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RAILWAY NOISE AND ITS PSYCHOACOUSTIC PARAMETERS

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Abstract: Noise can be assessed and analyzed using a multidimensional approach that takes into account the physical aspects of sound, its composition, frequency, psychoacoustic parameters (e.g. volume, sharpness, roughness, fluctuations strength) and the relationship between the listener and the sound source, information value of sound and cultural background. The quality of the acoustic environment is a term that is becoming more and more prominent. How to assess it, what descriptors and what criteria to use? The article deals with the issue of railway noise in terms of its psychoacoustic perception. The article does not aim to bring forward a complete solution to the issue but to present the issue as such.
Keywords: psychoacoustics, railway noise, descriptors

INTRODUCTION

Psychoacoustics is relatively a new branch of science studying acoustics and psychology. It examines the effects of sound on the human psyche. Unlike conventional physical quantities of acoustics, psychoacoustics has no limit values. It is because every person has a different perception and thus it is impossible to determine the action values. Sound can be analyzed and measured on the basis of physical conditions. The complete psychoacoustic analysis depends on the relationship between a person and his/ her perception.

Noise can be assessed and analyzed using a multidimensional approach that takes into account the physical aspects of sound, its composition, frequency, psychoacoustic parameters (e.g. volume, sharpness, roughness, fluctuations strength) and the relationship between the listener and the sound source, information value of sound and cultural background.

Sound annoyance depends on the sensitivity and subjective qualities, social and cultural background, and influences people's subjective approach to the sound source. Thus, the evaluation of the noise depends on the physical characteristics of the sound phenomenon, the psychoacoustic characteristics of the human ear and the psychological and social aspects.

DESIGNING THE EXPERIMENT

The experiment was carried out using a device used for binaural perception of sound. Binaural perception is the perception of sound with both ears. The size of human skull changes the perception of sound, thus allowing people to hear binaural sounds. The maximum deflection occurs at a frequency of about 1.500 Hz. The perception of phase differences between the ears is the innate ability of the brain that allows the perception of binaural sounds.

People are able to perceive phase differences when two continuous sounds of very similar frequency (up to 1.500 Hz) act on the auditory organs and the brain registers the phase differences between those sounds. Phase differences provide a listener with controlled information.

The brain combines and creates the sensation of the third - binaural sound - if such sound is mediated through stereo headphones or speakers. Most models based on Zwicker and Stevens' procedures for calculating the loudness of continuous sound have been implemented in the software installed in the measuring devices intended for the acoustic measurement.

MEASUREMENTS

The psychoacoustic engineering uses specialized measuring equipment (hardware and software). The hardware usually includes HSU – Head Shoulder Unit, HMS – Head Measurement System (Figure 1), binaural equalizer BEQ and digital programmable equalizer PEQ. Software usually includes software for recording, analyzing and evaluating measured data. We used software AremiS SUITE by the German company Head Acoustics.

Figure 1 . Psychoacoustic head HMS

QUALITY OF SOUND

The term "sound quality" is understood as the sum of all individual sound properties. In general, we can say that the sound quality is negative if the sound phenomena are perceived as unpleasant and disruptive, produce negative associations or are not typical for the given product. Similarly, the sound quality is positive if the sound phenomena are not perceived as intrusive but create pleasant auditory impressions or produce positive associations with regard to the product. Figure 2 shows all important parameters of sound quality in the environment. [1,2,5]

Figure 2. Parameters affecting the sound quality

Evaluation of environmental sounds is carried out by processing sound signals using audio – equivalent measurements and technical analyzes (mostly used in the automotive industry).

MEASUREMENT METHOD

Measurements were performed on a straight stretch of railway track at two measuring points - 7,5 m and 46 m from the track at the height of 1,5 m above the ground level. The place of measurement M1 is shown in Figure 3 together with the necessary technical equipment.

Figure 3. The place of measurement M1

The analysis of the results of the case study

During the measurements we recorded sound of more than 30 passing trains (passenger train, freight train, express train, IC, locomotive trains and others). Due to large result sets the following pages will present only a small demonstration of the evaluation methods.

The evaluation took into account the following psychoacoustic parameters:

- loudness,
- sharpness,
- roughness,
- fluctuation strength.

Passenger train

Passenger train no. 2 with 13 coaches coming from the right side at the distance of 7.5 m (Figure 4).

Figure 4. Psychoacoustic head turned toward the passing train

Figure 5 shows that the artificial head was turned facing the approaching train with its left ear facing the track. Perception of noise by left ear is marked in green. Then, by turning the head (continuous rotation) toward the passing train the right ear catches the noise of the passing train – marked in pink. The green mark shows first 15 seconds of noise when the head was facing the passing train. From Figure 5 it is clear that the head was turning between 15.5 sec. and 17.5 sec. - clearly audible from the recording of the passing train no. 2 and also visible from individual psychoacoustic parameters shown in this Figure. There is an obvious dynamic difference between the perception of the noise by left and right ear before and after the plastic head was turned around.

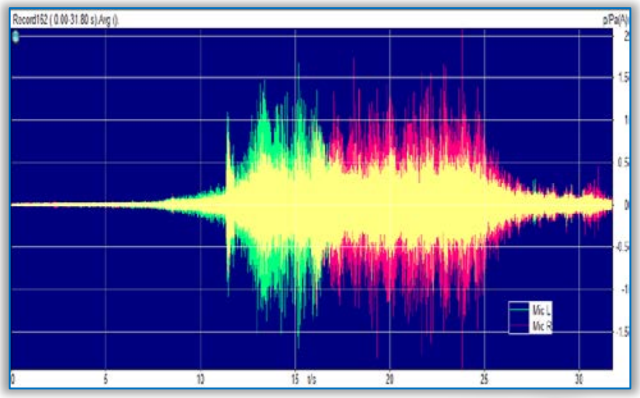

Figure 5. The time course of the sound pressure no.2

Table 1 shows the average value of the sound pressure level for train no. 2. Figure 6 shows the FFT analysis of the train no. 2 and Figure 7 shows psychoacoustic parameters of the train no. 2. Table 2 shows the values of psychoacoustic parameters of the evaluated train.

Table 1. The average sound pressure for train no. 2

The average sound pressure level L_{Aeq}	
Left ear	Right ear
82,68 dB	84,69 dB

Table 2. The average values of psychoacoustic variables train no.2

The average values of psychoacoustic parameters		
Psychoacoustic parameter	Left ear	Right ear
Volume [sone]	27,4	30,3
Rougness [asper]	2,54	2,71
Sharpness [acum]	2,16	2,31
Fluctuation strength [vacil]	0,0185	0,0248

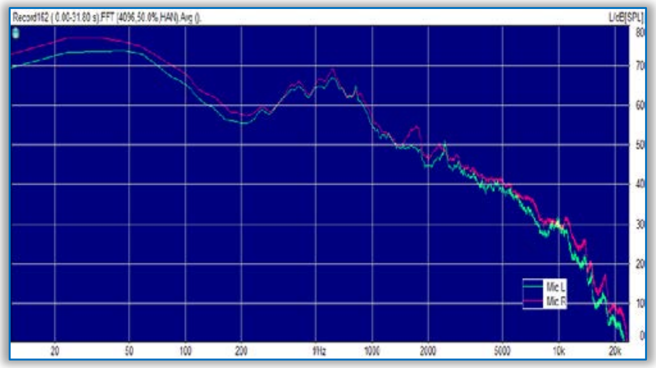

Figure 6. FFT analysis of the train no. 2

Thanks to the short distance from the track, the recording of the passing train captured the sounds of coaches' gears. That is why we can specify the exact number of passing train's coaches.

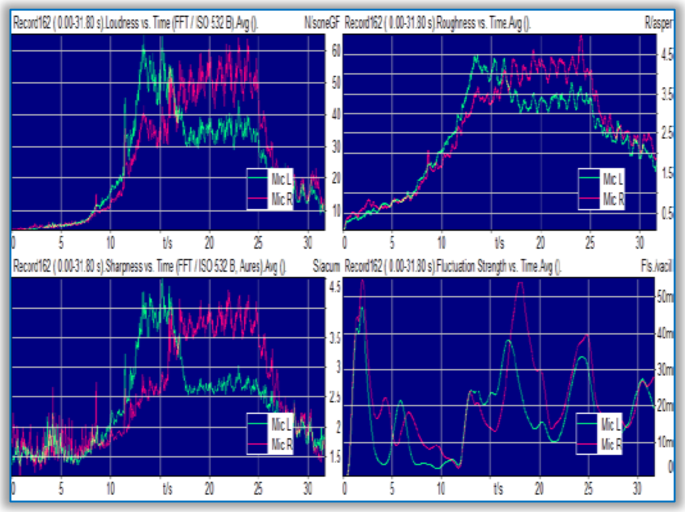

Figure 7. Psychoacoustic parameters of the train no. 2

A more detailed analysis of individual coaches of the train no. 2 was carried out subsequently. This is just a single passage of the selected coach (Figure 8 and Figure 9).

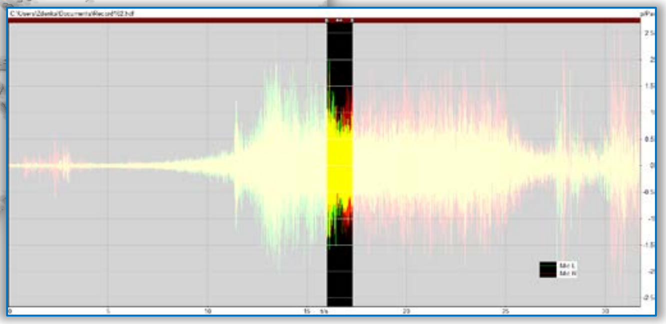

Figure 8. One time frame (16 – 17.3 sec.)

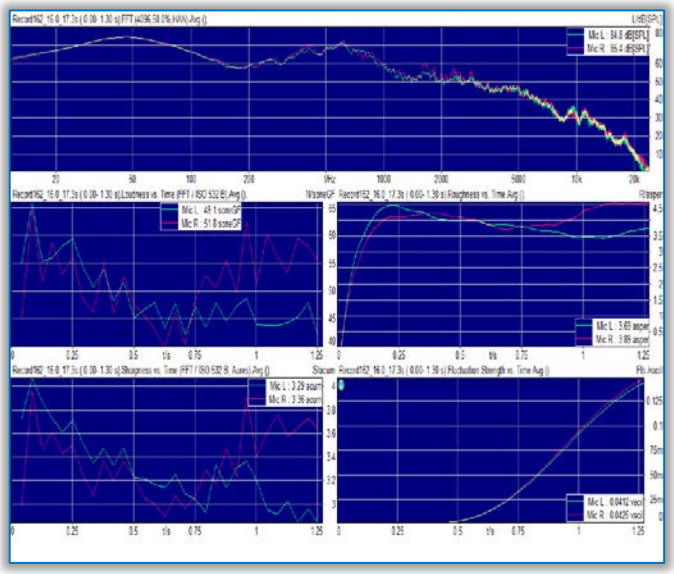

Figure 9. FFT analysis and psychoacoustic parameters of coach no.4

CONCLUSION S

Based on the measurements taken so far, their evaluation and further analysis, we can state the following:

- The binaural recording of sound showed there is difference between a stationary position of the acoustic head perpendicular to the track and when rotating the head smoothly towards the passing train.
- Not all recordings, especially those recorded with longer trains, recorded audible sounds of individual gears.
- This finding may mark the beginning of a detailed study of sounds made by gearing. This would help us in future to estimate some of the other properties of trains, especially the mechanical nature of coaches.

This knowledge about the properties of gears could improve some properties of trains with regard to their environmental impact.

SPECIAL THANKS

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