Breadth Cam Profile Design with Translating Roller Follower

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1. Introduction

A breadth cam gets its name because the centers of the rollers are a constant distance apart. With the motion of follower, a breadth cam mechanism can be classified as two types: one with a pair of translating motion followers, the other with a pair of oscillating motion followers, we consider the follower moving in combination of translation in this paper. This paper presents design solutions for cam type transfer unit in which feeding, lifting, and clamping motions are generated by cams. As knows to all, the breadth cam can eliminate the redundant preload by using a complementary cam to avoid jumping velocity between cam and followers. That is why it is needed to design a breadth cam here.

2. Shape Design for Breadth Cam with No Eccentricity

The main difficulty in the shape design for breadth cam is to calculate the coordinates to determine the profile through every contact point. In this paper, we propose a new method according to Kennedy's thiorem, by using instant velocity center the coordinates for every contact point is easily to be found even when the contact points changes at any instant moment.

2.1 Coordinates of Contact points with no eccentricity

As can be seen in Fig.1, it shows a breadth cam mechanism with a pair of rollers as followers, and its radial form has been Instant velocity center method. According to Kennedy's thiorem, the three instant velocity centers shared by three rigid bodies in relative motion to one another (whether or not connected) all lie on the same straight line. Fig.1 shows the construction necessary to find instant velocity centers in the breadth cam mechanism as I_{23}, with the cam rotates counter-clockwise at a constant angular velocity ω, and drives the pair of the followers to translate up and down in reciprocate motion.

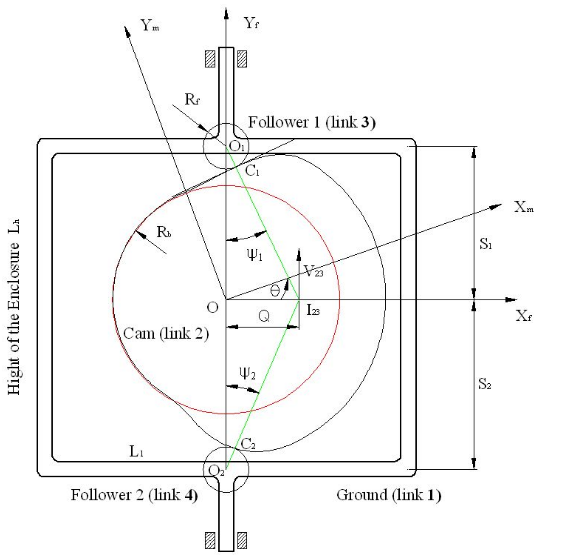

Fig. 1 Breadth cam shape for translating motion

Before deriving the profile equation of the breadth cam, two coordinate systems corresponding to this cam should be defined as shown in Fig.1: a stationary reference system $S_f(X_f,Y_f)$, and one mobile reference system $S_m(X_m,Y_m)$. The position and the orientation of the reference system S_m is defined by the input shaft rotation angle θ of Link 2, and the main equations for designing this cam shape are explained by the functions below.

The distance between the cam rotating center O and the instant velocity center I_{23} is defined to be Q, which can be expressed in terms of velocity υ here the same as the velocity of the enclosure as follows.

$$Q = \overline{OI_{23}} = \frac{dh}{d\theta} = \upsilon \tag{2.1}$$

The pressure angles for the upper and lower followers are as follows.

$$\psi_1 = \tan^{-1}\left(\frac{Q - {}^fR_{1x}}{{}^fR_{1y}}\right) \tag{2.2}$$

$$\psi_2 = \tan^{-1}\left(\frac{Q - {}^fR_{2x}}{{}^fR_{2y}}\right) \tag{2.3}$$

The coordinate of contact points for the upper and lower followers as C_1 and C_2 under S_m coordinate system are expressed in terms of the displacement S_1 and S_2 showing as followings.

$$\begin{Bmatrix} {}^mC_{1x} \\ {}^mC_{1y} \end{Bmatrix}_c = \begin{bmatrix} \cos\theta_c & \sin\theta_c \\ -\sin\theta_c & \cos\theta_c \end{bmatrix} \begin{Bmatrix} R_f \sin\psi_1 \\ s_1 - R_f\cos\psi_1 \end{Bmatrix} \tag{2.4}$$

$$\begin{Bmatrix} {}^mC_{2x} \\ {}^mC_{2y} \end{Bmatrix}_c = \begin{bmatrix} \cos\theta_c & \sin\theta_c \\ -\sin\theta_c & \cos\theta_c \end{bmatrix} \begin{Bmatrix} R_f \sin\psi_2 \\ -s_2 + R_f\cos\psi_2 \end{Bmatrix} \tag{2.5}$$

where θ_c is the rotating angle of the cam.

With the help of the above two equations, it is easy to define the rise and return motion of the breadth cam pitch curve exactly.

2.2 Example for breadth cam with no eccentricity

Case 1: TES Function

Here, we used the Thoren, Engemann, Stoddart (TES) function to design the cam shape, and the TES function is as follows:

$$s = h\left[1 + C_2\left(\frac{\theta}{\beta}\right)^2 + C_p\left(\frac{\theta}{\beta}\right)^p + C_q\left(\frac{\theta}{\beta}\right)^q + C_r\left(\frac{\theta}{\beta}\right)^r + C_w\left(\frac{\theta}{\beta}\right)^w\right] \tag{2.6}$$

where, p, q, r, w are equal to 10,20,30,40 with the value of C_2, C_p, C_q, C_r, C_w be equal to -1.5664,1.0000,-0.6667,0.2857, -0.0526 respectively due to the value of p, q, r, w.

Considered cam motion and basic geometric are presented by Tables 1 and 2, the corresponding displacement diagram is depicted in Fig.2.

Table 1 Follower displacement conditions of TES polynomial function

Segment	Cam angle	Rise and Return	Type of motion
1	0°~60°	10(mm)	TES Polynomial
2	60°~180°	0	Dwell
3	180°~240°	-10(mm)	TES Polynomial
4	240°~360°	0	Dwell

Table 2 Characters for cam shape of TES polynomial function

Base circle radius (R_b)	50mm
Roller follower radius (R_f)	10mm
Eccentricity (E)	0.0mm

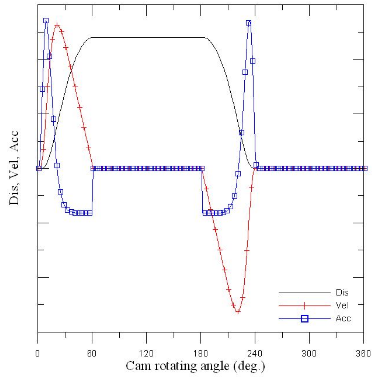

Fig. 2 s-υ-a characteristics for TES polynomial function

Then the cam shape can be easy to drawn like Fig.3 shows.

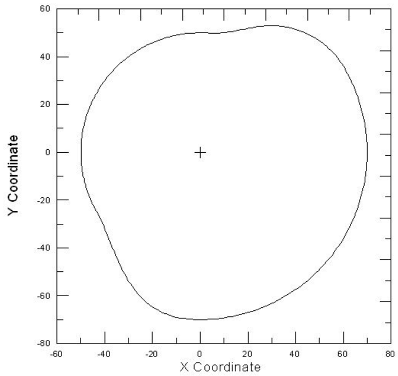

Fig. 3 Breadth cam shape for TES polynomial function

Case 2: 3-4-5-6 Polynomial Function

Here, we structure a polynomial cam design problem by using the 3-4-5-6 polynomial function to determine the cam shape with table 3 and 4, and the corresponding cam displacement diagram is presented in Fig.4:

$$s = h\left(64\left(\frac{\theta}{\beta}\right)^3 - 192\left(\frac{\theta}{\beta}\right)^4 + 192\left(\frac{\theta}{\beta}\right)^5 - 64\left(\frac{\theta}{\beta}\right)^6\right) \tag{2.7}$$

Table 3 Follower displacement conditions of 3-4-5-6 polynomial function

Segment	Cam angle	Rise and Return	Type of motion
1	0°~180°	15(mm)	3-4-5-6 Polynomial
2	180°~360°	-15(mm)	3-4-5-6 Polynomial

Table 4 Characters for cam shape of 3-4-5-6 polynomial function

Base circle radius (R_b)	100mm
Roller follower radius (R_f)	10mm
Eccentricity (E)	0.0mm

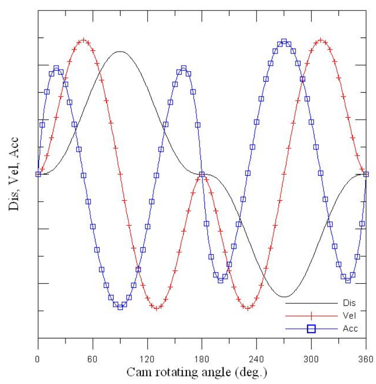

Fig. 4 s-υ-a characteristics for 3-4-5-6 polynomial function

Then the cam shape can be easy to drawn like Fig.5 shows.

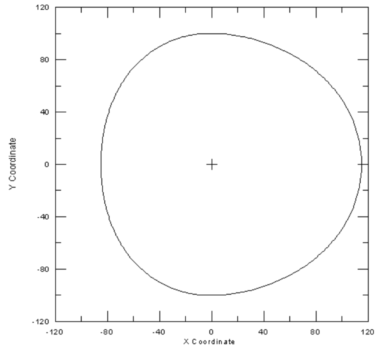

Fig. 5 Breadth cam shape for 3-4-5-6 polynomial function

3. Shape Design for Breadth Cam with Eccentricity

The profile equations for designing the breadth cam shape with consideration of eccentricity are as follows:

$$\begin{Bmatrix} {}^mC_{1x} \\ {}^mC_{1y} \end{Bmatrix}_c = \begin{bmatrix} \cos\theta_c & \sin\theta_c \\ -\sin\theta_c & \cos\theta_c \end{bmatrix} \begin{Bmatrix} E + R_f \sin\psi_1 \\ s_1 - R_f \cos\psi_1 \end{Bmatrix} \tag{3.1}$$

$$\begin{Bmatrix} {}^mC_{2x} \\ {}^mC_{2y} \end{Bmatrix}_c = \begin{bmatrix} \cos\theta_c & \sin\theta_c \\ -\sin\theta_c & \cos\theta_c \end{bmatrix} \begin{Bmatrix} -E - R_f \sin\psi_2 \\ -s_2 + R_f \cos\psi_2 \end{Bmatrix} \tag{3.2}$$

Case 1: 3-4-5-6 Polynomial Function

The 3-4-5-6 polynomial function has reconsidered to design the breadth cam system with eccentricity of 20mm (E=20mm, see Table 4).

The result is presented in Fig.6.

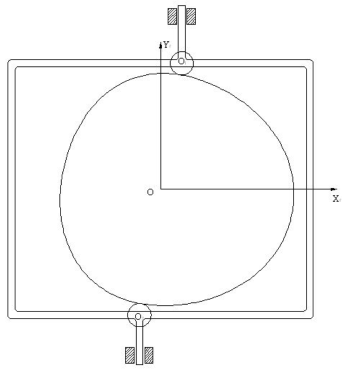

Fig. 6 Breadth cam system for 3-4-5-6 polynomial function with E=20mm

4. Conclusion

This paper presents a new type of design solutions for the breadth cam profile when whether there is an eccentricity or not. Several essential problems about the novel breadth cam mechanism, such as the relations between cam angles and geometric parameters, the allowable values of some angular decided parameters, the equations of cam profile with the rise motion as well as the return motion are solved, which are useful in the design and application of the mechanism.

Acknowledgment

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