Control Methods for Roll Instability of Articulated Steering Vehicles

- GROUP-7
- J.Radha krishna - ME16BTECH110
- Devang Kangad- ME16BTECH110
- Kazim khan pathan- ME16BTECH110
- Kollipara Anirudh- ME16BTECH11019
- M.Krishna Chaitanya- ME16BTECH11041

What is articulated steering?

- Articulated steering is a system by which a vehicle is split into front and rear halves which are connected by a vertical hinge. The front and rear halves are connected with one or more hydraulic cylinders that change the angle between the halves, including the front and rear axles and wheels, thus steering the vehicle. This system does not use steering arms, king pins, tie rods, etc. as does four-wheel steering. If the vertical hinge is placed equidistant between the two axles, it also eliminates the need for a central differential, as both front and rear axles will follow the same path, and thus rotate at the same speed. Articulated haulers have very good off-road performance.

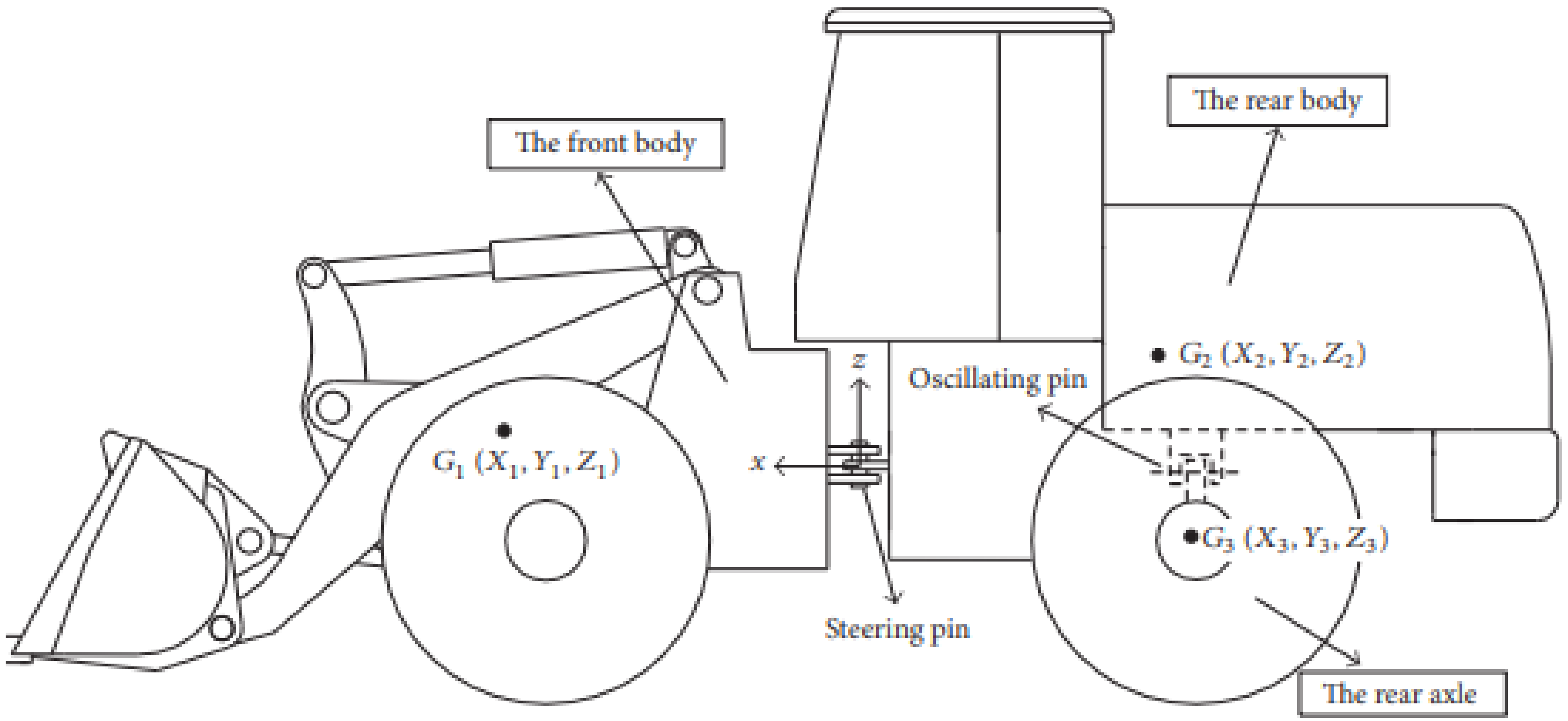
Advantages

Advantages:

- less complicated drivetrain, cheaper axles since two rears can be used, and being able to "wiggle" the truck through tight spots etc.
- Both maneuverability and traction of off-road vehicles are important for enhanced performance in applications on unpredictable and changing terrains. To combine these two important features, articulated frame steering has become popular.

The Dynamic Model of ASVs

- This study aims to establish an seven-degrees-of-freedom (DOF) nonlinear dynamic model for ASVs and to examine the control methods of active rollover protection
- This model is used to analyze the effects of active braking, active steering, and adjusting the swing bridge on the roll stability of ASVs.
- Typical ASVs comprise three parts, namely, the front body, the rear body, and the rear axle.


The front body
The rear body
$G_2\ (X_2, Y_2, Z_2)$
z
Oscillating pin
$G_1\ (X_1, Y_1, Z_1)$
x
$G_3\ (X_3, Y_3, Z_3)$
Steering pin
The rear axle

Physical Model

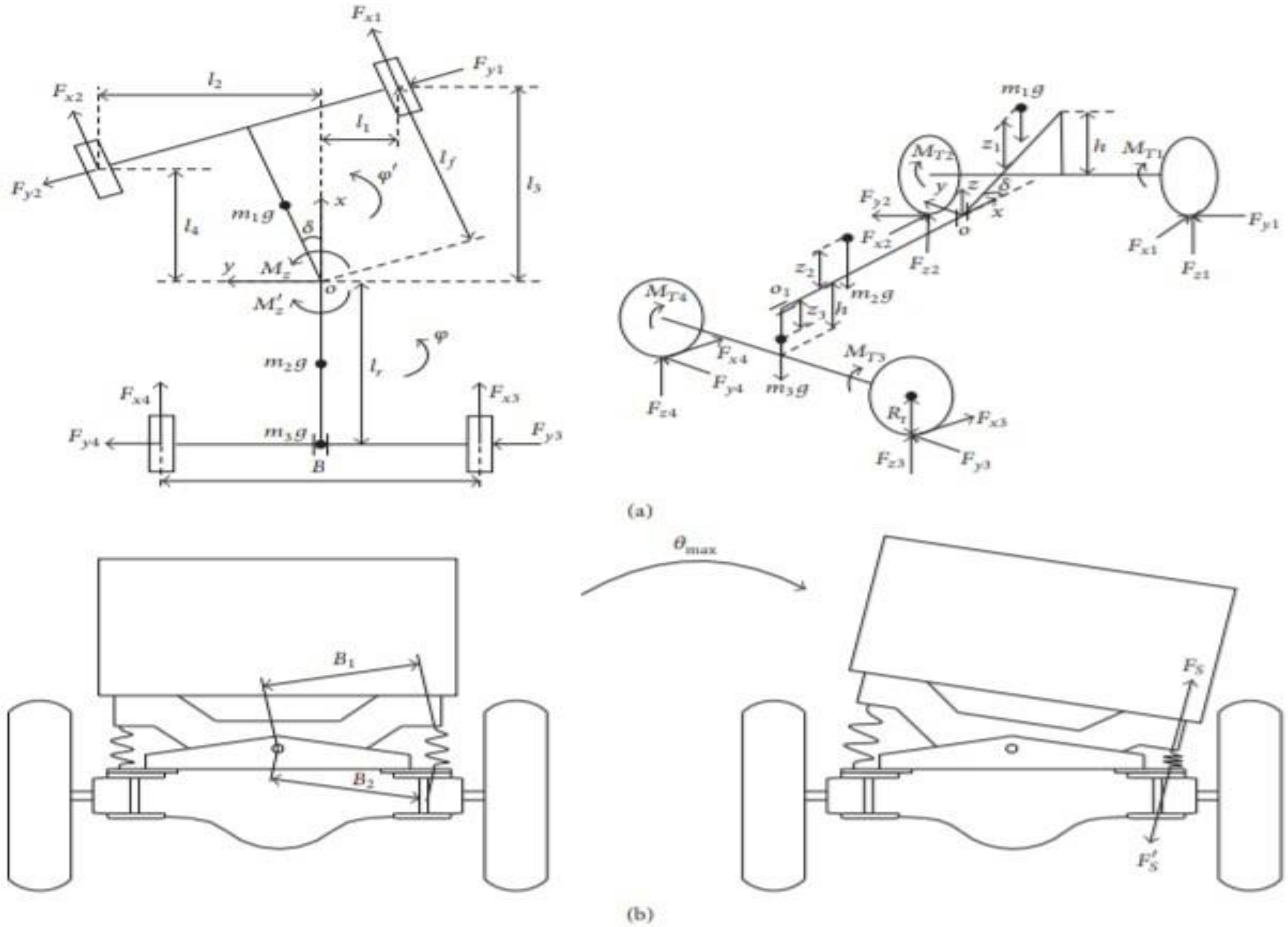
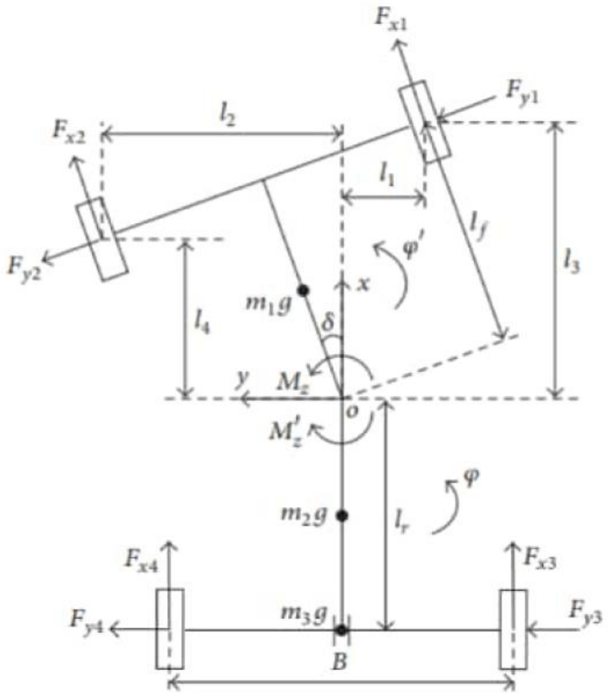
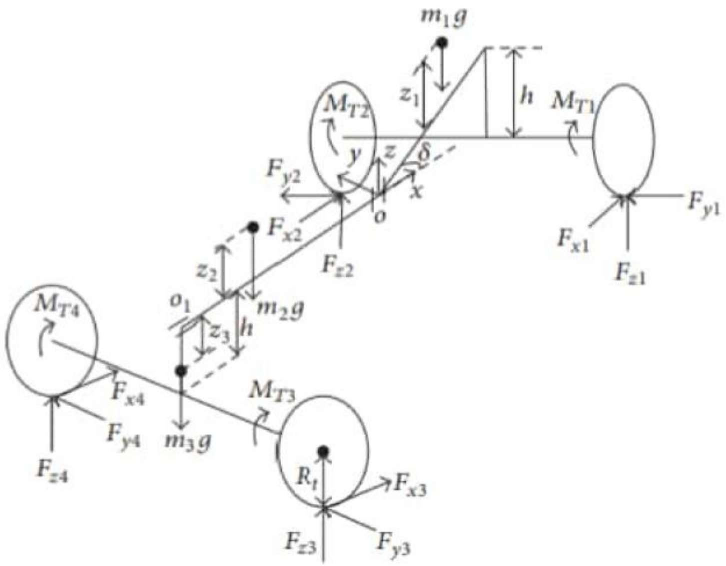


FIGURE 2: The model outline of vehicle movements.

Equation of DOF’s:





From the FBD we have seven DoFs

x-movement
y-movement
z-movement
pitch movement - φ
Roll movement of front and rear body - θ
Roll movement of rear axel - θ'
yaw movement ~~of~~ - ϕ

→ So from the D'alembert principle for multibody dynamics we can write equation of motion

(1) x-direction

$$m(\ddot{x} - \dot{y}\dot{\phi} + \dot{z}\dot{\varphi}) = \left(Fx_1 + Fx_2 + \left(\frac{MT_1 + MT_2}{Rt}\right)\right)\cos\delta - (Fy_1 + Fy_2)\sin\delta + \left(Fx_3 + Fx_4 + \left(\frac{MT_3 + MT_4}{R_T}\right)\right)$$

(2) y direction

$$m(\ddot{y} + \dot{x}\dot{\phi} - \dot{z}\dot{\theta}) = \left(Fx_1 + Fx_2 + \frac{MT_1 + MT_2}{Rt}\right)\sin\delta + (Fy_1 + Fy_2)\cos\delta + Fy_3 + Fy_4$$

(3) z direction

$$m(\ddot{z} + \dot{y}\dot{\theta} - \dot{x}\dot{\varphi}) = Fz_1 + Fz_2 + F_3 + Fz_4 - (m_1 g\cos\theta + m_2 g\cos\theta + m_3 g\cos\theta)\cos\varphi$$

(4) Roll motion of front and rear body

$$(J_{xx1} + J_{xx2})\ddot{\theta} = \left[\left(Fx_1 + Fx_2 + \frac{MT_1 + MT_2}{R_T}\right)\sin\delta + (Fy_1 + Fy_2)\cos\delta\right](R_t h)$$

$$- Fz_1 l_1 + Fz_2 l_2 - m_1 g(x_1\sin\delta - z_1\sin\theta) + m_2 g z_2\sin\theta + m_1 a_{n1} z_1\cos\theta + m_2 a_{n2} z_2\cos\theta - F_s B_1$$

(5) Roll motion of rear axle

$$J_{xx3}\ddot{\theta}' = (F_{y3}+F_{y4})(R_t+h) + \left(\frac{F_{z4}-F_{z3}}{2}\right)B + m_3 g z_3 \sin\theta' + m_3 a_{n3} z_3 \cos\theta' + F_s B_2$$

(6). Vehicle pitch motion

$$(J_{yy1}+J_{yy2}+J_{yy3})\ddot{\psi} = -F_{z1}l_3 - F_{z2}l_4 + (F_{z3}+F_{z4})l_r + m_1 g x_1 \cos\delta + m_2 g x_2 - m_3 g l_r + m_1\ddot{x}z_1 + m_2\ddot{x}z_2 + m_3\ddot{x}z_3 + \left\{(F_{y1}+F_{y2})\sin\delta - \left(F_{x1}+F_{x2}+\frac{M_{r1}+M_{r2}}{R_t}\right)\cos\delta\right\}(R+th) - \left\{\left(F_{x3}+F_{x4}+\frac{M_{r3}+M_{r4}}{R_t}\right)\right\}(R_t+h)$$

(7) Yaw motion of rear body

$$(J_{zz2}+J_{zz3})\ddot{\phi} = -(F_{y3}+F_{y4})l_r + (m_1 a_{n1}x_1 + m_2 a_{n2} x_2 + m_3 a_{n3} x_3) - \dot{M}_2$$

(8) Yaw motion of front body

$$J_{zz1}\ddot{\phi}' = (F_{y1}+F_{y2})l_f - m_1 a_{n1} x_1 + M_2$$

here

$$l_1 = B/2\cos\delta - l_f\sin\delta$$
$$l_2 = B/2\cos\delta + l_f\sin\delta$$
$$l_3 = l_f\cos\delta + B/2\sin\delta$$
$$l_4 = l_f\cos\delta - B/2\sin\delta$$

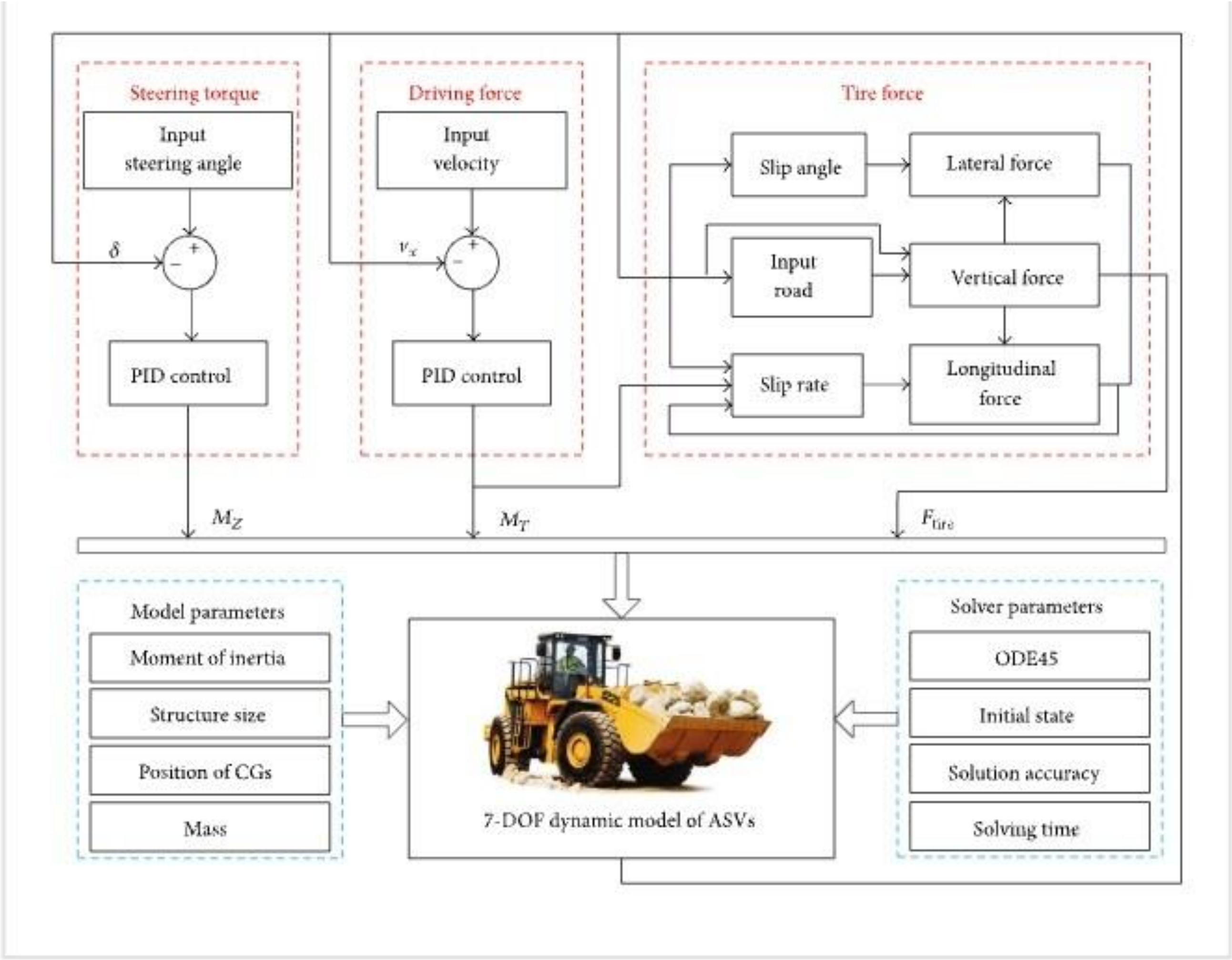
$$a_{n1} = \dot{x}\dot{\phi} - \dot{z}\dot{\theta} + \ddot{x}$$
$$a_{n2} = \ddot{y} + \dot{x}\dot{\phi} - \dot{z}\dot{\theta}$$
$$a_{n3} = \ddot{y} + \dot{x}\dot{\phi} - \dot{z}\dot{\theta}'$$

Fs is the contact Force which is generated when the swing bridge reaches the limit position. In order to calculate it contact process is assumed to be connected by a spring and damping system.
Fs can be given as

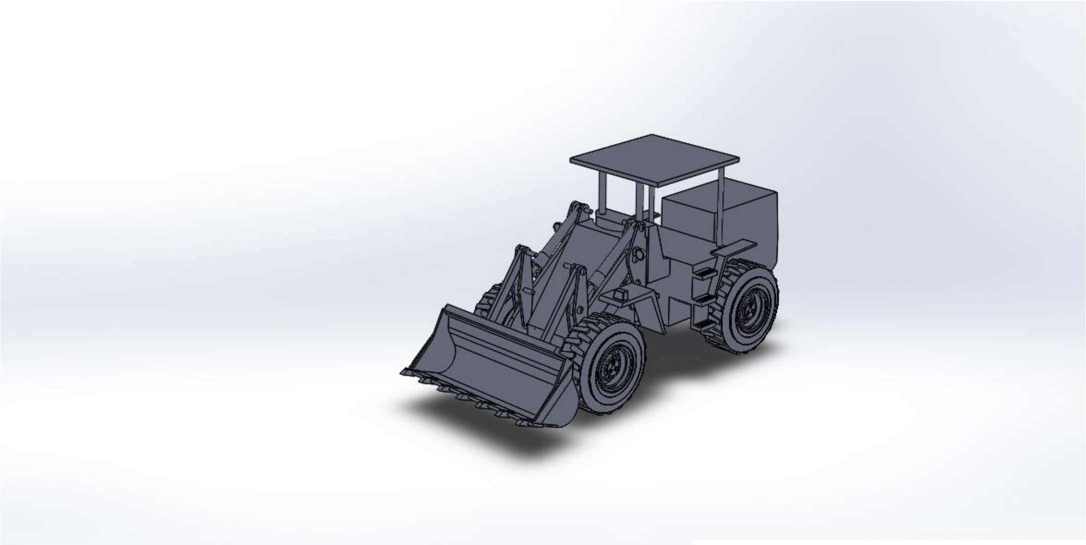
$$F_s = k_s(B_1\theta - B_2\theta') + C_s(B_1\dot{\theta} - B_2\dot{\theta}')$$

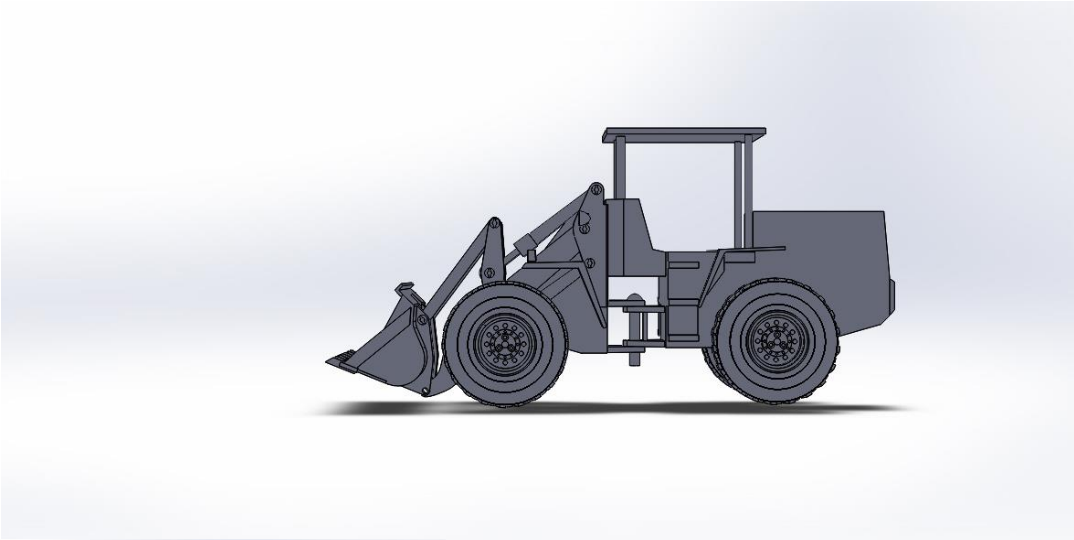
K_s is contact stifness C_s is contact damping, K_s and C_s is null when it does not reach maximum.

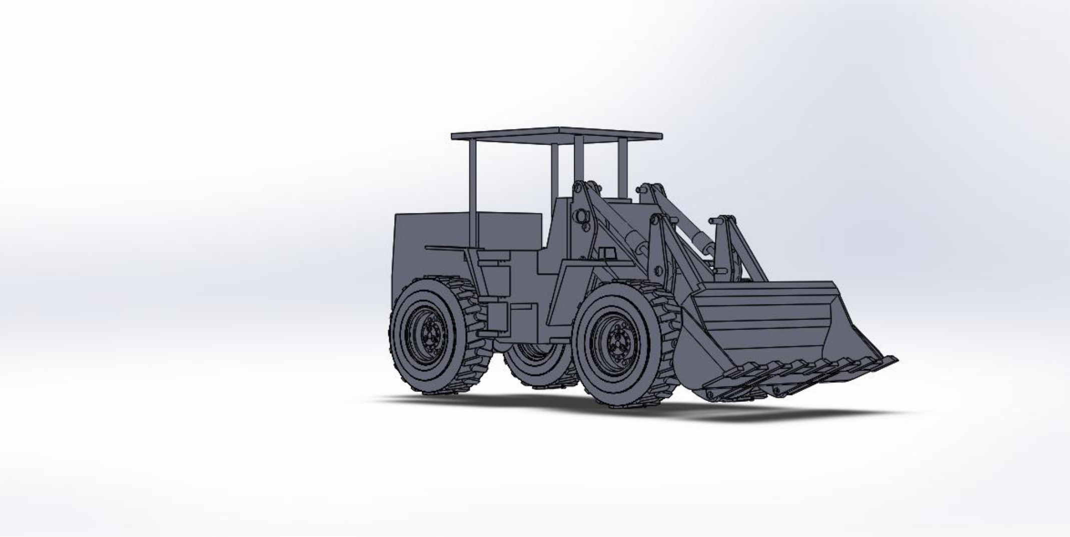
Mathematical Model



CAD Model



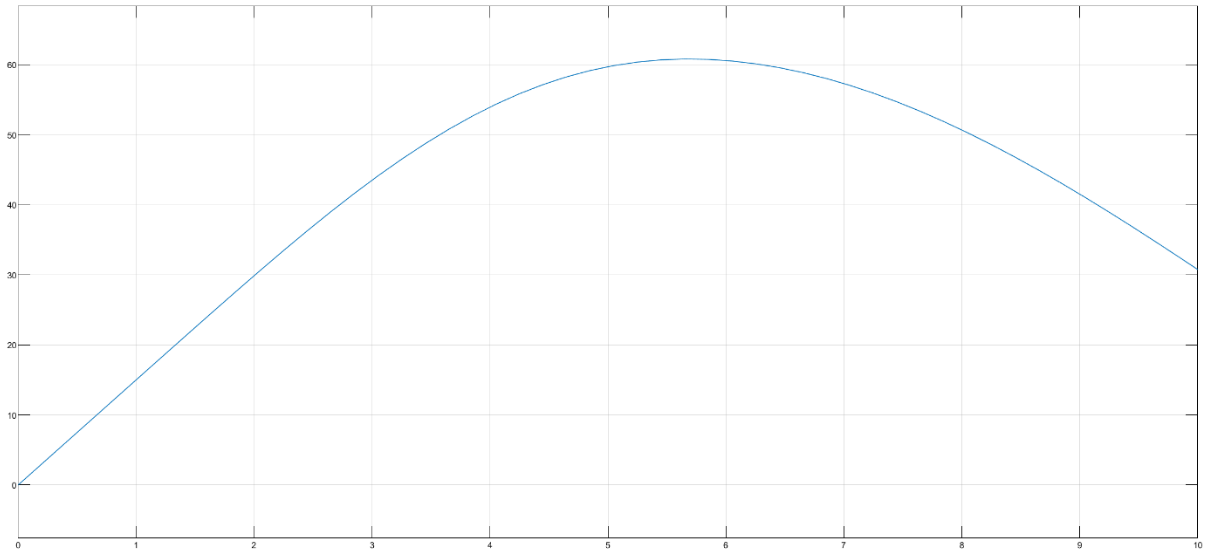




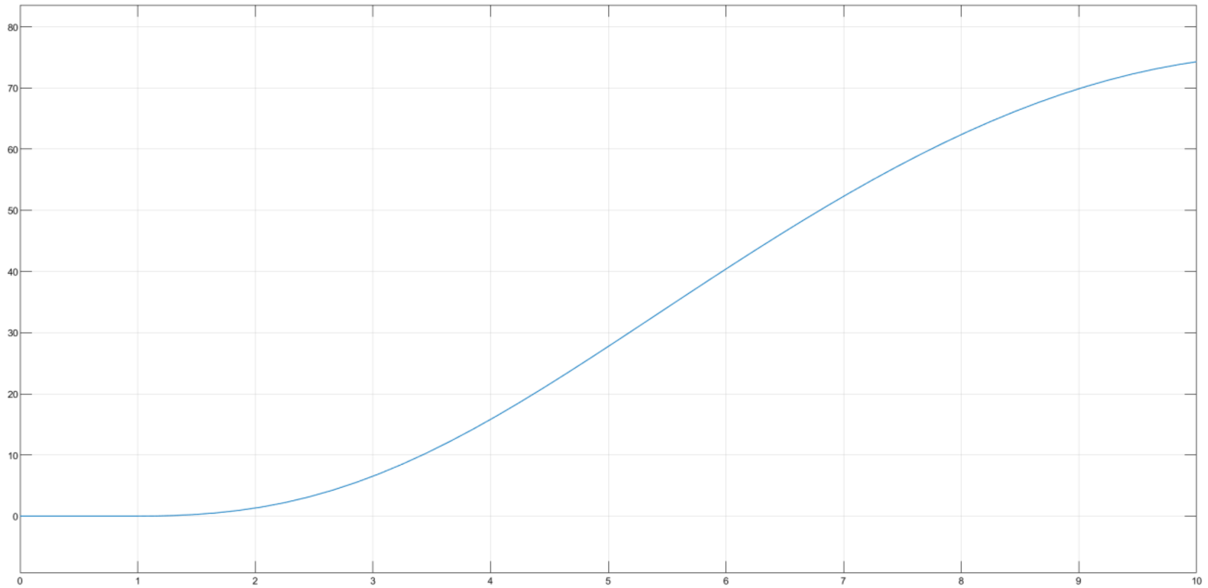
Simulation

Because the wheels on articulated wheel loader are parallel in most cases and the velocities are slower we can model them as bicycle model result of such model is given below steering input is given as step function

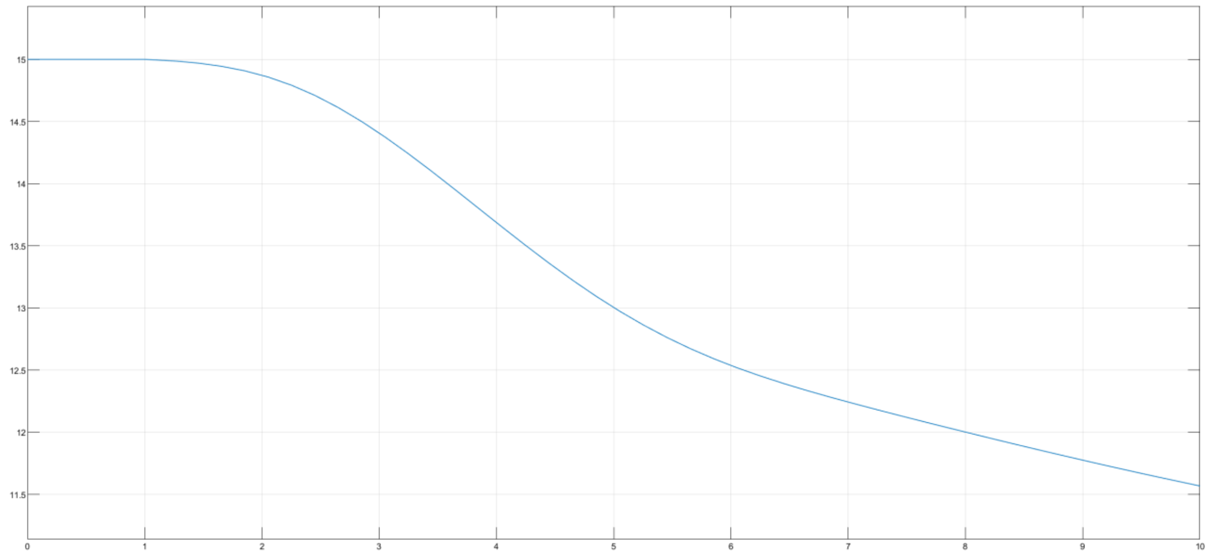
X-Coordinate



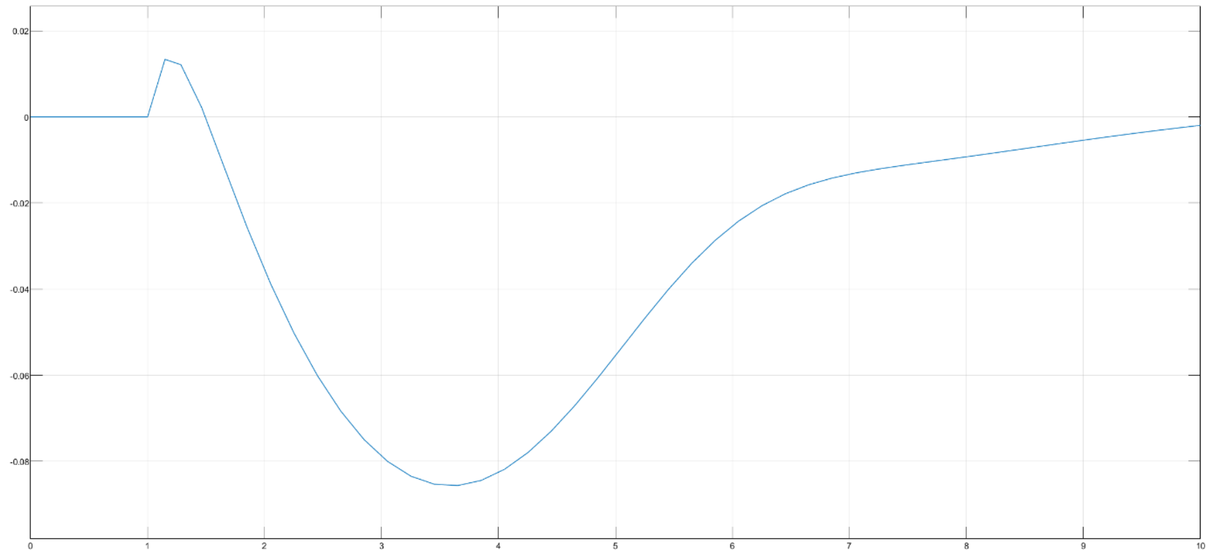
Y-Coordinate



Velocity



Slip angle



Reference

1. https://in.mathworks.com/matlabcentral/fileexchange/58683-vehicle-dynamics-lateral
2. Control Methods for Roll Instability of Articulated Steering Vehicles Xuefei Li, Jian Li, Lida Su, and Yue Cao.
3. Dynamic model and validation of an articulated steering wheel loader on slopes and over obstacles Xuefei Li, Guoqiang Wang, Zongwei Yao & Junna Qu.

THANK YOU