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The Forming Theory and the NC Machining for The Rotary Burs with the Spectral Edge Distribution

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Abstract

This paper researched the rotary burs with special cutting edges, which is the newest lay out of such tools, and represents the international direction of development and advanced level. So that improved the cutting condition of the cutter.

Keywords: Across edge, Rotary burs, NC machining

Introductions

For the ball ended or tipped rotary burs, the cutting edges must joint together at the tip, where the depth of the groove of cutting edge is zero in theory. In the vicinity of the tip, the grooves are very shadow, while the edges are very densely concentrated. So that the space is very limited, the cutting condition is very bed. In order to improve the cutting condition at the tip, the rotary burs with the spectral edge distribution is presented in this paper. In the vicinity of the tip, there are 2 kinds of cutting edges: one is called the main edge, it passing through the tip as the ordinary edge; another kind is called the branch edge, which did not passing through the tip. In the vicinity of the tip the main edges tack part into the cutting, while the branch edges did not tack part into the cutting, so that increased the space in the vicinity of the tip, and there for improved the cutting condition dramatically.

1. The special cutting edge

The ordinary cutting edge, is defined as the intersect curve of the inclined plane with the rotary surface of the cutter. The inclined angel of the plane is β_k. We have following relationship:

$$\sin\varphi = -\frac{L-x}{r} tg\beta_k \tag{1}$$

In the equation:

ϕ: The angel between the radiate line of any point on the edge and the xoy plane

L : The distance from the center of the ball to the intersect point of plane and the axis

r: The rotary radius of any point at the surface

β_k: The angel between the plane and the axis

The range of the x:$x \leq L$.

The special cutting edges, however, is defined as a series of intersect curves of a series of inclined planes with the rotary surface of the cutter. The inclined angels of the plane are β_{ki}. We have following relationship:

$$\sin\varphi_i = -\frac{L_i - x}{r} tg\beta_k \text{ i} \tag{2}$$

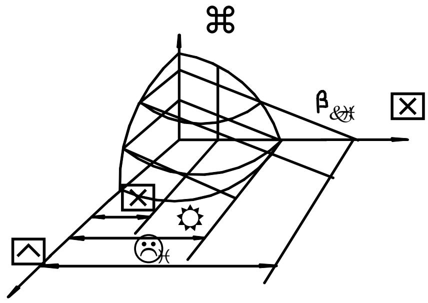

Figure 1. A series of intersect curves of a series of inclined planes with the rotary surface of the cutter

In the equation:

ϕ_i: The position angel

β_{ki}: The angel between the plane *i* and the axis.

L_i: The distance from the center of the ball to the intersect point of plane *i* and the axis.

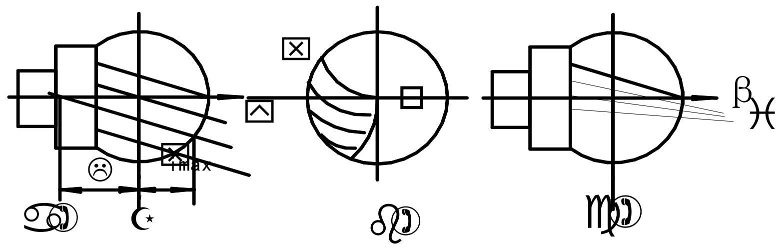

Figure 2. Rotary burs with the spectral edge distribution

2. The composed cutting edge

For the composed cutting edge, at the connecting point of two kind edges(x= x_g), the neighboring edges must have same position, and the two edges must satisfy the condition of smooth connection. That mines the plans to cut the ball should not be parallel with each other. Let the angel between the planes *i* and the axis is β_i, than we have:

$$\sin\varphi_i = -\frac{L_i - x}{r} tg\beta_i \tag{1}$$

In the equation:

ϕ_i: The position angel

r: The radius of the ball.

β_i: The angel between the plane *i* and the axis.

L_i: The distance from the center of the ball to the intersect point of plane *i* and the axis.

$$\cos\varphi_i \frac{d\varphi_i}{dx} = \frac{r + (L_i - x)\frac{dr}{dx}}{r^2} tg\beta_i$$

$$\frac{d\varphi_i}{dx} = \frac{1}{r\cos\varphi_i}[tg\beta_i - \frac{dr}{dx}\sin\varphi_i]$$

$$tg\beta = \frac{r}{\sqrt{1+(\frac{dr}{dx})^2}} \frac{d\varphi_i}{dx} = \frac{tg\beta_i - \frac{dr}{dx}\sin\varphi_i}{\sqrt{1+(\frac{dr}{dx})^2}\cos\varphi_i} \tag{2}$$

β: The helical angel of the edge.

In order that, at the connecting point of two kind edges, the neighboring edges have the same helical angel, and equal to the given helical angel β_i, there must have the following equation:

$$tg\beta_i = tg\beta_o\sqrt{1+(\frac{dr_g}{dx})^2}\cos\varphi_{ig} + \frac{dr_g}{dx}\sin\varphi_{ig} \tag{3}$$

In the equation:

β_0: The helical angel of the ordinary edge

r_g: The radius of the cutter at the point of connection

ϕ_{ig}: The position parameter of the edge at the point of connection

Tack the β_i into the equation (1), we can find L_i

$$L_i = -ctg\beta_i \sin\varphi_{ig} r_g + x_g \tag{4}$$

While the equation (4) can be rewritten into:

$$x_i^2(1+tg^2\beta_i) - 2L_i tg^2\beta_i x_i + (L_i^2 tg^2\beta_i - R^2) = 0 \tag{5}$$

3. The forming theory for the rotary burs with the spectral edge distribution

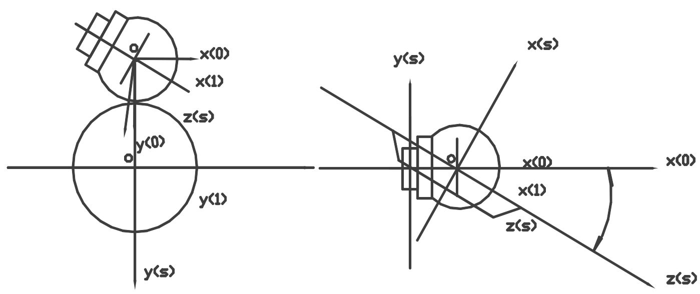

Figure 3. The coordinate system for the machining

The machining of the rotary burs with the spectral edge distribution is shown in fig.3. There are four systems:

(1) the fixed system $S^{(0)}$:

In the system, the original point is at the center of the ball, the axes $x^{(0)}, y^{(0)}$ are along the longitudinal and transverse direction of the machine tool.

(2) The system fixed to the Swinging base $S^{(1)}$:

In the system, the original point $O^{(1)}$ coincides with the point $O^{(0)}$, the angel between $z^{(0)}$ and $z^{(1)}$ is τ.

(3) The system fixed to the cutter $S^{(d)}$:

In the system $x^{(d)}$ rotate an angel φ about $S^{(1)}$

(4) The system fixed to the sand wheel $S^{(s)}$

In the system, the original point is at the center of the sand wheel, and moved with the sand wheel. $y^{(s)}$ and $y^{(o)}$ are parallel with each other. The angel between $y^{(0)}$ and $y^{(1)}$ is $\pi / Z - \sum$.

The transformation matrixes are as following:

$$M_{os} = \begin{bmatrix} \sin\sum & 0 & \cos\sum & x_c \\ 0 & 1 & 0 & y_c \\ -\cos\sum & 0 & -\sin\sum & z_c \\ 0 & 0 & 0 & 1 \end{bmatrix} \tag{6}$$

$$M_{o1} = \begin{bmatrix} \cos\tau & -\sin\tau & 0 & 0 \\ \sin\tau & \cos\tau & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad (7)$$

Refer to the Figure 3, the coordinate of the any point at the surface of sand wheel M_B is:

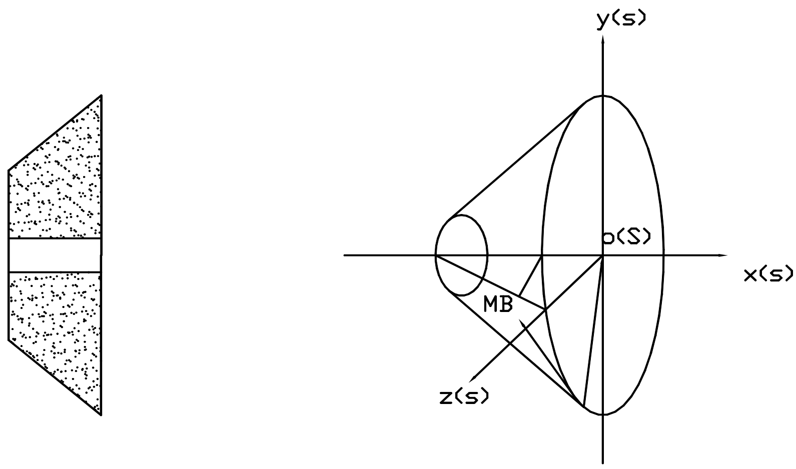

Figure 4. Sand wheel

$$x_{MB}^{(s)} = -(R - r_{mB})tg\alpha_B$$
$$y_{MB}^{(s)} = -r_{mB}\cos\theta_B \quad (8)$$
$$z_{MB}^{(s)} = r_{mB}\sin\theta_B$$

In the equation,

R : The radius of the sand wheel.

r_{mb} : The radius of the f the any point at the surface of sand wheel M_B

θ_B : The angular position parameter of the any point at the surface of sand wheel M_B

α_B : The angel of the cone of the sand wheel

The normal vector of the any point at the surface of sand wheel M_B :

$$\vec{n}_{MB}^{(s)} = (-\cos\alpha_B, -\sin\alpha_B\cos\theta_B, \sin\alpha_B\sin\theta_B) \quad (9)$$

When transformed into the fixed system:

$$x_{MB}^{(o)} = --(R - r_{mB})tg\alpha_B \sin\sum + r_{mB}\sin\theta_B\cos\sum + x_c$$

$$y_{MB}^{(o)} = -r_{mB}\cos\theta_B + y_c \quad (10)$$

$$z_{MB}^{(o)} = (R - r_{mB})tg\alpha_B\cos\sum + r_{mB}\sin\theta_B\sin\sum + z_c \quad (11)$$

$$\vec{n}_{MB}^{(o)} = (-\cos\alpha_B\sin\sum + \sin\alpha_B\sin\theta_B\cos\sum, -\sin\alpha_B\cos\theta_B, \cos\alpha_B\cos\sum + \sin\alpha_B\sin\theta_B\sin\sum)$$

The coordinate of the any point at the bottom of sand wheel in the system $S^{(s)}$:

$$x_{MA}^{(s)} = 0 \qquad y_{MA}^{(s)} = -r_{mA}\cos\theta_A \qquad z_{MA}^{(s)} = r_{mA}\sin\theta_A \quad (12)$$

And the normal vector:

$$\vec{n}_{MA}^{(s)} = (1, 0, 0) \quad (13)$$

When transformed into the fixed system:

$$x_{MA}^{(o)} = r_{mA}\sin\theta_A\cos\sum + x_c \qquad y_{MA}^{(o)} = -r_{mA}\sin\theta_A + y_c \qquad z_{MA}^{(o)} = r_{mA}\sin\theta_A\sin\sum + z_c \quad (14)$$

$$\vec{n}_{MA}^{(o)} = (\sin\sum, 0, \cos\sum) \quad (15)$$

The movement in manufacture:

The swinging angel of the Swinging base: $tg\tau = -\frac{dr}{dx}$

The rotation of the work: $\varphi = -\varphi_i$

The coordination of the center of the sand wheel:

$$x_c = x_{p(i+1)}^{(0)} + (R - r_{mB})tg\alpha_B \sin\sum \ - r_{mB} \sin\theta_B \cos\sum$$

$$y_c = y_{p(i+1)}^{(0)} + r_{mB} \cos\theta_B$$

$$z_c = z_{p(i+1)}^{(0)} - (R - r_{mB})tg\chi_B \cos\sum \ - r_{mB} \sin\theta_B \cos\sum$$

4. Examples

A ball end rotary burs with the spectral edge distribution, the basic parameters are as following:

The diameter of the ball: d = 13mm

The length of the cutter: l=10mm

The helical angel: β= 20^o

The number of the tooth: z= 24

When divided into 6 districts, one district contains 4edges.

The radius of the sand wheel: D= 100mm

The angel of the cone of the sand wheel: $\alpha_B = 50^o$

The machined rotary burs with the spectral edge distribution is as shown in Fig.5

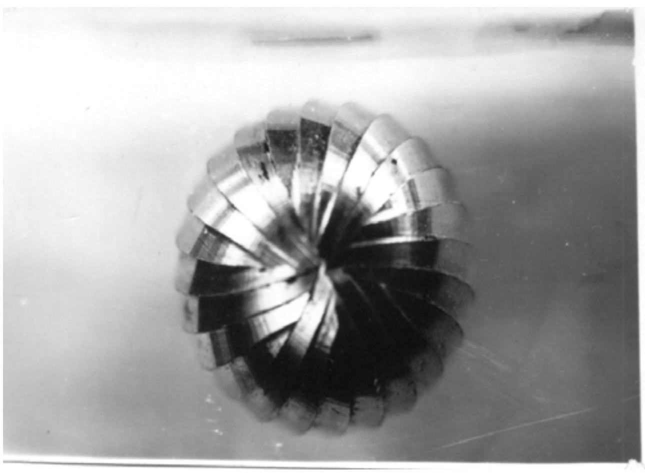

Figure 5. The rotary burs with the spectral edge distribution

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