Evaluating How an Increase in Train Speed Will Affect Ground Vibrations

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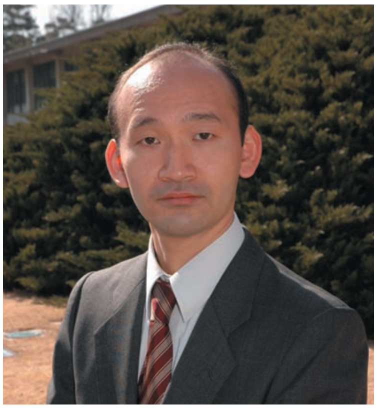


Since the Tokaido Shinkansen began operations in 1964, Shinkansen train speed has increased dramatically. But to avoid seriously impacting the trackside environment, it is important to quantitatively estimate the increase in ground vibrations that will result from higher train speeds.

Generally speaking, the relationship between train speed and ground vibration is expressed by the power of velocity law. Accordingly, when train speed changes from V_0 to V the increase in ground vibration level, ΔVL (dB), can be expressed as:

$$\Delta VL = 10\, n \log_{10} (V/V_0)$$

In the above equation, the speed power exponent n represents the train speed dependency of ground vibration level. For example, when n = 3.0, the ground vibration increases by about 1.4 dB as the train speed increases from 270 to 300 km/h. Even for the same line, the value of n varies according to ground conditions and other factors. In other words, an increase in train speed on a line may cause one localized part of the ground to vibrate more than the average ground vibration on that line. Additional measures would therefore be required to reduce vibrations there.

A recent study revealed that when Shinkansen train speed exceeded 300 km/h, under certain ground conditions a ground vibration of a very low frequency band of around 4 Hz prevailed. Until that study, such a low frequency band had been ignored as being inconsequential. Fig. 1 shows examples of ground vibration spectra obtained at comparatively soft parts of the ground. In those areas, the value of n was as large as 5.0 to 5.9. On the other hand, at comparatively satisfactory parts of ground, vibrations in the range of 12.5 to 16.0 Hz were prevalent, and the value of n was about 2.7.

Taking advantage of past and recent research results, we conducted research to develop a simple method for quantitatively evaluating the effect that an increase in train speed has on ground vibrations.

When a standard Shinkansen train runs at speeds of from 200 to 350 km/h, peak ground vibrations appear in each of three frequency bands — very low (2 to 4 Hz), low (6.3 to 12.5 Hz) and medium (20 to 40 Hz) — as shown in Fig. 2 (a). With the increase in train speed, these frequency bands shift toward the higher frequency range, and the peak value in each frequency band varies (Fig. 2 (b)). Of the five parameters (dS0, dS1, dVL0, dVL1 and dVL2) shown in Fig. 2, dS0 and dS1 represent ground vibration spectra characteristics before train speed increased, while dVL0, dVL1 and dVL2 indicate the degree of change of peak in each of the above three frequency bands. For each line, a vibration calculation model was created based primarily on a model for theoretical calculation of the effect of periodic axle load, a simple model for dynamic characteristics of the ground, and the results of train speed-up tests.

An example of calculation of the speed power exponent n using our proposed method is shown in Fig. 3. With our proposed model, it is easy to estimate how much an increase in train speed will change ground vibrations, using only a modest amount of ground information - mainly the thickness and average N value of the ground surface layer. We therefore consider it worthwhile to carry out a more detailed preliminary study on measures to estimate and control the increase in ground vibrations when planning to increase train speed.

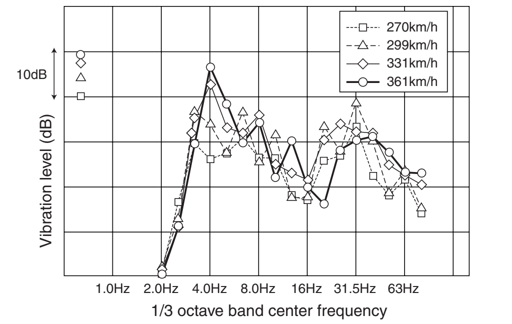


Figure 1. One-third octave band spectrums of measured ground vibrations

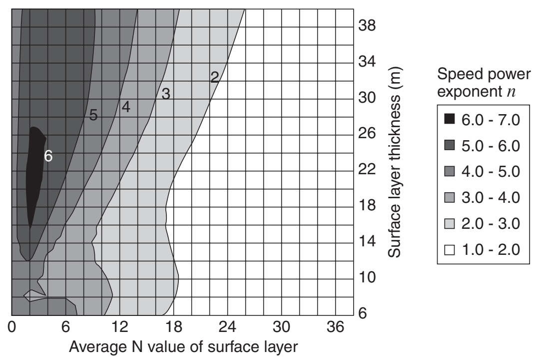
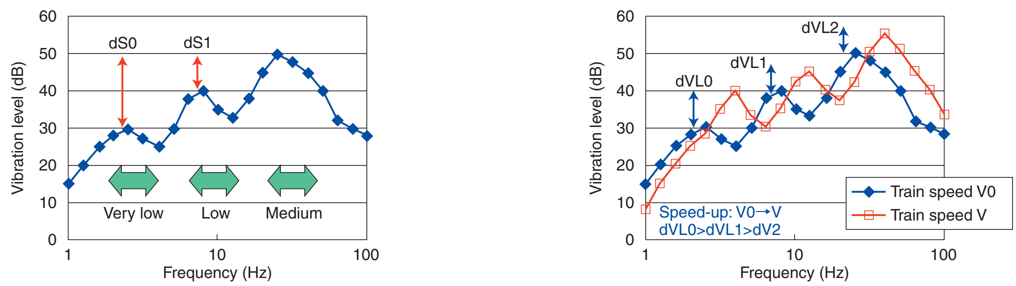


Figure 3. Example of calculation of speed power exponent n



(a) Ground vibration spectra before speed-up

(b) Change in ground vibration spectra due to speed-up

Figure 2. Change in ground vibration spectra due to speed-up