講演番号	002

Analysis of Handling Stability under Combined Steering and Road Irregularity Inputs (Second Report)

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KEY WORDS:**Vehicle Dynamics, Suspension System, driving stability,** Friction (B1)

Most studies of handling stability have been conducted on flat roads without surface irregularities, whereas ride comfort has primarily been investigated during straight-line driving without steering input. In this study, handling stability is examined under combined steering and road-surface irregularity inputs.

In the first report, a 5-DoF vehicle model was developed, and average vehicle response gains were calculated while considering three levels of road input, ranging from smooth to rough asphalt. This enabled the analysis of average steering response characteristics under combined steering and road irregularity inputs that closely represent real driving conditions. Furthermore, by incorporating suspension friction, its influence on planar motion was analysed through roll-angle characteristics and roll steer.

In the present paper, the effects of rear-wheel initial alignment caused by front–rear differences in suspension friction are investigated. In addition to friction, the velocity-dependent characteristics of shock-absorber damping force are considered as a nonlinear element of the suspension vertical force, and the variation of average steering response characteristics with the magnitude of road irregularity input is analysed.

Linear analysis that neglects friction and road irregularities shows that increasing the equivalent rear-wheel cornering power (CP) advances the lateral-force phase and improves yaw damping. However, as shown in Fig. 1, the first-order lead time constant of the lateral force generated by rear-wheel initial alignment is influenced by the rear-wheel roll damping ratio (P_r) and roll stiffness ratio (R_r). Furthermore, when $P_r/R_r < 1$, the time constant becomes negative in value above a certain vehicle speed, resulting in reduced yaw damping compared with lateral understeer.

When suspension friction and road irregularities are considered on a smooth road (Fig. 2), the friction force acts as a damping element equivalent to the damper. Consequently, the rear friction distribution (λ_r) affects the rear roll damping distribution (P_r). As a result, reducing λ_r decreases the equivalent CP (C_r) (normalised notation) and the equivalent lateral stiffness (k_{yr}) near the yaw-resonance frequency, leading to lower yaw-damping performance than that of lateral understeer.

As shown in Fig. 3, the damper exhibits a characteristic in which the damping coefficient decreases at stroke speeds above approximately 0.1 m/s. When driving on a rough asphalt road (Fig. 4), the RMS value of suspension velocity exceeds 0.2 m/s; consequently, the damping coefficients in the low-speed linear region (c_f, c_r) decrease by approximately 44%. This change affects roll-angle characteristics near the yaw-resonance frequency and, through roll steer, influences the yaw-rate gain.

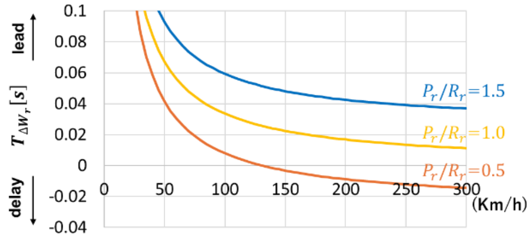

Fig.1 Comparison of time constants for Lateral Forces

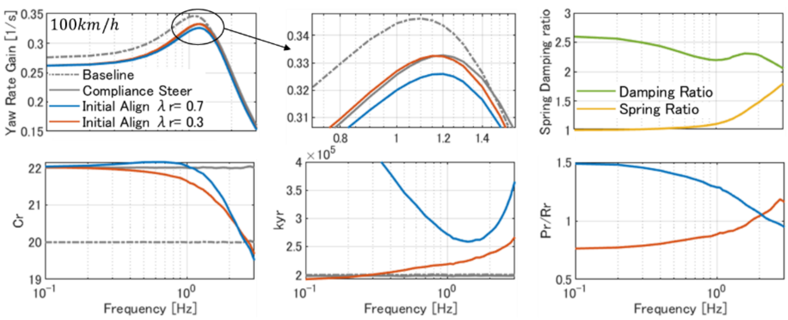

Fig.2 Frequency Response at Smooth Road with Suspension Friction

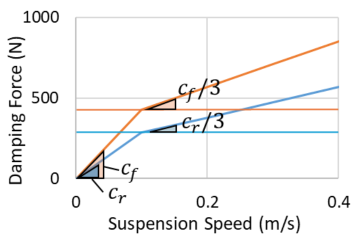

Fig.3 Damping Force Velocity Dependence

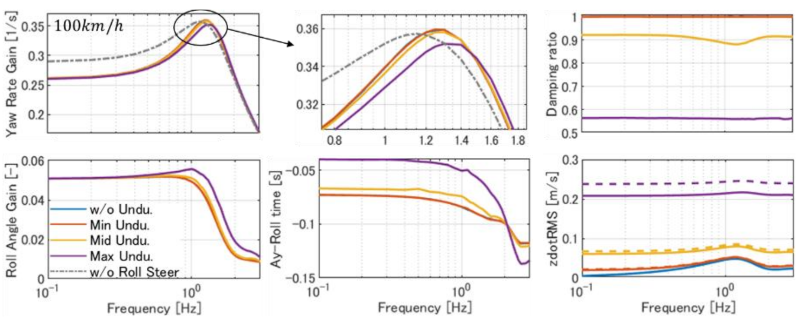

Fig.4 Frequency Response at Rough Road with Damping Force Velocity Dependence

2026 JSAE Annual Congress (Spring) - Summarized Paper

Issued on May 22, 2026