The Noise Level Analysis of Hybrid of Passenger-Freight Railway based on On-line Automatic Monitoring System

Xiao-mei XUAN
Graduate Department, China Academy of Railway Science, Beijing 100081, China
wanguan@rails.cn
Corresponding author’s e-mail: 1248879769@qq.com

Abstract. A large amount of data is accumulated from the German railway noise on-line monitoring system, which is online for the first time since 2019. In this paper, the monitoring system is introduced simply. By collating and analysing the monitoring data of the last year, overall noise level of current hybrid of passenger-freight railway in Germany and noise level of each measuring station is given for the first time respectively. Finally it is pointed out that the flow of freight is the key factor affecting the noise level of each station. It provides a basis for the follow-up research on the optimization of train traffic volume based on noise level.

1. Introduction
As early as in the 1990s, the problem of railway noise rose as a public concern [1], and is now still a blight in sustainable development of countries around the globe. In Japan and Germany that are early starters in railway construction, vibration and noise reduction of railways has been a priority in railway management [2]. Germany has stipulated in regulations on freight vehicle in its railway noise management laws that from December 2020, high-noise vehicles will be forbidden on the railway networks of Germany [3], and to implement these regulations, the German government invested much to replace the existing braking system of trains with low-noise braking systems [4], with a vision to reduce the noise at the root [5]. To assess the actual noise reduction effect of the new braking system, Germany released an online railway noise monitoring network in 2019 to keep track of the noise of freight railways. This online monitoring network cannot only provide transparent data to assess the effect of their investment, but accumulate data for the railway administration for long-term management. Currently, the monitoring network covers two thirds of the railways in Germany, which can reflect the general situation of the all railways in Germany. As the rail transit carries both freights and passengers, this network can monitor and analyze the noise levels of railways for both freights and passengers.

2. Automatic railway noise monitoring network in Germany

2.1. Principles for deployment of noise monitoring stations
A total of 19 online noise monitoring stations have been deployed along railways in Germany, and they have been put to use by batches. These stations cover the major heavy-traffic railways, and are representative of the whole networks in terms of the traffic, environment, and infrastructure to reflect the noise level of all railways in Germany. The deployment of stations has high standards: they must not be subject to interference of background noises reflected from the surroundings and should provide...
valid data for final analysis; stations are deployed along typical infrastructure including the rails and iron sleepers and on rails where no noise prevention facilities are installed, so that each monitoring station has the same monitoring conditions to facilitate horizontal comparison of the monitored results.

2.2. Components of the monitoring system
The major components of automatic noise monitoring system are the microphone, the axle counter and the control unit. The microphone is the noise sampling unit used to measure the noise pressure level; the axle counter is used to recognize the line and collect the parameters of the trains, such as the driving direction, time, passing time, speed and the length of the trains; the control unit is used to receive data from the microphone and the counter, compute and deliver the data to the central server.

3. Hybrid freight-passenger railway noise level analysis in Germany
Real-time noises on the railways are measured by such parameters as the weighted sound pressure level $L_{wA(t)}$, the maximum weighted sound pressure $L_{wA_{max}}$, the revealed sound level of the train when passing TEL and the equivalent sound pressure level $L_{eq,T}$.

All measured data are data about noises on railways without noise prevention measures.

According to the ISO noise measurement standard [6], the measuring positions are 7.5 m away from the railway central line and 1.2 m above the railway surface.

3.1. Real-time noise level of the railways
The automatic noise monitoring system uses the high-speed A-weighted sound level $L_{wA}$ to record the changes of sound pressure with time. Figure 1 shows the real-time noise changes of a station in ten minutes.

As shown in Figure 1, the station kept record of the noise level of two rails when trains passed by. In ten minutes, 12 trains passed, seven of which on Railway 1 and the rest five on Railway 2. When no trains were passing by, the background noise was 40-50dB (A); when trains were passing by, the noise pressure level increased to the maximum before declining back.

3.2. Single-train noise
The system kept record of the noises when only one train was passing by the station. When a train passed the station, the system recognized the rail that the train was on, the type, the length, the speed and other parameters of the train, as well as the initial time and the passing time of the monitoring, the maximum instantaneous sound pressure level, and the revealed sound pressure of noises when the train was passing. Table 1 shows the data of noises of trains, demonstrating parameters of noises when the train passed the station.

| Table 1. Noise data when the train passed the station. |
|-------------------------------------------------------|
| Time | Track | Train to | Type | Passing Time (s) | Length (m) | Speed (km/h) | Maximum level dB(A) | Revealed level dB(A) |
|------|-------|----------|------|-----------------|------------|-------------|--------------------|---------------------|

Figure 1. Continuous variation of sound pressure level curve of train.
Table 1 shows the noise data of a station in 30 minutes when trains passed. A total of nine trains passed within the 30 minutes, including six freight trains and three passenger trains; the passing time length was from 5.4 to 29.0 s; the minimum revealed sound pressure level was 85.4 dB(A) and the maximum was 90.8 dB(A); the maximum instantaneous sound pressure level was 97 dB(A). As the table shows, the statistics were random, demonstrating that the noise was caused by multiple factors and were relevant to factors including the passing speed, the type of the train and the length of the train.

3.3. Noise level distribution of the whole railway network

To reflect the noise level of the whole hybrid freight-passenger railway network in Germany from a macroscopic perspective, we randomly selected the equivalent daily sound pressure level of all stations within a cycle (32 days), $L_{m,24h}$ (a sub-cycle of 24 h, from 6:00 to 6:00 the next day), and plotted all the data into Figure 2 — hybrid freight-passenger railway noise level, conducted range distribution of data by the unit step size of 1 dB (A), as shown in Figure 3 — Distribution of noise range of hybrid freight-passenger railway.

| Time       | Location     | Type       | Passing Time | Passing Count | Sound Press Level |
|------------|--------------|------------|--------------|---------------|-------------------|
| 14:34:14   | Bremen       | Freight    | 14.8         | 373.8         | 91.3              | 88.0              |
| 14:30:53   | Bremen       | Freight    | 23.5         | 621.7         | 96.7              | 90.8              |
| 14:26:55   | Bremen       | Freight    | 25.4         | 678.9         | 92.8              | 87.2              |
| 14:26:10   | Wunstorf     | Passenger  | 5.8          | 181.5         | 88.6              | 85.4              |
| 14:22:14   | Bremen       | Passenger  | 4.9          | 154.7         | 91.2              | 86.8              |
| 14:12:45   | Bremen       | Freight    | 23.1         | 613.8         | 97.0              | 90.6              |
| 14:09:04   | Wunstorf     | Freight    | 28.4         | 746.2         | 94.7              | 87.1              |
| 14:06:54   | Bremen       | Passenger  | 5.4          | 181.6         | 90.4              | 87.8              |
| 14:04:44   | Wunstorf     | Freight    | 29.0         | 645.5         | 96.1              | 88.1              |

Figure 2. Hybrid freight-passenger railway noise level.
As Figure 2 shows, the average daily equivalent sound pressure level of all hybrid freight-passenger railways was around 71.3 dB(A). Figure 3 shows that 89% of the noise was within the range [67.1-76.1] dB(A). 64.9% of the collected data were within a range [69.1-74.1] dB(A), and 24.1% was within a range 2 dB(A) from the previous range, i.e. 10.9% of noise was within the range (67.1-69.1] dB(A) and 13.2% was within (74.1-76.1] dB(A).

3.4. Noise level analysis of different stations
Since the automatic noise monitoring system was put to use, the longest data series was accumulated for a year, and the shortest was for half a year. To analyze the noises measured from different stations would help understand the noise levels of different districts across the country and take corresponding measures. Figure 4 presents the monthly average noise levels of each measuring station since they are put to use.

As shown in Figure 4, the monthly average noise level of all stations was 72.3 dB(A), but each station showed large fluctuations in the noise level between 66 and 76 dB(A), and the gap between the maximum and the minimum was about 10 dB(A).

The selection of the measuring stations was based on the traffic, especially the proportion of freight trains, so the difference in noise level among stations may be related to the traffic of the station.

4. Impacts of the train traffic on the noise level
When the environment and the infrastructure of the measuring stations remain similar, to grasp the total traffic and the freight traffic will help analyzing the noise level of stations. With the train travelling data the system gathered, we calculated the monthly average traffic of stations and plotted it into Figure 5 — Monthly total train/freight train traffic.
The upper curve in Figure 5 refers to the traffic of trains, and the lower curve represents the curve of the freight train traffic. By comparing Figure 4 and Figure 5, we could find that the curve of the average monthly noise level of all stations and that of the freight train traffic followed the same trend. As shown in Figure 5, except Stations 2#, 11# and 14#, the curve of the freight train traffic of all stations and that for the total traffic were consistent. Detailed analysis is as follows.

- As shown in Figure 5, the Station 2# had the largest total traffic among all stations, reaching 8,700 trains/month, but its noise level did not rise accordingly but dropped. The freight traffic curve reveals that the freight traffic of Station 2# was small, taking up 50% of the total average traffic (2,480 trains/month);
- Figure 4 shows that Station 13# had the lowest average noise level among all stations, and that its freight train traffic was also the lowest, merely one fifth of the station that had the highest freight train traffic.
- To compare further, we selected stations that had similar total train traffic but had different freight train traffic for comparison. According to the noise levels of Stations 2# and 5# shown in Table 2, these two stations had similar total train traffic, but their noise levels were 3 dB(A) apart; Station 5# had a higher freight train traffic, and meanwhile a higher noise level.

Table 2. Comparison of noise level between Station 2# and 5#.

| Station | Noise (dB(A)) | Total flow (column/month) | Freight flow (column/month) | Freight proportion (%) |
|---------|---------------|---------------------------|----------------------------|-------------------|
| 2#      | 72.9          | 8731                      | 1330                       | 15.23             |
| 5#      | 75.9          | 8353                      | 3588                       | 42.95             |

Given analyses above, the total train traffic had a larger impact on the noise level than the freight train traffic did. When the total train traffic remained the same, a larger freight train traffic corresponded to a larger noise level, which indicates that the freight train traffic is a major factor that influences the noise level of the railway. In future research, we could make use of big data to identify the correlation between the railway noise, the train traffic, and the type of the trains, thereby providing a theoretical basis for optimized noise level-based train traffic design.

5. Conclusions
By analyzing the automatic online railway noise monitoring system of Germany, we reached the following conclusions.

First, the automatic railway noise monitoring system of Germany covers 2/3 of its total freight train railways and could provide data for the freight carrying capacity of the whole railway network;
Second, the noise monitoring system can provide real-time noise levels of the railways, recognize and keep track of the type, the length and the speed of trains passing by stations;

Third, the average sound pressure level of all hybrid freight-passerenger train railways was 71.3 dB(A), and 89% of the measured sound pressure level fell within the range [67.1 - 76.1] dB(A), among which 64.9% ∈ [69.1-74.1] dB(A), 10.9% ∈ (67.1-69.1] dB(A), and 13.2% ∈ (74.1-76.1] dB(A);

Fourth, the average monthly noise of all stations was within a range 66-76 dB(A), showing large fluctuations;

Last, the freight train traffic was a key factor that influences the railway noise level. When the total train traffic remains the same, a larger freight train traffic will result in a higher noise level. Optimizing the freight train carrying capacity based on the noise level will be conducive to management of noise along railways.

Fund Project:
Fund of China Academy of Railway Sciences 2018YJ128

References
[1] European Commission.(1996)Green Paper ‘Future Noise Policy’. Brussels.
[2] Cui Ri-xin. (2017)Research on vibration and noise Reduction Mechanism and Application of High-speed Railway Rail based on additional Damping structure [D]. Beijing Jiaotong University.
[3] (2017)Gesetz zum Verbot des Betriebs lauter Güterwagen. https://www.gesetze-im-internet.de/schl_rmschg/Schl%C3%A4rmenschG.pdf.
[4] P. Hübner.(2000)The Action Programme of UIC , CER and UIP on ‘abatement of railway noise emissions on goods trains’.Journal of sound and vibration,volume 231, Issue3:511-517.
[5] EU Commission.(2002)A study of European priorities and strategies for railway noise abatement. Annex I Retrieval of Legislation [R]. Directorate-General for Energy and Transport, Bruxelles.
[6] ISO3095:2013.Railway applications-Acoustics-Measurement of noise emitted by rail bound vehicles.