Model Development and Analysis of Four Bar Mechanism

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Abstract— Mathematical modeling / Simulation is a process of designing a model of a real system and conducting experiments with it for the purpose of understanding the behavior of the system. It is widely used for analyzing mechanisms also. Investigations of the various stages of mechanism design like synthesis and analysis using mathematical model is an effective tool by high development of computing technique, which enables complicated problems to be solved with minimum number of assumptions. Four bar mechanisms are widely used in automobiles and industrial applications. The present work aims at developing a computational environment for synthesizing and analyzing the mechanism both kinematically and kinetically. This work presents a simple and good mathematical model for getting the relevant parameters like link lengths, their velocities, their accelerations and the forces acting on it with the input of output function. The computational environment for the model is developed using a 'Ch' language, an embeddable C/C++ interpreter. The effect of varying parameters like link lengths, output functions on displacement, velocity, acceleration and forces has been studied.

Key words: Ch, C/C++ Interpreter, Mechanism, Synthesis, Design

I. INTRODUCTION

A. Ch Language

Harry H.Cheng and Dung T.Trang developed Ch language. Ch means C with high-level extensions. Also, Ch contains the initials of last and first name of Harry Cheng. Ch is an embeddable C/C++ interpreter for cross-platform scripting, shell programming, 2D/3D plotting, numerical computing, and embedded scripting. C/Ch/C++ allows user to use one language, anywhere and everywhere, for any programming tasks. Ch is not a new language. Ch is C+. Similar to gcc, VC++® and Sun cc which are C compilers that conform to the C language standard ratified by ANSI and ISO, Ch is interpretive implementation of the C language. It supports C99, C++ class, POSIX, C LAPACK, CGI, OpenGL, ODBC, X/Motif, Win32 and GTK+.

B. Mechanism

Mechanism is defined as a system of elements arranged to transmit motion in a predetermined fashion. In other words, Mechanisms are devices designed to produce specific constrained output motions.

C. Fourbar Mechanism

The four-bar mechanism is a very versatile linkage, which has been used extensively in a variety of machines, e.g. the Ackerman steering mechanism in automobiles, sewing machines, earth movers, packaging machines, automobile suspensions etc.

D. Coupler Point Curves

In a four bar mechanism, points belonging to the connecting rod usually constitute different types of curves with the motion of the input link. These points are known as Coupler points and corresponding generated curves are known as Coupler curves. Coupler (point) curves have found numerous applications in machine design such as in automobile machines like wrapping, packaging, weaving, vending etc. as well as in driving indexing systems.

E. Grashof Law:

The Grashof law states that the sum of the lengths of shortest and longest links must be less than or equal to sum of the lengths of remaining two links.
Grashof condition S + L = P + Q

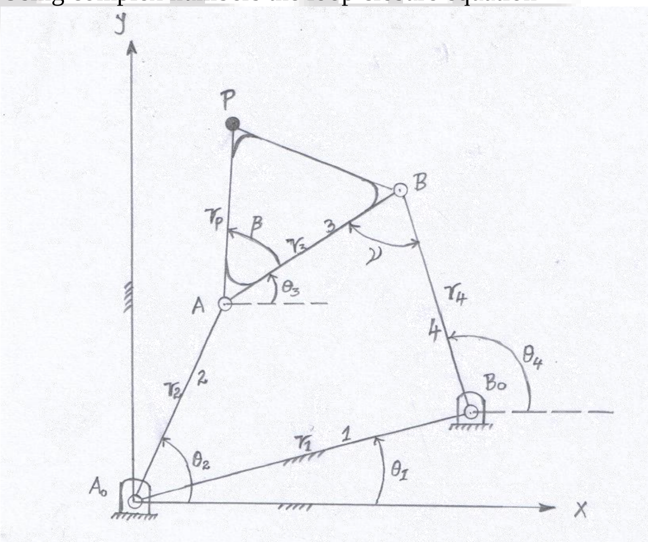
Depending on the arrangement and lengths of links, a four-bar mechanism can be classified as the following four linkage types

- Crank –Rocker
- Crank –Crank
- Rocker –Rocker
- Rocker–Crank

F. Position Analysis Is Carried Out By Using Following Mathematical Formulation Method

- Chebyshev spacing method used to calculate the input and output link angles phy 1 and phy 2.
- Freudenstein analysis method used to calculate the link lengths (r1,r2,r3,r4).

By using the input and output link angles and link lengths we can further proceed to find out θ_3, θ_4.
Using complex numbers the loop closure equation



Loop-Closure equation for the four bar mechanism is

R2 + R3 = R1 + R4 A

$$R_1 e^{i\phi_1} + R_2 e^{i\phi_2} = z = (x_3, y_3) \quad \text{B}$$

$$R_1 \cos\phi_1 + R_2 \cos\phi_2 = x_3 \quad \text{C}$$

$$R_1 \sin\phi_1 + R_2 \sin\phi_2 = y_3 \quad \text{D}$$

$$\cos\phi_1 = \left(\frac{x_3 - R_2\cos\phi_2}{R_1}\right) \quad \text{E}$$

$$\sin\phi_1 = \left(\frac{y_3 - R_2\sin\phi_2}{R_1}\right) \qquad \text{F}$$

$$y_3\sin\phi_2 + x_3\cos\phi_2 = \left(\frac{x_3^2 + y_3^2 + R_2^2 - R_1^2}{2R_2}\right) \qquad \text{G}$$

$$r_2 e^{i\theta_2} + r_3 e^{i\theta_3} = r_1 e^{i\theta_1} + r_4 e^{i\theta_4} \qquad 1$$

$$\theta_4 = \phi_2 = a\tan 2(y3, x3) \pm a\cos\left(\frac{(x_3^2 + y_3^2 + R_2^2 - R_1^2)}{2R_2\sqrt{x_3^2 + y_3^2}}\right) \qquad 2$$

$$\theta_3 = \phi_1 = a\tan 2(\sin\phi_1, \cos\phi_1) = a\tan 2\left(\frac{(y_3 - R_2\sin\phi_2)}{R_1}, \frac{(x_3 - R_2\cos\phi_2)}{R_1}\right) \qquad 3$$

- Equation 2 and 3 are derived from the equation 1.
- Equation 1 is derived from the equations A, B, C, D, E, F,G.
- Equations 2 and 3 are the output for one position of the 4 bar mechanism.
- For other positions the equations shall be derived by following the above procedure.

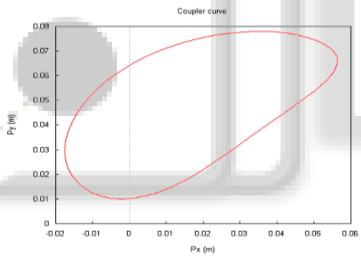
G. Various Position Analysis Of 4 Bar Mechanisms Using "Ch" Language

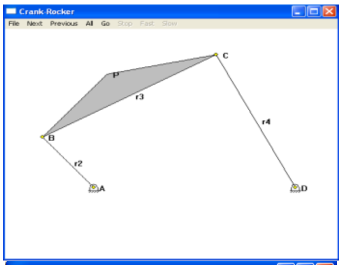
In Ch language given link lengths of a four-bar linkage and angles θ_1 and θ_2, the angular positions θ_3 and θ_4 can be solved using a function *complexsolve ( )*.

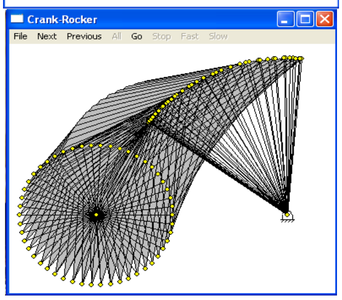
If we change input values in the program we can get various position.

1) Crank-Rocker

r1=0.10, r2=0.04, r3=0.10, r4=0.09 for theta is Zero.

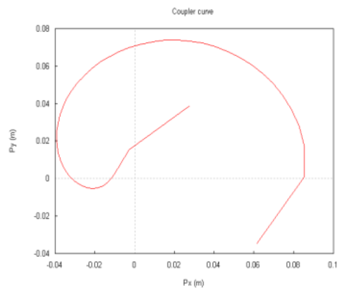


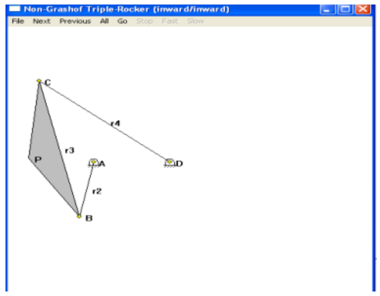


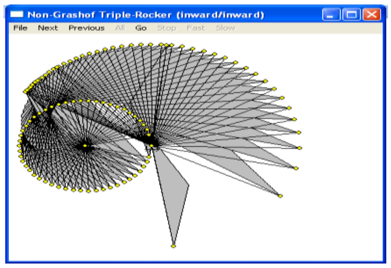


2) Non Grashof Condition (Inward-Inward)

r1=0.04, r2=0.04, r3=0.10, r4=0.09

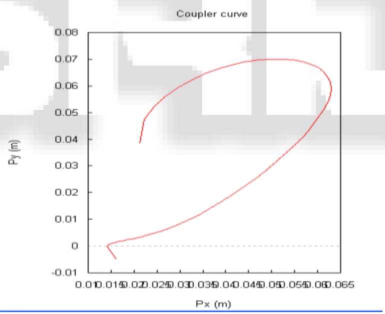


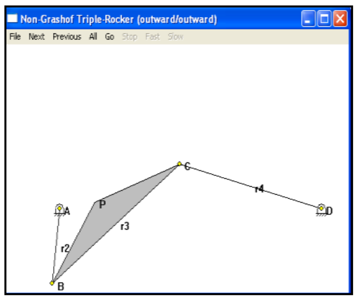


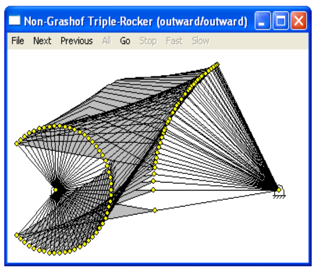


3) Non Grashof Condition (Inward-Inward)

r1=0.16, r2=0.04, r3=0.10, r4=0.09

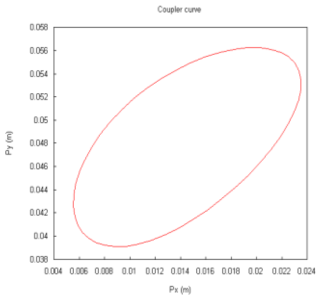


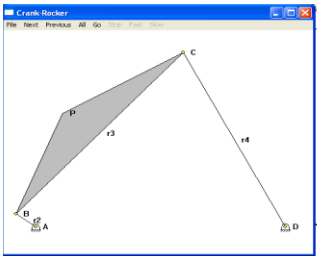


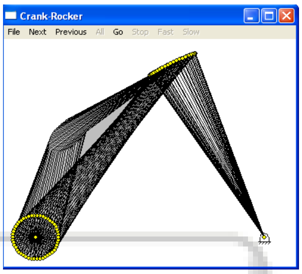


4) Crank-Rocker

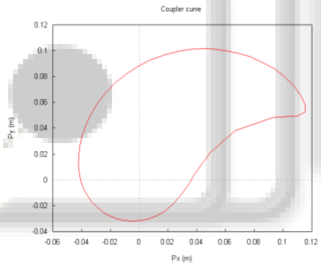
r1=0.10, r2=0.01, r3=0.10, r4=0.09

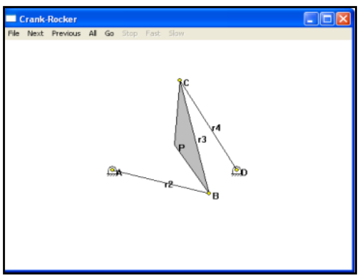


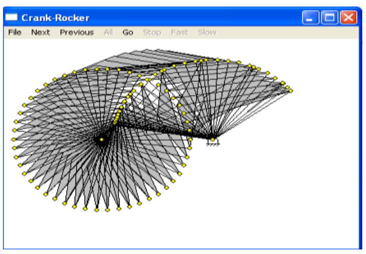




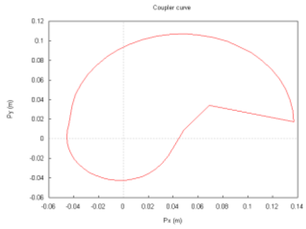
5) Crank-Rocker
r1=0.10, r2=0.08, r3=0.10, r4=0.09

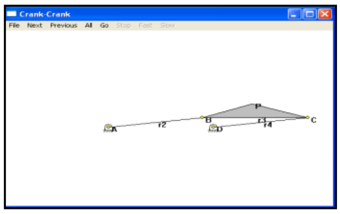


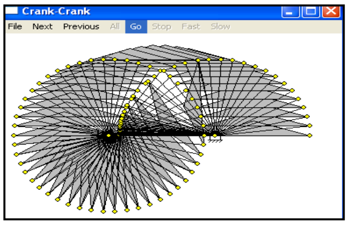




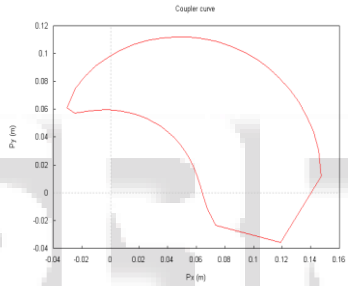
6) Crank-Crank
r1=0.10, r2=0.09, r3=0.10, r4=0.09

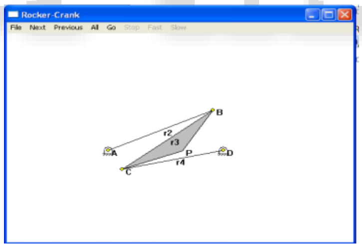


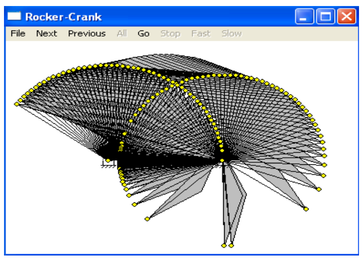




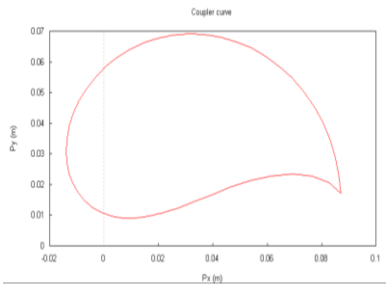
7) Rocker-Crank
r1=0.10, r2=0.10, r3=0.10, r4=0.09

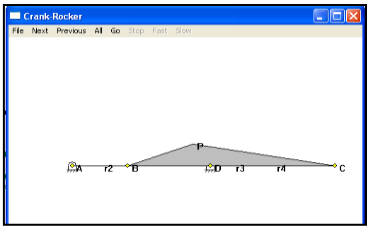


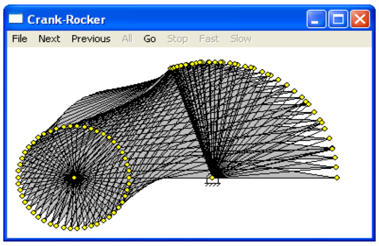




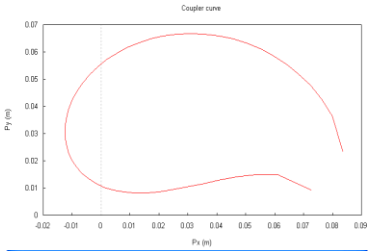
8) r1=0.10, r2=0.04, r3=0.15, r4=0.09

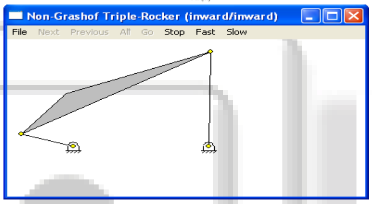


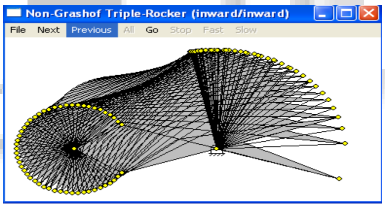




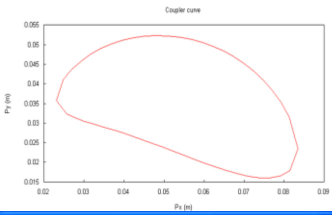
9) r1=0.10, r2=0.04, r3=0.16, r4=0.09

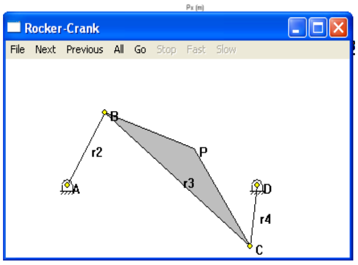


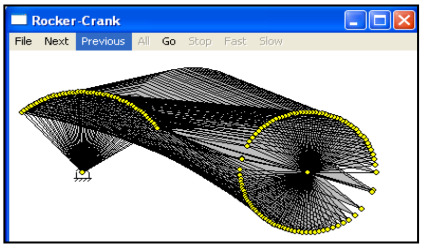




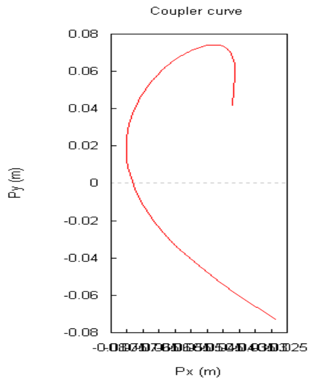
10) r1=0.10, r2=0.04, r3=0.10, r4=0.03

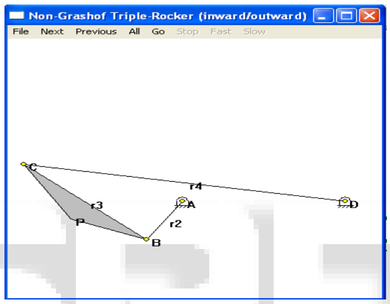


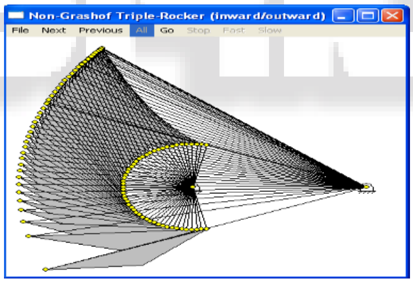




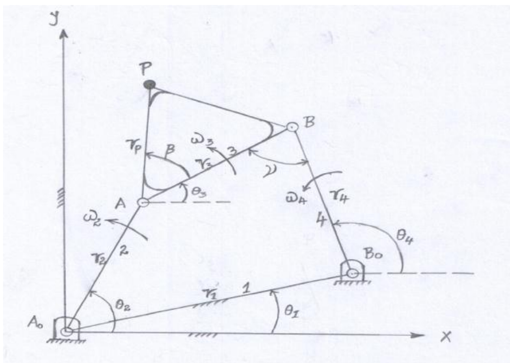
11) r1=0.10, r2=0.04, r3=0.10, r4=0.2







H. Angular Velocities Analysis Is Carried Out By Using Following Mathematical Formulation Method



The loop closure equation for velocity analysis is

$$R_B = r_2 + r_3 = r_1 + r_4 \quad (4)$$

$$r_2 e^{i\theta_2} + r_3 e^{i\theta_3} = r_1 e^{i\theta_1} + r_4 e^{i\theta_4} \quad (5)$$

$$R_B = r_2 + r_3 \quad (6)$$

$$R_B = r_1 + r_4 \quad 7$$

$$R_B = r_2 e^{i\theta_2} + r_3 e^{i\theta_3} = r_1 e^{i\theta_1} + r_4 e^{i\theta_4} \quad 8$$

$$R_B = r_2 + r_3 = r_1 + r_4 \quad 9$$

$$\frac{dR_B}{dt} = V_B = r_2 e^{i\theta_2} i \frac{d\theta_2}{dt} + r_3 e^{i\theta_3} i \frac{d\theta_3}{dt} = r_1 e^{i\theta_1} i \frac{d\theta_1}{dt} + r_4 e^{i\theta_4} i \frac{d\theta_4}{dt} \quad 10$$

$$V_B = r_2 e^{i\theta_2} i\omega_2 + r_3 e^{i\theta_3} i\omega_3 = r_1 e^{i\theta_1} i\omega_1 + r_4 e^{i\theta_4} i\omega_4 \quad 11$$

$$r_2\omega_2 i e^{i\theta_2} + r_3\omega_3 i e^{i\theta_3} = r_4\omega_4 i e^{i\theta_4} \quad 12$$

$$\omega 3 = -\frac{\omega_2 r_2 \sin(\theta_4 - \theta_2)}{r_3 \sin(\theta_4 - \theta_3)} \quad 13$$

$$\omega_4 = \frac{\omega_2 r_2 \sin(\theta_3 - \theta_2)}{r_4 \sin(\theta_3 - \theta_4)} \quad 14$$

Equations 13 and 14 are the outputs of angular velocity for one input value. For other values the equations shall be derived by following the above procedure

I. Various Angular Velocities of 4 bar Mechanisms Using "Ch" Language

In Ch language angular velocities are calculated using the four bar class member function
int angularVel (double *theta* [1:4], double *omega* [1:4], int *omega_id*);
For every input data the relevant output value can be arrived by the program.

1) Angular Velocities for input omega [2] =5(rad/sec)
Deg/sec: omega3=41.706, omega4=1258.029
Rad/sec: omega3=0.7279, omega4=2.2247
Angular Velocities
Deg/sec: omega3=93.957, omega4=80.905
Rad/sec: omega3=1.6399, omega4=0.1431

2) Angular Velocities for input omega [2]=6(rad/sec)
Deg/sec: omega3=50.047, omega4=1509.635
Rad/sec: omega3=0.8735, omega4=2.6696
Angular Velocities
Deg/sec: omega3=112.748, omega4=97.086
Rad/sec: omega3=1.9678, omega4=0.1717

3) Angular Velocities for input omega [2] =8(rad/sec)
Deg/sec: omega3=66.729, omega4=2012.846
Rad/sec: omega3=1.1646, omega4=3.5595
Angular Velocities
Deg/sec: omega3=150.331, omega4=129.448
Rad/sec: omega3=2.6238, omega4=0.2289

4) Angular Velocities for input omega [2] =10(rad/sec)
Deg/sec: omega3=83.411, omega4=2516.058
Rad/sec: omega3=1.4558, omega4=4.4494
Angular Velocities
Deg/sec: omega3=187.914, omega4=161.809
Rad/sec: omega3=3.2797, omega4=0.2861

5) Angular Velocities for input omega [2] =10(rad/sec)
Deg/sec: omega3=83.411, omega4=2516.058
Rad/sec: omega3=1.4558, omega4=4.4494
Angular Velocities
Deg/sec: omega3=187.914, omega4=161.809
Rad/sec: omega3=3.2797, omega4=0.2861v

The Position and angular velocities have been completed up to this line.

Acceleration and force analysis have to be continued and will be completed.

II. CONCLUSION

The analysis and simulation of the four-bar mechanism has been carried out successfully by considering all aspects like length of links, its position, and velocity on each link. The Position and angular velocities have been completed.

Acceleration and force analysis have to be continued and will be completed.

III. SCOPE FOR FUTURE WORK

In this work, the analysis and simulation is considered for a four-bar linkage alone In future the same procedure may be adopted for Crank-Slider mechanism, Geared five-bar linkage, Mutiloop Six-bar linkages and Cam-Follower systems also. There could be a possibility of grouping them to have a complete mechanism study and understanding package also.

