

Hydraulic Engine Mount - In Automotive Application

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Abstract: Hydraulic engine mounts are used in the automotive industries because they offer frequency and amplitude response. Such non-linear dynamic characteristics are examined by using analytical and experimental methods, both at the device level and within the context of a simplified vehicle model. A new lumped parameter non-linear mathematical model of the hydraulic mount is developed by simulating its decoupler switching mechanism and inertia track dynamics. The model is capable of capturing both the low- and high-frequency behaviour of hydraulic mounts. The two mounts considered here within differ by the means in which the decoupler is used to control the amplitude-dependent behavior of the hydraulic mount. Both of the mounts decoupler action introduces nonlinearities into the system; however, one mount illustrates parametric-type behavior.

Keywords: Hydraulic engine mount, decoupler, dynamic characteristics.

1. Introduction

The automobile engine–chassis–body system may undergo undesirable vibrations due to disturbances from the road and the engine. The vibrations induced by the road or the engine at idle are typically at the frequencies below 30 Hz. In order to control the idle shake and the road induced vibrations, the engine mount should be stiff and highly damped. On the other hand, for a small amplitude excitation over the higher frequency range (30–250 Hz) from the engine, a compliant and lightly damped mount is required for vibration isolation and acoustic comfort [1]. So, the engine mount must satisfy these two essential but conflicting criteria. This disparity between isolation characteristics and control characteristics has profoundly changed the way in which the automobile industry approaches mount design.

A conventional rubber mount cannot satisfy the conflicting requirements simultaneously as the lumped stiffness and the viscous damping are nearly invariant with excitation amplitudes and frequencies over the concerned excitation range (1–250 Hz). Consequently, at present, manufactures have increasingly used hydraulic engine mount (HEM), whose stiffness and damping characteristics can vary with excitation frequencies and amplitudes [1].

Hydraulic mounts have been used in the automotive industry since the mid-1980s as a means to provide an adaptive vibration isolation system to meet increasing customer demand for quieter and smoother riding vehicles [2]. More specifically, the hydraulic mount was introduced to provide a dual damping mode passive vibration isolator to control high-amplitude, low-frequency road-induced vibrations and low-amplitude, high-frequency engine-induced vibrations [3]. The hydraulic mount meets the requirements for a dual damping mode isolator by use of a device referred to as the decoupler in conjunction with a passage known as the inertia track.

2. Literature Review

Different kinds of engine mounting system, from elastomeric to hydraulic, and from passive to active, have been developed to improve the mount performance. Many recent studies have focused on studying and designing of hydraulic engine mounts. A comprehensive design and study on vibration isolating of engine and chassis has been established in an extensive range of amplitudes and frequencies by Haddow and Brach [10]. Adiguna *et al.* [11] in their latest research have focused on transient response of a typical hydraulic engine mount (HEM) in both analytical and experimental approaches leading to well-developed modelling of switching mechanism of decoupler. Geisberger *et al.* [3] experiments on a typical HEM show that in high frequencies the system has a strong nonlinear behaviour which is not predicted with the theoretical result. They have established the momentum equations for decoupler and inertia track fluids with one-orifice in both cases of excitations; high and low amplitudes. Therefore, it is not appropriate to apply their model for a simultaneous performance of components and both

orifices. They also have mentioned that the new theoretical model is not suitable to explain the high frequency behaviour (>250 Hz). The numerical analyses performed by Golnaraghi and Nakhai [12] shows that a simple nonlinear model clarifies the switching mechanism of the decoupler.

The nonlinear function of the decoupler is successfully modeled, examined, and applied by Golnaraghi and Jazar [8] utilizing a third-degree equation to describe a nonlinear damping. Adapting their model, Christopherson and Jazar [4] optimized a sprung mass suspended by an HEM and provided a design method.

3. A Typical Hydraulic Engine Mount

A typical HEM is illustrated in Fig. 1. At the top (A), the mount contacts the automobile engine, and at the bottom (B) it connects with car chassis. The HEM contains two rubber components (the rubber spring and rubber bellow), an upper

and a lower fluid chamber, an inertia track and a free decoupler. The fluid in the mount is usually water mixed with ethylene glycol. For low-frequency and large-amplitude excitations from the road or from the engine at idle, the rubber spring pumping action causes the free decoupler to reach the top or bottom constraint of the decoupler cage, and the fluid is forced to flow back and forth between two chambers mainly through the inertia track. Rubber bellows reduced vibrations, hold the parts together and allow movement due to ground settlement. Thus the HEM provide a large stiffness and damping at this time [1]. For high-frequency and small-amplitude excitation from the engine, fluid travels only around the decoupler, and causes the mount to behave as an elastomeric mount. So, in this simple passive isolation device, the stiffness and the damping are different for various excitation frequencies and amplitudes.

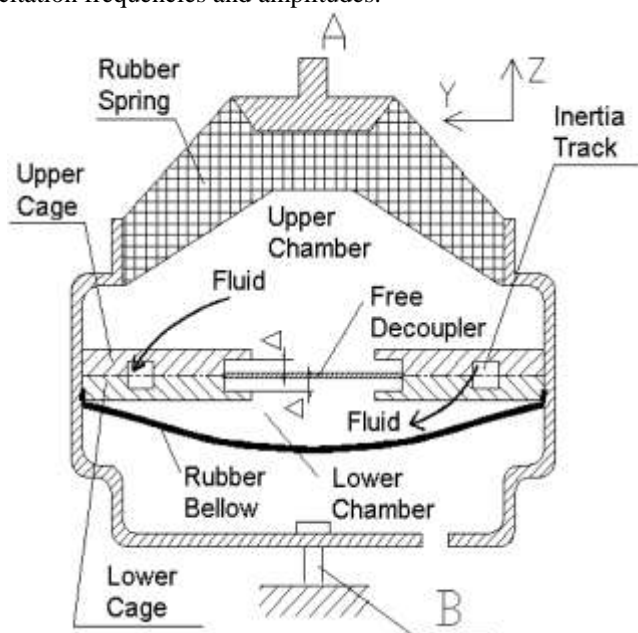
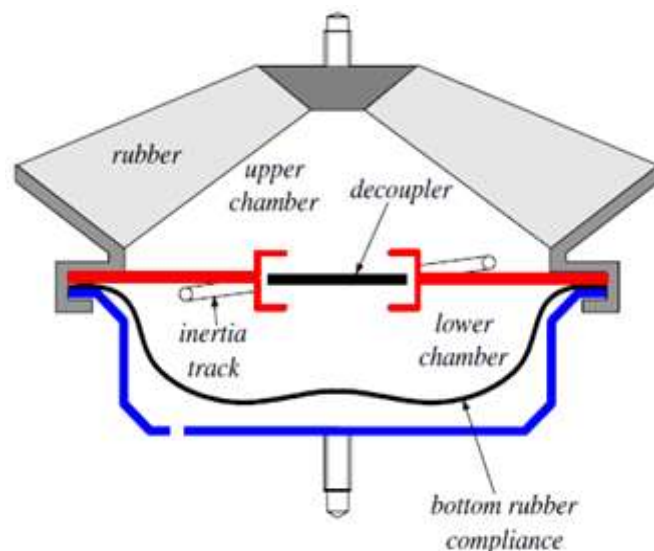


Fig.1. Cross-section of a HEM with a free decoupler and an inertia track [1]

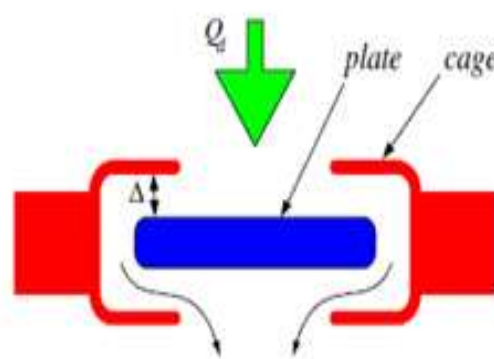
4. Floating-Decoupler-Type Hydraulic Mount

It is most commonly used form the hydraulic mount. It is as illustrated in Fig. 2, and consists of two fluid-filled chambers separated by a metallic plate containing the decoupler and inertia track. The **decoupler** is simply a disk that floats in the cage provided by the metallic plate, and acts as a mechanical switch to either allow fluid through or block fluid dependent upon the amplitude of excitation [4].

The inertia track is a long, small-diameter tube that runs circumferentially around the engine mount providing a very restrictive flow path between upper and lower chambers. Due to the restrictive nature of the inertia track, an increased viscous damping coefficient is realized for the system. This increased damping acts to reduce the acceleration transmissibility of the mount at low excitation frequencies. However, at increased excitation frequencies, the decoupler plate does not bottom out on the cage bounds. Instead it moves back and forth freely providing a relatively low flow restriction. Because the decoupler provides a low restriction to fluid flow, it becomes the preferred flow path, and acts on reducing the damping coefficient of the engine mount.



(a)



(b)

Fig. 2. Illustration of a floating-decoupler-type hydraulic mount [4]

If the decoupler is closed the fluid is forced to flow through the inertia track due to the relative motion of the system (motion of the engine and the motion of the vehicle structure), and when the fluid is forced through the inertia track the overall damping coefficient of the mount increases due to the highly restricted fluid motion through the channel. However, if the decoupler remains open the fluid motion between chambers is relatively unrestricted; therefore, the overall damping of the mount decreases. Hence, this design of engine mount relies upon determining the appropriate combination of inertia track size and decoupler gap size (see Fig. 2) to control the mount behavior.

5. Direct-Decoupler-Type Hydraulic Mount

It is an alternative to the aforementioned hydraulic mount. It is illustrated in Fig. 3 and fixes the decoupler directly to the engine side of the mount; therefore, the decoupler motion is controlled directly by the input excitation provided by the engine and vehicle structure. To accommodate the decoupler in this type mount an extra fluid chamber is introduced and it is from this chamber that the inertia track exits (see Fig. 3). This additional fluid chamber, labeled the middle chamber, provides a means by which to ensure activity of the inertia track, as opposed to relying on fluid pressure differentials to close the decoupler, to provide additional damping from the inertia track.

Therefore, the overall damping of this type of mount is less sensitive to decoupler gap size; however, the mount becomes increasingly dependent upon the inertia track geometry. This is not to say that the decoupler gap size and geometry are unimportant, quite the contrary; however, the inertia track is more prevalent as compared with the previous design. In addition, the decoupler does provide additional damping to the system when it approaches its cage bounds noting that as the decoupler moves it forces fluid out and around it (see Fig. 3); therefore, as the decoupler approaches the cage bounds the fluid resistance associated with it changes as a function of the decoupler position. This motion provides additional damping and increased nonlinearity to this type of mount [4].

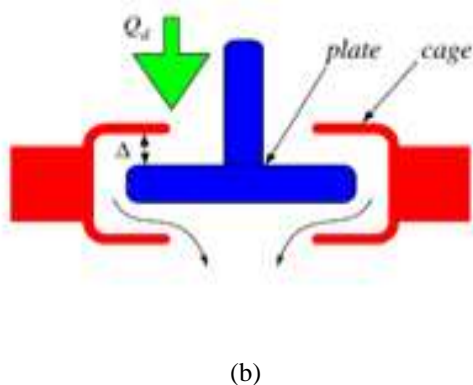
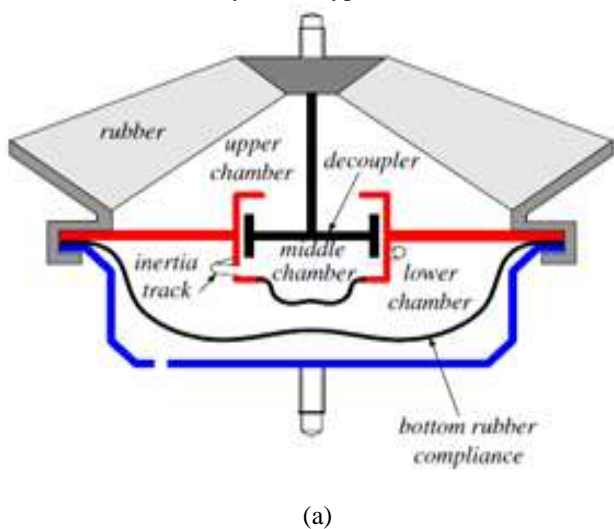
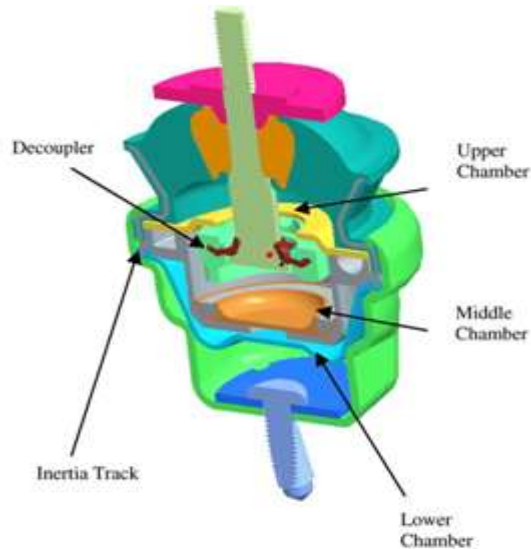


Fig.3. Illustration of a direct-decoupler-type hydraulic mount [4].

The standard method of controlling the amplitude-sensitive behavior is through the device of a mechanical switching device introduced as the floating-decoupler (see Fig. 2). An alternative method is to directly fix the decoupler to the input of the engine mount (see Fig. 3) thereby directly controlling the decoupler motion. Both of the aforementioned mounts are currently used in automotive applications and models of each mount may be seen in Figs. 4 and 5.



(a)



(b)



(c)

Fig.4. Direct-decoupler hydraulic mount[4]

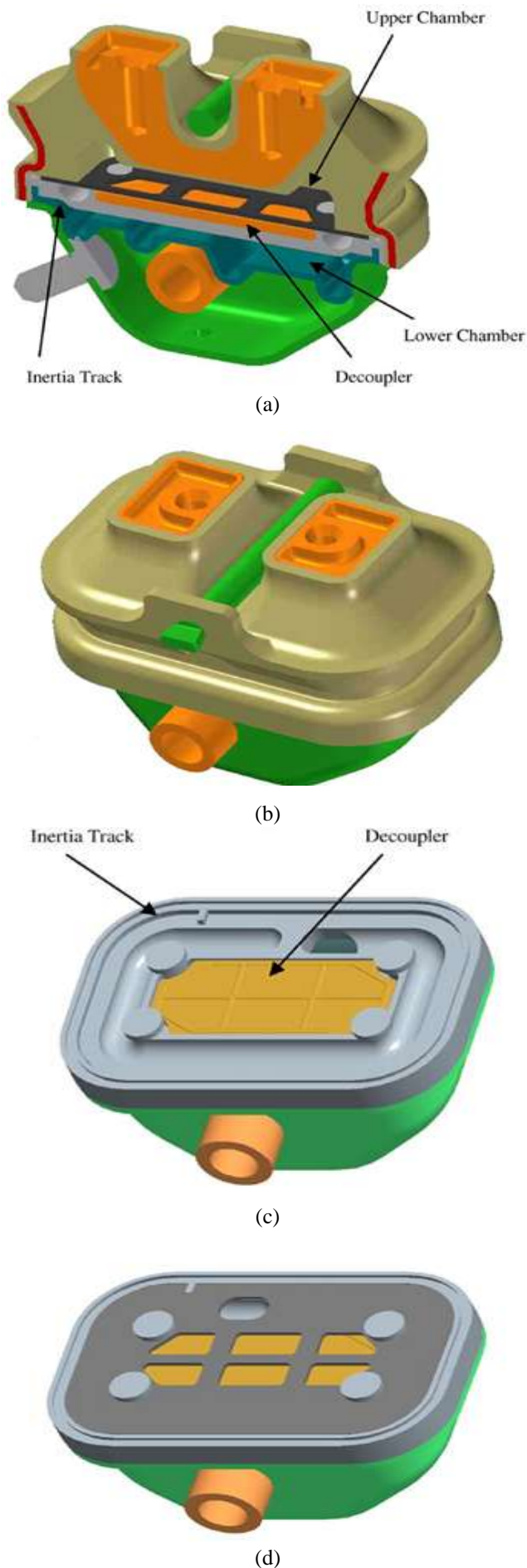


Fig.5. Floating-decoupler hydraulic mount[4].

This study has introduced a decoupler design motivated by the desire to improve upon the current floating-decoupler design. It compared to previously described floating-decoupler-type mounts with excellent agreement. The agreement between the two models indicated that by supporting the decoupler on thin, low-stiffness tabs, the overall steady-state response of the system is practically unaffected.

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Conclusion