# Inertial damper study in passenger cars using multi-body simulation models

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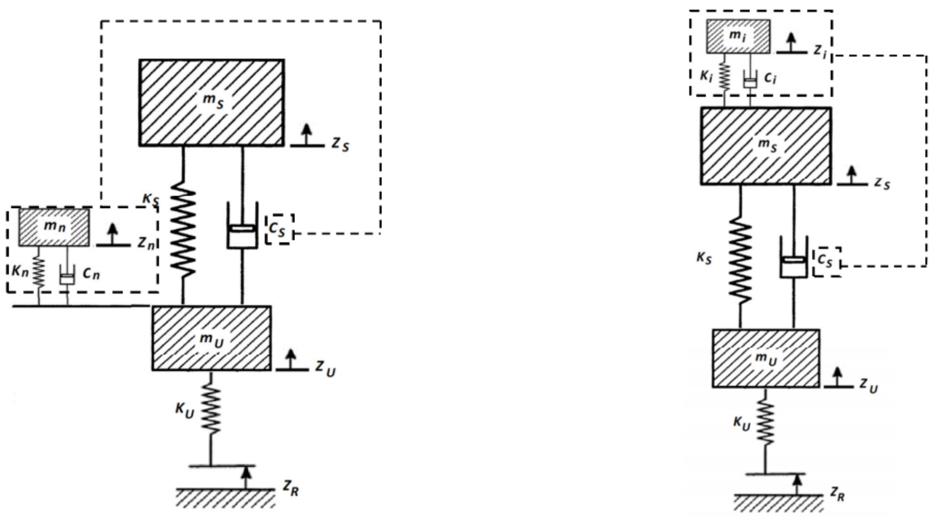
**Abstract**

Safety, ride quality, weight and costs are the key factors to be considered in the design process of passenger vehicles. In order to improve ride quality and safety factors, suspensions of vehicles play a key role, because they create the link between the sprung mass and road. Kinematic and compliance studies are commonly performed by means of multi-body simulations to optimize the relation between ride and handling. In this sense, dampers are one of the most influential components for vehicle dynamics. Traditionally, passive dampers are used in passenger vehicles to dissipate loads coming from road irregularities and to achieve proper ride and handling metrics. Nowadays, semi-active and active dampers are used to improve vehicle's safety and comfort. These dampers are developed increasing costs and installing electronic devices in the car. Other passive technologies are also used to provide different damping coefficients without using electronic controllers, which can be more interesting from a cost saving point of view. These technologies, presented in [1], can change the damping force as a function of the relative travel, excitation frequency, velocity or acceleration of the damper ends.

Inertial dampers are found into this group of passive dampers. They are built with an internal valve that can differentiate the movements resulting from the road and from the sprung mass. A design of this type of dampers could be seen in [2]. This type of dampers does not need any electronic supply, because they are activated by acceleration forces while traditional passive dampers can only provide resistance based on the relative velocity between sprung and unsprung mass. It has been proved that with the use of this technology there is a trend of improving the comfort of a vehicle during vertical dynamics excitations [3]. This study uses mathematical quarter car models, which are shown in Figure 1, to obtain these results.




(a) Inertial mass connected to the sprung mass (b) Inertial mass connected to the unsprung mass

Figure 1: Lumped quarter car model of an inertial damper [3].

As it is shown in Figure 1, the damping coefficient it is related with the movements of the inertial mass. These movements are caused because of acceleration inputs in the sprung or unsprung mass and he says that damper force could be approximately expressed by the Equation (1).

$$\mathrm{f_a} = \left[\mathrm{C_1} + \frac{\alpha}{1 \pm |(Z_i - Z_B)| \cdot \beta}\right] \cdot v_a \quad (1)$$

Where:

| | |
|---|---|
| $\mathrm{f_a}$ | Damping force |
| $\mathrm{C_1}$ | Damper coefficient |
| $\alpha$ | Proportionality factor |
| $Z_i$ | Inertial mass position |
| $Z_B$ | Inertial mass exciter position ($Z_s$ or $Z_u$ depending on the position) |
| $\beta$ | Proportionality factor |
| $v_a$ | Damper velocity |

The present study is focused on investigating the response of a multi-body modelled car, with the aim of optimizing vehicle dynamic metrics with the use of inertial dampers. First of all, an inertial damper is modelled in a quarter car model using multi-body software. For that purpose, the first step is to define the position of the inertial valve and the values for the inertial mass, spring rate and damping coefficient that better fits for a given car specification. After validating the formulation and the values used in the quarter car model, a full car model is created introducing the validated inertial damper formulation. Several road profiles were considered and results of full car multi-body model using traditional passive dampers and inertial dampers are compared in terms of ride and handling. Finally, during cornering or braking, roll and pitch metrics could be reduced with inertial dampers. Because of that, this work shows that comfort is increased while safety is maintained.

**References**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