line from the points of the ball bladeto the ball center and projection of the rake faceis b. We can get the distribution of the rake angles on the ball blade based on the anteriorfrom changedθand ∂ (Fig. 8, 9). It can be seen that the rake angle distribute quite reasonably: the rake angles of the rake face of the ball blade are the largerones, with the maximum as 32 ° and the minimum as 12 °,which distributelike thatfirst increases then decreasesfrom the top of the ball to the outer edge, that is smaller close to the top of the ball blade, bigger in the middle, then smaller near the circumference blade.

TABLE 1 : The measurement data of the rake angle of the ball blade

No.	Rotation angle ∂	Angle on the ball head θ	Rake angle b
1	2.72°	7.10°	15.18°
2	5.36°	13.47°	32.00°
3	7.37°	18.27°	28.88°
4	9.35°	22.86°	29.99°
5	11.30°	27.33°	30.56°
6	13.28°	31.75°	30.85°
7	15.293°	36.18°	30.95°
8	17.39°	40.70°	30.89°
9	19.63°	45.43°	30.67°
10	22.09°	50.53°	30.26°
11	24.94°	56.29°	29.59°
12	28.62°	63.52°	28.48°
13	34.72°	74.79°	22.68°
14	37.01°	78.74°	18.66°
15	39.21°	82.50°	16.47°
16	41.34°	86.10°	14.94°
17	43.40°	89.56°	12.83°

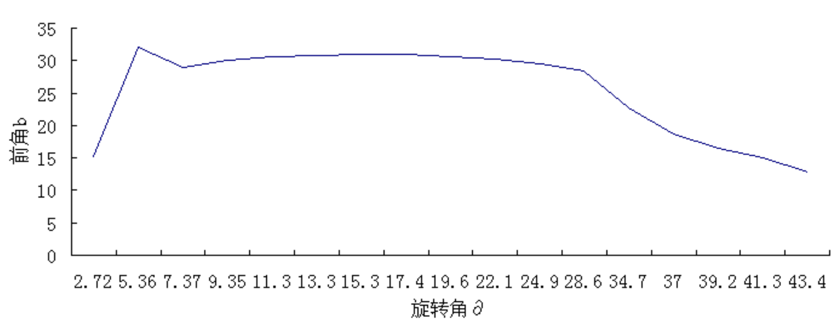


Figure 8 : The distribution of the rotation angle-rake angle

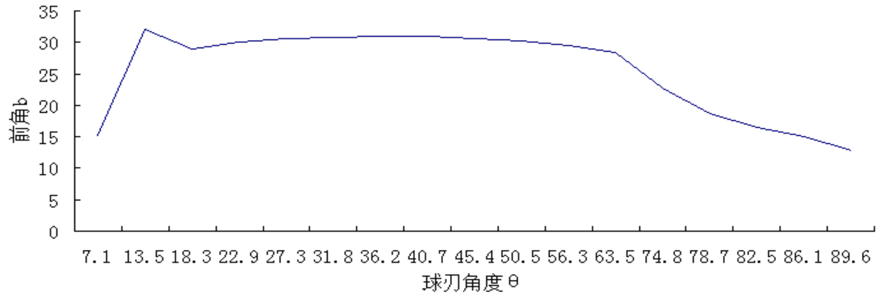


Figure 9 : The distribution of the ball blade angle-rake angle

CONCLUSION

Machining simulation system can simulate the grinding process of the rake face of the ball end mill better, andthe motion relationship proposed in the early stage can continuous grind the rake face of the ball blade and circumference blade,which verifies the validity of the mathematical model;the rake face of the ball blade continuous transit with that of circumference blade, and the blade curve of the balliss-shaped; the distribution of the rake face of ball blade in distributed in a reasonable way with a maximumas 32 °.

REFERENCES

[1] He Lin, Lishuai, etc; *Grinding simulation of the rake face of the ball end mill* [J], Journal of Mechanical Design and Manufacturing, **(2)**, 250-251 **(2009)**.

[2] Hebiao; *Research on the grinding processing of the new type of ball end mill* [D], Master thesis of Guizhou University, **6, (2005)**.

[3] Lishuai; *The secondary development and parametric design of solid works*[J], Journal of Zaozhuang College, **(2)**, 79-82 **(2010)**.

[4] Solid works corporation, Solid Works API help, [Z], **(2005)**.

[5] Bing Yinren, Yu Yongyang; *The geometrical models of the design and 2 - axis NC machining of a helical end-mill with constant pitch*, Journal of Materials Processing Technology, **(115)**, 265-270 **(2001)**.

[6] Zhu Mengzhou; *Mechanical engineers handbook* (second edition) [M], Mechanical Industry Publishing House, **(2000)**.

[7] Sun Liming; *Error compensation andstudy on the rake face of the ball end mill in the grinding simulation processing* [D], Master Thesis of Guizhou University, **6**, **(2009)**.

[8] Ren Bingyin,Tang Yuyong; T*he geometric modeling theory and its application in the ncmachining*[J], Journal of Harbin Industrial University press, **1**, **(2000)**.

[9] Shi Peilin, Wangwei, Tang Yuyong; *Research on the maths model in the ball end mill manufacturing* [J], Journal of Mechanical Engineering, **(5)**, 55-59 **(1994)**.