Analysis of unsprung mass vibration of rigid suspension during vehicle starting

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It is necessary to consider the coupling between the power train system and suspension system for the unsprung mass vibration that occurs when the vehicle starts(Fig. 1, Fig. 2). In this study, we constructed a dynamic model that takes into account the stiffness and inertia of the power train system in the suspension and tire models(Fig. 3), and confirmed that the model reproduces the actual vibration phenomenon(Fig. 4). Furthermore, we clarified the conditions for instability based on the relationship between the suspension vertical resonance and the power train system resonance using 3DOF model. Fig. 5 shows that simplified 3DOF model can estimate self-excited vibration.

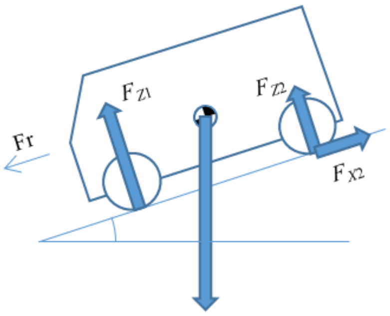


Fig.1 Longitudinal and Vertical Force during slope starting

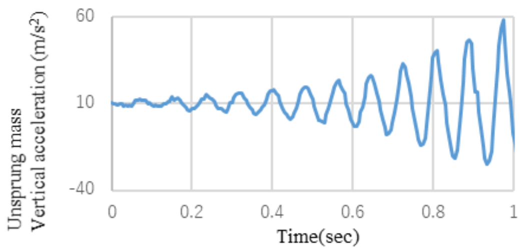
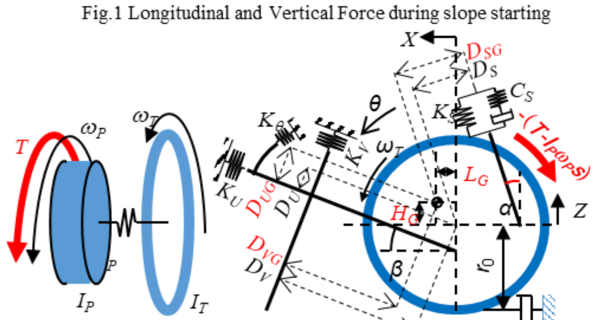


Fig.2 Unsprung mass Vertical acceleration during slope starting



I_P : inercia of power train
I_T : inercia of tire and wheel
I_C : inercia of unsprung mass (except for tire and wheel)
M_T : mass of tire and wheel
M_C : unsprung mass (except for tire and wheel)

Fig.3 Analysis Model (5DOF)

Consideration using simplified model (3DOF)
assuming $K_U = K_V = \infty$

P value

$$\lambda^2 \cong \frac{-({\omega_1}^2+{\omega_2}^2) \pm \sqrt{\boxed{({\omega_1}^2-{\omega_2}^2)^2 \pm \frac{4\mu K_Z K_P}{(M_C+M_T)I_T}\frac{r_0}{L}}}}{2}$$

where $\quad {\omega_1}^2 = \frac{K_A}{I_A} = (2\pi f_z)^2 \quad , \quad {\omega_2}^2 = \frac{K_P}{I_P} + \frac{K_P}{I_T} = (2\pi f_\omega)^2$

$$I_A = \left({D_V}^2 + {D_U}^2\right)(M_C+M_T) + I_C$$
$$K_A = L^2 K_Z + {D_A}^2 K_S$$
$$L = D_V \cos\beta + D_U \sin\beta$$
$$H = -D_V \sin\beta + D_U \cos\beta$$
$$D_A = L\cos\alpha + H\sin\alpha + D_S$$

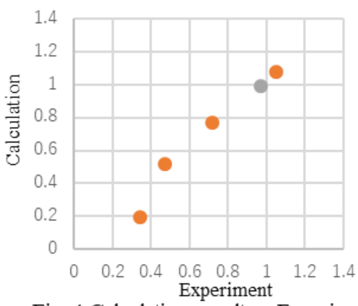


Fig. 4 Calculation result vs Experiment Result

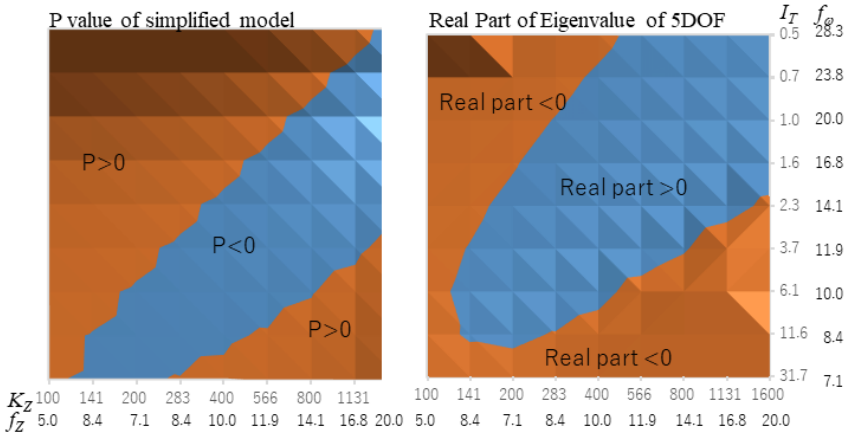


Fig.5 Comparison between simplified model and 5DOF model