A Method of Managing Wheel Loads and Lateral Forces Using Axle-Box Acceleration

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Railway tracks in Japan are maintained to standards that meet or improve on the criteria determined by track inspection cars for safe operations of train. This assumes that the wheel loads and lateral forces exerted on the rails do not exceed the specified safety limits. In practice, however, this assumption cannot be taken for granted because of short wavelength track irregularities that cannot be measured by track inspection cars. The excessive wheel loads or lateral forces are thought to lead to a rapid increase in track irregularities or a swift deterioration in track materials. It is important, therefore, to correctly assess the wheel loads and lateral forces that are actually generated by rail vehicles in service.

To estimate the wheel loads and lateral forces caused by short wavelength track irregularities, the Railway Technical Research Institute (RTRI) is now promoting researches on the application of axle-box acceleration. The axle-box acceleration is the vibration acceleration measured at the axle-box supporting the axle. It is known that the axle-box acceleration in the vertical direction correlates closely with the wheel load and that in the lateral direction it correlates with the lateral force. See Fig. 1.

The RTRI carried out frequency analysis of vertical/lateral axle-box accelerations and discussed a technique to estimate wheel loads/lateral forces from axle-box accelerations by applying the frequency response method to the frequency bands where the accelerations correlate closely with the wheel load/lateral force. The frequency response method involves performing inverse Fourier transformation on the frequency response functions of input/output waveforms and applying the result to the input waveform as a finite impulse response (FIR) filter to obtain the estimated output waveform.

Track irregularities also cause comparatively long wavelength variations in the wheel load and lateral force. Therefore, a technique has been developed to estimate wheel loads and lateral forces by applying the frequency response method to these long wavelength variations. In this study, the RTRI used both track irregularities and axle-box accelerations to estimate the variations in the wheel load and lateral force. See Fig. 2.

To obtain the waveforms of wheel loads and lateral forces by this method, the RTRI took the following three steps: (1) estimation of wheel loads having wavelengths of 6 m or more from cross-level irregularities and lateral forces having the same wavelengths from alignment irregularities, (2) estimation of wheel loads and lateral forces with a wavelength less than 6 m from axle-box accelerations and (3) superimposition of the results of (1) and (2) for each quantity. Figure 3 shows an example of the lateral force estimated from axle-box lateral acceleration. It proves that the occurrence of large lateral forces at 25 m-spaced rail joints can be estimated with great precision.

To control large wheel loads and lateral forces, it is necessary to eliminate short wavelength track irregularities. For this purpose, the RTRI intends to use track irregularities measured by the asymmetry chord offset method that enables assessment of track irregularities of shorter wavelengths than those obtained by the 10 m-chord offset method. Figure 4 shows a control flow chart for wheel loads and lateral forces using both axle-box accelerations and track irregularities obtained by the asymmetry chord offset method. According to this flow chart, the first step is to apply the above estimation technique to determine the locations where large wheel loads and lateral forces are anticipated to occur. Then, the next step is to carry out maintenance at the locations where wheel loads and lateral forces are anticipated to exceed the reference value by using the short chord offset obtained from the asymmetry offset chord track irregularities. This is because, as the wheel loads and lateral forces caused by short wavelength track irregularities largely depend on the train running speed, the most efficient way of remedying the problem is to give priority to elimination of short wavelength track irregularities at those locations where large wheel loads and lateral forces occur.

It is expected that the technique of using axle-box accelerations can also be applied for various other track management purposes apart from those introduced above for controlling wheel loads and lateral forces. The RTRI will promote research on this topic from different viewpoints in the future as well.

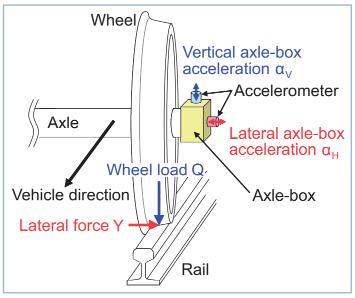

Fig. 1 Axle-box acceleration versus wheel load and lateral force

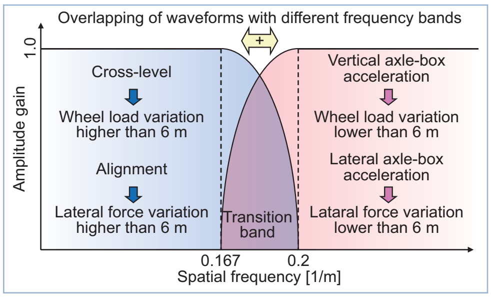

Fig. 2 A technique to estimate wheel load and lateral force

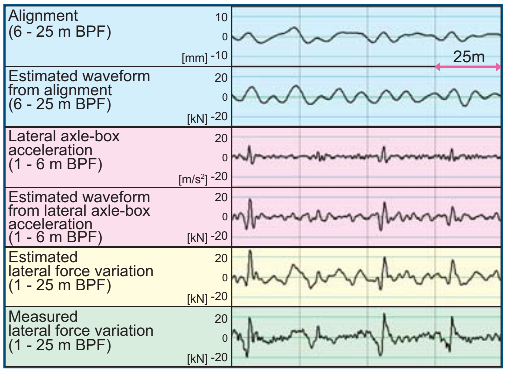

Fig. 3 An example of lateral force estimated from lateral axle-box acceleration

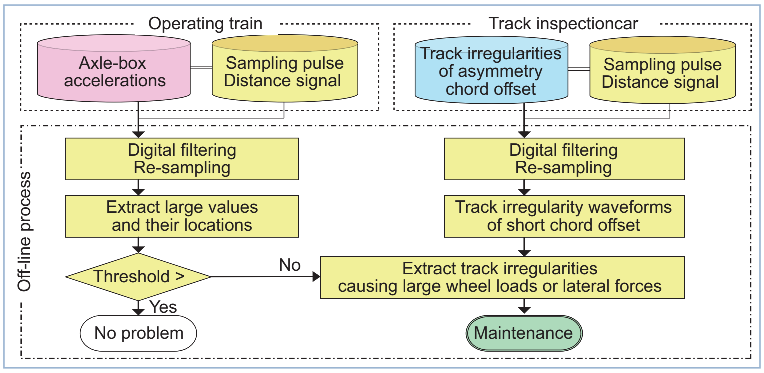

Fig. 4 A control chart for excessive wheel loads and lateral forces