文献翻译

英文原文：

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

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.

Keywords：Crank-and-rocker mechanism, Optimal transmission angle, Coefficient of travel speed variation

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.

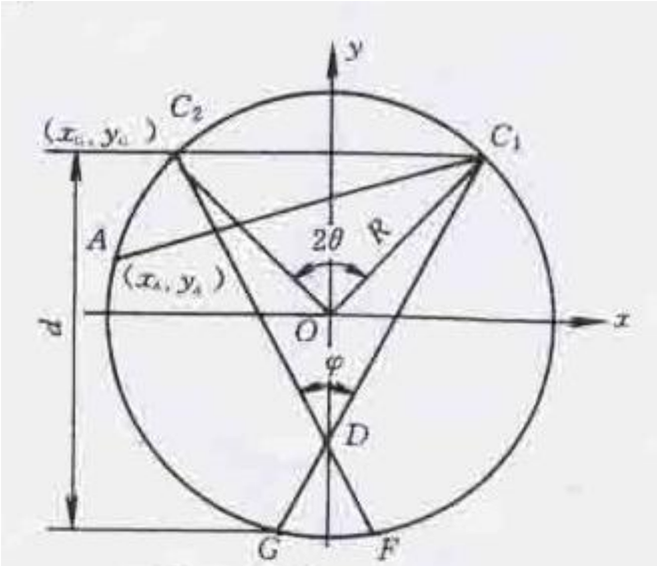

Fig.1 Position of point A

The coordinates of point A are

$$y_A = y_{C2} - h_0 \qquad (1)$$

$$x_A = \sqrt{R^2 - y_A^2} \qquad (2)$$

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.

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

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 $\gamma_{\min}$

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

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

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

$$\gamma'_{\min} = 180° - \gamma_{ma} \tag{6}$$

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)

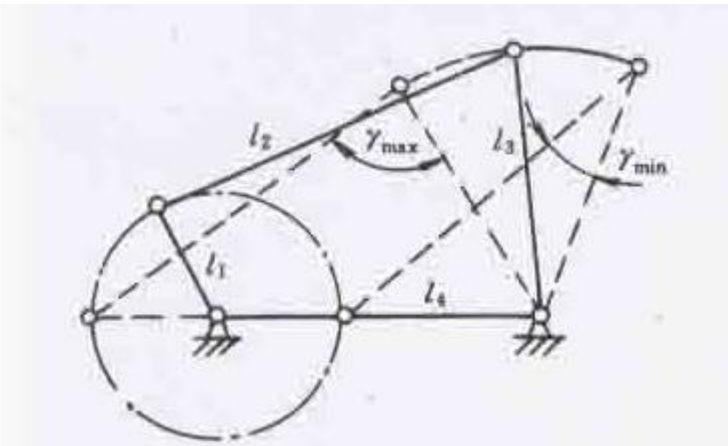

Fig.2 Position of minimum angle of transmission

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

Secondly, we find the maximum of $\gamma_{\min}$ corresponding to any oscillating angle φ which is chosen by small step in the permitted range (maximum of $\gamma_{\min}$ is different oscillating angle φ and 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 $\gamma_{\min}$ 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.

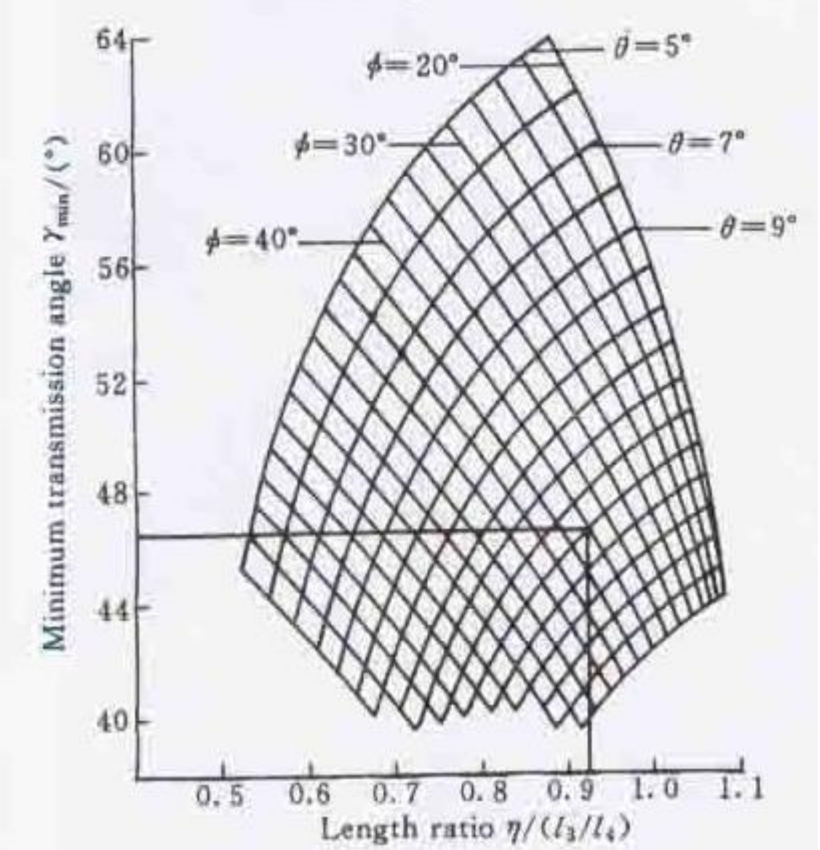

Fig.3 Figure of the optimal design

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 $\gamma_{\min}$ 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 the extreme included angle θ is found. The corresponding ratio of the length of bars l_3/l_4 is obtained consulting Fig.3.

$$\theta = \frac{K-1}{K+1} \times 180° \qquad (7)$$

(2) Choose 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

$\angle C_2C_1N = 90° - \theta$. Thus the point of intersection of C_2M and C_1N is gained.

Finally, draw the circumcircle of triangle ΔPC_1C_2.

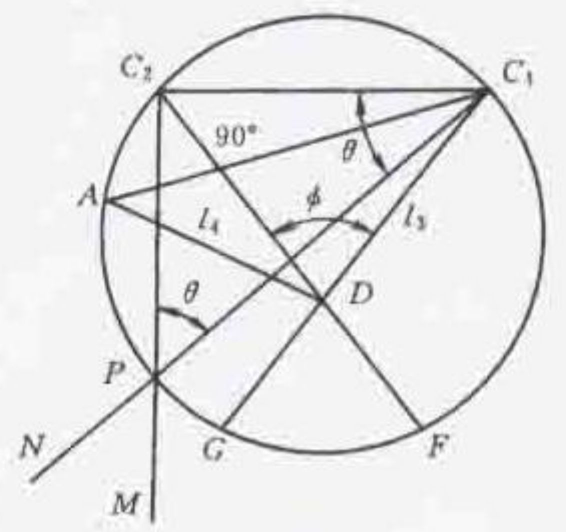

Fig.4 Case illustration

(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

$$l_1 = (AC_1 - AC_2)/2 \qquad (8)$$

and the length of the connecting bar

$$l_2 = AC_1 - l_1 \qquad (9)$$

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 $K = 1.1818$ and maximum oscillating angle $\varphi = 40°$. 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 angle $\theta = 15°$. 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

$$\gamma_{\min} = \arccos \frac{l_2^2 + l_3^2 - (l_4 - l_1^2)}{2 l_2 l_3} = 46.3698°$$

The results obtained by computer are $l_1 = 16.2227$ mm, $l_2 = 44.5093$ mm, $l_3 = 50.0000$ mm, $l_4 = 53.8986$ mm.

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

4. CONCLUSIONS

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.

译文：

认识曲柄摇臂机构设计的最优传动方法

摘要：一种曲柄摇臂机构设计的最优传动的方法被提出。这种优化组合设计被用来找出最优的传递参数。得出最优传递图。在图中，在极小的传动角度之间, 滑移速度变化系数，摇臂的摆动角度和杆的长度被直观地显示。 这是这种方法拥有的主要特征。根据指定的要求，它将传动角度之下的最优传动参数直接地表达在图上。通过这种方法，机械传动的特性能用以获取最优传动效果。特别是， 这种方法是简单和实用的。

关键字：曲柄摇臂机构　　最优传动角度　　滑移速度变化系数

0　介绍

由曲柄摇臂机构设计的常规方法, 在各种各样的参量之间很难找出优化组合的最优传动。通过本文介绍的图面设计方法可以帮助达到这个目的。在指定的情况下，通过观查设计图面, 我们就能得到每个参量和另外一个曲柄摇臂机构设计之间的联系。由因认识最优传动。

具体的设计的理论和方法， 以及它们各自的应用事例将在以下介绍。

1　优化传动设计的建立

优化传动的设计一直是设计师改进传输效率和追求产量的最重要的索引的当中一个。曲柄摇臂机构被广泛应用在机械传动中。如何改进工作效率和减少多余的功率损失直接地与滑移速度变化系数,摇臂的摆动角度和曲柄摇臂的比率有关系。这些参数的合理组合采用对机械效率和产量有重要作用, 这些主要体现在极小的传输角度上。

认识机械优化传动目的是找到极小的传输角度的最大值。设计参数是适度地减少限制而且分开的合理优化方法的结合。因此，完全限制领域的优化传动建立了。

以下步骤被采用在通常的设计方法。 首先，测量出摇臂的长度l_3和摇臂的摆动角度φ的初始值。 然后滑移速度变化系数K的值被定在允许的范围内。 同时，曲柄固定的铰接座标A可能被认为是任意值K。

1.1 曲柄摇臂机构杆的长度

由图 Fig.1，左弧C_2G是点A被允许的领域。点A的座标的选择从点C_2到点G。

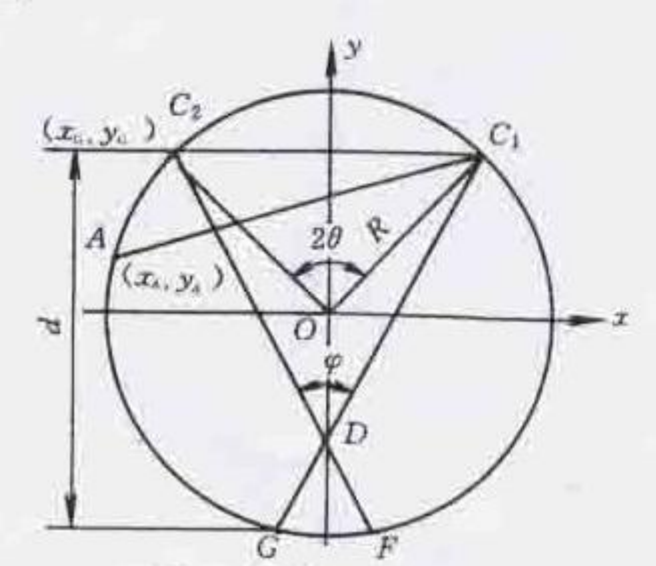

Fig.1 Position of point A

点A的座标是

$$y_A = y_{C_2} - h_0 \quad (1)$$

$$x_A = \sqrt{R^2 - y_A^2} \quad (2)$$

当h_0，高度，在 range(0 ，H) 被逐渐增加。如果选的越小,计算精度将越高。R是设计圆的半径。d是从C_2到G的距离。

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

计算弧AC_1和AC_2的长度，机械杆对应于点A的长度是 obtained[1,2] 。

1.2 极小的传动角度$\gamma_{\min}$

极小的传动角度$\gamma_{\min}$ (参见 Fig.2) 由 equations[3]确定

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

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

$$\gamma'_{\min} = 180° - \gamma_{\max} \quad (6)$$

由于 l_1 ——曲柄的长度(毫米)

l_2 ——连杆的长度（毫米）

l_3 ——摇臂的长度（毫米）

l_4 ——机器的长度（毫米）

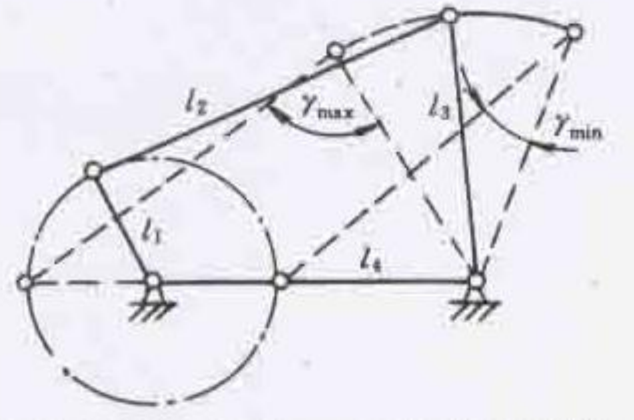

Fig.2 Position of minimum angle of transmission

首先，我们比较极小值 γ_{min} 和 γ'_{min} 。 并且我们记录所有 γ_{min} 的值大于或等于40°，然后选择他们之间的最大值。

第二，我们发现最大值 γ_{min} 对应于一个逐渐变小的范围的任一个摆动的角度 φ （最大值 γ_{min} 是不同于摆动的角度和滑移速度变化系数 K ）。

最后，我们相似地慢慢缩小摇臂 l_3 的长度。 因而我们能获得最大值 γ_{min} 对应于杆的不同长度，另外摆动的角度 φ 和滑移速度变化系数 K 。

Fig.3 成功的表达设计的目的。

它确定了无论是摇臂的长度 l_3 ,最大值 γ_{min} 出现的地点，只与摇臂的长度和机械的长度的比率 l_3/l_4 有关，当确定 l_3 时。

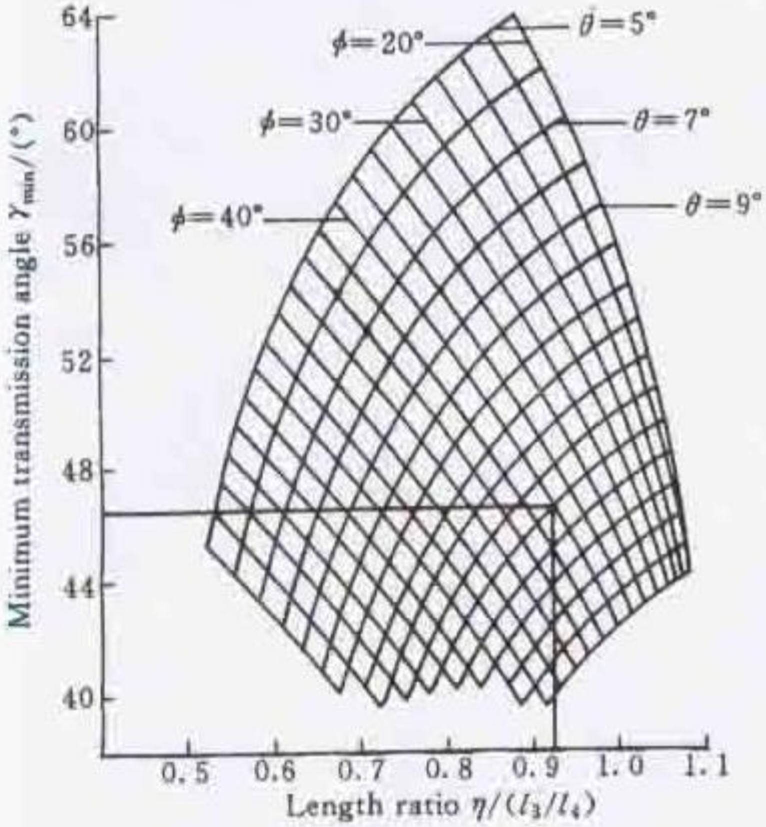

Fig.3 Figure of the optimal design

Table Part of computational value

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φ/(°)	γ_{min}/(°)	l_1/mm	l_2/mm	l_3/mm	l_4/mm
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60	41.071 4	47.981 6	117.871 3	100.00	126.222 6
70	<40				

2 设计方法

2.1 认识最优传动设计下滑移速度变化系数和摇臂的最大摆动的角度

设计步骤如下。

(1) 根据所给的 K 和 φ， 通常采取对发现极限角度 θ 的解释。 杆的长度的对应的比率 l_3/l_4 是从图 Fig.3 获得的 。

$$\theta = \frac{K-1}{K+1} \times 180° \qquad (7)$$

(2) 根据工作要求选择摇臂的长度 l_3， 机械的长度是从比率 l_3/l_4 获得的。

(3) 任意地选择固定的铰接的中心 D 作为端点，并且做一个等腰三角形,令一条边与摇臂的长度 l_3 相等 (参见 Fig.4)，令 $\angle C_1DC_2 = \varphi$。 然后做 $C_2M \perp C_1C_2$，连接 C_1N，并且做角度 $\angle C_2C_1N = 90° - \theta$。 因而增加了交点 C_2M 和 C_1N。 最后， 画三角形 ΔPC_1C_2。

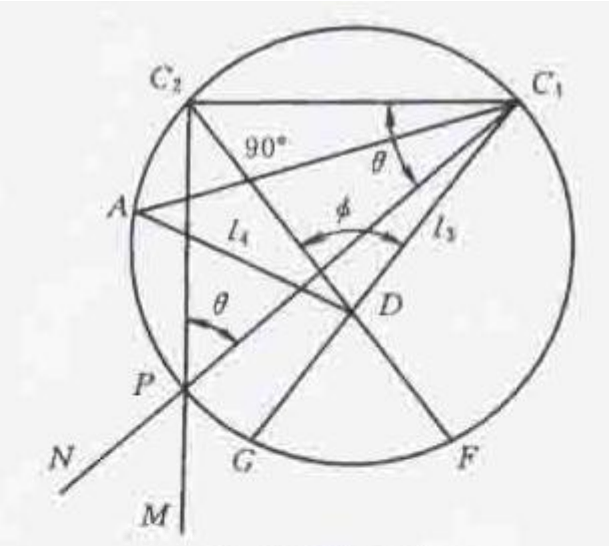

Fig.4 Case illustration

(4)以点 D 作为圆的中心，l_4 为半径画圆弧。 弧 C_2G 交点在 A 点。 点 A 是曲柄的固定铰接的中心。

所以, 从曲柄的长度

$$l_1 = (AC_1 - AC_2)/2 \qquad (8)$$

并且连杆的长度

$$l_2 = AC_1 - l_1 \qquad (9)$$

我们将获得曲柄摇臂机构包括l_1，l_2，l_3和l_4。因而优化传动加工会在指定的情况下进行。

2.2 认识优化传动设计下摇臂的长度(或机械的长度) 和滑移速度变化系数

我们采取以下步骤。

(1)根据选择的K确定杆的适当比率l_3/l_4。 此外，我们得出机械 l_4 (摇臂的长度l_3) 。

(2) 摇臂对应的摆动的角度可以从图 Fig.3 获得。 并且我们计算出极限角度。

然后根据 2.1 重覆(3) 和(4)

3 设计例子

已知的条件是, 滑移速度变化系数$K = 1.1818$和最大摆动角度$\varphi = 40°$。 提出曲柄摇臂机械优化传动图方法设计方案。

首先， 通过公式(7)，我们能计算出极限角度$\theta = 15°$。 然后，我们通过表格 Fig.3 查出$l_3 / l_4 = 0.93$以及θ和φ的值。

假设$l_3 = 50\,\text{mm}$, 然后我们将得出$l_4 = 50 / 0.93 = 53.76\,\text{mm}$。

然后, 做 sketch(omitted) 。

最后, 算出杆的长度分别是$l_1 = 16\ \ \text{mm}, l_2 = 46\ \ \text{mm}, l_3 = 50\ \ \text{mm}, l_4 = 53.76$ mm.

极小传动角度是

$$\gamma_{\min} = \arccos \frac{l_2^2 + l_3^2 - (l_4 - l_1^2)}{2 l_2 l_3} = 46.3698°$$

结果由计算可得$l_1 = 16.2227\ \ \text{mm}$， $l_2 = 44.5093\ \ \text{mm}$， $l_3 = 50.0000\ \ \text{mm}$，$l_4 = 53.8986\ \ \text{mm}$。

在运用 Auto CAD 制图设计的情况, 可达到非常精确设计结果。

4 结论

认识图解法解答曲柄摇臂机构的最优传动。这种方法是简单和实用的。通常在机械设计中, 将 0.1 毫米作为最小有效精度是足够的。