2022-01-0613 Published 29 Mar 2022

Vehicle Surge Reduction Technology during Towing in Parallel HEV Pickup Truck

Shingo Okaya and Jun Kokaji Toyota Motor Corporation

Luis Quinteros Toyota Motor North America Inc.

Yoshio Hasegawa and Seiji Masunaga Toyota Motor Corporation

Citation: Okaya, S., Kokaji, J., Quinteros, L., Hasegawa, Y. et al., “Vehicle Surge Reduction Technology during Towing in Parallel HEV Pickup Truck,” SAE Technical Paper 2022-01-0613, 2022, doi:10.4271/2022-01-0613.

Received: 25 Jan 2022 Revised: 25 Jan 2022 Accepted: 21 Jan 2022

Abstract

This paper proposes a technology to reduce vehicle surge during towing that utilizes motors and shifting to help ensure comfort in a parallel HEV pickup truck. Hybridization is one way to reduce fuel consumption and help realize carbon neutrality. Parallel HEVs have advantages in the towing, hauling, and high-load operations often carried out by pickup trucks, compared to other HEV systems. Since the engine, motor, torque converter, and transmission are connected in series in a parallel HEV, vehicle surge may occur when the lockup clutch is engaged to enhance fuel efficiency, similar to conventional powertrains. Vehicle surge is a low-frequency vibration phenomenon. In general, the source is torque fluctuation caused by the engine and tires, with amplification provided by first-order torsional driveline resonance, power plant resonance, suspension resonance, and cabin resonance. This vibration is amplified more during towing. Therefore, this paper proposes two surge reduction technologies to help achieve fuel efficiency and surge at the same time during towing. One technology is a gear shift control that avoids engine operating zones where two or more resonance frequencies coincide, which is realized by changing the equivalent inertia via appropriate gear selection. The second technology is an anti-vibration control, which makes effective use of the hybrid system motors by adding motor torque to suppress the relative displacement between the driveline and the tires.

1. Introduction

The reduction of automotive CO_2 emissions is an important part of measures for achieving carbon neutrality. For this reason, automakers have been applying hybridization technologies to pick-up trucks, which have a high market share in North America. Since pickup trucks are required to operate under heavy loads such as towing and hauling, a parallel HEV configuration is often adopted rather than a series parallel HEV. (Fig. 1) In a parallel HEV powertrain, the engine, motor, torque converter, and transmission are connected in series. The torque converter contains a lockup clutch that is engaged under certain driving conditions to contribute to fuel efficiency [1]. This paper focuses on a vibration phenomenon called vehicle surge [2, 3], in which vibration is amplified when the lockup clutch is engaged. (Fig. 2) Vehicle surge (hereinafter referred to simply as surge) is a low-frequency vibration phenomenon that occurs when torque fluctuations of the engine and tires (the sources) are amplified [4] by torsional driveline resonance, power plant resonance, suspension resonance, and cabin resonance. During towing, which is a frequent usage scenario in the North American market, the vehicle surge may increase more than expected due to the increase in engine torque.

This paper clarifies the mechanism behind this increase in surge in a body-on-frame vehicle during towing. Focusing on the frequency and peak level of the torsional driveline resonance, it was found that target performance for fuel efficiency and surge can be achieved at the same time by applying gear shift control and anti-vibration control using the Motor Generator (MG).

2. Mechanism of Surge

This section describes the surge phenomenon that occurs in body-on-frame vehicles and the mechanism by which it increases during towing.

2.1. Surge in Body-on-Frame Vehicles

Surge in a body-on-frame vehicle is a vibration phenomenon in the longitudinal direction of the vehicle that occurs especially at wide-open throttle (WOT) and other high engine torque regions when accelerating at a constant rate (Fig. 3).

FIGURE 22 Vehicle surge reduction effect by measures.

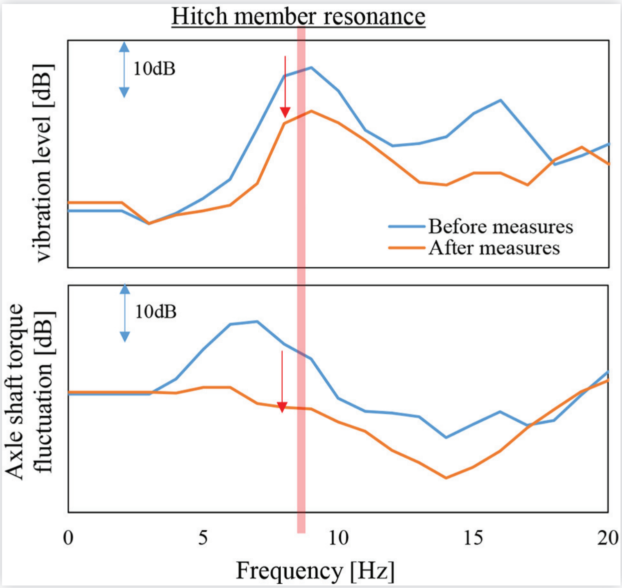


FIGURE 23 Vehicle surge reduction effect by measures.

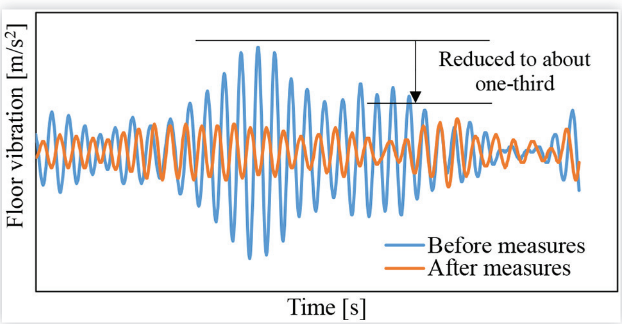


FIGURE 24 Vehicle surge reduction effect by measures.

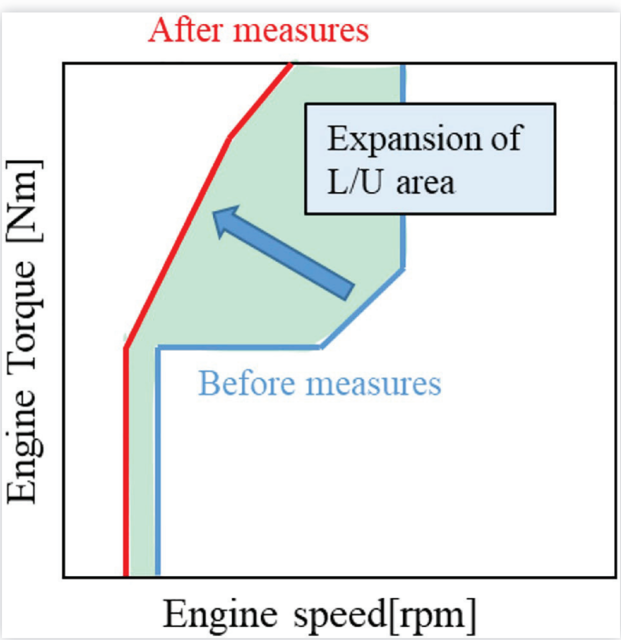
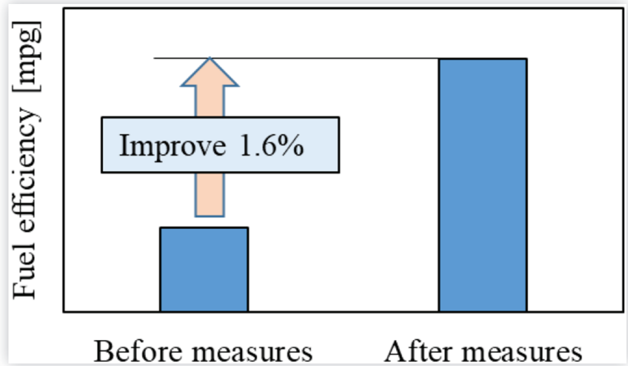


FIGURE 25 Vehicle surge reduction effect by measures.



5. Summary/Conclusions

This paper examined the interaction of fuel efficiency and surge during towing of a parallel HEV pickup truck. As a result, we obtained the amplification mechanism of surge during towing and the reduction technology as follows.

1. Surge during towing is amplified not only by the increase in engine torque but also by the occurrence of a new resonance in which the vehicle and trailer are masses and the hitch member is a spring.
2. During high torque usage, downshifting lowers the peak frequency of the first-order torsional driveline resonance. This moves the first-order driveline resonance away from the hitch member resonance and reduces surge.
3. An MG Anti-vibration control that adds motor torque to suppress the relative displacement between the drive line and the tire was installed to reduce the peak level of driveline torsional fluctuation. Vehicle surge was reduced by canceling the torsional fluctuation by anti-vibration control.
4. Implemented the gear shift and anti-vibration controls in an actual vehicle and confirmed the effect. As a result, we were able to achieve the target level of both fuel efficiency and vehicle surge.

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Contact Information

shingo_okaya@mail.toyota.co.jp

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ISSN 0148-7191