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Design of Traverse Cam for Yarn Winding on Twisting Machine

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Abstract: A twisting machine is to twist yarns for improving yarn strength. After twisting yarns, the twisting machine winds yarns into a bobbin. The traverse mechanism is very important part of winding mechanism. Because it performs uniform winding onto the bobbin. the traverse cam is the main part of the traverse mechanism. This paper proposes design method of the traverse cam using the relative velocity method [4,5]. The relative velocity method is used to calculate the relative velocity of the follower versus the cam at the center of roller, and then to determine the contact point using the geometric relationship and kinematical constraints. Finally, we present examples verifying the accuracy of the proposed methods.

Keywords: Twisting machine, Traverse cam, Design, Relative velocity

Introduction

The traverse system is very important device of the twisting machine. It makes winding yarn uniformly wound onto the bobbin without being repeated at the same position. There are various traverse systems the traverse cam system is commonly used. Its shape is simple and it has high performance. The design of the traverse cam is very important because the shape of winding onto bobbin is controlled by the traverse cam. If the traverse cam is not exactly designed, yarn has the problem to over-wind and collapse into bobbin.

The traverse cam shape is cylindrical. The cylindrical cam was studied by many researchers. The analytic method is studied by Phande [1], the vector analysis is studied by Kim [2] and the differential geometry method is studied by Yan [3].

In this paper, the traverse cam for twisting machine is designed by using the relative velocity method. This method [4,5] is used to solve many design problems and can exactly design the cam profile and clearer than other method. The relative velocity method is more clearer and easier than other shape design method. Most of shape design method used velocity. Some methods are used differential equations. And other methods are similar. The relative velocity method based on geometry condition. So, this method is more clearly and more easy.

In design procedure, first several local coordinates are defined. The velocities of cam and follower are represent in each coordinate system. Those velocities transforms to the a reference coordinate. And then, the relative velocity is calculated. The contact points are analysed using the relative velocity method. The CAD Program is developed by using the proposed method. Two types of traverse cam example is given to verify the proposed method.

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Traverse Cam

Figure 1 shows the traverse cam system. In the figure, the traverse cam is rotated in the constant speed rate and the yarn guide is moving right and left reciprocally by translating follower. Yarn is uniformly wound by yarn guide. Figure 1(a) shows the traverse cam system with single-groove and Figure 1(b) shows the traverse cam system with multi-groove.

Main part of traverse cam system is cylindrical cam with translating roller follower. Its shape is shown in Figure 2. In the figure, cam rotating axis and follower translating axis are parallel. The follower has the roller to be contacted at the cam. The cam is contacted at the roller of follower and its contact part is called rib. Shape of rib is called "groove".

Design of Traverse Cam Using Relative Velocity Method

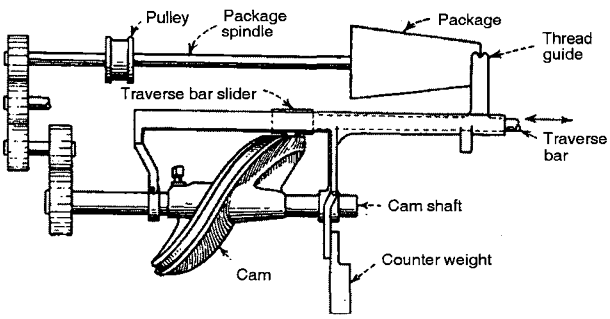
Relative Velocity Method

Relative velocity is the velocity of the object between two moving objects. They are parallel at point of contact in case that two objects contact [4,5]. If relative velocity and tangential line of contact point are not parallel in case that two objects are not meet or penetration.

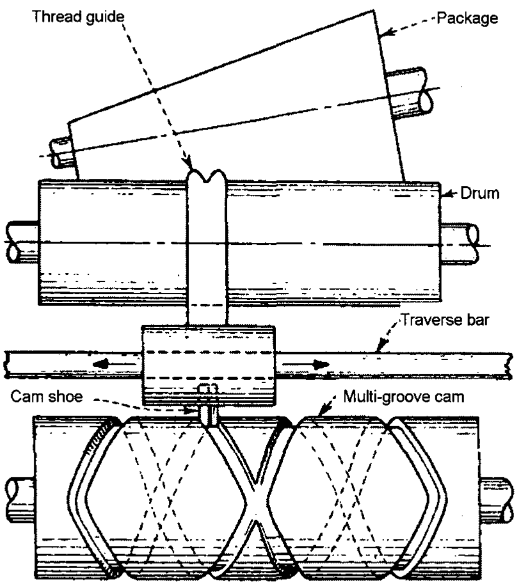
In the Figure 3, object 1 and object 2 are contacted. Object 1 has moving velocity V_1 and object 2 has moving velocity V_2. Relative velocity of two objects is shown in Figure 3. In the figure, $V_{2/1}$ is relative velocity of object 2 with respect to object 1. It presents moving direction and velocity of object 2 with respect to object 1. Therefore, the analysis of contact point is available because the tangential line of contact point and relative velocity object 1 and object 2 are positioned in parallel condition.

Coordinates Definition

Several local coordinates to cylindrical cam system with



(a) Single-groove cam type



(b) Multi-groove cam type

Figure 1. Mechanical traverse system [6].

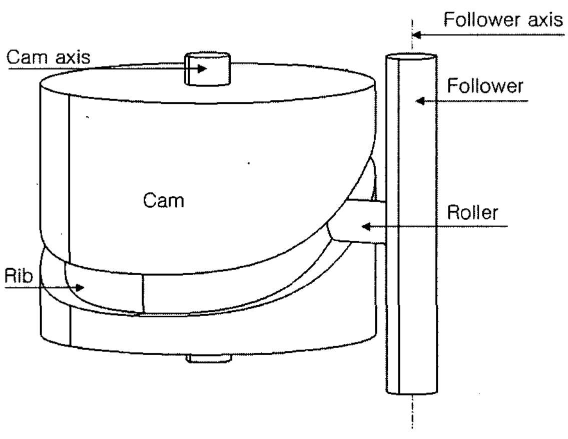


Figure 2. General feature of cylindrical cam and translation follower.

roller follower are defined. Local coordinates are used to define velocity of cam and follower according to each

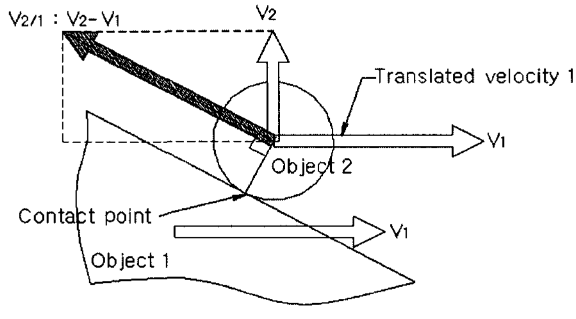


Figure 3. Relative velocity and contact points.

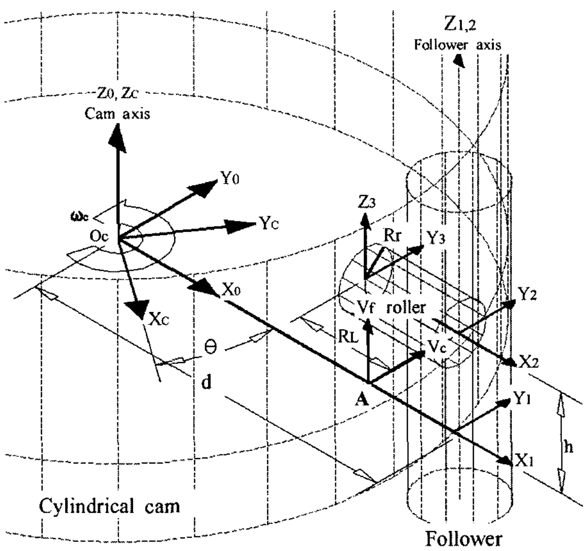


Figure 4. Coordinate systems and velocity of cylindrical cam and translating roller follower.

coordinate respectively. They are used to complete the shape of cam to analyze contact points.

In the Figure 4, O_C indicates the center of rotation of cam, θ_C indicates the distance from displacement of displacement curve to basic position of roller, ω_C indicates the rotational velocity of cam, d indicates the horizontal distance from center of cam to center of follower, h indicates the moving height from the vertical position of roller in given displacement diagram. R_L indicates the roller height of follower. R_r indicates the radius of roller.

Five local coordinates are defined. 0-coordinate are based coordinate. C-coordinates are rotated clockwise direction with rotating angle of cam from 0-coordinates. 1-coordinates are moved with the distance d to 0-coordinates. 2-coordinates are moved with the distance h from 1-coordinates. 3-coordinates are located at the end of roller and are moved in the distance - R_L. Equation (1) presents the transformation matrix from 0-coordinates to 3-coordinates and equation (2) is the transformation matrix from C-coordinates to 0-coordinates.

$$T_3^0 = \begin{bmatrix} 1 & 0 & 0 & d-R_l \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & h \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad (1)$$

$$T_0^C = \begin{bmatrix} \cos\theta_C & \sin\theta_C & 0 & 0 \\ -\sin\theta_C & \cos\theta_C & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad (2)$$

Profile Design Using Relative Velocity Method [4,5]

Cam velocity at point A is given in equation (3).

$$\begin{aligned} V_{Cx_0} &= V_{Cx_3} = 0 \\ V_{Cy_0} &= V_{Cy_3} = (d-R_l)\omega_C \\ V_{Cz_0} &= V_{Cz_3} = 0 \end{aligned} \quad (3)$$

Equation (3) based on 0-coordinates are transformed into 3-coordinates. Therefore, the result has the same one. If velocity of follower is expressed in 3-coordinates, the result is the same as equation (4).

$$\begin{aligned} V_{fx_3} &= 0 \\ V_{fy_3} &= 0 \\ V_{fz_3} &= v\omega_C \end{aligned} \quad (4)$$

where v is velocity of displacement diagram and ω_C is rotational velocity of cam. Equation (5) is derived by obtaining the relative velocity of follower with respect to cam by using equation (3) and equation (4). Directional angle of relative velocity is given as equation (6).

$$\begin{aligned} V_{f/c\,x_3} &= 0 \\ V_{f/c\,y_3} &= (R_l-d)\omega_C \\ V_{f/c\,z_3} &= v\omega_C \end{aligned} \quad (5)$$

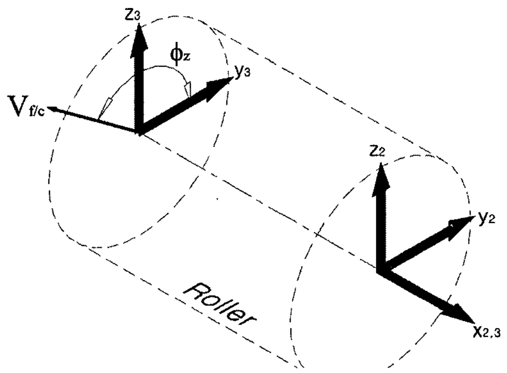


Figure 5. Directional angle and relative velocity.

$$\phi = \tan^{-1}\frac{V_{f/c\,z_3}}{V_{f/c\,y_3}} = \tan^{-1}\left(\frac{v}{R_l-d}\right) \quad (6)$$

As mentioned before, relative velocity and tangent line of contact point are parallel. Contact points are given in equation (7).

$$\begin{aligned} Q_{x_3} &= 0 \\ Q_{y_3} &= R_r\cos(\phi\pm 90^\circ) \\ Q_{z_3} &= R_r\sin(\phi\pm 90^\circ) \end{aligned} \quad (7)$$

In equation (7), "±" sign means that number of roller contact point is two. Base coordinates of equation (7) are 3-coordinates. Equation (3) transform 3-coordinates into 0-coordinates and transform to C-coordinates and then cam profile equations are completed. Therefore, the transformation, from 3-coordinates to 0-coordinates, is given by equation (8) and the transformation, from 3-coordinates to 0-coordinates, is given by equation (9). Equation (10) is obtained by substituting equation (7) into equation (8) and equation (11) is obtained by substituting equation (10) into equation (9). Finally, the profile equation is obtained as equation (11).

$$Q_0 = [T_3^0]^{-1}Q_3 \quad (8)$$

$$Q_C = T_0^C Q_0 \quad (9)$$

$$\begin{aligned} Q_{x_0} &= -(d-R_l) \\ Q_{y_0} &= R_r\cos(\phi\pm 90^\circ) \\ Q_{z_0} &= -h + R_r\sin(\phi\pm 90^\circ) \end{aligned} \quad (10)$$

$$\begin{aligned} Q_{x_C} &= Q_{x_0}\cos\theta_C + Q_{y_0}\sin\theta_C \\ Q_{y_C} &= -Q_{x_0}\sin\theta_C + Q_{y_0}\cos\theta_C \\ Q_{z_C} &= Q_{z_0} \end{aligned} \quad (11)$$

Traverse Cam Design Example

Example I : Single-Groove Type Traverse Cam

First example is the single-groove type of traverse cam.

Table 1. Data table of displacement curves for traverse cam

Section	Cam angle	Curve	Motion	Displacement
1	0 °~ 15 °	Curve (2-order polynomial)	Rise	5.9 mm
2	15 °~ 165 °	Line (1-order polynomial)	Rise	118.2 mm
3	165 °~ 180 °	Curve (2-order polynomial)	Rise	5.9 mm
4	180 °~ 195 °	Curve (2-order polynomial)	Return	5.9 mm
5	195 °~ 345 °	Line (1-order polynomial)	Return	118.2 mm
6	345 °~ 360 °	Curve (2-order polynomial)	Return	5.9 mm

Table 1 shows the displacement curve data for design. Table 2 shows the design data of traverse cam. The results of designed traverse cam are shown in Figure 6 and Figure 7.

Table 2. Design parameters of single-groove type of traverse cam

Item	Values
Cam radius	109
Cam height	180
Cam base height	10
Distance between cam axis and follower axis	119
Roller radius	15
Roller height	27
Rotational direction	CCW
Reciprocation motion	Reciprocation

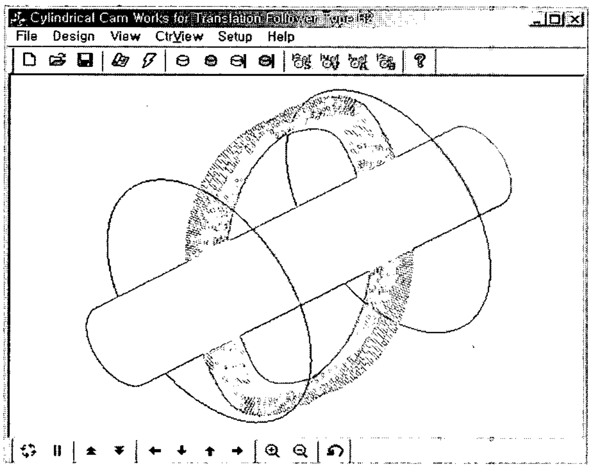


Figure 6. Designed shape of the single-groove type of traverse cam.

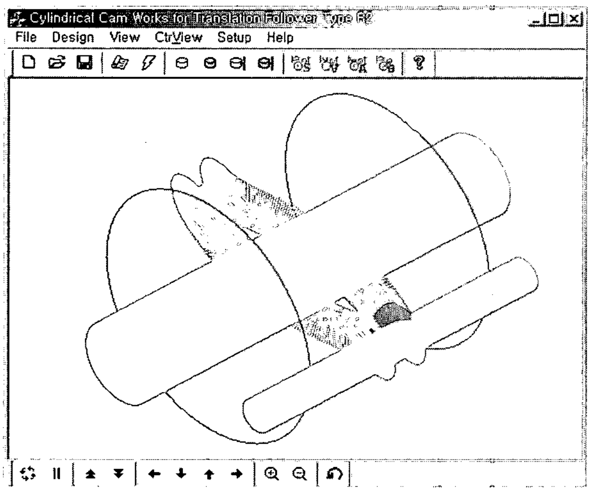


Figure 7. Simulation of the single-groove type of traverse cam system.

Figure 6 shows the cam shape, and Figure 7 shows the simulation of the shot of cam-follower.

Example II : Multi-Groove Type Traverse Cam

Second example is the multi-groove type of traverse cam. Table 3 shows the displacement curve data for design. Table 4 shows the design data of the traverse cam. The results of designed traverse cam are given in Figure 8 and Figure 9. Figure 8 shows the cam shape. Figure 9 shows the simulation of the cam-follower.

Table 3. Data table of displacement curves for multi-groove type of traverse cam

Section	Cam angle	Curve	Motion	Displacement
1	$0^{\circ}\sim 15^{\circ}$	Curve (2-order polynomial)	Rise	1.7 mm
2	$15^{\circ}\sim 705^{\circ}$	Line (1-order polynomial)	Rise	156.6 mm
3	$705^{\circ}\sim 720^{\circ}$	Curve (2-order polynomial)	Rise	1.7 mm
4	$720^{\circ}\sim 735^{\circ}$	Curve (2-order polynomial)	Return	1.7 mm
5	$735^{\circ}\sim 1425^{\circ}$	Line (1-order polynomial)	Return	156.6 mm
6	$1425^{\circ}\sim 1440^{\circ}$	Curve (2-order polynomial)	Return	1.7 mm

Table 4. Design parameters of multi-groove type of traverse cam

Item	Values
Cam radius	109
Cam height	230
Cam base height	20
Distance between cam axis and follower axis	119
Roller radius	15
Roller height	27
Rotational direction	CCW
Reciprocation motion	Reciprocation

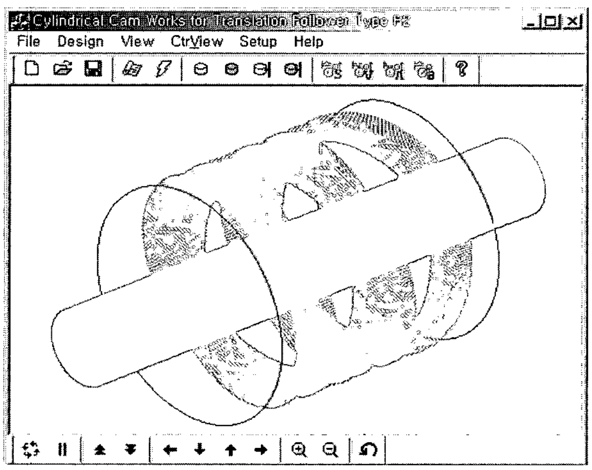


Figure 8. Designed shape of the multi-groove type of traverse cam.

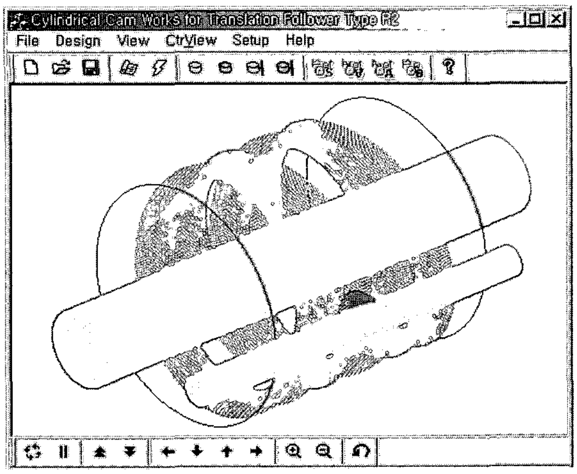


Figure 9. Simulation of the multi-groove type of traverse cam system.

Conclusion

In this paper, we researched the design method of traverse cam for twisting machine. The precise design of the traverse cam is required to improve the productivity and capability of the winding machine. We used the relative velocity method for precise design of traverse cam.

Several local coordinates are used to analyze the relative velocity and contact points. The design equation of traverse cam is derived after analysis steps of the relative velocity and contact points.

The simulation of two types of traverse cam is accomplished to verify the usefulness of the proposed design method and profile design equations.

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