J. Indian Inst. Sci., 66, Apr. 1986, pp. 247–252

Planar slider-crank mechanisms adjustable for prescribed dead-center positions*

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Abstract

The utility of planar slider-crank mechanisms can be greatly enhanced if they are made adjustable for different time ratios and length of strokes of the slider. Three problems of adjustable slider-crank mechanism are discussed. The region in which best transmission characteristics are obtained has been determined. The procedures outlined are of direct utility to the designer.

Key words: Mechanisms, kinematics, slider crank, adjustability, time ratio, transmission criterion.

1. Introduction

The centric slider crank executes the forward and return strokes with equal timings as opposed to the offset slider-crank mechanism. The offset slider crank is used in mechanisms where working stroke is to be slower than the faster return stroke or *vice versa*. Figure 1 shows the dead-center positions of the offset slider-crank mechanism. The angle θ_{12} of crank A_0A corresponds to the motion of the slider B from the inner dead center position B_1 to the outer dead center position B_2, the length B_1B_2 being S_{12}, the stroke of the slider. For prescribed dead center positions slider-crank mechanisms can be synthesized using the procedures in Tao[1], Hain[2] and Bagci[3]. A similar approach is adopted here for adjustable slider-crank mechanisms, an area which has not received much attention in recent years. A literature survey[4] indicates that no work has been carried out on planar adjustable slider-crank mechanisms which have applications in bottling plants and presses[5].

2. Synthesis

Case 1

It is required to synthesize an offset slider-crank mechanism for a specific time ratio T_r and stroke S_{12} for the original device and the same time ratio T_r but a different stroke S'_{12} for the adjusted device.

The time ratio T_r is defined as

* First presented at the National Conference on Machines and Mechanisms held at the Indian Institute of Science, Bangalore, during February 19–21, 1985.

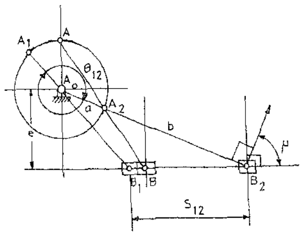

FIG. 1. Two dead-centei positions of slider-crank mechanism.

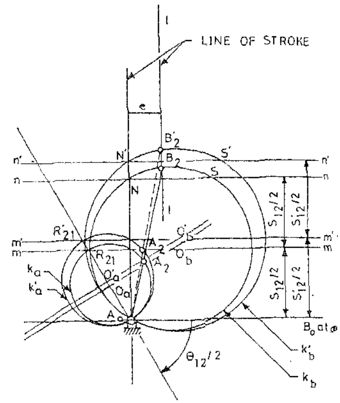

FIG. 2. Adjustment A.

$$T_r = \frac{\text{Input crank rotation for forward stroke}}{\text{Input crank rotation for return stroke}} = \frac{\theta_{12}}{360 - \theta_{12}}$$

$$i.e.\ \theta_{12} = \frac{360\ T_r}{T_r + 1}$$

The relative pole R_{21} and circles k_a and k_b are determined (fig. 2) corresponding to the time ratio T_r and stroke S_{12} $(=B_1B_2)$ using the procedure in Tao[1].

Keeping point A_0 and line A_0B_0 fixed the above procedure is repeated to determine the relative pole R'_{21} and circles k'_a and k'_b corresponding to the time ratio T_r same as earlier and a new stroke S'_{12} $(=B'_1B'_2)$.

Sectors NS and $N'S'$ of the circles k_b and k'_b are loci of the slider pivot B in original and adjusted position respectively[1]. Out of the three link lengths of the offset slider-crank mechanism (namely the input crank A_0A, connecting rod AB and offset e), any one length can be specified and held constant with the other two being varied to attain the adjusted device. Three types of adjustments are as a consequence possible.

Adjustment A: Offset e constant (fig. 2)

Draw line l–l parallel to the required direction of motion of slider and at the specified constant distance e from A_0. Line l–l intersects sectors $N'S'$ and NS at points B'_2 and B_2.

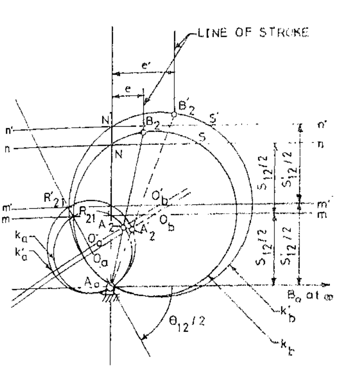

FIG. 3. Adjustment B.

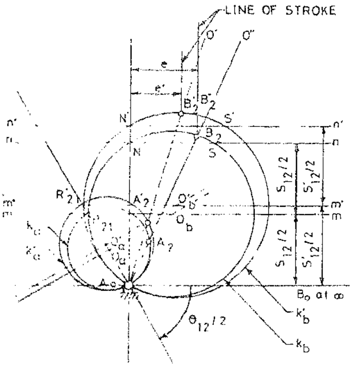

FIG. 4. Adjustment C.

Join $B_2'A_0$ and B_2A_0 to intersect circles k_a' and k_a in points A_2' and A_2 respectively. Linkages $A_0A_2B_2$ and $A_0A_2'B_2'$ are the required solutions to the problem.

Adjustment B: Input crank length A_0A constant (fig. 3)

With center A_0 and radius equal to specified crank length A_0A draw a circular arc intersecting k_a and k_a' in points A_2 and A_2'. The lines A_0A_2 and A_0A_2' or their extensions intersect sectors NS and $N'S'$ in points B_2 and B_2' respectively. Linkages $A_0A_2B_2$ and $A_0A_2'B_2'$ are the required linkages.

Adjustment C: Connecting rod length AB constant (fig. 4)

Draw rays A_0O', A_0O'', etc., through point A_0 at any regular angle from A_0N' to intersect, sector $N'S'$ in points B_2', B_2'', etc., and circles k_a' and K_a in points A_2' and A_2, etc. Select any mechanism whose connecting rod length in original and adjusted positions (A_2B_2 and $A_2'B_2'$) matches the specified one. Figure 4 shows the solution of the problem which has been arrived at after many trials.

The graphical synthesis method discussed above can be applied to two more cases as follows.

Case 2

It is required to synthesize a slider-crank mechanism for time ratio T_r and stroke S_{12} which could after adjustment provide a new time ratio T_r' but the same stroke S_{12}.

Referring to fig. 5, relative poles R_{21} and R'_{21}, circles k_a, k'_a and k_b, k'_b corresponding to time ratios T_r and T'_r and constant stroke S_{12} are determined. The sectors NS and $N'S'$ are the loci of B and B' (the slider pivot B) for the original and adjusted linkages respectively. Further steps are along the graphical synthesis procedure explained in Case 1, which can now be applied for adjustments to either crank, offset or connecting rod.

Case 3

It is required to synthesize an offset slider-crank mechanism for time ratio T_r and stroke S_{12} which could after adjustment provide a new time ratio T'_r and a new stroke S'_{12}.

Referring to fig. 6, relative poles R_{21} and R'_{21}, circles k_a, k'_a and k_b, k'_b corresponding to time ratios T_r, T'_r and strokes S_{12}, S'_{12} respectively are determined. As explained in Case 2, the sectors NS and $N'S'$ are the loci of B and B' (the slider pivot B) for the original and adjusted linkages respectively. The graphical synthesis procedure explained in Case 1 can now be applied for the three different types of adjustments keeping one link length constant at a time.

3. Transmission angle

So far we have discussed the general procedure for synthesis of the adjustable slider-crank mechanisms. It is well known that the transmission angle is an important criterion and its minimum and maximum values form the basis for the final selection of a given mechanism from the numerous solutions available. The transmission angle μ with the crank as input is measured as shown in fig. 1 and it should be maintained within

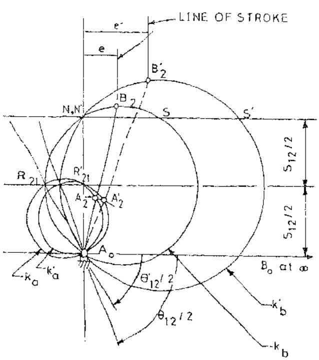

FIG. 5. Case 2.

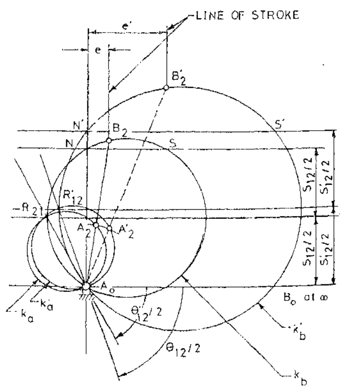

FIG. 6. Case 3.

reasonable limits of $90 \pm \delta$ both for the original and adjusted linkage and throughout the rotation of the input crank.

As shown in fig. 7 for Case 1, after constructing circles k_a and k'_a and sectors NS and $N'S'$, choose a few positions B at regular angular intervals ψ from the line A_0N'. Construct the corresponding linkages and measure minimum (μ_{min}) and maximum (μ_{max}) values of the transmission angle that they experience. Figure 8 shows the plot of μ_{min} and μ_{max} against angle ψ. Figure 8 drawn for various time ratios from 0.64 to 0.8 is valid for any stroke. The geometrical construction reveals that for different stroke lengths the size of circles k_a and k_b increase proportionately. Hence for any given time ratio and a given ψ the values of μ_{min} and μ_{max} are independent of the stroke.

Note that the value μ_{min} increases with increase in time ratio T_r. Further if one were to set the limit on μ as $90 \pm \delta$ and if $\delta = 45°$ can be tolerated then it is noticed that the time ratio of both original and adjusted mechanism should be restricted to above 0.8. Further the synthesis is to be carried out with ψ lying in a small range midway between 5° and 25° both for the original as well as the adjusted device. This ensures that the value of μ_{min} is above 45°. It may be noted from fig. 8 that the value of μ_{max} is always reasonably close to 90°. A designer can vary the dimensions of the linkages in the region shown shaded in fig. 8 in order to ensure a reasonable μ_{min}. This applies to both the original and the adjusted linkages.

4. Conclusion

Synthesis procedures have been presented for adjustable slider-crank mechanisms for different time ratios and constant strokes, constant time ratios and different strokes as

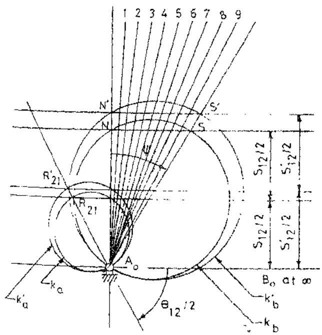

FIG. 7.

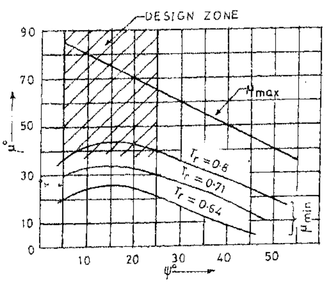

FIG. 8.

well as for both different time ratios and different strokes. The method yields a design zone in which mechanisms selected for adjustability experience desired minimum transmission angles leading to practical solution to the problem.

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