Research into high-speed trains noise generation

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Abstract

The process of high-speed train noise generation is examined in this article. The method and results of measurements taken on Renfe railways in Spain on trains of AVE 103 series at a speed of 300 km/h are shown. Sound increase rate tracking for estimation of sound event impact on a person and increased range of sound event duration for the equivalent sound level determination.

Key words: high-speed train, noise generation processes, method of measurement.

Introduction

At present the process of high-speed train noise generation has not been researched enough, and none of the methods of calculation developed in such countries as Japan, China, South Korea, Germany and France, where the infrastructure of high-speed railways is highly developed and has been successfully operated for a long time, is officially approved and universal for application.

According to the theoretical model of the sound field generation when the train reaches the speed of 250 km/h and the further speed increase, the aerodynamic noise becomes prevailing in the overall sound level. Pantograph, train forebody and undercar space are the main sources of aerodynamic noise. Apart from aerodynamic noise, rolling and engine noise contribute to overall sound level. Significant impact on the sound field generation is exerted by the noise source level represented in Table 1 according to [3, 4].

Table 1.
The high-speed train noise source level

Noise sources	High of location, m
Engine	2,5-3,0
Rolling	0,2-0,3
Aerodynamic	
Train forebody	2,5-3,5
Undercar space	0,8-1,0
Pantograph	4,5-6,0

To verify the theoretical information about the process of high-speed train noise generation, the article writers took measurements on Renfe railways in Spain (in Spanish - Red Nacional de Ferrocarriles Españoles – 'The national railway network of Spain') on the line between Barcelona and Madrid. The measurements were taken on the railway sections with maximum operational train speed of 300 km/h for AVE 103 –series with rolling stock length of 200 m and 400 m.

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1. Measuring technique

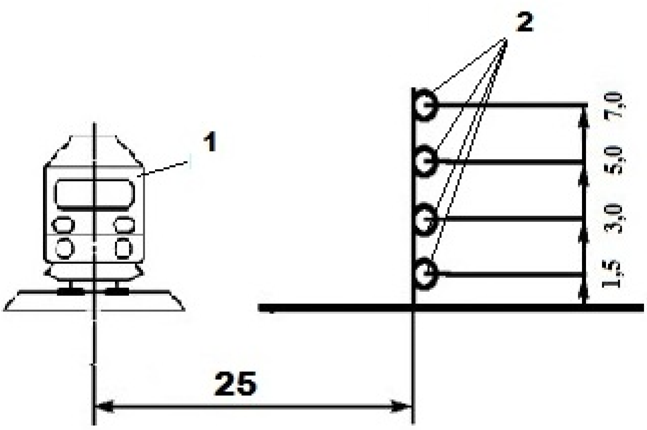
The authors developed the measuring techniques allowing to evaluate both sound field properties at level variation (1,5 m – 7,0 m above the ground) and the process of noise propagation on the ground and its decrease with distance due to divergence.

In this article the results of measurements obtained from determining the sound field properties due to level variation during high-speed train movement on the flat ground.

To identify the prevailing noise sources points at heights of 1.5 m, 3.0 m, 5.0 m, 7.0 m were selected. All microphones were installed simultaneously on the 7-meter tripod at a distance of 25 m from the railway axis.

The measurements were taken in the mode of multi-recording by Russian- and Spanish-manufactured noise level meters with fixation of the mean-square, equivalent and peak sound levels, octave and 1/3-octave spectrum.

The scheme of sound levels measurements and the general view of the measurement unit on the flat ground is presented in Fig. 1.



a)

б)

Fig. 1. a) the scheme of sound levels measurements on the flat ground: 1 – rolling stock, 2 – microphones; b) general view of the measurement unit

The measurements were taken on the line between Barcelona and Madrid on the railway sections with maximum operational train speed of 300 km/h: Vilafranca del Penedès – Gelida. The plan of the measurement site is presented in Fig. 2.

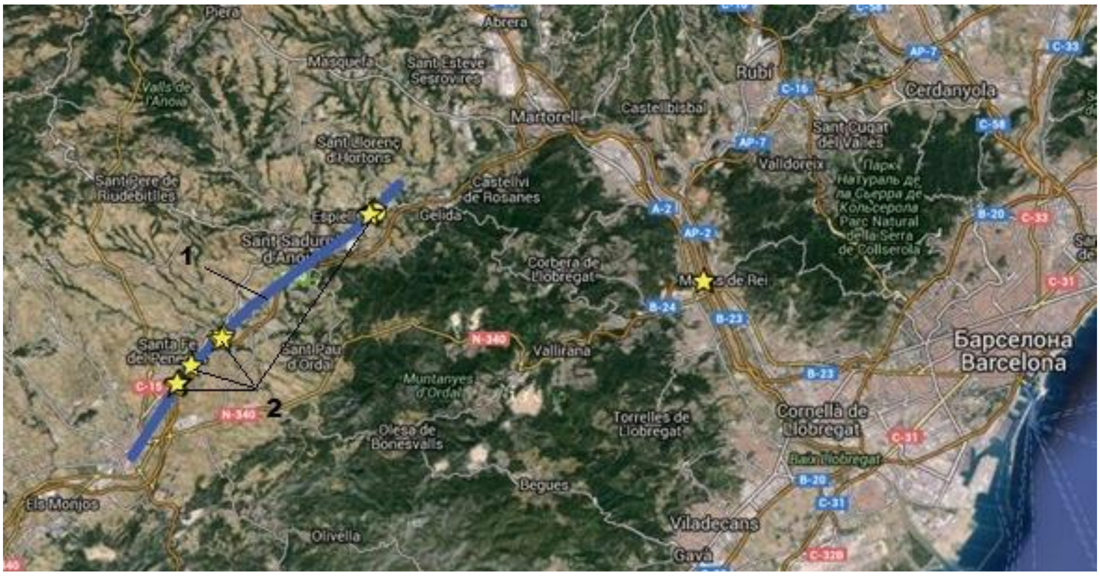


Fig. 2. The plan of the measurement site: 1 – railway sections with maximum operational train speed of 300 km/h, 2 – measurement points

2. Measurement results analysis

According to GOST 31296.1-2005 (ISO 1996-1:2003) maximum time-weighted and frequency-weighted sound pressure level is the highest a-weighted sound pressure level at a given time interval. When the measurement results were processed, the maximum sound levels were taken using 'slow' time characteristics of the noise level meter.

The results of measuring the vertical section of the noise field at a distance of 25 m from the railway axis during train movement at a speed of 300 km/h are shown in Table 2.

Table 2
Maximum sound level measurement results

Level of measure point, m	$L_{AS\max}$, dBA (the average value of all measurements)	The difference between the sound levels at a height of 1.5 m and 7.0 m
7,0	88-90	Δ = 2-3 dBA
5,0	87-89	
3,0	86-88	
1,5	85-87	

The results of measurements show that at the height 7,0 m the maximum sound levels are higher than at the height of 1,5 m by 2-3 dBA on average, which confirms the theoretical data about the prevalence of pantograph aerodynamic noise over other sources of noise, including rolling noise, in the overall sound field at train speeds of 300 km/h. In its turn, the research conducted in Russia on the trains with lower speeds (up to 200 km/h) indicate the predominance of the rolling noise [3], which also experimentally verifies the limit speed of 250 km/h as a condition of the primary noise source dislocation in the overall level from the rolling noise to aerodynamic noise (pantograph noise).

It should also be noted that according to GOST 31296.1-2005 (ISO 1996-1:2003) duration of the sound events was taken as the time interval during which the sound level generated by the train was different from the background sound level by more than 10 dBA. Thereby for a train with length of 400 m the sound event lasted for 17 sec on average, while the time interval from the start time of background sound level variation (including the time interval when the difference between background sound level and the sound level created by the event occurrence less than 10 dBA) to its return to baseline levels was 35 sec, which is more than 2 times higher than the previously determined duration of the sound events, while actual passing of the train by the observation point takes 4.8 sec.

The same parameters for the train with length of 200 m were 13 sec, 30 sec and 2,4 sec accordingly.

The diagram of maximum sound level variation from background to peak values with the timeline application is represented in Fig. 3.

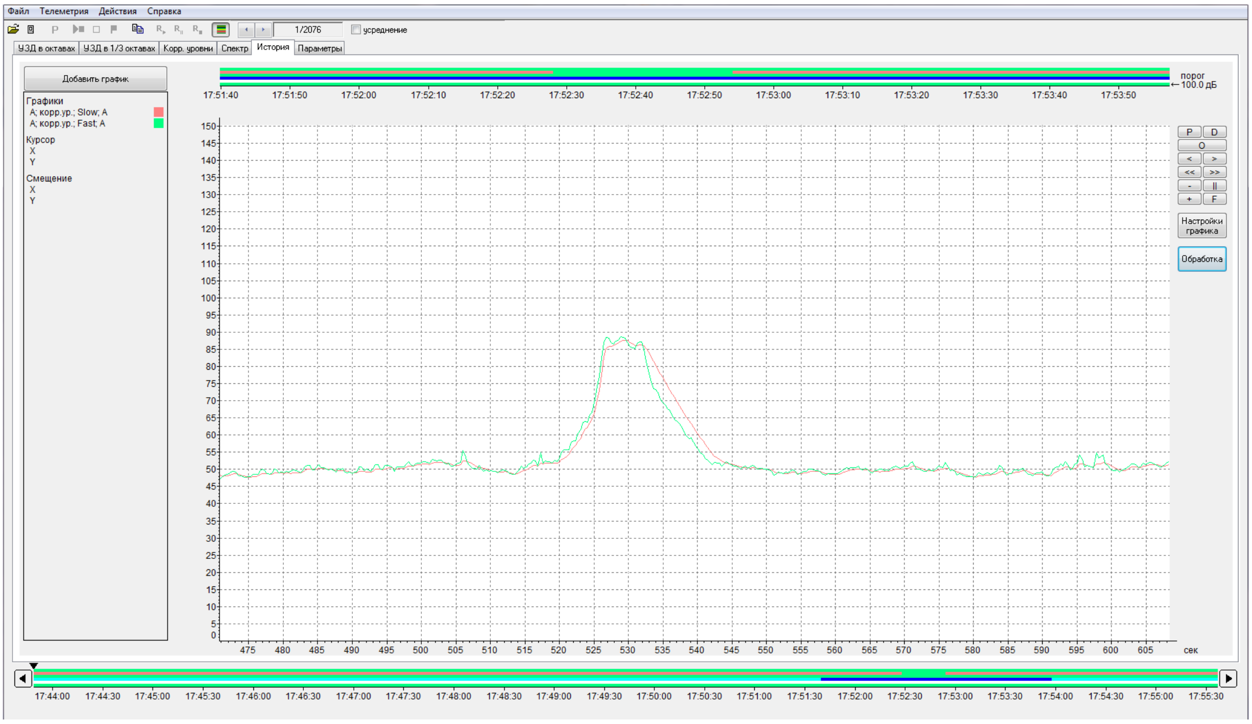


Fig. 3. Maximum sound level variation at train passage at a speed of 300 km/h

Maximum rate of noise increase in the diagram under review is observed at 525-527 sec and is approximately 8 dBA/sec (during the direct train passage by the observation point), while at the approach of the train the sound increase rate is about 1,5 dBA/sec, which is 6 times lower. It is known that apart from the noise type, the speed of noise increase also affects its perception by people.

According to the analysis of the diagram of maximum sound level increase during high-speed trains passage by the observation point, it should be noted that when determining the duration of a sound event according to the current regulatory base valid on the territory of the Russian Federation, duration the sound levels of the approaching train are not taken into consideration when the difference between background and generated sound levels is less than 10 dBA, which is almost half the period of the air pressure variation in the environment relative to the initial level. Taking this interval into account may be useful and appropriate in determining the equivalent sound level generated by a single sound event (passing of the train). Also, there is no criterion for evaluating sound events depending on the sound increase rate in the current regulations. The introduction of this parameter can be useful for studying the impact of various noise sources on people.

Conclusion

The results of research into noise generation process while passing of the high-speed trains carried out on Spanish railways on trains of the AVE 103 –series with speed of 300 km/h allowed to draw the following conclusions:

- the prevalence of aerodynamic sources of noise (pantograph) in the overall level is proved;
- it is suggested to take into account the time interval at sound level increase with a difference of less than 10 dBA with background levels on-site when the train is approaching and moving away for more reliable determination of the equivalent sound level and its subsequent evaluation;
- it is suggested to introduce the parameter of the sound increase rate for describing the noise sources characteristics and assessment of the degree of sound event exposure on people.

References

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