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Reduction of Longitudinal Vibration by Side-View Arrangement of Suspension

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In recent years, as tires have become less flat, their grip has tended to improve, but there is a reverse reaction that increases longitudinal and lateral vibration input from unsprung. On the other hand, the demand for ride quality is increasing, and the importance of designing in consideration of these vibrations is increasing.

This study proposes a technique to reduce vehicle longitudinal vibration by combining a suspension model with elastic principal axes and a tire longitudinal force model. Furthermore, by considering the coupling with the suspension member and the differential gear, and by using the actual tire input characteristics measured in the drum projection test, it is shown that it is possible to reduce the vehicle longitudinal vibration at projection ride-over.

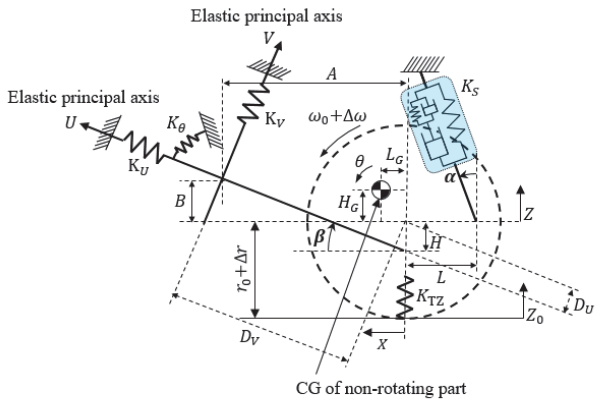

Fig. 1 Unsprung 3-DOF model

Figure 1 shows a model of unsprung motion. The unsprung is divided into a non-rotating part and a rotating part. Two orthogonal axes in the side−view plane, where the direction in which the force is applied and the displacement direction of the non-rotating part match, are defined as the elastic principal axis, and are shown as V and U. Based on this model, the equations for unsprung motion are organized, and the longitudinal excitation force is expressed as $F_X = F_{X0} - \tan\beta' K_X Z - \tan\alpha' K_S' Z$. The first term represents "longitudinal forces due to tires," the second term represents "longitudinal forces due to link reaction forces," and the third term represents "longitudinal forces due to the tilt of absorbers." By setting B/A and α', it is possible to design to reduce the longitudinal force of the tire and the longitudinal vibration of the vehicle.

Next, the case of projection ride-over input is discussed. In this case, longitudinal tire input above 30 Hz must also be considered. In this frequency range, it is necessary to consider the effects of the suspension member and the differential gear suspension system, so a 9-DOF under-spring model is considered by adding these elements. In addition, in order to reproduce the vibration phenomenon of the actual vehicle, the tire input is replaced by the frequency response characteristics obtained from the drum projection test.

In this model, due to the existence of the tire rotation resonance and the differential gear suspension resonance, an anti-resonance, i.e., a valley of amplitude due to the switching of vibration modes, appears at the frequency between them. By bringing this valley of amplitude closer to the tire rotation resonance, the longitudinal vibration can be reduced. Specifically, if the resonance frequency of the differential gear is raised by increasing the mount stiffness, the frequency of the anti-resonance is also raised, and the longitudinal vibration around the tire rotation resonance can be reduced.

The numerical simulation results were verified by actual driving tests on a multi-link rear suspension vehicle. As a representative example, Figure 2 shows the results in case of the projection ride-over. By using the tire dynamic characteristics during the drum projection ride-over test, it can be confirmed that the numerical simulation reproduced the vibration phenomena of the actual vehicle. In addition, by bringing the anti-resonance frequency of the differential gear close to the tire rotation resonance frequency, the longitudinal acceleration around the tire rotation resonance frequency could be reduced as expected.

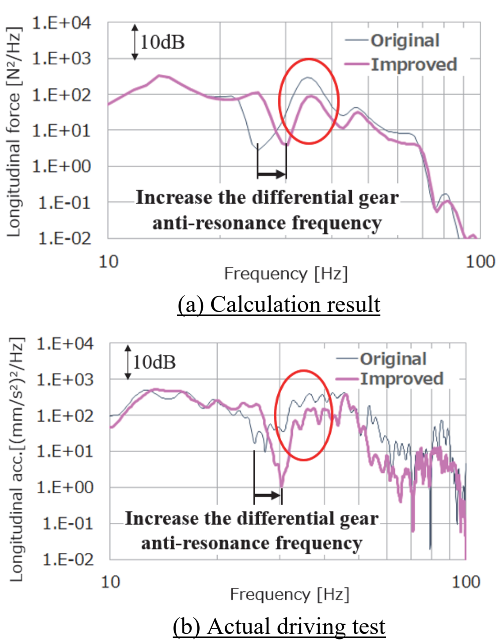

Fig. 2 Experimental verification at projection ride-over

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