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Mechanism Analysis and Counter Measure Study for Electrified Vehicles with Drive Line and Chassis Co-Simulation

Akiyoshi Tsuji [1)]　**Yuga Okada** [1)]　**Takao Sugai** [1)]

1) Toyota Motor Corporation
1 Toyota-Cho, Toyota City, Aichi Prefecture, 471-8572, Japan (E-mail: akiyoshi_tsuji@mail.toyota.co.jp).

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The vehicle electrification towards carbon neutrality is essential. In the development of electrified vehilces, we face unique issues which are not cared in the development of conventional vehicles only with ICE. As an example, this report introduces the phenomenon that the coupling vibration caused by the interaction of inertia and torsional stiffness of chassis, drive line and mounted powertrain including motor generator affects the vehicle ride quality. The co-simulation representing this behavior across systems is utilized to study counter measures.

Fig. 1 shows the co-simulation environment which is built to represent the vehicle behavior and phenomena on a computer. This environment has four subsystems. In order to synchronize the data exchange cycle across these subsystems, the four subsystems are arranged on one co-simulation platform. The test pattern of transient calculation is explained. The driving force is applied from the initial speed of 0 [km/h], and after reaching the target vehicle speed of 20 [km/h], the driving force is removed and the vehicle transitions to coasting. In this condition, the coefficient of friction μ between the tires and the road surface is changed from 1.0 to 0.3 and the braking force is applied to the front and rear wheels travelling on the slippery road surface, and the simulation is performed until the vehicle stops. Then, the frequencies calculated by FFT analysis are evaluated both for the vehicle vibrations generated before and after braking force application.

The torsional vibration during deceleration in this condition causes vibrational phenomenon where the tire exceeds the friction limit. It is found that this vibration is generated by the dynamic reaction between the two torsional inertia of the motor and the tire wheel shown in Fig. 2. Then, it can be seen that the driveshaft between the motor and the tire wheel is twisted, and the direction of the driveshaft torque changes periodically. Therefore, the driveshaft torque works in the same way in some condition as the braking torque. If the driveshft torque increases in the same direction as the braking torque during repetitive ABS depressurization, the locking tendency will progress, mismatching the expected slip rate by ABS. The example of that countermeasure is shown in Fig. 3, which decreases the driveshaft torsional vibration by the feedback control of the proportional control gain configuration shown in Eq. (1). In conclusion, (1) the guideline is shown to study measures to reduce the vibration focusing on the driveshaft torque behavior during ABS operation. (2) A concrete effect estimated from simulation when this countermeasure is applied (see Fig. 4) is shown.

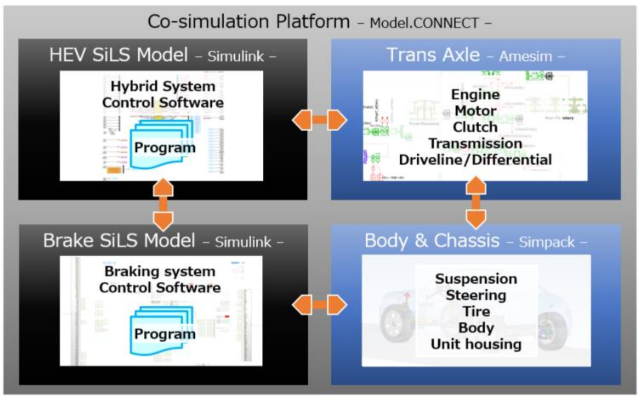

Fig.1 Co-Simulation Environment.

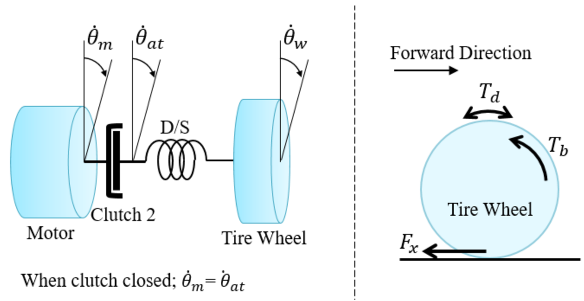

Fig.2 Resonance Reduction Model.

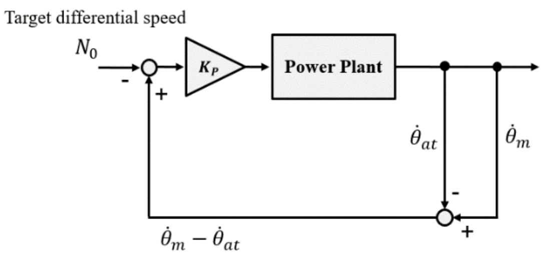

Fig.3 Clutch 2 Difference Rotation Control.

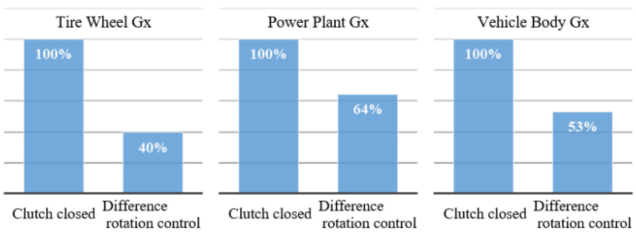

Fig.4 Simulation of Acceleration Ratio.

$$T_m = K_P\{(\dot{\theta}_m - \dot{\theta}_{at}) - N_0\} \tag{1}$$

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