Analysis of cylindrical cam molded surface

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Abstract

The mold surface of cylindrical cam is very complex. There are some questions in designing and using by unfolding picture of cylindrical cam. The thesis infers and builds the mathematical models of cylindrical cam through the theoretical analysis from the nature of space motion cylindrical cam. The models provide the theoretical reference of right projecting, manufacturing and examining.

Keywords: axial cam, spiral surface, equation

1 Introduction

Cam mechanism is a kind of typical facility. Owing to realizing expected motion with simply structure, cam is widely used in all kinds of machinery. Although cam is designed easily and moving perfectly, it is difficult to ensure the accurate process of cam molded surface, especially the cylindrical cam. The topic examines the designing and using of cylindrical cam surface.

2 The coordinates of the cutter and workpiece

Cam path of cylindrical roller includes arc, spiral line and transition arcs. The arc on cylindrical cam is a line perpendicular to cylindrical axis in unfolding picture. The spiral line on cylindrical cam is a line tilted to the cylindrical axis and the dip angle is spiral angle.

Cylindrical cam's molded surface is very complex as shown in the Figure 1. It consists of four arc paths and four spiral paths.

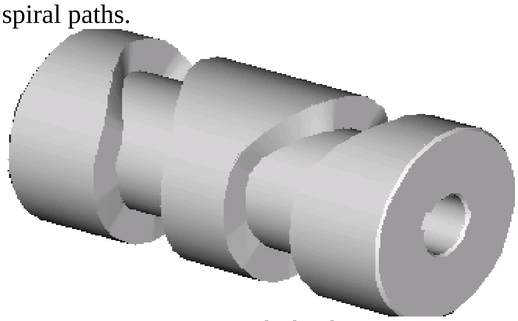

FIGURE 1 cylindrical cam

In order to design and analysis, the length of unfolding picture expanded from cylindrical cam excircle is $2\pi r$ (r is a radius of excircle). In expanded picture, transverse coordinate indicates axial location of cam path. The track of roller centre line is the theoretical line of cam. The practical lines of cam path are two lines which are round of roller whose centre is on the graph. The Figure 2 is the unfolding picture of cylindrical cam. In this picture, the centre line of are path which is horizontal line and the centre line of spiral path which is bias line. The completely cam path sees lines forming by cylindrical surface, when cylindrical roller is moving along the centre of unfolding picture.

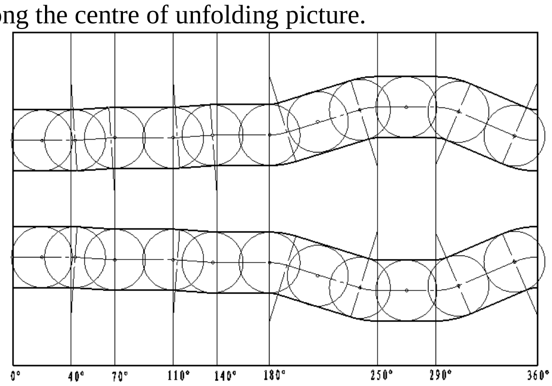

FIGURE 2 Expanded view along conductor rail of cylindrical cam

In order to provide a comprehensive analysis, it is necessary to establish two coordinate systems for cutter and workpiece to display space relation in the Figure 3.

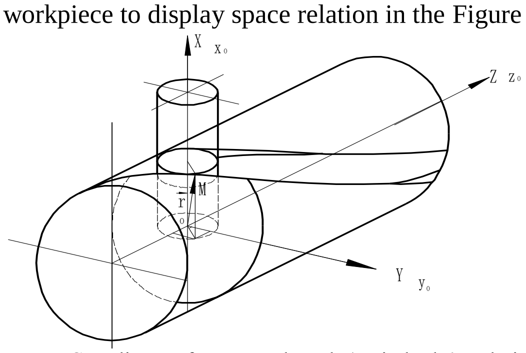

FIGURE 3 Coordinate of cutter and work (main body's relation in space)

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Workpiece coordinate system is *O-X Y Z, c*utter coordinate system O-X_0 Y_0 Z_0.

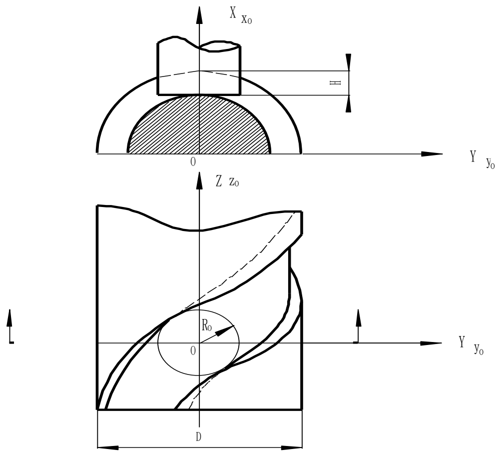

FIGURE 4 Relationship of plane projection of cutter and work

X_0-axis of cutter is perpendicular to *Z*-axis of workpiece. The projection relationship of cutter and workpiece is displayed in the Figure 4. From the Figure 5, the equation of the cutter surface of revolution which is cylindrical is that:

$$\begin{cases} X_0 = R_0 \times c\tan\alpha \\ Y_0 = R_0 \times \cos\varphi \\ Z_0 = R_0 \times \sin\varphi \end{cases} , \quad (1)$$

where R_0-roller radius, α, φ – parameters. Having one α angle and one φ angle can confirm point *M* on the cylindrical surface. From Y_0-axis, anticlockwise is positive and clockwise is negative.

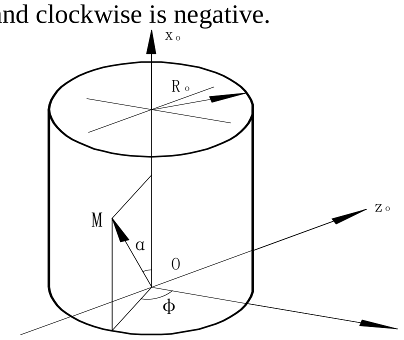

FIGURE 5 Revolution surface of cutter (in the same coordinates as Figure 3)

3 The contact line equation of cutter surface revolution and workpiece spiral surface

The contact condition of cutter revolution surface and workpiece spiral surface is displayed in Figure 3. The radius vector of point *M* which is relative to origin *O* of cutter and workpiece coordinate system is showed as follows.

To cutter:

$$OM = \vec r = x_0\vec i + y_0\vec j + z_0\vec\kappa . \quad (2)$$

To workpiece:

$$OM = \vec r = x\vec i + y\vec j + z\vec\kappa . \quad (3)$$

Now $x_0 = x$, $y_0 = y$, $z_0 = z$, $\vec i$, $\vec j$, $\vec\kappa$ are the vectors of *X*-axis, *Y*-axis, *Z*-axis.

If rotation angular velocity of cutter revolution surface and workpiece are ω_0 and ω_I, the line velocity of point M with cutter moving is showed as follows:

$$\vec V_0 = \omega_0(\vec i \times \vec r) . \quad (4)$$

The line velocity of point *M* with workpiece moving is showed as follows:

$$\vec V_I = \omega_I(\vec k \times \vec r + p \times \vec k) . \quad (5)$$

P-spiral parameter $p = \frac{p_z}{2\pi}$ (p_z -helical pitch).

So the speed of relative movement is showed as follows:

$$\vec V_x = \vec V_i - \vec V_0 = \omega_I(\vec k \times \vec r + p \times \vec k) - \omega_0(\vec i \times \vec r) . \quad (6)$$

As the contact condition at point *M* of cutter revolution surface and workpiece spiral surface is $\vec V_x \perp \vec n$, then:

$$\vec V_x \times \vec n = 0 . \quad (7)$$

So $\omega_I(\vec\kappa \times \vec r + p \times \vec\kappa) \times \vec n - \omega_0(\vec i \times \vec r) \times \vec n = 0$.

As cutter revolution surface is known and the line velocity $\vec V_0$ is vertical with normal $\vec n$, $\omega_0(\vec i \times \vec r) \times \vec n = 0$ Then the contact condition is showed as follows:

$$(\vec\kappa \times \vec r + p \times \vec\kappa) \times \vec n = 0 . \quad (8)$$

Expressing by components, the contact condition is

$$\vec\kappa \times \vec r = \vec\kappa \times (x_0\vec i + y_0\vec j + z_0\vec\kappa) = x_0\vec j - y_0\vec i . \quad (9)$$

As of $\vec n = \frac{\partial\vec r}{\partial\alpha} \times \frac{\partial\vec r}{\partial\varphi}$ so:

$$\vec n = -R_0^{\,2}(c\tan\alpha)'\sin\varphi\vec\kappa - R_0^{\,2}(c\tan\alpha)'\cos\varphi\vec j . \quad (10)$$

Equations (9) and (10) lead to Equation (8). Cylindrical equation $x_0 = R_0 c\tan\alpha$ was introduced into. So $R_0 c\tan\alpha + p\tan\varphi = 0$, where $R_0 c\tan\alpha = a$, a is independent variable and radius of spiral line in cylindrical cam which changes scope is $\frac{D}{2} \sim \frac{D}{2} - H$. (*D*-workpiece diameter; *H*-depth of spiral path.) So the contact condition is that:

$$a + p\tan\varphi = 0\,. \qquad (11)$$

So the contact equation is:

$$\begin{cases} a + p\tan\varphi = 0 \\ x_0 = \sqrt{R^2 - (R_0\cos\varphi)^2} \\ y_0 = R_0\cos\varphi \\ z_0 = R_0\sin\varphi \end{cases}. \qquad (12)$$

4 The equation of workpiece spiral surface

When the contact line rotates round Z-axis moving spiral with known contact equation, workpiece spiral surface is found.

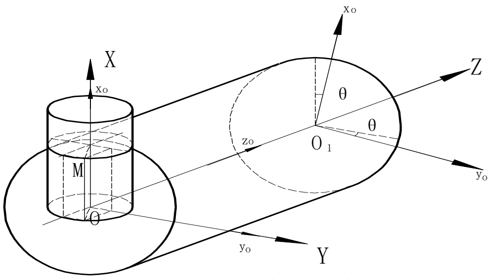

FIGURE 6 Cutter's coordinate played helical motion in work's coordinate

The contact line is obtained as *O*-*X*, *Y*, *Z* coinciding with O_1-X_0 Y_0 Z_0. When cutter coordinate system moves from *O*-*X*, *Y*, *Z* to O_1-X_0 Y_0 Z_0, it rotates θ angle and moves *P* along *Z*-axis. Now the coordinate point *M* in is found in the Figure 5.

Equations (12) follows from the Equation (1), the spiral surface equation is:

$$\begin{cases} x = \sqrt{R^2 - (R_0\cos\varphi)^2}\cos\theta - R_0\sin\theta\cos\varphi \\ y = \sqrt{R^2 - (R_0\cos\varphi)^2}\sin\theta + R_0\cos\theta\cos\varphi \\ z = R_0\sin\varphi + p\theta \end{cases}. \qquad (13)$$

From the equating, we know the contact line is not a line but a space curve and the spiral surface is also a space surface.

The spiral surface's shape and location is decided not only by the cylindrical diameter, cam path's depth and spiral line's helical pitch, but also by the diameter of roller. In addition, when finishing machining, the diameter of cylindrical cutter is equal to the roller diameter in order to ensure the accuracy. Otherwise, cylindrical roller can't move along the path and affect the moving stability.

5 Conclusions

The topic sets up the mathematical models of cylindrical cam surface and the course is clear and concise. The models grasp the nature of space motion of the facility. The equations have universal meaning, strong operability and good use for reference value for analysis of other cams.

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