A New Vertical Vibration Control System
– Development and Commercialization –

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In some track sections where current maintenance criteria are not so high, cars can exhibit rigid body vibration (bouncing/pitching vibration) in the vertical direction when they pass rail joints or run on tracks with large irregularities. As this motion is often detrimental to ride comfort, it is essential to decrease vertical car-body vibration in order to guarantee satisfactory ride comfort for passengers on board the cars running in such sections.

Active or semi-active suspension systems are effective in reducing car vibrations, but such suspension systems have not been employed for trains in service to reduce vibration in the vertical direction. However, RTRI has developed a secondary suspension vibration control system using vertical vertical hydraulic dampers and actually applied it to sightseeing limited express trains on narrow-gauge lines.

Figure 1 illustrates the vertical vibration control system of the secondary suspension. The car is equipped with four sets of variable damping vertical dampers arranged in parallel to the secondary suspension. Based on the information from the acceleration sensors installed at four places on the car-body, the control unit calculates the force to be generated by dampers to decrease vertical car-body vibration acceleration and transmits the information as a command current to the dampers.

Figure 2 shows a variable damping vertical damper. The installation length of the damper is the same as that of a conventional vertical damper to ensure easy replacement. Without requiring large-scale remodeling on cars, therefore, it is possible to introduce the new system by simply installing a control unit, acceleration sensors and newly developed dampers to replace the conventional ones.

Figure 3 represents the algorithm to control dampers. It applies the sky-hook control law separately to each of the vertical bounce, pitch and roll components, with the sky-hook gains adjusted based on running tests.

Figure 4 shows a photo of the control unit, equipped with functions to control the damping force of each damper and to monitor failures/abnormalities of dampers, sensors and the system as a whole.

Figure 5 graphically represents the car-body vertical vibration acceleration Power Spectral Density (PSD) in the sections where vertical rigid body mode vibration is particularly conspicuous, as measured in the running tests on a local line. A peak of acceleration PSD due to rigid body mode vibration is observed at approximately 1.7 Hz. When dampers were controlled, vibration in the frequency band of 1 to 2 Hz decreased, with the PSD peak at 1.7 Hz decreased by 80%.

As a result, the L_T value, a ride comfort evaluation index generally used in Japan, dropped approximately by 4 dB. For reference, smaller L_T values indicate better ride comfort. It is generally accepted that passengers feel a difference in ride comfort, when the L_T value changes by 3 to 5 dB.

The developed system has been incorporated into JR Kyushu's sightseeing limited express trains in revenue service, " Ibusuki no Tamatebako" (seen in Fig.6) and "Hayato no kaze".

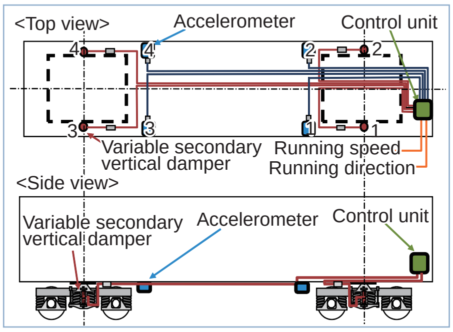

Fig. 1 Composition of the vertical vibration control system

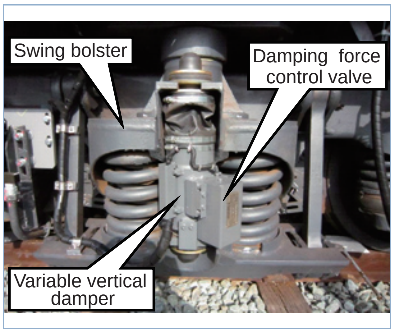

Fig. 2 A variable damping vertical damper

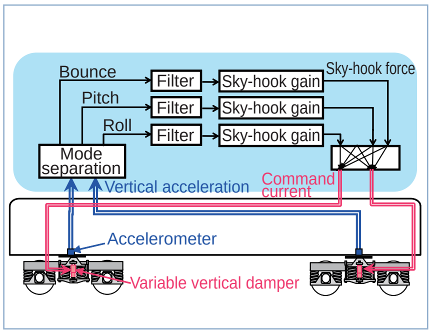

Fig. 3 Control algorithm

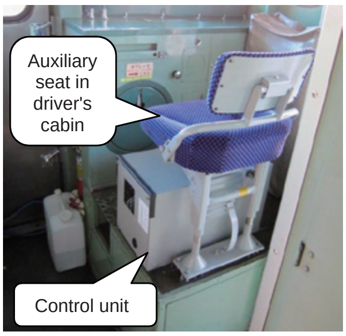

Fig. 4 A control unit

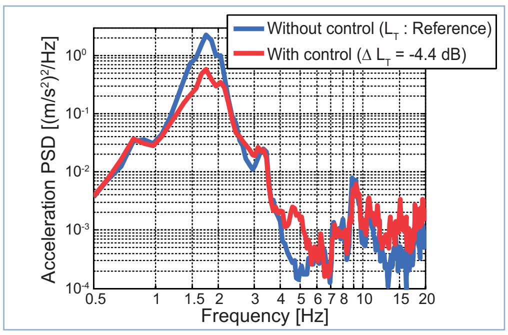

Fig. 5 Car-body vertical vibration acceleration PSD at 75 km/h, measured immediately above the bogie

Fig. 6 Sightseeing limited express train "Ibusuki no Tamatebako" installed with the new system