A Generalized Approach For Measurement Of Performance Of Planar Mechanism Using Relative Velocity Method.

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Abstract

Mechanism are designed for desired output or required performance for specified input. Error in link length results in variation in the performance of mechanism. Machines are consisting of mechanism for their successful operations. The link length inaccuracies are due to no. of factors like machining errors deflection of link, clearances in joint etc. Due to manufacturing defects & clearances, the link length varies. This variations in link length causes variations in designed performance of mechanism. In this paper a simple class I four bar mechanism is analyzed, assuming that links are rigid. Design engineer wants tight tolerances for accurate performance; while on other hand manufacturing engineer prefer loose tolerances. This paper proposes an approach to identify the effect of change in link length on the performance of the mechanism, using relative velocity method.

Keyword: Mechanism, Keyward2: Relative Velocity Analysis, Keyward3: Performance

1. Introduction

If a number of links are assembled in such a way that motion of one cause constrained and predictable motion to other it is called as mechanism. A mechanism transmites a motion, force, tourage etc. A machine is a mechanism or combination of mechanisms, which apart from imparting definite motion to the parts, also transmit available mechnical energy into some kind of desired work. Thus mechanism is a fundamental unit for motion transmition. Generally mechanism used in machine is responsible for the performance of machine and required output. A mechanism with four link is called as simple four bar chain mechanism.

Many research has been carried out on performance evaluation of mechanism due to inadequate tolerance on link length and clearance in joint. In this links are assumed as rigid. For this purposes, graphical approach is used, but analytical approach is also an alternate method.

2. Relative velocity method

Relative velocity method for determining the velocity of different points in the mechanism may be used to any configuration Diagrams. It is based on The concept that velocity of any point on a link with respect to another point on same link is always perpendicular to the line joining this point on the space diagram. The present research work attempt to arrange the link of four bar chain mechanism in descending order of sensitivity that is ratio of change in output performance to change in link length. To obtain desired performance close tolerances will be provided on some sensitive links and normal on remaining links to optimize the cost. Relative velocity method is used for the analysis of the four bar mechanism. Which is a graphical method and easy to check complete solution to the problem.

3. Performance

Performance of mechanism is expressed in term of desired output, position and location. In case when the mechanism has to work as force or torque manipulator the performance can be expressed as ratio of effort & load. In this performance of mechanism is defined by at any angular position of crank. This maximum torque can be specified as the ideal performance. If variation in the performance of fabricated mechanism is with in tolerance limit mechanism should be accepted. However if the variation is not within the limit further performance analysis is required.

Angular velocity ratio is inversely proportional to torque ratio. If Input torque is known output torque can be determine. Performance using angular velocity ratio is given by equation,

$$\frac{T_4}{T_2} = \frac{W_2}{W_4}$$

4. Approach

The analysis of four bar mechanism using relative velocity method can be divided into three phases

a) Position analysis
b) Velocity analysis
c) Performance analysis

a) **Position analysis :** Checking the Grashof condition

It is useful to determine class of mechanism

$L_{max} + L_{min} \leq P + Q$ – Class I mechanism

$L_{max} + L_{min} \geq P + Q$ – Class II mechanism

where,
L max = maximum length link
L min = minimum length link
P & Q = Remaining two links

Calculating output angle :
Output angle can the calculated using relation

$$\Phi_{1,2} = 2\tan^{-1}\left[\frac{-B \pm \sqrt{B^2 - 4AC}}{2A}\right]$$

where, θ = Input angle
$A = (1-K_2)\cos\theta - K_1 + K_3$
$B = -2\sin\theta$
$C = K_1 - (1 + K_2)\cos\theta + K_3$

$$K_1 = \frac{d}{a}$$

$$K_2 = \frac{d}{c}$$

$$K_3 = \frac{a^2 - b^2 + c^2 + d^2}{2ac}$$

a, b, c, d, are length of links respectively.

b) Velocity analysis :
Graphical approach is used for velocity analysis of four bar mechanism.

$$W_2 = \frac{2pN_2}{60}(rad/\sec)$$

where , w_2 = angular velocity of crank
N_2 = angular speed of crank
v_2 = length of crank x w_2
v_2= velocity of crank (m/s)
Using velocity of crank drawing velocity diagram & measuring velocity of coupler (v_3) & follower (v_4) resp.
To calculate angular velocity of follower or output link.
V_4 = length of follower x w_4

$$W_4 = \frac{V_4}{\text{lenght Of Follower}}$$

W_4 = angular velocity of follower.

c) Performance analysis :

$$R_V = \frac{W_4}{W_2} = \frac{\text{ang.Velocity of o/p link}}{\text{ang.Velocity of i/p link}}$$

$$M.A. = \frac{\text{Torque on o/p link}}{\text{Torque on i/p link}} = \frac{T_4}{T_2}$$

$$\frac{T_4}{T_2} = \frac{W_2}{W_4}$$

5. Mathamatical Calculation

The four bar mechanism which is selecting for analysis purpose it's dimension are as follows

Links	Nomenclature	Dimensions
AB (Link 2)	Crank	40
BC (Link 3)	Coupler	150
CD (Link 4)	Follower	80
AD (Link 1)	Frame	150

Input angle (θ) = 60^0, Input torgue (T_2) = 50 Nm.

POSITION ANALYSIS

Position analysis is divided in to two stages -

Check The Grashof Condition:
Grashof condition is useful to determine the class of the mechanism whether it is Class I or Class II mechanism. It is given by,

$L_{max} + L_{min} \leq P + Q$

Where,
L_{max} = *maximum length of the link*
L_{min} = *minimum length of the link*
P & Q = Remaining two links

Above condition is satisfied. Thus, given mechanism is Class I mechanism.

Output Angle Calculations :
Output angle of four bar mechanism can be calculated using the equation,

$$\emptyset_{1,2} = 2tan^{-1}\left(\frac{-B \pm \sqrt{B^2 - 4AC}}{2A}\right)$$

Where,
$A = (1 - K_2)cos\theta - K_1 + K_3$
$B = -2sin\theta$
$C = K_1 - (1 + K_2)cos\theta + K_3$

Where,
$K_1 = 3.75$
$K_2 = 1.875$
$K_3 = 1.25$
$A = (1 - 1.875)\,cos60 - 3.75 + 1.25$
$A = -2.937$
$B = -1.732$
$C = 3.75 - (1 + 1.875)cos60 + 1.25$
$C = 3.562$
$\emptyset_1 = -110.24°$
$\emptyset_2 = 80.40°$

Velocity analysis

We use graphical approach for velocity analysis of the four bar mechanism which is more accurate.

$$\omega_2 = \frac{2\pi N_2}{60}\ rad/sec$$

Where, ω_2 is angular velocity of the crank
N_2 Is angular speed of the crank

$$\omega_2 = \frac{2 \times \pi \times 120}{60}$$

$$\omega_2 = 12.566\ rad/sec$$

We have,

$V_2 = l(AB) \times \omega_2$

Where, V_2 is the velocity of link 2

$l(AB) = r, radius\ of\ the\ crank$

$V_2 = r \times \omega_2$

$V_2 = 0.502\ \ m/s$

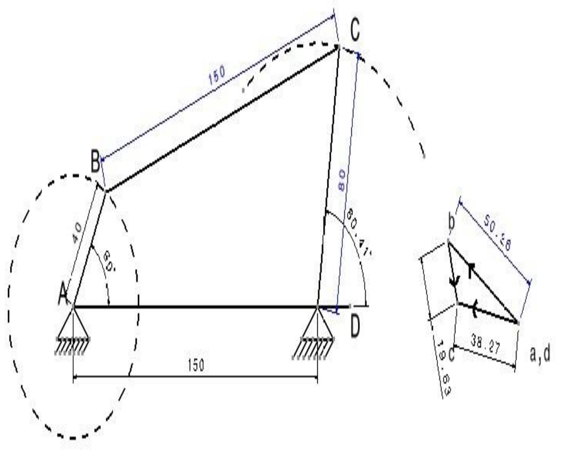

fig. a) Four Bar Mechanism   fig.b) Velocity Diagram

All Dimensions are in mm

Figure shows a Crank Rocker Four Bar Mechanism alongwith Its Velocity Diagram

Measure V_3 & V_4 from the velocity diagram.

$V_3 = \ 0.198\ m/s$

$V_4 = \ 0.382\ m/s$

To calculate angular velocity of output link

Where, V_4 $is\ the\ velocity\ of\ link\ CD$.

$$\omega_4 = \frac{V_4}{l(CD)}$$

$\omega_4 = 4.775$

PERFORMANCE ANALYSIS :
Angular Velocity Ratio = w_4/w_2

$$R_v = \frac{4.775}{12.566}$$

$R_v = 0.3799$

Mechanical Advantage = T_4/T_2

$$M.A. = \frac{T_4}{T_2}$$

Output Torgue T_4, $\frac{T_4}{T_2}$- $= \frac{\omega_2}{\omega_4}$

$T_4 = 131.58\ Nm$

Link(2) Crank mm (a)	Link(3) Coupler mm (b)	Link(4) Follower mm (c)	Link(1) Frame mm (d)	Input angle	Input Torque T_2 Nm	Angular Velocity ratio R_V	Mechanical Advantage MA	Output Torque T_4 Nm	% Variation
39	150	80	150	60	50	0.3859	2.5909	136.23	3.77
40	150	80	150	60	50	0.3799	2.6316	131.58	NIL
41	150	80	150	60	50	0.3928	2.5452	127.26	3.28

Result

Table shows the values obtained of Angular velocity ratio, Mechanical advantage and percentage variation in the performance from standard performance for crank length $40^{\pm 1}$mm.

Conclusion

The proposed analytical method is useful in determining performance variation of any planar four bar mechanism cause due to dimensional inaccuracies. Computer aid can help in easy workput of possible variation in link dimension.

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