Technical Analysis 1 – Alexis Fernandez

Analyze a car's suspension system. Select optimal suspension system for maintaining vehicle stability, passenger comfort, and sensor accuracy, particularly for the LiDAR based autonomous navigation system.

$$m = 250\ kg$$

$$k = 105\ N/m$$

Determine the damping coefficient b and evaluate the system's behavior under different configurations. The goal is to ensure passenger comfort and minimize vibrations or excessive motion that could interfere with LiDAR measurements.

The response of a damping system can be modelled with the differential equation:

$$m\ddot{x} + b\dot{x} + kx = 0$$

Where:

$m = 250\ kg$ is the mass

$k = 105\ N/m$ is the spring constant

b is the damping coefficient

An underdamped system would result in slight oscillations when hitting a bump on the road that would eventually settle, which while it may contribute to passenger comfort, it would most likely cause inaccuracies in the LiDAR measurements. An overdamped system would not have these oscillations but would take much longer to settle, which can make the vehicle response feel very slow. On the other hand, we would ideally want to achieve a critically damped system which would allow the suspension to settle as quickly as possible in order to optimally minimize the vibrations and achieve the best performance in the LiDAR sensor readings.

The damping occurring in the system in comparison to a critically damped system is characterized by the damping ratio ζ:

$$\zeta = \frac{b}{2\sqrt{mk}}$$

For the damping ratio:

$$\zeta < 1 \rightarrow Under\ Damped$$

$$\zeta = 1 \rightarrow Critically\ Damped$$

$$\zeta > 1 \rightarrow Over\ Damped$$

This ratio can be used to determine the critical damping coefficient. Substituting $\zeta = 1$, we get:

$$b_{critically\ damped} = 2\sqrt{mk}$$

$$b_{critically\ damped} = 2\sqrt{250\ kg \times 105\frac{N}{m}}$$

$$b_{critically\ damped} = 2\sqrt{26\ 250\ \frac{kg^2}{s^2}}$$

$$b_{critically\ damped} \approx 2 \times 162.019\frac{kg}{s}$$

$$b_{critically\ damped} \approx 324.037\frac{kg}{s}$$

We can now evaluate the system in different damping conditions using the critically damped coefficient:

$$b < 324.037\frac{kg}{s} \rightarrow Under\ Damped$$

$$b \approx 324.037\frac{kg}{s} \rightarrow Critically\ Damped$$

$$b > 324.037\frac{kg}{s} \rightarrow Over\ Damped$$

Because the goal is to achieve a critically damped system for best performance, using a damping coefficient of $b \approx 324.037$ would be optimal. This would ensure rapid stabilization of the car's suspension system, providing for an optimal balance with better passenger experience and more accurate data acquisition for LiDAR sensors to be used.