

Estimation of Grip Margin and Road μ focusing on Motor Drive System Vibration

Eiichi Ono¹⁾ Norio Yonezawa²⁾ Tadakatsu Koyabu³⁾

1) Toyota Central R&D Labs., Inc., Personalized Mobility Research-Domain,
41-1 Yokomichi, Nagakute, Aichi, 480-1192, Japan (E-mail: e-ono@mosk.tytlabs.co.jp)

2) Toyota Central R&D Labs., Inc., Personalized Mobility Research-Domain,

3) Denso Corporation, Electric Powertrain Systems Advanced Development Div.,
2-1, Nagane, Sato-cho, Anjo, Aichi, 446-8511, Japan

KEY WORDS: Vehicle dynamics, Tire/wheel, Road environment recognition, SDV, Motor drive system [B1]

The resonance phenomenon observed in wheel speed varies depending on the road surface friction condition. By utilizing this characteristic, it becomes possible to estimate the grip margin and the road surface friction coefficient (μ). In this paper, we propose an estimation method that makes use of the driveshaft resonance phenomenon in motor-driven vehicles shown in Fig.1.

The transfer function from motor torque T_D to drive shaft torsional velocity $\omega_D - \omega$ is described by the following equations.

$$\omega_D - \omega = G(s) \cdot T_D$$

$$G(s) = \frac{c_1 \cdot s^2 + K_S \cdot c_{0k} \cdot s}{s^3 + (d_2 + d_{2k} \cdot K_S) \cdot s^2 + (d_1 + d_{1k} \cdot K_S) \cdot s + d_{0k} \cdot K_S}$$

Coefficients of the transfer function $G(s)$ are described by linear function of μ slope K_S . Then, μ slope K_S can be estimated by using input signal T_D and output signal $\omega_D - \omega$.

The grip margin ε defined by

$$\varepsilon = 1 - \frac{F}{\mu F_z}$$

can be described using a μ slope K_S as

$$\varepsilon = \left(\frac{K_S}{K_{S0}} \right)^{3/2},$$

where, F is tire horizontal force, F_z is tire vertical force and K_{S0} is driving stiffness. Furthermore, road μ can be described as

$$\mu = \frac{F}{F_z} \cdot \frac{1}{1 - \varepsilon}.$$

Fig.2 shows experimental results on dry asphalt road and ice road. μ slope K_S , grip margin ε and road μ can be estimated by using the experimental data. Tabel 1 shows estimation results. The results demonstrate the performance of the proposed method, and cloud utilization by multiple vehicles is expected.

Table 1 Estimation results

Road Condition	$\frac{K_S}{K_{S0}}$	Grip margin ε	Friction coefficient μ
Dry asphalt	0.91 (0.73-1.0)	0.91 (0.62-1.0)	1.08 (0.26-1.2)
Ice	0.34 (0.21-0.78)	0.19 (0.10-0.69)	0.12 (0.11-0.32)

(Variation range)

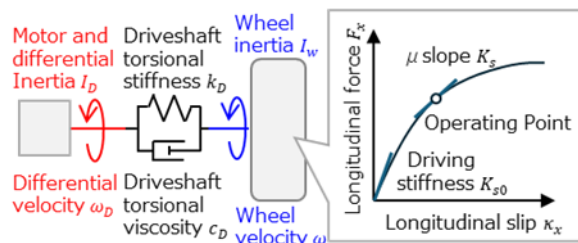
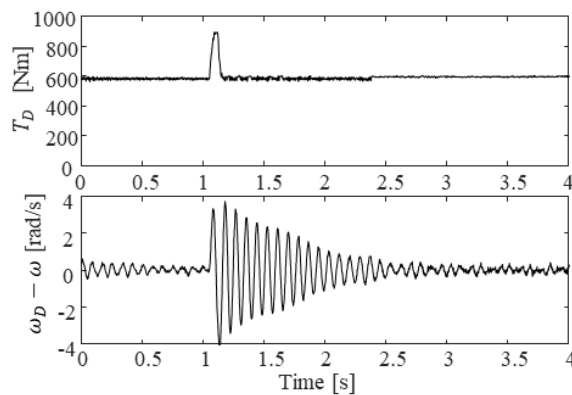
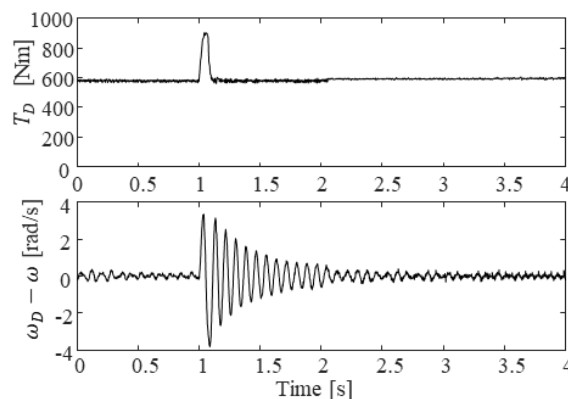


Fig.1 Tire and Driving System



(1) Dry asphalt



(2) Ice

Fig.2 Experimental results