Breadth Cam Profile Design with Oscillating Roller Follower

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1. Introduction

The common cam mechanism consists of a cam with one follower. But, a breadth cam mechanism has two followers in type of a built-in body. The breadth cam mechanism can be classified as two types with the motion of follower: one with a pair of reciprocating motion followers, the other with a pair of oscillating motion followers. This paper presents design solutions for the breadth cam system with a pair of oscillating roller followers by using instant velocity center method. And it also developed an automatic program using Microsoft Visual C++ program which can quickly and easily draw a 2D cam profile through the displacement diagram.

2. Profile design for Breadth cam in oscillating motion

The main topic in the shape design for the breadth cam is to calculate the coordinates to determine the profile through each contact point. In this paper, we propose a new method according to velocity and geometric relationships at instant velocity centers between cam and followers when the contact points changes at any instant moment.

As shown in Fig.1, a breadth cam mechanism has a pair of rollers as oscillating followers: Mechanism contains a cam and two followers, and followers are built in one body rotated by a pivot.

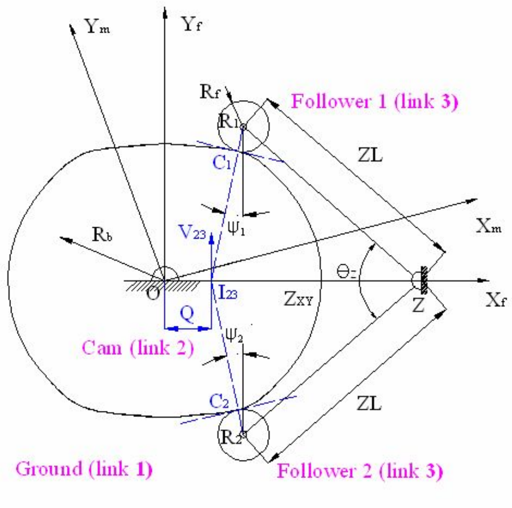

Fig. 1 Breadth cam mechanism for oscillating motion

It is defined the distance to pivot as in Eq. (1), where Z_x and Z_y are the coordinates of pivot.

$$z_{xy} = \sqrt{z_x^2 + z_y^2} \tag{1}$$

For deriving the profile equation of the breadth cam, two coordinate systems 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.

In Fig. 1, point O is the cam center, point R_1 and R_2 are the roller center of followers, Z_{xy} is the distance to pivot. This Breadth cam mechanism has 3 Instant velocity centers: Cam center (I_{12}), pivot (I_{13}), and I_{23}. Instant velocity center I_{23} is defined a crossed point between the horizontal line and the normal line at the contact point through the roller center.

By the velocity and geometric relationships at Instant velocity centers, the distance Q between the cam center and the instant velocity center I_{23} is derived as in Eq. (2) in terms of follower's velocity.

$$Q = \overline{OI_{23}} = \frac{Z_{xy}\dfrac{d\phi}{d\theta}}{1+\dfrac{d\phi}{d\theta}} = \frac{Z_{xy}v}{1+v} \tag{2}$$

The contact angles for the upper and lower followers are as followings. Here, R_x and R_y are the coordinates of roller center.

$$\psi_1 = \tan^{-1}\left(\frac{Q - {}^{p}R_{1x}}{{}^{p}R_{1y}}\right) \tag{3}$$

$$\psi_2 = \tan^{-1}\left(\frac{Q - {}^{p}R_{2x}}{{}^{p}R_{2y}}\right) \tag{4}$$

The coordinate of contact points for the upper and lower followers as C_1 and C_2 under S_m coordinate system are expressed as in Eq. (5).

$$\begin{aligned} {}^{m}C_x &= {}^{f}C_x\cos(\theta_c+\theta_p) + {}^{f}C_y\sin(\theta_c+\theta_p) \\ {}^{m}C_y &= -{}^{f}C_x\sin(\theta_c+\theta_p) + {}^{f}C_y\cos(\theta_c+\theta_p) \end{aligned} \tag{5}$$

Here, θc and θp are the cam rotating angle and the follower oscillating angles in the fixed coordinate.

3 Applications of Breadth cam profile design

Case 1: Breadth cam profile with no dwell motion

Here, we used the 3-4-5-6 polynomial function in Eq. (6) for the follower displacement to design the breadth cam shape.

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

And the displacement conditions and basic parameters are presented by Table 1 and 2. The corresponding displacement diagram is depicted in Fig.2. Then the cam shape can be easy to drawn in Fig.3.

Table 1 Displacement conditions for cam 1

Segment	Cam angle	Motion type	Function
1	0°~90°	5(mm) Rise	3456 Polynomial
2	90°~180°	-5(mm) Return	3456 Polynomial
3	180°~270°	5(mm) Rise	3456 Polynomial
4	270°~360°	-5(mm) Return	3456 Polynomial

Table 2 Design parameters for cam 1

Base circle radius (R_b)	74.8528mm
Roller follower radius (R_f)	10mm
Pivot of follower (Z_{xy})	120mm
Follower length(Z_L)	84.8528mm

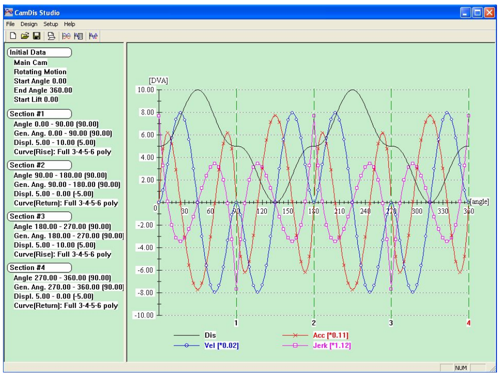

Fig. 2 s-υ-a characteristics for cam 1

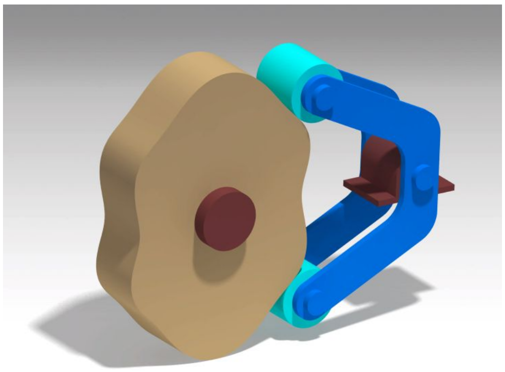

Fig. 3 Breadth cam shape with no dwell motion

Case 2: Breadth cam profile design with 10 degree dwell motion

Here, we structure the displacement conditions 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. Then the cam mechanism can be easy to drawn in Fig.5.

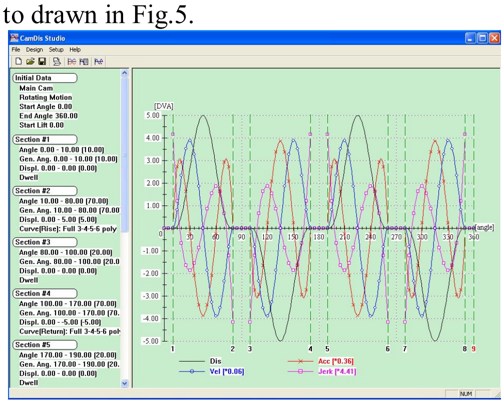

Fig. 4 s-υ-a characteristics for cam 2

Table 3 Displacement conditions for cam 2

Segment	Cam angle	Motion type	Type of motion
1	0°~10°	0	dwell
2	10°~80°	5(mm) Rise	3456 Polynomial
3	80°~100°	0	dwell
4	100°~170°	-5(mm) Return	3456 Polynomial
5	170°~190°	0	dwell
6	190°~260°	5(mm) Rise	3456 Polynomial
7	260°~280°	0	dwell
8	280°~350°	-5(mm) Return	3456 Polynomial
9	350°~360°	0	dwell

Table 4 Design parameters for cam 2

Base circle radius (R_b)	80mm
Roller follower radius (R_f)	20mm
Pivot of follower (Z_{xy})	150mm
Follower length(Z_L)	106.2393mm

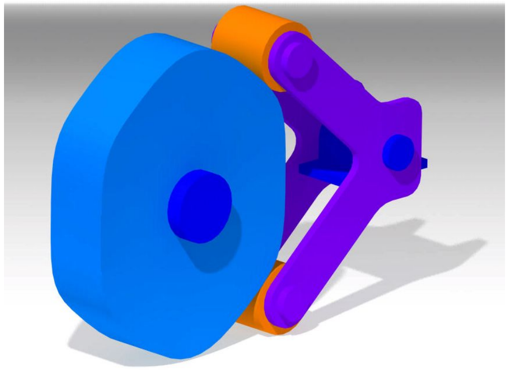

Fig. 5 Breadth cam shape with 10 degree dwell motion

4. Development of program

A breadth cam designing program is developed. It used the Microsoft Visual C++ program and the MFC languages to design a computer aided designing system called "Breadth Cam V1" program. By using the s-v-a characteristics of the follower displacement, a user-friendly connection with the design and dynamic simulation program of breadth cam mechanism is developed in the following figure, which has great practical and theoretical applications for design.

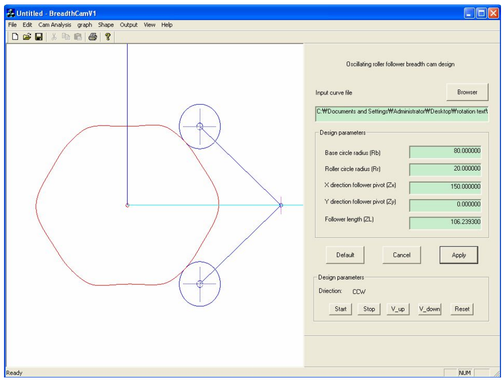

Fig. 6 Breadth cam system designing program

5. Conclusion

This paper presents a new design solution for the breadth cam profile with a pair of oscillating motion followers. Several essential parameters about the breadth cam mechanism are solved, such as cam angles, geometric constraints and the allowable values of follower lengths for the cam profile equations with the rise motion as well as the return motion, which are very useful in the design and application of the breadth cam mechanism.

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