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Active damping of torsional vibration on the powertrain of power-split vehicle

Xun Zhang[a], Hui Liu[a,b,c*],Chen yinqi[a]

[a]School of Mechanical Engineering, Beijing Institute of Technology, Beijing 100081,China
[b]National Key Lab of Vehicular Transmission, Beijing 100081,China
[c]Collaborate Innovation center of Electric Vehicle of Beijing，Beijing 100081,China

Abstract

In this paper, a Linear-Quadratic-Gaussian (LQG) controller with estimator has been implemented for the suppression of torsional vibration on the powertrain of a power-split vehicle caused by an abrupt acceleration. Two motor/generators in the transmission are applied to improve the drive comfort and guarantee the dynamic response. An equivalent model of planetary gear has been put forward to simplify the transmission. The simulation results show that the LQG controller suppresses the vibration effectively

Keywords: *Active control; torional vibration; power-split vehicle; LQG controller*

1. Introduction

Electro-mechanical transmission (EMT) is a power-split transmission which can change speed ratio continually by several sets of planetary gears. It is composed of an engine, two motor/generators and several sets of planetary gears. This kind of transmission can be driven in electrical mode and mechanical mode. It has good dynamic characteristic and fuel economy. Since powertrain is naturally a low damped oscillatory system, an abrupt accelerate or other disturbance will cause the driveline oscillation which will reduce the drive comfort. At the same time, oscillation in the driveline will damage the component and reduce the lifetime. It is necessary to damp the torsional vibration in the transmission.

Several control strategies have been proposed to suppress the vibration of the transmission. Some papers focus on traditional vehicles, and use engine as the actuator. In [1] an extended RQV controller was used to control the engine torque to suppress the vibration on the transmission of traditional vehicles.

* Corresponding author. Tel.: +86-13701074363
E-mail address: lh@bit.edu.cn

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In [2], LQR torque compensator is applied for driveline oscillation damping. In [3] a MPC strategy is proposed to improve driving comfort. In [4] a feedback compensator was used on an electric vehicle to suppress the vibration of the driveline. However, few papers are found about the vibration suppression on parallel serial hybrid vehicle. This paper proposes a LQG controller to damp the vibration on power-split vehicle using the motor/generator as the actuator.

2. Driveline Modeling

Power-split transmission is composed of several planetary gears. Engine, motor/generator and load are connected to the four ports of the transmission. Fig.1. is the architecture of a power-split vehicle and the vehicle parameters are shown in Table 1. It is assumed that the driveline main flexibility is in the drive shaft and torsion damper. The elasticity and backlash of gears are neglected.

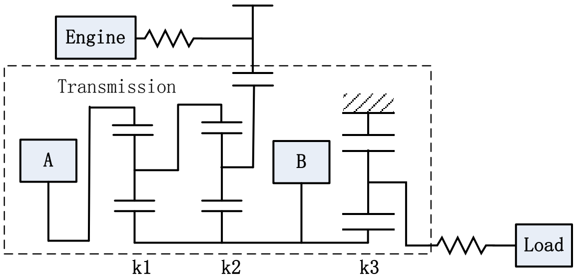

Fig. 1. Architecture of power-split vehicle

The transmission of power-split vehicles, which is different from that of traditional vehicles and electrical vehicles, has two degree of freedom. In order to obtain better efficiency, the engine can be operated on the optimal operating line. Because of the kinematic constrains determined by the connection of the planetary gears, the speed of motor and generator are determined by the speed of input and output according to

$$\omega_A = \alpha_{11}\omega_i + \alpha_{12}\omega_o \tag{1}$$

$$\omega_B = \alpha_{21}\omega_i + \alpha_{22}\omega_o \tag{2}$$

where $\alpha_{11}, \alpha_{12}, \alpha_{21}, \alpha_{22}$ are constant coefficients determined by the connection of the planetary gears.

According to Lagrange equation, the dynamic equation is obtained as

$$J_{ii}\ddot{\theta}_i + J_{io}\ddot{\theta}_o = -\beta_{ai}T_a + \beta_{bi}T_b + T_i \tag{3}$$

$$J_{oi}\ddot{\theta}_i + J_{oo}\ddot{\theta}_o = -\beta_{ao}T_a + \beta_{bo}T_b - T_o \tag{4}$$

where T_A is the torque of motor A, T_B is the torque of motor B.

From equations (3)~(4), the dynamic equation of input port and output port can be represented as

$$J_i^*\ddot{\theta}_i = T_i + \gamma_{ai}T_a + \gamma_{bi}T_b + \gamma_{oi}T_o \tag{5}$$

$$J_o^*\ddot{\theta}_o = \gamma_{io}T_i + \gamma_{ao}T_a + \gamma_{bo}T_b + T_o \tag{6}$$

where J_i^*, J_o^* are equivalent rotational inertia of input port and output port. $\gamma_{11}, \gamma_{12}, \gamma_{21}, \gamma_{22}$ are constant coefficients determined by the connection of the planetary gears and rotational inertia of each gear in the transmission.