A detailed measurement and analysis study has been carried out to determine both the variability of noise from high speed trainsets when in operation in respect of SEL and $L_{\text{max}}$ data. The aim of the study was to demonstrate the extent to which the variability of train noise occurs in actual operating conditions and whether it is appropriate to rely on future predictions of train noise from the new railway lines without describing an uncertainty budget or confidence level.

Keywords: $L_{\text{max}}$, SEL, high speed, railway

1. Introduction

This paper assesses the uncertainty of the produced noise between trains of the same class and speed. The trains assessed for this study are the Pendolino trains run by Virgin and the British Rail Class 800 trains run by the Great Western Railway. ACCON UK has conducted noise measurements of the above trains and analysed the data to provide the different $L_{\text{Amax}}$ and SEL values. The purpose of this paper is, through extended data analysis and noise measurements, to identify the difference between the noise levels of the same train types with a 95% confidence level.

2. Noise measurement methods

2.1 ISO 3095:2013 – Measurement of noise emitted by rail bound vehicles

Railway exterior noise is encountered both along open track and in and around депorts, stops, stations and other holding locations. Rolling noise is one of the main sources which contain a significant and sometimes dominant noise contribution from the track. This International Standard is intended to characterize the noise emission from the unit, minimizing the influence of the track.

2.2 Calculation of Rail Noise (1995)

Supplement 1 to the Calculation of Rail Noise (1995) produced by the Department of Transport (Department for Transport, 1995) [1], describes the methodology that should be utilised to determine $L_{\text{Aeq,16hr}}$ and $L_{\text{Aeq,8hr}}$ from high speed trains.
2.3 CNOSSOS – EU

Common Noise Assessment Methods in EU (CNOSSOS – EU) [2], is the methodology designed to be utilised by EU member states for strategic noise mapping. The assessment of rail noise analyses multiple sources including rolling noise, traction noise, aerodynamic noise, impact noise, squeal noise, braking noise and additional effects. The methodology is not currently utilised within the United Kingdom.

3. Measurements

ACCON UK has conducted a series of noise measurements to identify the noise levels produced by the Pendolino trains and the Class 800 trains operating on Network Rail lines.

3.1 Measurement Locations

The noise levels produced by the Pendolino trains were measured in Carpenters Park (MP1), which is located near Watford. The noise levels produced by the Class 800 trains were measured in a field near Purley Rise, Reading (MP2).

Both of those locations are considered to be suitable for train noise measurements, as the ground is level with the railway lines and the ambient noise in the area is low and does not therefore affect the accuracy of the measurements and no adjustment of the measured train noise levels is required.

3.2 Location MP1

MP1 was located in a grass area to the east of the B4542 road in Watford. Trains at this location were measured at speeds between 120kph and 194kph.

3.3 Location MP2

MP2 was located in a grass field in Westbury Lane in Purley Rise near Reading. Trains at this location were measured at speeds between 134kph and 201kph.

3.4 Ambient Noise

Care was taken to ensure that the noise from other sources did not influence the measurements significantly. The maximum value of the \( L_{Aeq,Tp} \) at 20 s of ambient noise over all microphone positions was at least 10 dB below the \( L_{AFmax} \) (or \( L_{Aeq,Tp} \)) obtained when measuring the noise from the train unit in the presence of ambient noise.

3.5 Equipment and measurement details

The noise levels were measured with the use of a Norsonic 118 sound level meter. The sound level meter holds a current certificate of calibration. The equipment was field calibrated before and after the measurement period to ensure that it had remained within reasonable calibration limits (± 5 dB).

The noise level meter was placed approximately 15 metres away from the closest railway track that the trains were passing by on, at a height of 1.5 m above the ground. The speed of the trains was measured with the use of a speed gun located such as to minimise any under-range speed measurements.

4. Comparison of Results

Figure 1 and Figure 2 below, identify the time history of the \( L_{Amax} \) for a Pendolino and a Class 800 train respectively.

The results of the noise measurement surveys are shown in graphical format in Figure 3 and Figure 4 below for the Pendolino trains and Figure 5 and Figure 6 for the Class 800 trains. The graphs identify
the predicted $L_{A\text{max}}$ over the speed of each trainset. Figure 7 and Figure 8 identify the predicted SEL over the speed of each trainset respectively.

Figure 1: Relationship between time and $L_{A\text{max}}$ for the Pendolino trains.

Figure 2: Relationship between time and $L_{A\text{max}}$ for the Class 800 trains.
Figure 3: Relationship between speed and $L_{A_{\text{max}}}$ for the Pendolino trains running towards Euston.

It can be identified from Figure 3 that there is a wide spread of $L_{A_{\text{max}}}$ levels for pass-by events at similar speeds. The trend line in red identifies a $\pm 2.98$ dB with a 95% confidence level.

Figure 4: Relationship between speed and $L_{A_{\text{max}}}$ for the Pendolino trains running towards Milton Keynes.

It can be identified from Figure 4 that there is a normal spread of $L_{A_{\text{max}}}$ levels for pass-by events at similar speeds. The trend line in red identifies a $\pm 1.66$ dB with a 95% confidence level.
Figure 5: Relationship between speed and $L_{A_{\text{max}}}$ for the Class 800 trains running towards Reading.

It can be identified from Figure 5 that there is a wide spread of $L_{A_{\text{max}}}$ levels for pass-by events. However, at some points, there is a higher difference level. The trend line in red identifies a $\pm 2.31$ dB with a 95% confidence level.

Figure 6: Relationship between speed and $L_{A_{\text{max}}}$ for the Class 800 trains running towards Didcot.

Figure 6: Relationship between speed and $L_{A_{\text{max}}}$ for the Class 800 trains running towards Didcot.
It can be identified from Figure 6 that there is a wide spread of $L_{A\text{max}}$ levels for pass-by events at similar speeds. The trend line in red identifies a $\pm 5.19$ dB with a 95% confidence level.

Figure 7 and Figure 8 below, presents the relationship between the SEL and the speed for the Pendolino and the Class 800 trains respectively.

![Figure 7: Relationship between speed and SEL for the Pendolino trains.](image7.png)

It can be identified from Figure 7 that there is a wide spread of SEL levels for pass-by events at similar speeds. The deviation in noise level from the attributed trend line is shown to be $\pm 2 – 4$ dB.

![Figure 8: Relationship between speed and SEL for the Class 800 trains.](image8.png)
It can be identified from Figure 8 that there is a minor spread of SEL levels for pass-by events at similar speeds. The deviation in noise level from the attributed trend line is shown to be $\pm 2 - 4$ dB.

It is important to understand that the spread of train noise data can occur as a result of a variety of mechanisms which include both wheel and rail roughness. Accordingly, where this can be controlled it is more likely that prediction of train noise is more likely to be accurate and with a tighter spread of measurement results. The use of regular maintenance on the rail vehicles and the rails should ensure that over time there is no creep upwards in the measured rail noise events.

5. Conclusions

The spread of data in the Pendolino train measurements, identify that it would not be possible to accurately predict the maximum noise levels or the SEL within $\pm 4$ dB which casts uncertainty on the determination of future noise impacts from the use of the Pendolino trains on other or new railway lines. It can therefore be determined that extreme care should be taken when determining a model of the maximum noise levels or the SEL emanating from the Pendolino train line, due to the uncertainty of the noise levels according to speed.

For the Class 800 trains, there is no significant spread between the SEL over the various speed results. Therefore, it is reasonably safe to assume that a $\pm 1 - 2$ dB is considered normal when assessing noise levels in those types of trains. The limited spread of data for the Class 800 trains when compared to the Pendolino trains may very well be the difference in the Class 800 trains being newer and potentially better maintained.

It can be identified from the above Figures that not unsurprisingly trains with different speeds can produce the same $L_{A_{\text{max}}}$ noise levels. What this means is that there is a difference in overall noise levels between different trains which needs to be factored into any uncertainty budget when providing predictions of train noise levels for new railway lines.

REFERENCES
