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Synthesis of Planar Mechanisms, Part IX: Path Generation using 6 Bar – 2 Sliders Mechanism

Galal Ali Hassaan
Department of Mechanical Design & Production, Faculty of Engineering,
Cairo University, Giza, Egypt
Email: galalhassaan@ymail.com

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Abstract:

This research paper aims at studying the generation of a crescent path using a 6 bar – 2 sliders planar mechanism. This mechanism can generate crescent paths of different confutations depending on the location of the point on the mechanism coupler and the dimensions of the mechanism within a dimensions range assigned by an optimal synthesis of the mechanism. The x-span of the generated path equals the mechanism stroke. Normalized dimensions are used to provide wide application of the paths obtained. The generated crescent paths have a normalized y-span from 0.067 to 1.13 indicating the wide range of the generated crescent path.

Keywords — **Planar mechanisms synthesis, 6 bar – 2 sliders mechanism, path generation, crescent path.**

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I. INTRODUCTION

This is the 9th paper in a series of research papers published by the author in the field of mechanism synthesis. In this work the author presents a new family of crescent paths generated by the coupler of a 6 bar – 2 sliders mechanism. The author hopes that this series of research papers facilitates learning and application of mechanism synthesis by mechanical engineering students and practicing engineers.

Ananthasuresh and Kota (1993) proposed a two steps method for the synthesis of the complete coupler curve by extending Blechmadt and Uicker's method to all types of four bar coupler curves. It was possible to show the curve before the linkage dimensions determined [1]. Pennock and Sankaranayanan (2003) presented a graphical technique to locate the center of curvature of the path traced by a coupler point of a planar SDOF geared seven bar mechanism. Their technique was purely geometric. They included an analytical technique called 'the method of kinematic coefficients' to check the graphical technique [2]. Bulatovic and Djordjevic (2004) considered optimal synthesis of a four bar linkage by method of controlled deviations. They illustrated their technique through an example of synthesis of a four bar linkage whose coupler point traces a straight line [3].

Smaili, Atallah and Zeineddine (2005) presented OptimaLink, a MATLAB based code to facilitate the teaching/learning of mechanism design. They outlined the OptimaLink's structure, its use and provided an application example to demonstrate the usefulness of the code [4]. Chu and Sun (2007) proposed the mathematical representation of coupler curve of the spherical four bar mechanism. They discovered the relationship between coupler curve and the basic dimensional types. Their formulas could compute the position for coupler point, true size and installing dimensions of the spherical four bar mechanism [5]. Soong and Wu (2009) presented a method for designing a variable coupler curve four bar mechanism with one link replaced by an adjustable screw-nut link and driven by a servomotor. They presented also a derivation of the adjustable link lengths and the specific angular displacement of the driving link corresponding to the desired coupler curve [6].

Tari and Su (2010) studied the synthesis of a slider-crank four bar linkage whose coupler point traces a set of predefined task points. They formulated the problem for up to eight precision points in polynomial equations. They proposed a solution process based on the classical homotopy and the secant homotopy methods [7]. Yue, Su and Ge (2011) presented a preliminary work towards an automatic design framework for path generation with planar linkages. They built a library of planar four bars with 2897 linkages containing near four million curves and tested the search algorithms with a numerical example [8]. Abdulkadar and Deshmukh (2013) simulated four bar rigid link mechanism using the software CATIA V5. The constraints defined in the CATIA sof and the simulation tool provided means to check the motion and path generation [9].

Wasnik, Sonpimple and Undirwade (2014) studied the solution methods of optimal synthesis of a path generator linkage using non-conventional approach. They could decrease the path error and processing time [10]. Khader (2015) developed a software for synthesizing the coupler point's path of Chebyshev crank-rocker mechanism for three precision positions satisfying optimum range of transmission angle and unit time ratio using the Visual Basic language. The developed software could afford clear animation of the synthesized mechanism [11]. Sun, Liu and Chu (2015) presented a synthesis method for the open loop path generation of a four bar mechanism using the Haar wavelet. They presented four examples to verify the accuracy and practicability of the proposed theory [12].

II. MECHANISM

A line diagram of the mechanism used in the crescent path generation is shown in Fig.1 [13].

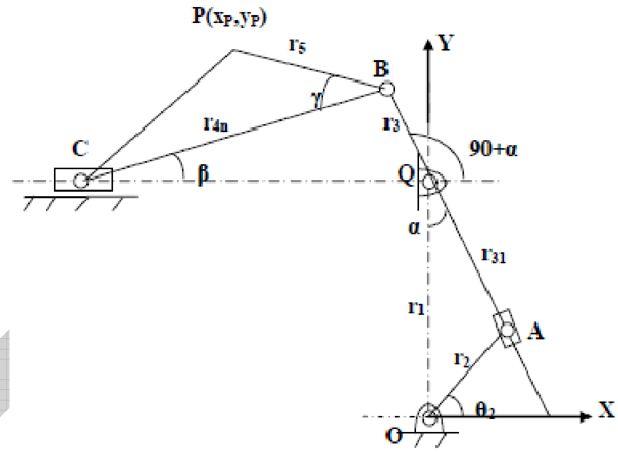

Fig.1 The 6 bar-2 sliders mechanism [13]

The driving link of the mechanism is its crank OA which rotates fully, and its output is the output slider at C. The coupler BCP is used to generate an open-loop bowel type paths for its point P. The location of point P is defined by the dimension r_5 and the angle γ between BC and BP. The optimal synthesis of the 6 bar – 2 slider mechanism was carried out by the author revealing the following normalized dimensions for specific normalized stroke, S_n [13]:

- For $S_n = 1$:
  $r_{1n} = 2$; $r_{3n} = 1$; $r_{4n} = 4$
- For $S_n = 2$:
  $r_{1n} = 1.2$; $r_{3n} = 1.2$; $r_{4n} = 4$
- For $S_n = 3$:
  $r_{1n} = 1.2$; $r_{3n} = 1.8$; $r_{4n} = 4$

III. COUPLER POINT COORDINATES

The coupler point is P in Fig.1. It has the coordinates x_P and y_P relative to the fixed frame of reference OXY.

From the geometry of the mechanism corresponding to any arbitrary crank angle θ_2, the normalized coupler point P coordinates x_{Pn} and y_{Pn} are given by:

$$x_{Pn} = r_{3n}\cos(90+\alpha) + r_{5n}\cos(180+\beta-\gamma) \qquad (1)$$

$y_{Pn} = r_{1n} + r_{3n}\sin(90+\alpha) + r_{5n}\sin(180+\beta-\gamma)$ (2)

where:

α is the angle between link 3 and the vertical axis Y (Fig.1). α is given by:

$$\alpha = \tan^{-1}\{\sin(90-\theta_2) / [r_{1n} - \cos(90-\theta_2)]\}$$

β is the angle between the coupler side BC and the line of action of the output slider at C. It is given by:

$$\beta = \sin^{-1}\{r_{3n}\sin(90 - \alpha) / r_{4n}\}$$

γ is the coupler angle at joint B. It is one of the input parameters defining the position of the coupler point P. The other parameter is the coupler side r_{5n}.

Eqs.1 and 2 are the core for drawing the coupler point path in terms of the crank angle θ_2 and the mechanism dimensions. The mechanism dimensions depend on its stroke according to the optimal synthesis of the mechanism [13]. Therefore, the final parameters used in designating the coupler point path will be the mechanism stroke, coupler dimension r_{5n} and coupler angle γ.

IV. PATHS OF THE COPUPLER POINT P

A MATLAB code is written applying Eqs,1 and 2 for:

- Mechanism normalized stroke, S_n: 1 , 2 and 3.
- Coupler normalized dimension, r_{5n}: 0.4, 0.8, 1.2, 1.6 and 2.
- Coupler angle, γ: 0, 20, 40, 60, 80, 100, 120, 140, and 160 degrees.

MATLAB is a very useful tool in this aspect since it generates the path and provide complete analysis of each path [14].

Samples of the coupler point P path for different mechanism parameters are shown in Figs.2 through 7.

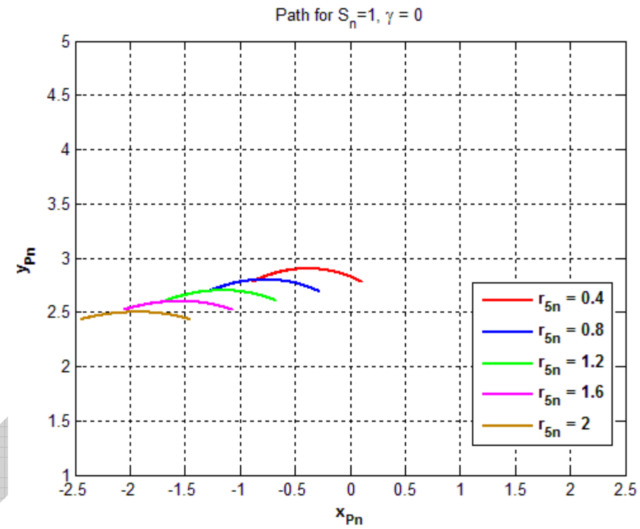

Fig.2 Coupler point P path for S_n=1, γ=0.

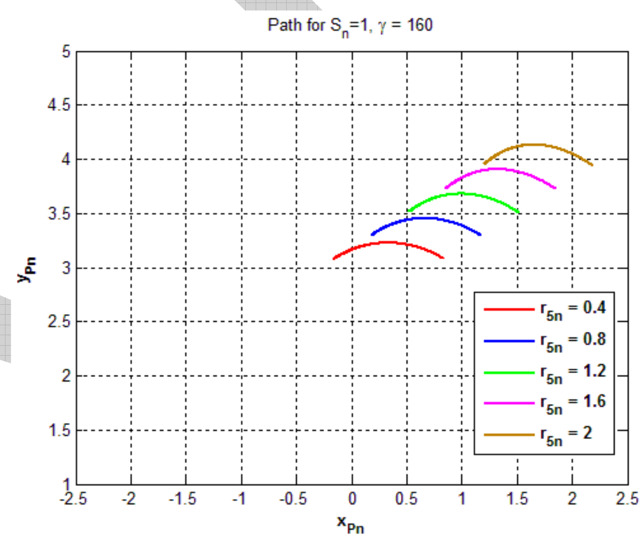

Fig.3 Coupler point P path for S_n=1, γ=160.

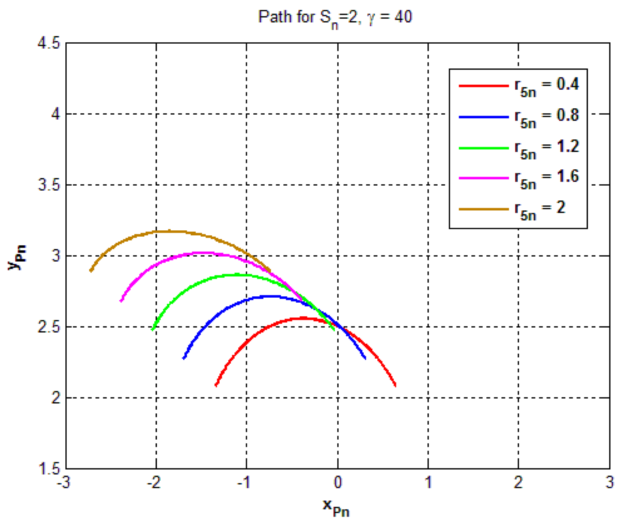

Fig.4 Coupler point P path for S_n=2, γ=40.

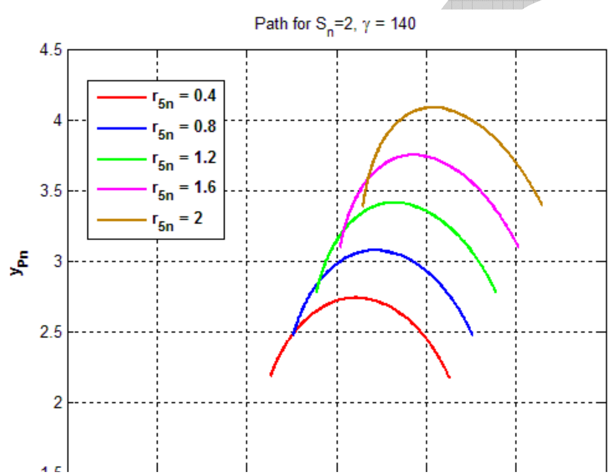

Fig.5 Coupler point P path for S_n=2, γ=140.

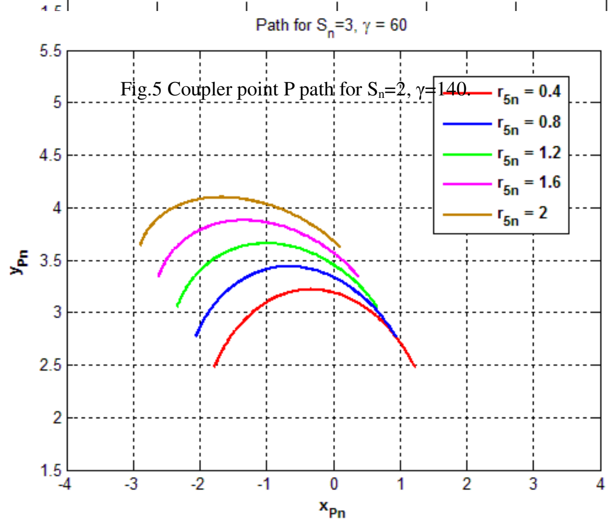

Fig.6 Coupler point P path for S_n=3, γ=60.

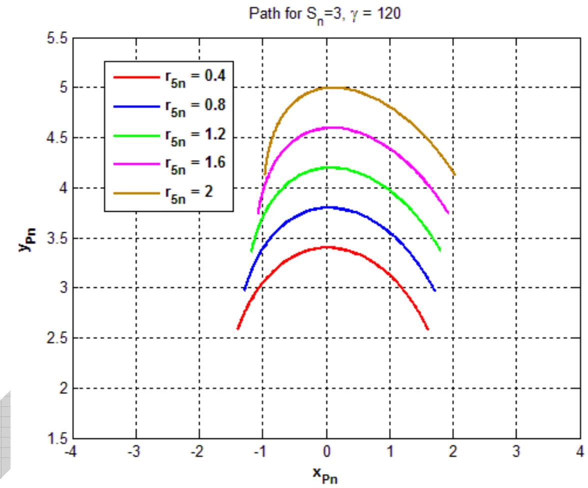

Fig.7 Coupler point P path for S_n=3, γ=120.

All the paths are open and have a crescent shape of a specific x and y span.

V. PATH S X AND Y SPAN

The x and y span are characteristics of the generated coupler point path. They depend on the mechanism stroke and point P parameters (r_{5n} and γ).

The x span of all the generated paths equals the normalized stroke. The y span depends of the parameters S_n, r_{5n} and γ as shown in Figs.8 through 12.

- For γ = 0 and 20 degrees (Fig.8):

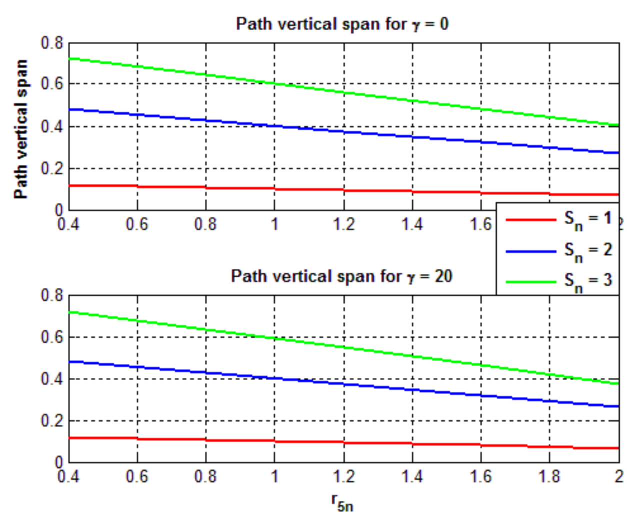

Fig.8 Path y span for γ=0 and 20 degrees.

- For γ = 40 and 60 degrees (Fig.9):

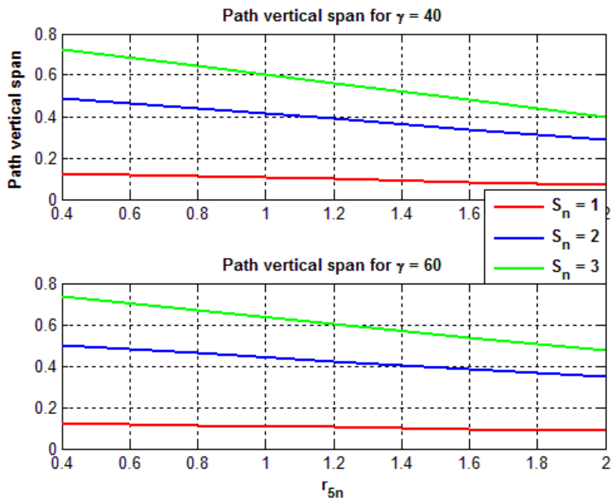

Fig.9 Path y span for γ=40 and 60 degrees.

- For γ = 80 and 100 degrees (Fig.10):

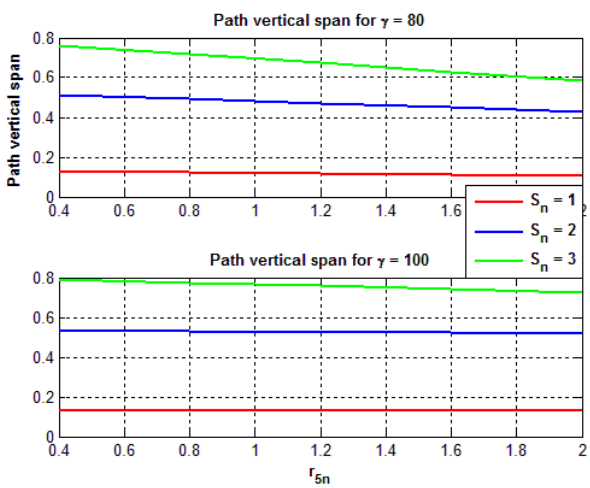

Fig.10 Path y span for γ=80 and 100 degrees.

- For γ = 120 and 140 degrees (Fig.11):

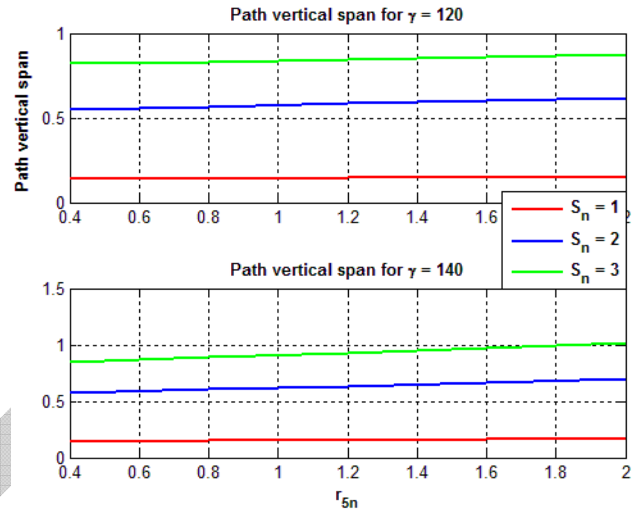

Fig.11 Path y span for γ=120 and 140 degrees.

- For γ = 160 degrees (Fig.12):

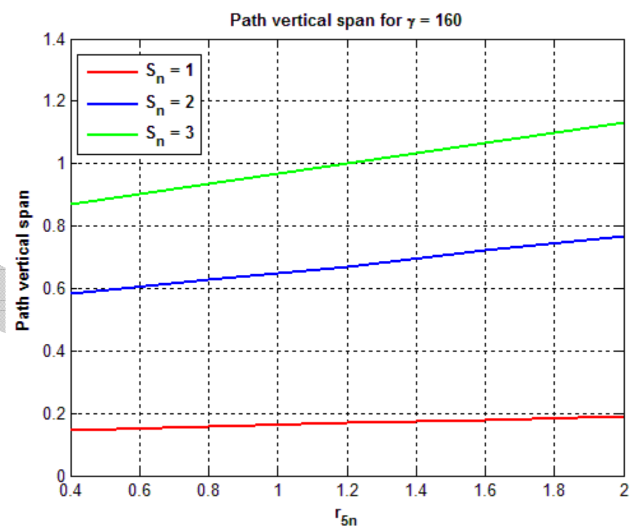

Fig.12 Path y span for γ=160 degrees.

VI. CONCLUSIONS

- An open crescent path was generated using a 6 bar – 2 sliders mechanism.
- The mechanism dimensions were according to the optimal synthesis of the mechanism.
- Only three levels of the mechanism stroke were considered: 1, 2 and 3.

- The generated crescent path was function of the mechanism stroke, dimensions and coupler point location.
- The coupler point location was defined by one of the coupler sides and its orientation.
- There was a great variety in the generated path.
- The span of the path in the horizontal direction was fixed at the mechanism stroke.
- The span of the path in the vertical direction was function of the mechanism stroke and the coupler point location.
- The normalized y-span could be as small as 0.0655.
- Smaller values of the y-span could be obtained by selecting smaller normalized mechanism stroke approximating a straight line path.
- The normalized y-span could be as large as 1.13.
- Bigger values of the y-span could be obtained by selecting greater normalized mechanism stroke.
- The generated crescent paths help the design engineer to select proper dimensions of the 6 bar – 2 sliders mechanism for specific applications requiring this type of paths.

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BIOGRAPHY

Galal Ali Hassaan:

- Emeritus Professor of System Dynamics and Automatic Control.
- Has got his B.Sc. and M.Sc. from Cairo University in 1970 and 1974.
- Has got his Ph.D. in 1979 from Bradford University, UK under the supervision of Late Prof. John Parnaby.
- Now with the Faculty of Engineering, Cairo University, EGYPT.
- Research on Automatic Control, Mechanical Vibrations , Mechanism Synthesis and History of Mechanical Engineering.
- Published more than 100 research papers in international journals and conferences.
- Author of books on Experimental Systems Control, Experimental Vibrations and Evolution of Mechanical Engineering.
- Chief Justice of International Journal of Computer Techniques.
- Member of the Editorial Board of a number of International Journals including IJCT.
- Reviewer in some international journals.
- Scholars interested in the author's publications can visit:

http://scholar.cu.edu.eg/galal