Analysis of Aerodynamic Noise Source Distribution by Wind Tunnel Tests

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To analyze the mechanism of aerodynamic noise generated when rolling stock runs at high speed and develop noise reducing measures, it is effective to search noise sources by wind tunnel tests. A paraboloidal apparatus collecting sound that combines a microphone and a paraboloid of an ellipsoidal reflector, 1 m in diameter, has been used to search noise sources with a large-scale low-noise wind tunnel installed in Wind Tunnel Technical Center (WTTC) at Maibara as an instrument for searching noise sources since it started operation. So as to improve the precision of acoustic measurement, WTTC has developed an ellipsoidal apparatus to collect sound as a new noise-source searching instrument to replace the conventional one. This instrument has a microphone equipped at the closer focal point of the reflector, 1.7 m in diameter, that has a profile generated by rotating the part of an ellipse around its major axis to have a strong directivity for the other focal point (Fig. 1). It has substantially improved resolution, especially in high-frequency bands, to separate two 100 mm-apart sound sources in the 5 to 20 kHz band, in contrast to the conventional sound-collecting paraboloidal apparatus that was not able to separate two sound sources unless they were about 400-mm apart from each other (Fig. 2). As the frequency of aerodynamic noise in reduced scale model tests tends to shift to a higher side, the new apparatus exercises its power in the measurement in model tests in particular.

WTTC employed the ellipsoidal apparatus newly developed for collecting sound to measure the aerodynamic noise generated from a 1/5 scale Shinkansen car model and determined the detailed noise source distribution of a Shinkansen car running at high speed (Fig. 3). As a result, it was proved that the aerodynamic noise caused by railway vehicles comes mainly from the parts where local profile changes along the carbody, such as the wipers at the upper part of the head car and door handles outside the driving cab. Based on the data obtained from this test, WTTC proposed a technique to model the sources of the aerodynamic noise observed at various parts of the test model and determine their contributions to the noise level in the far field. By applying this technique to the experimental data given through the 1/5 scale Shinkansen model car test, WTTC estimated the noise level developed at various parts of Shinkansen cars except pantographs at a 25 m-distant point when it runs at 300 km h^{-1} (Fig. 4). Table 1 shows the noise levels that reflect the length of train composition and the effect of noise barriers. The Table also shows that the contribution of the aerodynamic noise at the truck is the highest, followed by that generated from the part above the gap between cars in the case of a train running on a viaduct section installed with sound barriers. The detailed distribution and contributions of noise sources thus obtained will be useful in determining the measures to reduce Shinkansen car noise.

In the past several years, a number of tests have been performed by using the large-scale low-noise wind tunnel at Maibara and similar facilities in Japan to acquire knowledge of the aerodynamic noise caused by rolling stock in wide ranges, mainly due to the information available through the high-performance wind tunnel at Maibara and refined techniques for tests and measurement. WTTC will continue wind tunnel tests, improve the technique for tests further, and promote research and development to establish wind tunnel tests as a tool to investigate and reduce the aerodynamic noise emitted by running rolling stock.

ACKNOWLEDGEMENT

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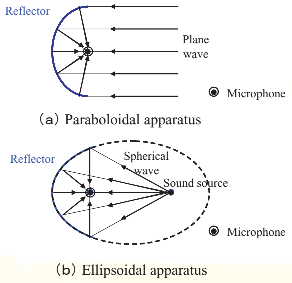

Figure 1. Principle of paraboloidal apparatus and ellipsoidal apparatus.

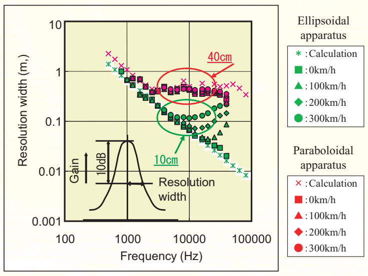

Figure 2. Resolution width of ellipsoidal apparatus and paraboloidal apparatus at different wind velocities.

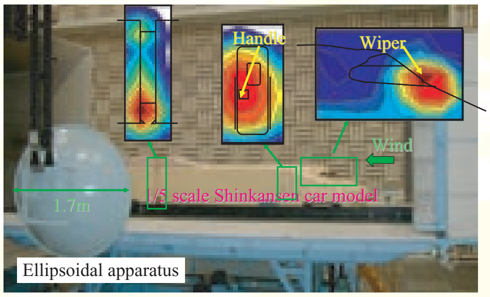

Figure 3. Noise source distribution measured by ellipsoidal apparatus.

Table 1. Estimated Sound Pressure Levels of Aerodynamic Noise Generated from Individual Parts of the Shinkansen Car[a]

Noise source position	Sound pressure level / dB
Gaps between cars (upper parts)	65
Bogies	62
Driving cab doors	58
Gaps between cars (lower parts)	58
Lower parts of leading car	57

[a] Train speed, 300 km h^{-1}; train length, 200 m; measuring point, 25-m away from the track; construction, elevated viaduct with sound barriers of 2-m height.

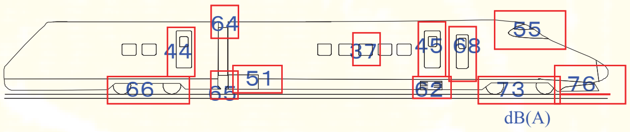

Figure 4. Estimated sound pressure levels of aerodynamic noise generated from individual parts of the Shinkansen car. Train speed, 300 km h^{-1}; measuring point, 25-m away from the track; sound barrier, not available.