Reduction of Carbody Vertical Bending Vibration by Controlling the Primary Suspension Damping Force

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With the increase in speed and the decrease in weight of railway vehicles, the carbody vertical elastic vibration (particularly the primary bending vibration) has become noticeable. This vibration can lead to a deterioration in the vehicle vertical ride quality. Therefore, various measures to reduce this vibration have been proposed. In any of the vibration-reducing methods that have been proposed so far, the force required to restrain the vibration is applied directly to the carbody by a suitable means, with or without control of the force. The salient characteristic of the method proposed in the present R&D is that it controls the damping force of the primary suspension system to restrain the vibration of the trucks that are the major cause of carbody vibration, thereby reducing the vibration of the carbody. By controlling the damping force of the air spring (secondary suspension system) as well as that of the primary suspension system, it is also possible to reduce the vibration in rigid body mode, and further improve the ride quality.

System configuration

As shown in Fig. 1, the system is composed of acceleration sensors, variable damping axle dampers and a controller installed on the truck frame. Where necessary, acceleration sensors are also installed on the carbody. Based on data obtained by the acceleration sensors, the controller calculates the optimum damping force for reducing the primary bending vibration of the carbody and controls the damping force of the variable damping axle damper.

The variable damping axle damper (Fig. 2) has such a high response that it is capable of controlling damping forces up to approximately 10 Hz. The decline in damping force when the damper displacement amplitude is extremely small is kept to a minimum. Since the space required for installation and the maximum damping force of the variable damping axle damper are the same as those of the passive axle damper currently in use, the two types of dampers are interchangeable even in terms of the strength required for the damper attachment bracket, etc. When the air spring damping force is also to be controlled, an air suspension with a built-in variable damping valve (Fig. 3) and sensors for measuring air spring displacement are used.

Results of excitation testing at rolling stock test plant

The system was mounted on a test vehicle modeled on an actual Shinkansen car and subjected to an excitation test simulating the actual running conditions at the RTRI rolling stock test plant. Fig. 4 shows the power spectral density (PSD) of vertical vibration acceleration at the floor of the carbody center. Peak PSD caused by the carbody primary bending mode was observed in the neighborhood of 8.5 Hz. It was found that the vibration could be reduced to approximately 15% by controlling the axle dampers. In addition, with the aim of confirming the improvement in ride quality by the reduction of vibration, the test car's ride quality level (L_T), which is used as an indicator of ride quality of railway vehicles in Japan, was calculated. The calculation results are also shown in Fig. 4. It was confirmed that the control of the damping force by the system was effective in improving the ride quality—reducing the L_T value by about 4 dB.

When the air suspension damping force was controlled at the same time, the vibration in rigid body mode around 1 Hz decreased to about one-half in terms of PSD peak value, and the L_T value improved by about 4.5 dB.

Future plans

The system was mounted on a Shinkansen test car, which was subjected to a running test. As a result, it was confirmed that the system effectively reduced the carbody vertical bending vibration and reduced the L_T value by 3 dB or more. In the future, we have plans to press ahead with activities to put the system into practical use— including cutting the cost of the variable damping axle damper, mass-producing the system, and carrying out long-term durability tests with prototypes.

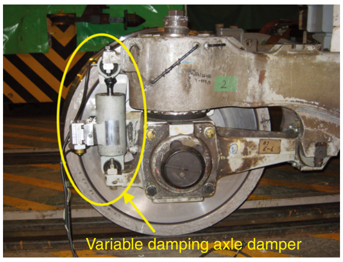

Fig. 2 Installation of variable damping axle damper

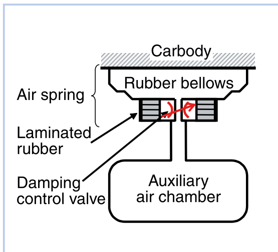

Fig. 3 Air suspension with variable damping valve

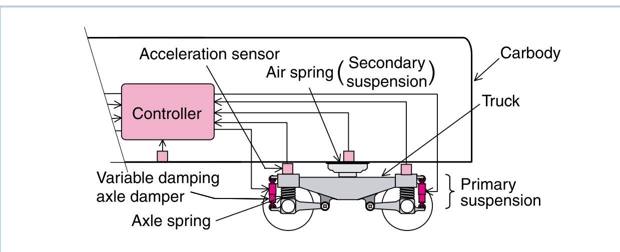

Fig. 1 System configuration

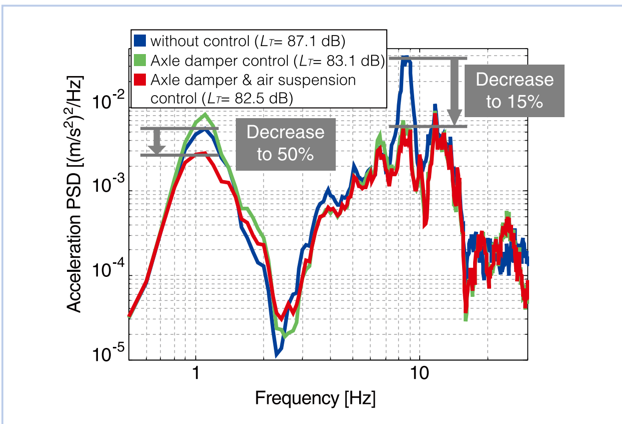

Fig. 4 Acceleration PSD at the floor of carbody center