Investigation into Suppressing the Bending Vibration of Railway Vehicle Carbody with Piezoelectric Elements

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Recent railway vehicles are being made increasingly lighter in weight, allowing for an increase in train speed. This in turn contributes to improvements in promptness, the saving of energy, etc. On the other hand, there are cases in which the vertical bending vibration of carbodies becomes conspicuous, due mainly to a decrease in their rigidity and damping. This vibration often occurs in the frequency range to which human beings are very sensitive. Since the vibration causes passenger comfort to decline, effective measures to suppress it are increasingly called for.

Under that condition, RTRI has proposed various measures to suppress the bending vibration of carbodies. Some of those measures have already been put into practical use in commercial vehicles. In the future, however, it is expected that the demand for speed and riding comfort will become stronger. It is, therefore, necessary for us to propose, in addition to the measures we have developed for railway vehicles of conventional construction, a new measure that permits suppressing the bending vibration of carbodies more effectively while reducing the carbody weight still more, through the introduction of new materials, new functions and control technology. In this context, the author et al. are developing a new vibration suppression technique that utilizes piezoelectric elements, which are electrically shunted by an external circuit (shunt circuit). We aim to apply our new technique to suppressing the bending vibration of railway vehicle carbodies.

Typically, the piezoelectric element generates a voltage when subjected to strain. Piezoelectric elements are used to suppress the bending vibration of carbodies as follows. When the vibration occurs as shown in Fig. 1, a strain is produced in the piezoelectric elements attached to the carbody as the carbody is deformed. As a result, a voltage is generated. When a shunt circuit including a resistor is connected to the elements, the voltage generated by the elements causes a current to flow to the circuit. As the current flows through the resistor in the shunt circuit, the electric energy is dissipated in the form of Joule heat. In this way a loss of energy occurs. Since the electric energy was originally produced by the bending vibration of the carbody, the energy loss has a damping effect on the carbody, thereby suppressing the bending vibration.

Before applying the above technique to an actual vehicle, we attached a total of eight piezoelectric elements (each measuring 155 mm x 40 mm x 3 mm), four on each of the right and left side beams of a 1:5 scale model of Shinkansen car 4.9 m in overall length and about 300 kg in mass as shown in Fig. 2 (photo at left), and subjected the model to a stationary vibration test using an electrodynamic shaker to confirm the vibration-suppressing effect. The frequency response between excitation force and carbody center acceleration is shown in Fig. 2 (diagram at right). Although the total mass of the elements was approximately 1.1 kg, or only about 0.4% of the mass of the model, the amplitude of bending vibration decreased to less than one-half.

In the future, we intend to study methods for attaching the elements to actual vehicles and carry out performance confirmation testing (stationary vibration test and running test) after estimating the required number of elements, predicting the damping performance of elements, etc. using a simulation model, in order to put the new technique into practical use.

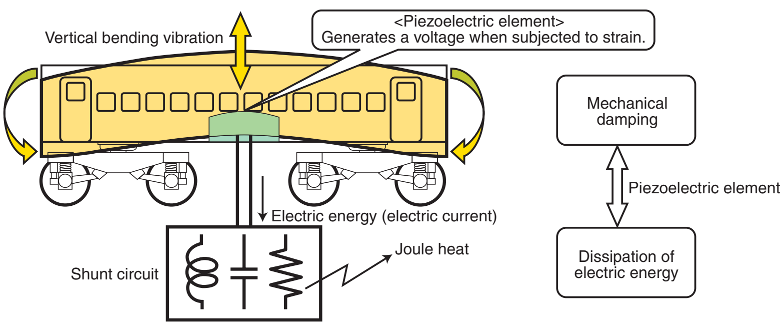
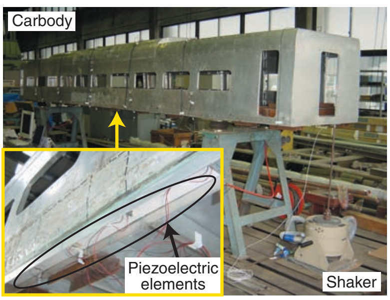


Figure 1. Scheme of bending vibration suppression technique using piezoelectric element and shunt circuit



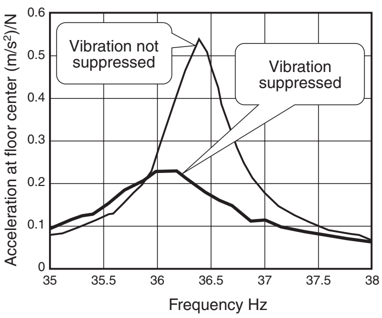


Figure 2. Scene of vibration test with 1:5 scale model of Shinkansen car (left) and results of vibration test (right)