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Vasile Bacria, Nicolae Herişanu

Considerations upon the Characteristic Frequency Spectra of some Road Transportation Means

The noise generated by the road transportation means is characterized by frequency spectra, acoustic pressure levels and their variations in time. The sources of vibration and noise depend on the transportation mean type. Therefore every transportation mean identifies itself by characteristic frequency spectrum and noise level. Using the recording of the frequency spectra of the transportation means, one can identify the attenuation methods of the generated noise. In this paper we present some results obtained in the study of the noise generated by the road transportation means using the frequency spectra.

Keywords: *road transportation means, noise, frequency spectra*

1. Introduction

Transportations means such as trams, buses, trolleybuses, microbuses, cars, trucks, tractors or motorcycles generate noise and vibrations which propagate in the environment. They are characterized by specific frequency spectra, acoustic pressure levels and their variation in time. Therefore it is possible to identify the noise sources from the road transportation means and the characteristics of the noise, propagation ways, noxious effects and attenuation methods.

The noise generated by transportation means taking part in the road traffic arises from the engine, the transmission systems, the breaking system, the air resistantce and the rolling. Figure 1 presents the average spectra of the noise for different categories of vehicles, such as trucks with Diesel engines, trucks with internal combustion engines, trams, buses, cars, trolleybuses and motorcycles.

In the case of trams, it predominate the noise generated by the rolling, the mating gears, the electrical engine and the device which controls the opening and closure of the doors.

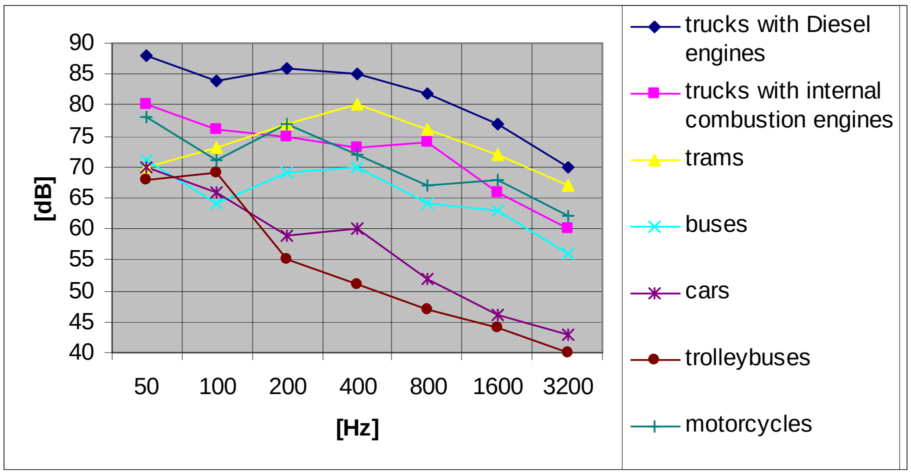

Fig.1. Average spectra of the noise for different categories of vehicles

The most important sources of noise in the case of buses are the engine, the drive links, the gases exhaust and also the chat between passengers. In the case of cars, the noise is generated by the engine, gases exhaust, rolling and brakes. The most important sources of noise in the case of trucks are the engine, the drive links, gases exhaust, striking back of the flame and rolling. In case of motorcycles, the noise generated by gases exhaust predominates.

Improper maintenance of transportation means having deficiencies concerning gases exhaust and braking system increases the noise in the road traffic.

The noise due to the road traffic depends on the traffic intensity and its composition and also on the vehicle speed.

2. Noxious effects of the noise

The noise generated by the road transportation means is extremely injurious for the human being's life and activity. Thus, for the 70 dB(A) equivalent noise level during the daytime, 60% of the population in the urban areas is disturbed [7].

The noises affect human being's nervous system generating psycho-physiological and blood circulation modifications as well as sleep disturbances. Also the visual function and the endocrine gland are adversely affected. At the same time, the noise generates auditory tiredness and sonorous trauma.

In order to reduce the effects of the noise in the urban area, there are established limit values, which cannot be exceeded. These limits are characterized by the equivalent noise level, by the noise curves (C_z) and also by the percentage noise level L_{10}. The equivalent noise level corresponds to an equivalent intensity which could be constant during the whole considered period and it is defined by the relation

$$L_{AeqT} = 10\lg\left[\frac{1}{t_2 - t_1}\int_{t_1}^{t_2}\frac{p_A^2(t)}{p_0^2}dt\right] \quad (1)$$

where p_0 is the reference acoustic pressure (20 μPa) and $p_A(t)$ is the weighted instantaneous pressure of the acoustic signal. Eq.(1) defines the continuous equivalent level of acoustic pressure A-weighted, measured in dB, determined in a time interval which starts at t_1 and ends at t_2.

The noise curves (C_z) define the relation between the characteristic frequency of a sound and the proper acoustic pressure level in the conditions of a subjective equivalent intensity. In this respect, the Romanian standard STAS 10009-88 "Urban acoustics" established the admissible limits of the noise level in urban environment, differentiated on zones and functional endorsements.

The admissible limits for the noise in the urban area are briefly presented in table 1.

Table 1.

Street type (according to STAS 10144-80)	L_{eq} [dB]	C_z [dB]	L_{10} [dB]
I – main	75-85	70-80	85-95
II - linking	70	65	75
III -collecting	65	60	75
IV-local serving	60	55	70

In the same time, the location of residential buildings on streets which situate in different technical categories or at the limit of some functional areas, as well as the road traffic must be arranged so that the admissible limits for the exterior noise level be assured (more precisely: 50 dB or C_z45 curve). This noise level is measured in a point located at 2 meters distance from the building's wall, according to SR 6161/1-2008.

3. Propagation ways of the noise

During the activity of the noise sources in the road traffic, their vibrations propagate in the surrounding environment as spherical and cylindrical waves and, at long distance, as plane waves.

In case of vibrations propagating as spherical waves in an elastic, homogeneous and isotropic environment, the acoustical pressure in a point of the acoustic field is determined by the expression [3]

$$p = \rho_0 \omega \frac{A}{r} \sin(\omega t - kr + \alpha) \qquad (2)$$

where r is the radial coordinate, A is the amplitude of the spherical wave having the frequency f=ω/2π, which propagates from the source with the speed c and k=ω/c is the wave number.

In the same time, there appear some cases when vibrations generated by the road transportation means propagate uniformly and the acoustic pressure in a point of the acoustic field can be written as [3]

$$p = A\left[J_0(kr) + jY_0(kr)\right]e^{-j\omega t} \qquad (3)$$

where A is a constant, J_0 is the first degree and zero-th order Bessel function and Y_0 is the second degree and zero-th order Bessel-Neumann function.

At short distance from the source, Eq.(3) becomes:

$$p = j\left(\frac{2A}{\pi}\right)\ln(kr)e^{-j\omega t} \qquad (4)$$

while for long distance from the source, it reads

$$p = A\sqrt{\frac{2}{\pi kr}}e^{j\left[k(r-ct)-\frac{\pi}{4}\right]} \qquad (5)$$

In the same way, taking account that the propagation of the perturbation can happen under the form of plane waves and considering only the case of divergent wave, the acoustic pressure in a point of the acoustic field is given by [4]

$$p = \rho_0 \omega A \sin(\omega t - kx + \varphi) \qquad (6)$$

Propagation of spherical, cylindrical and plane waves is characterized by the variation of the acoustic pressure in a specific point the acoustic field. Using the instantaneous acoustic pressure one can compute the equivalent acoustic level of the noise defined by Eq.(1).

Effectively, the equivalent noise level can be obtained through computations using Eq.(1) or it can be measured using specific measurement and analysis equipment such as the Bruel & Kjaer 2250 analyzer made by Bruel and Kjaer, which allows the measurement and recording of many characteristic descriptors of the noise as well as the spectral analysis in frequency bands of 1/1 or 1/3 octave.

4. Frequency spectra of the road transportation means

A main source of noise and vibration at the road transportation means are the engines. The Diesel engines are characterized by a noise depending on the speed of the engine and also on the cylinder capacity. It is known that the noise level at Diesel engines increases approximately proportional with the third power of the speed. It has also been established that the Diesel engines of small cylinder capacity but high speed can produce a noise higher than some bigger cylinder capacity, but low-speed engines.

Experimentally it was established that the maximum levels generated by internal combustion engines ranges between 110-120 dB and in case of speed modification between minimum and maximum speed, the noise level increases with 12-18 dB. In the same time, when the load increases, obviously the noise increases accordingly.

In the frame of the engine noise spectrum, there are the following component fundamental series:

$$f_1 = k\frac{n}{60};\ f_2 = k\frac{ni}{60\tau};\ f_3 = k\frac{nz}{60}i' \qquad (7)$$

where k is the number series 1,2,3,..., n is the speed of the engine crankshaft [r.p.m.], i is the number of cylinders, i' is a reduction ratio, τ is the working rhythm (τ =1 for two-stroke engines, τ =2 for four-stroke engines), z is the tooth number of the gear wheels.

The first series is caused by incorrect balance of the machine parts which turn with the same speed as the crankshaft. The second series is determined by the noise impulses which appear in the combustion process at the opening and closing of the admission valves and the pressure impulses in the fuel filling installation. The third series usually corresponds to the noise impulses which appear in the work of the tooth gears or ventilators.

The main components which correspond to the indicated series are located in the low frequency field of the acoustic spectrum.

In the same time, an important contribution to the noise generated by vehicles has the tire/road contact. This one also appears in the frequency spectrum of the vehicle.

Every road transportation mean has a characteristic noise frequency spectrum. Figs. 2-8 present the frequency noise spectra of a tram (fig.2), a microbus (fig.3), a car (fig.4), a truck (fig.5) and a motorcycle (fig.6).

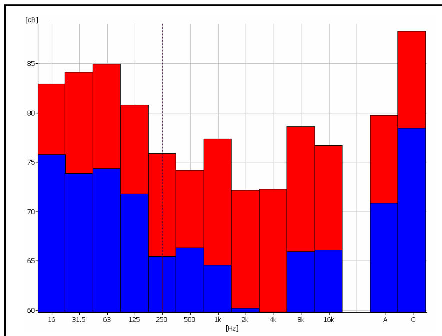

Fig.2

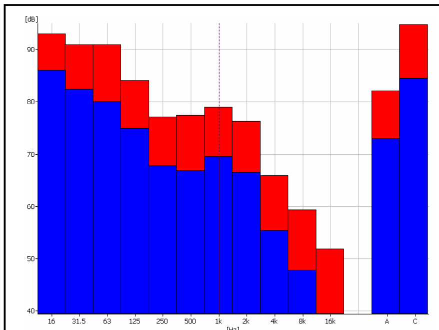

Fig.3

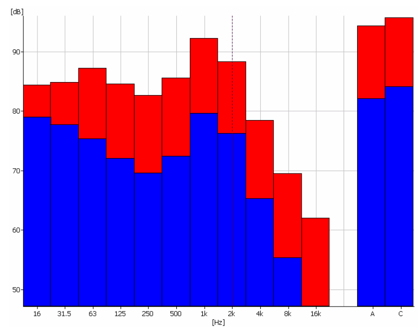

Fig.4

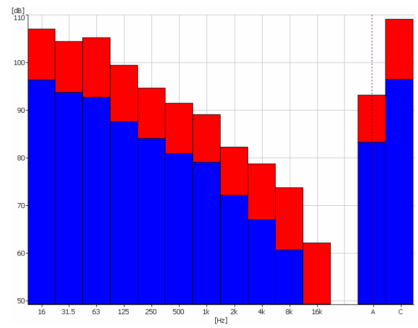

Fig.5

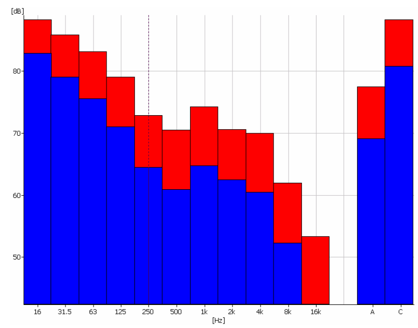

Fig.6

The diagrams presented in figs.2-6 highlights the spectra in terms of un-weighted equivalent noise level (blue bars) and unweighted maximum noise level (red bars), as well as the total A-weighted and C-weighted noise level (the last two bars from the right-hand side of the diagrams). From these diagrams one can be observed that the noise spectra specific for tramways, microbuses and motorcycles are characterized by constitutive parts of low frequencies while in case of cars pre-dominate the low ones and the middle one, too.

These diagrams are useful for establishing conclusions about noxious effects of the noise and some decreasing measures.

5. Conclusion

In order to establish the way which the road transportation means generate noise that affects the environment, it is necessary to investigate the acoustic field generated by them. This one can be investigated using appropriate devices, such as the Bruel & Kjaer 2250 analyzer. This equipment allows the measurement and recording of many characteristic descriptors of the noise as well as the spectral analysis in frequency bands of 1/1 or 1/3 octave.

Using the characteristic frequency spectra of the transportation means we can characterize the noxious effects and establish the proper noise abatement methods.

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Addresses:

- Prof. Dr. Vasile Bacria, "Politehnica" University of Timişoara, Bd. Mihai Viteazu, nr. 1, 300222, Timişoara, bacria@mec.upt.ro
- Conf. Dr. Eng. Nicolae Herişanu, "Politehnica" University of Timişoara, Bd. Mihai Viteazu, nr. 1, 300222, Timişoara, herisanu@mec.upt.ro