IN-LINE SLIDER CRANK MECHANISM

A MAJOR PROJECT REPORT

Submitted by

CH.EN.U4AIE20001	ANBAZHAGAN E
CH.EN.U4AIE20053	RAMYA POLAKI
CH.EN.U4AIE20069	TRINAYA KODAVATI
CH.EN.U4AIE20031	SMITHIN REDDY
CH.EN.U4AIE20035	ABHIRAM KUNCHAPU

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AMRITA SCHOOL OF ENGINEERING, CHENNAI

AMRITA VISHWA VIDYAPEETHAM

CHENNAI – 601103, TAMIL NADU

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AMRITA VISHWA VIDYAPEETHAM

AMRITA SCHOOL OF ENGINEERING, CHENNAI, 601103

BONAFIDE CERTIFICATE

This is to certify that the major project report entitled “**IN-LINE SLIDER CRANK MECHANISM”** submitted by

CH.EN.U4AIE20001	ANBAZHAGAN E
CH.EN.U4AIE20053	RAMYA POLAKI
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CH.EN.U4AIE20035	ABHIRAM KUNCHAPU

in partial fulfilment of the requirements for the award of the **bachelor of Master of Technology** in **COMPUTATIONAL ENGINEERING MECHANICS** is a bonafide record of the work carried out under my guidance and supervision at Amrita School of Engineering, Chennai.

Signature

Mr.KL Vasudev

Asst.Professor, Mechanics Dept

This project report was evaluated by us on ……………...

INTERNAL EXAMINER EXTERNAL EXAMINER

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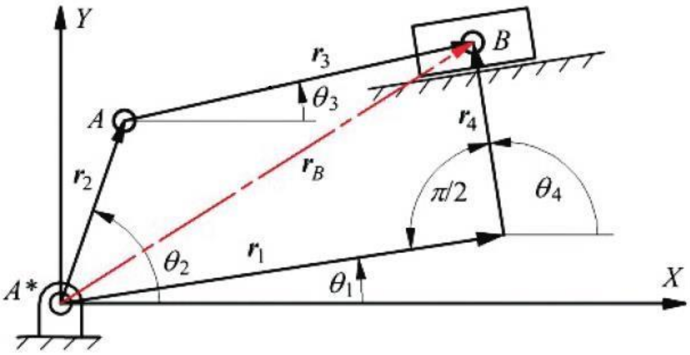
IN-LINE SLIDER CRANK MECHANISM:



This is basically the off-set slider crank mechanism. So, to make it in-line slider crank we have to make θ_1 and r_4 to zero.

DERIVATION:

From the above diagram we can observe that,

- The link r_1 is a fixed link making an angle θ_1 i.e. 0.
- The link r_2 is the crank making an angle θ_2.
- The link r_3 is the slider making an angle θ_3.
- The link r_4 is not considered here as it is in-line slider-crank mechanism.

Considering the link lengths as r_1, r_2 and r_3

Time period for crank to rotate a full revolution:

$$T = \frac{2\pi}{\omega_2}$$

$$\frac{d\theta_2}{dt} = \omega_2$$

$$\int d\theta_2 = \omega_2 \int dt$$

Integrating on both sides:

$\theta_2 = \omega_2 \times t + \theta_0$

POSITIONAL ANALYSIS:

$\overrightarrow{r_B} = \overrightarrow{r_2} + \overrightarrow{r_4} = \overrightarrow{r_2} + \overrightarrow{r_3}$

$r_1(\cos\theta_1 i + \sin\theta_1 j) + r_4(\cos\theta_4 i + \sin\theta_4 j) = r_2(\cos\theta_2 i + \sin\theta_2 j) +$
$r_3(\cos\theta_3 i + \sin\theta_3 j)$

By separating i ang j terms

i = $r_1\cos\theta_1 + r_4\cos\theta_4 = r_2\cos\theta_2 + r_3\cos\theta_3$ → 1

j = $r_1\sin\theta_1 + r_4\sin\theta_4 = r_2\sin\theta_2 + r_3\sin\theta_3$ → 2

r_1, r_2, r_3, r_4 → Given($r_4 = 0$)

θ_1, θ_4→constant ($\theta_1 = \theta_4 = 0$)

$\theta_{2,}\theta_3$→ $Variable$

Substituting equation 1 and 2 with the above values

$r_3cos\theta_3 + r_2cos\theta_2 = r_1$ → 3

$r_3sin\theta_3 = -r_2sin\theta_2$ → 4

$(r_1 - r_2cos\theta_2)^2 = (r_3cos\theta_3)^2$

$(-r_2sin\theta_2)^2 = (-r_3sin\theta_3)^2$

${r_3}^2 = (r_1 - r_2cos\theta_2)^2 + {r_2}^2sin^2\theta_2$

${r_3}^2 = {r_1}^2 + {r_2}^2cos^2\theta_2 - 2r_1r_2\cos\theta_2 + {r_2}^2 sin^2\theta_2$

${r_3}^2 = {r_1}^2 + {r_2}^2 - 2r_1r_2\cos\theta_2$

$\cos\theta_2 = \dfrac{{r_3}^2 - ({r_1}^2 + {r_2}^2)}{-2r_1r_2}$

$$\sin\theta_3 = \frac{-r_2 \sin\theta_2}{r_3}$$

<u>VELOCITY ANALYSIS:</u>

$$\dot{\vec{r}}_1 + \dot{\vec{r}}_4 = \dot{\vec{r}}_2 + \dot{\vec{r}}_3$$

$$\dot{r}_1\left(\cos\theta_1 i + \sin\theta_1 j\right) = r_2\dot{\theta}_2\left(-\sin\theta_2 i + \cos\theta_2 j\right) + r_3\dot{\theta}_3\left(-\sin\theta_3 i + \cos\theta_3 j\right)$$

$$\dot{r}_1 \cos\theta_1 \;=\; -(r_2\; \dot{\theta}_2 sin\theta_2 +\; r_3\; \dot{\theta}_3 sin\theta_3)$$

$$\dot{r}_1 \sin\theta_1 \;=\; -(r_2\; \dot{\theta}_2 cos\theta_2 +\; r_3\; \dot{\theta}_3 cos\theta_3)$$

$$\dot{r}_1 = \; -(r_2\; \omega_2 sin\theta_2 +\; r_3\; \omega_3 sin\theta_3) \rightarrow 5$$

$$0 = \; r_2\; \omega_2 cos\theta_2 +\; r_3\; \omega_3 cos\theta_3$$

$$\omega_3 = -\frac{r_2\; \omega_2 cos\theta_2}{r_3 cos\theta_3} \quad \rightarrow 6$$

<u>ACCELERATION ANALYSIS:</u>

$$\dot{r}_1(\cos\theta_1 i + \sin\theta_1 j) = r_2\dot{\theta}_2(-\sin\theta_2 i + \cos\theta_2 j) + r_3\dot{\theta}_3(-\sin\theta_3 i + \cos\theta_3 j)$$

$$\dot{r}_1(\cos\theta_1 i + \sin\theta_1 j) = r_2\ddot{\theta}_2(-\sin\theta_2 i + \cos\theta_2 j) - r_2\dot{\theta}_2(-\cos\theta_2 i + \sin\theta_2 j) + r_3\ddot{\theta}_3(-\sin\theta_3 i + \cos\theta_3 j) + r_3\dot{\theta}^2{}_3(-\cos\theta_3 i + \sin\theta_3 j)$$

$$\ddot{r}_1 \cos\theta_1 = -r_2\ddot{\theta}_2 \sin\theta_2 - r_2\dot{\theta}^2{}_2 \cos\theta_2 - r_3\ddot{\theta}_3 \sin\theta_3 - r_3\dot{\theta}^2{}_3 \cos\theta_3 \rightarrow 7$$

$$\ddot{r}_1 \sin\theta_1 = r_2\ddot{\theta}_2 \cos\theta_2 - r_2\dot{\theta}^2{}_2 \sin\theta_2 - r_3\ddot{\theta}_3 \cos\theta_3 - r_3\dot{\theta}^2{}_3 \sin\theta_3 \quad \rightarrow 8$$

$r_1, r_2, r_3, r_4 \rightarrow$ Given($r_4 = 0$)

$\theta_1, \theta_4 \rightarrow$constant ($\theta_1 = \theta_4 = 0$)

$\theta_{2,}\theta_3 \rightarrow Variable$

$\ddot{\theta}_2 = 0\; as\; angular\; velocity\; is\; constant$

Substituting equation 7 and 8 with the above values

$\ddot{r}_1 = -r_2\dot{\theta}^2{}_2 \cos\theta_2 - r_3\ddot{\theta}_3 \sin\theta_3 - r_3\dot{\theta}^2{}_3 \cos\theta_3 \rightarrow 9$

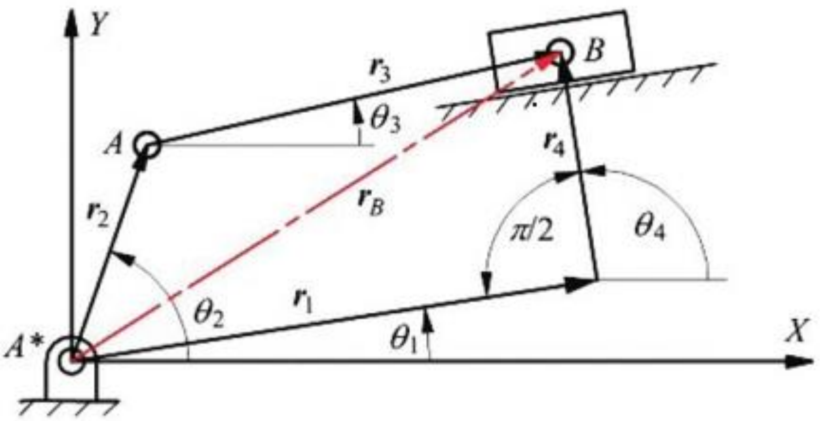
$0 = -r_2\dot{\theta}^2{}_2 \sin\theta_2 - r_3\ddot{\theta}_3 \cos\theta_3 - r_3\dot{\theta}^2{}_3 \sin\theta_3 \quad \rightarrow 10$

From eq 10

$\ddot{\theta}_3 = \frac{-r_2\dot{\theta}^2{}_2 \sin\theta_2 - r_3\dot{\theta}^2{}_3 \sin\theta_3}{r_3 cos\theta_3} \rightarrow 11$

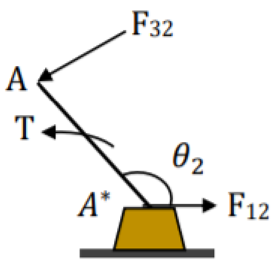
Now we can substitute the value of $\ddot{\theta}_3$ in eq 9 to find $\ddot{r}_1$

STATIC FORCE ANALYSIS:

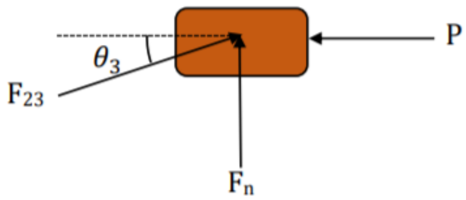


This is basically the off-set slider crank mechanism. So, to make it in-line slider crank we have to make θ_1 and r_4 to zero .

Considering link A^*A:



Considering the block:



Applying equilibrium conditions:

$\sum \boldsymbol{F_x} = \mathbf{0}$**:**

$P = F_{23}cos\theta_3$ → 12

$\sum \boldsymbol{F_y} = \mathbf{0}$**:**

$F_n = F_{23}sin\theta_3$

Moment at $\boldsymbol{A^*}$**:**

$T = -F_{32} \times l_2(\sin(\theta_2 + \theta_3)$ → 13

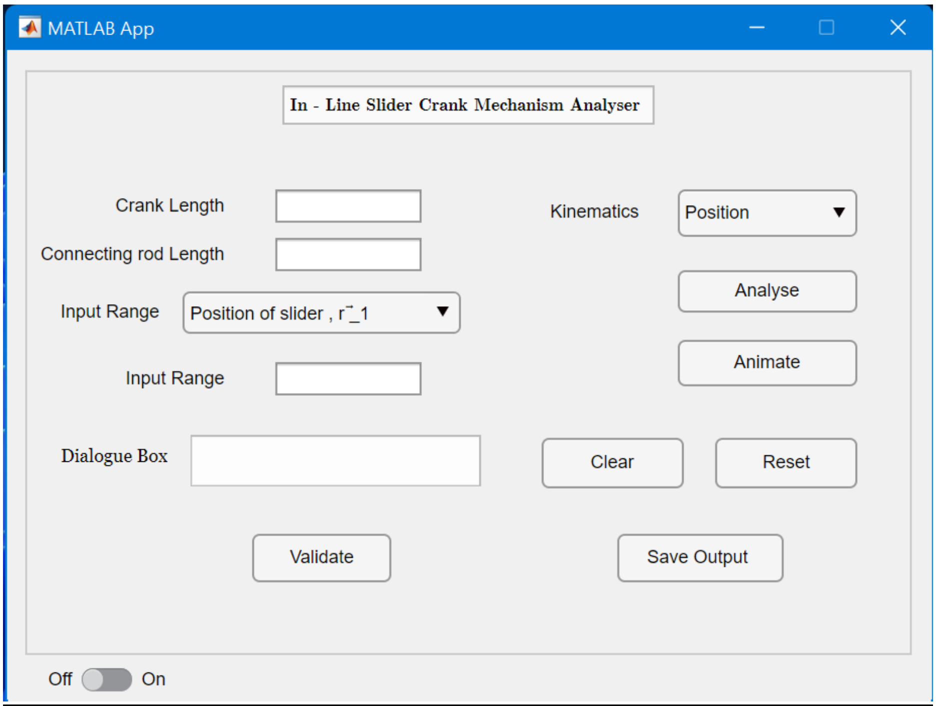
Substituting [1] in [2]:

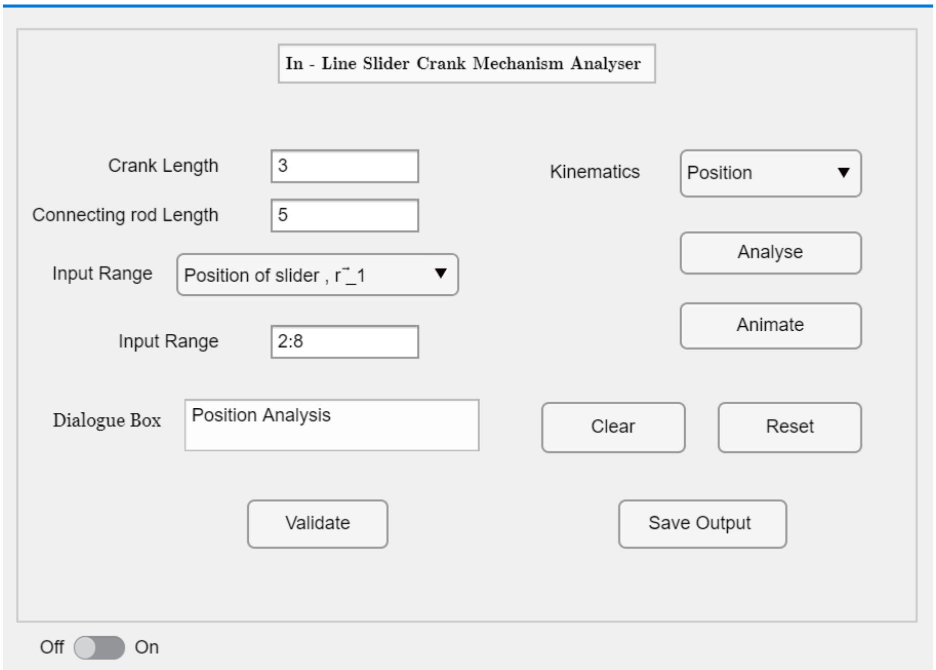
$$T = -\frac{P}{cos\theta_3} \times l_2(\sin(\theta_2 + \theta_3)) = -P \times l_2[sin\theta_2 + cos\theta_2 tan\theta_3]$$

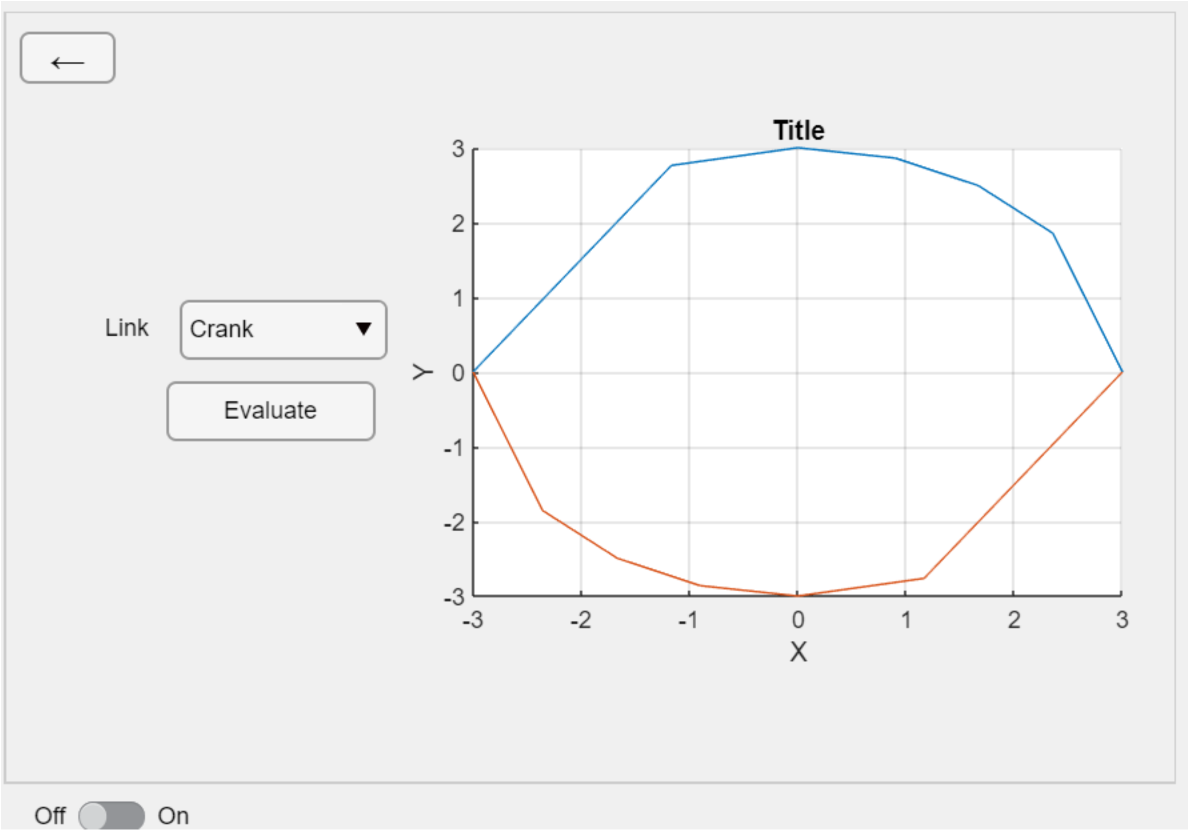
EXAMPLE:

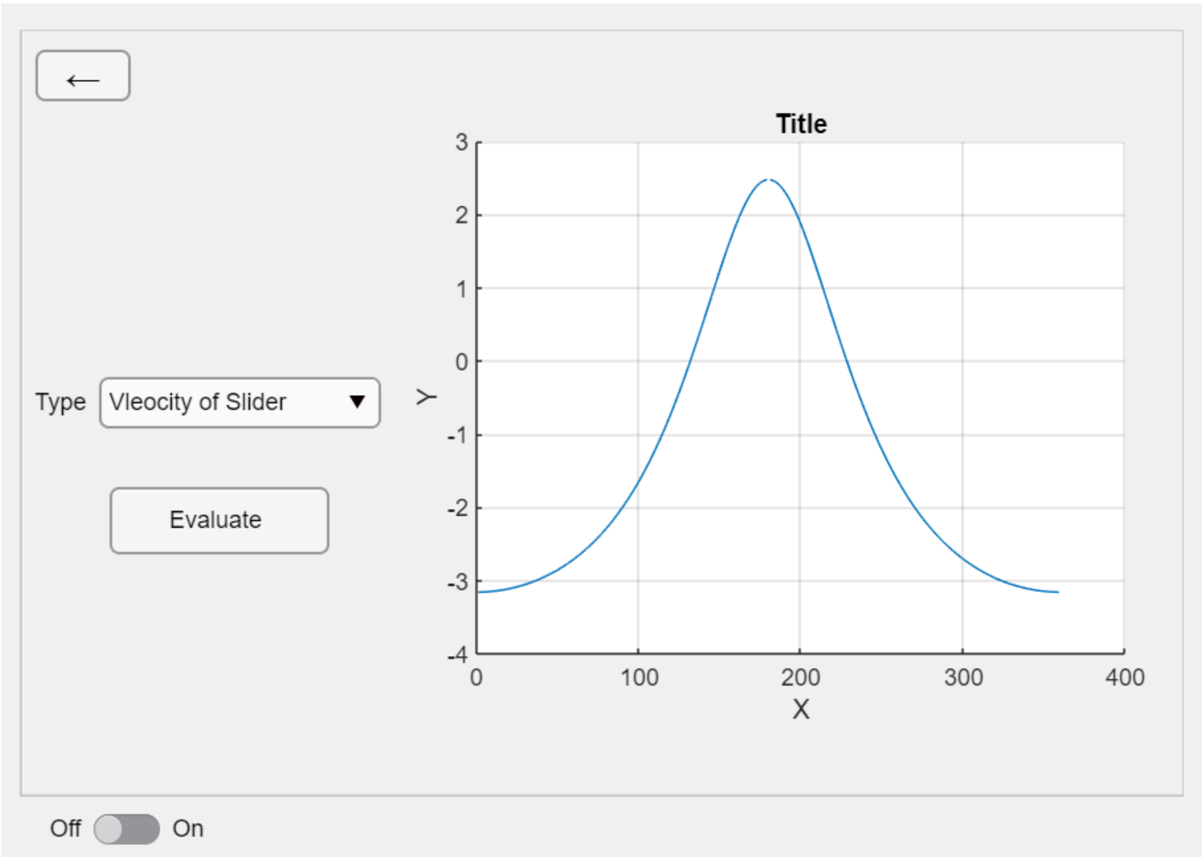
APPENDIX:

Main Frame Of GUI :


MATLAB App
In - Line Slider Crank Mechanism Analyser
Crank Length
Connecting rod Length
Input Range
Position of slider , r¯_1
Input Range
Dialogue Box
Kinematics
Position
Analyse
Animate
Clear
Reset
Validate
Save Output
Off
On


In - Line Slider Crank Mechanism Analyser
Crank Length
3
Connecting rod Length
5
Input Range
Position of slider , r¯_1
Input Range
2:8
Dialogue Box
Position Analysis
Kinematics
Position
Analyse
Animate
Clear
Reset
Validate
Save Output
Off
On


←
Title
Link
Crank
Evaluate
Y
X
Off
On


←
Title
Type
Vleocity of Slider
Evaluate
Y
X
Off
On

Position :

```
% r2 = crank ; r3 = connecting rod
       r2 = str2num(app.CrankLengthEditField.Value);
       r3 = str2num(app.ConnectingrodLengthEditField.Value);
         if(app.InputRangeDropDown.Value=="Position of slider , r ⃗_1")
             r1 = str2num(app.InputRangeEditField.Value);

             for i =1: length(r1)

             theta2(i) =acosd(((r1(i)^2)+(r2^2)-(r3^2))/(2*r1(i)*r2));
             theta3(i) = asin((-r2*sind(theta2(i)))/r3);
             end

           negtheta2=  180+fliplr(theta2);

            if(app.LinkDropDown.Value=="Crank")
                x = r2*cosd(theta2);
                y = r2*sind(theta2);
                x_= r2*cosd(negtheta2);
                y_= r2*sind(negtheta2);

                 plot(x,y,"Parent",app.UIAxes);
                 hold(app.UIAxes,'on');
                 plot(x_,y_,"Parent",app.UIAxes);
                 hold(app.UIAxes,'off');
            elseif(app.LinkDropDown.Value=="Slider")
                plot(theta2,r1,"Parent",app.UIAxes);

            end

         elseif(app.InputRangeDropDown.Value=="Angle of Crank    , θ_2")
            theta2=str2num(app.InputRangeEditField.Value);
             theta3 = asin((-r2*sind(theta2))/r3);

              if(app.LinkDropDown.Value=="Crank")
                x = r2*cosd(theta2);
                y=  r2*sind(theta2);

               plot(x,y,"Parent",app.UIAxes);
              elseif(app.LinkDropDown.Value=="Slider")

                r1=r2.*cosd(theta2)+r3.*cosd(theta3);

                 plot(theta2,r1,"Parent",app.UIAxes);

              end
```

Velocity :

```
[r1,r2,r3,theta2,theta3] = func(app);
n=(r3/r2);
```

```
if(app.InputRangeDropDown.Value=="Position of slider , r ⃗_1")
for i = 1:length(theta2)
                     w_crank(i) = (((r1(i)/r2)-
1)*2*n)/(sind(2*theta2(i))+(2*n*sind(theta2(i))));
                      w_conn(i) =(-
r2*cosd(theta2(i))*w_crank(i))/(r3*cosd(theta3(i)));
                       v_s(i)=((-r2*sind(theta2(i))*w_crank(i))+(-
r3*sind(theta3(i))*w_conn(i)));
                        v_crankx=w_crank(i)*r2*cosd(theta2) ;
                        v_cranky=  w_crank(i)*r2*sind(theta2)';
                        v_connx =w_conn(i)*r3*cosd(theta3);
                         v_conny = w_conn(i)*r3*sind(theta3);
                end


                if(app.TypeDropDown.Value=="Angular Velocity of Crank")
                     plot(r1,w_crank,"Parent",app.UIAxes2);
                      hold(app.UIAxes2,'on');

plot(r1,v_crankx+v_cranky,"Parent",app.UIAxes2,"Color",'red');
                        hold(app.UIAxes2,'off');
                elseif(app.TypeDropDown.Value=="Angular Velocity of
Connectiong Rod")
                     plot(r1,w_conn,"Parent",app.UIAxes2);
                     hold(app.UIAxes2,'on');

plot(theta2,v_connx+v_conny,"Parent",app.UIAxes2,"Color",'red');
                        hold(app.UIAxes2,'off');
                elseif(app.TypeDropDown.Value=="Vleocity of Slider")
                    plot(r1,v_s,"Parent",app.UIAxes2);
                end

             elseif(app.InputRangeDropDown.Value=="Angle of Crank    , θ_2")
               for i = 1:length(theta2)
                      w_crank(i) = (((r1(i)/r2)-
1)*2*n)/(sind(2*theta2(i))+(2*n*sind(theta2(i))));
                      w_conn(i) =(-
r2*cosd(theta2(i))*w_crank(i))/(r3*cosd(theta3(i)));
                 v_s(i)=((-r2*sind(theta2(i))*w_crank(i))+(-
r3*sind(theta3(i))*w_conn(i)));
                     v_crankx=w_crank(i)*r2*cosd(theta2) ;
                        v_cranky=  w_crank(i)*r2*sind(theta2)';
                        v_connx =w_conn(i)*r3*cosd(theta3);
                         v_conny = w_conn(i)*r3*sind(theta3);
               end


                if(app.TypeDropDown.Value=="Angular Velocity of Crank")
                       plot(theta2,w_crank,"Parent",app.UIAxes2);
                       hold(app.UIAxes2,'on');

plot(theta2,v_crankx+v_cranky,"Parent",app.UIAxes2,"Color",'red');
                        hold(app.UIAxes2,'off');
```

```
                elseif(app.TypeDropDown.Value=="Angular Velocity of
Connectiong Rod")
                    plot(theta2,w_conn,"Parent",app.UIAxes2);
                    hold(app.UIAxes2,'on');

plot(theta2,v_connx+v_conny,"Parent",app.UIAxes2,"Color",'red');
                        hold(app.UIAxes2,'off');
                elseif(app.TypeDropDown.Value=="Vleocity of Slider")
                     plot(theta2,v_s,"Parent",app.UIAxes2);
                end

            end
```


REFERENCE:

- Lecture 12 – Position, velocity and acceleration analysis of planar mechanism
- Lecture 13 – Static Force Analysis
- https://in.mathworks.com/matlabcentral/answers/352410-in-app-designer-how-do-i-make-a-button-to-save-that-saves-my-data-from-the-different-uitables-and-e
- https://www.sathyabama.ac.in/sites/default/files/course-material/2020-10/SME1206-1_0.pdf