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Research Paper

KINEMATIC SYNTHESIS OF A PROFILE CUTTING MECHANISM

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Profiles are generally cut by laser machine. To cut a required profile, the laser cutter has to trace the path of the profile. A planer mechanism can be used for cutting a profile by fixing the laser cutting point to the coupler link at a specific point. The proposed research work is an attempt to synthesize a four bar class-I mechanism to cut an elliptical profile with specified dimension. The four bar mechanism is synthesized by using freudenstein's equation and laser cutting point is located on the coupler curve by trial and error method to get the specified elliptical profile. (With given major axis and minor axis).

Keywords: Four bar mechanism, Synthesis, Simulation

INTRODUCTION

A mechanism is the heart of a machine. It is a device that transforms one motion, for example the rotation of a driving shaft, into another, such as the rotation of the output shaft or the oscillation of a rocker arm. A mechanism consists of a series of connected moving parts which provide the specific motions and forces to do the work for which the machine is designed. One of the main objects of designing a mechanism is to develop a system that transforms motion in a specific way to provide mechanical advantage. A typical problem in mechanism design is coordinating the input and output motions. A mechanism designed to produce a specified output as a function of input is called a function generator. A system that transmits forces in a predetermined manner to accomplish specific work may be considered a machine. A machine is usually driven by a motor which supplies constant speed and power. It is the mechanism which transforms this applied motion into the form demanded to perform the required task. The study of mechanisms is very important. With the tremendous advantages made in the design of instruments, automatic controls, and automated equipment, the study of mechanisms takes on new significance. Once a need for a machine or mechanism with given

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characteristics is identified, the design process begins. Detailed analysis of displacements, velocities and accelerations is usually required. Kinematics is the study of motion. The study of motions in machines may be considered from the two different points of views generally identified as kinematic synthesis and kinematic analysis. Kinematic analysis is the determination of motion inherent in a given mechanism. Kinematic synthesis is the reverse problem: it is the determination of mechanisms that are to fulfill certain motion specifications.

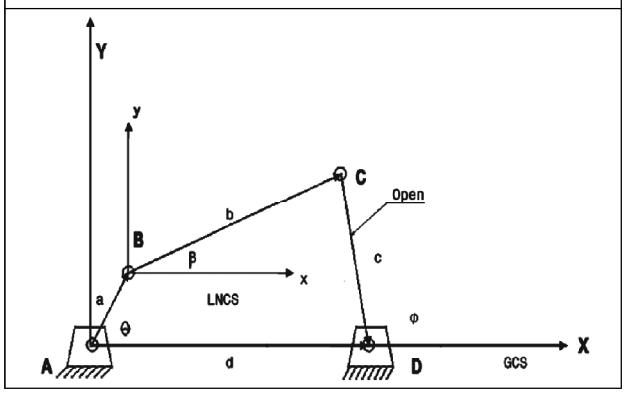
DESIGN OF MECHANISM

The design of mechanism carried out in two stages

1. Synthesis of mechanism, i.e., deciding the dimensions of various links of mechanism to generate the desired motion.
2. Design of mechanism, i.e., finding out the cross section of various links on the basis of external forces, moments and torques acting on it.

The propose work is an attempt to synthesize a four bar chain to generate and identify a point on the coupler link to trace a desired elliptical profile (Figure 1).

Figure 1: Four Bar Mechanism



RESEARCH METHODOLOGY

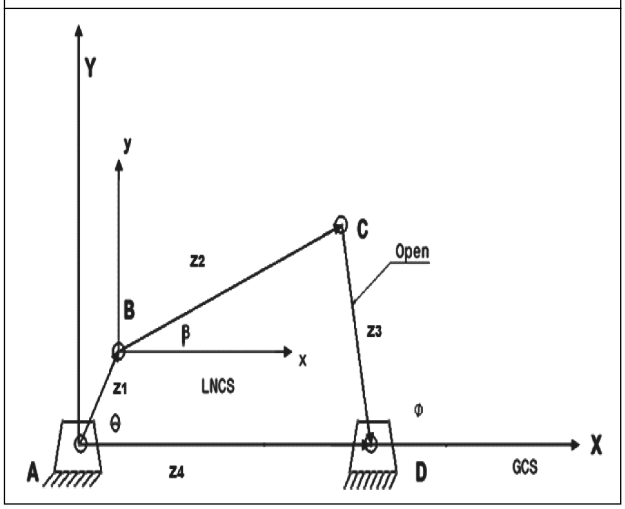
The steps of research methodology are as follows

- Synthesis of mechanism to generate desired profile.
- Identification of a cutting point on coupler link to generate desired profile and Simulation of generated profile.
- Error analysis.

SYNTHESIS OF FOUR BAR CHAIN TO GENERATE GIVEN ELLIPTICAL PROFILE

A four bar chain, as shown in Figure 2, is to be synthesized to generate desired elliptical profile with major axis 40 mm and minor axis 30 mm. It is assumed that the fixed link Z_4 is 72 mm and length of other link find out by using 3 precision point method and Freudenstein's equation Figure 2 shows the four bar mechanism.

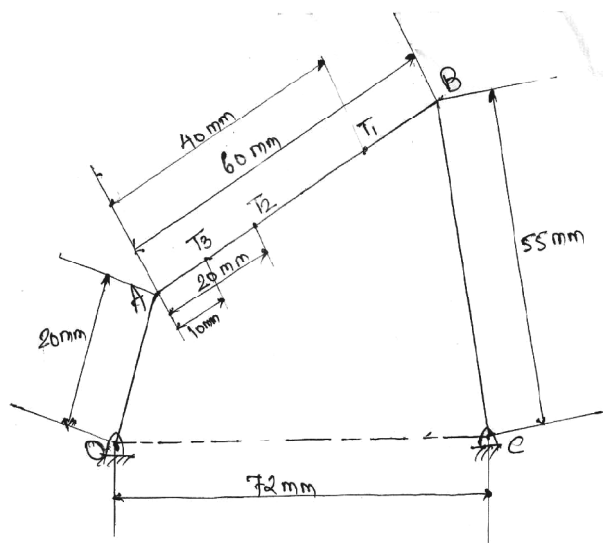
Figure 2: Synthesized Four Bar Mechanism



To identify the trace point on the coupler link 3 trace point are assumed at 10 mm, 20 mm and 40 mm from pin A of the coupler link

Figure 3 shows the synthesized mechanism with link dimensions and three trace points T_1, T_2 and T_3 on the coupler link. The coupler curves for this trace points were drawn by graphical methods. It was observed that the point T_3 generate the profile with major axis and minor axis nearest to the major and minor axis of the desired elliptical profile.

Figure 3: For Trace Points T1, T2 and T3



The four bar mechanism to generate elliptical profile with major axis 40 mm and minor axis 30 mm is synthesized by using 3 precision point method and Freudeinstein's equation.

Steps in synthesizing four bar mechanism are:

- $0 < x < 360$
- $\Delta\theta = 360°$, $\Delta\Phi = 60°$
- $\Phi_s = 0°$, $\theta_s = 0°$

  where,

  x – Precision Positions

  θ – Input Angle

  Φ – Output Angle

- By chebychev spacing $Xj = \Delta X/2(1 - \cos(\Pi\,(2j-1)/2n))$
- $\theta j = \Delta\theta/\Delta X(Xj - X1)$
- $\Phi j = \Delta\Phi/\Delta Y(Yj - Y1)$
- By Freudenstein's equation $K_1\cos\theta + K_2\cos\Phi + K_3 = -\cos(\theta - \Phi)$
- Calculate K_1, K_2, K_3
- Assume any one link length $Z_1 = 72$ mm
- $K_1 = Z_1/Z_4$, $K_2 = -Z_1/Z_4$, $K_3 = Z_3^2 - Z_2^2 - Z_1^2 - Z_4^2/2 * Z_2 * Z_4$

SIMULATION

A simulation of a system is the operation of a model of the system. The model can be reconfigured and experimented with; usually, this is impossible, too expensive or impractical to do in the system it represents. The operation of the model can be studied, and hence, properties concerning the behavior of the actual system or its subsystem can be inferred. In its broadest sense, simulation is a tool to evaluate the performance of a system, existing or proposed, under different configurations of interest and over long periods of real time.

Simulation is used before an existing system is altered or a new system built, to reduce the chances of failure to meet specifications, to eliminate unforeseen bottlenecks, to prevent under or over-utilization of resources, and to optimize system performance.

The required ellipse is given by equation

$x2/a2 + y2/b2 = 1$

where, $a = 40$ mm; $b = 30$ mm

The four bar chain is synthesize by using Freudenstein's equation and generate the

dimensions of synthesize four bar chain are Z_1 = 72 mm, Z_2 = 20 mm, Z_3 = 60 mm, Z_4 = 55 mm. The steps involved are:

Selection of Trace Points: The trace points on the coupler link were selected by trial and error method. For the coupler link three trace points T_1, T_2, and T_3 were selected at distance of 40 mm, 20 mm and 10 mm respectively from pin A (Figures 4, 5 and 6).

Figure 4: Simulation of Coupler Curves for Trace Point T_1

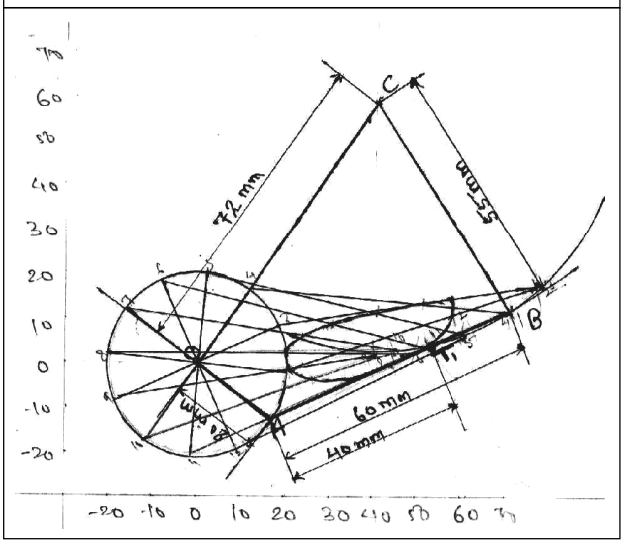


Figure 5: Simulation of Coupler Curves for Trace Point T_2

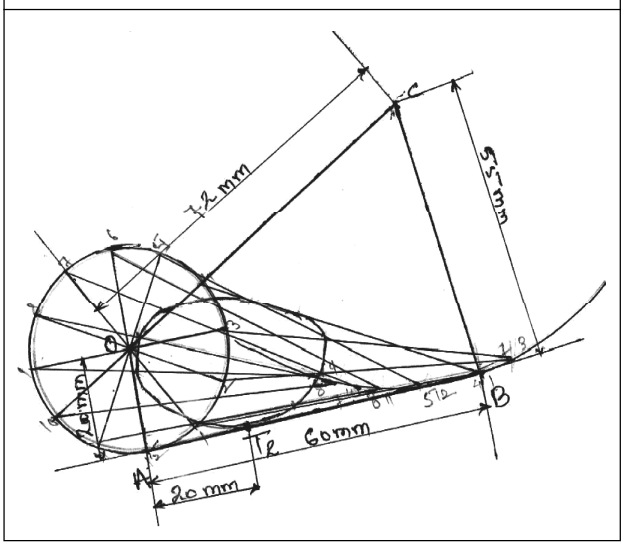
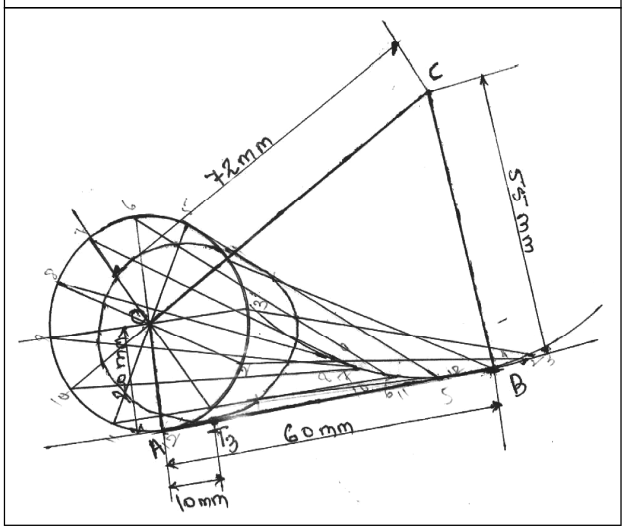


Figure 6: Simulation of Coupler Curves for Trace Point T_3



ERROR ANALYSIS

Error analysis is carried to find out, i.e., the difference between the coordinate of the desired elliptical profile and actually generated profile.

Table 1 shows the values of y coordinates on ideal ellipse to be generated (y) and the values of y coordinates (y_a) on actual ellipse traced by trace point T_3. The table also shows the calculated values of error i.e., = (Y_a – Y),and e^2. The root mean square error was calculated and is 9.5 mm.

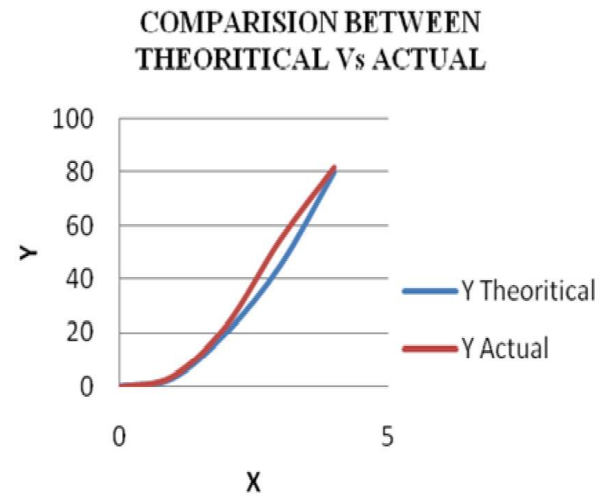
Suppose the equation of curve to be generated is $y = 5x^2$.

Table 1: Error Analysis of Desired Elliptical Profile and Actual Generated Profile

S. No.	Y	Y_a	E	e^2
1.	29.7 mm	33.7 mm	4.0	16.0
2.	29.0 mm	32.9 mm	3.9	15.2
3.	27.8 mm	31.5 mm	3.7	13.7
4.	29.7 mm	33.7 mm	4.0	16.0
5.	29.0 mm	32.9 mm	3.9	15.2
6.	27.8 mm	31.5 mm	3.7	13.7

By substituting different values of *x* the corresponding values of y are evaluated. The blue curve in Figure 7 shows the theoretical profile to be generated. Table 1 shows values of *y* corresponding to different values of *x*. suppose the red curve shows the actual profile generated by laser cutting point, the square root error can be evaluated as under:

Figure 7: Comparision Between Theoritical vs. Actual



Σe^2 = (16.0 + 15.2 + 13.7 + 16.0 + 15.2 + 13.7) = 89.6

$e = \Sigma e^2$

e = 89.6

= 9.5 mm

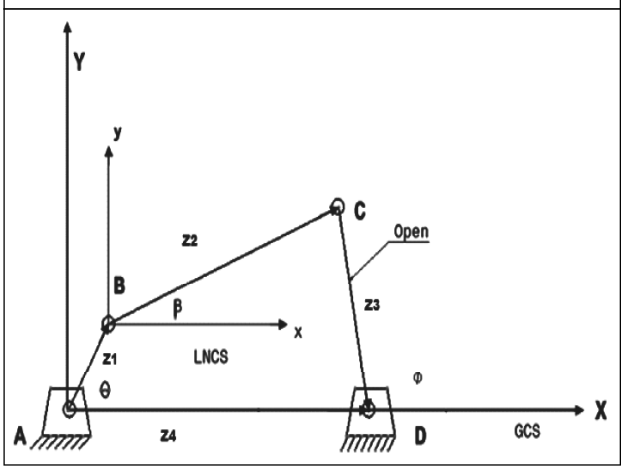
So, the mean square root error is 9.5 mm.

RESULTS AND DISCUSSION

The important results, conclusions and scope of further work, on the basis of present research work were as under.

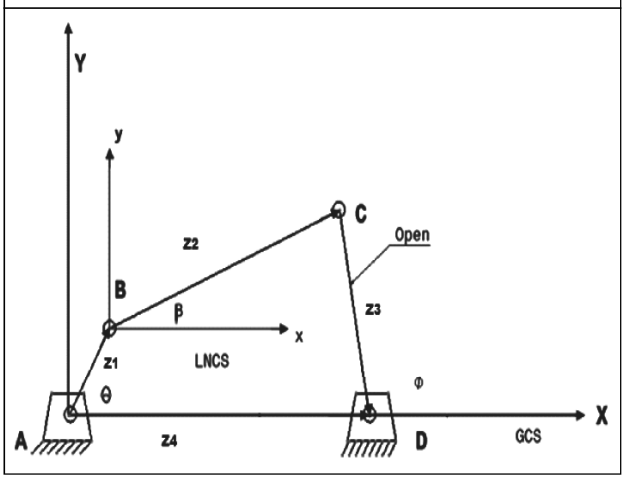
- Link dimensions of synthesized mechanisms were shown in Figure 8. Z_1 = 72 mm, Z_2 = 20 mm, Z_3 = 60 mm, Z_4 = 55 mm.

Figure 8: Four Bar Mechanism



- To Generate the elliptical profile three cutting points were considered on coupler link at distance of AT_1 = 40 mm, AT_2 = 20 mm, AT_3 = 10 mm (Figure 9).

Figure 9: For Trace Points T_1, T_2 and T_3



- The major axis and minor axis for ellipses generated by coupler point T_1, T_2, and T_3 were shown in Table 2.

Table 2: Trace Points

S. No.	Coupler Point	Distance from Pin A	Major Axis	Minor Axis
1.	T_1	40 mm	40 mm	15 mm
2.	T_2	20 mm	36 mm	34 mm
3.	T_3	10 mm	40 mm	34 mm

- Trace point T_3 at a distance of 10 mm from pin A is selected as laser cutting point.
- The root mean square error for generated ellipse comes out to be 9.5 mm.

CONCLUSION

The conclusion based on above research work is:

- The laser cutter point on coupler link for generating a given profile can be established by using following steps.
- Synthesizing the four bar chain by using freudenstein's equation and chebyshev equation method.
- By simulating the coupler curves by selecting a number of points on coupler curve.
- For each of the coupler point the error, i.e., root mean square error is evaluated for required cutting profile and profile generated by trace point. the trace point for which this error is minimum should be selected as a laser cutting point.

FURTHER SCOPE OF WORK

The methodology described in conclusion can be used to synthesize any mechanism and identify the trace point to generate any desired profile.

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