Journal of ENVIRONMENTAL Treatment Techniques

Enviro. Treat. Tech.

ISSN: 2309-1185

Journal web link: http://www.jett.dormaj.com

Field Investigation of Metro Rolling Noise

Javad Sadeghi[1], Araz Hasheminezhad[2]*

1- Centre of Excellence in Railway Transportation,
2- M.Sc of Railway Engineering, School of Railway Engineering, Iran University of Science and Technology, Narmak, 16844, Tehran, Iran.

Received: 05/05/2014 Accepted: 31/05/2014 Published: 12/06/2014

Abstract

This paper presents a field study on railway noise measurement in a tight curve and a tangent track of Tehran Metro Network in Iran. Nowadays as railway and metro tracks often pass through densely populated areas, especially in central parts of big cities, noise is usually the most common reason given for objecting to railway developments. As a result, significant progress has been made in noise control over the last decades. More recently, high interest was given to measuring railway noise and understanding the different sources contributions in order to help reducing global external noise. In this research, sections of Tehran Metro Network, which are located near a high resident people density area with a limited but significant traffic, were selected. In these sections, railway noise seemed to have been tolerated in the past, but is today increasingly being considered as a nuisance for the residents. Noise generated by the railway vehicle was recorded by field tests based on the acoustic standard ISO 3095. Measured noise levels in two different test sections including the tangent track and the curve have been evaluated and compared. Furthermore, metro rolling noise has been detected and separated using band-pass filtering.

Key words: Field Tests, Noise Sources, Rolling noise

1 Introduction

Although metro is an environmentally friendly means of transport, it is perceived as noisy. Noise can produce annoyance or in more extreme cases, adverse effects on human health such as increased stress, high blood pressure or cardiovascular diseases [1]. Public opposition to new metro lines developments is often focused on the noise impact, either because this is the perceived nuisance or sometimes because it is a convenient handle to legitimize objections. Nowadays as metro lines often pass through densely populated areas, especially in central parts of big cities, noise is usually the most common reason given for objecting to metro developments and as a result, significant progress has been made in noise control over the last decades. Assigning high priority to solving problems related to metro noise is quite imperative for railway administrations. The discussion on metro noise has become very important in several countries as metro transport increases and plays a more important role in greening transportation. More recently, high interest is then given to measuring metro noise and understanding the different sources contributions in order to help reducing global external noise [1]. Noise has been the subject of significant research effort in terms of understanding the mechanisms of generation and its contributing factors with the aim of developing concepts for its reduction. Railway noise has been studied extensively since the 1970s and models of railway noise prediction are now well established. Thompson's book [1-12] is a comprehensive reference covering the overall topic of railway noise and vibration, including analysis of rolling noise mechanisms, modeling and control. Theoretical models such as TWINS which was developed by Thompson provide the key to understanding and controlling noise and vibration. Many standards and guidelines have also been developed regarding railway noise and vibration. Three European or international standards are particularly relevant to rail irregularities and noise including EN ISO 3095, EN 15610, and EN 13231-3[3]. Among these, the standard ISO3095 specifies the conditions required to achieve reliable, reproducible measurements of the noise emitted by railway vehicles [2]. Its appendix gives a description of rail roughness measurement and processing techniques, which specifies the acoustic roughness of a test section to be used for acoustic type testing of railway vehicles required for researches. Although, noise prediction models such as TWINS give a clear understanding of the sources of railway noise, but there is no comprehensive reference that covers field measurement of metro noise based on a widely spread standard in railway engineering. This paper attempts to fill some of these gaps by presenting field measurements of metro noise and it presents measurements of noise induced by the passage of railway vehicles in service operation based on acoustic standard ISO 3095 which is up

Corresponding author: Araz Hasheminezhad, M.sc of Railway Engineering, School of Railway Engineering, Iran University of Science and Technology, Narmak, 16844, Tehran, Iran, 1684613114 | Tel: +98 21 77240540, E-mail: Arazcivileng@yahoo.com.

to now, the only widely spread standard for rail roughness measurement that can be referred to. In this regard, this study begins by presenting test site location, test set up and measurements of noise induced by the passage of railway vehicles in service operation and then of the corresponding noise sources detection. Then rolling noise separation using Band-pass filtering has been carried out in the tangent track and the curve. The following parts show the application of a series of field measurements for metro noise that have led to research satisfying results.

2 Test Site

Test sites were required to perform field measurements and collect related historical data. Test track sections were selected after exploring several sections taking into consideration limited selection criteria. The selection criteria were prepared to reflect the research objectives and methodology. Tehran is the most important Iranian cities, industrial and economic centre in several sectors with a high resident people density in the urban and suburban area live about 8 million people. As indicated in Figure 1, the test site is located near a high resident people density area with a limited but significant traffic in which railway noise seemed to have been tolerated in the past, but is today increasingly being considered as a nuisance for the residents. A small radius curve and a tangent track in Tehran Metro Network in Tehran were selected as reference where noise is a known problem. Track features of the existing situation are shown in Table 1. The considered track section is uniform along its length. The railway track is ballasted and has two parallel tracks in standard gauge (1435m), without any gauge widening also in the curve. The track under study corresponds to the tangent track with 47 m length, the inner rail of a curve, having approximately 300 m radius and 25 m length. Traffic is mainly composed of trains of the urban passenger service. Figures 2 and 3 illustrate two pictures of the track sections including the tangent track and the curve at the measurement site.

3 Noise Measurement Test Procedures

Noise in the track sections was measured in March 2012 between 8:00 and 10.00 A.M for a special type of railway vehicle which characteristics has been given in Table 2 and its picture in Figure 7. The measurements were performed in accordance with the standard ISO 3095, as indicated in Figure 4. Microphones were positioned at 7.5 m from track centre and 1.2 m above the top of the rail as shown in Figures 5 and 6. The weather conditions (wind speed and wind direction, temperature and rain) were controlled before and during the measurements. The used measurement equipment is summarized in Table 2.

Figure 1. Measurement Site Location

Figure 2. Measurement Site Location - The tangent track

Figure 3. Measurement Site Location – The curve

Noise measurements have been performed based on the geometrical elements that allow testing the trains at a maximum operating speed as shown in Figures 8 and 9. The results of noise measurement have been analyzed as follows.

Table 1. Track system at Measurement site

Component	Type
Track	Ballasted-CWR
Rail	UIC 60 rail (steel grade 900A)
Fastening system	Vossloh
Sleeper	B70

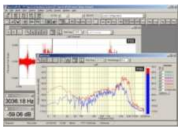
4 Test Results

The sound pressure level presented versus time in terms of seconds for the registered train passage are shown in Figures 10 and 11. The speed for the train passage was approximately 40 km/h because of the imposed speed limit on the track. As can be seen in these Figures, noise signal in the tangent track and the curve comprises wide spread of frequencies which is contributed to different sources.

4.1 Separation of Railway Noise Sources

Noise is a by product of the power generated by the engines and the interaction of the rolling stock and the tracks. With the massive and large loads of most freight and passenger trains, it is not surprising how much noise a train generates.

Table2 -Noise Measurement Equipment

Equipment	Type	Picture
Microphone at the tangent track	AT8015 CARACTERISTIQUES TECHNIQUES	
Microphone at the curve	E-818 SII	
Sound Level Calibrator	TES 1356	
Data Recorder	LAPTOP P4 ACER INTEL PENTIUM	
Software	SpectraLAB	

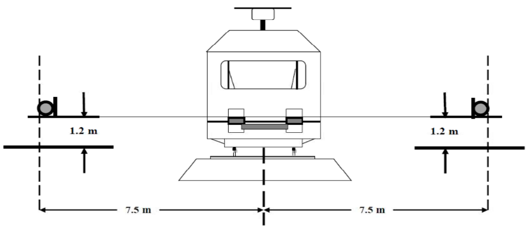


Figure 4. Microphone position in accordance with the standard ISO 3095

Figure 5. Microphone position in accordance with the standard ISO 3095 in the tangent track


Figure 6. Microphone position in accordance with the standard ISO 3095 in the curve


Figure 7. Railway Vehicle used in field measurements

Figure 8. Noise Recording by railway vehicle passing in the tangent track

Figure 9. Noise Recording by railway vehicle passing in the curve

Table2-Railway Vehicle characteristics

Railway Vehicle Type	TM3
Year of Fabrication	2003
Total length	140 m
Distance between bogies' axles	19 m
Distance between bogies' wheels	2 m
Total width	2.6 m
Total height	3.6 m
Maximal travelling speed	80 km/h
Total train weight (8 wagons and 2 locomotives)	240 t
Wagon length	19 m
Bogie frame	H Type
Bogie weight	7470 kg
Bogie type	Bolster Without Osbestos
Wheel Diameter	1200mm

There are a number of noise sources associated with the operational railway, of these, rolling noise is often considered to be the most important. Aerodynamic noise is another source; but this only applies to high-speed trains. Train horns are another source, but in this case, horn soundings are distant. Rolling noise is generally higher from poorly maintained rail vehicles, and from trains running on poorly maintained infrastructure. Aerodynamic noise is particularly relevant for high-speed lines. Engine noise is most relevant at lower speeds up to about 30 km/h, rolling noise above 30 km/h and aerodynamic noise dominates above 200 km/h. The most important noise source is rolling noise, which affects all kinds of train. The only relevant sources in Tehran Railway Network as shown in following are the traction and the wheel-rail interaction of the railway vehicles and the track. Locomotives generate noise from the air intake, engine casing, traction, and exhaust. Because of their low rotational movement, the locomotive engines normally generate low-pitched noise. Locomotive noise in this case is transient because the locomotives usually pass relatively quickly. In other words, they are not expected to idle or perform back-and-forth movements on a regular basis. Railway vehicles generate rolling noise, which the sound is associated with the vibration of the wheels, the bogie, the body of the railway vehicle, and the interaction of the wheels with the rails and sleepers on the track. Previous researches have shown that rolling noise is a significant source of railway noise and originates mostly from the wheels and rail - not the bogie or the railway vehicle bodies[1]. The character of railway noise is a low frequency bass sound as the locomotives pass. The rolling noise, however, is largely a mid-frequency spectrum where the ear is more sensitive. Because the duration of rolling noise is typically much longer than locomotive noise, the rolling noise is the dominant impact. The propagation of wheel and rail noise to residents in Tehran Railway Network is dominant because the most significant effect on the noise emissions from wheels and wheels are their roughness. Since noise is a product of vibration, the rounder and smoother the wheel and the rail are, the lower the vibration and the lower the noise. In this case, a regular pattern of roughness has been occurred on the track, which creates a corrugation in the rail, which is the main reason of railway rolling noise. Sections of the tangent track and the curve having severe corrugation have been revealed in Figures 12 and 13.

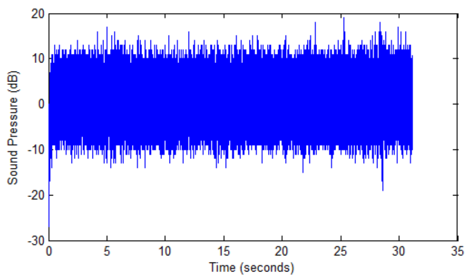


Figure 10. The noise measurement signal at the tangent track

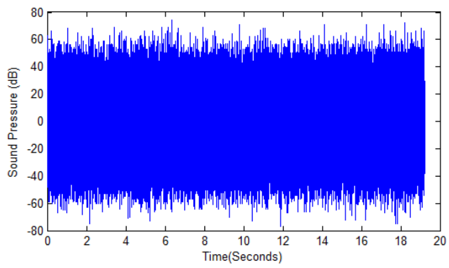


Figure 11. The noise measurement signal at the curve

Figure12. Rail corrugation at the tangent track

Figure 13. Rail corrugation at the curve

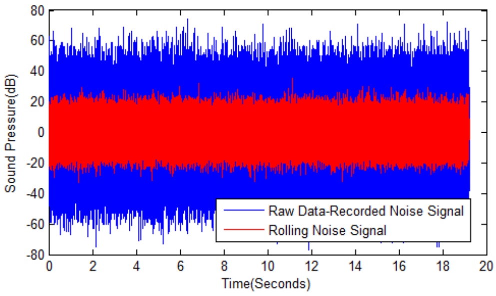


Figure 14. Extracted rolling noise from original noise signal at the tangent track

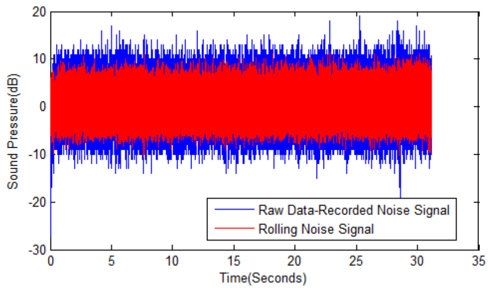


Figure 15. Extracted rolling noise from original noise signal at the curve

In this paper, railway rolling noise as the dominant source of railway noise has been extracted using band-pass filtering of Butterworth filter of order 4. Because of the rolling noise extraction from original recording noise signal, no noise information was obtained on the effects of other noise sources like traction noise. From the Literature review on railway noise and measurement of rail irregularity, it could be assumed that the frequency range of importance for rolling noise is considered to be 100–5000 Hz by Thompson [1]. In this paper, band-pass filtering was executed by wavelength of mentioned by Thompson to extract only the signal related to rolling noise. Figures 14 and 15 illustrate the extracted rolling noise signal using Band-Pass Filtering for the tangent track and the curve. As shown in these Figures, rolling noise in the tangent track is much more than the curve. In fact, for the tangent track, railway noise contributing source is rolling noise.

5 Conclusions

Railways and in particular metros are a sustainable and climate friendly means of transport. Nonetheless, metros do influence the environment. The most important effect is noise, especially the noise emitted from trains in high resident people density areas. The propagation and excess attenuation of railway noise are described by prediction models such as TWINS. However, because of limited accuracy in prediction models, particularly for large distances in Railway Network Projects, it was required to measure metro noise in field study which obviously can be a very accurate estimate in accordance with a widely spread standard for railway noise. This research was a response to this need by conducting a field measurement of railway noise in two sections of Tehran metro network in accordance with Acoustic Standard ISO3095. Through this study, the analysis of measured noise levels on the curve and the tangent track has been evaluated and compared. Furthermore, railway noise sources have been detected and separated using band-pass filtering. In that case, the accuracy of detecting railway noise sources has been improved.

Acknowledgments

The study reported in this paper was performed in Tehran railway Network that was funded by Tehran Urban and Suburban Railway Operation Co. The authors are grateful for this support and the advice, co-operation and help of the following: Eng. M.H.Esmaeili, Eng. S.Cheraghi, Eng M. Aghaei and Eng. M.Ashari without whom this research would not have been completed.

References

1 Thompson DJ. Railway noise and vibration: mechanisms, modeling and means of control. Oxford, UK: Elsevier, 2009.
2 EN ISO 3095:2005. Railway applications – acoustics – measurement of noise emitted by rail bound vehicles.
3 Remington PJ, Rudd MJ, Ver IL, et al. Wheel/rail noise, parts I-V. Journal of sound and vibration 1976; 46: 359–451.
4 Remington PJ. Wheel/rail rolling noise what do we know? What don't we know? Where do we go from here? Journal of Sound and vibration 1988; 120: 203–226.
5 Thompson DJ, Hemsworth B, Vincent N, et al. Experimental validation of the TWINS prediction

program for rolling noise, parts 1 and 2. Journal of Sound and vibration، 193 (1996) 123–147.
6 TWINS (Track Wheel Interaction Noise Software), Theoretical and User's Manual (version 3.0), TNO Institute of Applied Physics, Delft, The Netherlands, 1999.
7 S. Grassie, J. Kalousek, Rail corrugations. Characteristics, causes and treatments, Proceedings of the Institution of Mechanical Engineers Part F – Journal of Rail and Rapid Transit 207 (1993) 57–68.
8 EN 15610:2009. Railway applications – noise emission – rail roughness measurement related to rolling noise generation.
9 EN 13231-3:2006. Railway applications – track – acceptance of works – part 3: acceptance of rail grinding, milling and planning work in track.
10 Nielsen JCO and Ekberg A. Acceptance criterion for rail roughness level spectrum based on assessment of rolling contact fatigue and rolling noise. Wear، 271 (2011) 319–327.
11 J.C.O. Nielsen, A. Ekberg, R. Lundén, Influence of short-pitch wheel/rail corrugation on rolling contact fatigue of railway wheels, Proceedings of the Institution of Mechanical Engineers Part F – Journal of Rail and Rapid Transit 219 (2005) 177–187.
12 A. Ekberg, E. Kabo, J.C.O. Nielsen, R. Lundén, Subsurface initiated rolling contact fatigue of railway wheels as generated by rail corrugation, International Journal of Solids and Structures 44 (2007) 7975–7987.