Brake Car Noise Monitoring and Assessment

Peter Edwards

Professor Jie Pan
School of Mechanical and Chemical Engineering

Chris Wakeling
CEED Client: Rio Tinto

Abstract

When ore filled trains enter a dumping cycle after arriving at the ports, a compressor brake car (CB car) is attatched to the rear of the train to provide the compressed air and a dragging brake. The CB cars used by Rio Tinto at the Parker Point dumpers have been identified as the cause of high pitch squealing. As operations occur in such close proximity to Dampier residents, excessive noise is an issue that affects Rio Tinto's social licence to operate within the local community. Since their introduction at the Parker Point dumpers, a variety of projects have aimed to reduce the noise created by the CB cars. This project will monitor and assess the noise levels produced by the CB cars, assess the effectiveness of prior modifications and to determine the most appropriate methods of noise reduction in the future. Initial results indicate that none of the current modifications have provided sufficient noise attenuation. Wheel temperature measurements suggest that noise damping technologies usually reserved for passenger rail could be applied to this heavy haul application.

1. Introduction

Rio Tinto Iron Ore's Rail Division services 13 mines via a mainline system of approximately 1,400km of track. Each train is operated by a single driver and comprises 3 locomotives hauling up to 234 ore cars. A fully loaded train can be up to 2.4km in length and weigh up to 30,000 tonnes.

When loaded trains arrive at the ports, ore is removed by one of five rotary car dumpers, three located in Dampier, at Parker Point and East Intercourse Island, and two at Cape Lambert. This project is concerned with the two Parker Point dumpers in Dampier only. During dumping, an indexing machine moves the entire train two car lengths towards the rotary dumpers, positioning the cars for dumping. As a result of the train's length and the draft package (spring-damper system) between ore cars, in-train forces propagate along the train each time the train is indexed through the dumper. This leads to high loading and wear of couplers and draft packages, and in some undesirable instances the separation of the train.

To prevent train separations a compressor brake car (CB car) is used to provide a retarding force at the rear end of the train which reduces in-train forces. The CB cars provide this retarding force by way of a brake system that consists of brake blocks being applied to the tread of the wheel. The application of the braking system has a tendency to produce a high pitch squeal which is a problem that affects the local community in Dampier and has resulted in multiple complaints. There are several CB cars with various adaptations aimed at minimizing the brake squeal. However, no solution has yet been achieved. This project is in line with Rio Tinto's 2011 environmental improvement plan and noise exposure reduction targets of twelve percent in 2013 exposure.

1.1 Mechanisms of noise generation

A review of current literature has identified flange squeal and brake squeal as the most common sources of squealing noise in rail applications. Flange squeal involves the grinding of the wheel rim on the rail head and typicaly occurs around bends in the track (Thomson, 2006). Brake squeal arrises from a stick slip interaction between the brake and wheel tread that excites the system at its natural frequency (Wagner, 2010). By comparing the frequency plots of both flange squeal (measured from ore cars navigating a curve) and brake squeal (measured during a trains braking application) it is possible to rule out flange squeal as the cause of the undesirable noise. A frequency plot of a flange squeal event shows excitation over a broad upper frequency range, measurements of the CB cars, however, show relatively narrowband excititation at high frequencies, typical of a brake squeal event.

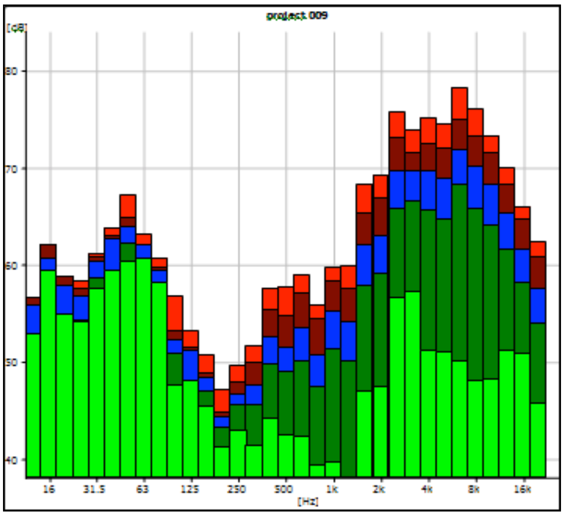

Figure 1. Typical flange squeal frequency Plot.

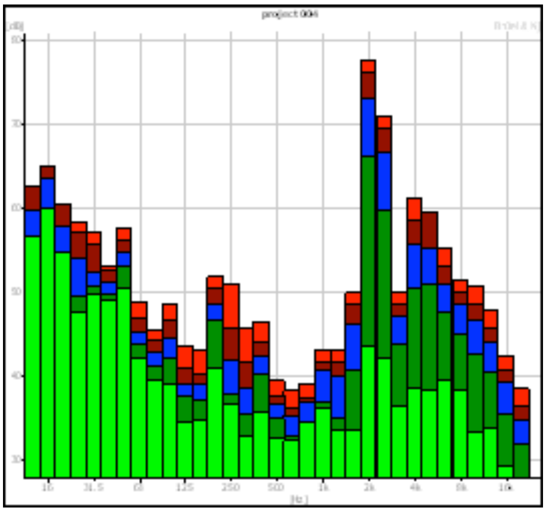

Figure 2. Typical brake squeal frequency plot.

1.1 Noise monitoring

By monitoring the brake noise it will be possible to determine the sound levels and the frequency at which the squeal occurs. This will provide an insight into the scale of the noise problem and determine what noise damping methods can be succesfully adopted.

Initialy, permanant noise monitors were to be installed on each of the brake cars as the noise was reported to only occur intermitantly, however after significant delays in supply this became an unfeasable option due to the time constraints of the project. After observing the CB cars in the dumping cycle, it became evident that the brake squeal was relitively predictable and reliable. This allowed noise monitoring of the brake cars with a handheld sound level meter which simplified the analysis of measured data.

1.3 Noise damping techniques

Many noise damping and attenuating techniques have been applied to the brake cars. These include the trial of alternate brake shoe materials, noise skirting around the brake cars and even plans to lubricate the wheel rim. There are a variety of modifactions that are still present on the CB cars. The most commmon is an application of damping paints and coatings to the face of the wheels. However, studies show that the large mass (500kg) of the wheel is likely to limit the success of such methods (Mead, 1998).

When SKM was engaged to address the problem of brake car noise, their solution was to model the brake beams in a coupled relationship to the wheels. Knowing the resonantant frequency and modes of oscilation, masses were placed at specific location on the brake beam with the intention of damping the aplitude of oscilation. Its been suggested by those that worked on the project that the positioning and mass were required to be very specific and the method was not ideal for the intended aplication.

The latest damping technique employed is known as constrained layer damping (CLD) which consists of a resiliant material sandwiched between two rigid plates. This was then connected to the face of the wheel. When the plate deforms due to vibration, shear forces occur in the damping material which convert the kinetic energy of vibration to heat energy. Although basic in concept, the cost of outfitting the five brake cars with CLD in 2008 exceeded 1.4 million dollars. Only one CB car remains with CLD applied to its wheels.

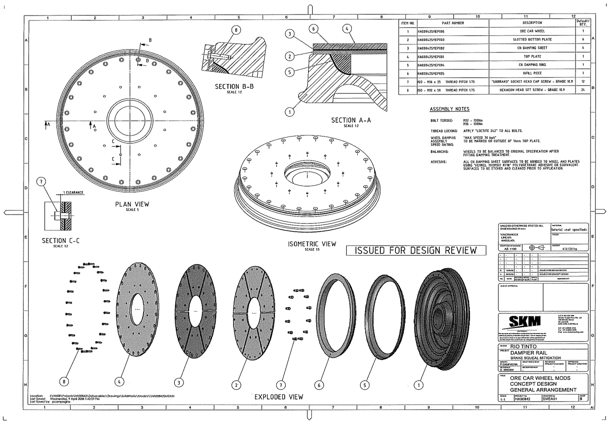

Figure 3. Constrained layer damping solution designed by SKM.

Many damping techniques that have succesfully been adopted for passenger rail have not been applied to heavy haul applications as the wheel temperature is generaly much greater. As the brake cars are only utilized over a short route it is possible that the wheels do not generate excessive heat and can be modified with technologies typicaly reserved for passenger rail. This project will determine whether these technologies are applicable on the CB cars.

1.4 Project objectives

The project hopes to achieve the following objectives.
- Establish baseline noise levels.
- Compare the effect of current modifications on each of the CB cars.
- Review state-of-the-art noise damping methods.
- Assess the most appropriate options future work

2. Process

2.1 Noise monitoring

As per the recommendation of the standards AS 1055.1-1997 and AS 2377-2002 a class one sound level meter will be used to measure the brake car noise. This meter will conform with

AS IEC 61672.1-2004 and will be calibrated accordingly. Although the methods for the measurement of railbound vehicle noise (AS 2377-2002) was referred to, the specific applications and dynamics of the brake cars makes many aspects of the standard irrelevant. Because of this reference was also made to the standard for the discription and measurement for environmental noise (AS 1055.1-1997)

To assess the noise emited from the CB cars, a Bruel and Kjear 2250 sound level meter was used. The meter allowed the recording of the 1/3 octave frequency domain. It also had the ability to record .wav files of the occuring noise. These can be analysed to produce narrowband analysis of the sound. Although the meter did not log data in the time domain, this could be modeled by taking data at set intervals along the track.

In order to analyse the data recorded by the sound level meter B & K utility software was used. The software produced sound level plots across the frequency domain and provided the option to export sound data to a microsoft excell file format.To anylise and edit the .wav files, a freeware application called 'audacity' was used. This software is commonly used in industry and often bundled with acoustic devices. The files could then undergo fft analyis in matlab software available at UWA.

In order to determine the effect of the CB cars postion in the dumping cycle and the elevation in wheel temperature, measurements were recorded at various positions along the track. The first at the beginning of the dumping cycle, adjacent to the dampier community. The second in front of 'Kangaroo Hill' acomodation within the parker point site and the third in front of the Parker Point workshop. The three positions are 750m apart and represent the sections of track closest to residences and workplaces.

The sound level meter will be positioned three meters from the side of the track and one meter off the ground. Where possible it will be located adjacent to the noisiest wheelset. The sound level meter will be calibrated before and after each measurement. If a calibration drift greater than 1dB is present the measurement will be disgarded as per AS IEC 61672.1-2004.

2.2 Wheelset temperature identification

To gain an understanding of typical wheelset temperatures to determine what damping materials could potentially be applied to the wheels, an IR temperature measurement gun was used. Measurements were taken from the brake block and the side of the wheels outer rim (as the rim itself is lusterous it cannot directly be measured). To improve the accuracy of the reading, black tape can be applied to the wheel to provide better emissivity, however the measurement device was able to compensate for a range of emisivities.

Measurements are taken at the time and location of the sound level recordings. As well as this, measurements will be taken at the end of the braking cycle and at significant brake applications to determine the peak temperatures encountered.As measurements will be taken at a relatively cool time of year, calculations will be made to account for increased solar radiation as steel components in the direct sunlight will heat up significantly.

3. Results and Discussion

Table 1 (below) outlines the modifications that have been applied to each of the brake cars., while Table 2 summarises the results of the CB car noise monitoring

	Modification		
Brake Car	Constrained layer Damping	Deci-Damp Paint	Brake Weights
CB01	No	No	No
CB02	1 wheel set	No	No
CB03	Yes	No	No
CB04	No	Yes	Yes
CB05	Yes	No	Yes

Table 1. Brake car modification distribution.

Brake Car Number	Location	Temp	Key Resonant Frequency	LZFmax at resonant frequency	LZeq at Resonant Frequency	Broadband LAeq	Dumper
CB-01	Position 1	35.6	4000	94.7	81.5	83	CD3P
CB-01	Position 1	48	4000	93.1	81.7	83.6	CD3P
CB-01	Position 2	57.1	4000	87.3	74.8	76.9	CD3P
CB-01	Position 2	40.2	4000	91.4	78.5	80.5	CD3P
CB-01	Position 3	59	4000-5000	86.2	73	77.7	CD3P
CB-01	Position 3	48.2	4000	94.7	81.6	83.6	CD3P
			Average	**91.2**	**78.5**	**80.9**	
CB-02	Position 1	41.2	2500	96.5	81.9	83.4	CD4P
CB-02	Position 1	43	2500-4000	94.9	80.5	85.5	CD4P
CB-02	Position 2	43.2	2500-5000	88.1	75.5	79.1	CD4P
CB-02	Position 3	51	2500-5000	81	72.4	75.5	CD3P
			Average	**90.1**	**77.6**	**80.9**	
CB-03	Position 1	N/A	N/A	N/A	N/A	N/A	N/A
CB-03	Position 2	39	500-800, 4000	89.3	71.8	76.3	CD3P
CB-03	Position 3	44.6	800, 4000	93.6	80	83.8	CD3P
CB-03	Position 3	48.7	800, 4000	91.5	75.1	78.8	CD3P
			Average	**91.5**	**75.6**	**79.6**	
CB-05	Position 1	39.5	800	87.9	65.2	68.5	CD3P
CB-05	Position 1	32	100, 500	83.3	74.2	68.8	CD4P
CB-05	Position 2	52.1	800, 2500	97	75.7	78.6	CD3P
CB-05	Position 2	39.8	N/A	N/A	N/A	71.2	CB4P
CB-05	Position 3	40	500, 2500	99	80	83	CD3P
CB-05	Position 3	41.2	800, 2500	95	72.4	96.3	CD3P
			Average	**92.4**	**73.5**	**77.7**	

Table 2. Noise monitoring results

When analysing the data it can be seen that a change in wheel tread/brakeblock temperature has no correlation to the noise produced nor does location in the dumping cycle as suggested in prior work by acoustic consultants (SVT 2006). The data suggests that CLD attenuates the general noise of the brake cars, and limits the rate of occurance of squeal, however, when squeal does occur it is typicaly louder than that of an unmodified wheel. It should be noted that the frequency of the squeal is significantly lower and at multiple resonancies making it less irritating. It is possible that the altered geometry or the additional weight of the wheel could be contributing to this. Without the measurement of CB-04 it is too early to comment on the effectiveness of the brake weights or damping material applied to the wheelsets.

4. Conclusions and Future Work

Further monitoring is required to capture data relating to brake car CB-04. This will allow all modifications to be compared with relative independents.

From the data, one can conclude that brake squeal in the CB cars is dependant on the car number and therefore the modifactions applied. None of the noise attenuation measures have properly addressed the issue of brake squeal. As the process of trial and error based modifications are costly and have not provided the desired attenuation. There is a need to be able to accurately model the system to more reliably predict the effect of future modifications. By using the data gathered, the real system and modifications can be compared to a computer model as a measure of its accuracy.

5. References

SVT Engineering Consultants, 2006. *Comparison of Site Noise Measurements between the Constrained Layer Damped Wheels with Dec-Damped Brake Car Wheels.*

Standards Australia 1997, *Acoustics - Description and measurement of environmental noise - General procedures.* AS 1055.1-1997. Standards Australia Online.

Standards Australia 2002, *Acoustics - Methods for the measurement of railbound vehicle noise.* AS 2377-2002. Standards Australia Online.

Standards Australia 2004, *Electroacoustics - Sound level meters - Specifications*. AS IEC 61672.1-2004. Standards Australia Online.

U. von Wagner, G. Spelsberg-Korspeter, 2010. *Minimal Models for Squealing of Railway Block Brakes*, Springer-Verlag.

Thomson, D. and Jones, C., 2006. *Handbook of Railway Vehicle Dynamics*. Florida: Taylor & Francis Group, LLC

Mead , D.J., 1998. *Passive Vibration Control*, John Wiley and Sons