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INFLUENCE OF THE CONDITION OF THE RAILWAY SUPERSTRUCTURE ON TRAFFIC NOISE ON THE REGIONAL LINE

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Abstract

Most of the railway lines in Slovakia were built in the second half of the 19th century, or until 1918 (the establishment of Czechoslovakia). Except for the post-World War II period, when approximately 71 % of the Slovak lines had to be renewed, limited funds have been spent on repair and reconstruction works on the lines located in the Slovak territory [1]. Nowadays, there is an effort to modernize the main railway lines but also to revamp the local lines. This is also a case of the line section Poltár - Utekáč, where in the near future a sleeper, which is in very poor technical condition, will be replaced by a Y-type sleeper. On this occasion, the impact of the new structure on the noise emission from the sleeper should also be assessed.

Keywords:

Railway track;
Railway superstructure;
Sleeper;
Noise measurements;
Noise emission.

1 Introduction

Many human activities cause noise, but traffic has the largest share in it. The railway transport is generally considered to be more environmentally friendly when comparing to other modes of transport, especially in terms of air pollution because of smaller specific energy consumption and using electric traction. The share of rail transport in noise pollution is 14 % of total traffic noise [2]. As noise has a negative impact on human health, the Regulation 549/2007 of the Ministry of Health of the Slovak Republic determines the permissible values of noise in the outdoor environment. These values are considered for the built-up area and compliance with the permissible noise values is verified by hygienic measurements 1.5 m from the facade of residential houses [3].

Railway noise is produced from a combination of three main source mechanisms: rolling noise, engine noise and aerodynamic noise. Like road traffic noise, each source mechanism is dependent on the speed of the train. Rolling noise (or rail/wheel noise) is produced by the interaction between the train wheels and the track surface. The mechanical processes required to power a train and propel it forward result in significant engine noise. Examples include exhaust noise, noise from fans and cooling systems, engine and transmission vibrations among others. Modern high-speed trains travel at such high speeds that their movement through the air causes significant aerodynamic noise. It becomes a significant noise source at very high speeds, normally in excess of 200 km/h [4-6].

2 Methodology

This paper deals with experimental measuring and evaluation of the noise pressure levels caused by railway transport on the railway track Poltár – Utekáč, which is situated in the south of central Slovakia.

On the test section of the Poltár - Utekáč line, only technical measurements were performed according to the STN EN ISO 3095 Railway standard. Acoustics - Measurement of noise emitted by rolling stock [7], in order to determine the difference in noise emissions from the both structures.

The measured data were automatically recorded by sound level meters and subsequently analyzed on a PC under laboratory conditions. A total of 6 equivalent sound pressure level measurements $L_{Aeq,t}$ were performed at each measuring point with a weighting filter A.

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Like the human ear, this weighting filter A effectively cuts off the lower and higher frequencies that the average person cannot hear [8].

The World Health Organization (WHO) acknowledges environmental noise as one of the top environmental risks' health and well-being. Exposure to high levels of noise has adverse effects in the short and long term [9]. Besides the monitoring and evaluation of the acoustic condition on a particular railway line, for better possibilities to reduce the noise, new methods of acoustic measurement with the purpose of localization of increased noise of rolling stock have been developed during the last years, e.g. [10].

2.1 Location of measurement

A text section at km 24.544 to 25.099 near the village of České Brezovo was chosen to evaluate the acoustic situation on the line section Poltár - Utekáč. On this section of railway line, a reference track section with the application of Y-shaped sleepers is expected to be established. Noise measurements should show the difference between the sound pressure emitted by the original railway superstructure and the new construction of the railway superstructure.

The topography of the terrain and obstacles on the route has a decisive influence on the noise emissions from the source of its origin to its surroundings. The test section consists of two contra flexure transition curves, between which there is a short intermediate direct section, Fig. 1. A measuring station was placed on each of the curves in such a way that there were no obstacles in the path of noise propagation to the receiving microphone, as well as the vegetation would cause the least possible noise attenuation. Both noise measurement stations were located on the left side of the railway line in the direction of its stationing.

Measuring station locations:

- 1st site situated in km 25.000, Fig. 2 and 3 - is located in a curve r = 240 m, in terms of track gradient it is 6.1 ‰ in ascending gradient.
- 2nd station situated at km 24.800. Fig. 4 and 5 - located in a curve r = 245 m and in ascending gradient of 17.8 ‰.

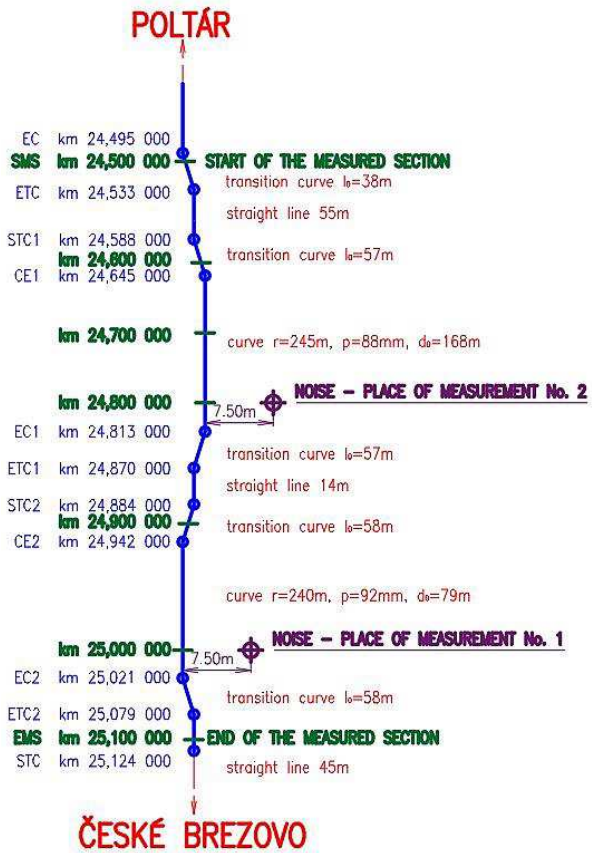


Fig. 1: Measuring stations 1 and 2: EC – end of the curve, ETC – end of the transition curve, STC – start of the transition curve, CE – curve entry, SMS – start of the measured section, EMS – end of the measured section.



Fig. 2: View of the railway track at the measuring point at station No. 1.



Fig. 3: Location of the measuring microphone at station No. 1.



Fig. 4: View of the railway track at the measuring point at the station No. 2.



Fig. 5: Location of the measuring microphone at the station No. 2.

The measuring microphones were placed at both stations at the distance of 7.5 m from the track axle and 1.2 m above the rail head.

2.2 Railway track

The single-track railway line has a sleeper structure formed by T-rails with a stiff fastening formed by various fastening elements, which are mainly on wooden and only occasionally on concrete sleepers, Fig. 6.



Fig. 6: The current state superstructure - stiff fastening on wooden and occasionally also on concrete sleepers.

2.3 Traffic data

Operation on the railway line is provided with diesel traction by motor units series 813 + 913, which consist of a motor car series 813 and a driving car series 913, Fig. 7 and 8. Wheel/rail contact is the dominant source of noise, but in diesel traction, engine noise is more dominant at low speeds. The line speed is reduced from V = 60 km/h to V = 40 km/h on the railway section due to safety reasons (replacement of a secured level crossing of a local road with an unsecured crossing).

The traffic intensity is also very low, with 23 passenger trains passing between 6:00 and 22:00 on the line section and a 1 freight train once a week.



Fig. 7: View of the driving car series 913.



Fig. 8: Motor multiple unit series 813 and 913.

2.4 Noise measurements

Noise measurement took place on 27 October 2020 on the line section Poltár - Utekáč in the village of České Brezovo. Climatic conditions during measurement:

- air temperature: 13 ÷ 15 °C,
- wind speed: 3 ÷ 4 m/s (south-western),
- average barometric pressure calculated on the sea level: 1013.25 hPa,
- weather: partly cloudy - clear.

Instrumentation: At the station No. 1, which was arranged by VVÚŽ staff, the following instrumentation was used:

a) List of sound pressure measuring instruments used: hand-held sound pressure level meter type 2250 Brüel & Kjaer, measuring microphone pre-polarized ½″ 4952 for the Brüel & Kjaer outdoor environment, Fig. 9. Operational control device: Sound level calibrator type 4231.

b) Other auxiliary devices: Laser speed meter, type Pro Laser IV.

c) Software used: BZ-5503 Measurement Partner Suite (audio transmission), Evaluator Type 7820, version 4.16.2; (sound evaluation), Microsoft Excel computer program; (calculations).

At the station No. 2, arranged by UNIZA staff, the following equipment was used:

a) List of sound pressure measuring instruments used: hand-held sound pressure level meter type 2250 Brüel & Kjaer, measuring microphone pre-polarized ½″ 4189 for the Brüel & Kjaer outdoor environment, Fig. 10. Operational control device: Sound level calibrator type 4231.

b) Other auxiliary devices: Speed meter Bushnell speed radar gun.

c) Software used: BZ-5503 Measurement Partner Suite; Microsoft Excel computer program.



Fig. 9: Hand-held sound pressure level meter type 2250 Brüel & Kjaer with measuring microphone at the station No. 1.



Fig. 10: Hand-held sound pressure level meter type 2250 Brüel & Kjaer with measuring microphone at the station No. 2.

3 Measurement results

Both measurements were performed from 9:00 to 15:00 at the same time. The equivalent sound pressure level of the noise of six trains was measured at both stations, namely 3 trains in the direction Utekáč - Poltár (even train numbers) and 3 trains in the direction Poltár - Utekáč (odd train numbers).

Measurement results from station No. 1 are listed in Table 1 and the results from the 2nd station are shown in Table 2. Used abbreviations and measured quantities:

- $L_{pAeq,Tp}$ – A-weighted sound pressure level measured during the interval *Tp* during passage of the train [dBA]; a filter takes into account the sensitivity of human hearing,
- $L_{pAF\max}$ – the maximum value of the A-weighted sound pressure level determined during the time interval of the train passage using the time weighting F (fast),
- *L*95 - sound pressure level A exceeded in 95 % of the time from the considered (measured) time interval in dBA; this level is practically close to the background noise,
- *V* – instantaneous speed of a train [km/h],
- U-P – train running direction from Utekáč station to Poltár station,
- P-U – train running direction from Poltár station to Utekáč station,
- Rt - regional train.

Table 1: Measurement results from station No. 1.

No.	Train	Direction	V_1 [km/h]	Number of wagons	$L_{pAF\max}$ [dBA]	$L_{pAeq,Tp}$ [dBA]	*L*95 [dBA]
1.	Rt 6612	U - P	35	1	81.7	78.2	33.6
2.	Rt 6615	P - U	37	2	83.2	79.5	34.7
3.	Rt 6616	U - P	36	2	81.7	77.2	32.0
4.	Rt 6619	P - U	39	2	82.7	79.4	42.8
5.	Rt 6621	P - U	39	2	83.0	80.5	46.8
6.	Rt 6620	U - P	39	2	83.9	80.5	42.5

Table 2: Measurement results from station No. 2.

No.	Train	Direction	V_2 [km/h]	Number of wagons	$L_{pAF\max}$ [dBA]	$L_{pAeq,Tp}$ [dBA]	*L*95 [dBA]
1.	Rt 6612	U - P	41	1	85.4	77.6	67
2.	Rt 6615	P - U	30	2	84.2	79.1	69.66
3.	Rt 6616	U - P	40	2	83.8	77.6	70.7
4.	Rt 6619	P - U	44	2	85.6	80.3	72
5.	Rt 6621	P - U	34	2	103.6	97.8	81
6.	Rt 6620	U - P	53	2	96.7	90.1	82.96

A comparison of maximum and equivalent noise levels during the passage of a train from both stations can be seen from Table 3.

Table 3: Comparison of measurement results from stations No. 2 and 1.

Train	$V_2 - V_1$ [km/h]	Station No. 1		Station No. 2		Difference station No. 2 - 1 [dBA]	
		$L_{pAF\max}$ [dB]	$L_{pAeq,Tp}$ [dB]	$L_{pAF\max}$ [dB]	$L_{pAeq,Tp}$ [dB]	$L_{pAF\max}$ [dB]	$L_{pAeq,Tp}$ [dB]
Rt 6612	6	81.7	78.2	85.4	77.6	3.7	-0.6
Rt 6615	-7	83.2	79.5	84.2	79.1	1.0	-0.4
Rt 6616	4	81.7	77.2	83.8	77.6	2.1	0.4
Rt 6619	5	82.7	79.4	85.6	80.3	2.9	0.9
Rt 6621	-5	83.0	80.5	103.6*	97.8*	20.6	17.3
Rt 6620	14	83.9	80.5	96.7*	90.1*	12.8	9.6

* Rt 6621 and 6620 passing with sound signal.

It is clear from Table 3 that the trains passed at station No.2 at a higher speed, due to the greater distance from the unprotected road crossing. Higher $L_{pAF\max}$ values also correspond to this higher speed, while the equivalent level of train passage was approximately the same. The last two measurements (passage of trains Rt 6621 and 6620) were marked at station No. 2 by the sound signal of the trains, which caused a big difference in the comparison of noise levels $L_{pAF\max}$ and $L_{pAeq,Tp}$ of both stations.

4 Discussion

The problem with the evaluation is that the motor multiple units run at low speeds 35 to 50 km/h on the railway section in question, which caused that the sound from the engine was dominant and there was no clear noise from rolling of the wheel on rail, which should be dominant in higher speeds above 45 km/h. At station No. 2, trains passed at a slightly higher speed, which corresponds not only to slightly higher values than the maximum $L_{pAF\max}$, but also to the equivalent sound pressure level $L_{pAeq,Tp}$.

At station No. 2, a mower was working, which also resulted in the ambient noise $L95$, which was higher in the case of this station, this noise also being logarithmically added to the value of the equivalent noise level during the train passage. Also during the last two train passages, a sound signals (warning) sounded at the second station, which is visible in the difference of noise levels between the stations, Table 3.

5 Conclusions

The reason for noise measurements on the Poltár - Utekáč line section is a comparison of the existing railroad structure and the new one from the noise point of view. The line section Poltár - Utekáč is a single-track old railway on which a renovation is expected to be carried out in the near future. In the test section near the village of České Brezovo, there is to be a sleeper, which is in a very poor technical condition, is to be replaced by the construction of the Y-type sleeper, which is to be built into the structure of the railway superstructure in 2021. Noise measurements should show the difference between the sound pressure emitted by the original sleeper (railway superstructure) and the new design of the sleeper.

Based on the experience from the noise measurements carried out in 2020, more measurements are expected in 2023 (spring) at a speed of 60 km/h. During the measurement the road crossing during will be closed.

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