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Synthesis of Slider Crank Mechanism Using Matlab

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Research Scholar

Abstract – In the present work the results of a theoretical investigation on synthesis of a slider crank mechanism using MATLAB is done. A theoretical expression for the motion of piston P in terms of crank length r, connecting rod length l, and constant angular velocity of the crank ω is derived. Thus obtained displacement equation is used in this synthesis.

Commonly it is observed that we get a sinusoidal wave for the simple slider crank mechanism. In this synthesis it is found that it is not possible to get the sinusoidal wave for 'n=l/r' values ranging from 0.007 to 3 for the mechanism. Also the piston will not move even though the crank rotates when connecting rod length is equal to crank radius. This can be clearly seen by the animation output. This mechanism can be implanted in future applications.

◆

I. INTRODUCTION

The base of dynamic mechanism operation of engine is slider crank mechanism, which consists of crankshaft, connecting rod and piston. Slider crank mechanism, arrangement of mechanical parts designed to convert straight-line motion to rotary motion, as in a reciprocating piston engine, or to convert rotary motion to straight-line motion, as in a reciprocating piston.

The reciprocating engine mechanism is often analyzed, since it serves all the demands required for the convenient utilization of natural sources of energy such as gaseous, liquid fuels and steam, for generation of power.

To convert rotary motion into reciprocating motion, the slider crank is part of a wide range of machines, typically pumps and compressors. Another use of slider crank is in toggle mechanisms, also called knuckle joints. The driving force is applied at the crankpin so that, at TDC, a much larger force is developed at the slider.

II. DESIGN PROBLEM

A slider mechanism is shown in below figure. Derive an expression for the motion of the piston P in terms of crank length r, connecting rod length l, and constant angular velocity of the crank ω.

Find the value of l/r for which the amplitude of every higher harmonic is smaller than that of the first harmonic by a factor of at least 25.

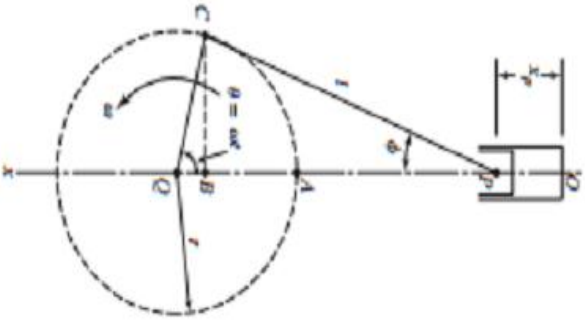


Fig. slider crank mechanism

III. PROCEDURE ADOPTED

The procedure to solve this problem is divided into two parts and they are,

1. Analytical Method

The procedure adopted in solving this problem is,

i. To derive an expression for the motion of the piston P in terms of crank length r, connecting rod length l, and constant angular velocity of the crank ω.

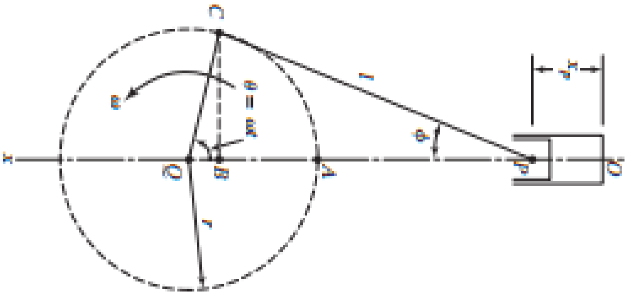
ii. To find the value of l/r for which the amplitude of every higher harmonic is smaller than that of the first harmonic by a factor of at least 25.

2. Animation Method

Checking the analytical results by using MATLAB animation method for different values of n= l/r.

IV. ANALYTICAL METHOD

Derivation of the slider crank mechanism:



Consider the slider crank mechanism shown in above figure. Let θ be the angle turned through by the crank OA = r when the slider B has moved by an amount x to the right, and Ø the angle which the connecting rod AB=l makes with the line of stroke.

$$x = r + l - (OC + BC)$$

$$x = r + l - (r\sin\theta + l\cos\emptyset)$$

$$x = r(l - cos\theta) + l(1 - \cos\emptyset)$$

Now, $AC = r\sin\theta = l\sin\emptyset$

$$\sin\emptyset = (r/l)\sin\theta$$

Let, $n = l/r$

Then, $\cos\emptyset = [1 - \sin^2\emptyset]\text{^}.05$

$$= [1 - \sin^2\theta/n^2]\text{^}.05$$

$$x = r[(1 - cos\theta) + l\{1 - (1 - (\sin^2\theta/n^2))\text{^}^{.05}\}$$

$$x = r\left[(1 - cos\theta) + n\{1 - \left(1 - (\sin^2\theta/n^2)\right)\text{^}^{.05}\}\right]$$

$$\approx r[(1 - cos\theta) + (\sin^2\theta)/2n]$$

The above equation is used for finding the l/r ratio by writing simple MATLAB program.

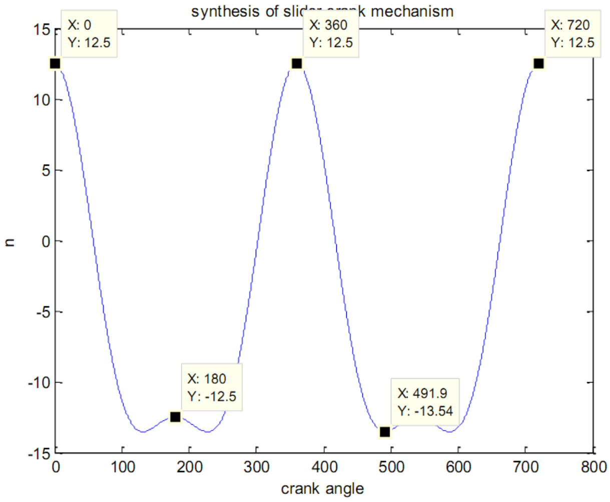
V. MATLAB SOLUTION

The MATLAB program for above equation is as below,

M-file program:

```
n=.6667;

r=12.5;

t=0:.1:720;

a=1-cosd(t);

b=1-cosd(2*t);

c=4*n;

d=r-(r*(a+(b/c)));

plot (t,d)

xlabel (‘crank angle’)

ylabel (‘n’)

title(‘synthesis of slider crank mechanism’)
```

When this program is executed the following graph appears.



In the above graph the maximum displacement from the mean position represents the amplitude of the wave form (i.e A=13.5mm).

VI. ANALYTICAL SOLUTION

From the above plot graph the value of n=x1/xh as follows,

Let, x1=amplitude of first harmonic.

xh=amplitude of higher harmonic to be calculated.

y=amplitude of higher harmonic at BDC.

Now from the graph, x1= 13.5mm

xh= (x1-y)/2

= (13.5-12.5)/2

xh= 0.5mm

Therefore we've n=x1/xh=13.5/0.5=27

Also we've, n=l/r

For n=0.6667 and r=12.5mm we get the value of 'l' as,
l= n × r =0.6667×12.5=8.33375mm

Hence for the ratio, n=x1/xh=13.5/0.5=27

We achieved the condition that the amplitude of every higher harmonic is smaller than that of the first harmonic by a factor of at least 25.

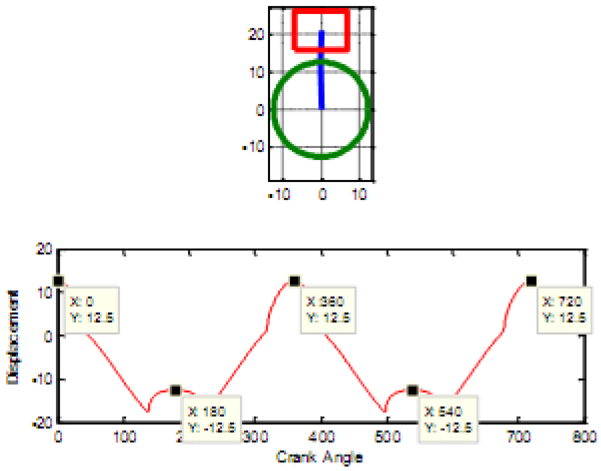
Therefore, the value of 'l' is equal to 8.33375mm and the value of 'r' is equal to 12.5mm.

VII. VALIDATION BY ANIMATION ANALYSIS

The project problem is validated by this below m-script written for the animation of simple slider crank mechanism. From the animation it can be clearly understood that how exactly the piston reciprocates for different crank angles and for different n=l/r values.

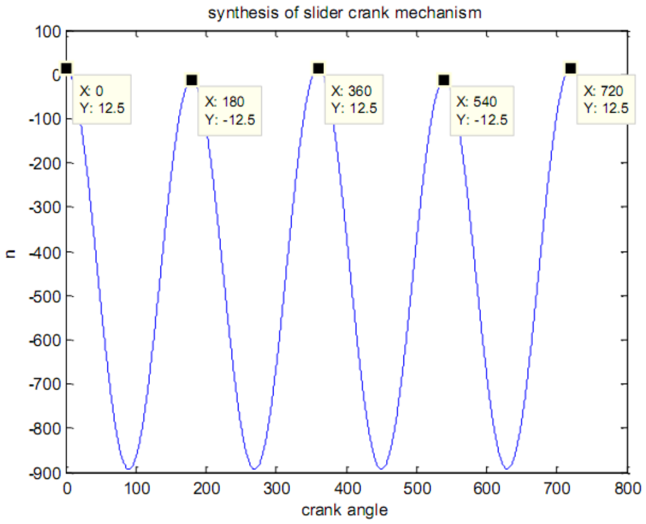
```
%This m-script shows a simple
simulation for the crank-slider
mechanism for
% the crank shaft-piston mechanism
% l = rod length (distance between
piston pin and crank pin)
% r = crank radius (distance
between crank pin and crank
center, i.e. half stroke)
% A = crank angle (from cylinder
bore centerline at TDC)
% x = piston pin position (upward
from crank center along cylinder
bore centerline)

%The crank-slider mechanism
scretch

%   P
%   o
%      o
%       o
%         o N
%        *
%       *
%      *
%   O

% O [0,0] is the pivot of the
crank shaft
n=0.6667;
r=12.5;
l=n*r;
X=[0 0 0];
Y=[0 r r+l];
X_Piston=[-7 7 7 -7 -7];
Y_Piston=[l-5 l-5 l+5 l+5 l-5];
subplot(2,1,1)
h =
plot(X,Y,'LineWidth',4,'XDataSourc
e','X','YDataSource','Y');
axis([-1.1*r 1.1*r  -1.5*r
1.5*r+l]);
set(gca,'DataAspectRatio',[1 1 1])
grid on
hold('all')
subplot(2,1,1)
g =
plot(X_Piston,Y_Piston,'r','LineWi
dth',4,'XDataSource','X_Piston','Y
DataSource','Y_Piston');
angle=0:0.01:2*pi;
x_circle=r.*cos(angle);
y_circle=r.*sin(angle);
subplot(2,1,1)
i=plot(x_circle,y_circle,'LineWidt
h',4);
t=0:.1:720;

m=r*cosd(t)+sqrt(l^2-
r^2*sind(t).^2)-l;
subplot(2,1,2)
j=plot(t,m,'r','linewidth',1);
xlabel('Crank Angle')
ylabel('Displacement')
for A=0:0.08:4*pi
    x=r*cos(A)+sqrt(l^2-
r^2*sin(A)^2);
    N=[r*sin(A) r*cos(A)];
    P=[0 x];
    X=[0 r*sin(A) 0];
    Y=[0 r*cos(A) x];
    Y_Piston=[x-5 x-5 x+5 x+5 x-
5];
    refreshdata(h,'caller')
    refreshdata(g,'caller')
    refreshdata(i,'caller')
    refreshdata(j,'caller')
    drawnow
    pause(.2)
end
```

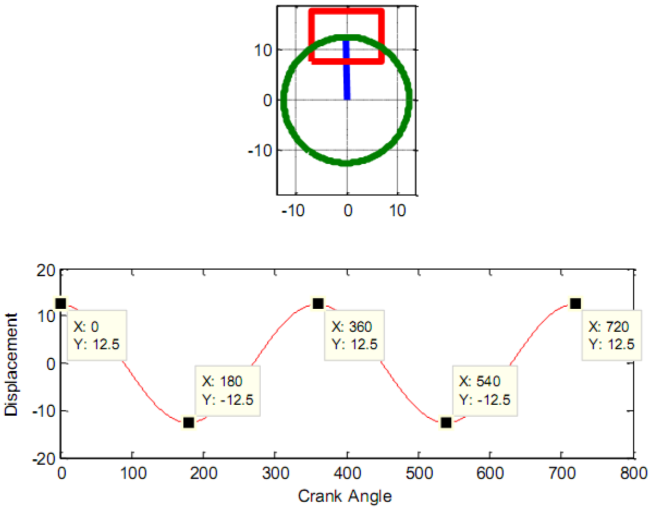
The following graph appears when the animation m-script file is executed. From the graph it is observed that the wave form is not sinusoidal and at particular angle amplitude varies to small interval of time within the completion of one complete cycle.



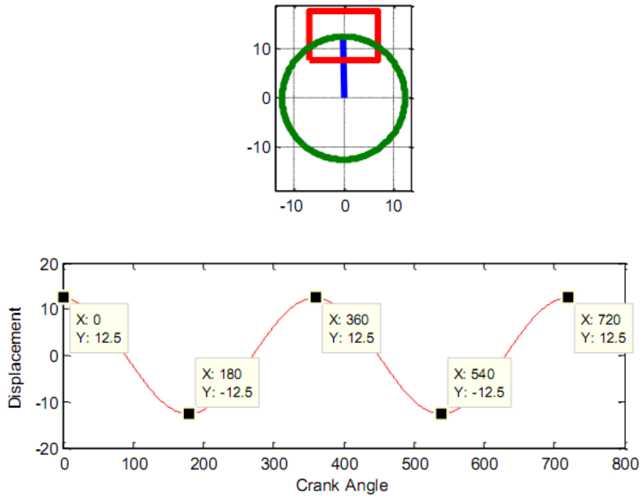
COMPARISIION OF RESULT PLOTS

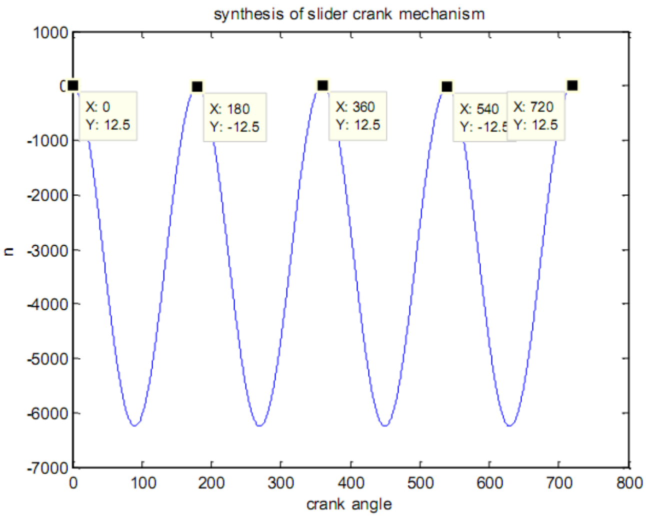
For n=0.007 and l=.0875mm, when r=12.5mm



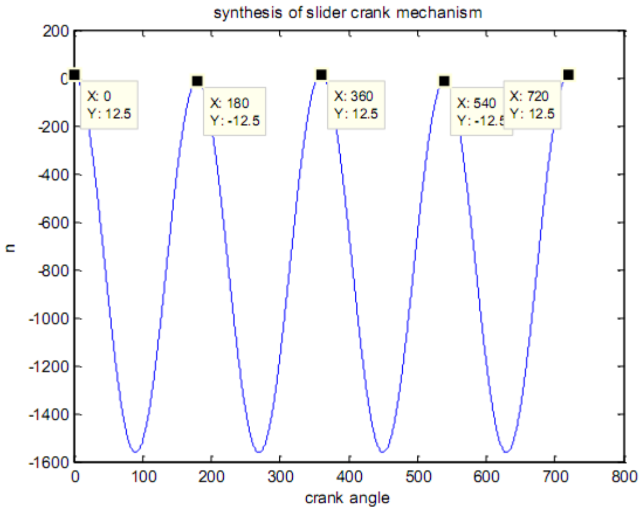


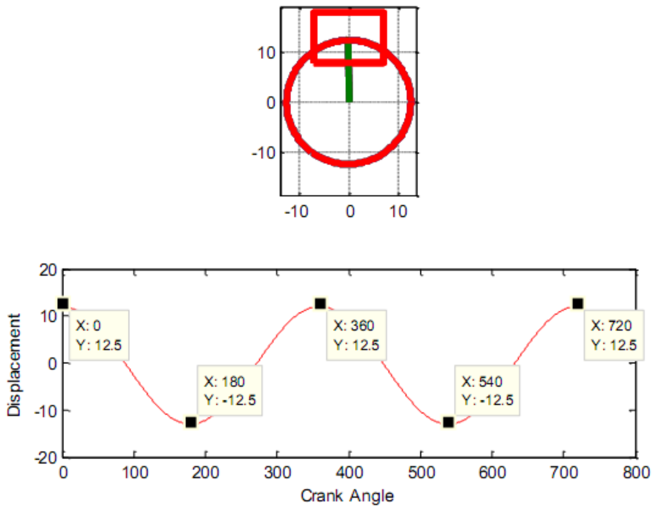
For n=0.01 and l=0.125mm, when r=12.5mm.



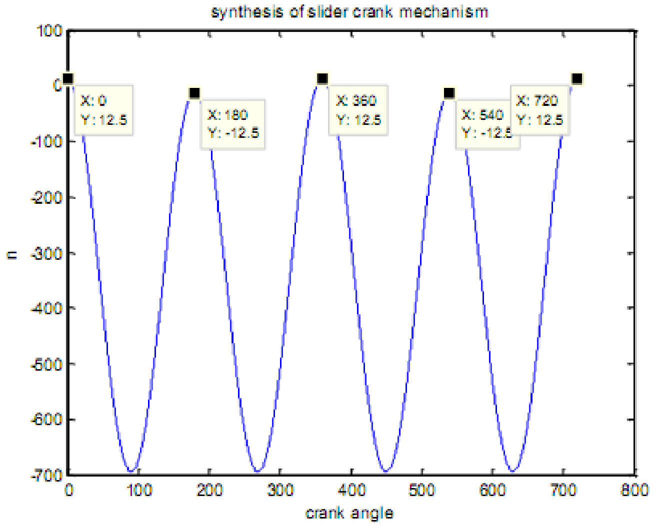


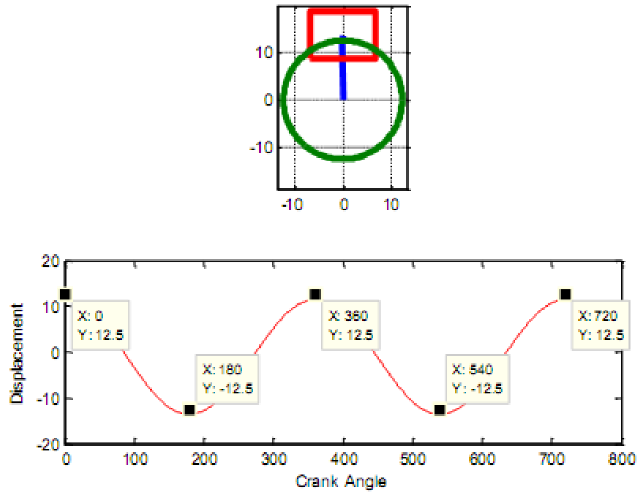
For n=0.04 and l=0.5mm, when r=12.5mm.



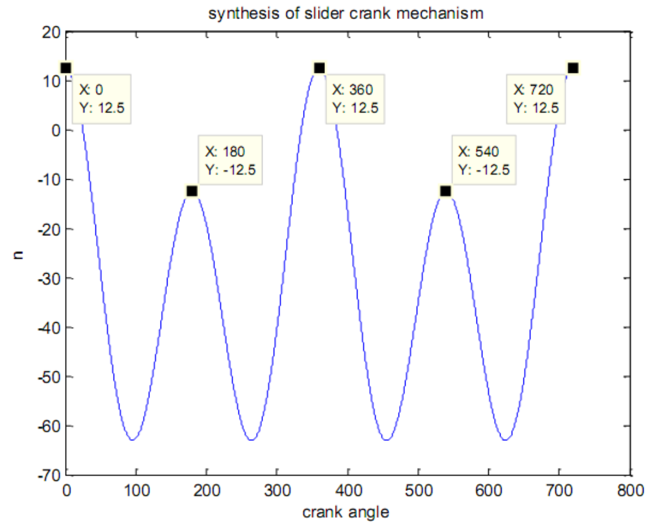


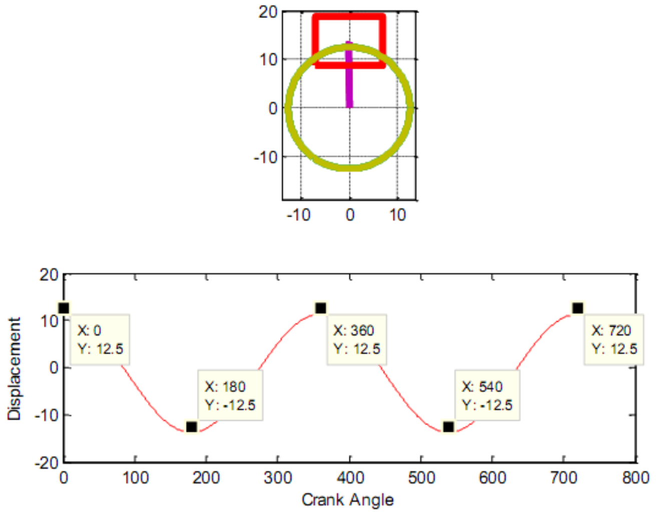
For n=0.09 and l=1.125mm, when r=12.5mm.



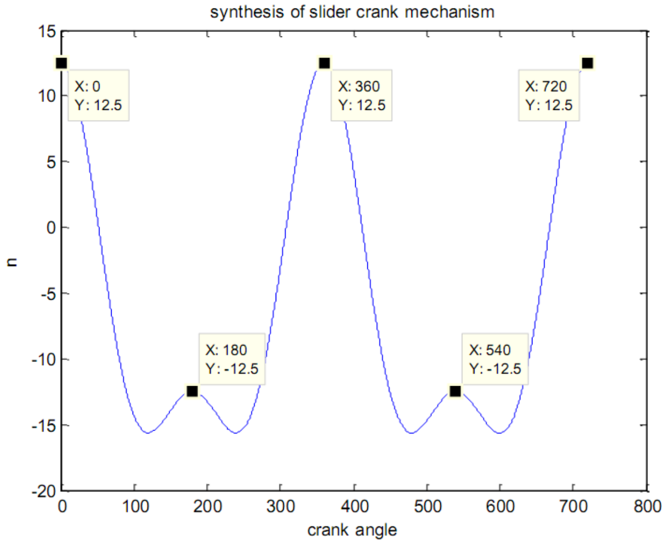


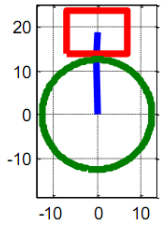
For n=0.1 and l=1.25mm, when r=12.5mm.

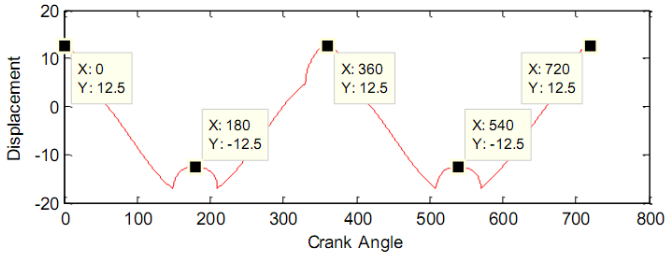




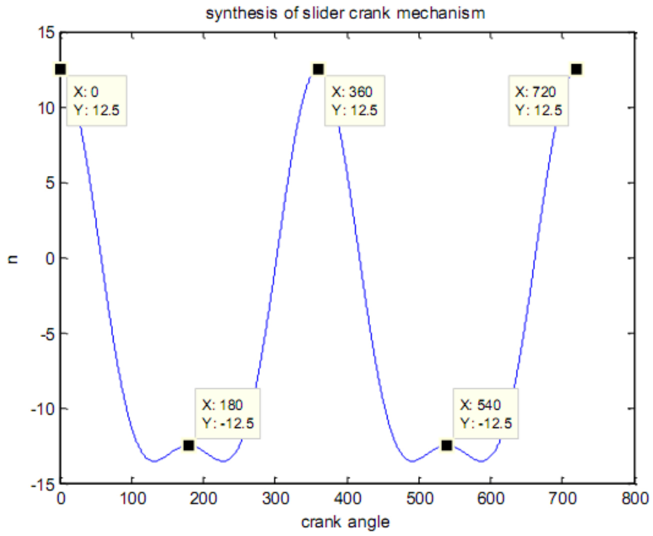
For n=0.5 and l=6.25mm, when r=12.5mm.

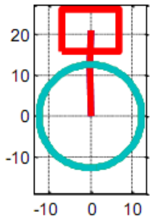


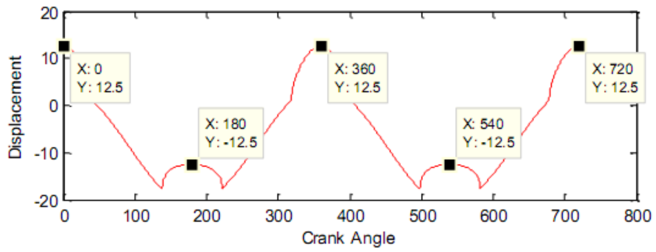




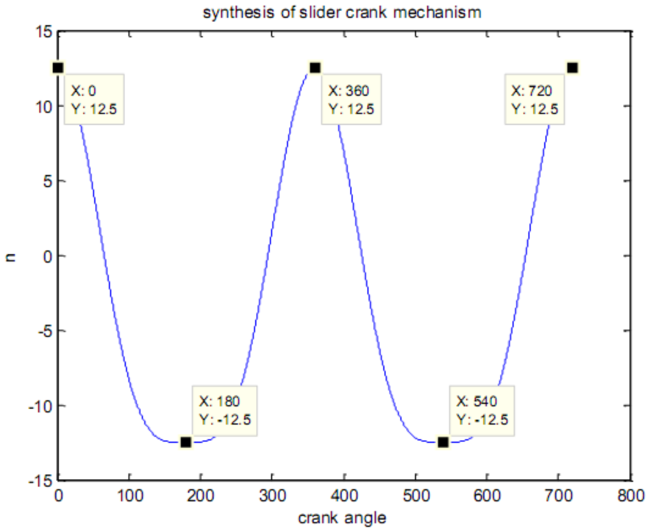
For n=0.6667 and l=8.33375mm, when r=12.5mm.

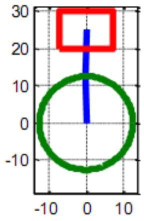


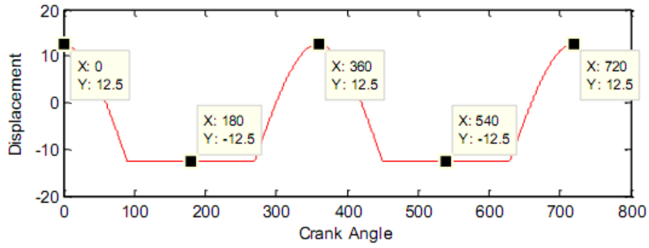




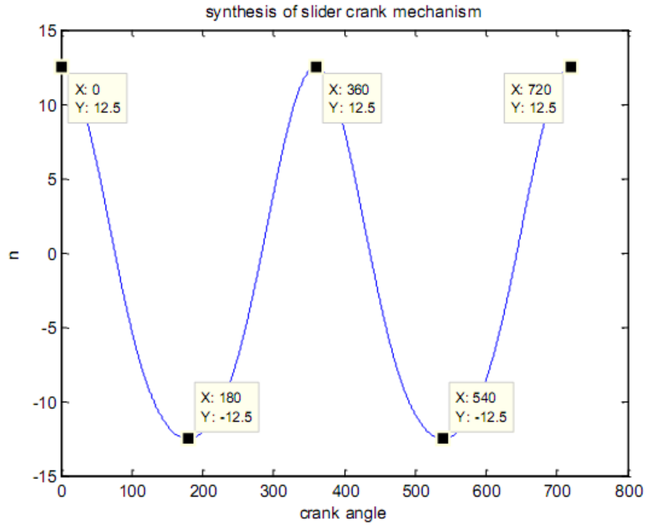
For n=1 and l=12.5mm, when r=12.5mm.

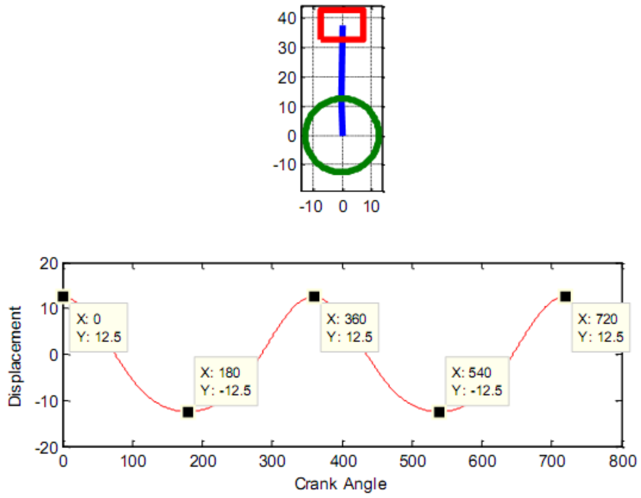




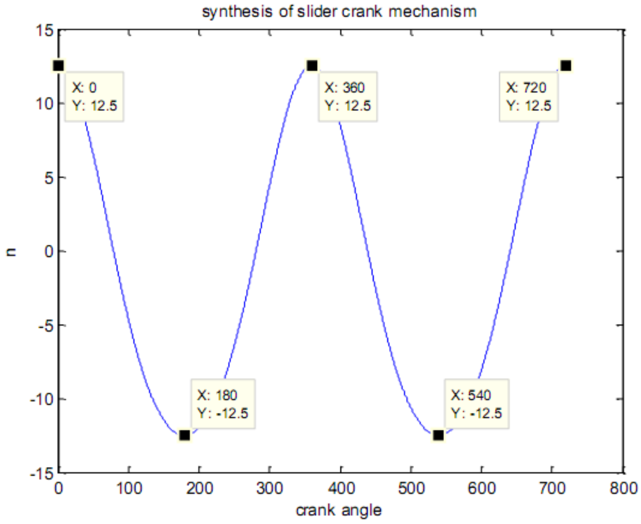


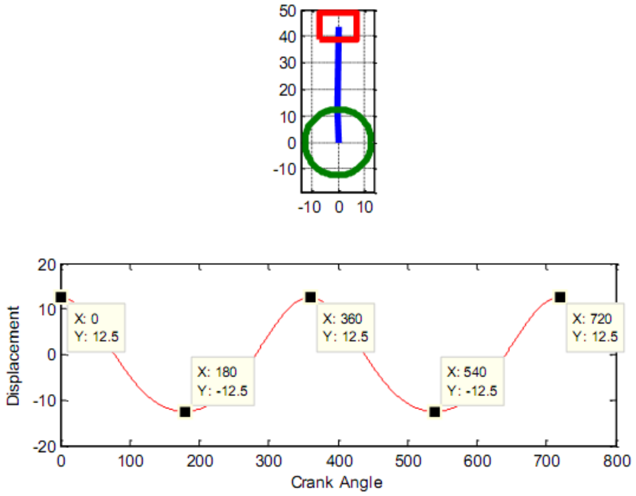
For n=2 and l=25mm, when r=12.5mm.



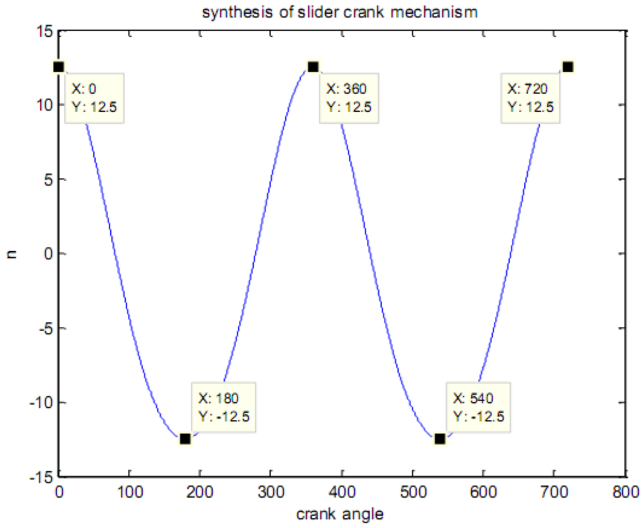


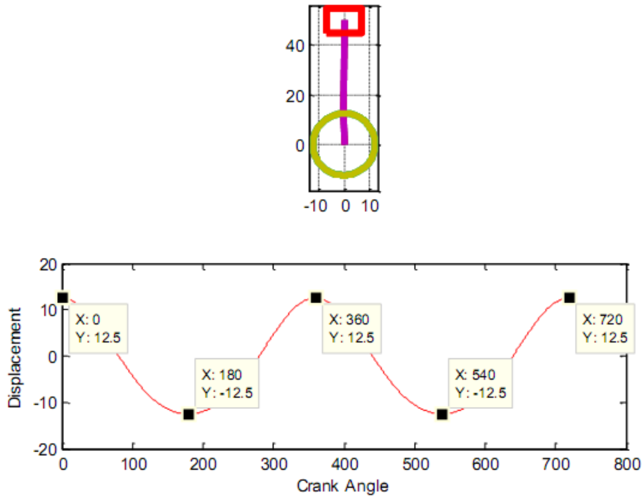
For n=2.5 and l=31.25mm, when r=12.5mm.



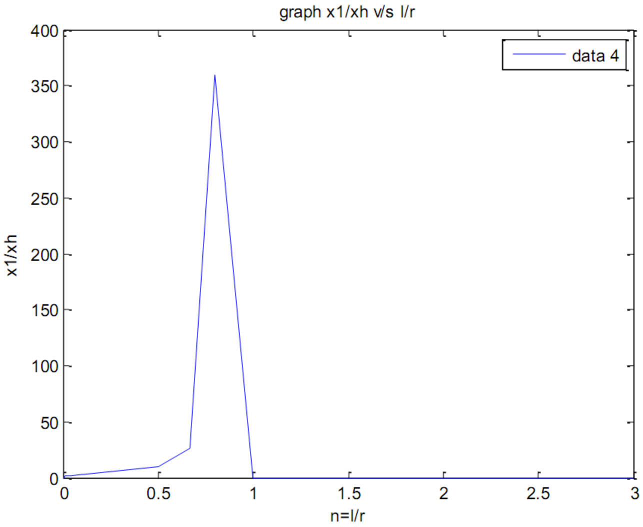


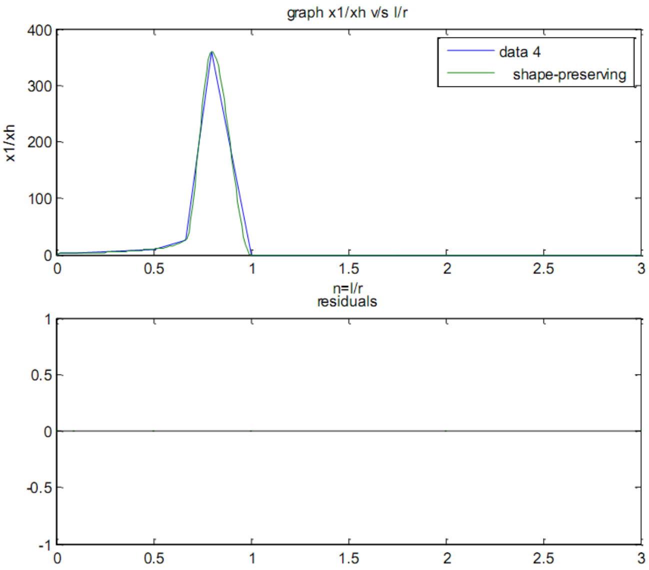
For n=3 and l=37.5mm, when r=12.5mm.





VIII. GRAPH OF N=X1/XH V/S N=L/R





IX. CONCLUSION

It is concluded from the graphs obtained for this simple slider crank mechanism analysis made for the conditions defined in the problem; the following results are found and validated from the MATLAB animation.

It is not possible to get the sinusoidal wave for the ratio of n=l/r values ranging from 0.007 to 3 where ‘l’ is connecting rod length and ‘r’ is crank radius.

It is found that when connecting rod length(l)= crank radius(r), the piston is stationary for 180° when the crank is rotating from the angle 90° to 270° in one complete cycle.

It is concluded from analysis that we get a sinusoidal wave when n=l/r ratio is less than 0.007 and more than 3.

REFERENCES

Mechanical Vibrations by Singiresu. S. Rao. 5th edition, Printice Hall Publications, Page no.120.

Getting started with MATLAB by Rudra Pratap, OXFORD university press.

H.D.Desai, “Computer aided kinematic and dynamic analysis of a horizontal slider crank mechanism for single cylinder four stroke IC engine” proceedings of the world congress on Engineering 2009,VOL II, WCE 2009,July 1-3, 2009, London, U.K.

Mohammad Ranjbarkohan, Mansour Rasekh, Abdol Hamid Hoseini, Kamran Kheiralipour, and Mohammad Reza Asadi “Kinematics and kinetic analysis of the slider crank mechanism in otto linear four cylinder Z24 engine” Journal of Mechanical Engineering Research Vol.3(3), pp.85-95, March 2011.

*H. Jiménez[1], I. Hilerio2, M. Gómez3, B. Vázquez4, G. D. Álvarez5, G. Rosas6 “SLIDER-CRANK MECHANISM”, 8th World Congress on Computational Mechanics (WCCM8). 5th. European Congress on Computational Methods in Applied Sciences and Engineering (ECCOMAS 2008) June 30 – July 5, 2008 Venice, Italy.

Chih-Cheng Kaoa,c, Chin-Wen Chuangb, Rong-Fong Funga*, “The self-tuning PID control in a slider–crank mechanism systemby applying particle swarm optimization approach”, Elsevier Mechatronics 16 (2006) 513–522, Received 14 March 2006.

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