Curving noise from the Western Australian freight rail network: wayside monitoring and mechanism analysis

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ABSTRACT

Curving noise from freight rail movements in the Perth metropolitan area have been investigated using Transport for NSW (TfNSW)'s Wayside Noise Monitoring System (WNMS) at a test location (Site A) with an approximately 400-m radius rail curve section. The trackside noise, rail vibration and wheelset position and steering angle as measured by the WNMS kit have been analysed in detail alongside supporting measurements of environmental noise and vibration. The predominant mechanisms for curving noise have been further analysed and identified. The correlation between high curving noise events and rolling stock types has also been investigated, followed by discussions on possible effective at-source noise control measures. This study found that on the basis of monitoring data being consistent with previous research elsewhere, the principle mechanisms of curving noise at the test location are most likely steering-controlled.

1 INTRODUCTION AND AIMS

A working group established by Freight and Logistics Council Western Australia (FLCWA) with members from both relevant government agencies and private rail operators has developed a Work Plan which involves detailed investigation of freight rail noise and vibration generation mechanisms. An identified test location (Site A) with a track radius at approximately 400 metres is considered to have a high potential for curving noise generation. The types of freight rolling stock are extremely diverse, from single locomotives of 6 axles to very long trains with nearly 500 axles. The aim of the study was to identify the likely cause of the curving noise generation and areas for improvement.

2 METHODOLOGY

Wayside monitoring was conducted throughout a three week period in 2017 using Transport for NSW (TfNSW)'s Wayside Noise Monitoring System (WNMS) (Jiang, March & April 2016). In total, 508 train passby events were detected and analysed.

3 RESULTS AND DISCUSSION

Table 1 summarises the measurement results associated with high noise (L_{Aeq} > 100 dB re 20 µPa) events detected. As can be seen from last column within the table, close to 40% of the total passby events have high noise events occurred within the individual passby durations.

Table 1: Results summary of detected high noise events

Total High Noise Events	Events with Squeal Only	Events with Flanging Only	Events with Squeal + Flanging	Events with undetermined high noise source	Average Number of High Noise Axle Events per Passby	% of Total Passbys with High Noise Events
2,694	289	1,528	422	455	5.3 (2-5% axles)	39.2%

3.1 Noise level vs speed

Overall speed can be a contributing factor causing the tracking positions to move outward, if speeds are significantly above the balance speed (i.e. speed at which the centripetal force on a rail vehicle operating at a given speed will be exactly equal to the force of gravity acting laterally down track inclined at a certain superelevation) of the curve. The estimated balance speed at the monitoring location is illustrated in Figure 1 based on curve radii and superelevation data received. Upon entry it is approximately 33 km/h but rapidly reduces to 20 km/h as the curve radius decreases to around 400 m.

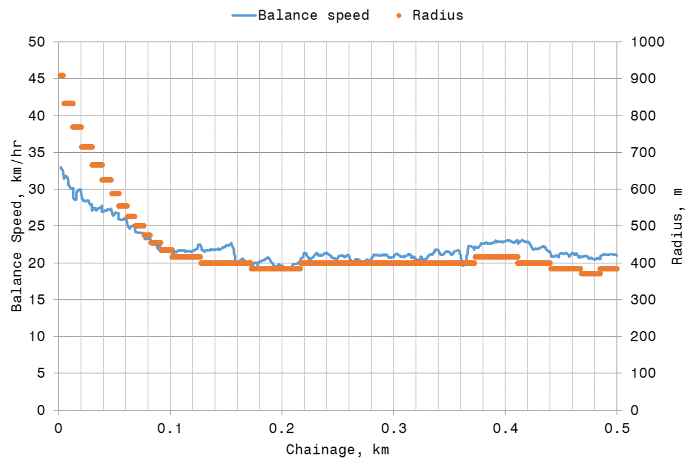

Figure 1: Estimated balance speed and curve radius versus chainage

Where the speed detected by the WNMS is substantially above the balance speed throughout the entire curve, it could be a risk factor regarding noise generation. To investigate further, scatter plots showing the relationship between measured L_{Amax} and L_{Aeq} noise level and speed for the monitoring site are shown in Figure 2.

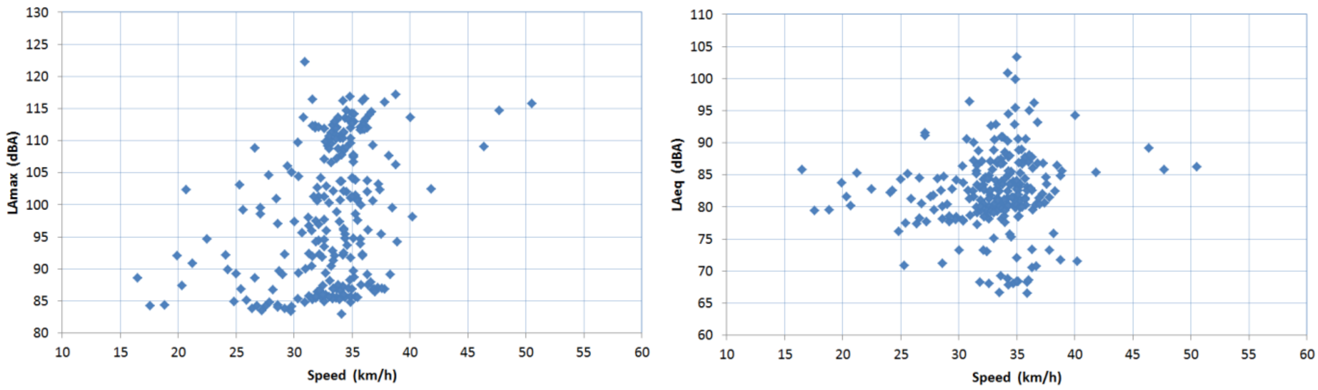

Figure 2: L_{Amax} (left) and L_{Aeq} (right) noise level at 1.2 m distance vs train speed, Site A

The noise level vs speed plots in Figure 2 indicate that:

- The majority of trains transitioned through the curve at between 25 km/h and 40 km/h, predominantly in the range of 30 to 35 km/h;
- There is a relatively weak relationship observed between train speed and L_{Aeq} noise levels;
- There is also a weak relationship observed between train speed and L_{Amax} noise levels (which more closely track squeal noise events) which has much higher scattering range than L_{Aeq} noise levels. High L_{Amax} levels more consistently appear with speeds above 30 km/hr, which is a point well above the balance speed;

The weak relationships observed between train speed and L_{Amax} and L_{Aeq} noise levels are due to the fact that both L_{Amax} and L_{Aeq} noise levels, particularly L_{Amax}, were dominated by curving noise effects such as flanging and squeal, rather than by pure rolling noise which normally increases with increasing speed.

3.2 Noise level vs axle count of train passbys

Scatter plots showing the relationship between measured L_{Amax} and L_{Aeq} noise level and axle count of train passbys for the monitoring site are shown in Figure 3. These noise level vs axle count plots indicate that:

- Passbys of longer trains (with more wagons/axles) tend to have higher L_{Amax} levels, with the increased 'chance' of bad wheels or wagons being with that passby. Higher noise (L_{Amax} > 110 dB re 20 µPa) events are predominantly from passbys with more than 200 axles. This is due to the fact that longer trains with more axles have more potential instances of squeal or flanging noise generating high noise levels; and
- There is no clear relationship between passby axle counts and L_{Aeq} noise levels as demonstrated in the right panel within Figure 3.

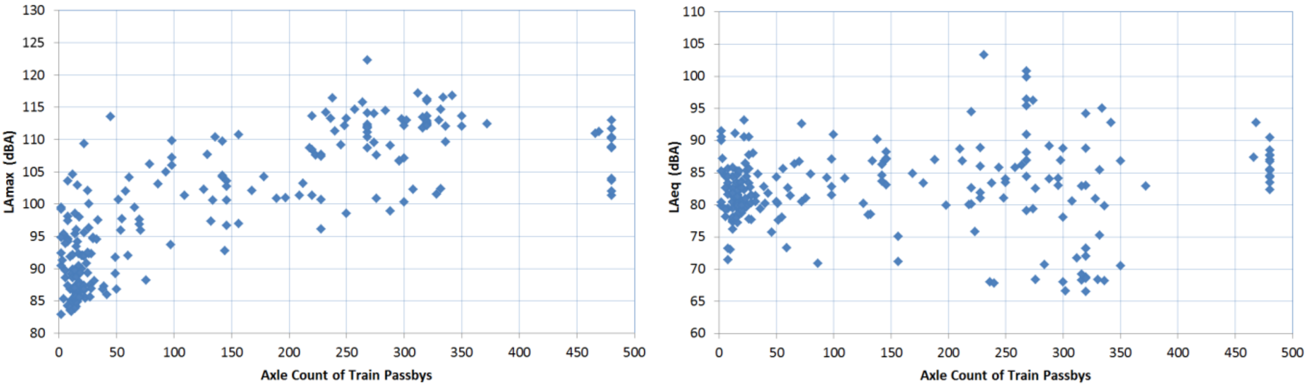

Figure 3: L_{Amax} (left) and L_{Aeq} (right) noise level at 1.2 m distance vs axle count of train passbys, Site A

3.3 Curving noise types

In addition to the overall passby noise metrics of L_{Amax} and L_{Aeq}, the WNMS processing software (Jiang, March 2016) also identifies the type of curving noise event during each passby, whether caused by wheel squeal, flanging noise or other noise generating mechanisms. The algorithm within the WNMS software compares the relative vibration on the High Rail and the Low Rail for each event to attribute the noise event to the wheel rolling on either the High Rail or the Low Rail (Jiang, March & April 2016).

The number of each type of high curving noise event identified at the monitoring site are summarised in Table 1 above. Events where squeal or flanging was identified in isolation are reported separately to events where both flanging and squeal were identified simultaneously. Essentially,

- Flanging noise is present for all high noise events (L_{Aeq} > 100 dB re 20 µPa) during a passby;
- Squeal noise occurs for all noise peaks with large Angle of Attack (AoA) values. AoA values are the angle between the tangent of a railway rail and the wheel.

To recognise the dominant noise generating mechanisms, an event is taken to be dominated by either squeal or flanging if the contribution of one is at least 5 dB higher than that of the other. If the two contributions are within 5 dB difference then the event is recognised as both a squeal and flanging event. "Other" events are those in which the L_{Aeq} noise levels as above the 100 dB trigger level, but neither flanging nor squeal was detected. These other events are potentially due to high rolling noise as the result of high track roughness or corrugation. This "other" noise is potentially also present in squeal and flanging events.

As presented in Table 1, flanging is the most common noise generating mechanism for the high noise events identified. Squeal is also a significant noise generating factor, and in many cases is accompanied by flanging. Given the proportion of axles with high noise events (2-5%) and noise levels typically around L_{Amax} 110 dB at 15 metres as measured, the curving noise is evidently 'Steering Controlled' as categorised by Anderson et al (2008).

3.4 Angle of attack and squeal mechanism analysis

Ideally on curves, wheelsets are aligned radially and a stiff bogie frame overcomes stability issues at high speed. However, there are non-ideal conditions on curves where for example:

- At low speeds, the front wheelset has a large yaw angle and the front outer wheel flange may contact the high rail. The rear inner wheel flange may also contact the low rail; and
- At higher speeds, both outer wheel flanges may contact the high rail.

The wheel AoA and tracking position (TP, i.e. Lateral position of a wheel relative to the track centre line) may be useful indicators of these effects. Figure 4 presents an example passby event showing measured AoA, TP, speed and noise levels.

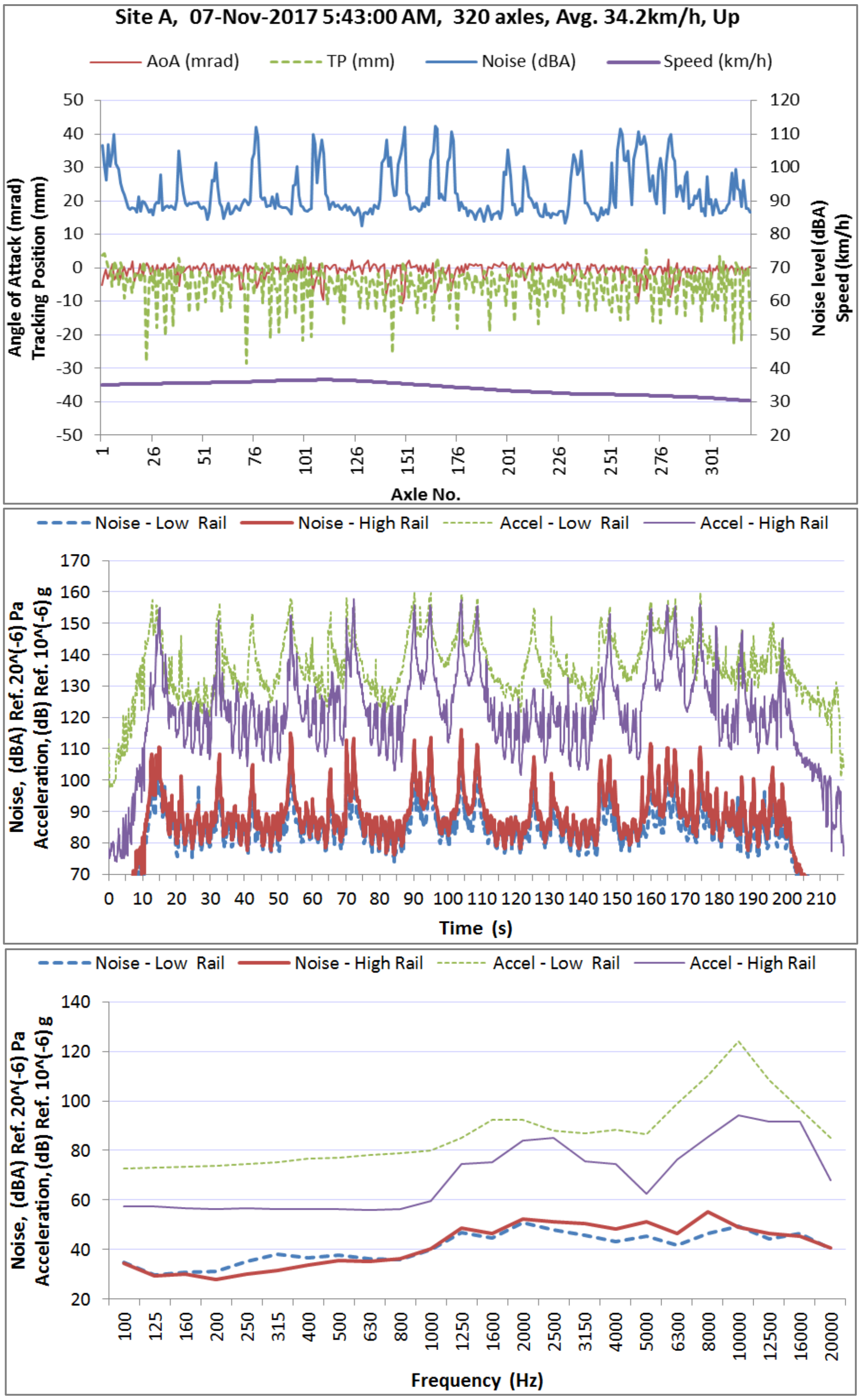

Figure 4: Example WNMS passby results, Site A: (top) overall AoA, TP, noise and vibration overall levels per axle; (middle) noise levels versus time; and (bottom) passby spectral sound pressure and acceleration levels.

Without local rail roughness data, differences in vibration between rails are estimated using the average vibration difference for passby axles without squeal or flanging noise contributions. Detailed review of the 16 noisiest passby events (L_{Amax} >= 115 dB re 20 µPa) over the entire monitoring period, along with their wheel AoA and TP, as well as the noise and vibration results.

The detailed analyses found that:

- The most significant noise events generally are squeal or squeal + flanging events;
- The large AoA values are all negative;
- The squeal events have strong correlation with large AoAs and with elevated TPs towards the positive direction; and
- High Rail has higher vibration levels than Low Rail for most of high squeal noise events.

Based on possible squeal mechanisms documented in TfNSW's WNMS - Data Analysis Manual (Jiang, March 2016), it is evident that for squeal events as the above instances wheels are attacking the High Rail as the large AoA values are all negative and the tracking positions tends to move towards the High Rail. The wheel squeal noise is predominantly originating from the High Rail gauge corner as the vibration from High Rail is higher than Low Rail for most of squeal events.

4 CONCLUSIONS

On the basis of wayside noise and vibration monitoring and analysis via TfNSW's WNMS, as well as similar freight rail curving noise studies undertaken elsewhere in Australia, this study confirmed that the principle mechanisms of curving noise from freight rail movements at the test site (Site A) are considered to be steering-controlled.

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