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NOVEL METHOD OF REALIZING THE OPTIMAL TRANSMISSION OF THE CRANK-AND-ROCKER MECHANISM DESIGN

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Abstract: A novel method of realizing the optimal transmission of the crank-and-rocker mechanism is presented. The optimal combination design is made by finding the related optimal transmission parameters. The diagram of the optimal transmission is drawn. In the diagram, the relation among minimum transmission angle, the coefficient of travel speed variation, the oscillating angle of the rocker and the length of the bars is shown, concisely, conveniently and directly. The method possesses the main characteristic. That it is to achieve the optimal transmission parameters under the transmission angle by directly choosing in the diagram, according to the given requirements. The characteristics of the mechanical transmission can be improved to gain the optimal transmission effect by the method. Especially, the method is simple and convenient in practical use.
Key words: Crank-and-rocker mechanism Optimal transmission angle
Coefficient of travel speed variation

0 INTRODUCTION

By conventional method of the crank–and-rocker design, it is very difficult to realize the optimal combination between the various parameters for optimal transmission. The figure-table design method introduced in this paper can help achieve this goal. With given conditions, we can, by only consulting the designing figures and tables, get the relations between every parameter and another of the designed crank-and-rocker mechanism. Thus the optimal transmission can be realized.

The concerned designing theory and method, as well as the real cases of its application will be introduced later respectively.

1 ESTABLISHMENT OF DIAGRAM FOR OPTIMAL TRANSMISSION DESIGN

It is always one of the most important indexes that designers pursue to improve the efficiency and property of the transmission. The crank-and-rocker mechanism is widely used in the mechanical transmission. How to improve work ability and reduce unnecessary power losses is directly related to the coefficient of travel speed variation, the oscillating angle of the rocker and the ratio of the crank and rocker. The reasonable combination of these parameters takes an important effect on the efficiency and property of the mechanism, which mainly indicates in the evaluation of the minimum transmission angle.

The aim realizing the optimal transmission of the mechanism is how to find the maximum of the minimum transmission angle. The design parameters are reasonably combined by the method of lessening constraints gradually and optimizing separately. Consequently, the complete constraint field realizing the optimal transmission is established.

The following steps are taken in the usual design method. Firstly, the initial values of the length of rocker l_3 and the oscillating angle of rocker φ are given. Then the value of the coefficient of travel speed variation K is chosen in the permitted range. Meanwhile, the coordinate of the fixed hinge of crank A possibly realized is calculated corresponding to value K.

1.1 Length of bars of crank and rocker mechanism

As shown in Fig.1, left arc C_2G is the permitted field of point A. The coordinates of point A are chosen by small step from point C_2 to point G.

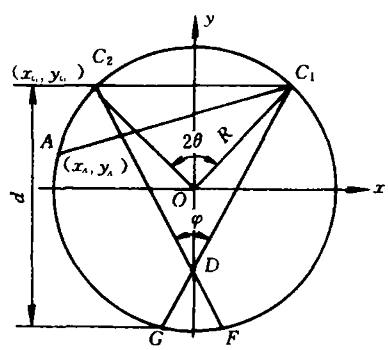

Fig.1 Position of point A

The coordinates of point A are

$$y_A = y_{C_2} - h_0 \tag{1}$$

$$x_A = \sqrt{R^2 - y_A^2} \tag{2}$$

where h_0, the step, is increased by small increment within range$(0,H)$. If the smaller the chosen step is, the higher the computational precision will be. R is the radius of the design circle. d is the distance from C_2 to G.

$$d = l_3 \cos\frac{\varphi}{2} + \left[2R\cos(\frac{\varphi}{2} - \theta) - l_3\right]\cos\frac{\varphi}{2} \tag{3}$$

Calculating the length of arc AC_1 and AC_2, the length of the bars of the mechanism corresponding to point A is obtained[1,2].

1.2 Minimum transmission angle γ_{min}

Minimum transmission angle γ_{min} (see Fig.2) is determined by the equations[3]

$$\cos\gamma_{min} = \frac{l_2^2 + l_3^2 - (l_4 - l_1)^2}{2l_2l_3} \tag{4}$$

$$\cos\gamma_{max} = \frac{l_2^2 + l_3^2 - (l_4 + l_1)^2}{2l_2l_3} \tag{5}$$

$$\gamma'_{min} = 180^\circ - \gamma_{max} \tag{6}$$

where l_1——Length of crank(mm)
l_2——Length of connecting bar(mm)
l_3——Length of rocker(mm)
l_4——Length of machine frame(mm)

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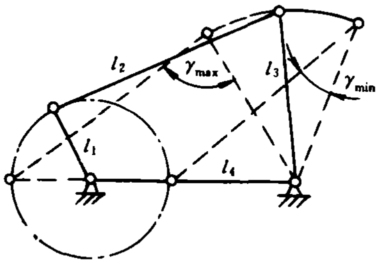

Fig.2 Position of minimum angle of transmission

Firstly, we choose minimum comparing γ_{min} with γ'_{min}. And then we record all values of γ_{min} greater than or equal to 40° and choose the maximum of them.

Secondly, we find the maximum of γ_{min} corresponding to any oscillating angle φ which is chosen by small step in the permitted rrange(maximum of γ_{min} is different with the coefficient of travel speed variation K).

Finally, we change the length of rocker l_3 by small step similarly. Thus we may obtain the maximum of γ_{min} corresponding to the different length of bars, different oscillating angle φ and the coefficient of travel speed variation K.

Fig.3 is accomplished from Table for the purpose of diagram design.

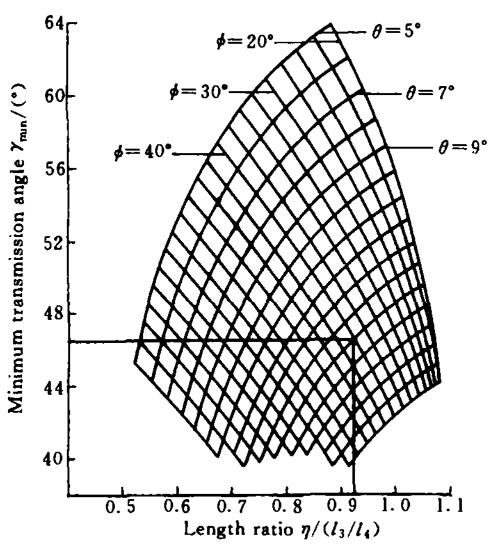

Fig.3 Figure of the optimal design

Table Part of computational value

		K=1.117(θ=10°)			
φ/(°)	γ_{min}/(°)	l_1/mm	l_2/mm	l_3/mm	l_4/mm
20	55.994 1	16.650 2	58.968 0	100.00	99.954 2
30	54.171 9	24.991 7	81.157 3	100.00	109.166 0
40	51.411 2	33.135 5	102.723 5	100.00	121.100 4
50	48.364 8	41.108 7	119.772 7	100.00	132.926 1
60	44.860 4	48.759 7	136.022 4	100.00	144.744 3
70	41.072 4	56.119 4	147.128 3	100.00	153.398 9

		K=1.182(θ=15°)			
φ/(°)	γ_{min}/(°)	l_1/mm	l_2/mm	l_3/mm	l_4/mm
20	49.607 2	16.417 4	46.347 8	100.00	94.742 4
30	48.615 8	24.390 8	70.674 7	100.00	99.558 8
40	46.539 3	32.449 5	89.018 7	100.00	107.797 3
50	44.092 4	40.377 6	103.799 6	100.00	116.955 4
60	41.071 4	47.981 6	117.871 3	100.00	126.222 6
70	<40				

It is worth pointing out that whatever the length of rocker l_3 is evaluated, the location that the maximum of γ_{min} arises is only related to the ratio of the length of rocker and the length of machine frame l_3/l_4, while independent of l_3.

2 DESIGN METHOD

2.1 Realizing the optimal transmission design given the coefficient of travel speed variation and the maximum oscillating angle of the rocker

The design procedure is as follows.

(1) According to given K and φ, taken account to the formula

$$\theta = \frac{K-1}{K+1}\times 180° \tag{7}$$

the extreme included angle θ is found. The corresponding ratio of the length of bars l_3/l_4 is obtained consulting Fig.3.

(2) Chosen the length of rocker l_3 according to the work requirement, the length of the machine frame is obtained from the ratio l_3/l_4.

(3) Choose the centre of fixed hinge D as the vertex arbitrarily, and plot an isosceles triangle, the side of which is equal to the length of rocker l_3(see Fig.4),and $\angle C_1DC_2=\varphi$. Then plot $C_2M\perp C_1C_2$, draw C_1N, and make angle $\angle C_2C_1N$=90° − θ. Thus the point of intersection of C_2M and C_1N is gained. Finally, draw the circumcircle of triangle $\triangle PC_1C_2$.

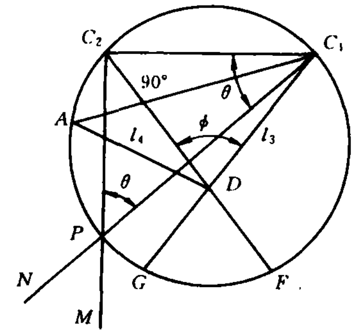

Fig.4 Case illustration

(4) Plot an arc with point D as the centre of the circle, l_4 as the radius. The arc intersections arc C_2G at point A. Point A is just the centre of the fixed hinge of the crank.

Therefore, from the length of the crank

$$l_1 = (AC_1 - AC_2)/2 \tag{8}$$

and the length of the connecting bar

$$l_2 = AC_1 - l_1 \tag{9}$$

we will obtain the crank and rocker mechanism consisted of l_1, l_2, l_3, and l_4. Thus the optimal transmission property is realized under given conditions.

2.2 Realizing the optimal transmission design given the length of the rocker (or the length of the machine frame) and the coefficient of travel speed variation

We take the following steps.

(1) The appropriate ratio of the bars l_3/l_4 can be chosen according to given K. Furthermore, we find the length of machine frame l_4(the length of rocker l_3).

(2) The corresponding oscillating angle of the rocker can be obtained consulting Fig.3. And we calculate the extreme included angle θ.

Then repeat (3) and (4) in section 2.1.

3 DESIGN EXAMPLE

The known conditions are that the coefficient of travel speed variation K=1.181 8 and maximum oscillating angle φ=40°. The crankandrocker mechanism realizing the optimal transmission is designed by the diagram solution method presented above.

First, with Eq.(7), we can calculate the extreme included an-

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gle θ=15° . Then, we find l_3/l_4=0.93 consulting Fig.3 according to the values of θ and φ.

If evaluate l_3 =50 mm, then we will obtain l_4=50/0.93= 53.76 mm.

Next, draw sketch(omitted).

As result, the length of bars is l_1=16 mm, l_2=46 mm, l_3=50 mm, l_4=53.76 mm.

The minimum transmission angle is

$$\gamma_{\min} = \arccos\frac{l_2^2 + l_3^2 - (l_4 - l_1^2)}{2l_2 l_3} = 46.369\ 8°$$

The results obtained by computer are l_1=16.222 7 mm, l_2=44.509 3 mm, l_3=50.000 0 mm, l_4=53.898 6 mm.

Provided that the figure design is carried under the condition of the Auto CAD circumstances, very precise design results can be achieved.

4 CONCLUSIOUS

A novel approach of diagram solution can realize the optimal transmission of the crank-and-rocker mechanism. The method is simple and convenient in the practical use. In conventional design of mechanism, taking 0.1 mm as the value of effective the precision of the component sizes will be enough.

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