SNS COLLEGE OF TECHNOLOGY

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DEPARTMENT OF AUTOMOBILE ENGINEERING

COURSE NAME : 19AUT302 – VEHICLE DYNAMICS AND STRUCTURES

III YEAR / V SEMESTER

Unit 3 – Vertical Dynamics

Topic : Design and analysis of Active suspension using Quarter car model

INTRODUCTION

- The design and analysis of an active suspension system using a quarter car model involves developing a model that simulates a vehicle's vertical dynamics over rough terrain.
- A quarter car model approximates a vehicle as a 2-degree-of-freedom system, representing the interaction between the suspension and the road for a single wheel.

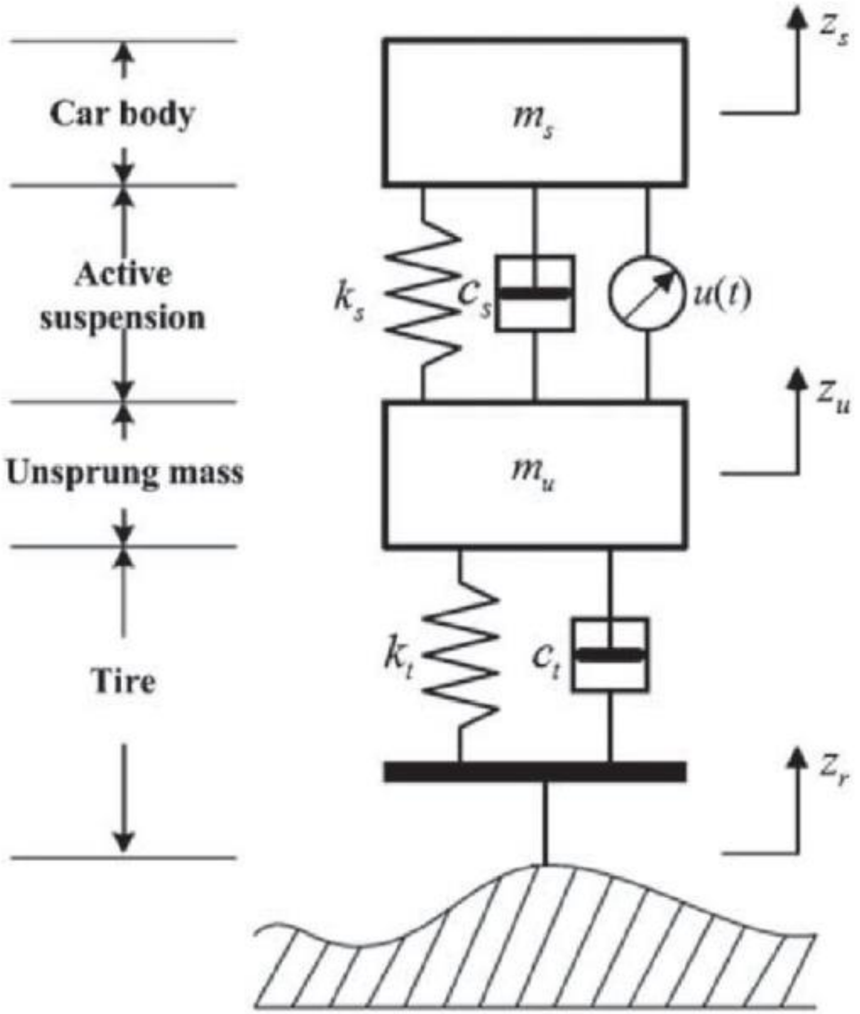
OVERVIEW

- The quarter car model consists of two masses:
  - **Sprung mass (m_1):** Represents the vehicle body.
  - **Unsprung mass (m_2):** Represents the wheel and axle assembly.
- The suspension system is designed to isolate the vehicle's body (sprung mass) from road disturbances.
- In an **active suspension**, additional forces (usually from actuators) are introduced to improve ride comfort and stability.

KEY COMPONENTS

- **Sprung mass (m_1):** Mass of the vehicle's body over the suspension.
- **Unsprung mass (m_2):** Mass of the wheel, tire, and other components.
- **Spring (k_1, k_2):** Suspension spring (k_1) and tire stiffness (k_2).
- **Damper (c_1):** Suspension damping coefficient.
- **Active force (F_a):** Force generated by an actuator in the active suspension system.
- **Road disturbance (z_0):** Input representing road irregularities.

ACTIVE SUSPENSION SYSTEM USING QUARTER CAR MODEL



MATHEMATICAL MODELLING

- The quarter car model can be represented by two second-order differential equations that describe the motion of the sprung and unsprung masses.
- These equations involve Newton's second law for vertical motion:

For the **sprung mass**:

$$m_1\ddot{z}_1 = -k_1(z_1 - z_2) - c_1(\dot{z}_1 - \dot{z}_2) + F_a$$

For the **unsprung mass**:

$$m_2\ddot{z}_2 = k_1(z_1 - z_2) + c_1(\dot{z}_1 - \dot{z}_2) - k_2(z_2 - z_0) - F_a$$

Where:

- z_1 and z_2 are the displacements of the sprung and unsprung masses.
- $\dot{z}_1, \dot{z}_2$ are the velocities, and $\ddot{z}_1, \ddot{z}_2$ are the accelerations.
- F_a is the control force applied by the actuator.

ACTIVE SUSPENSION CONTROL DESIGN

- The goal of active suspension control is to improve **ride comfort** and **road handling** by adjusting the suspension dynamics in real-time using sensors and actuators.
- Control strategies typically include PID Control (Proportional-Integral-Derivative), Optimal Control (LQR), Model Predictive Control (MPC)
- The control force is designed based on the vehicle's response to road disturbances and the desired performance objectives, such as minimizing body acceleration, minimizing suspension deflection, and limiting the tire-road force variation.

SIMULATION OF QUARTER CAR MODEL

To analyze the suspension system, a simulation can be conducted using software such as MATLAB/Simulink. The steps are as follows:

- **Step 1: Define Parameters:** Set values for sprung mass (m_1), unsprung mass (m_2), spring stiffness (k_1, k_2), damper coefficient (c_1), and initial conditions for displacements and velocities.
- **Step 2: Implement Equations of Motion:** Code the differential equations into Simulink or MATLAB.
- **Step 3: Apply Road Disturbance Input:** Introduce road profiles like a sine wave, bump, or random road disturbance to simulate the vehicle's interaction with uneven roads.

SIMULATION OF QUARTER CAR MODEL

Step 4: Analyze System Response:

- ❖ **Sprung mass displacement** (ride comfort),
- ❖ **Suspension travel** (suspension stroke),
- ❖ **Tire force variation** (road holding),
- ❖ **Body acceleration** (ride comfort),
- ❖ **Active force requirements** (actuator limits).

PERFORMANCE METRICS FOR ANALYSIS

The performance of the active suspension system is evaluated based on several key metrics:

- ❖ **Ride comfort:** Measured by the acceleration of the vehicle body (sprung mass).
- ❖ **Road holding:** Ensured by controlling the contact force between the tire and road.
- ❖ **Suspension travel:** Must be within safe limits to avoid bottoming out or topping out of the suspension.
- ❖ **Actuator effort:** Evaluating the force applied by the actuator in the active suspension.

THANK YOU !!!