

General Modeling of Nonlinear Isolators for Vehicle Ride Studies

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ABSTRACT

The advancements made in modeling and parameter identification of nonlinear isolation components in the underlying investigation confirm the importance of accurate Multibody Dynamics modeling of these components for reducing vibration and/or improving ride comfort.

Considering dynamic stiffness and loss angle characteristics, the proposed nonlinear isolation component uses the Bouc/Wen hysteresis model for excitation amplitude dependency and a transfer function for excitation frequency dependency. Various combinations of Bouc/Wen hysteresis parameters result in different shapes for hysteresis loops and allows for modeling a wide range of soft and stiff isolator characteristics.

The effect of the proposed isolation component on ride studies is illustrated by simulating a maneuver on a road profile using the OpenCRG road description with SimXpert Motion Workspace and Adams/Car. Tire belt dynamics are captured by adding a rigid ring part to the PAC2002 tire model [1].

INTRODUCTION

The automotive industry relies more and more on simulation tools to analyze the performance of vehicles. MSC Software provides powerful simulation tools to analyze vehicle behaviour: SimXpert Motion Workspace and Adams/Car, the industry standard tool for system-level virtual prototyping. Extensions for Ride applications add detail to virtual prototypes for vehicle dynamics to obtain more reliable ride & comfort models.

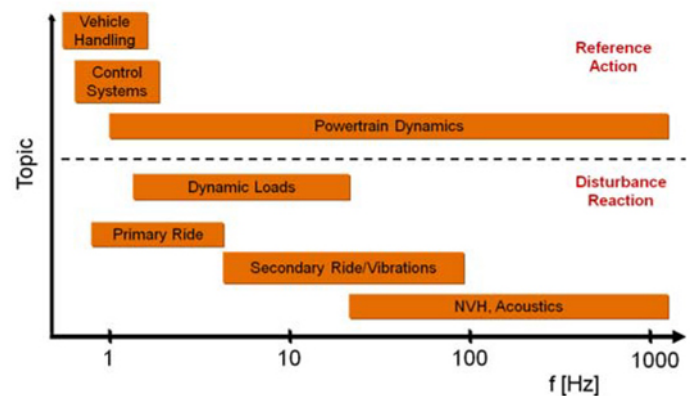


Fig. 1. Vehicle performance classifications arranged by primary frequency range

ISOLATION COMPONENT MODEL

Usually a vehicle is equipped with isolator components to provide an optimal compromise between vehicle response and driver's comfort.

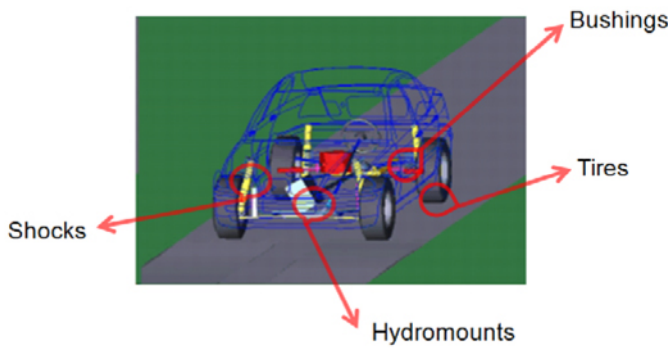


Fig. 2. Isolator component examples

The proposed isolation component model describes the important effects, such as dependency of dynamic stiffness on displacement and frequency as well as damping on frequency and can be divided in 3 elements as shown in the Figure below.

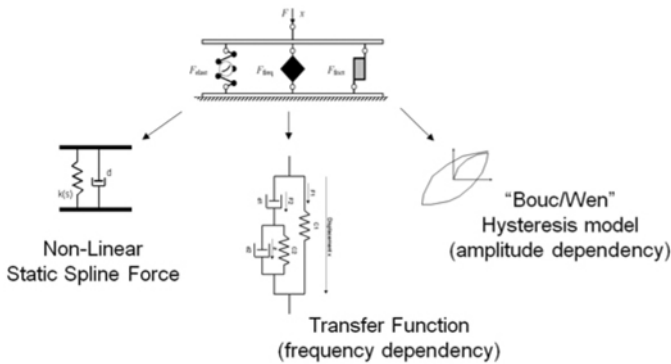


Fig. 3. General isolator component schematic

ELEMENT 1. NON-LINEAR STATIC SPLINE FORCE

Force versus deflection is modeled by means of a spline function.

ELEMENT 2. TRANSFER FUNCTION

Utilizing the general visco-elastic material model, the dependency of dynamic stiffness and damping on frequency is modeled by a variable order transfer function. Visco-elastic materials are those for which the relationship between stress and strain depends on time. For the general form of the visco-elastic material model yields

$$(p_0 + p_1 \frac{\partial}{\partial t} + p_2 \frac{\partial^2}{\partial t^2} + \dots + p_n \frac{\partial^n}{\partial t^n}) \sigma_t = (z_0 + z_1 \frac{\partial}{\partial t} + z_2 \frac{\partial^2}{\partial t^2} + \dots + z_m \frac{\partial^m}{\partial t^m}) \epsilon_t$$

Where σ_t is the stress, ϵ_t the strain and p, z material property parameters.

Taking the Fourier transform results in following transfer function:

$$G(s) = \frac{\sigma(s)}{\epsilon(s)} = \frac{z_0 + z_1 s + \dots + z_m s^m}{p_0 + p_1 s + \dots + p_n s^n}$$

This approach allows for modeling of any combination of Maxwell and Kelvin type material models including hydraulic effects.

An example of a hydromount is shown in Figure 4.

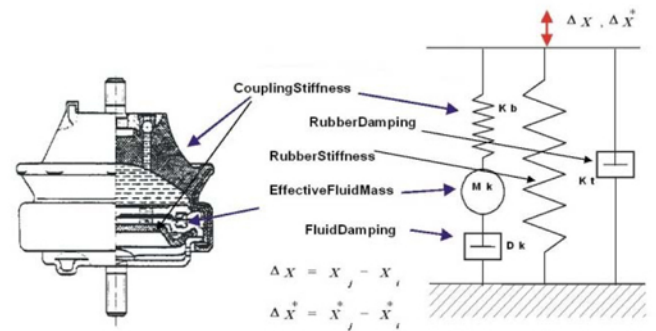


Fig. 4. Hydromount example

ELEMENT 3. BOUC/WEN HYSTERESIS MODEL

The dependency of dynamic stiffness on amplitude is modeled by the Bouc/Wen hysteresis model [2] which is a system of nonlinear differential equations defined by:

$$\ddot{x} + 2\zeta\omega\dot{x} + a\omega^2x + (1-a)\omega^2z = f(t)$$

$$\dot{z} = -\gamma|\dot{x}|z^{(n-1)}z - \beta\dot{x}|z|^n + a\dot{x}$$

Where

- α : rigidity ratio ($0 \leq \alpha \leq 1$)
- ζ : linear elastic viscous damping ratio ($0 \leq \zeta \leq 1$)
- ω : pseudo-natural frequency of the system (rad/s)
- a : parameter controlling the hysteresis amplitude
- β, γ, n : parameter controlling the hysteresis shape ($n \geq 1$)

The variable z is a virtual displacement which accounts for the dependency of the nonlinear restoring force, i.e. $(1-a)\omega^2z$, on both current and previous displacement. The model is capable of producing different shapes for the hysteresis loops and allows for modeling of soft and stiff isolators. An example of the different shapes by varying β and γ is given below.

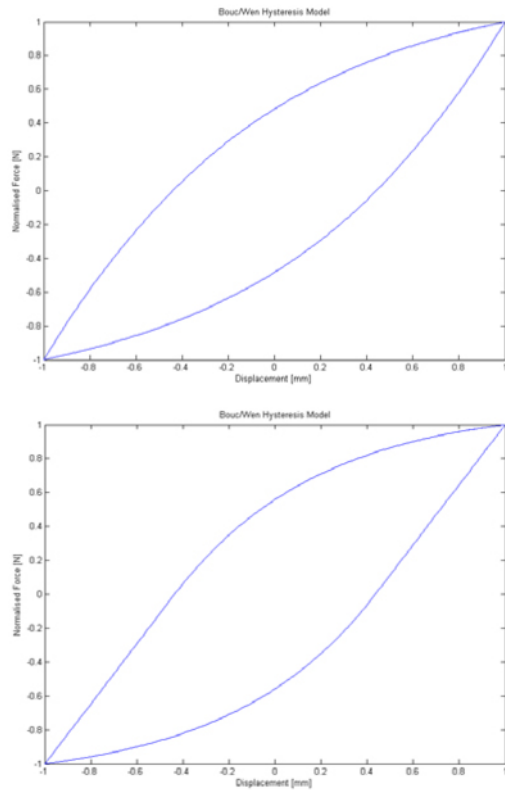


Fig. 5. Hysteresis shapes: top figure $\beta+\gamma>0$ $\beta-\gamma<0$ / bottom figure $\beta+\gamma>0$ $\beta-\gamma=0$

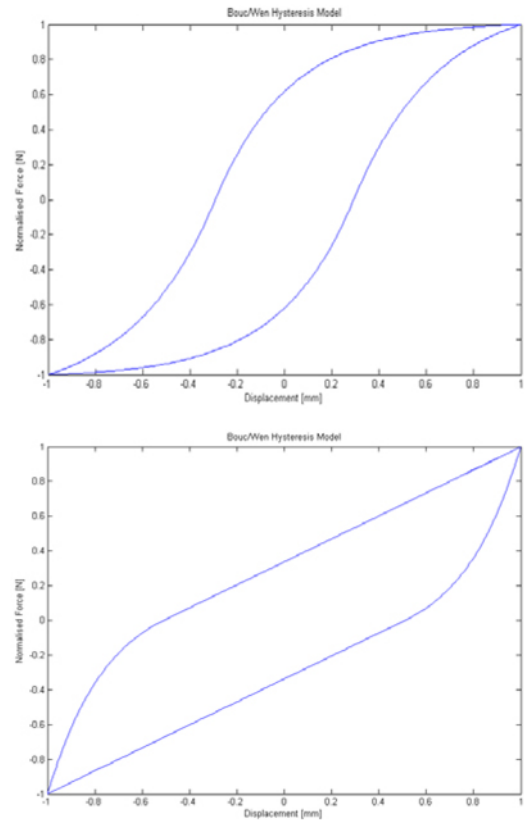


Fig. 6. Hysteresis shapes: top figure $\beta+\gamma>\beta-\gamma>0$ / bottom figure $\beta+\gamma=0$, $\beta-\gamma<0$

ISOLATOR PARAMETER IDENTIFICATION

The MSC Isolator Parameter Identification Tool [3] is used to fit isolator test data (static stiffness, hysteresis and dynamic stiffness and phase for 0.1, 0.3 and 1.0 mm amplitude) provided by an OEM Vehicle Manufacturer.