Study of motion analysis of four bar mechanism

Anil B Ghubade[1], Anil Kumar[2]

[1,2]Assistant Professor, School of Mechanical Engineering, Lovely Professional University, Punjab, India-144411.

Corresponding Author- Anil B Ghubade, **Email Id-** anil.18325@lpu.co.in

Abstract

Four bar mechanism are the simplest closed loop kinematic linkage. They perform a wide variety of motions with a few simple parts. They were also popular in the past due to the ease of calculations, prior to computers, compared to more complicated mechanisms. Four bar mechanism find many applications in engineering analysis. Therefore, this paper aims to understand the four-bar mechanism and various applications in solving engineering problem.

Introduction

Four bar mechanism are the simplest closed loop kinematic linkage. They perform a wide variety of motions with a few simple parts. They were also popular in the past due to the ease of calculations, prior to computers, compared to more complicated mechanisms [1].

With increasing machine speed, rigid link assumption is no more valid, hence, links of the mechanism are subjected to vibration. Stability analysis of a vibrating system gives the speeds at which the system response is unbounded. It is necessary to avoid these speeds or to provide sufficient damping for better performance of the system. This paper presents the theoretical work done for stability analysis, which is simple and can be extended to any mechanism in general. It gives the speed ranges, in which response is unbounded, and presents the study of the response at various speeds for undamped system.

A function generator linkage that approximates a parabolic output.

- Pantograph (four-bar, two DOF)
- Crank-slider, (four-bar, one DOF)
- Grashof, (four-bar, one DOF) At least one link can rotate 360°
- Five bar linkages often have meshing gears for two of the links, creating a one DOF linkage. They can provide greater power transmission with more design flexibility than four-bar linkages.
- Six bar, single DOF linkages offer greater design flexibility than four-bar linkages, but require more parts and are more difficult to design:

- Watt kinematic chain
- Watt I, II
- Stephenson kinematic chain
- Stephenson I, II, III
- Klann Linkage which functions as a walking mechanism creating nearly straight-line output from a rotary input; six-bar.

Parallel and straight line mechanisms:

- James Watt's parallel motion and Watt's linkage [2]
- Peaucellier–Lipkin linkage, the first planar linkage to create a straight-line output from rotary input; eight-bar, one DOF.
- A Scott Russell linkage, which converts linear motion, to (almost) linear motion in a line perpendicular to the input.

- Chebyshev linkage, which provides nearly straight motion of a point with a four-bar linkage.
- Hoekens linkage, which provides nearly straight motion of a point with a four-bar linkage.
- Sarrus linkage, which provides motion of one surface in a direction normal to another[3].

Kinematic Joints

The members in a mechanism are connected by kinematic joints. A kinematic joint is formed by direct contact between the surfaces of the members forming that joint. The contact between the surfaces of the members can be point contact, line contact or area contact. The joints are classified according to the type of contact and relative motion of the members. The contact stresses developed will also depend on the contact type [4].

There are two types of joints according to the type of contact:

1. Lower pair joint

2. Higher pair joint

Lower pair joint has area contact between the two mating surfaces of the members forming joint, as in the case for slider, revolute and hinge.

Higher pair joint has the contact between the mating surfaces as point or line contact as in the case for cam pair and cam-follower.

But a third category of kinematic joint can also be created which is comprised of the joints formed by combination of two or more lower and/or higher pair joints. Such joints are termed as Compound Joints.

3. **Compound Joints.**

Lower Pair Joints: -The two members forming a lower pair joint have area contact between the two mating surfaces. The contact stress is thus small for lower pair joint as compared to higher pair joints. Lower pair joints have long service life as the wear and stressess are spread over larger surface area of contact and also allows for better lubrication. The degrees of freedom for a lower pair of joints are usually less as the requirement for area contact between the members constrains the geometry of the joint.

Higher Pair Joints: -The contact between the two members of higher pair has point or line geometry. The contact stress for a higher pair joint is large because of very small contact area. If there is pure rolling contact between the members then at any point of time the contact point or line is at rest. There is no relative sliding between the contact surfaces and thus friction and wear will be negligible. The degrees of freedom for a higher pair of joint can be high as the point or line contact allows for less constrained motion of members [5].

Compound Joints: -Lower pair and/or higher pair joints are combined as per the design requirement to obtain compound joints. Compound joints composed of higher pair joints can be kinematically equivalent to lower pair joints or vice versa. By such combination's desirable features from the combining joints are retained to obtain robust joints [6].

Mechanisms

The simplest example for a mechanism will be a liver hinged at a wedge. It transfers input motion at one end to the output motion on the other end. A scissors is a combination of two livers; the mechanical work from one end can be transformed to cutting motion on the output end. The two livers in scissors are connected together by a joint (revolute joint). A slightly more complex mechanism is a slider crank mechanism [7]. Thus, mechanisms can be defined as assembly of rigid members connected to each other through joints. A mechanism transfers the input motion or work at the input point or point of actuation to one or more output points. Like in case of slider crank mechanism, the input rotational motion of the crank is transferred to the slider as a reciprocating motion.

Motion

A subject that was treated in the undergraduate mechanisms or kinematics course was what in physics is termed kinematics, the analysis of motion without consideration of forces. This is a study of the mathematical relations between displacement s, velocity v and acceleration a in the motion of a particle along a line in one to three dimensions. It is an elementary and concrete subject, one that can be successfully presented in pre-college work, which brings together a number of essential techniques that should be well-known to any engineer. It involves algebraic manipulation, graphical methods, differential and integral calculus, and numerical methods. It can suggest computer programs and provide interesting examples. Moreover, it is of great practical utility. Kinematics is treated at the beginning of every general physics course, as is vector notation. Its review in Kinematics was useful, considering the tendency of engineering students to forget anything learned in Physics. Actually, this is not surprising, since it is really a matter of developing maturity. Learning is essentially an iterative process [8]. Rotational motion about a fixed axis is analogous to one-dimensional motion along a line, where angle θ corresponds to s, angular velocity ω corresponds to v, and angular acceleration α corresponds to a. The velocity and acceleration of a point on a rotating body is also considered. The more difficult analysis of the kinematics of a rigid body is usually left for advanced courses, but is properly a part of our study here. It is sufficient to concentrate on rectilinear motion, since motion in a plane is simply the superposition of motions at right angles to each other. Galileo first pointed this out clearly, and it is a fundamental concept, by no means inherently obvious. Acceleration, however, connects motion in different directions. These things are all examples of Galilean Invariance. Motion in a plane can be described by coordinates, such as rectangular or polar. Vectors are only a notational convenience, as all calculations are eventually done with coordinates, but vectors have a conceptual meaning that is also important. Motion with zero acceleration, or with constant velocity, is simple: the particle moves in a straight line so that $s = so + vot$, where so is the initial displacement when time $t = 0$, and vo is the constant velocity. Clearly, $v = vo = ds/dt$, and $s = so + \int(t,to)vodt$. These are trivial relations when the acceleration is zero, but give valid results when it is not. They serve to illustrate differentiation and integration. Motion with a constant specified acceleration a is a very important case, since many motions can be described in terms of intervals where the acceleration is assumed constant. We have $a = dv/dt$ as well as $v = vo + \int(t,to)a\ dt$, which are relations true even when a is not constant. With a = constant, the velocity increases linearly, $v = vo + at$. The average velocity between two times differing by t is $vav = (v1 + v2)/2$, where v1 and v2 are the velocities at the beginning and end of the interval. By average velocity, we mean that the distance covered is $s = vavt$. Therefore, $s(t) = so + vavt = so + vot + at2$, a very familiar expression. The initial displacement so and the initial velocity vo often make formulas rather complex, so that coordinates are chosen to make them zero, a skill that it is important to learn.

Approaches to Four Bar Mechanism

Mechanisms are required to follow the specified path and pass through the desired points as closely as possible. For some mechanisms it is more desirable that they should pass through the specified points and for some other mechanisms following the path is more important. There are two approaches to four bar linkage synthesis.

Precision Position Approach: In this approach the position through which the mechanism is desired to pass are selected and, in the solution, mechanism is compelled to exactly pass through these positions. In this approach it is difficult to control the path of mechanism between the specified points. The precision position approach generally employs graphical methods of synthesis. If the design positions are more than three than the solutions become complex and computer program is used for synthesis [9].

Path Optimization Approach: In this approach a large number of design positions are selected and the overall deviation of mechanism from these design points is minimized. For this approach numerical optimization techniques are employed using computers.

References

1. Muller, M. (1996). A novel classification of planar four-bar linkages and its application to the mechanical analysis of animal systems. Philosophical Transactions of the Royal Society of London. Series B: Biological Sciences, 351(1340), 689-720.
2. Pei, X., Yu, J., Zong, G., & Bi, S. (2014). Design of compliant straight-line mechanisms using flexural joints. Chinese journal of mechanical engineering, 27(1), 146-153.
3. Beroz, J., Awtar, S., Bedewy, M., Tawfick, S., & Hart, A. J. (2011, November). Compliant microgripper with parallel straight-line jaw trajectory for nanostructure manipulation. In Proceedings of 26th American Society of precision engineering annual meeting, Denver, USA.
4. Flores, P. (2004). Dynamic analysis of mechanical systems with imperfect kinematic joints.
5. Muir, P. F., & Neuman, C. P. (1988, April). Dynamic modeling of multibody robotic mechanisms: Incorporating closed-chains, friction, higher-pair joints, and unactuated and unsensed joints. In Proceedings. 1988 IEEE International Conference on Robotics and Automation (pp. 1546-1551). IEEE.
6. Lee, H. T., Chen, M. H., Jao, H. M., & Liao, T. L. (2003). Influence of interfacial intermetallic compound on fracture behavior of solder joints. Materials Science and Engineering: A, 358(1-2), 134-141.
7. Radcliffe, C. W. (1994). Four-bar linkage prosthetic knee mechanisms: kinematics, alignment and prescription criteria. Prosthetics and orthotics international, 18(3), 159-173.
8. Barnes, R. M. (1949). Motion and time study.
9. Valentini, P. P., & Pennestrì, E. (2018). Compliant four-bar linkage synthesis with second-order flexure hinge approximation. Mechanism and Machine Theory, 128, 225-233.