Amplitude and frequency characteristics of acoustic field influenced by tram

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**ABSTRACT**

Tram, as a light rail vehicle, is a very personalized by operator. It is typically that on one tram net different types of trams are operated. However, regardless of the manufacturer and the product generation, trams operate in urban area influenced on the acoustic climate of City. The article presents the customized and unstandardized acoustic research related to the evaluation of noise generated by different types of tram. In the tests single and multi-microphones system was used for description and detailed analysis of acoustic field generated by tram. All action was focused on bogies as a most important noise source. Paper includes methodology of the research with a comparative analysis of trams with bogie covers and without of them. Description of the acoustic field phenomenon with matrix measurements was presented in two domains: amplitude and frequency. The results were related to the normative measurements prepared according to the methodology described in ISO 3095.

**Keywords:** Tram, bogie covers, vibroacoustic activity; I-INCE Classification of Subjects Number(s): 13.4.3

1. **INTRODUCTION**

Testing of trams in acoustic aspect is prepared and performed according to standard ISO 3095 Acoustics – Railway applications – Measurement of noise emitted by railbound vehicles. Universal methodology defined in the quoted document can be described as a dedicated to classic rail vehicles and infrastructure. Geometric conditions of noise measurements and guidance for track conditions are very hard to achieve in tram systems. Narrowly urban development, different track technologies used on tram system and other factors make that it is necessary to consider the development of dedicated guidelines for the assessment of tram noise. Moreover, trams are the ”local problem” and differently than the classic rail vehicles will not be subject to standardization in full option. In practice the “local problem” means there is no detailed description of the interaction of the vehicle with the track and the minimum requirements in terms of vibroacoustics. In literature can be funded many papers and books developed different models of vibroacoustic consequences of rail vehicle moving \[1,2,3,4\]. Unfortunately, the absolute majority of the number of publications covers of classic rail vehicles. There are exceptions, which primarily indicate the area of measures to minimize the negative impact of the rail vehicle in urban area. Such an approach requires a complex modelling especially that of different types of vehicles operates in cities (on one tram network) is considerable. It does not improve the situation that individual sections of the tram lines also may be made of different technology from each other. For example, in the knowledge of the number of combinations tram type – the type of track is 98 (14 types of trams and 7 types of tracks). In such a situation, it is proposed to use the vibroacoustic activity as a global measure of describing the vehicle-track system in vibroacoustic domain \[5,6,7,8\]. The latest work of authors pointed out the impact of infrastructure dynamics on the vibrations and noise signals generated by different trams \[9\] and impact of tram wheels structure characteristics on vibroacoustic parameters of tram \[10\].

Below is presented the next stage of work on the identification of the impact of the vehicle feature on the level of tram vibroacoustic activity. The paper include experimental results of pass-by tests with bogie covers and without of them.

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2. EXPERIMENTAL TEST

2.1 Methodology

The basis to tests and study are developed tools based on methodology prepared and still develop in Laboratory of Integrated Diagnostic Systems PUT (PL) [8]. During the pass-by tests the set of microphones were used. Microphone matrix was used for recording of tram sounds close to moving tram (1 m from external rail of track). In desribed experiment the dimension of microphone matrix was suitable to record the sounds generate by mechanical part of drive unit – bogies. The matrix covers all space between head of rail, bogie and small part of car body. In this case all mechano-acoustic area with high level of acoustic activity was covered. The last microphone was localized in normative distance – 7.5 m form axis of track and 1.2 m above the rail head. The measurement set of transducers is shown in Figure 1.

Sound recording was performed with a set of nine microphones Brüel&Kjaer type 4189-A-021 mounted on one terminal. In this set consists of a 1/2" microphone with typical frequency range of working 6.3 Hz to 20 kHz and a dynamic range from 14.6 to 146.0 dB. Acquisition unit based on Brüel&Kjaer Pulse® system with cassette 3560C.

Because of the agreement between the manufacturer and the Poznan University of Technology the type of tested tram remains for authors. The test conditions were typically for pass-by test: straight, flat, classical track in good technical state and constant speed 50 kilometers per hour. All data were recorded during night period due to minimalizing influence of cars and different sound sources on results. The sound was recorded with 6 tram rides for each situation (with bogies’ cover mounted in typical way and with uncover drive unit).

2.2 Analysis

All signals were performed in amplitude and frequency domain. Cause of the basis for assessing a vehicle is ISO 3095 standard first at all the comparative study were done. Figure 2 presents average spectrum of sound recorded for tram with bogies’ covers and without of theme.
As expected the sound level generated by tram with cover bogies is lower. Measured difference between noise generated by the same tram with covered and uncovered bogies is 1.7 dB, respectively to 73.7 dB(A) and 75.4 dB(A). The biggest difference in one third octave band is in frequency 1250 Hz. The difference is 4.6 dB, respectively to 61.8 dB(A) and 66.4 dB(A). But, as shown on Figure 2, the negative differences can be founded. The "negative" means that the bogies’ cover can be treated as an additional sound source. The negative influence of the cover can be noticed in bandwidth 200-315 Hz. It is surprising that the biggest difference is 2.5 dB in 200 Hz third octave band. To avoid an error in the identification of the problem, impact test of track was done.

As it can be seen on Figure 3 the resonance frequency of track is ca. 100 Hz. Go back to Figure 2 can be seen negative changes in the band 100 Hz. Difference is 1.4 dB and is no effect in global signal level (over then 30 dB below the average noise level). Next analysis based on signals from microphone matrix, which has been shown as CPB spectra on Figure 4.
As can be seen on figure 4 in both cases the matrix microphones recorded different signals. For microphone No. 1 can be seen significant influence of rolling noise especially in lower frequency. Differences between both situations (tram with covers and without them) are not as big as in case of microphone 9 (ca. 1 m above the head of rail).

Comparing the spectra of signals from the matrix to the reference signal confirmed possibility of observation of different phenomena. In the next step the spectra of the signals from the matrix and reference were compared. Correlation coefficients for the analyzed spectra were calculated with respect to the reference spectrum (normative measurement point). The effect of analysis is shown on Figure 5.

From the Figure 5 can be read that similarity measured by the correlation coefficient rise for measurements with tram equipped with bogie covers. Moreover, stability of graph is higher in case of tram with bogie covers.
3. CONCLUSIONS

Presented experimental studies provided information about the bogies’ covers acoustic effectiveness. In typical cases bogies’ covers are used as an element of tram with only an aesthetic function. Based on experience with different types of trams and different assumptions to designing a covers it can said that can be reduced the noise propagation problem. The average reduction of sound pressure is about 1.7 to 2.4 dB for measurements carried out according to standard ISO 3095.

The use of arrays of microphones to measure the tram noise in pass-by test can reduce time for verification of the designed cover with detection its effectiveness.

Due to the necessity of tram testing in-situ conditions it is expected by the manufacturers that reference measurements can be preceded by a study in the near acoustic field almost in the production hall. It is important from point of view destination of products and poorly defined operation conditions. In this situation using of impact test to fast estimation of track parameters, propagation conditions and sound distribution can be basis to reducing of external costs of transport.

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