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A novel approach for lower frequency performance design of hydraulic engine mounts

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Abstract

Nonlinear damping property of the inertia track for a generic hydraulic engine mount (HEM) is identified by experimental method and simulation approach using commercial software ADINA. The experimental method and data processing technique for obtaining linear and nonlinear resistances of fluid motion in the inertia track are presented. Three kinds of HEMs with different number of inertia tracks are designed and manufactured, and their frequency response characteristics are investigated by experimental and analytical methods. The linear and nonlinear lumped parameter (LP) models for an HEM with multiple inertia tracks (MIT) are proposed. The peak frequency of the HEM's loss angle is derived from the linear LP model and expressed in an explicit form, and the dynamic stiffness and the loss angle of an HEM are obtained from the nonlinear LP model. The calculated dynamic performances of an HEM with MITs using the proposed LP models are compared favorably with the experimental data, which validates the proposed models. The analytical methods and conclusions are instructive for the design and the tuning of the lower performance of a passive and a semi-active HEM.

Keywords: Hydraulic engine mount; Multiple inertia tracks; Lumped parameter models; Determination of linear- and nonlinear-resistances; Analysis of lower frequency performances

1. Introduction

1.1. Motivation

Hydraulic engine mount (HEM) is widely used in a vehicle to isolate the powertrain from the road excitations in vertical direction and torques excitation from the engine around the crankshaft. One of the advantages of an HEM is that it can provide large damping in certain frequency. The frequency usually equals to one of the natural frequencies of the powertrain mounting system, and it is determined largely by the characteristics of the inertia tracks if the configuration and material performances of the HEM's rubber spring are fixed. In designing lower performance of an HEM, engineers more concern about the peak frequency of the loss angle, the value of the loss angle, and the ration of the maximum dynamic stiffness to the static stiffness of the HEM. These performances are determined by the characteristics of the HEM' s rubber spring, the fluid viscosity and density, and the inertia track, etc. In the design stages, the influences of these factors on the performances of an HEM must be estimated with the effective models and methods.

Different models are proposed to estimate the dynamic performances of an HEM, and the two typical models are lumped parameter (LP) model [1–3] and the fluid structure interaction (FSI) model [4,5]. The advantages of a LP model are that each lumped parameter in the model has a clear physical meaning, and the peak frequency in loss angle of the HEM can be expressed explicitly as a function of lumped parameters. However, to predict the properties

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of an HEM in design stage using LP model, the lumped parameters must be estimated by calculation methods, which is a difficult task to get some parameters by conventionally formulae, such as resistances of the inertia track. To calculate the dynamic characteristics of an HEM using FSI model, only stress versus strain relations of rubber material, the fluid physical parameters and the HEM sizes are needed, and these parameters are easy to get in design stage while the relation between the peak frequency of loss angle and the parameters is implicit.

In designing an HEM, it is usually difficult to tune the peak frequency of loss angle to a prescribed value with only one inertia track due to size limitations of the cross-section area and the length of the inertia track. At present, most researches focus on their studies to an HEM with only one inertia track [1–3,5–9,12]. The influences of the inertia track numbers on the dynamic performances of an HEM and the application cases of the HEM with multiple inertia tracks (MIT) are not fully understood. And the relevant calculation methods and experimental results for the dynamic properties of an HEM with MITs are not readily available in present published references.

Therefore, the chief objectives of this article are to develop experimental and calculation methods to obtain resistances of an inertia track, and to disclose influences of the number and the geometry size of inertia track on the dynamic performances of the HEM by experiments and simulation approaches.

1.2. Literature review

There is substantial body of literature on estimation of the dynamic performances of an HEM under lower frequency and large amplitude excitations. Singh et al. [1] and Colgate et al. [7] provide an excellent literature review on the dynamic characteristic descriptions and the modeling methods for an HEM with an inertia track and with or without a decoupler. Singh et al. [1–3] provide linear and nonlinear LP models to calculate the dynamic performance of an HEM with one inertia track. The lumped parameters in the models are usually obtained by experiment from the HEM or its components. Therefore, it is difficult to calculate the dynamic performances of an HEM in the design stage. Geisberger et al. [6] present a complete LP model for an HEM with an inertia track and a free decoupler and a unique experimental apparatus to identify the lumped parameters in the LP model. Because the mode is attempted to capture all details of an HEM, it is too complicated for engineers to estimate the dynamic properties of the HEM. Colgate et al. [7] carry out a novel experiment on the HEM with an inertia track and a free decoupler, and several specially prepared mounts. They establish piecewise linear LP model to simulate the HEM's behavior for large amplitude and small amplitude excitations. The lumped parameters in the model are obtained through parameter identification techniques from the frequency response of HEMs or by experiment. Shangguan et al. [9] present a method for calculating lumped parameters in the LP model for an HEM with one inertia track and a free decoupler based on nonlinear finite element analysis (FEA) methods and FSI FEA techniques using commercial software ADINA [10]. Although the methods for estimating the static stiffness, volumetric stiffness and the equivalent piston area are effective, the method for computing resistances of the inertia track is too complicate, and the calculated results are not validated by experiments.

Based on the existing references, it is clear that no effective and simple methods are available to predict the resistances of the inertia track, and no efforts have been made to analyze the influences of the number of inertia tracks on the dynamic performances of an HEM to the best of our knowledge.

1.3. Example cases and objectives

Experimental results show that the dynamic performances of an HEM under lower frequency and large amplitude excitations are determined largely by the inertia track, the rubber spring and the fluid, and the influences of the decoupler on the lower frequency performances of an HEM can be ignored [5]. Thus, for the lower frequency performance analysis of an HEM, the HEM with inertia track is taken as a studying object. The configuration of an HEM with only one inertia track is illustrated in Fig. 1. In an engine mounting system, three or four mounts are used to support engine or transmission, out of which one or two is typically the HEM. The device is mounted to the engine in end A and to the chassis or cradle in end B. Physical components contributing to the dynamic performances of an HEM include the followings. The rubber spring has two functions: to support the static load of the engine and contribute significantly to the static stiffness and slightly the damping of the HEM. The rubber bellow serves principally to enclose the fluid. The cage is a metal or plastic plate that separates the upper chamber and lower chamber. Cast in the cage are inertia track. The inertia track is a

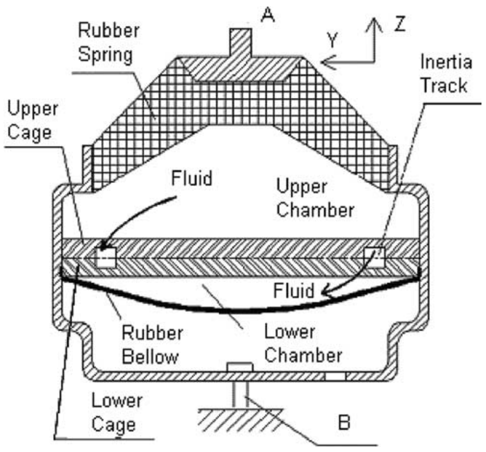

Fig. 1. Configuration of an HEM with one inertia track.