ROLLER-CHAIN MECHANISMS, PART I: GENERAL CONCEPT

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ABSTRACT

A new concept of mechanisms is introduced using combination of flexible and rigid links. It is possible to construct groups of mechanisms to achieve a variety of motions such as intermittent, reverse, continuous, oscillatory or combination of them.

INTRODUCTION

Plane mechanisms consisting of rigid links are used to achieve certain output motions. Variety of motions are obtained by using simple chains consisting of links and four joints. For example oscillatory motion (four bar crank-rocker mechanism), reciprocating motion (crank-slider mechanism), quick return motion (crank-slotted-lever mechanism), intermittent motion (Geneva and ratchet mechanisms) [1]. In addition, certain complex motions may be obtained by incorporating mechanisms consisting of combinations of simple chains. For example function generation with two variables [2], polynomial displacements and/or velocity characteristics [3]. Flexible elements are used up till now for motion transmission; e.g. belt drives, rope drums and chain-sprocket drives.

There is no real attempt to use them as active parts for motion generation. The only application was by Rankers [4]. He suggested a mechanism consisting of a toothed belt combined with a geared slider-crank mechanism carrying a pinion to produce continuous belt motion with temporary stops. Also, Ref. [5] can be consulted.

The objective of this work is to introduce the idea of constructing mechanisms using flexible links combined with rigid links. The flexible element is mainly a roller-chain-sprocket drive. Belt-pulley drives may be used.

THE SUGGESTED MECHANISM

The mechanism, Figure (1), consists of a number of sprockets n (≥ 2) placed in a general orientation provides the input motion. The output motion is obtained through a crank of length R and a coupler of length L. The crank shaft is located at an arbitrary point Q. The coupler is jointed to the chain at some point B.

ANALYSIS OF MOTION

Position Analysis

The path of joint B consists of regions of straight and a circular portions. Consider a region between two adjacent sprockets, say number i and i + 1. It consists of a straight portion from point I to II, and a circular portion from II to III. It is worth noting that the motion during the straight portion is equivalent to a slider-crank mechanism, Figure (2-A), and during the circular portion is equivalent to a four-bar mechanism, Figure (2-B).

Input Motion

The displacement S of joint B, is related to the uniform angular displacement of the driving sprocket, θ_1 and is given by:

For the straight portion (I - II), the linear displacement, S, is:

$$S = r_1 \theta_1 \qquad (1)$$

For the circular portion (II - III), the angular displacement of either sprocket (i + 1) or joint B is given by:

$$\theta_{i+1} = r_1 \bullet \theta_1 / r_{i+1} \qquad (2)$$

The vector equations representing the position of the system are given by the complex number form as:

i) For straight portion i.e. $0 \le \theta_1 \le \gamma_s$

$$R\, e^{j\phi} + L\, e^{j\theta}{}_1 = L_i\, e^{j\alpha}{}_i + r_i\, e^{i\phi}{}_i + S\, e^{j\psi}{}_i \qquad (3)$$

The imaginary and real parts of this equation are:

$$R\sin\phi + L\sin\theta_1 = L_i\sin\alpha_i + r_i\sin\phi_i + S\sin\psi_i$$
and
$$R\cos\phi + L\cos\theta_1 = L_i\cos\alpha_i + r_i\cos\phi_i + S\cos\psi_i \qquad (4)$$

ii) For circular portion i.e. $0 \le \theta_1 \le \gamma_c$

$$R\,e^{j\phi} + L\,e^{j\theta}{}_1 = L_{i+1}\,e^{j\alpha}{}_{i+1} + r_{i+1}\,e^{j\varepsilon}{}_{i+1} \qquad (5)$$

The two parts of this equation are:

$$R\sin\phi + L\sin\theta_1 = L_{i+1}\sin\alpha_{i+1} + r_{i+1}\sin\varepsilon_{i+1}$$
and
$$R\cos\phi + L\cos\theta_1 = L_{i+1}\cos\alpha_{i+1} + r_{i+1}\cos\varepsilon_{i+1} \qquad (6)$$

Where γ_s and γ_c: Total angular displacements which are corresponding to the straight and circular portions respectively.

L_i, α_i, ϕ_i, ..., γ_s, γ_c : Parameters can be estimated from the geometry of the mechanism, Figure (1).

From equations (4) and (6), it is possible to obtain two equations for ϕ as a function of θ_1. The first corresponds to the motion over the straight portion, while the other corresponds to the motion over the circular portion.

The value of ϕ, over a complete cycle of joint B, θ_d, is obtained by adding the response of the consequent regions of other two adjacent sprockets.

The complete kinematic analysis and constraint equations will be given in next part of this work.

POSSIBLE OUTPUT MOTIONS

Several output motions can be obtained by applying certain constraints on the configuration of the system. For the purpose of demonstration some examples are introduced. However, a complete analysis and/or synthesis for each group will be presented in details in successive parts.

Intermittent Motions

A dwell motion, Figure (3), of the output link can be obtained if its length R is equal to the distance L_1, distance between its centre Q and the centre of a sprocket O_1, and the coupler length L is equal to the radius of this sprocket r_1.

For example if n = 2, r_1 = L = 30, r_2 = 20, R = L_1 41.2, x_1 = 40, X_2 = 20, Y_1 = Y_2 = 10, L_2 = 23mm, = 22.5° (0.125π), α_2 = 145° (0.8π).

Continuous Motions

This motion can be obtained if n = 2, r_1 = r_2 = 20, = R = L_1 = L_2 = X_1 = X_2 = 30mm, Y_1 = Y_2 = 0, = 0, α_2 = 180 (π), as shown in Figure (4).

Reverse Motions

If n = 2, r_1 = 20, r_1 = 20, r_2 = 30, L_1 = X_1 = 100, = 80, R = 60, L_2 = X_2 = 0mm, α_1 = α_2 = 0°, continuous motion with a reverse period, Figure (5), obtained.

Oscillatory Motion

If n = 2, r_1 = r_2 = 20, L = R = 40, L_1 = 57, X_1 = 50, X_2 = 10, L_2 = 31, Y_1 = Y_2 = 30mm, α_1 = 50° (0.277π),
α_2 = 102° (0.57π), an oscillatory motion is obtained, Figure (6).

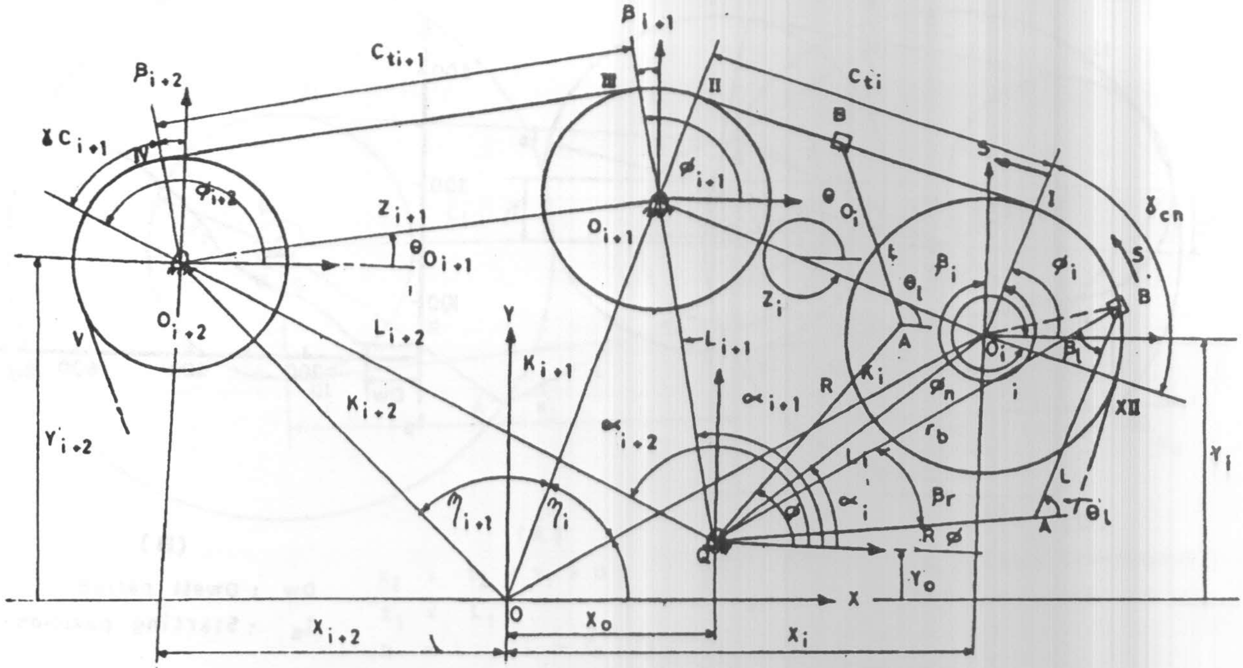
Combinations of Motions

It is possible to construct a roller-chain mechanism which gives a combination of the previous motions. For example, intermittent-reverse motion, Figure (7), is possible, if n = 2, r_1 = 30, r_2 = 20, L = r_1, R = 35, L_1 = X_1 = 35, L_2 = X_2 = 45, Y_1 = Y_2 = 0mm, α_1 = 0, α_2 = 180 (π).

It can be concluded that in order to avoid locking, branching and interference problems, as well as to insure obtaining the desired motion, the above analysis for each group has restrictions and limitations for the configuration and the parameters of the system. This is the scope of the successive parts of this work.

CONCLUSION

This work has shown that roller-chain mechanisms have great potentiality in the field of theory of machines. They may be used as an effective tool for solving complex motion requirements. In addition, they can be used as an effective way for function generation.



Flexible system with Multi - sprockets combined with crank R and coupler L .

Figure 1.

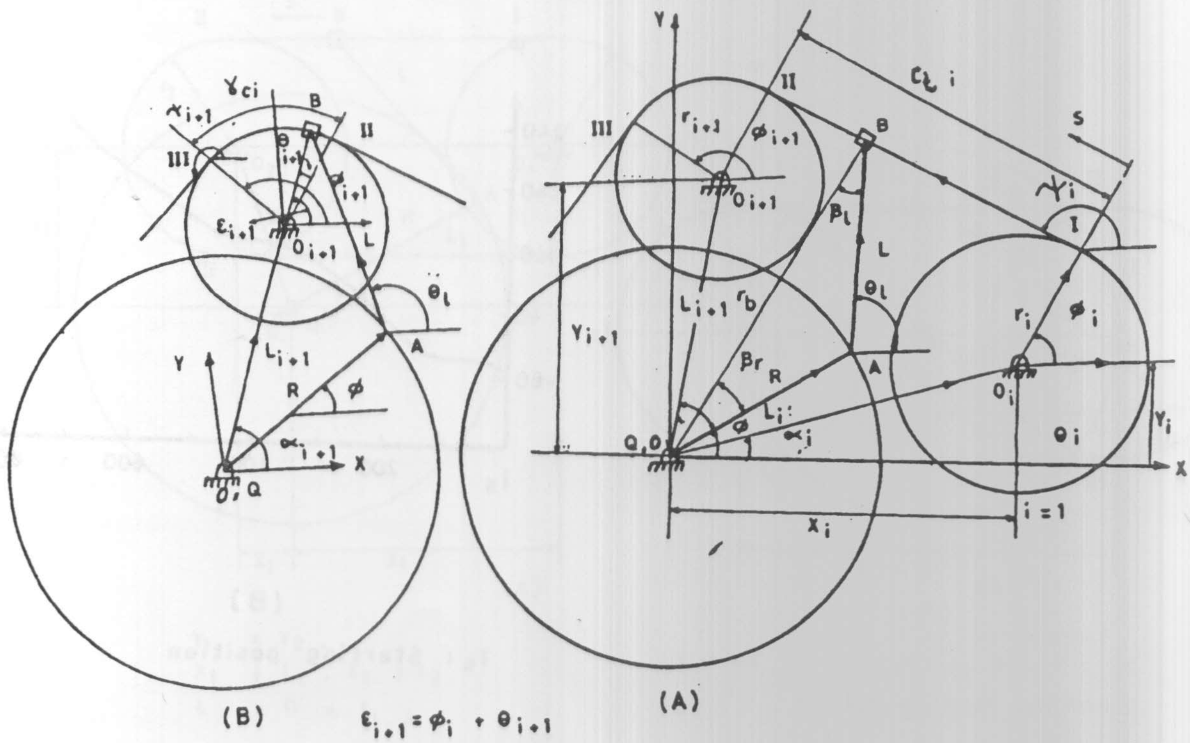


Figure 2.

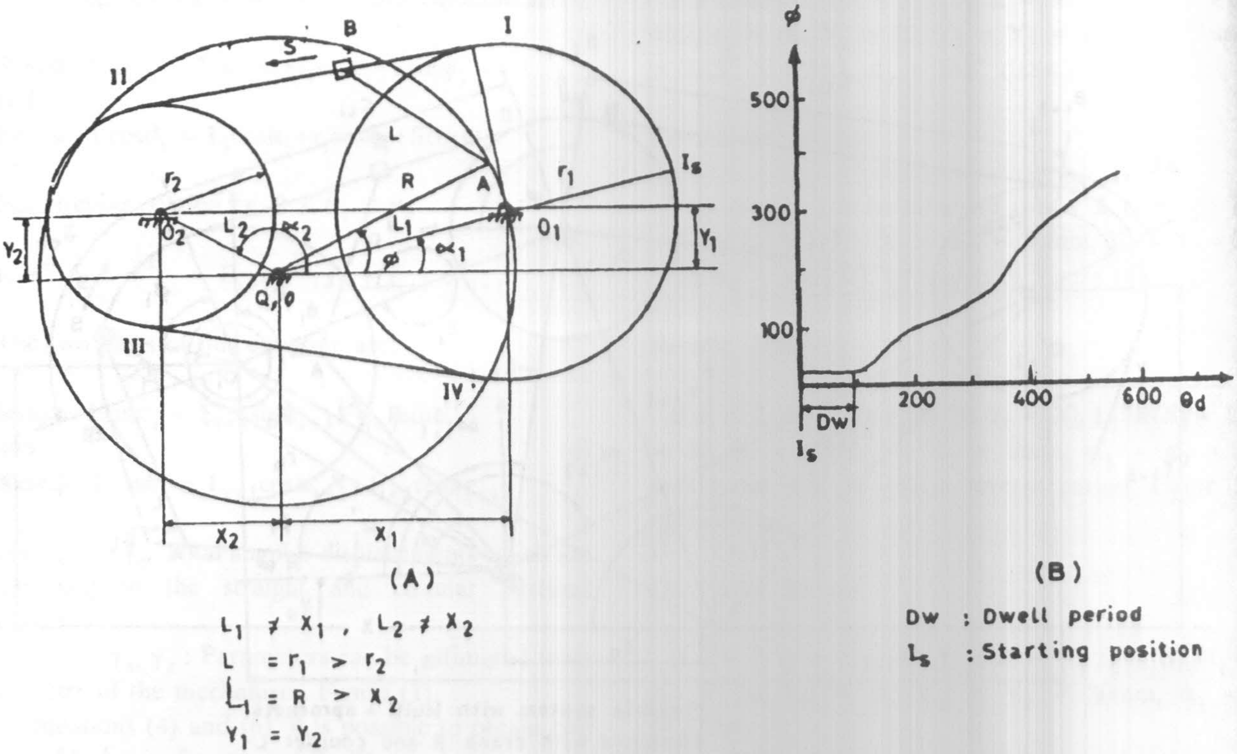


Figure 3.

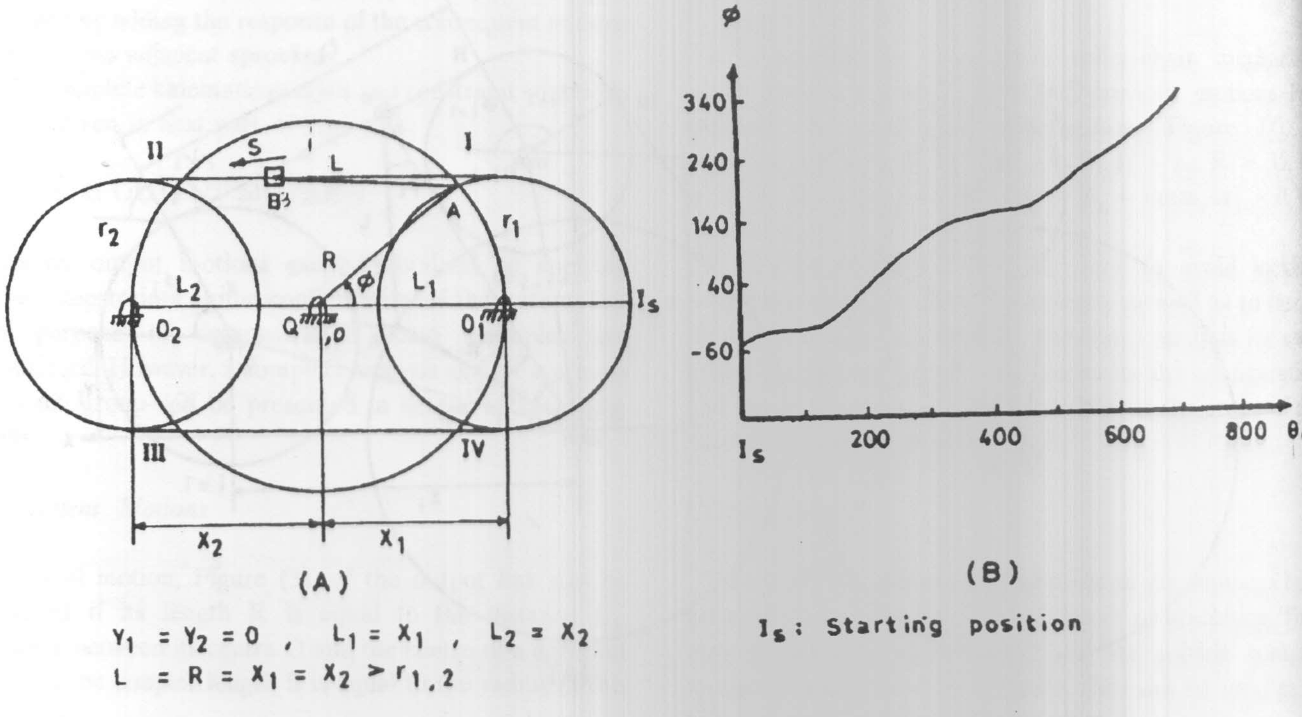


Figure 4.

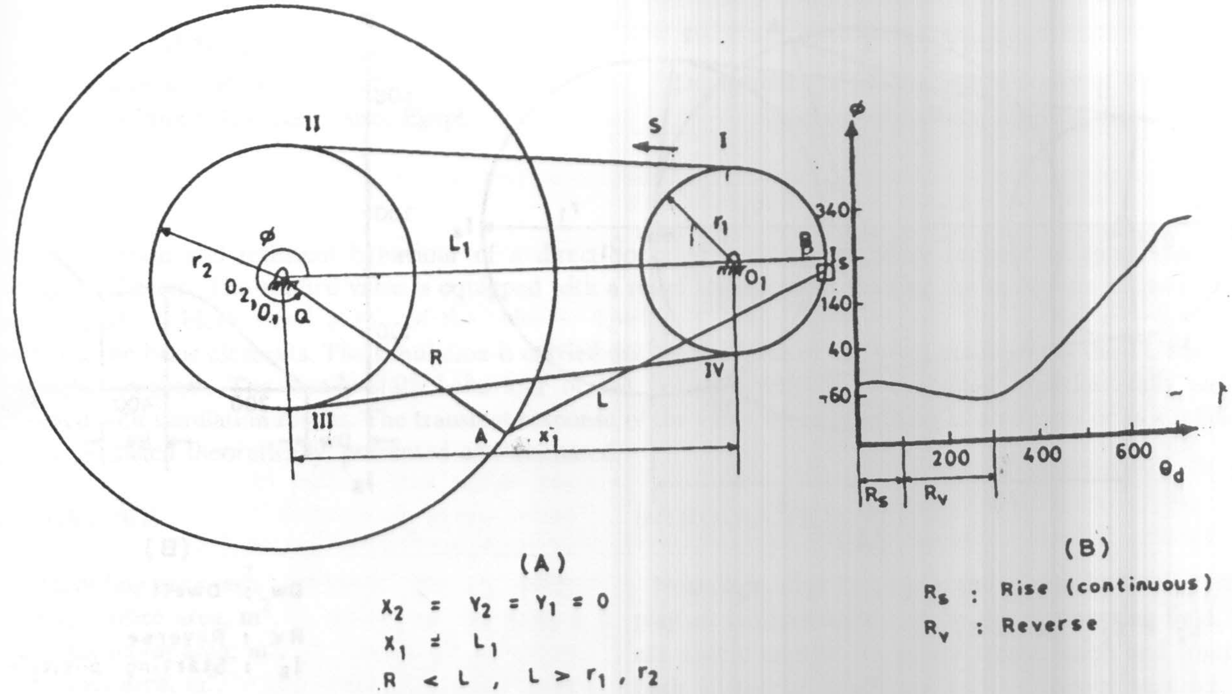


Figure 5.

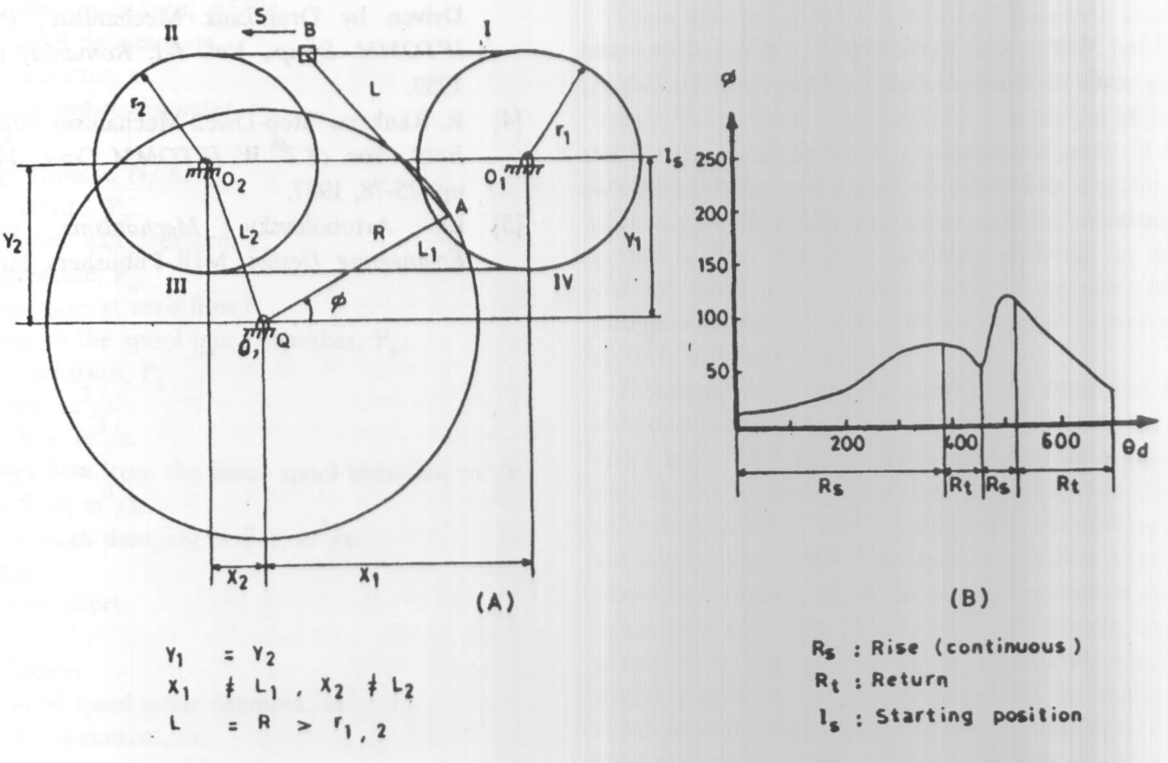


Figure 6.

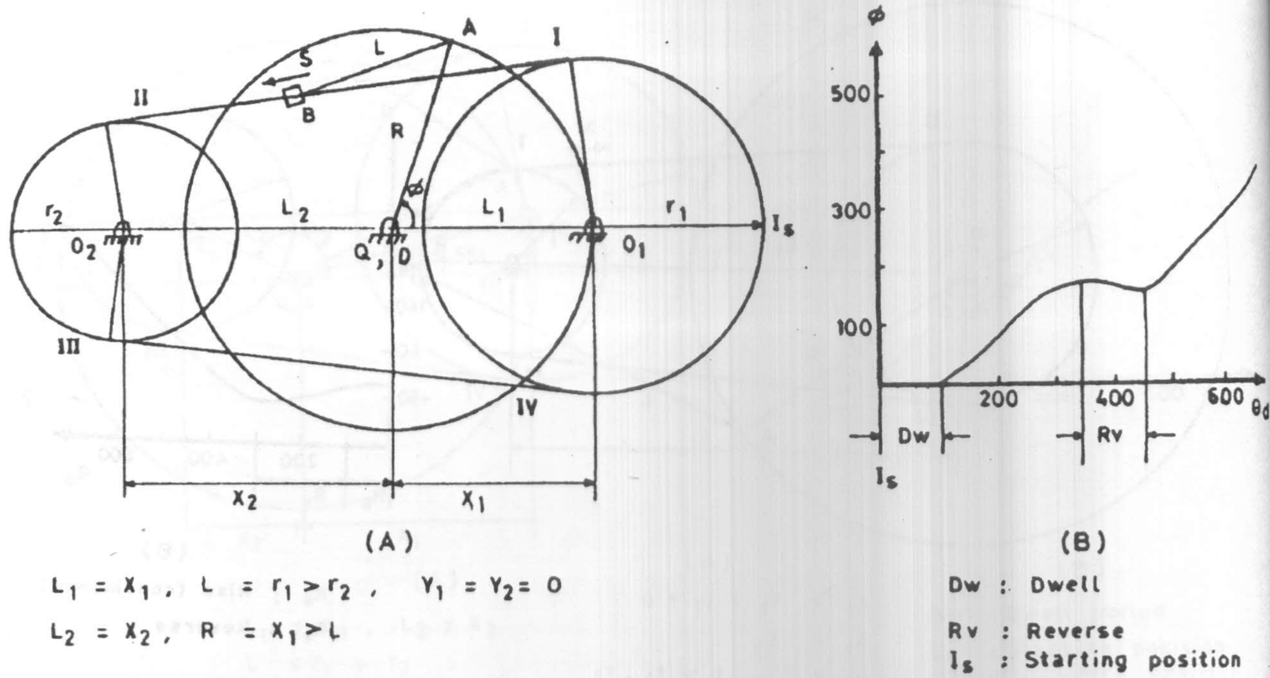


Figure 7.

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