Motion Conversion with the Crank-Slider Mechanism regarding Transfer Quality (Part 2)

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Abstract. The paper demonstrates the use of a diagram for synthesis of the crank-slider mechanism, matching a given input angle and a desired output stroke, for the best possible transfer quality (transmission angle). The diagram is part of a new proposal of the German guideline VDI-2126 (1989). Examples concerning non-symmetric solutions – applicable to larger input angles - are presented that show the procedure to achieve sufficient transfer quality and to choose or avoid dead points. The transfer functions of the solutions of a typical example are drawn to discuss the various design options.

Key words: Dimension synthesis, Transmission angle, Space occupation, Dead point, VDI-2126.

1 Introduction

In [2] the development of the synthesis procedure of the mechanism has been described. The procedure is supported by a diagram, repeated here as Fig. 1, that provides a quick overview of the various design options of both symmetric and non-symmetric solutions. In case of larger input angles (angular stroke $\varphi_H > 180°$) only a non-symmetric solution can be applied. Because that part of the synthesis theory concerns a new proposal for [1], examples will be presented here to discuss this type of synthesis problem.

The diagram has been constructed such that a point (a value for the two parameters *e/r* and *b/r*) represents a mechanism solution. For a drawing of the mechanism and the explanation of parameters see [2]. The user can obtain the following information from the diagram:

- The smallest value of the transmission angle (lines $\mu_{\min}$),
- The occurrence of a dead point at start of the motion interval (line L_A),
- The occurrence of a dead point at the end of a given interval (line φ_M),
- The third parameter value *t/r* assuming optimum transmission angle,
- Relative size of the output stroke (line s_M, only valid for the case of a dead point at end).

Discussion on how to choose a point in the diagram will be done by means of examples (chapter 3). How to complete the synthesis procedure by determination of the mechanism dimensions will be explained first in chapter 2.

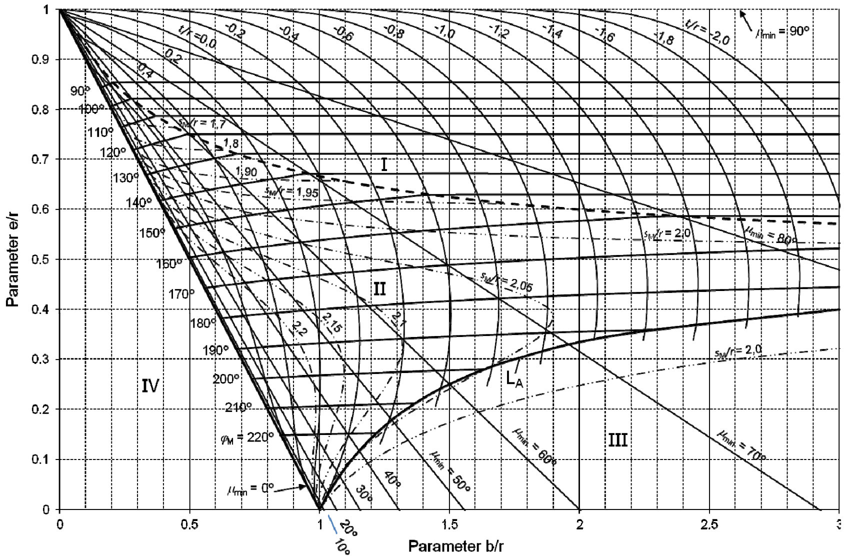

Fig. 1 Diagram

2 Calculation of the mechanism dimensions

The diagram of Fig. 1 concerns the synthesis parameters: the dimensions are taken relative to crank length *r*. When the two parameter *e/r* and *b/r* are known (chosen or calculated, guided by the diagram) the mechanism dimensions still need to be determined. This can be done with the Eqs (1-5) below that can be used in all situations. For explanation of the various parameters and angles see the figures in [2]. Instead of calculation with Eq. (4), the approximated value of parameter *t/r* can also be obtained from the diagram. The value of s_H/r can be obtained from the diagram only in case of a dead point at the end of the interval ($s_H = s_M$). Eq. (5) provides s_H in the general case.

$$\cos \mu_{\min} = \frac{1 - e/r}{b/r} \tag{1}$$

$$\cos\alpha = 2 \cdot e/r - 1 \tag{2}$$

$$\cos\mu_2 = \frac{\cos(\varphi_H - \alpha) - e/r}{b/r} \tag{3}$$

$$t/r = \sin\alpha - b/r \cdot \sin\mu_{\min} \tag{4}$$

$$s_H/r = \sin(\varphi_H - \alpha) - b/r \cdot \sin\mu_2 + t/r \tag{5}$$

The crank length *r* follows by dividing the given value of s_H and the result of Eq. (5), after which all other dimensions (*e*, *b* and *t*) are thus known.

3 Examples

A crank-slider mechanism has to be designed that, for a given input angle $\varphi_H = 200°$, shows a slider displacement $s_H = 1000$ mm. Four options will be considered:

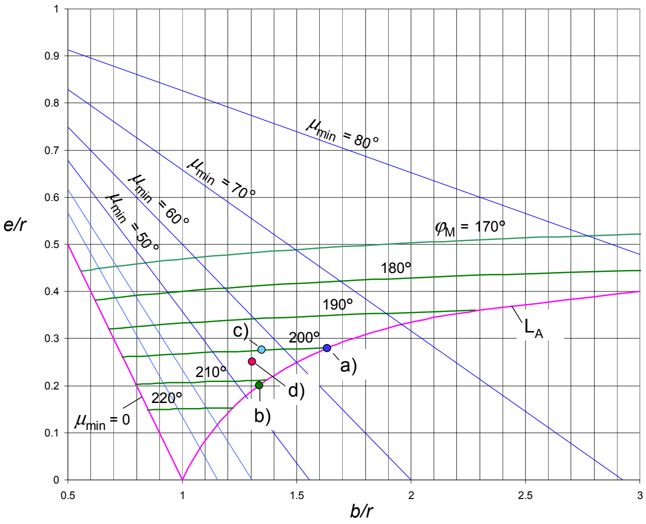

Fig. 2 Characteristic design solutions

a) With a dead point both at start and at end. In the diagram this concerns the intersection point of the lines $\varphi_M = 200°$ and L_A. The point is marked with character a) and a blue dot in Fig. 2, which is an outline of the diagram. Obviously this is the solution with the best possible μ_{min}–value. To find this point accurately Eq. (6) in [2] must be solved: $e/r = 0.2801$. Applying Eq. (4) in [2] yields $b/r = 1.6366$.

b) With a dead point at start only. This solution will exist for any point on the line L_A, where $\varphi_M > 200°$, for instance with a chosen value $e/r = 0.2$. That point is marked with character b) and a green dot in Fig. 2. Applying Eq. (4) in [2] yields $b/r = 1.3333$.

c) With a dead point at the end. Any point on the line $\varphi_M = 200°$ will have this property, like the one marked with character c) and a light blue dot in Fig. 2. The simplest way to determine the point precisely is by choosing the e/r value (although this choice is very sensitive). With $e/r = 0.275$ the b/r –value can be obtained with Eq. (9) from [2] and Eq. (2): $b/r = 1.3419$ The diagram shows clearly how much the μ_{min}–value will be reduced for any choice on that line.

d) With no dead point at all. Any point below the line $\varphi_M = 200°$ will do. The point marked with character d) and a red dot shows such a point. Now both parameters can be chosen, like for instance here $e/r = 0.25$ and $b/r = 1.3$.

Table 1 below shows the results of calculating the remaining parameters and intermediate results, Eqs. (1-5), followed by the mechanism dimensions.

Table 1. Calculated results of the examples

Quantity	Eq. nr	case a)	case b)	case c)	case d)
μ_{min}	(1)	63.9°	53.1°	57.3°	54.8
α	(2)	116.09°	126.87°	116.74°	120°
μ_2	(3)	83.9°	86.1°	83.3°	86.6
t/r	(4)	-0.5717	-0.2667	-0.2361	-0.1958
s_H/r	(5)	2.05	2.0206	2.09	2.0868
r		487.8 mm	494.9 mm	478.6 mm	479.2 mm
b		798.4 mm	659.9 mm	642.2 mm	623.0 mm
e		136.6 mm	99.0 mm	131.6 mm	119.8 mm
t		-278.9 mm	-132.0 mm	-113.0 mm	-93.8 mm

4 Analysis of results

The transfer functions of the sample mechanisms as calculated in the previous chapter have been drawn using a proven numerical method for kinematic analysis [3]. Fig. 3 shows the transfer functions and Fig. 4 the first derivatives (transfer functions of order one). These figures show the effect of the chosen design options. Especially in Fig. 4 it is clear where the dead points occur: the start value or the end value of the function will then be zero. Mechanisms a) and b) have a dead point at start, mechanisms a) and c) have a dead point at the end of the motion.

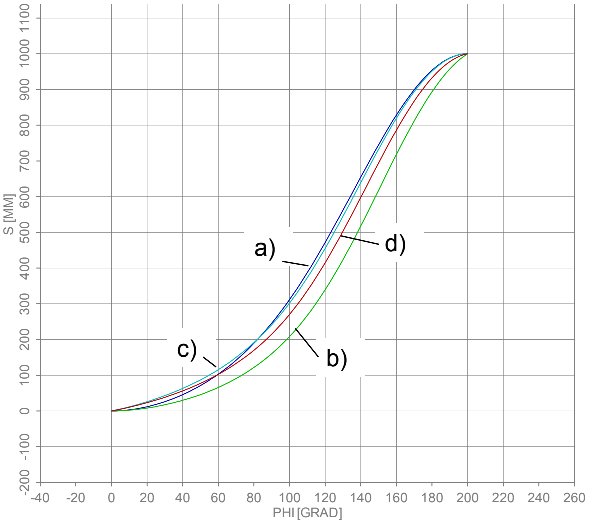

Fig. 3 Transfer functions (order 0)

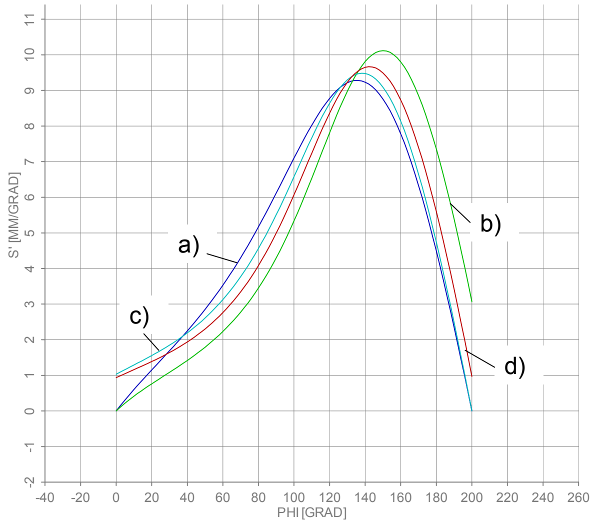

Fig. 4 Transfer functions (1st order)

5 Conclusions

To demonstrate the use of a newly developed diagram for synthesis of the crank-slider mechanism several examples have been worked out. They show that the problem of matching larger input angles and desired output strokes can adequately be solved with so-called non-symmetric solutions. The examples show pretty good transfer quality ($\mu_{\min}$ is 53° or better) and dead points can be included or not. Synthesis parameters can be estimated with the diagram or they can be calculated using mostly simple formulas. The mechanism dimensions follow then by scaling the parameters such that the demanded output stroke will be generated.
The examples confirm that the new synthesis procedure works well and that the current VDI-guideline can be improved indeed.

6 References

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