Robust $H_{\infty}$ Controller in a MRF Engine Mount for Improving the Vehicle Ride Comfort

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In this paper, a robust controller is designed with the help of a Magnetorheological fluid (MRF) for a semi-active engine mount. To do so, an 8-DOF vehicle model is chosen in which the road roughness and engine vibration are the disturbance inputs to the system and the mass of the vehicle is taken into account as an uncertainty. In addition, the maximum magnitude and frequency of the force applied to the vehicle body by the actuators are limited in the ranges of 0~1500N and 0~10Hz, respectively. To validate such a design, the proposed controller is compared with a PID controller. The comparison results show that the proposed controller has a good performance while dealing with uncertainties such a way that using it leads to transmitting the engine vibration frequency less than 6%. It is also shown that the vibrations due to disturbances entering the system are effectively reduced in the system including the proposed controller.

1. INTRODUCTION

Recently, the use of Magnetorheological (MR) engine mounts for improving Noise, Vibration and Harshness (NVH) performance has been increasing due to their interesting properties. These properties result from the use of a smart Magnetorheological Fluid (MRF), which has the ability to respond quickly to the applied magnetic field in a range of frequencies. Engine idle vibrations and uneven road-induced vibrations are usually below 50 Hz. The frequency of the driving engine vibrations is usually between 50 and 200 Hz with its vibration magnitude being less than 3.0 mm.1 An engine mount is thus required to be designed in such a way that the mentioned vibrations are properly damped at both frequency ranges.2 The first evaluation of the MR engine mounts performance by replacing the hydraulic fluid within the engine mount with MR fluid is done. The MR fluid flows within the chambers of the engine mount and leads to reduced transmission of engine vibrations to the body through changing engine mount stiffness in the driving engine vibrations.3,4 By comparing the characteristics of an ideal engine mount with those of a typical elastomeric engine mount and smart engine mounts containing MR fluid, Sarkar et al.5 found that the mentioned smart engine mounts and ideal engine mount have a similar performance. In references,6–8 increasing the MRF stiffness through the enhancement intensity of the magnetic field applied to the fluid reduces the transmission of engine vibrations to the vehicle body. However, the mentioned references have been only characterized the mount properties without using any controller. An engine mount has been designed based on the flow mode in references.9 As described in which, the dimensions of an engine mount are specified by determining the damping force and yield stress of the LORD Corporation’s Magnetorheological Fluid (MRF 132 LD) for obtaining an optimal vibration isolation. However, such a structure has not been used for any car application.

Since the reduction of the road roughness impact is important for improving vehicle ride comfort, it must also be modeled and considered in the controller design. In order to improve the vehicle, ride comfort, a random road profile used for the design of MR damper in references.10,11 The stability of control systems is also an important issue. Since the major part of the instability is due to the existence of noises and uncertainties, an efficient technique must be required in the design approach to reduce the potential errors and disturbance effects. In references,12 several control strategies that use MNF are described. These strategies include Skyhook controller, PID controller, LQG, Sliding Mode controller and $H_{\infty}$ controller. The advantages and disadvantages of each method have been pointed out. It was finally shown that the $H_{\infty}$ controller has a good role in achieving stabilization with guaranteed performance of the system. In references,13–15 suspension systems in combination with an $H_{\infty}$ have been designed to improve vehicle performance. The control targets car body, travel, and suspension deflection are stabilized in a short amount of time in comparison with passive suspension. The sensitivity analysis has been shown that the active suspension system is able to work when sprung mass changes, which may occur when passengers are added. In references16 a robust Model Reference Adaptive Controller (robust MRAC) has been employed for an active engine mount. In which, the $H_{\infty}$ control scheme and an adaptive one (MRAC) are combined for controlling the mount. Simulation results show that robust MRAC is effective in reducing the transmitted force from the engine to the chassis. Such active mounts can provide good vibration isolation performance.17–20 However, they have some drawbacks such as structural complexity, high energy consumption, and high cost, which lead to restricting their using in the industry. For solving the problems due to the mentioned shortcomings of the active mounts, semi-active mounts that use MR fluids are presented.21–24 It was reported that such semi-active mounts have controllable damping properties by applying the magnetic