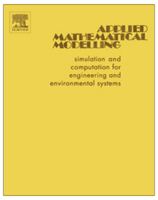
Applied Mathematical Modelling 39 (2015) 6471–6490

Contents lists available at ScienceDirect

Applied Mathematical Modelling

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



Driveline oscillation control by using a dry clutch system

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A R T I C L E   I N F O

Article history:
Received 7 March 2014
Received in revised form 19 December 2014
Accepted 19 January 2015
Available online 18 February 2015

Keywords:
Shuffle
Shunt
Driveline vibration
Dry clutch
Friction model

A B S T R A C T

The reduction of vehicle driveline vibrations such as shuffle and shunt by controlling a dry clutch system is studied in this paper. For this purpose a dynamic model for the driveline of a typical passenger car including backlash, clutch friction model and tire slip is developed. A linear controller is designed for the clutch control and damping of driveline vibrations. The results of this research show that by using a dry clutch system, vehicle longitudinal vibrations can be controlled effectively. Moreover, this method does not have the disadvantages of other solutions including deteriorating air pollution and vehicle performance. In addition it involves low costs especially in cars with automated manual transmission system (AMT).

1. Introduction

Drivability comprises a series of factors related to the driving comfort and depends on the feelings of a driver during driving and plays an important role in the commercial success of a vehicle. This factor mostly depends on the vehicle responses during the transient driving conditions, for example gear shifting, accelerating and braking. As the vehicle driveline incorporates elastic elements, it vibrates during transient conditions. These vibrations that are transferred to the vehicle body cause vehicle longitudinal vibrations and affects drivability and passenger comfort in a negative way. Major driveline vibrations occur during tip-in, tip-out and gear shifting. The driveline vibrations are categorized as shunt, shuffle, judder, rattle and clatter.

Shunt is the percent of the first overshoot and shuffle is the duration of vehicle longitudinal oscillations in the transient response as graphically demonstrated in Fig. 1. Shuffle occurs during sudden changes in the transferred torque from engine to the driveline because of the presence of the elastic elements and backlash in a driveline. These vibrations occur in the range of 1–10 Hz and coincide with human body resonance frequency range. For example, shoulder frequency is between 4–6 Hz, stomach frequency is between 4–8 Hz and upper body frequency is between 3–6 Hz [1]. Thus, controlling these longitudinal vibrations is important.

The reduction of the driveline vibrations has been an important research area approached by many researchers. Engine torque control during the transient conditions is a major concept for the driveline oscillation control. The control of spark advance of engine is one of the methods in which controller uses the engine torque dynamics to actively control the driveline vibrations. Berriri et al. [2], Fredriksson et al. [3], Lagerberg et al. [4] and Lefebvre et al. [5] are among several researchers who have used this method. Another solution method is controlling the engine air/fuel ratio. In this method, the engine output torque is controlled by adjusting the air/fuel mixture (Petterson et al. [6]). Third approach is the control of electronic gas

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http://dx.doi.org/10.1016/j.apm.2015.01.061

Nomenclatures:

Symbol	*Description*
A	frontal area
b	damping coefficient
B	damping
C_d	drag coefficient
c_s	driveline damping coefficient
f_{slip}	coulomb friction
f_{stick}	stiction friction
f_R	rolling resistance coefficient
f_v	viscous coefficient of damping
g	gravitational acceleration
F	force
F_a	aerodynamic force
F_r	rolling resistance force
F_t	traction force
F_z	tire normal load
I	Inertia
I_f	flywheel inertia
I_t	transmission inertia
I_w	tire inertia
k	stiffness coefficient
K	gain
K	stiffness
k_s	driveline stiffness
m	vehicle mass
n	overall gear ratio
N_c	desired clutch force
r_w	tire rolling radius
r_c	clutch equivalent radius
s	Laplace variable
S	slip
t	time
T_c	clutch torque
T_e	engine torque
v	velocity
V_{rel}	relative velocity
Greek letters	
α	backlash angle
β	road gradient
μ	friction coefficient
θ	rotation angle
ρ	air density
ω	angular velocity
ω_e	engine angular speed
ω_d	clutch angular speed

pedal used by Northcote [7]. It is shown that this method has attenuated sudden changes in transferred torque to the driveline and has controlled the vibrations.

Driveability enhancement in hybrid electric vehicles (HEVs) is achievable by means of electric motor control. Kou and Weslati [8] used a sliding mode control technique for attenuating vehicle shuffle. For the proposed control approach, reference states were computed for different transmission modes and the tracking errors were calculated using actual measured states. Also Syed et al. [9] presented the design of an active damping wheel-torque control system to improve the drivability of a power-split Ford Escape HEV.

Solution methods outlined above each has its own advantages and disadvantages. In the spark advance engine control method, altering the spark timing against the original combustion settings will in general impair the engine pollution. Also