Recent Challenges in the Practical Implementation of Operational Rail Noise Control in Australia.

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ABSTRACT

This paper provides an overview of some recent developments in rail noise management practice with a particular focus on some of the challenges (both technical and non-technical) that often confront the implementation of effective mitigation. The paper illustrates these challenges by reference to a range of operational rail noise and vibration examples covering: ground-borne noise, in-tunnel noise, train horns, wheel squeal, stabling yards and level crossings.

INTRODUCTION

Thompson (2007) noted that railway noise is now quite well understood and that control at source is increasingly recognised as more cost effective than measures such as noise barriers. But, at the same time, Thompson pointed out that "the practicalities of the rail industry are such that it faces many pressures that make it resistant to change".

This paper explores some of these challenges by way of case studies of some recent noise mitigation projects. To some extent this builds on the excellent insight into the technical challenges of rail noise control given in Thompson's paper. However, this paper also aims to expand on some of the non-technical challenges and, in particular, to highlight the importance of a critical review of the underlying purpose of operating procedures and characteristics that give rise to some of the noise issues in the first place.

Section 3 of Thompson's paper identifies 5 steps in approaching railway noise as a classical noise control problem; they may be summarised as follows:

- step 1: Identify the dominant source
- step 2: Quantify the various paths or contributions
- step 3: Understand how each source (and path / contribution) can be influenced
- step 4: Develop and test actual designs
- step 5: Address practical constraints

But, in addition to the "five Thompson steps", this paper highlights that a critical review of the underlying purpose of operating procedures and noise mitigation objectives (referred to as "step 0") is an important precursor, as explained further below.

RAILWAY OPERATING PROCEDURES AND RULES

Some of the significant sources of rail noise are caused (or governed by) railway operating procedures and rules. Audible warning systems are obvious examples of such procedures, such as the train horn, level crossing bells, or beeps and announcements to warn that train doors are about to close. Other examples include public address announcements on stations, the procedure for stabling trains overnight (sometimes with ancillary equipment running), and the need for some trains to idle at signals (sometimes for extended periods) to await a clear path for the onward journey.

Before considering a technical approach to noise arising from these procedures, it is clearly important to address: why the procedure is necessary; what the purpose of the procedure is; and whether this purpose can be achieved by an alternative procedure with lower noise levels. These questions form the critical review of the underlying purpose, referred to in this paper as "step 0", because it should occur before embarking on the "five steps" to noise control.

One example relates to audible warning signals from level crossings. These clearly serve an important safety purpose, but sometimes also lead to noise complaints from nearby neighbours. A review of the applicable standards for level crossings (and associated warning systems) identified a number of inconsistencies in the required sound levels. Among other things, it was found that a product type-test standard was being applied unnecessarily as an operational standard for field installations and that the definition of "ambient noise" (above which the level crossing warning should be audible) was not well defined (Hough et al, 2011). As a result of these reviews it may be possible to reduce the sound levels of level crossing warning systems and, thereby, minimise environmental noise impacts on neighbours. More importantly, however, these reviews will allow a better understanding of the underlying safety function of the audible warnings - without which it would be impossible to consider noise control without potentially undermining safety.

A second example relates to a historical procedure for drivers to routinely sound the horn when departing from station platforms. This had been a long standing procedure in NSW railways and was enshrined in Network Rule NTR 408 (SafeTracks, 2010). The practice dated back to when there were less reliable means of alerting passengers that a train was about to move. An extensive review was prompted by concerns about noise pollution from horns and concluded that the practice no longer delivered a safety benefit and could therefore be removed.

Train horns also often constitute the dominant noise source at stabling yards (Wilkinson Murray, 2010). Procedures require drivers to sound the horn in the event of an emergency (real, or perceived), although this is not a common occurrence. But horns are routinely sounded in yards on a much more regular basis for two purposes: to test the horn function before operating the train on the main line; and to warn of imminent movement of the train. By critically reviewing the operating rules it has been possible to identify a number of ways to reduce the noise impact of these procedures, including:

- removing the need to test the "country" horn (typically 5 dBA louder than the "town" horn);
- removing the need to test the horn at the trailing end of the train;
- moving trains to a designated location, as far as possible from surrounding receivers, to test the "town" horn (at the leading end of the train); and
- considering alternative methods for warning of imminent movement (such as a broad-band alarm).

It is clear from the forgoing examples that noise levels can sometimes be reduced (or indeed, in some cases, eliminated) without recourse to noise control engineering. However, the time required to achieve results must not be underestimated; the process generally involves safety risk assessments; industry consultation and updates to standards and/or procedures. The benefits can be very worthwhile, but generally they cannot be achieved within the timescale required for a specific project.

NOISE MITIGATION OBJECTIVES

A clear definition of the underlying purpose of noise control is also an important prerequisite for successful noise mitigation. This seems like an obvious step, yet it is frequently omitted.

For example "reduce rail noise levels by X dBA" may seem clear and noise control objectives for rail projects often take this form when projected noise levels exceed applicable guideline values. But the real objective is seldom this simple; in many cases the underlying motivation is to address the actual impact of noise on the affected community. Consider the contrast between these two hypothetical examples involving an objective to mitigate the impact of a predicted increase in rail noise levels of 1.5 dBA.

Hypothetical example 1 involves changing the track speed in an area from 50 km/h to 56 km/h, resulting in an estimated 1.5 dBL_{Aeq} increase in rolling noise. For broadband continuous noise, a 2 dB change is generally considered barely noticeable. While rolling noise is not continuous, it is broadband, so it might therefore be considered that the proposed speed change (and associated 1.5 dBA noise increase) would result in a "barely noticeable" change and that it would be very unlikely to have a major impact. Despite this, if it was decided to pursue noise mitigation, it can be seen that the objective to reduce rail noise levels at source by a "barely noticeable" 1.5 dBA would be sufficient to offset the effect of the speed change.

Hypothetical example 2 involves timetabling an additional 125 trains per day on an existing line that currently handles 300 trains per day. Assuming train speeds and types etc are unchanged, the increase in traffic would result in 1.5 dBL_{Aeq} increase in noise, generally considered to be "barely noticeable". But many residents are likely to notice the significant increase in the frequency of train passby events (and their associated noise). Reducing noise levels at source, such that each train passby event is a "barely noticeable" 1.5 dBA quieter, deals with the overall (L_{Aeq}) noise level but does not address the noticeable increase in traffic intensity. To deal with this would arguably require a more substantial (and noticeable) noise reduction of more than 1.5 dBA.

MANAGING THE TECHNICAL CHALLENGES OF RAIL NOISE CONTROL

The importance of the "five Thompson steps" for rail noise control can be illustrated by some recent examples of projects that considered the use of rail dampers, with varying degrees of success.

The first example relates to the Kingsgrove to Revesby Quadruplication (K2RQ) project, part of the rail clearways program in Sydney. Rolling noise was identified as the dominant source (Parker and Weber, 2010), thereby achieving Thompson step 1. The use of rail dampers, an emerging technology from Europe, was identified as having the potential to provide more cost-effective noise mitigation than barriers and building treatments, based on measurement data documented in the literature. A trial was therefore carried out but the results showed rather disappointing performance and rail dampers were therefore not adopted for the project.

There are a number of reasons why this trial did not provide the results that were initially expected and it is instructive to review this in terms of Thompson steps 2, 3 and 4. It should be emphasised that this is not a criticism of the project – rail damping had not been trialled before in Australia and some of the techniques for quantifying rail damping are still under development (Li).

Measurements to quantify the contributions to the rolling noise source at the project site were not carried out (Thompson step 2) and, instead, it was assumed that the mechanism was broadly consistent with findings reported in the literature from other railways. Theoretical modelling, taking into account local conditions, was not carried out (Thompson step 3) to understand how the rolling noise source mechanism might be influenced by rail damping (and, perhaps, to review the validity of the assumption made in step 2). Finally, limited work was done in advance of the trial to design the rail damping system to influence the source as intended (step 4).

The trial indicated that rail dampers would provide around 1 dBA of noise benefit rather than the 2 to 4 dBA reduction reported from overseas trials. Parker and Weber provide an excellent review of the underlying reasons for this and highlight, in particular, the influence of rail pad stiffness (typically much stiffer in Australia than in Europe) and wheel roughness. But the end result was that rail dampers were not accepted as a valid form of noise mitigation for the project and, more importantly, key stakeholders in the rail industry interpreted the trial results to mean "rail dampers are a waste of time and will not be considered further on this network".

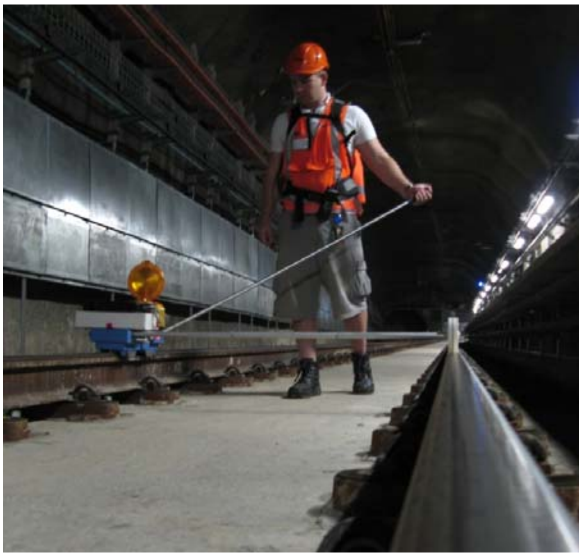

Figure1: Rail roughness measurement using the Corrugation Analysis Trolley

The next example involves the in-train noise issue on the recently completed Epping to Chatswood Rail Link (Coker and Anderson, 2010). Rolling noise was soon identified as the dominant source (Thompson step 1) rather than some of the other suggested explanations (such as wheel squeal and/or flanging noise). Despite some initial views that main contribution to the problem must surely be tunnel reverberation, rail roughness (Figure 1) and very lightly damped rail were quickly recognised as important factors (step 2).

Time did not permit detailed theoretical modelling to fully understand how each source component could be influenced, but this was instead achieved by means of a series of site trials and experiments (step 3) before progressing to the design and testing stage (step 4). The net result was that a practical solution was identified and implemented to achieve sufficient noise reduction (10 dBA) to resolve the issue. The solution involved the first use in Australia of sound absorption in track "4-foot" (Figure 2) and a special adaptation of normal rail grinding, not used anywhere else on RailCorp's network.

Figure 2: Installation of track-bed absorption

And, in contrast to the K2RQ example, rail dampers were found to contribute a very worthwhile 4 dBA to the noise reduction, leading to a reversal of the previously held view that "rail dampers are a waste of time and will not be considered further on this network". What followed were the largest single installation of rail dampers in the world at the time and the first in-tunnel installation (Figure 3).

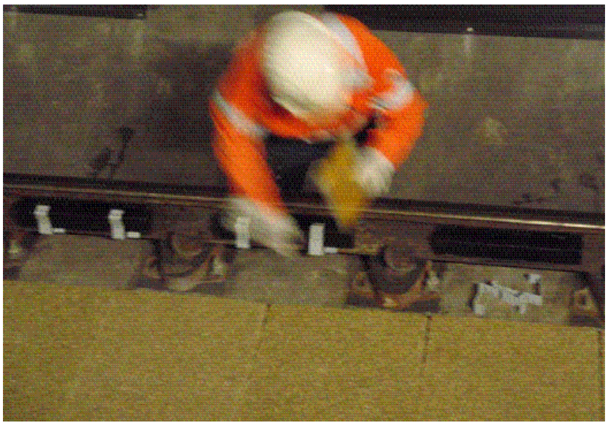

Figure 3: Installation of rail dampers

The final example relates to curve noise (wheel squeal and flanging). This has long been recognised as a technically complex issue, and good progress has been made by Jiang & Dwight (2006) and others (such as Bullen et al and Cowley et al) in identifying the source components (step 1) and their paths (Jiang et al, 2010), step 2. A rail CRC project is working hard to develop theoretical models that adequately explain the issue so that a better understanding can be achieved of how each component of the source can be influenced (Rail CRC project R1.128); step 3.

Ideally steps 1, 2 and 3 would be completed before proceeding to design and test mitigation designs (step 4). But, as is often the case when noise issues escalate, there is a strong motivation to make a start on trials of practical mitigation measures so a number of mitigation trials have already been carried out or are proposed. This includes a trial of rail dampers for the purpose of curve noise control.

Rather than halt or delay these trials to allow completion of the noise control steps (1 to 3), it must be recognised that the real-life pressures will sometimes override strict adherence to the technical methodology. In these circumstances the objectives should be to:

- Obtain the best possible technical insight into the trial so that, even if the overall result is not judged as a success, the underlying mechanisms can be better understood.
- Manage the expectations of the trial and the associated risk that an unsuccessful trial can undermine the reputation of a potentially powerful mitigation technology.

In summary, the technical steps for noise control are entirely logical, but practical circumstances often put them under pressure. On some occasions this can be overcome, but in other cases it is simply necessary to "swim with the tide" (rather than against it) while minimising risk and extracting as much technical value from the project as possible.

ADDRESSING PRACTICAL CONSTRAINTS

Addressing practical constraints in rail noise control (Thompson step 5) is a significant challenge in itself and, as noted in Thompson's paper, often involves the critical issue of safety.

To the lay person, some of the potential safety implications of noise control measures are obvious. A barrier structure near to the track, for example, presents an obstacle to emergency egress from the path of an oncoming train. But many of the safety issues are less obvious; for the rail damping technique, for example, safety concerns include: the toxicity of the bonding agent (particularly during installation in confined spaces, such as tunnels); the potential interference to signal circuits; and the shielding of part of the rail from visual inspection for corrosion and fatigue cracks. In many cases these safety concerns can be assessed and managed to reduce the risk to acceptable levels. However, it must be recognised that, until the safety implications are satisfactorily addressed, the process of introducing new rail noise control technology can not progress.

Availability of safe access to the track is also a significant practical constraint in the rail industry, and is often underestimated. Much of the monitoring work necessary to properly identify the dominant noise sources (step 1) and their components (step 2) can only be safely carried out or instrumented during track possessions. In some parts of the network these are rare, with the result that there are sometimes conflicts between routine inspection / maintenance tasks and noise investigations.

In addition to safety issues, there are of course a host of other practical constraints to noise control in an operating railway environment, as illustrated by the proposal to replace the existing rail fasteners in a rail tunnel under a theatre in Sydney. The dominant source of the problem (ground-borne rail noise in the theatre) was established many years ago (step 1); the paths were studied (step 2); the potential for each component to be modified was reviewed (step 3) and a design proposal was established (step 4) approximately 10 years ago involving the replacement of the existing rail support system with the Pandrol Vanguard system (a very resilient rail baseplate, Figure 4).

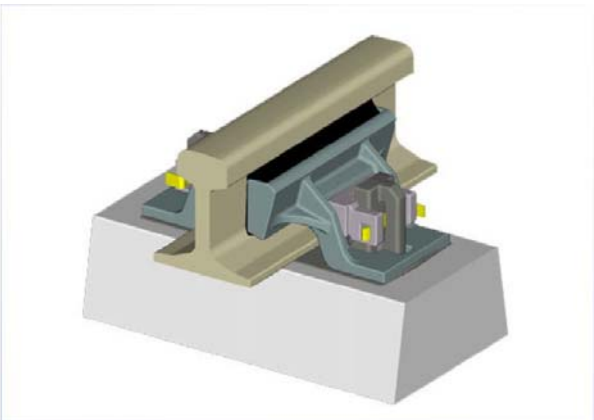

Figure 4: The Pandrol Vanguard resilient support system (picture courtesy of Pandrol)

A number of the practical constraints were addressed, such as the critical limit on headroom in the tunnel (meaning that the rail height could not be raised) and the need for a construction methodology that facilitates phased installation over successive night-time track possessions. But, until recently, a number of practical questions remained, meaning that the proposal could not be pursued. These included: whether the existing track slab had sufficient remaining design life to warrant the proposed fastener replacement (Figure 5); and whether the existing slab would need to be modified to allow the resilient fasteners to work and/or to prevent unwanted dynamic interaction and corrugation development.

Figure 5: Core drilling an existing track slab to investigate remaining design life

Another perspective on the issue of "practical constraints" is the broader organisational and industry context. The transport task is the core business for a railway, not noise control. While the need to manage noise is widely recognised in the rail industry, this represents just one step towards a technically robust, strategic, long term approach to understanding and managing the issue.

In terms of understanding the issue, the reality is that the rail industry at large will always struggle with some of the technical subtleties and complexities of rail noise. For example:

- "Rail roughness" to a rail engineer is synonymous to "rough track" (such as severe corrugations, wheel burns and other defects, Figure 6) rather than the sub-micron undulations in rail surface profile that are invisible to the naked eye, yet control rolling noise (Hanson et al, 2011). The same applies to wheel roughness.

Figure 6: Example of "rough track" (as distinct from rail roughness)

Figure 7: Scratch marks visible on rail head immediately after grinding

- Elevated noise after rail grinding is invariably assumed to relate to the "scratch marks" that are often visible on the rail head immediately after the grinding process (Figure 7), despite the fact that the contact filter attenuates this effect (for example, White 2011). As patiently reiterated by Hanson (letter to RTSA, 2011), longer wavelength undulations are the real cause of elevated noise levels after grinding (Figure 8).

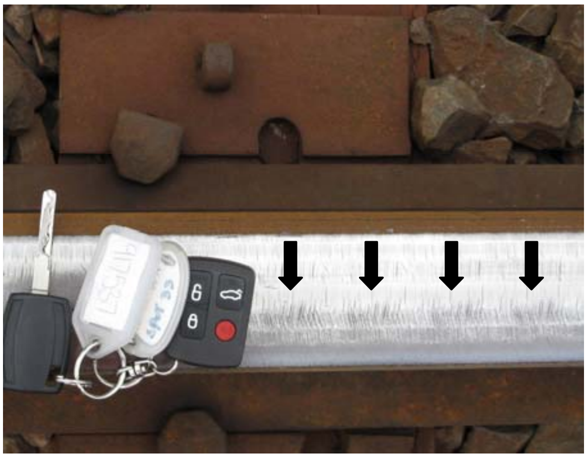

Figure 8: Evidence of undulations due to rail grinding

- Resilient rail fasteners and baseplates are often confused with rail dampers. Surely rubberised rail supports must contribute damping to the system? Of course, the reality is that, while the overall system damping may increase, the effective rail damping actually *decreases* as the rail support becomes more resilient (Thompson, 2009).

- "Noise issues" are generally considered as causes of annoyance and complaint, while the broader impacts of noise (such as health) are often overlooked. As a result, the impact of noise from "noisy defects" (such as wheel burns) or specific "high noise" issues (such as wheel squeal) is acknowledged while the impact of "normal rolling noise" may not be.

In terms of managing the issue, the reality is that project timeframes and "core business" will often take precedence over the ideal sequence of steps towards noise mitigation. The challenge for the acoustic engineer is to assist the rail industry to rapidly address priority issues as they arise, while using them as stepping stones towards a longer term vision where possible. The involvement of a number of rail industry partners in the Rail CRC research project on noise is an excellent example of this, whereby practical trials carried out by the industry are studied in detail by an academic research team to understand the underlying mechanisms and develop robust noise control solutions.

CONCLUSIONS

This paper uses a number of practical examples to illustrate the importance of Thompson's 5 steps to rail noise control. The paper also highlights the importance of properly defining the underlying need for certain noise generating procedures and the noise control objectives, and emphasises the significance of the challenges associated with step 5 (addressing practical constraints).

REFERENCES

Bullen, R & Jiang, J, *Algorithms for Detection of Rail Wheel Squeal*, Proceedings of 20th International Congress on Acoustics, 23-27 August 2010, Sydney, Australia.

Coker, D & Anderson, D, *Reducing In-Train Noise on the Epping to Chatswood Rail Link*, Conference on Rail Engineering, September 12 – 15 2010

Cooperative Research Centre for Rail Innovation, Project R1-128, *Improved Noise Management*, http://www.railcrc.net.au

Cowley A, Kopke U, Lindqvist P, Hamilton R, Rennsion D, Southern C and Sowden M, *Operating the RailSqad wheel-rail noise monitoring system*, 7th International Conference on Contact Mechanics and Wear of Rail/Wheel Systems, 2006

Hanson, D, Letters to the Editor, Railway Technical Society of Australasia, NSW Chapter Newsletter, July 2011

Hanson, D., Anderson, D, Schulten, C, Boxoen, T, *Some Pitfalls in Using AS2377:2002 for Passby Noise Measurement*, Submitted for Acoustics 2011

Hough, C, Schulten, C, Burgemeister, K, Shimada, S, *Ambient Noise Levels for Assessing Level Crossing Audible Warning Devices,* Submitted for Acoustics 2011

Jiang, J & Dwight, R, *Determining wheel-rail wear conditions using wheel-rail noise*, 7th International Conference on Contact Mechanics and Wear of Rail/Wheel Systems, September 24-26 2006

Jiang, J., Dwight R., and Anderson, D., *Field Verification of Curving Noise Mechanisms*, IWRN10, 18-22 October 2010

Li, W, Jiang, J, Dwight, R, Schulten, C, *An investigation of a method for track decay rate measurement using train pass-bys* Submitted for Acoustics 2011

Parker, A, Weber, C, *Rail Dampers – The First Australian Field Trial*, Proceedings of 20th International Congress on Acoustics, 23-27 August 2010, Sydney, Australia

SafeTracks, *NTR 408 Using train whistles and TWP 160 Driver procedure at stations*, Issue 05, 2010

Thompson, D, *But Are the Trains Getting Any Quieter?*, 14th International Convention on Sound & Vibration, 9 – 12 July 2007

Thompson, D, *Railway Noise and Vibration: Mechanisms, Modelling, Means of Control*, Elsevier 2009, ISBN-13: 978-0-08-045147-3

White, M, *New Techniques in Rail Grinding and Rail Flaw Detection*, Presentation to the NSW Chapter of the Railway Technical Society of Australasia, June 2011

Wilkinson Murray, *Emu Plains Stabling Project - Noise & Vibration Assessment*, Review of Environmental Factors for Emu Plains Stabling Yard and Associated Works, November 2010, Appendix I (www.railcorp.info /community/emuplains accessed September 2011)