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DYNAMIC ANALYSIS AND DESIGN CALCULATION METHODS FOR POWERTRAIN MOUNTING SYSTEMS

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ABSTRACT−A method for dynamic analysis and design calculation of a Powertrain Mounting System (PMS) including Hydraulic Engine Mounts (HEM) is developed with the aim of controlling powertrain motion and reducing low-frequency vibration in pitch and bounce modes. Here the pitch mode of the powertrain is defined as the mode rotating around the crankshaft of an engine for a transversely mounted powertrain. The powertrain is modeled as a rigid body connected to rigid ground by rubber mounts and/or HEMs. A mount is simplified as a three-dimensional spring with damping elements in its Local Coordinate System (LCS). The relation between force and displacement of each mount in its LCS is usually nonlinear and is simplified as piecewise linear in five ranges in this paper. An equation for estimating displacements of the powertrain center of gravity (C.G.) under static or quasi-static load is developed using Newton's second law, and an iterative algorithm is presented to calculate the displacements. Also an equation for analyzing the dynamic response of the powertrain under ground and engine shake excitations is derived using Newton's second law. Formulae for calculating reaction forces and displacements at each mount are presented. A generic PMS with four rubber mounts or two rubber mounts and two HEMs are used to validate the dynamic analysis and design calculation methods. Calculated displacements of the powertrain C.G. under static or quasi-static loads show that a powertrain motion can meet the displacement limits by properly selecting the stiffness and coordinates of the tuning points of each mount in its LCS using the calculation methods developed in this paper. Simulation results of the dynamic responses of a powertrain C.G. and the reaction forces at mounts demonstrate that resonance peaks can be reduced effectively with HEMs designed on the basis of the proposed methods.

KEY WORDS : Automotive powertrain mounting systems, Hydraulic engine mounts, Motion and vibration control of a powertrain, Analysis and calculation methods

NOMENCLATURE

K_c^* : complex stiffness of a mount
K' : storage stiffness of a mount
K'' : loss stiffness o f a mount
K_d : dynamic stiffness of a mount
ϕ : loss angle of a mount
C : damping coefficient of a mount
GCS : global coordinate system
LCS : local coordinate system of a mount
k_{ui}, k_{vi}, k_{wi} : static stiffness of the th mount in its LCS
x_i, y_i, z_i : location of the th mount in GCS.
k_u', k_v', k_w' : storage stiffness of a mount in its LCS
k_u'', k_v'', k_w'' : loss stiffness of a mount in its LCS
I_{XX}, I_{YY}, I_{ZZ}, I_{XY}, I_{YZ}, I_{ZX} : inertia properties of the powertrain in GCS

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1. INTRODUCTION

A powertrain (an engine and a transmission) mounting system (PMS) generally consists of a powertrain (engine and gearbox) and several mounts connected to a base structure (Yu *et al.*, 2001). A mount used in PMS is usually a rubber mount (rubber boned to metal), or a hydraulic engine mount (HEM). The force versus displacement relation (F-D relation for short) of a rubber mount or an HEM is determined by its rubber components. The dynamic stiffness and loss angles of the two kinds of mounts under low-frequency and large-amplitude excitations are quite different (Yu *et al.*, 2001). One advantage of an HEM is that it can provide large damping around a frequency value (Shangguan and Lu, 2004). Motion control and vibration isolation of a powertrain are very common and important engineering design problems in automobiles and ships (Tao *et al.*, 2000). The challenge in designing a PMS is to select the appropriate