

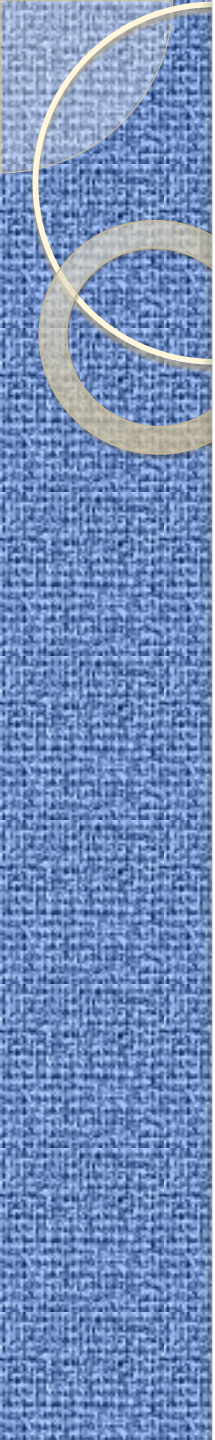
# Vehicle Lateral Stability Using Active Suspension



# Introduction

Lateral stability in vehicles depends on the ability to corner at speeds without skid in the lateral direction.





Lateral motion stability is achieved by an intelligent combination of actuators which control the following parameters at each wheel independently:

- Suspension forces
- Braking forces
- Engine torques

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# Aim of the project

In this presentation, we develop a model for suspension design to optimize between ride comfort and ***lateral performance***.

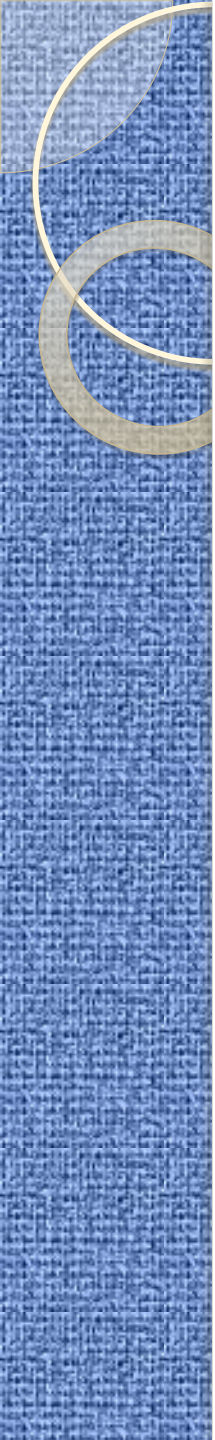
***Cornering performance*** of the vehicle is limited by the normal load available to the inner wheel

# Role of Suspension

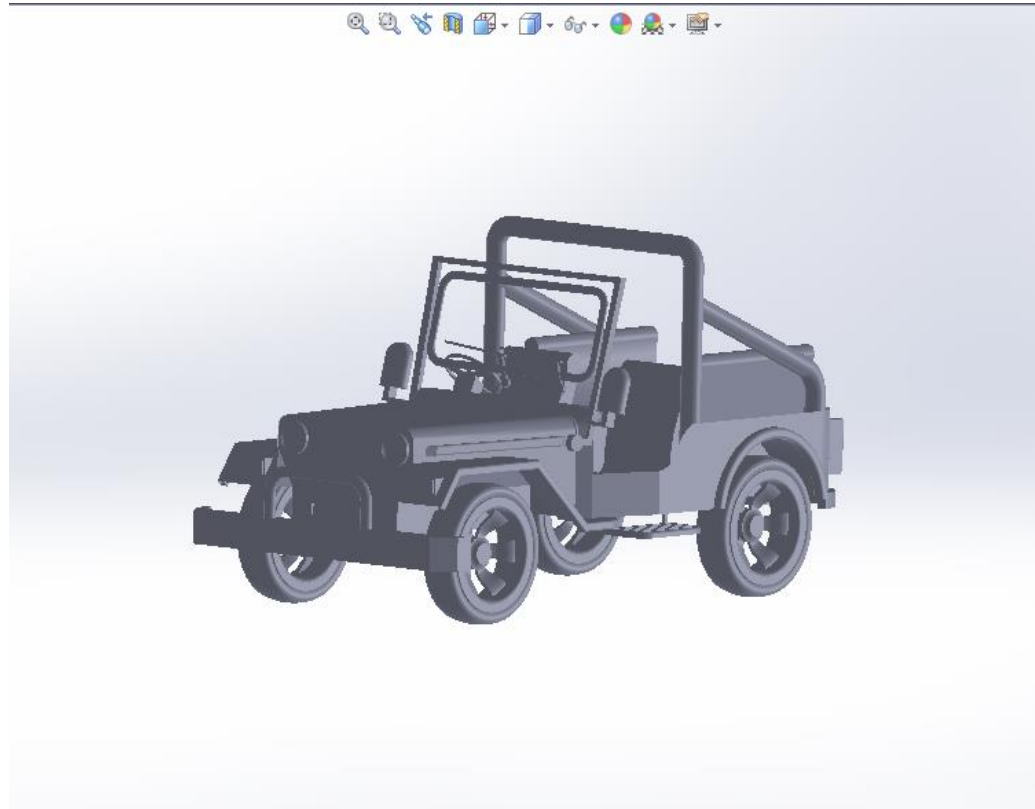
Suspension systems play an important role in the following parameters

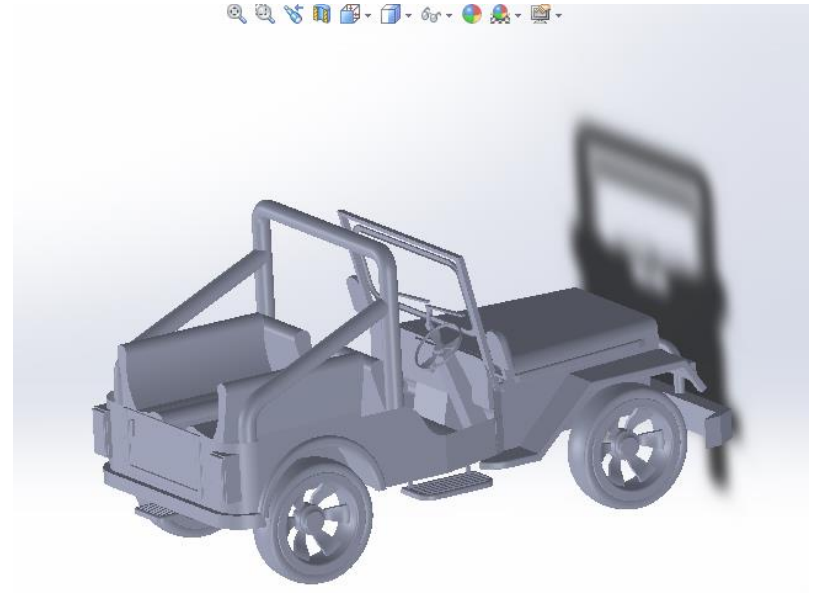
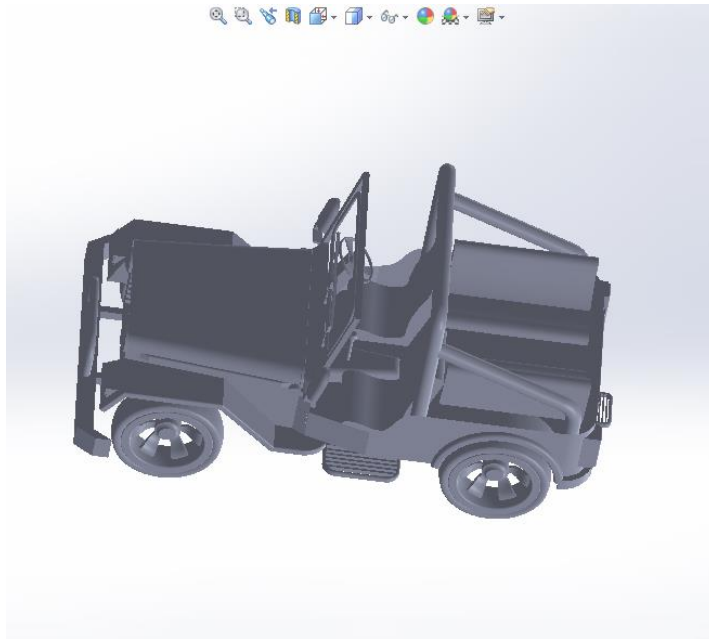
- Weight distribution
- Roll of the vehicle
- Ride quality
- Pitch of the vehicle
- Manoeuvrability



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- In traditional suspension systems, it becomes increasingly complicated to manoeuvre the car at higher speeds.
  - This is because the various parameters such as the weight distribution, roll rate and pitch rate are at unfavourable values.

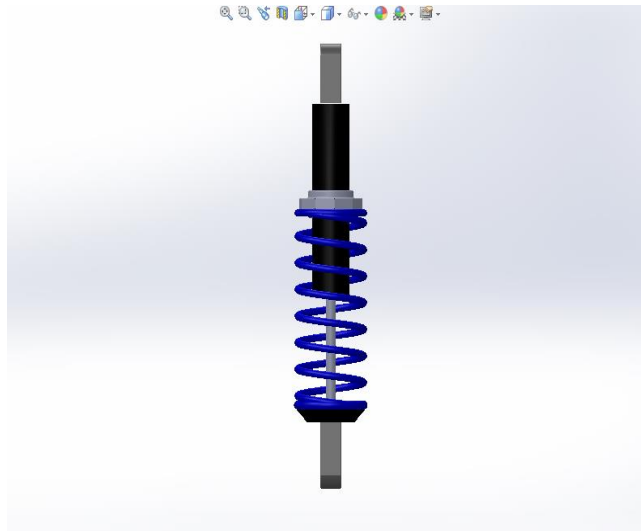
# Car CAD Model



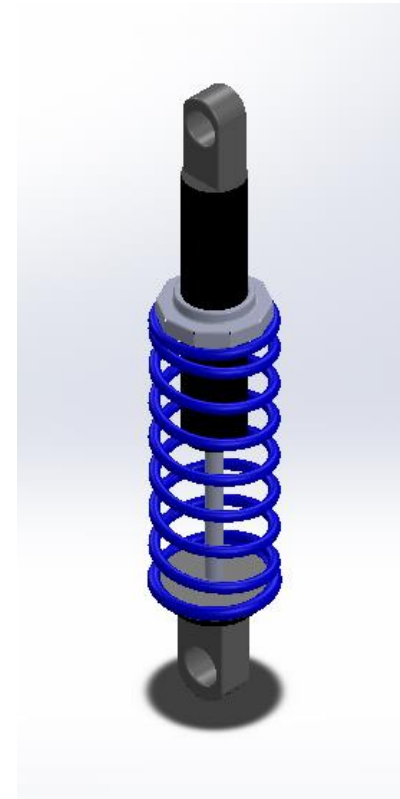




# Suspension CAD Model



Side view



Isometric view

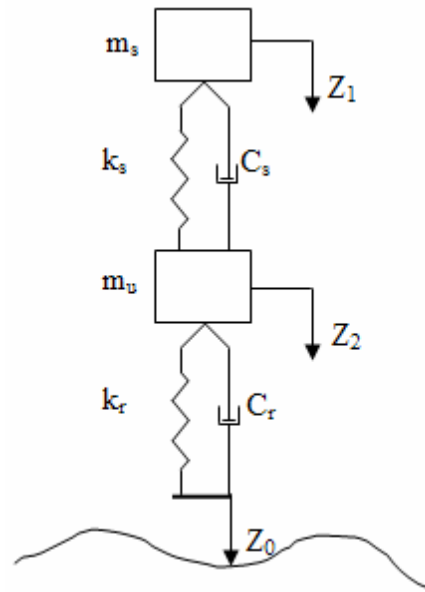


# Traditional Suspension Systems

Traditional suspension systems consist of a spring-damper system. It is explained as follows :

# Quarter Car Model

- The quarter car model is a model that models the motion of a single suspension system.



# Governing Equations

$$m_s \ddot{z}_1 + C_s (\dot{z}_1 - \dot{z}_2) + k_s (z_1 - z_2) = 0$$

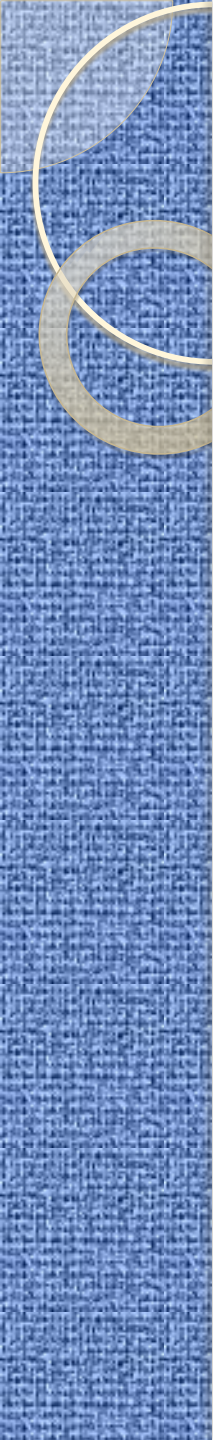
$$m_u \ddot{z}_2 + C_s (\dot{z}_2 - \dot{z}_1) + k_s (z_2 - z_1) + C_t \dot{z}_2 + k_t z_2 = C_t \dot{z}_0 + k_t z_0$$

$$\begin{bmatrix} m_s & 0 \\ 0 & m_u \end{bmatrix} \begin{bmatrix} \ddot{z}_1 \\ \ddot{z}_2 \end{bmatrix} + \begin{bmatrix} k_s & -k_s \\ -k_s & k_s + k_t \end{bmatrix} \begin{bmatrix} z_1 \\ z_2 \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \end{bmatrix}$$

$$\det[k - \omega^2 M] = 0$$

$$f_1 = \frac{1}{2\pi} \sqrt{\frac{k_s k_t}{k_s + k_t} \frac{1}{m_s}} \quad (\text{body motion})$$

$$f_2 = \frac{1}{2\pi} \sqrt{\frac{k_s + k_t}{m_u}} \quad (\text{wheel hop})$$

- 
- Damping will have an effect on the amplitudes of motion even though it does not have a significant effect on the natural frequencies.
  - A convenient way to solve for the amplitudes is to use a complex number approach (assume  $z = |z|e^{i\omega t}$ ).



# Active Suspensions

- Next generation evolution of suspension design
- Depending on the control algorithms, the forces, damping coefficients can be varied conveniently to suit the ride and performance.

# Working

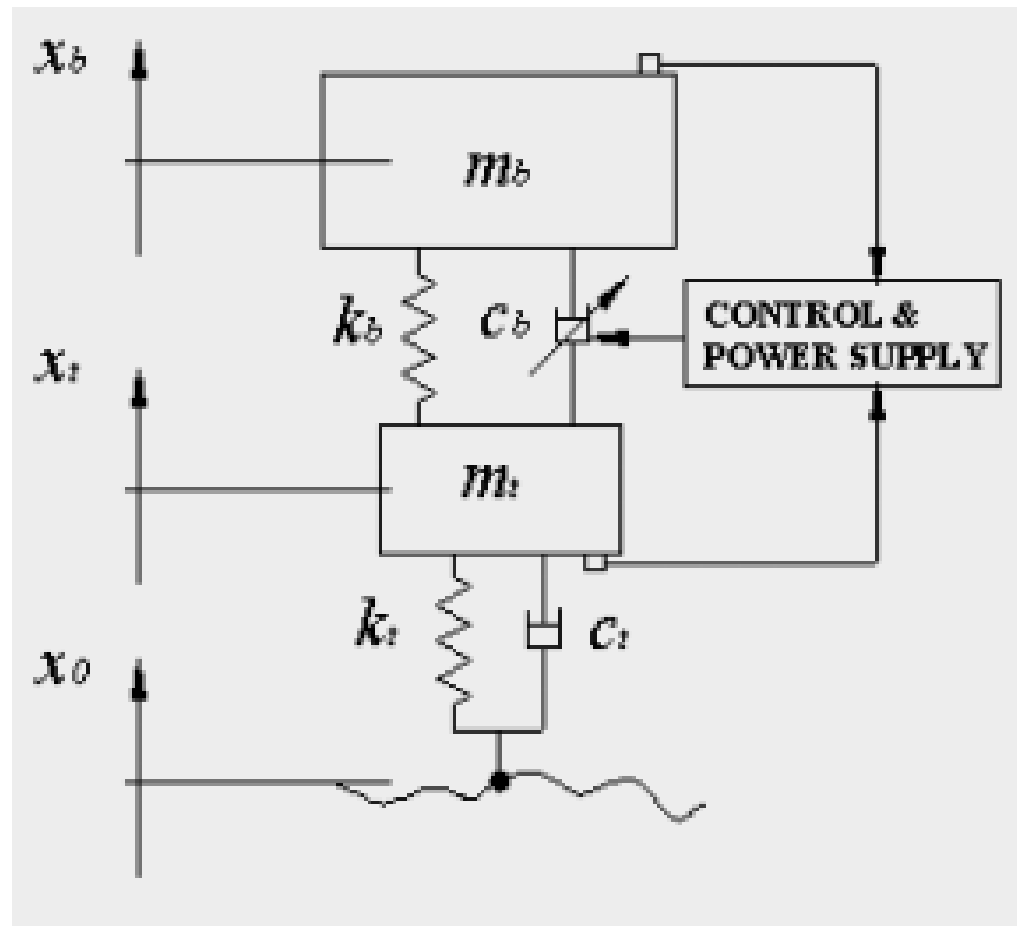


Magnetorheological  
fluid

Magnetorheological Suspension Assembly

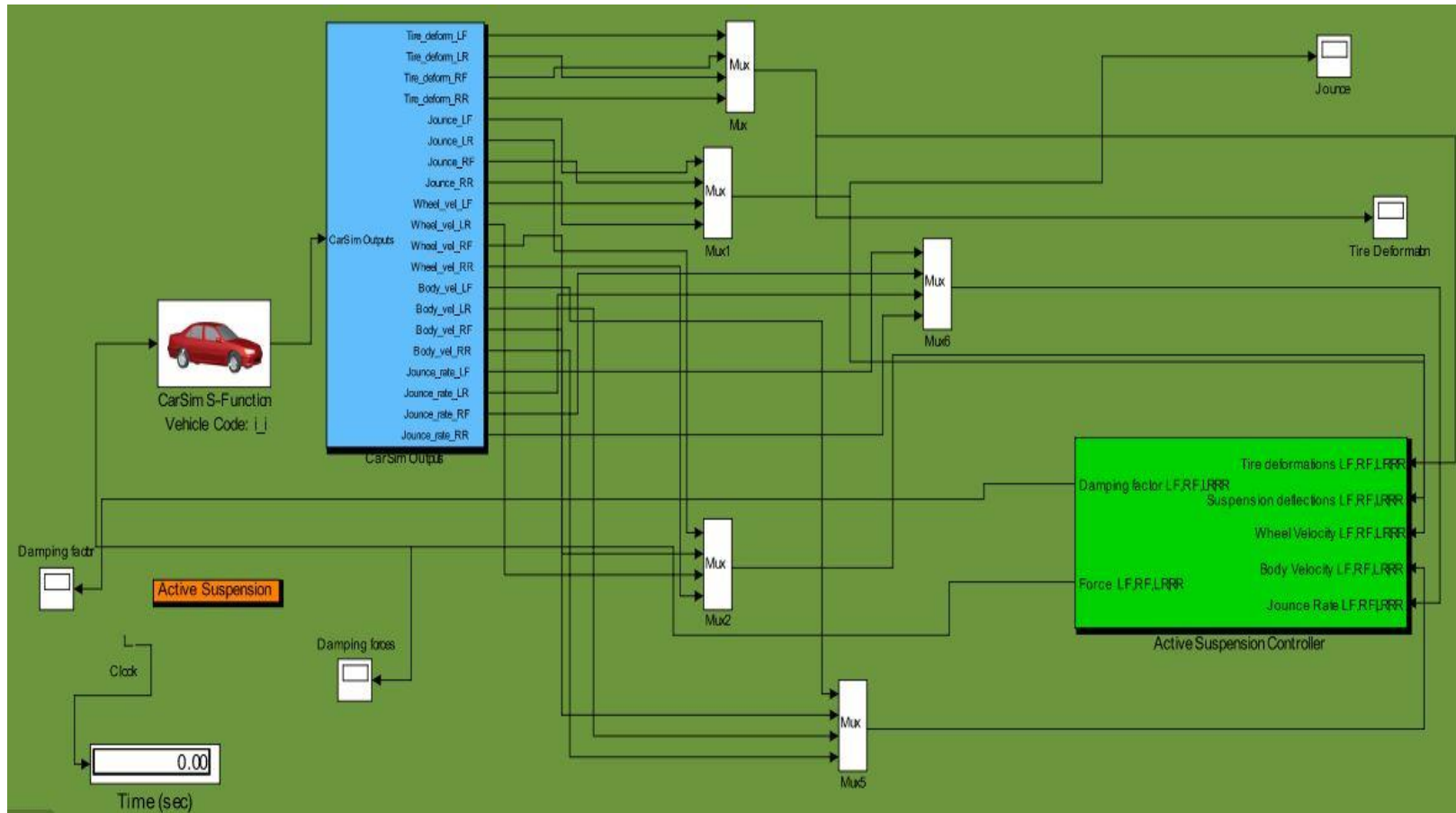
# Principle behind

- When a magnetic field is applied between the two ends, there is an increase in the viscosity of the MR fluid.
- Due to this, there is a variation in the damping coefficient.
- Thus, a calculated magnetic field can be applied for a required change in the damping coefficient.



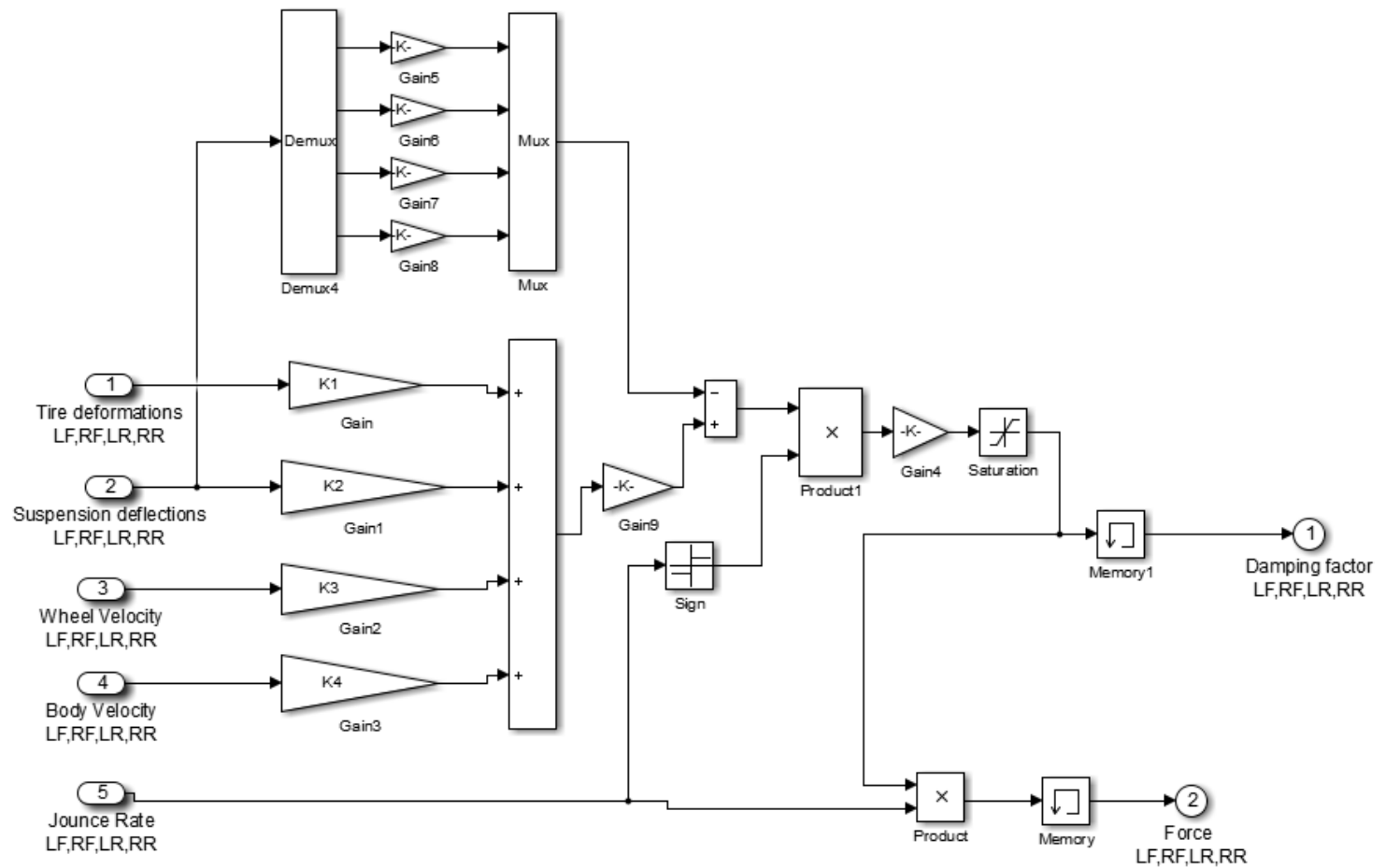
Schematic diagram of the system

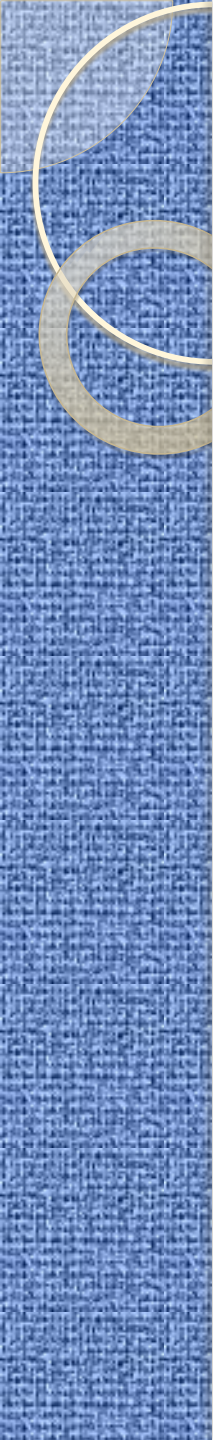
# Implementation in Simulink





# Controller design



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- The various gains associated can be seen in consecutive steps in the simulink model
  - The *Simulink* model was imported to *Carsim*.
  - The model was implemented and its performance was compared with a car lacking active suspension.

# CarSim Implementation

- Car parameters

Sprung mass=750 kg

Unsprung Mass=90 kg

Track width=1.78 m

Wheelbase=2.3 m

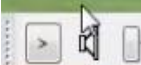
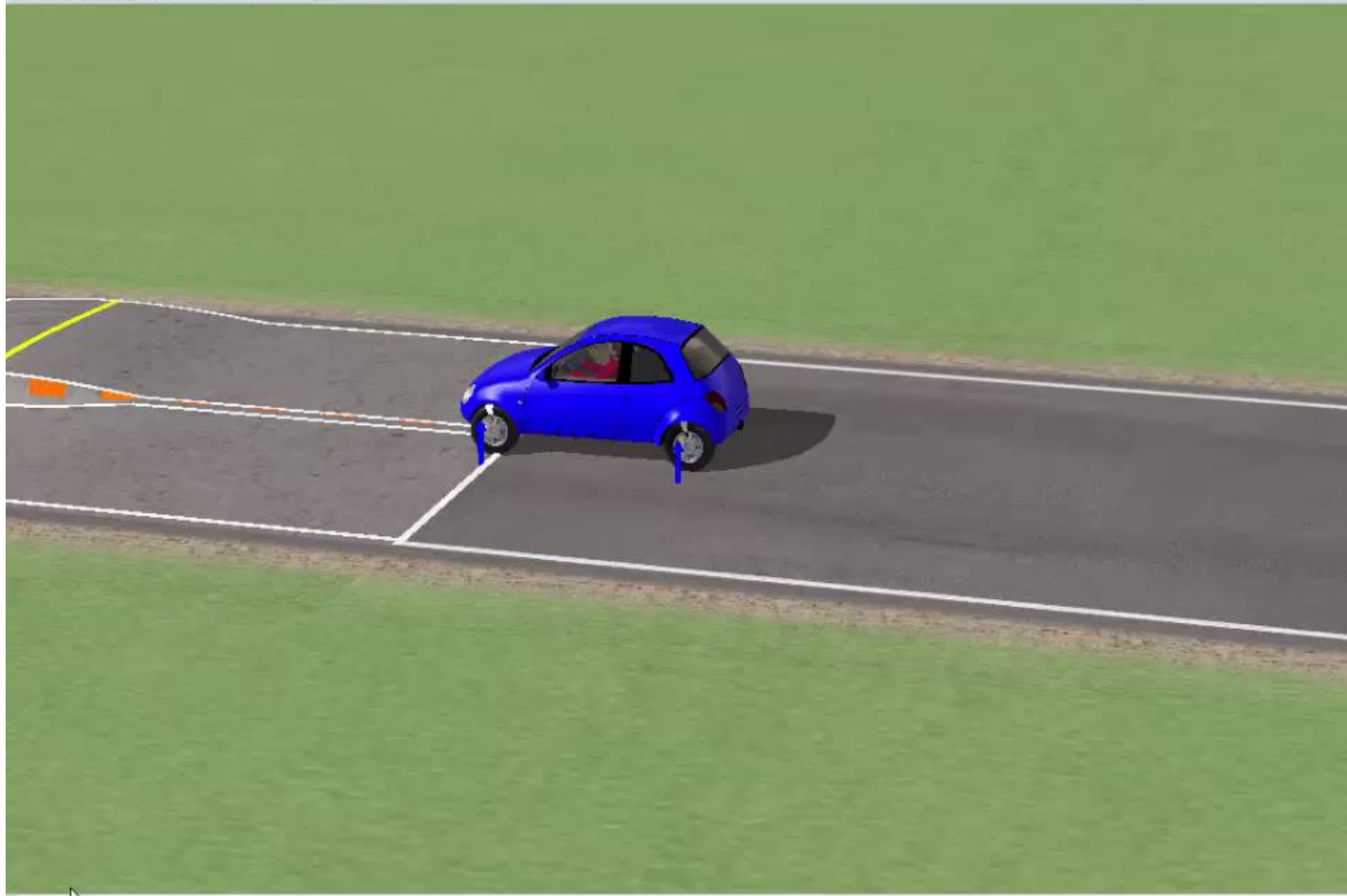
Spring stiffness 153kN/m – front  
82kN/m - rear

75kW front-wheel drive 4-speed  
gearbox

Front and rear independent suspension.

VS Visualizer - CarSim - ChassisTwist #AS <Testings\_vatsalya>

File View Playback Plot Tools Help



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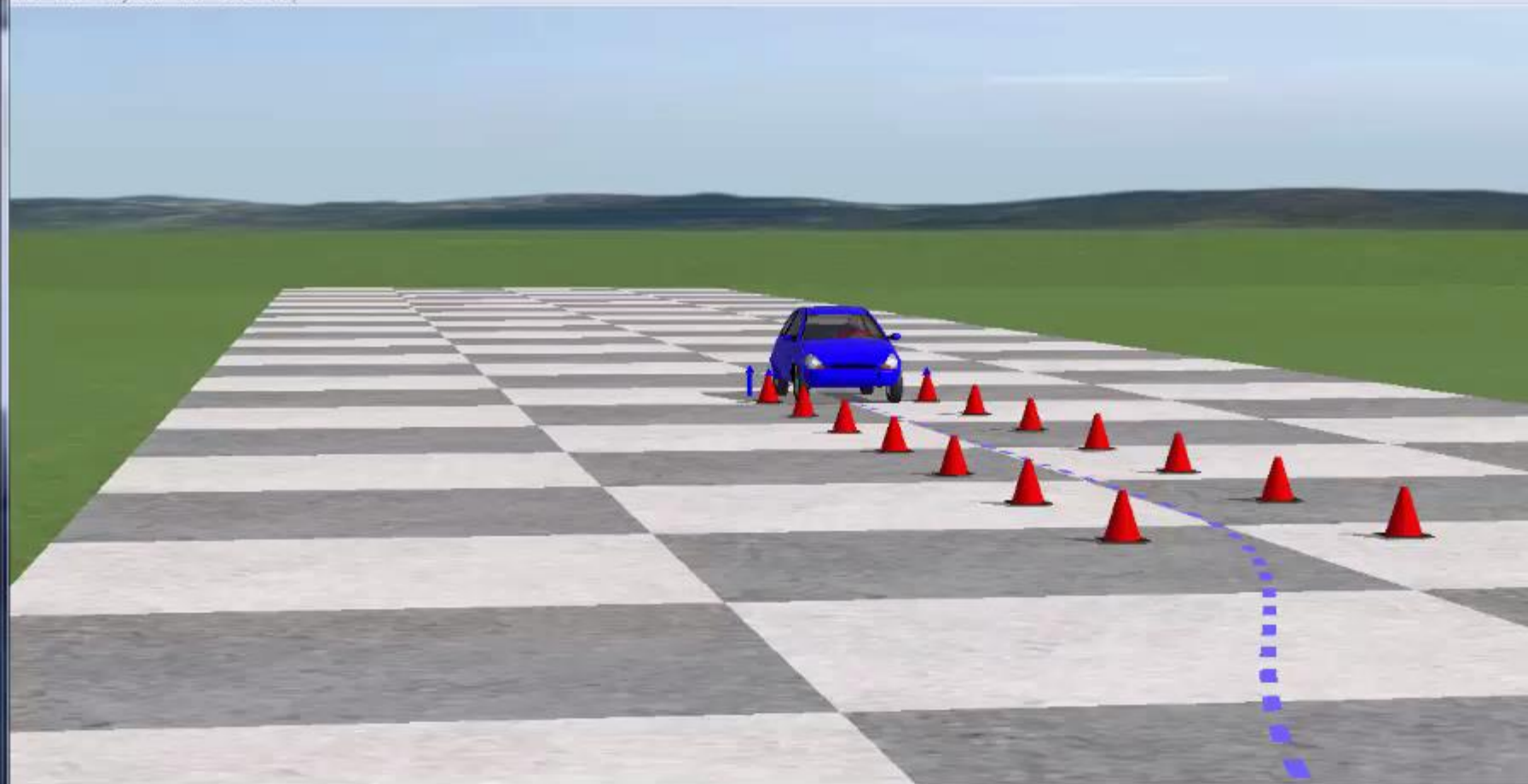


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VS Visualizer - CarSim - DoubleLaneCh-AS <Testings\_vatsalya>

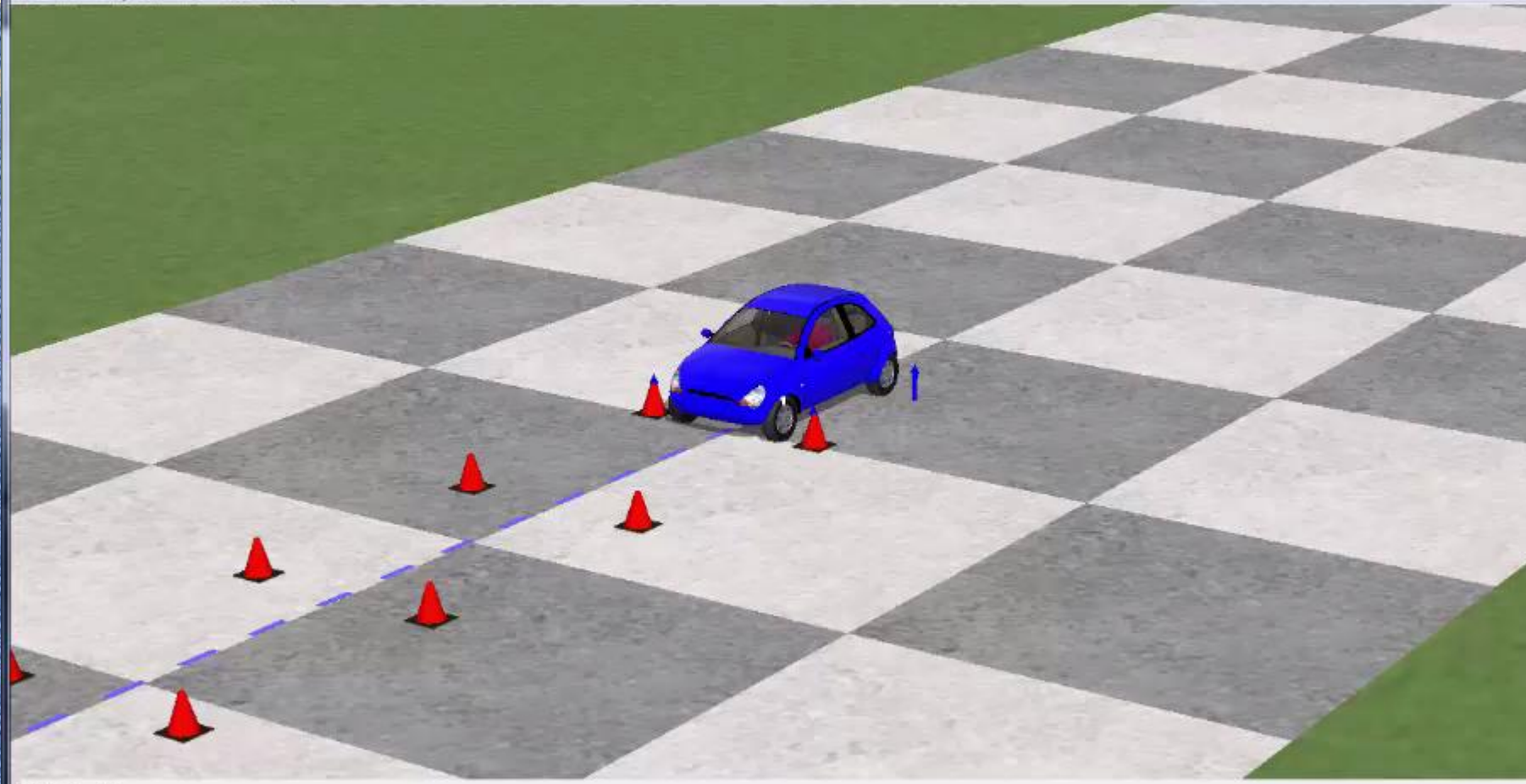
File View Playback Plot Tools Help



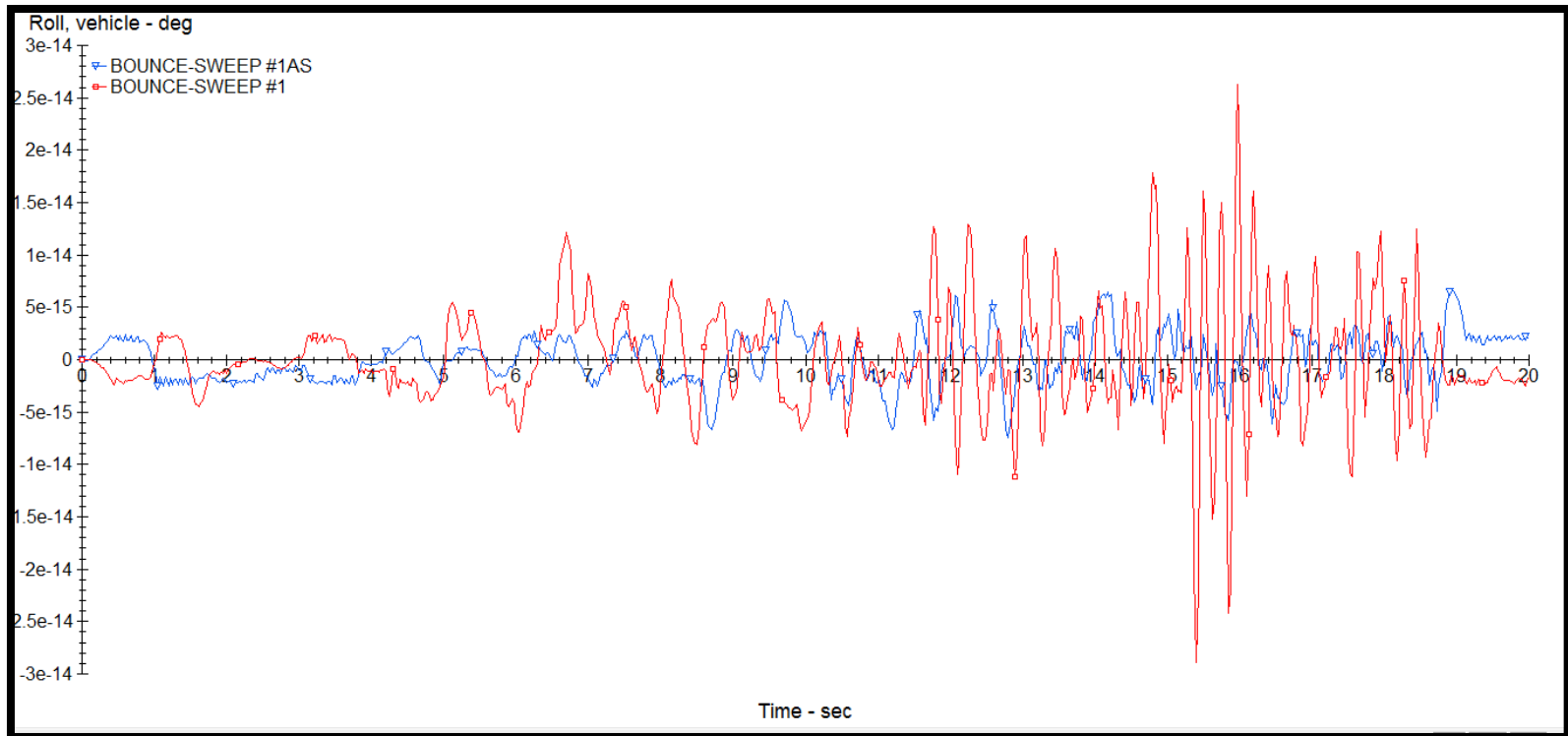


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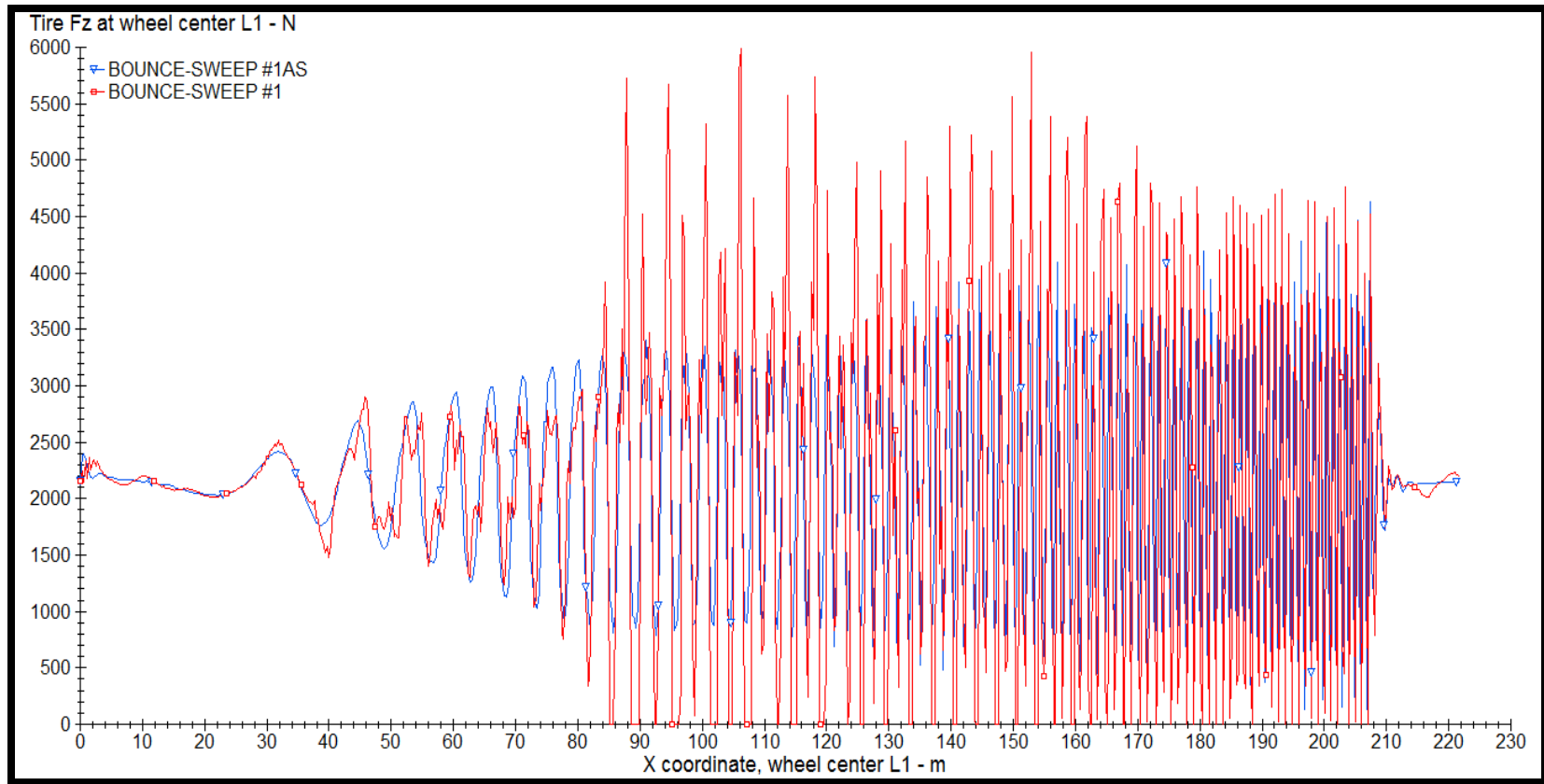
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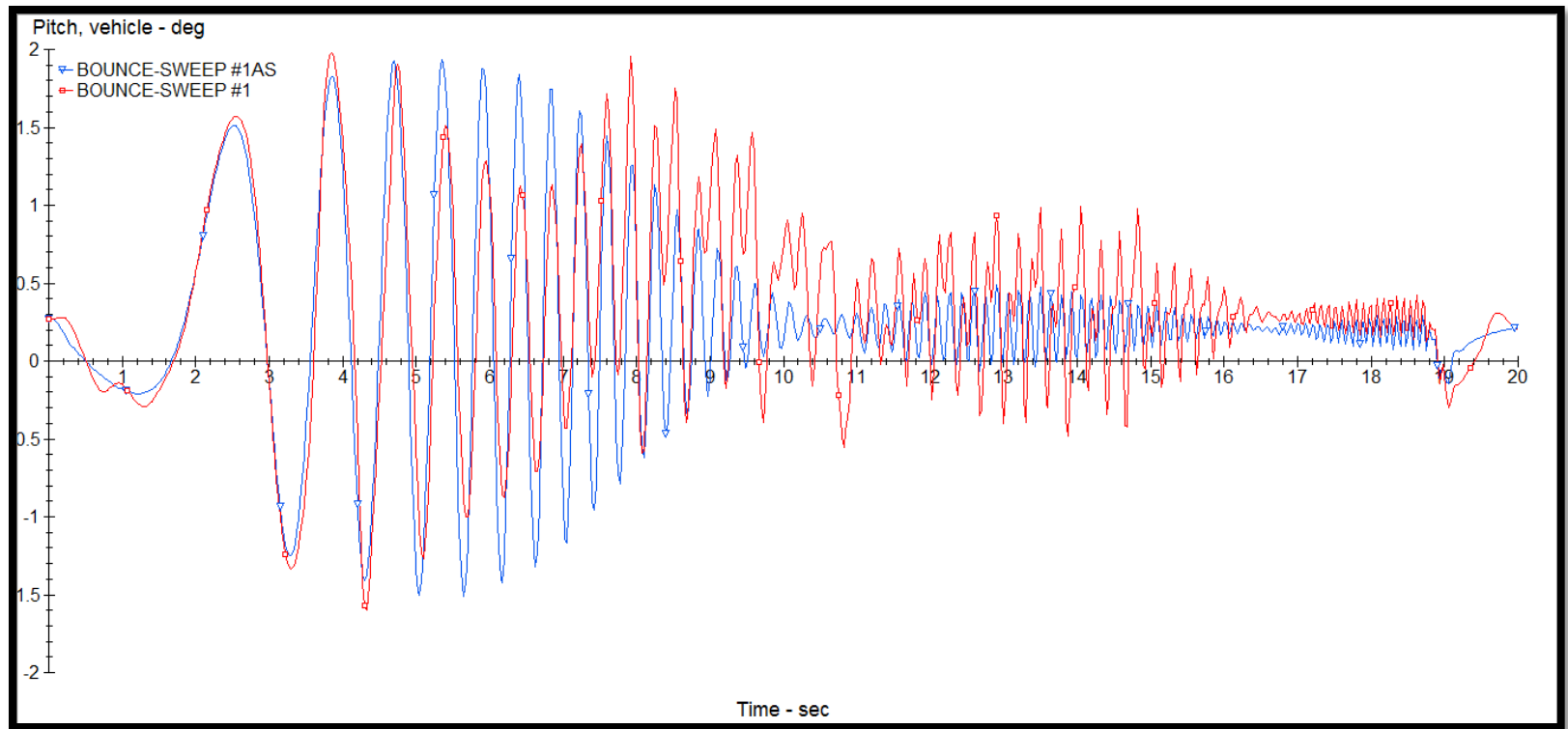
# Important plots



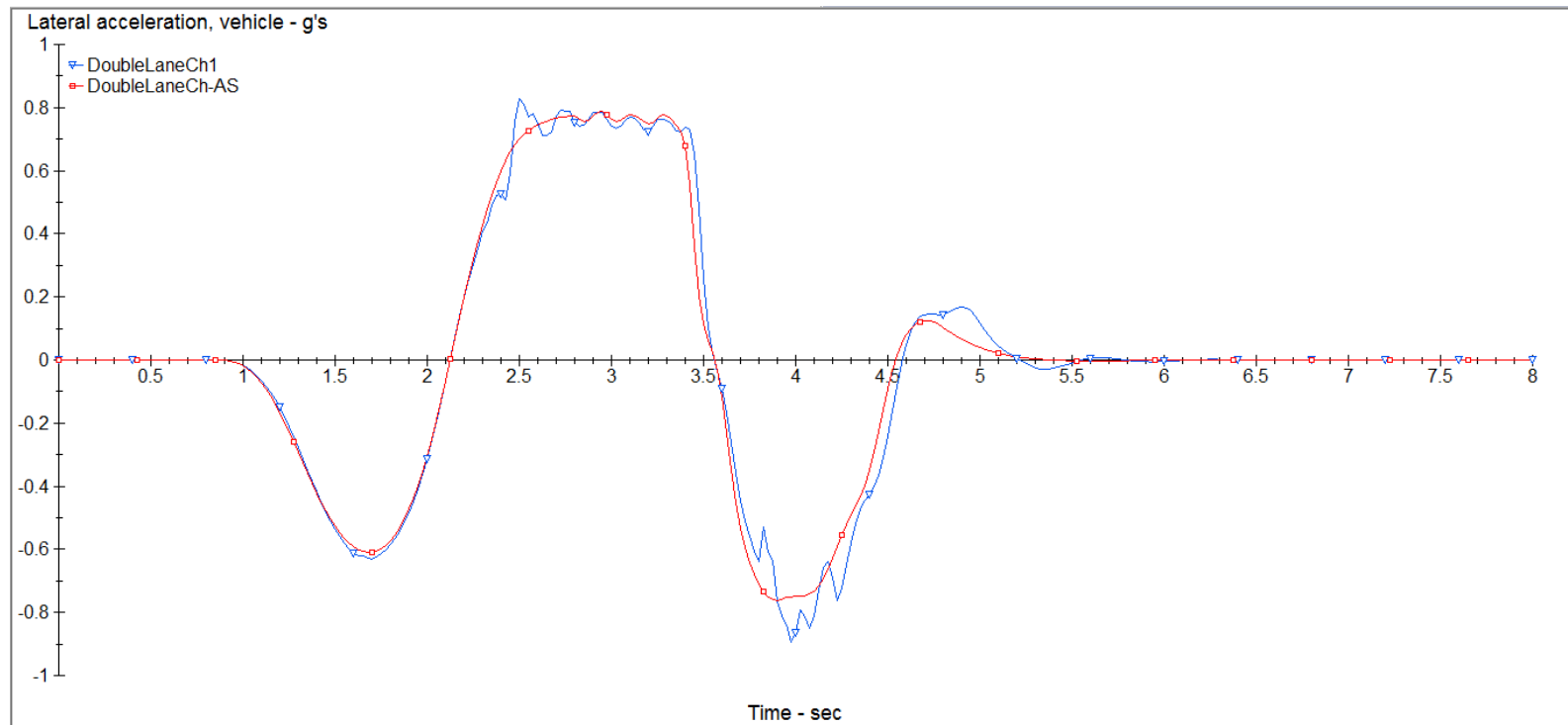
The active suspension model reduces roll considerably



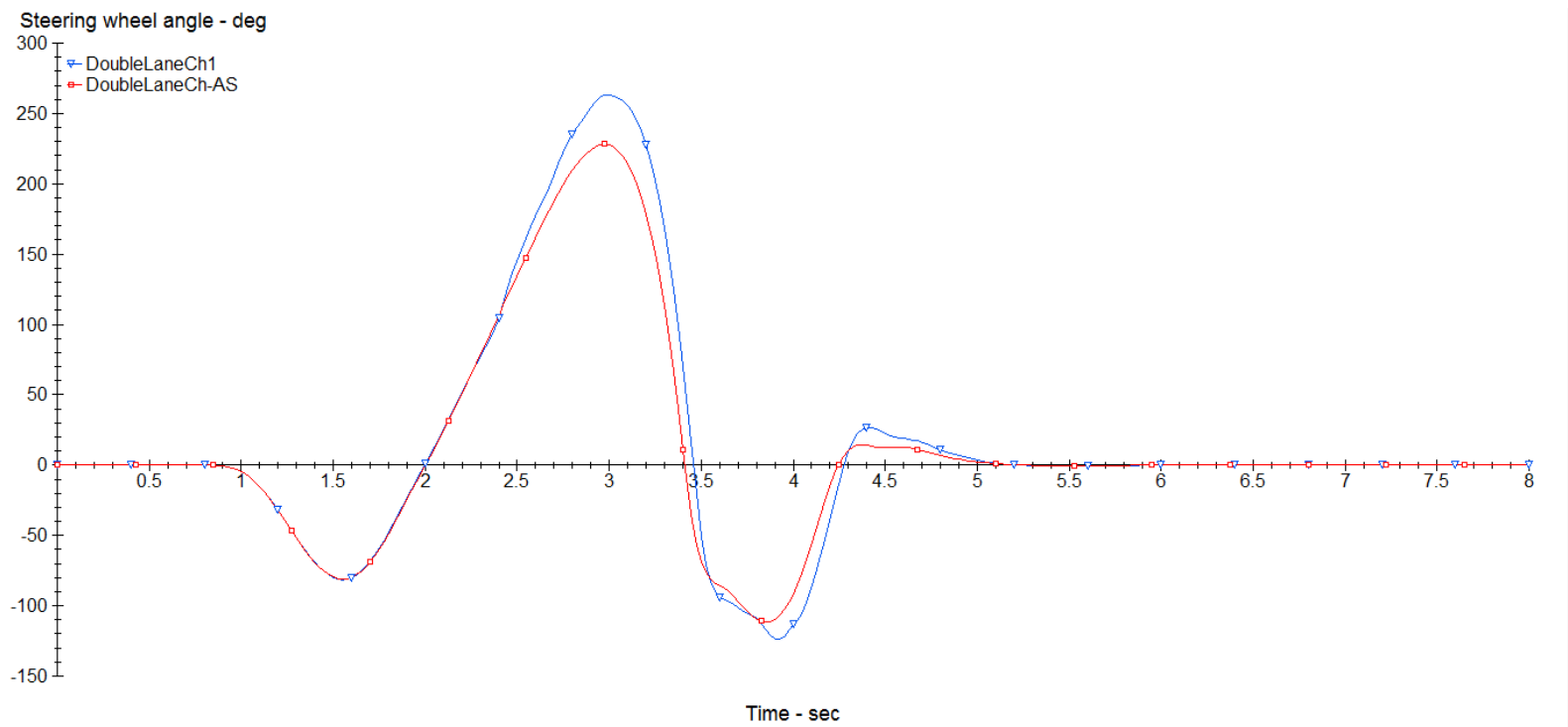
Vertical force – measure of *passenger comfort*

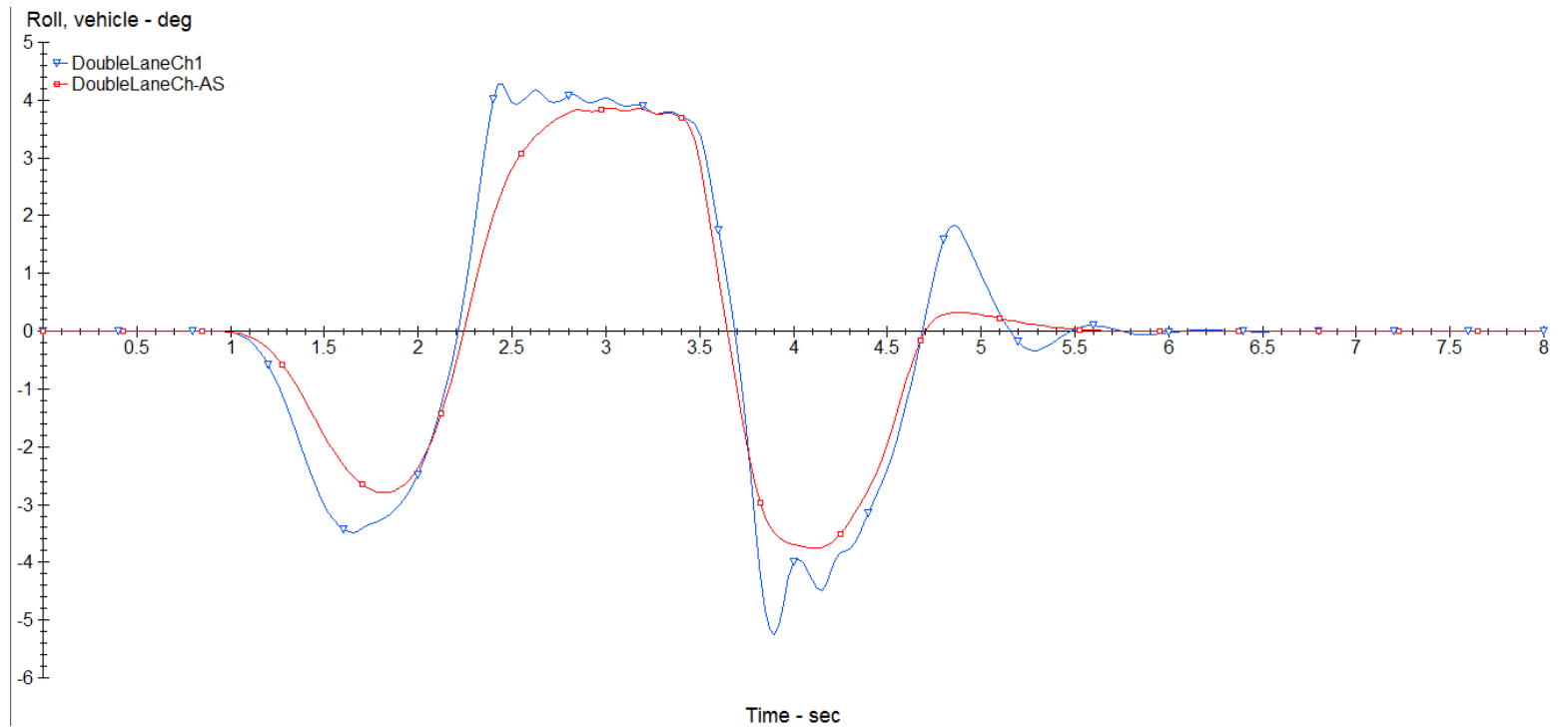


Active suspension reduces the ***pitch***









# References

- Jorge de-J Lozoya-Santos, Ruben Morales-Menendez and Ricardo A Ramirez-Mendoza. *Evaluation of on–off semi-active vehicle suspension systems by using the hardware-in-the-loop approach and the software-in-the-loop approach*
- V. Drobnya, M.Valasek. *Vehicle Lateral Dynamics Stabilization Using Active Suspension*
- Zhu R and Niu L. *Research on co-simulation and test of semi-active suspension*. In: 2nd international conference on computer modelling and simulation, Sanya, Hainan, People's Republic of China, 22–24 January 2010, pp. 353–357. New York: IEEE.
- Ramli R. *Dynamic simulation of semi-active suspension systems for durability analysis*. PhD Thesis, University of Leeds, Leeds, UK, 2007.
- Mechanical Simulation Corporation. *CarSim mechanical simulation references and help files*.
- *MatLab Help Files*