TECHNICAL REPORT

TEAM MEMBERS

محمد حسني محمد ابراهيم 21011116

كريم ايهاب حمادة عبد الرؤوف 21010979

زياد حسام محمد السعيد عثمان 21010567

كريم السيد محمد محمد سريح 21010978

حنين اسامة محمد احمد 21010480

نوران هشام ابوالفتوح ابوالفتوح 21011497

ندى محمد ابراهيم محمد 21011467

عمر ابراهيم محمد الدمرداش عبد الله 21010854

احمد محمد احمد صالح 21010144

محمد خالد محمد الرخاوي 21011128

Abstract

It was required to make an application to a certain chosen mechanism and the Ackermann steering mechanism was chosen to fulfill the requirements.

Steering Mechanism

Ackermann steering geometry is a geometric arrangement of linkages in the steering of a car or other vehicle designed to solve the problem of wheels on the inside and outside of a turn needing to trace out circles of different radii.

When a vehicle is steered, it follows a path that is part of the circumference of its turning circle, which will have a center point along a line extending from the axis of the fixed axle. The steered wheels must be angled so that they are both at 90 degrees to a line drawn from the circle center through the center of the wheel. Since the wheel on the outside of the turn will trace a larger circle than the wheel on the inside, the wheels need to be set at different angles.

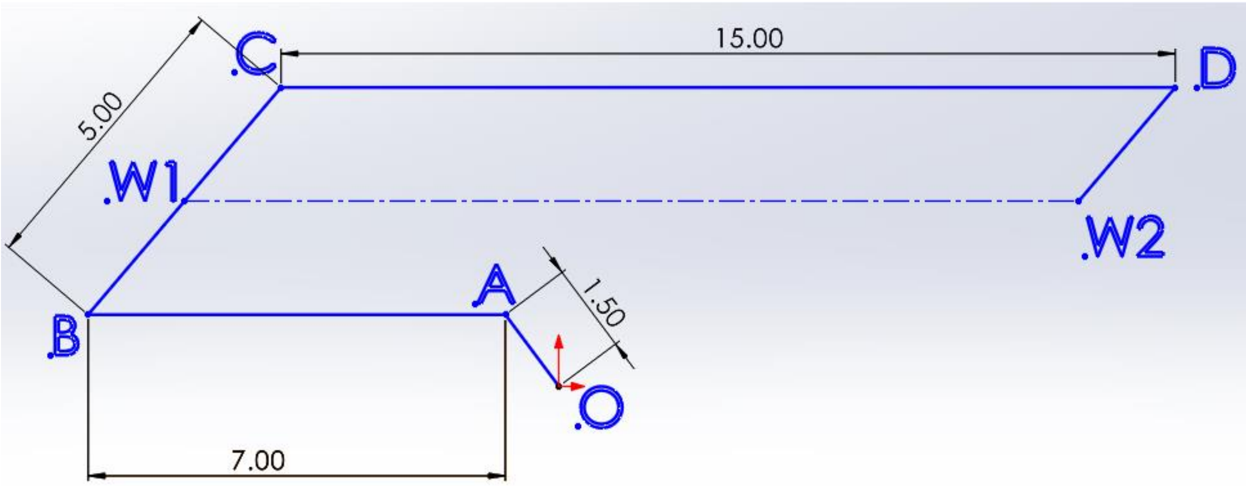
The Ackermann steering geometry arranges this automatically by moving the steering pivot points inward to lie on a line drawn between the steering kingpins and the center of the rear axle. The steering pivot points are joined by a rigid bar, the tie rod. This arrangement ensures that at any angle of steering, the center point of all the circles traced by all wheels will lie at a common point.

The steering mechanism is represented and operated using an electric circuit, Arduino, and a motor driver using acrylic arms.

A mobile application is designed to operate it wirelessly.

Analysis :

Kinematic Chain :



$$OA = link\ 2,\quad AB = link3,\quad BC = link4,\quad CD = link5,\quad DW_2 = link6$$

$O = Motor,\ W_1 = Wheel\ 1,\ W_2 = Wheel\ 2,\ y_B = y_A,\ \theta_3 = 180°$

Position Analysis :

$$OA = r_2 e^{i\theta_2} \Rightarrow \quad x_A = r_2 cos\theta_2, \quad y_A = r_2 sin\theta_2$$

$$OB = OA + AB$$

$$x_B + iy_B = x_A + iy_A + r_3 e^{i\theta_3} \Rightarrow x_B = x_A + r_3 cos\theta_3, \quad y_B = y_A + r_3 sin\theta_3$$

$$OC = OB + BC$$

$$x_C + iy_C = x_B + iy_B + r_4 e^{i\theta_4} \Rightarrow x_C = x_B + r_4 cos\theta_4, \quad y_C = y_B + r_4 sin\theta_4$$

$$OW_1 = OB + BW_1$$

$$x_{W_1} + iy_{W_1} = x_B + iy_B + BW_1 e^{i\theta_4} \Rightarrow x_{W_1} = x_B + BW_1 cos\theta_4, \quad y_{W_1} = y_B + BW_1 sin\theta_4$$

Velocity Analysis :

$$V_A = iw_2 r_2 e^{i\theta_2} \Longrightarrow V_A^x = -w_2 r_2 sin\theta_2, \quad V_A^y = w_2 r_2 cos\theta_2$$

$$V_B = V_A$$

$$V_{W_1} = V_B + V_{W_1B} \Longrightarrow V_{W_1}^x = V_B^x - w_4 r_4 sin\theta_4, \quad V_{W_2}^y = V_B^y + w_4 r_4 cos\theta_4$$

$$V_C = -V_B$$

$$V_C = V_{W_1} + V_{CW_1} \Longrightarrow V_C^x = V_{W_1}^x - w_4 r_4 sin\theta_4, \quad V_C^y = V_{W_1}^y - w_4 r_4 cos\theta_4$$

$$w_4 = \frac{V_B^x}{BW_1 sin\theta_4}$$

$$V_D = V_C$$

$$V_{W_2} = V_D + V_{DW_2} \Longrightarrow V_{W_2}^x = V_D^x - w_6 r_6 sin\theta_6, \qquad V_{W_2}^y = V_D^y - w_6 r_6 cos\theta_6$$

$$w_6 = \frac{V_C^x - V_{W_1}^x}{r_6 sin\theta_6}$$

Acceleration Analysis :

$$A_A^x = -w_2^2 r_2 cos\theta_2 - \alpha_2 r_2 sin\theta_2$$

$$A_A^y = -w_2^2 r_2 sin\theta_2 + \alpha_2 r_2 cos\theta_2$$

$$A_B = A_A + A_{BA} \Longrightarrow A_B^x = A_A^x + (-w_3^2 r_3 cos\theta_3 - \alpha_3 r_3 sin\theta_3), \qquad A_B^y = A_A^y + (-w_3^2 r_3 sin\theta_3 + \alpha_3 r_3 cos\theta_3)$$

$$A_C = A_B + A_{BC} \Longrightarrow A_C^x = A_B^x + (-w_4^2 r_4 cos\theta_4 - \alpha_4 r_4 sin\theta_4), \qquad A_C^y = A_B^y + (-w_4^2 r_4 sin\theta_4 + \alpha_4 r_4 cos\theta_4)$$

$$A_D = A_C + A_{DC} \Longrightarrow A_D^x = A_C^x + \left(-w_5^2 r_5 cos\theta_5 - \alpha_5 r_5 sin\theta_5\right), \qquad A_D^y = A_C^y + (-w_5^2 r_5 sin\theta_5 + \alpha_5 r_5 cos\theta_5)$$

$$A_{W_1} = A_B^x + iA_B^y + (-w_4^2 + i\alpha_4) BW_1 e^{i\theta_4}$$

$$A_{W_2} = A_D^x + iA_D^y + (-w_6^2 + i\alpha_6) r_6 e^{i\theta_6}$$

Force Analysis :

$$x_i = -m_i A_{G_i}^x, \qquad y_i = m_i A_{G_i}^y, \qquad T_i = -I_i \alpha_i$$

$$g_{ix} = g_i cos\theta_i, \qquad g_{iy} = g_i sin\theta_i, \qquad r_{ix} = r_i cos\theta_i, \qquad r_{iy} = r_i sin\theta_i$$

$$A_{G_3}^x = (-w_3^2 cos\theta_3 - \alpha_3 sin\theta_3) g_3$$

$$A_{G_3}^y = (-w_3^2 sin\theta_3 + \alpha_3 cos\theta_3) g_3$$

$$A_{G_4}^x = (-w_4^2 cos\theta_4 - \alpha_4 sin\theta_4) g_4$$

$$A_{G_4}^y = (-w_4^2 sin\theta_4 + \alpha_4 cos\theta_4) g_4$$

$$T_3 + y_3(g_3) + y_{23}(r_3) = 0$$

$$y_{23} = \frac{-T_3 - y_3 g_3}{r_3}$$

$$y_{43} = -(y_3 + y_{23}) = -\left(y_3 + \frac{-T_3 - y_3 g_3}{r_3}\right)$$

$$x_3 + x_{23} + x_{43} = 0$$

$$x_{23} = -(x_3 + x_{34})$$

$$T_4 + x_4\left(g'_{4y}\right) + x_{34}\left(r_{4y}\right) - y_4(g_{4x}) - y_{34}\left(r_{4y}\right) = 0$$

$$x_{34} = \frac{-T_4 - x_4\left(g_{4y}\right) + y_4(g_{4x}) - y_{43}\left(r_{4y}\right)}{r_{4y}}$$

$$x_{54} = -(x_{34} + x_4)$$

$$y_{54} = -(y_4 + y_{34})$$

$$x_2 + x_{32} + x_{12} = 0$$

$$x_{12} = -(x_2 + x_{32}) = -(x_2 + x_3 + x_{34})$$

$$y_{12} = -(y_{32} + y_2) = -\left(\frac{T_3 + y_3 g_3}{r_3} + y_2\right)$$

$$T_5 + y_5(g_5) + y_{65}(r_5) = 0$$

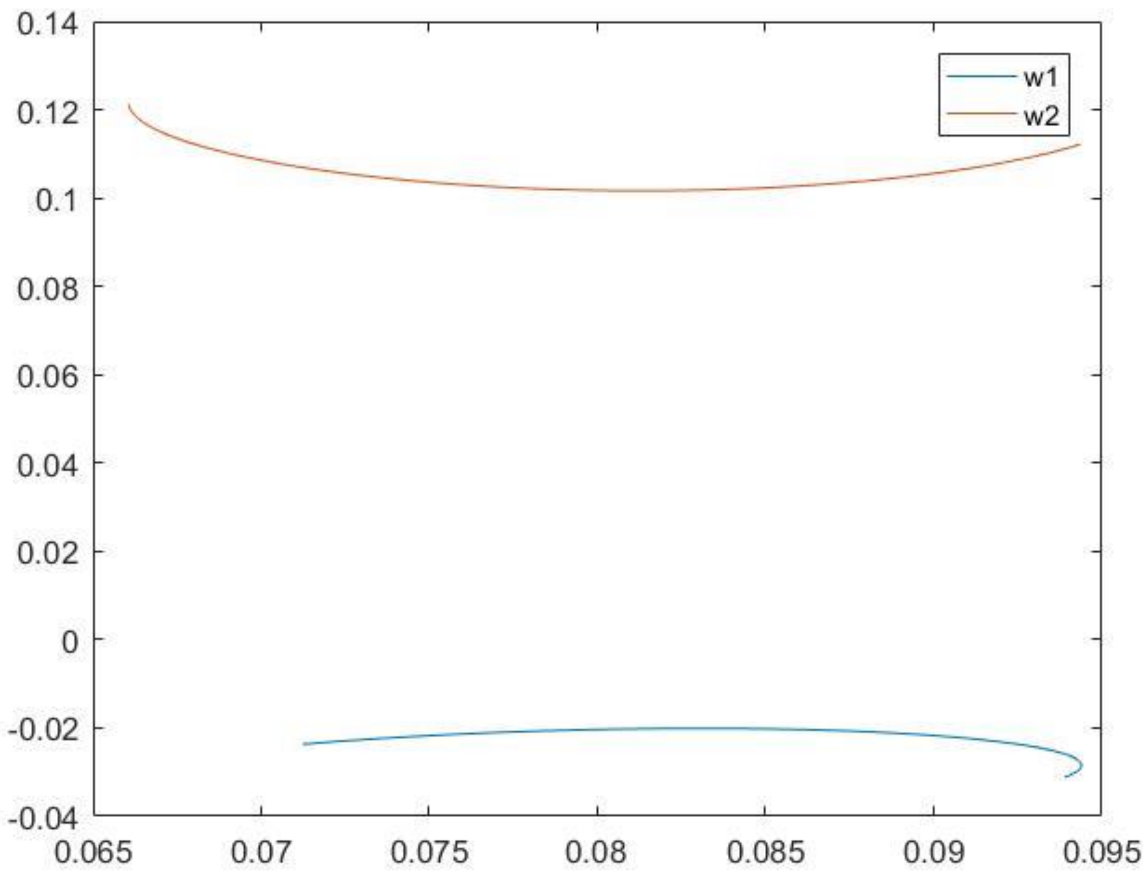
$$y_{65} = \frac{-T_5 - y_5 g_5}{r_5}$$

$$x_{65} - (x_5 + x_{45})$$

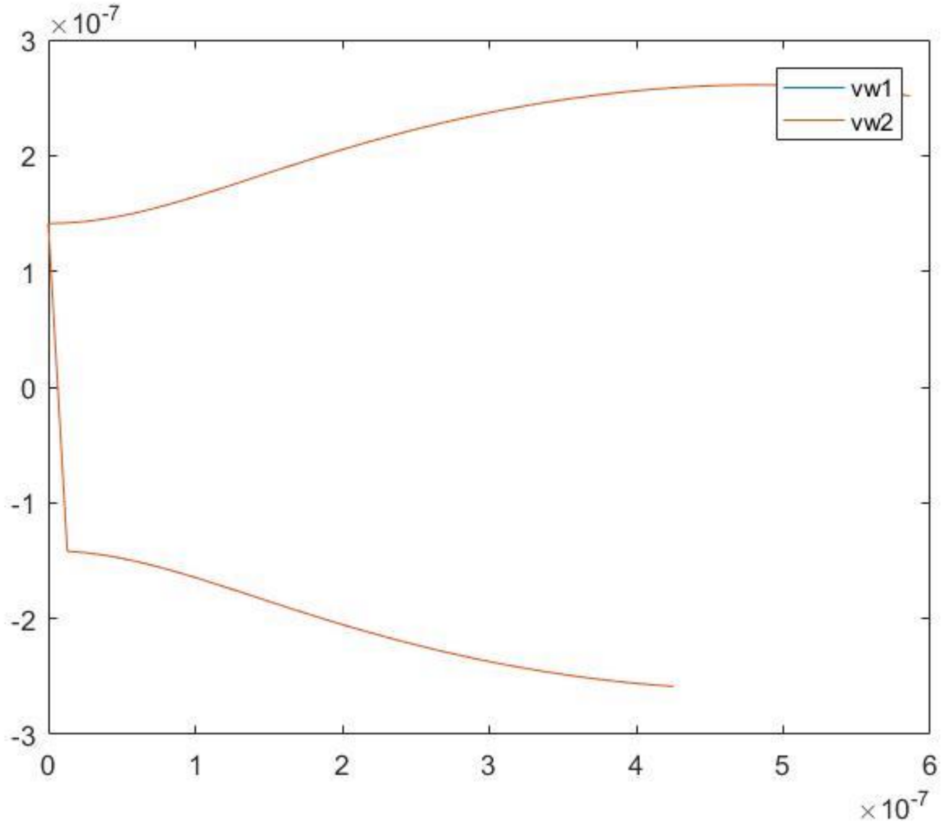
$$M_{16} + T_6 - x_6(r_{6y} - g_{3y}) + y_6(r_{6x} - g_{3x}) - x_{56}(r_{6y}) + y_{56}(r_{6x}) = 0$$

Graphs analyzed using MATLAB :

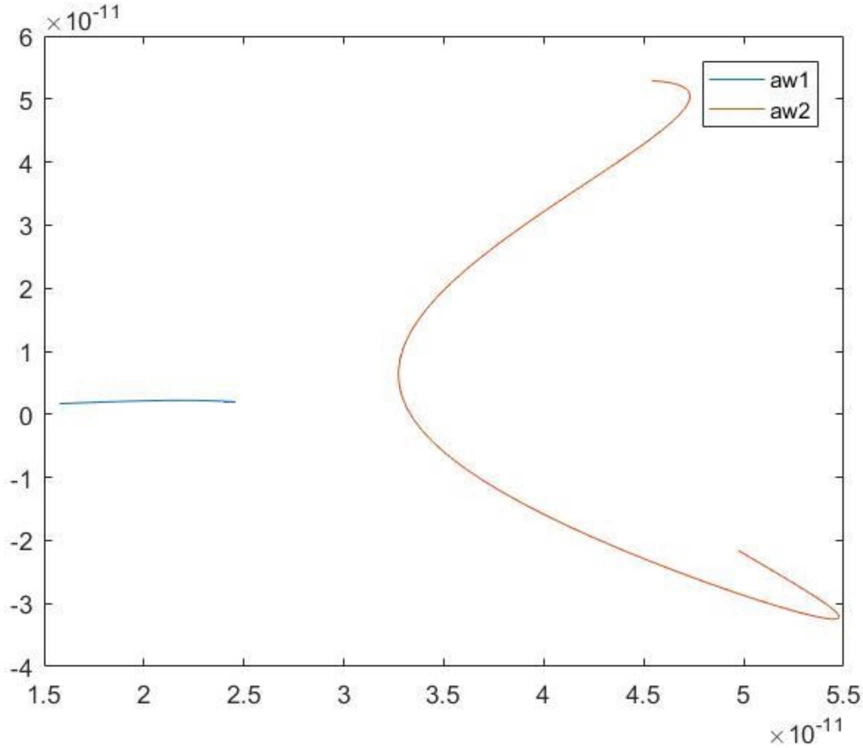
Position Analysis :



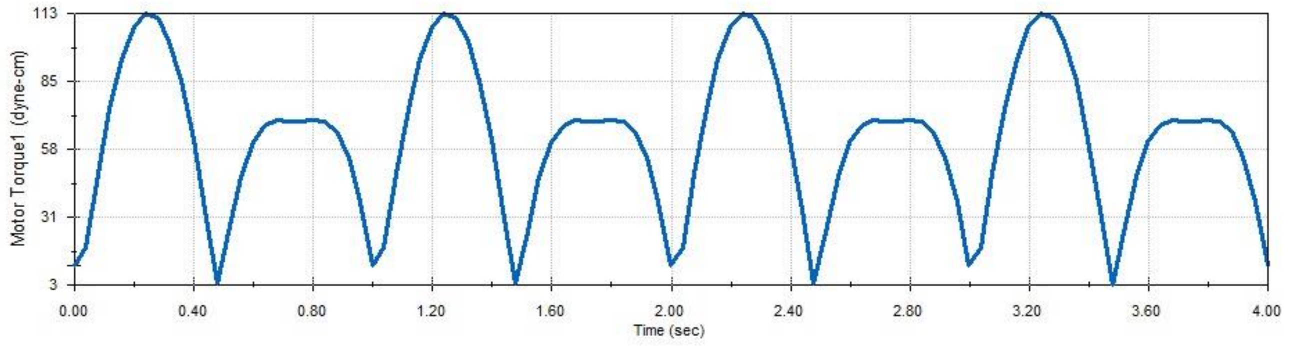
Velocity Analysis :



Acceleration Analysis :



Torque Graph analyzed using SOLIDWORKS :



Taking the MATLAB codes into consideration :

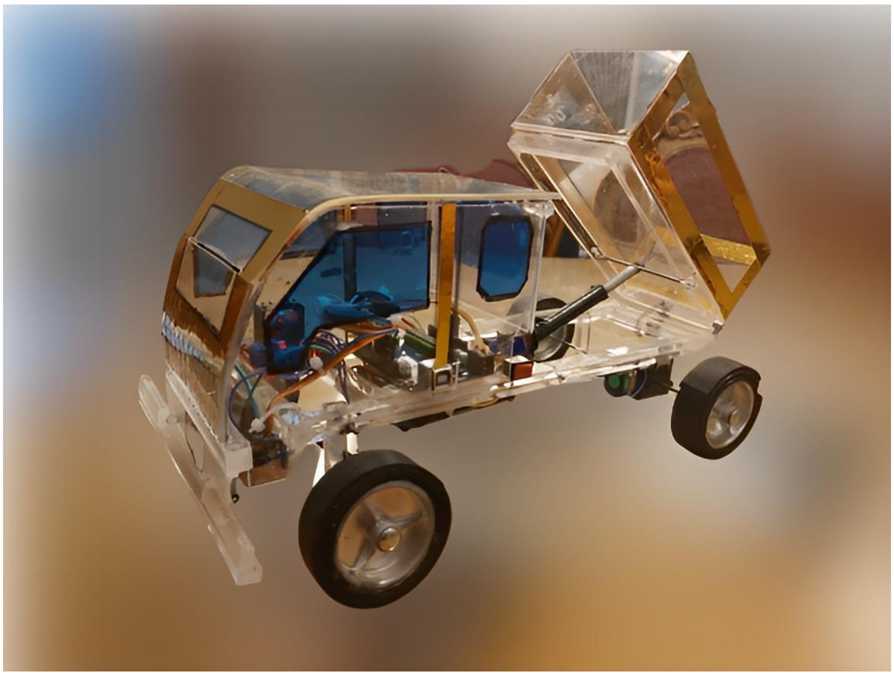
```
% Define the geometry of the 4-bar mechanism
r2 = 0.015; % Length of link OA
r3 = 0.07; % Length of link AB
r4 = 0.05; % Length of link BC
r5 = 0.15; % Length of link CD
r6 = 0.025; % Length of link DW2
BW1 = 0.025; % Length of link BW1
ya = 0.015;
yb = 0.015;
yc = 0.085;
yd = 0.085;
yw1 = 0.025;
yw2 = 0.025;
% Define the initial position of the mechanism
theta2 = 30:180; % Angle of link OA
% Define the angular velocities of the mechanism
omega2 = 0.000031998; % Angular velocity of link OA
% Define the angular accelerations of the mechanism
alpha2 = 0; % Angular acceleration of link OA
% Calculate the position of the mechanism
xa = r2.*cosd(theta2);
ya = r2.*sind(theta2);
xb = xa + r3.*cosd(180);
yb = ya + r3.*sind(180);
```

```
theta3 = 0;
theta4 = asind((yc-yb)/r4);
xc = xb + r4.*cosd(theta4);
yc = yb + r4.*sind(theta4);
xw1 = xb + BW1.*cosd(theta4);
yw1 = yb + BW1.*sind(theta4);
xd = xc + r5.*cosd(0);
yd = yc + r5.*sind(0);
theta5 = 0;
theta6 = asind((yw2-yd)/r6);
xw2 = xd + r6.*cosd(theta6);
yw2 = yd + r6.*sind(theta6);
w1 = sqrt(xw1.^2 + yw1.^2);
w2 = sqrt(xw2.^2 + yw2.^2);
%Calculate the velocity of the mechanism
vax = -omega2.*r2.*sind(theta2);
vay = omega2.*r2.*cosd(theta2);
vbx = vax;
vby = vay;
omega3 = 0;
omega4 = (vbx)/(BW1.*sind(theta4));
vw1x = vbx - omega4.*BW1.*sind(theta4);
vw1y = vby + omega4.*BW1.*cosd(theta4);
vcx = -vbx;
vcy = -vby;
omega5 = 0;
omega6 = (vcx-vw1x)/(r6.*sind(theta6));
vw2x = vw1x;
vw2y = vw1y;
vdx = vw2x + omega6.*r6.*cosd(theta6);
vdy = vw2y - omega6.*r6.*sind(theta6);
vw1 = sqrt(vw1x.^2 + vw1y.^2);
vw2 = sqrt(vw2x.^2 + vw2y.^2);
%Calculate the acceleration of the mechanism
```

```
aax = -omega2.^2.*r2.*cosd(theta2)-alpha2.*r2.*sind(theta2);

aay = -omega2.^2.*r2.*sind(theta2)+alpha2.*r2.*cosd(theta2);

alpha3 = 0;

abx = aax - omega3.^2.*r3.*cosd(theta3)-alpha3.*r3.*sind(theta3);

aby = aay - omega3.^2.*r3.*sind(theta3)+alpha3.*r3.*cosd(theta3);

aw1x = abx + (-omega4.^2.*r4.*cosd(theta4)-alpha4.*r4.*sind(theta4));

aw1y = aby + (-omega4.^2.*r4.*sind(theta4)-alpha4.*r4.*cosd(theta4));

alpha4 = (abx - omega4.^2.*r4.*cosd(theta4))/(r4.*sind(theta4));

acx = aw1x + (-omega4.^2.*r4.*cosd(theta4)-alpha4.*r4.*sind(theta4));

acy = aw1y + (-omega4.^2.*r4.*sind(theta4)+alpha4.*r4.*cosd(theta4));

alpha5 = alpha2;

adx = acx + (-omega5.^2.*r5.*cosd(theta5)-alpha5.*r5.*sind(theta5));

ady = acy + (-omega5.^2.*r5.*sind(theta5)-alpha5.*r5.*cosd(theta5));

alpha6 = (2.*abx - omega4.^2.*r4.*cosd(theta4) - alpha4.*r4.*sind(theta4) +
omega6.^2.*r6.*cosd(theta6))/r6.*sind(theta6);

aw2x = adx + (-omega6.^2.*r6.*cosd(theta6)-alpha6.*r6.*sind(theta6));

aw2y = ady + (-omega6.^2.*r6.*sind(theta6)-alpha6.*r6.*cosd(theta6));

aw1 = sqrt(aw1x.^2 + aw1y.^2);

aw2 = sqrt(aw2x.^2 + aw2y.^2);

end;
```

Truck Bed

The truck bed mechanism is inspired by the toggle mechanism constructed from three acrylic arms attached using chloroform as adhesive material. Using a servo motor, a fixed shaft, and a movable nut. When the servo rotates clockwise, the nut unscrews, and the shaft pushes the bed upwards. When the servo rotates anti-clockwise, the nut screws and the shaft let the bed back into its place. The mechanism is used to lift weights using rotational motion into push-pull linear motion using a thread.



Driving Mechanism (Gears)

Using 5 spur gears with the same module aligned together as a compound gear train with a worm gear having the same module provides an enhancement and enlargement in the motor's torque.