Wind tunnel noise measurements on full-scale pantograph models

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Summary: Noise reduction of pantographs is of special importance for the operation of high-speed trains, since the pantograph noise cannot be treated with passive counter measures like sound barriers. Therefore the noise emission of pantographs was investigated in an acoustically treated wind tunnel for air speeds up to 400km/h. The aims were to determine the noise reduction potential of pantographs, to investigate their aerodynamic behavior, to validate existing theoretical models, to compare measurement techniques and wind tunnels. Two pantographs, which are in service today in Germany and Japan, were used as references. Two full-scale models of high-speed pantographs were tested in several configurations. The achieved noise reduction of the models compared to the reference pantographs confirmed the theoretical results.

INTRODUCTION

Within the scope of collaboration between DB AG and JR-East, joint wind tunnel tests were undertaken in Maihara (Japan) to determine the acoustics and aerodynamics of high-speed current collectors (1). DB tested the following four current collector types (with numerous sub-variants):

1. Crossed-arm type pantograph DSA350SEK as the reference (Figure 1);
2. Telescopic current collector model HPP of Adtranz with one contact strip;
3. Retrofittable single-armed pantograph ASP of DB (one or two contact strips, Figure 2);
4. Single-arm type pantograph PS206 of JR-East.

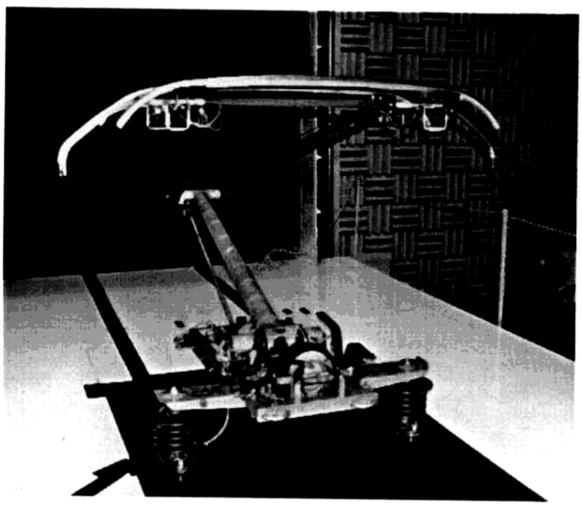

Figure 1: DSA350SEK in test section

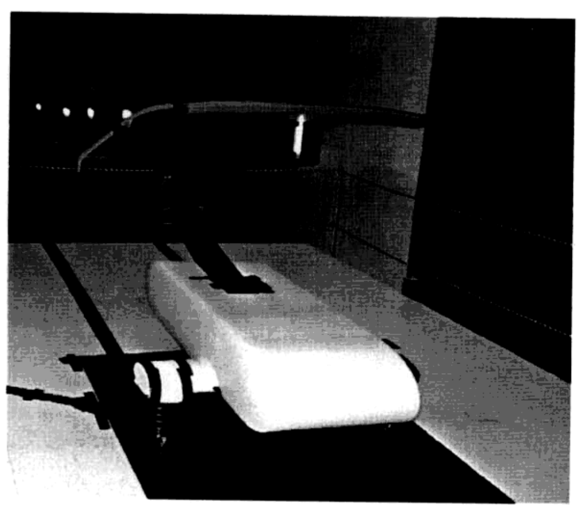

Figure 2: ASP in test section

The main objectives of the wind tunnel analysis in Maihara are summarized here:

- Determining the acoustic improvement potential of the current collectors and the aerodynamic forces occurring on the pantograph head
- Acoustic comparison of the German and Japanese standard current collectors
- Comparison of the DNW and RTRI wind tunnel with reference to the results obtained with the current collector DSA350SEK
- Validation and / or enhancement of the DB simulation tools of pantograph noise.

MEASUREMENTS

The wind tunnel of RTRI (Rail Technical Research Institute) in Maihara is a Göttingen-type tunnel. The configuration used for acoustic measurements has an open measuring section with a nozzle cross-section area of 3m * 2.5m. The maximum airstream velocity is 400 km/h. Various microphone systems were used for the acoustic measurements:

- One microphone array as a directional microphone
- A parabolic reflector microphone for sound source location
- One microphone with a spherical characteristic at a height of 1.5m above the floor of the wind tunnel hall at a lateral distance of 5 m from the emission center.
- One microphone with a spherical characteristic at a lateral distance of 5m from the center of the tunnel at the level of the pantograph heads.

A gauge was used for measurement of the aerodynamic lift, drag and pitching moment of the DB-pantograph head. To verify the CFD calculations, a series of pressure holes was produced in the pantograph head featuring two contact strips.

The following parameters were varied (wherever possible):

- Airstream velocities 115, 170, 230, 280, 330, 350, 400 km/h
- Airstream direction (knee upstream/downstream)
- Yaw angles 0°, 3°, 8°
- Pantograph head angles of attack 0°, -2°
- Pantograph head height above measuring platform: 1500mm, 1200mm, lowered

The contributions of individual current collector structures to the overall noise emission was examined, wherever possible: either by using the parabolic reflector microphone or by successive detachment of the current collector structures.

RESULTS

The results described here are only the results for the pantographs DSA350SEK and ASP. The results for the Adtranz-Pantograph and the Japanese PS206 are not shown.

In the spectrum of the DSA350SEK, the level peaks are influenced by the contact strip (550Hz), the pantograph horn (900Hz) and the stroke limiting cage (3500Hz), which can be identified by way of the Strouhal relationship. The yaw angle (i.e. the inclined airstream) has only a slight influence. For high speeds, the overall level decreases with an increasing airstream angle, but the decrease amounts to less than 0.5 dB. Also the airstream direction (knee upstream /downstream) only has a slight influence on the noise emitted. With the knee downstream, the noise emission for the individual speeds is between 0.5 and 1 dB higher than with knee upstream.

The modifications on the horn and the stroke limiting cage of the DSA350SEK led to a reduction of the overall sound pressure level of maximally 1.2 dB(A). In the spectra (Figure 3) the influences of the modifications on the noise components generated by the pantograph horn and the stroke limiting cage can be seen clearly. The whistling of the stroke limiters is reduced by more than 10 dB, and the level of the affiliated third octave band is reduced by more than 7 dB.

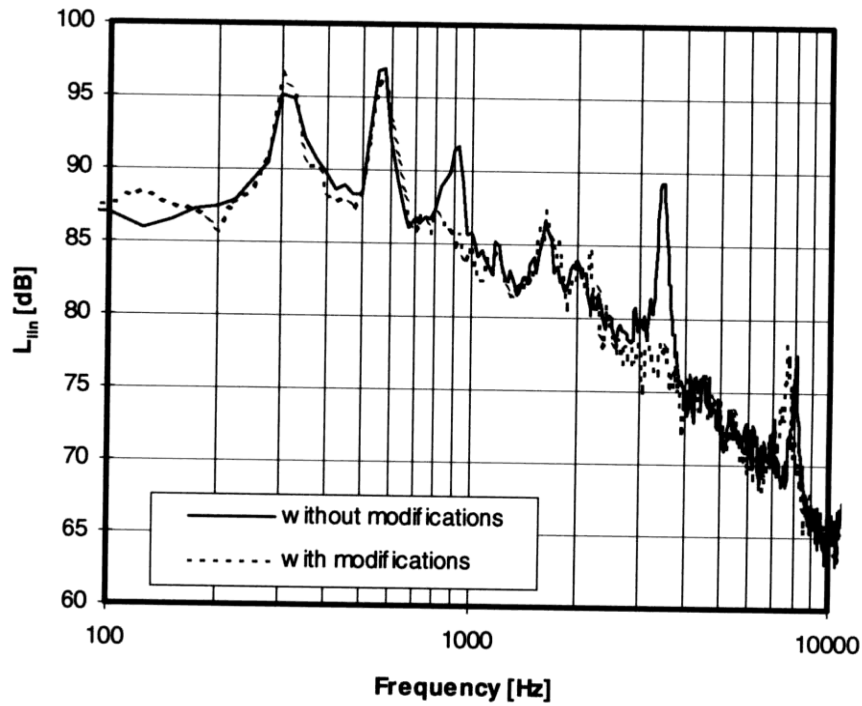

Figure 3: Influence of DSA350SEK head modifications (330 km/h)

The analysis of the ASP (DB-pantograph) shows that, besides the pantograph head, the insulators (initially the same ones that were also used for the DSA350SEK) and the interaction between the frame and lower arm while running with the knee in upstream direction have a strong influence on the total acoustic radiation. To enable analyses of the pantograph head, the airstream was limited to the area above the insulators. Running with the knee in downstream direction, the total level was between 3.4 and 6.4 dB(A) lower than with the knee upstream. The following pantograph experiments were therefore conducted with the knee downstream. The yaw angle and pantograph head angle of attack lead to changes in the total sound level of less than 1 dB(A). Besides a variant with one contact strip, one with two contact strips, which conforms to the requirements of the DB line network, was also analyzed. By means of various modifications, with the variant featuring two contact strips it was possible to achieve a 9.1 dB(A) level reduction in comparison with the reference current collector and, with the variant featuring one contact strip, it was even possible to achieve a level reduction of 11 dB(A), in each case with non-optimized DB insulators. Measurements on Japanese insulators permit the conclusion that, when using such insulators, improvements of 10.9 dB(A) are possible for the current collector featuring two contact strips and up to 14.2 dB(A) are possible for the current collector featuring one contact strip (relative to the reference). The results of the various improvements in noise emission relative to the DSA350SEK are shown in Figure 4.

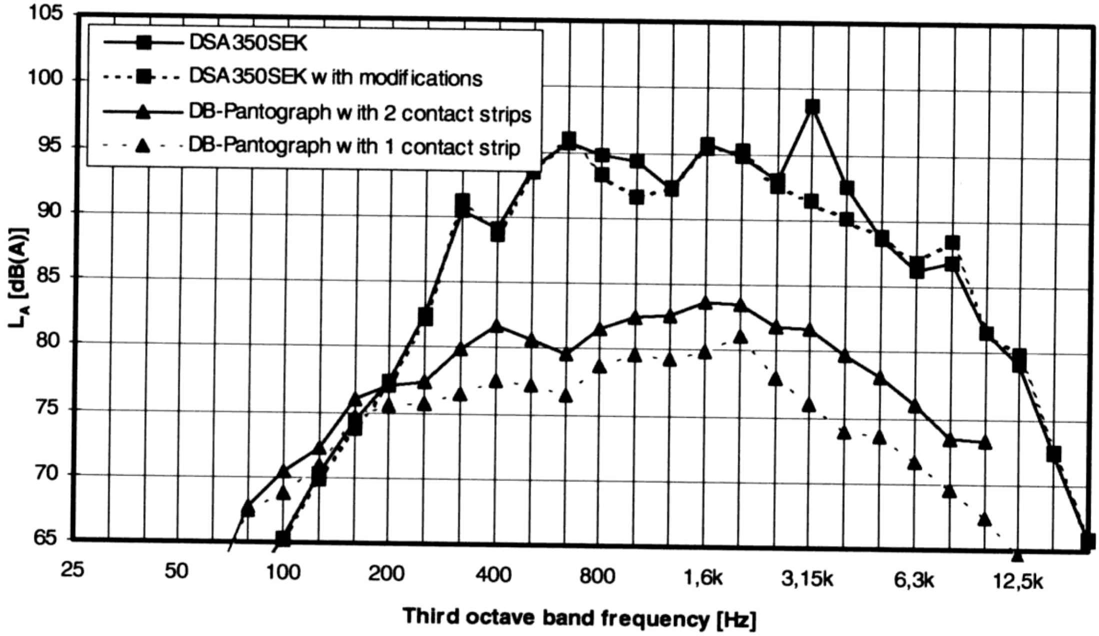

Figure 4: Comparison of pantograph noise emission (330km/h)

Following is a summary of the aerodynamic results of the measurements on the ASP:

- For all pantograph head configurations tested, the lift coefficients for zero angle of attack were positive. The future development must focus on reducing the stationary loads in order to be able to control the contact forces.
- The amplitudes of the instationary forces are high, especially for the variant with two contact strips. Because of the problem of contact force control, these fluctuations have to be reduced. This could be done by means of reducing the pantograph head area and introducing sharp edges.

The comparison of the measured values with the theoretical predictions showed a very good agreement.

REFERENCES

(1) Lölgen, Th., Huber, Th., Willenbrink, L., Schuster, P., Bunk, E., "Akustisch und aerodynamisch optimierte Stromabnehmer -gemeinsame Messkampagne von DB AG (FTZ) und JR East im Windkanal des RTRI in Maihara" Deutsche Bahn, Bericht 53411, München, Dezember 1998