Semi Active Suspension System

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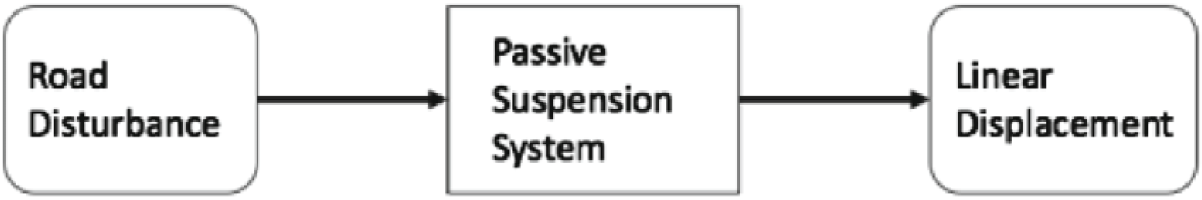
Problem Statement:

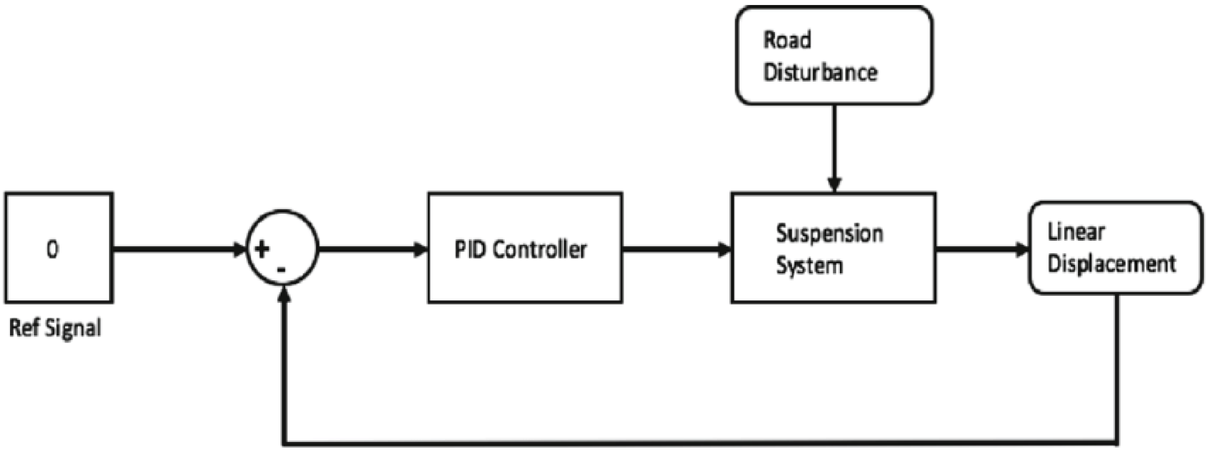
Modeling, simulation, and control of semi active suspension system for Automobiles under MATLAB Simulink.

Requirements:

1. Input
   Road Profile:
   - Sine wave
   - Random Input
2. Block Diagrams
   A. Passive Suspension System



   B. Semi Active Suspension System

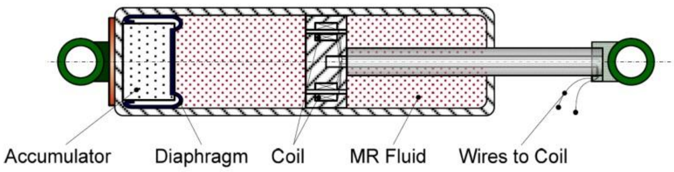


3. Parameters

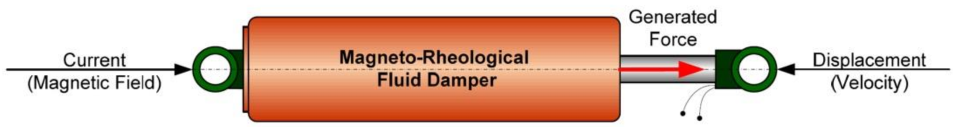
Parameters	Unit	Value
Sprung Mass	K_g	
Unsprung Mass	K_g	
Suspension spring coefficient	N/m	
Tire spring coefficient	N/m	
Suspension damper coefficient	N.s/m	
Tire damper coefficient	N.s/m	

4. Dampers

Magnetorheological dampers (MRD) are among the most promising semi-active devices used nowadays in automotive engineering. The key feauture of an MRD is the magnetorheological oil, a particular type of oil whose rheological properties can be altered by applying a magnetic field; by controlling the field (i.e., the current in a solenoid) variable damping can be produced.



(a) Hardware structure



(b) Working principle

4.1 MR Damper Design

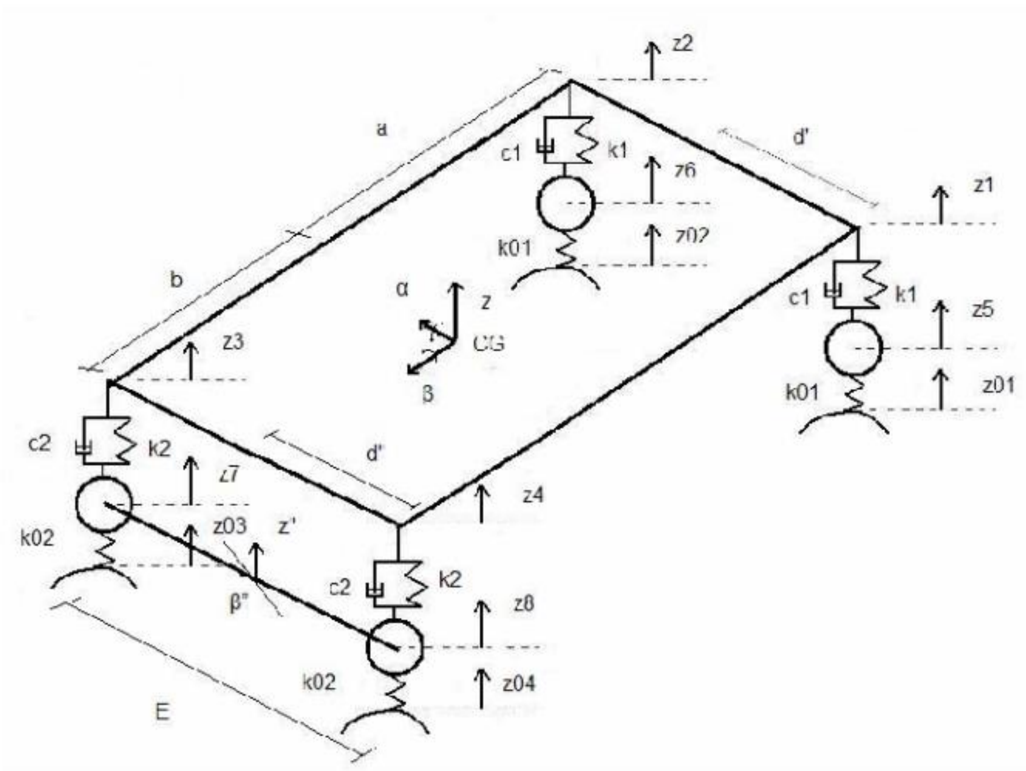
The design procedure of the MR damper involves the following steps:

- determination of input data and choice the design solution
- choice of the working MR fluid
- determination of the optimal gap size and hydraulic design
- magnetic circuit design.

5. Degree of freedom
   The motion of a vehicle with the nonholonomic constraint of the road has six degrees of freedom (6DOF), classified as follows:
   - longitudinal translation (forward and backward motion)
   - lateral translation (side slip)
   - vertical translation (bounce or heave)
   - rotation around the longitudinal axis (roll)
   - rotation around the transverse axis (pitch)
   - rotation around the vertical axis (yaw)

6. Mathematical Equations for Semi-active suspension system
   The 7DOF vehicle ride model extends the half car model to the entire vehicle: 3DOF are used for the sprung mass (bounce, roll and pitch), while the unsprung masses have 4DOF (1DOF for each tyre), as depicted in Fig. The governing equations can be written compactly in matrix form (bold letters denote matrices and vectors):

$$\boldsymbol{M\ddot{q}} + \boldsymbol{P^T C P \dot{q}} + \boldsymbol{P^T K P q} + \boldsymbol{F_d} = -\boldsymbol{P^T K_0 z_0} - \boldsymbol{P^T C_0 \dot{z}_0}, \qquad (2.10)$$



The vertical displacement vector $z \in \Re^8$ is defined as:

$$z = [z_1, z_2, z_3, z_4, z_5, z_6, z_7, z_8]^T$$

(the vertical displacements are not all independent).

Let $\boldsymbol{q}$ be the vector of generalised co-ordinates:

$$\boldsymbol{q} = [q_1, q_2, q_3, q_4, q_5, q_6, q_7]^T$$

with the following choice of co-ordinates:

$$q_1 = z\,;\ q_2 = z_5\,;\ q_3 = z_6\,;\ q_4 = z^{''}\,;\ q_5 = \alpha\,;\ q_6 = \beta\,;\ q_7 = \beta^{''},$$

z and $\boldsymbol{q}$ being related by the matrix $\boldsymbol{P}$, dependent upon the vehicle geometry:

$$z = \boldsymbol{P}\boldsymbol{q}.$$

Consider the vertical displacement vector and the matrix $\boldsymbol{P}$ being defined as:

$$\boldsymbol{P} = \begin{bmatrix} 1 & 0 & 0 & 0 & -a & d' & 0 \\ 1 & 0 & 0 & 0 & -a & -d' & 0 \\ 1 & 0 & 0 & 0 & b & d'' & 0 \\ 1 & 0 & 0 & 0 & b & -d'' & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 & \frac{E}{2} \\ 0 & 0 & 0 & 1 & 0 & 0 & -\frac{E}{2} \end{bmatrix},$$

where a and b are the distances of the front and rear of the vehicle from its centre of gravity, d' and d'' are, respectively, the front and rear half-track lengths and E the inter-wheel distance.

The road input vector $\boldsymbol{z_0}$ is then defined as:

$$\boldsymbol{z_0} = [z_{01}, z_{02}, z_{03}, z_{04}]^T.$$

Defining the vector $\boldsymbol{f}$ of the forces applied to sprung and unsprung masses

$$\boldsymbol{f} = [\boldsymbol{f}_1, \boldsymbol{f}_2, \boldsymbol{f}_3, \boldsymbol{f}_4, \boldsymbol{f}_5, \boldsymbol{f}_6, \boldsymbol{f}_7, \boldsymbol{f}_8]^T.$$

where $\boldsymbol{K}$ is the stiffness matrix:

$$\boldsymbol{K} = \begin{bmatrix} k_1 & 0 & 0 & 0 & -k_1 & 0 & 0 & 0 \\ 0 & k_1 & 0 & 0 & 0 & -k_1 & 0 & 0 \\ 0 & 0 & k_2 & 0 & 0 & 0 & -k_2 & 0 \\ 0 & 0 & 0 & k_2 & 0 & 0 & 0 & -k_2 \\ -k_1 & 0 & 0 & 0 & k_1 + k_{01} & 0 & 0 & 0 \\ 0 & -k_1 & 0 & 0 & 0 & k_1 + k_{01} & 0 & 0 \\ 0 & 0 & -k_2 & 0 & 0 & 0 & k_2 + k_{02} & 0 \\ 0 & 0 & 0 & -k_2 & 0 & 0 & 0 & k_2 + k_{02} \end{bmatrix}$$

and $\boldsymbol{K_0}$ is the unsprung mass stiffness matrix

$$\boldsymbol{K}_0 = \begin{bmatrix} 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ -k_{01} & 0 & 0 & 0 \\ 0 & -k_{01} & 0 & 0 \\ 0 & 0 & -k_{02} & 0 \\ 0 & 0 & 0 & -k_{02} \end{bmatrix}.$$