Computer Aided Analysis of Four bar Chain Mechanism

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1. Abstract:

To study the motion of a four bar mechanism, knowledge of velocity and acceleration analysis is required. The analysis of velocity and acceleration depend upon the graphical as well as analytical methods. The graphical approach is suitable for finding out the velocity and acceleration of the links of a mechanism in one or two positions of the crank. However, if it is required to find these values at various configurations of the mechanism or to find the maximum values of maximum velocity or acceleration, it is not convenient to draw velocity and acceleration diagrams again and again. In that case, analytical expressions for displacement, velocity and acceleration in terms of general parameters are derived. To get values of velocity and acceleration of a four bar mechanism at different positions of the crank, a computer program is developed. This paper deal with analysis of a four bar mechanism to determine values of velocity and acceleration at different positions of the crank using digital computer

Keywords: Mechanism, Four bar chain mechanism, Velocity analysis, Acceleration analysis

2. Introduction:

If a number of bodies are assembled in such a way that motion of one causes constrained and predictable motion to the others, it is known as mechanism. A mechanism transmits and modifies a motion. A machine is a mechanism or combination of mechanisms which, apart from imparting definite motion to the parts, also transmit and modifies the available mechanical energy into some kind of desired work. Thus, mechanism is a fundamental unit for motion transmission. Generally, mechanism

used in a machine is responsible for the performance of machine and required output. A mechanism with four links is called as simple mechanism. A four bar mechanism is much preferred mechanical device for the mechanization and control of motion due to its simplicity and versatility. Basically, it consists of four rigid links which are connected in the form of a quadrilateral by four bar joints. When one of the links is fixed, it is known as linkage. A link that makes complete revolution is known as crank, link opposite to the fixed link is known as coupler and fourth link is known as rocker.

To study motion of a four bar mechanism, knowledge of velocity and acceleration analysis is necessary. For this purpose, graphical approach is generally used. But values of velocity and acceleration changes with respect to time for different positions of the crank. So analytical approach is alternate method and preferable than graphical to save time and cost. For that, a computer program is prepared to solve this problem and to get the values of velocity and analysis at different positions of the crank.

3. Mathematical formulation:

To different the values of velocity and acceleration at different positions of a crank, analytical expressions in terms of general parameters are derived.

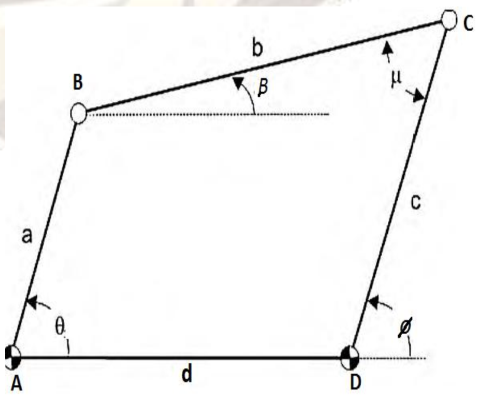

Fig. Four bar chain mechanism

Let,
Link AB – a- Crank
Link BC – b – Coupler
Link CD – c- Rocker
Link AD – d- Fixed link
θ – Input angle
Ø – Output angle

As, O/P angle is a function of I/P angle, we have

Ø=f (a, b, c, d, θ) …………………… (1)

Thus, if values of a, b, c, d and θ are known, we can find out relationship between θ and Ø. To determine the relationship between O/P and I/P links, we will use expressions of displacement, velocity and acceleration.

3.1 Displacement Analysis:

Position of the O/P link given by Ø can be calculated using equation (2)

$Ø=2\tan^{-1}\{[-B\pm\sqrt{B^2 - 4AC}]/2A\}$……… (2)
Where,
A= k-[a* (d-c) *cos θ] – c*d
B = -2*a*c *sin θ
C = K-[a (d+c)cos θ] +c*d
$2k = a^2-b^2+c^2+d^2$

A relationship between the coupler link position β and I/P link θ can also be found using eq^n (3)

C*sinØ= a sin θ + b sin β………… (3)

3.2 Velocity Analysis:

Let, ωa, ωb, ωc be the angular velocities of the links AB, BC and CD respectively. Value of ωa is given, value of ωb and ωc can be calculated using eq^n (4.1 & 4.2)

$W_b = -a*W_a*\sin(Ø - \theta) / b*\sin(\theta-\beta)$… (4.1)

$W_c = a*W_a*\sin(\beta - \theta) / c*\sin(\beta - Ø)$… (4.2)

3.3 Acceleration Analysis:

Let α_a , α_b, α_c be angular acceleration of links AB, BC, CD respectively. As per data given in the problem, link AB rotates at uniform angular velocities. In this case, acceleration of input link will be zero i.e. there is no need to calculate it. α_b, α_c can be calculated using equations-

$$\alpha_b=\frac{[a*\alpha_a*\sin(Ø - \theta) - \{a*(W_a^2)*\cos(Ø - \theta)\} - \{b*(W_b^2)*\cos(Ø - \beta)\} + c*W_c^2]}{b*\sin(\beta - Ø)}$$

$$\alpha_b=\frac{[a*\alpha_a*\sin(\beta - \theta) - \{a*(W_a^2)*\cos(\beta - \theta)\} - b*W_b^2 + c*(W_c^2)\cos(\beta\, Ø -)]}{c*\sin(\beta - Ø)}$$

4. Manual Calculation:

For the analysis of a four bar mechanism, we consider a problem of which, we have to find out solutions at an instant for various positions of the crank with some interval manually.

4.1 Example: In a four bar link mechanism, the dimensions of the links are as under:
AB = 20mm, BC = 66 mm, CD = 56 mm, AD = 80mm. AD is the fixed link. The crank AB rotates at uniform angular velocity of 10.5 rad/sec in the CCW direction. Determine the angular displacements, angular velocities and angular accelerations of the O/P link DC and coupler BC for a complete revolution of the crank at an interval of 40^0.

a = 20mm; b = 66mm; c = 56mm; d = 80mm

$2K = a^2 - b^2 + c^2 + d^2$
$= 20^2 - 66^2 + 56^2 + 80^2$
= 5588
K = 2790

A = K – a(d – c)cosθ – cd (since,θ = 40^0)
= 2790 – 20(80- 56) cos 40^0 – (56*80)
= -2057.70

B = -2ac*sinθ
= -2*20*56*sin (40)
= -1439.84

C = K – a (d + c)*cosθ + cd
= 2790 – 20(80 + 56)* cos(40) + (56*80)
= 5186.35

$Ø = 2*\tan^{-1}\{ (-B \pm \sqrt{B^2 - 4AC})/ 2A\}$
$= 2\tan^{-1} \{[-1439.84 \pm \sqrt{(-1439.84)^2 - (4*-2057.70*5186.35)}]/ (2*-2057.76)\}$
$= -113.27^0$ 0R 120^0

5. Programmable Calculation:

For the analysis of a four bar mechanism, we consider a problem of which, we have to find out solutions at an instant for various positions of the crank with some interval with the help of computer program in 'C' language.

```
#include<studio.h>
#include<conio.h>
#include<math.h>
void main()
{
int i,j,iht,th,theta,limit,ins;
float
a,b,c,d,vela,acca,thet,aa,bb,cc,bet1,bet2,betd1,betd2
,num1,num2,phi1,ph1,unroot,undroot,pi,k,phh,phi2,
ph2,vel2,dtht;
float
num[2],phi[2],ph[2],bet[2],betd[2],b1[2],b2[2],b3[2
],b4[2],c1[2],c2[2],c3[2],c4[2],accc[2],accb[2],velb
[2],velc[2];
clrscr();
printf{"entervalues a,b,c,d,vela,acca,theta,limit\n");
scanf("%f%f%f%f%f%f%d%d",&a,&b,&c,&d,&v
ela,&acca,&theta,&limit);
printf("thet,vela,acca,phi,beta");
printf("velc,velb,accc,accb\n");
ins=1;
if(vela==0 &&acca>0)ins=0;
pi=4*atan(1);
iht=360/theta;
if(vela>0&& acca==0)(ins=0;iht=360/theta);
if(ins==1) iht=theta;
dthet=pi*2/iht;
if(vela==0 && acca>0iht=iht+limit/theta;
for(j=0;j,iht+1,j++)
{
if(j>(iht-360/theta-1) && ins==0)acca=0;]
thet=j*dthet;
if(ins==1)(j=iht; thet=theta*pi/180);
th=theta*j;
if(ins==1)th=theta;
k=(a*a-b*b+c*c+d*d)/2;
aa=k-a*(d-c*cos(thet)-c*d;
bb=2*a*c*sin(thet);
cc=k-a*d+c*cos(thet)+c*d;
unroot=bb*bb-4*aa*cc;
if(unroot>0)
{
undroot=sqrt(unroot);
num[0]=-bb+undroot;
num[1]=-bb-undroot;
```

Solution:

```
for(i=0;i<2;i++)
{
phi[i]=atan(num[i]*0.5/aa)*2;
ph[i]=phi[i]*180/pi;
bet[i]=asin((c*sin(phi[i])-a*sin(thet))/b);
betd[i]=bet[i]*180/pi;
velc[i]=(a*vela*sin(bet[i]-thet))/(c*sin(bet[i]-
phi[i]));
velb[i]=(a*vela*sin(phi[i]-thet))/(b*sin(vet[i]-
phi[i]));
c1[i]=a*acca*sin(bet[i]-thet);
c2[i]=a*pow(vela,2)*cos(bet[i]-
thet)+b*pow(velb[i],2);
c3[i]c*pow(velc[i],2)*cos(phi[i]-bet[i]);
c4[i]c*sin(bet[i]-phi[i]);
accc[i]=(c1[i]-c2[i]+c3[i]/c4[i];
b1[i]=a*acca*sin(phi[i]-thet);
b2[i]=a*pow(vela,2)*cos(phi[i]-thet);
b3[i]=b*pow(velb[i],2)*cos(phi[i]-bet[i])-
c*pow(velc[i],2);
b4[i]=b*sin(bet[i]-phi[i]);
accb[i]=(b1[i]-b2[i]-b3[i]/b4[i];
printf("%6.2d%6.2f%8.2f%8.2f%8.2f%6.2f%6.2f%
6.2f%6.2f\n",th,vela,acca,ph[i],betd[i],velc[i],velb[i
],accc[i],accb[i]);
}
}
vela=sqrt(vela*vela+2*acca*dthet);
}
getch();
}
```

5.1Example: In a four bar link mechanism, the dimensions of the links are as under:
AB = 20mm, BC = 66 mm, CD = 56 mm, AD = 80mm.
AD is the fixed link. The crank AB rotates at uniform angular velocity of 10.5 rad/sec in the CCW direction. Determine using the program, the angular displacements, angular velocities and angular accelerations of the O/P link DC and coupler BC for a complete revolution of the crank at an interval of 40^0.

Solution:

Obtained using the program is given below:

Obtained using the program is given below:

thet	Vela	acca	phi	beta	velc	velb	Accc	Accb
00	10.5	0.00	-110.74	-52.51	-3.50	-3.50	-37.58	18.56
00	10.5	0.00	110.74	52.51	-3.50	-3.50	37.58	-18.56
40	10.5	0.00	-126.30	-61.47	-4.06	-0.83	15.50	50.99
40	10.5	0.00	103.821	38.99	0.07	-3.15	56.46	20.96
80	10.5	0.00	-139.02	-58.74	-2.51	2.03	26.17	31.04
80	10.5	0.00	110.16	29.87	2.92	-1.62	27.30	22.42
120	10.5	0.00	-145.28	-48.22	-0.77	3.26	26.64	4.54
120	10.5	0.00	123.49	26.44	3.77	-0.20	-0.66	21.44
160	10.5	0.00	-144.69	-36.44	1.12	2.75	29.94	-16.40
160	10.5	0.00	136.77	28.52	2.96	1.32	-22.41	23.99
200	10.5	0.00	-136.77	-28.52	2.96	1.32	22.41	-23.99
200	10.5	0.00	144.69	36.44	1.12	2.75	-29.94	16.40
240	10.5	0.00	-123.49	-26.44	3.77	-0.20	0.66	-21.44
240	10.5	0.00	145.28	48.22	-0.77	3.20	-26.64	-4.54
280	10.5	0.00	-110.16	-29.87	2.92	-1.62	-27.30	22.42
280	10.5	0.00	139.02	58.74	-2.51	2.03	-26.17	-31.04
320	10.5	0.00	-103.82	-38.99	0.07	-3.15	-56.46	-20.96
320	10.5	0.00	126.30	61.47	-4.06	-0.83	-15.50	-50.99

I/P variables :

vela-angular velocity of I/P link AB (m/s)
acca-angular acceleration of I/P link AB (m/s^2)
theta-interval of O/P angle(here it is 40^0)

O/P variables:

thet-angular displacement of I/P link AB (degrees)
phi -angular displacement of O/P link CD (degrees)
beta -angular displacement of coupler link BC (degrees)
velc-angular velocity of I/P link AB (rad/sec)
velb-angular velocity of O/P link CD (rad/sec)
accc-angular acceleration of O/P link DC (rad/s^2)
accb-angular acceleration of coupler link BC (rad/s^2)

6. Conclusion:

The proposed analytical method using computer programming is useful in determining the values of velocity and acceleration analysis at different positions of the crank. On the basis of result and analysis, it is concluded that this present method is very fast and less laborious and very efficient than graphical method. Also errors due to the graphical method are eliminated by this present method which gives better result.

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