講演番号	222

文献番号	20225222

Description of Vibration Phenomena in Steering Response by Energy Transmissibility

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KEY WORDS: **Vibration, Noise, Ride quality,** Vehicle body running vibration, Statistical energy analysys [B3]

Yaw and roll motions, which are steering responses, are coupled and vibration phenomena. Meanwhile, the authors are utilizing statistical energy analysis methods to predict and address vibration problems. This method has a Coupling Loss Factor, which describes the degree of energy transmissibility. In this study, the equations for the energy transmissibility of a two-degree-of-freedom vibration system are applied to yaw and roll motions. The energy transmissibility between yaw and roll are used to describe steering characteristics and the effects of roll stiffness and roll damping on steering response. This study deals with the vehicle model shown in Fig.1, which simply represents yaw and roll motions. Chapter 2 describes the equations of motion for this model. Chapter 3 describes the derivation of evaluation formulas for energy transmissibility in two-degree-of-freedom vibration systems and examples of their use.

Chapter 4 outlines the application of energy transmissibility and steering characteristics to yaw and roll motions. The energy transmissibility between yaw and roll obtained by applying the system are given by Equation (1). The uncoupled natural angular frequencies ω_r and $\omega_\emptyset$ of yaw and roll, the damping properties Δ_r and Δ_ϕ, and the coupling parameter $\kappa_{r\phi}$ are used. These parameters are derived from the yaw and roll equations of motion as the following equations (2) to (6), respectively. For steering characteristics, neutral steer, understeer and oversteer that take into account the strength and weakness of the steering are studied, respectively. In the case of neutral steer, yaw and roll are not coupled because the energy transmissibility are zero. In understeer and oversteer, the magnitude of the energy transmissibility is also proportional to the strength of the steering characteristics. The peak of the energy transmissibility occurs at the vehicle speed common to all characteristics, which is caused by the zero sideslip angle when the vehicle turns and the uncoupled natural angular frequencies of yaw and roll are when they coincide. In addition, the energy transmissibility is discontinuous in the oversteer characteristic. This speed is consistent with the stability limit speed. The reason for the match is that the condition for a negative value in the root sign of equation (2), which is the natural angular frequency of yaw, is consistent with the stubility factor.

Chapter 5 describes the effects of roll stiffness and roll damping on the energy transmissibility between yaw and roll. Decreased roll stiffness increased the energy transmissibility between yaw and roll. This is due to the fact that the yaw energy does not stay in the vehicle but is more easily transferred due to the increased roll movement. Perhaps as a result, the overall roll angle response increased. The energy transmissibility between yaw and roll increased with decreasing roll damping. In addition, the convergence of the transient response portion of the roll angle has worsened, and the roll angle is now prone to free vibration. Increased energy transmissibility so that it now oscillates freely up to the response of yaw rate.

$$\eta_{r\phi} = \frac{1}{\omega}\frac{{\kappa_{r\emptyset}}^2(\Delta_r + \Delta_\phi)}{(\omega_r^2 - \omega_\phi^2)^2 + (\Delta_r + \Delta_\phi)(\omega_r^2\Delta_\phi + \omega_\phi^2\Delta_r)} \quad (1)$$

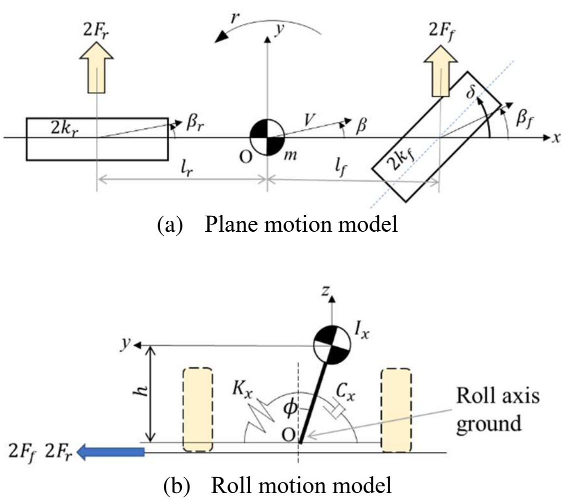
$$\omega_r = \sqrt{\frac{4k_f k_r (l_f + l_r)^2}{m I_z V^2} - \frac{2(l_f k_f - l_r k_r)}{I_z}} \quad (2)$$

$$\omega_\emptyset = \sqrt{\frac{K_x - m g h_x}{I_x}} \quad (3)$$

$$\Delta_r = \frac{2}{V I_z}(l_f^2 k_f + l_r^2 k_r) \quad (4)$$

$$\Delta_\phi = \frac{1}{I_x}\left\{C_x + \frac{2h^2}{V}(k_f + k_r)\right\} \quad (5)$$

$$\kappa_{r\phi} = \frac{2h}{V\sqrt{I_z I_x}}(l_f k_f - l_r k_r) \quad (6)$$



(a) Plane motion model

(b) Roll motion model

Fig.1 Vehicle model