Mechatronics 21 (2011) 250–260

Contents lists available at ScienceDirect

Mechatronics

journal homepage: www.elsevier.com/locate/mechatronics

Vibration control for active seat suspension systems via dynamic output feedback with limited frequency characteristic

Weichao Sun, Jinfu Li, Ye Zhao, Huijun Gao *

Space Control and Inertial Technology Research Center, Harbin Institute of Technology, Harbin, China

ARTICLE INFO

Article history:
Received 11 June 2010
Accepted 2 November 2010
Available online 30 November 2010

Keywords:
Active seat suspension systems
Dynamic output feedback
Finite frequency
H_∞ control

ABSTRACT

This paper investigates the problem of H_∞ control for active seat suspension systems via dynamic output feedback control. A vertical vibration model of human body is introduced in order to make the modeling of seat suspension systems more precise. Meantime, different from the existing H_∞ control methods which conduct disturbance attenuation within the entire frequency domain, this paper addresses the problem of H_∞ control for active seat suspension systems in finite frequency domain to match the characteristics of the human body. By using the generalized Kalman–Yakubovich–Popov (KYP) lemma, the H_∞ norm from the disturbance to the controlled output is decreased over the chosen frequency band between which the human body is extremely sensitive to the vibration, to improve the ride comfort. Considering a practical situation of active seat suspension systems, a dynamic output feedback controller of order equal to the plant is designed, where an effective multiplier expansion is used to convert the controller design to a convex optimization problem. Compared with the entire frequency approach for active seat suspension systems, the finite frequency approach achieves better disturbance attenuation for the concerned frequency range, while the performance constraint is guaranteed in the controller design, which is verified by a practical example with certain and random road disturbances.

1. Introduction

Ride vibrations associated with a prolonged seating are the main risk factors for lumbago or backache, which seriously affect the mental and physical health of drivers or passengers and reduce their working efficiency. Thus, improving ride comfort which has developed as an applied science, is urgent. The first requirement to increase ride comfort is to attenuate the vibration transmission from the chassis to the driver. To achieve this goal, the vehicle seat suspension system plays an important role.

Between the human body and the automotive cabin, seat suspensions are not only to support the human body but also to isolate vibrations caused by rough road. Therefore, good seat suspension systems can significantly enhance ride comfort, which makes the seat suspension control become a hot topic. Recently, combining active vibration control mechanism with advanced control algorithms to design and analyze suspension systems has been a popular and effective way, and attracted considerable attention [1,2,6,8,14,18,25]. The core idea is to use active control method in suspension systems to reduce the impact of disturbance. This leads to the so-called active seat suspension system.

Most of the early studies for active seat suspension systems mainly confined their scope to vibration control of a rigid dummy mass on the seat. Without biodynamics included, it is clearly not precise enough to regard the complicated human body as a rigid mass for the individual difference. Various biomechanical models have been developed to describe the human motion, from 1 degree-of-freedom (DOF) to 15 DOF. These models can be grouped as lumped parameter models which consider the human body as several rigid bodies, springs and dampers.

Development of an active seat suspension system should be accompanied by the methodologies to control it, so that the design specifications can be satisfied. In general, the design specifications include two aspects for the active seat suspension system. The first one is ride comfort, which refers to isolating passengers from vibration and shock caused by road roughness. The second one can be seen as a constraint, limited suspension stroke, which means to keep suspension displacement within an allowable range. These two requirements are conflicting, for example, enhancing ride comfort results in larger suspension stroke, while an excessive suspension bottoming can lead to a considerable deterioration of ride comfort. Hence, extensive literature focuses on the choice of control methodologies to manage the trade-off between the two performance requirements, based on various control strategies, such as linear quadratic Gauss (LQG) [22,26], H_∞ control, [9,10] and adaptive control [4,13,19]. Among the proposed methods, the H_∞ active

* Corresponding author.
E-mail addresses: 1984sunweichao@gmail.com (W. Sun), lifking2009@gmail.com (J. Li), zhaoye8810@gmail.com (Y. Zhao), hjgao@hit.edu.cn (H. Gao).

0957-4158/$ - see front matter © 2010 Elsevier Ltd. All rights reserved.
doi:10.1016/j.mechatronics.2010.11.001