Research on noise characteristics and control technology of heavy haul railway in China

Lin Shao*, Yanliang Li, Yingqing Chen
China Academy of Railway Sciences, Beijing, China

*Corresponding author e-mail: 06121812@bjtu.edu.cn

Abstract. This paper briefly describes the development process and the characteristics of heavy haul railway in China, summarizes the current situation of noise impact of heavy haul railway at home and abroad, and researches on low-noise control technologies of heavy haul trains. The noise characteristics of China's heavy haul railways were studied through field tests. The results showed that when the passing velocity of heavy haul trains increased from 60km/h to 100km/h, the regression coefficient K of radiated noise and velocity was 20-25. Through the comparative analysis of the noise between the heavy haul train and the freight train, it is proved that the low-noise control technologies have significant noise reduction effect.

1. Overview of heavy haul railways in China
The development of heavy haul railway in China has experienced four stages since 1980s. The first stage is in the mid-1980s. Due to the technical and economic reasons, it mainly operated heavy-haul trains by retrofitting existing railway lines. The second stage is from the mid-1980s to the early 1990s. Since the development of economic construction has reached a new stage, the existing railway lines cannot meet the demand of heavy haul freight volume. The third stage is from the early 1990s to the early 21st century, through retrofitting busy freight lines, the 5000t heavy-haul trains started operation; The fourth stage is from the beginning of the 21st century to the present. The 20,000t heavy haul trains were put into operation on the Datong-Qinhuangdao Railway by applied heavy haul technologies. And the operation test of 30,000 t heavy haul trains was completed [1]. After continuous energy-expansion and technical innovation, the Datong-Qinhuangdao Railway has reached the maximum freight volume of the world's heavy haul railway.

According to the “Code for Design of Heavy Haul Railway” which is released by the National Railway Administration of China, the definition of heavy haul railway refers to the following aspects. The traction of the train reaches 8000t and above, and the axle load up to 27t and above. The annual freight volume is more than 40Mt which runs on lines longer than 150km. Heavy haul railways should condition to at least two of the above three circumstances [2].

Compared with other countries, the main characteristics of China's original heavy haul transport are its large volume, long marshalling, high density, fast speed and small axle load [3]. The development of large freight volume requires the application of large axle load. Therefore, China has made continuous efforts to improve the axle load, and it was successfully applied in heavy haul railway locomotives and vehicles. The comprehensive test of 30t axle load heavy haul train has completed in the Watang–Rizhao railway.
Due to the differences between marshalling and line conditions of the heavy haul railway and the normal speed railway, the influence of environmental noise and propagation mode are different. The noise characteristics of heavy haul railway are mainly low frequency, and the duration is long. The surrounding residents’ subjective feeling of annoyance increased, which is easy to cause social problems. An inappropriate increase of axle load leads to substantial increase of wheel and rail dynamic response, and increase of vibration and noise. Therefore, it is necessary to develop low dynamic response and low noise heavy haul railway.

2. Current situation of heavy haul railway noise

At present, the Datong-Qinhuangdao Railway and Shuo-Huang railway in China have an axle load of 25t. Through investigation, the current situation of heavy haul railway noise is as follows. The noise of 35t axle load heavy haul train in United States is 80 dB (A), while Australian is 85 ~ 87 dB (A). The noise of freight train in German is 76 dB (A), while Italian is 86 dB (A). The noise of 25t axle load heavy haul train in the Datong-Qinhuangdao Railway is 82 dB(A), which is slightly higher than the noise of American heavy haul train but lower than that of Australian heavy haul train.

Based on the comparative analysis of the main technical parameters and noise test results of domestic and foreign heavy-haul railways, Gu preliminarily proposed that the noise of China's 25t heavy-haul railways is 82 dB(A) [4].

In general, the noise of 35t axle load heavy haul train in United States is lower than that in other countries. The heavy haul diesel locomotive adopts radial bogie technology, which will reduce the impact of the wheel to the rail. Compared with the traditional, 75% of impact is reduced. The noise is closely related to the condition of railway line and locomotive vehicle technology.

3. Research on noise control technologies of heavy haul railway

Compared with the United States and other countries, the axle load of existing heavy-haul railway lines in China is 25t. In order to improve heavy haul railway transport capacity, the axle load of trains needs to be improved. However, environmental noise caused by the increase of axle load has become the bottleneck of the development. Therefore, both home and abroad are focusing on the development of low-noise heavy haul railway engineering and locomotive technology.

In 1996, the European Railway Research Institute (ERRI) carried out the project of "Silent Freight", which aims to reduce the vehicle component of noise by 10dB. The solutions include optimized wheel shape, damping treatments, and bogie shrouds, etc. And the "Silent Track" project was complementary to “Silent Freight", which aims to reduce the component of noise from the track by 10dB. The purpose of the International Union of Railways (UIC) Action Programme is to develop braking systems for freight vehicles. The European Rolling Silently (ERS) project (2002-2005) continued the research on the new LL-type brake blocks for retrofitting to tread-braked freight wagons [5].

In order to develop the axle weight of heavy haul trains from 25t to 30t, China has focused on the following low dynamic bogie technology and integrated braking technology related to vibration and noise. At the same time, the lightweight design of the vehicle is achieved. The related new technologies are as follows.

(1) Radial bogie technology with low dynamic action of wheel and rail

The bogie has a radial effect when passing through the curve, which will reduce the dynamic action of wheel and rail. Also, it will reduce lateral and vertical vibration of wheel and rail system, and effectively reduce radiation noise.

(2) Bogie integrated braking technology

The integrated braking system has the advantages of light weight, high transmission efficiency and good relieving performance, etc. The results show that the brake noise is reduced effectively.

(3) Lightweight vehicle technology

With the light weight design concept, the structure of vehicle is optimized, and the weight of the vehicle is reduced. As the wheel-rail interaction force is reduced, the wheel-rail noise is reduced either.
4. Field test study on noise characteristics of heavy haul railway

In view of the development of large axle load heavy haul train in China, the field noise test of heavy haul railway was carried out.

4.1. Field test study on noise characteristics

The environmental noise test points are arranged 25m from the railway track, and 3.5m above the rail surface. The measure parameter is equivalent continuous A-weighted sound pressure level, and the formula is as follows.

\[
L_{Aeq,Tp} = 10 \log \left[ \frac{1}{T_p} \int_{t_2}^{t_1} \frac{p_A^2(t)}{p_0^2} dt \right]
\]  

In formula (1), \(T_p\) is the test period and \(T_p = t_2 - t_1\), \(p_A(t)\) is the instantaneous A-weighted sound pressure, and \(p_0\) is the reference sound pressure (20μPa).

When heavy-haul trains pass at different speeds, the relation between radiated noise and speed of train operation is shown in figure 1.

![Figure 1. The noise and velocity relation curve of heavy haul train.](image)

The radiated noise of heavy haul train increases gradually with the increase of speed. Regression analysis is conducted on the test data of radiated noise of heavy-haul trains. The formula of the relationship between radiated noise and velocity is as follows.

\[
L(V) = K \cdot \log \left( \frac{V}{V_0} \right) + L_0
\]  

In formula (2), \(K\) is the regression coefficient, \(V\) is the passing speed of the train, and \(V_0\) is the reference speed.

According to the noise data analysis of the field test, the value of \(K\) is 20–25, while \(L_0\) is the equivalent A-weighted sound pressure level at the speed of 60km/h. As the speed increases from 60km/h to 100km/h, the sound level increases by about 5dB (A).

4.2. Comparative analysis of environmental noise between heavy haul train and freight train

Compared with the conventional freight railway, the heavy haul railway has significant differences in functional requirements, technical characteristics and transport organization mode, etc. Due to the characteristics of large axle load and long marshalling, the effect of heavy haul railway on line infrastructure is significantly different from that of conventional freight railway.

The conditions of line and locomotive in heavy haul railway are different from that of conventional freight railway, and the noise characteristic is closely related to the technical conditions of line and...
locomotive, etc. Different engineering construction standards and corresponding technical parameters will cause different environmental noise. The axle load of heavy-haul railways in China has developed to 30t by adopting a large number of vibration and noise reduction technologies. In order to verify the effectiveness of the vibration and noise reduction technologies for heavy haul trains, this paper carries out a comparative analysis on the environmental noise of heavy haul railway and conventional freight railway. The results are shown in FIG. 2-3.

![Figure 2. Comparison of radiated noise between freight train and heavy haul train at 80km/h](image1)

![Figure 3. Comparison of noise spectrum between freight train and heavy haul train at 80km/h](image2)

The analysis shows that the sound levels of locomotive of freight train and of heavy haul train are basically identical, but for carriage noise, the heavy haul train is 5 dB (A) lower than freight train. Compared with the conventional freight train, heavy haul train has heavier axle load and greater traction mass. It is attributed to the improvement of vibration and noise reduction technologies that the noise of heavy haul trains is reduced under the above adverse conditions. And the vibration and noise reduction technologies include radial bogie technology, lightweight vehicle technology and etc.

The sound level of the heavy haul railway is higher than that of the freight railway in the low frequency band of 31.5Hz and 40Hz, which is mainly due to the characteristic frequency caused by the spacing of fasteners. It is directly affected by the axle load, while the sound level of the heavy haul railway is lower than that of the freight railway in other frequency bands.

5. Conclusion
Noise and vibration are the primary problems in the development of heavy-haul railway. A lot of research work has been carried out to reduce the vibration and noise of heavy haul railway in China.
Technologies to reduce noise and vibration of heavy haul railway, such as low-power radial bogie, integrated braking and lightweight vehicle, have been studied. The influence characteristics of noise in heavy haul railway are obtained through field test, and the noise distribution mode with the change of speed (60km/h~100km/h) is analyzed. The result shows that the regression coefficient K is 20-25. It is further verified that the noise of heavy haul train is 5dB (A) lower than that of conventional freight rain. It shows that the noise control technologies of heavy haul railway in China has achieved remarkable results, which provide support for further development of heavy haul railway construction.

Acknowledgments
This work was supported by Research and Development Project of China Railway Corporation (Project No. 2016Z001), and Research and Development Project of China Academy of Railway Sciences (Project No.2015YJ024).

References
[1] SHEN Ruiyuan, Development and prospect of rolling stock technology in China,Journal of the China Railway Society. 2019, 41(1), 36-42.
[2] National Railway Administration of China, Code for Design of Heavy Haul Railway.2017.
[3] TIAN Baoshuan, Opertion and Development of Railway Heavy Haul Transport Technology in the World, Rolling Stock, 2015,53(12),10-19.
[4] Gu Xiaoaan, Determination of noise source value of heavy haul railway in environmental impact assessment, Environmental Impact Assessment, 2014(5), 48-50.
[5] David Thompson. Railway Noise and Vibration: Mechanisms, Modelling and Means of Control.Oxford,UK:Elsevier,2009. chapter 7.