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A high-frequency first-principle model of a shock absorber and servo-hydraulic tester

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ABSTRACT

The aim of this paper is to present the model of a complete system, consisting of a variable damping shock absorber and a specialized servo-hydraulic tester, used to evaluate the vibration levels produced by a shock absorber. This kind of evaluation is used within the automotive industry to investigate shock absorbers, as an alternative to vehicle-level tests. The purpose of such testing is to quantify a shock absorber's ability to transfer the mid- and high-frequency content of the vibrations passing from the road profile, through the suspension, to the vehicle body. The first-principle non-linear model formulated, derived and validated in this paper allows laboratory test conditions to be reproduced. It also provides an understanding of structural vibrations in regard to the dynamical interactions between the shock absorber, its basic components (e.g. valve systems), mounting elements, and the hydraulic actuator. The model is capable of capturing important dynamical properties over a wide operating range, yet is only moderately complex. The model has proved to be qualitatively suitable and quantitatively accurate based on validation work performed for the entire frequency range of interest, i.e. 0–700 Hz. The application scope of this study covers the engineering need to develop a simulation tool for high-frequency shock absorber design optimization.

1. Introduction

The roles of a shock absorber working in the vehicle suspension are, in a sense, contradictory. Firstly, an ideal shock absorber should guarantee good road handling, secondly, it has to be designed for durability, thirdly, the radiated noise and emitted vibrations should have as little power as possible, and lastly, it should ensure passenger comfort. Noise is the audible effect of structural and forced vibrations, and its reduction is carried out by shock absorber manufacturers as a product design and optimization activity. The subject has increased in importance due to computer-controlled variable damping systems, which were recently launched into the passenger car market [3,14]. The introduced systems were able to change damping into a function of the sensed road profile and driver inputs (braking and steering). These systems require more effort when optimizing noise and vibration because of controllable changes in damping force which correspond to road conditions, whose effect is not present in conventional shock absorbers.

Noise and vibration evaluation is performed on the entire vehicle under road and laboratory conditions. However, it is also frequently performed on isolated systems of gradually increasing complexity in laboratory conditions, i.e. suspension

Abbreviations: FF, feed forward; FFT, fast Fourier transformation; NVH, noise, vibration and harshness; PID, proportional integrate and derivative; PSD, power spectral density

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