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ANALYSIS OF THE INFLUENCE OF DIFFERENT MEANS OF TRANSPORT ON THE LEVEL OF TRAFFIC NOISE

Summary. One of the factors influencing the level of traffic noise is the type of vehicles moving on the roads. The paper presents comprehensive research, as conducted by the authors, which sought to assess the traffic noise level generated by different means of transport. A comparison is made between the noise generated by personal cars, a truck and different types of motorcycle. The maximum sound level and the equivalent sound level emitted by the investigated means of transport were analysed in the entire frequency band and in the individual 1/3 octave bands. Based on the research, conclusions have been formulated regarding the influence of the different types of means of transport and their speeds on traffic noise near a road, along with possible ways to reduce its level.

Keywords: truck; personal car; motorcycle; noise; traffic speed

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1. INTRODUCTION

Noise is one of the most negative effects of using cars. Traffic noise negatively affects the environment in the vicinity of the road, while often significantly reducing the quality of life in human habitats [12,32,37]. Its level is influenced by a number of factors, including the most important ones:

- traffic speed and intensity
- typology of traffic streams
- road surface type and condition
- type of car tyres
- type of motor in the car.

In [23,42], noise is defined as a type of environmental pollution, which disturbs normal living functions by influencing conversations and sleep quality, or by causing changes in human health. In [41], it was assessed that social costs of environmental noise may reach as much as 2% of GDP.

In order to improve the situation, the respective legislation is being constantly modified so as to improve the acoustic climate in the vicinity of roads from a long-term perspective. Currently, the basic regulations presented in [24] govern the permissible limits of noise in the vicinity of roads, depending, among others, on the time of day and night, as well as on the purpose of the buildings and places surrounding the road. In cases where the permissible traffic noise is exceeded, measures should be taken related to the construction of the road and its surroundings. The solution that is most often recommended involves the use of acoustic barriers, less so any reduction in traffic speed or a change in the type of road surface. Research on the possible solutions to be applied in order to reduce the negative impact of road traffic on the environment can be found, inter alia, in: [2,6,11,20,21,26,28,29,33,35,36,38] about the effectiveness of acoustic barriers; [,4,5,8,9,16,17,18,30,31] about the effects of traffic intensity and car movement speed; and in [1,510,14,15,19,22,23,40,44] concerning the influence of different types of road surface on the noise level, including in [14,22], which considers the use of so-called quiet surfaces.

Another group of laws governing the level of traffic noise includes regulations related to permissible sound levels emitted by vehicles. These regulations apply to approval tests [27] and to the periodic inspection of vehicles at testing stations [25]. The former are toughened every few years by relevant EU laws, the latest of which were introduced by a regulation of the European Commission in 2014 [27]. These laws will considerably reduce the level of noise emitted by vehicles in three successive stages: 2016, 2020 and 2024.

In order to reduce the negative impact of traffic noise on the environment, models are being created to forecast traffic noise. The models are described in detail, inter alia, in [7,13,34,43].

The paper presents comprehensive research, as conducted by the authors, which sought to assess the traffic noise level generated by different means of transport. A comparison is made between the noise generated by personal cars, a truck and different types of motorcycles. The maximum sound level and the equivalent sound level emitted by the investigated means of transport were analysed in the entire frequency band and in the individual 1/3 octave bands. Based on the research, conclusions have been formulated regarding the influence of the different types of means of transport and their speeds on the traffic noise near a road, as well as possible ways to reduce its level.

2. METHOD OF CONDUCTING ROAD TESTS

To evaluate the influence of different means of transport on the level of traffic noise, vehicles representative of typical personal cars, trucks and motorcycles were chosen. Measurements were conducted separately for each of the vehicles, so as to ensure identical conditions, without the influence of variable environmental conditions and traffic intensity on the recorded noise level. Tests were performed at a road section made of asphalt, in a good technical condition.

The measurements of traffic noise were performed for the following vehicles (Fig. 1):

- Personal cars:
  - I - a medium class estate car with a self-ignition engine of a new design; at constant speeds of 52, 75 and 98 km/h (which corresponded to the constant rotational speed of the engine of about 2,200 min^{-1}).
  - II - a compact van with a self-ignition engine of an old design; at constant speeds of 53, 75 and 93 km/h (which corresponded to the constant rotational speed of the engine of about 2,000 min^{-1})
- A truck:
  - A tractor unit with a curtain-side semi-trailer; at constant speeds of 50, 70 and 90 km/h (which corresponded to the constant rotational speed of the engine of about 1,100 min^{-1} (at 50 and 70) and 1,300 min^{-1} (at 90), in 10th, 11th and 12th gear)
- Motorcycles:
  - A tourist motorcycle with an engine cubic capacity of about 600 cm^3 *
  - A sports motorcycle with an engine cubic capacity of about 600 cm^3 *
  - A cruiser with an engine cubic capacity of about 600 cm^3 *
  -

** Measurements for the motorcycles were taken at constant speeds of 50, 70 and 90 km/h, respectively, in third gear*

The vehicles tested were in a good technical condition.

The measurements were taken using the modified controlled pass-by method (CPB), at a distance of 7.5 m from the centre of the vehicle movement line, with a microphone placed at a height of 1.2 m (Fig. 2) and a constant speed maintained for the vehicle being tested [27]. During the experiment, at least three runs of the vehicle, meaningful in terms of the measurement, were performed with each of the vehicles, and the measured values were averaged.

A Bruel & Kjaer 2250 digital sound analyser with an anti-wind attachment was used for this purpose. The analyser used during the measurements is presented in Fig. 3. The measurements were performed in the frequency range from 12.5 Hz to 20 kHz and in 1/3 octave bands. The maximum sound level, L_{AFmax}, and the equivalent sound level, L_{Aeq}, were recorded for the vehicles passing by the sound recording point at a 50-m distance. The results were adjusted by means of correction curve A. The tests were conducted in good weather conditions, with the recorded levels of environmental sound lower by at least 15 dB(A) than the values recorded for the tested vehicles.

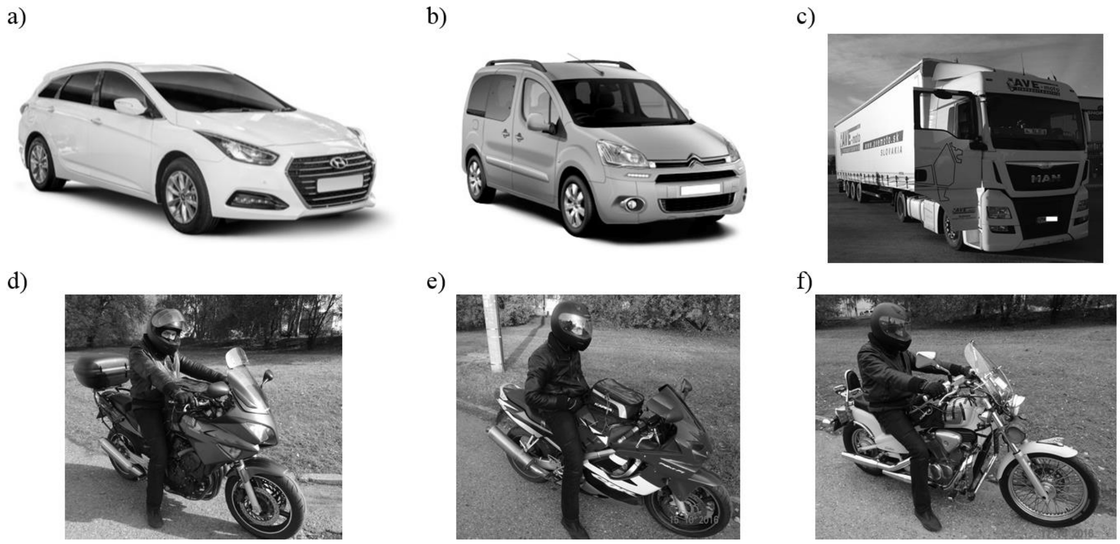


Fig. 1. Means of transport used in the tests

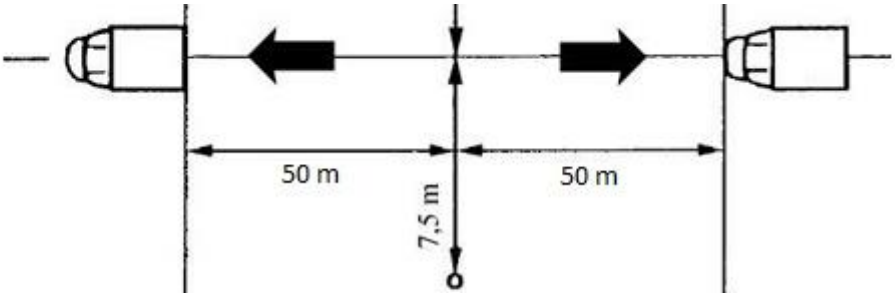


Fig. 2. Method of measurement

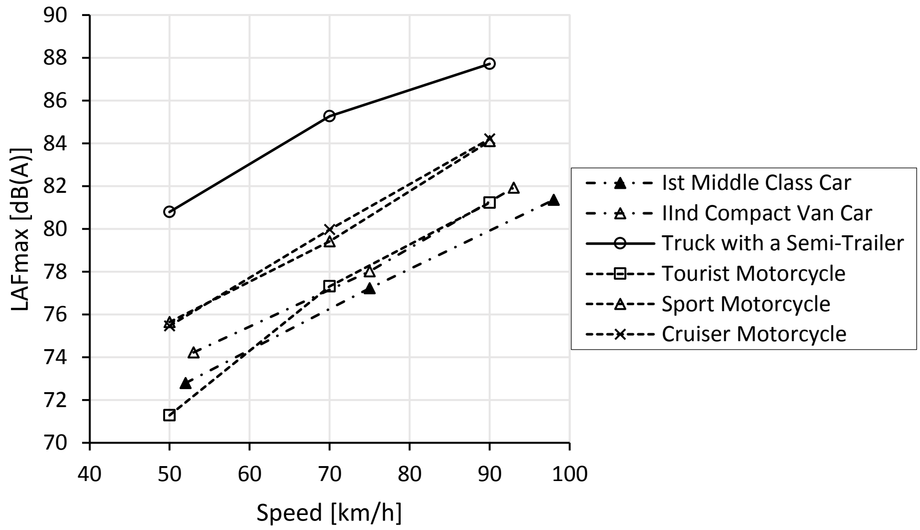
Fig. 3. View of the Bruel & Kjaer 2250 sound analyser in one of the places where measurements were taken

3. RESULTS AND DISCUSSION

Fig. 4 presents the recorded maximum, L_{AFmax}, and the equivalent, L_{Aeq}, sound levels generated by the means of transport subjected to tests at different traffic speeds.

The results show that the maximum sound level, L_{AFmax}, recorded at a distance of 7.5 m from vehicles passing by at a constant speed, depended to a large degree on the type of vehicle. The tests show that the highest sound level was recorded for the truck with a semi-trailer. Each time, the value of the recorded sound level exceeded 80 dB(A) and was higher by 5-10 dB(A) than in the case of the other vehicles.

a)



b)

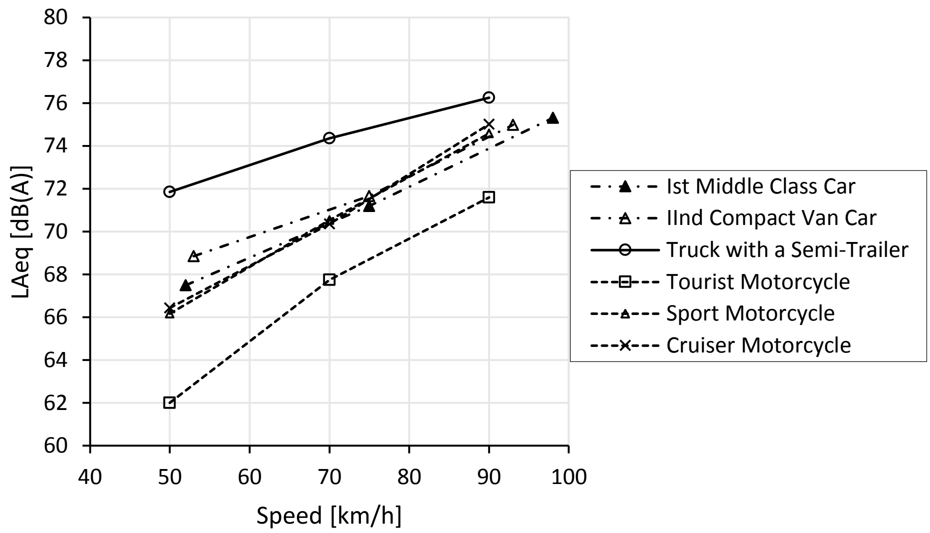


Fig. 4. Measurement results of maximum, L_{AFmax}, and equivalent, L_{Aeq}, sound levels generated by different means of transport

The tests also showed that motorcycles generate a significant maximum sound level; in this case, the recorded maximum sound levels depended on the type of tested motorcycle. It can be observed that the sports motorcycle and the cruiser generated similar sound levels with values exceeding 75 dB(A), while the tourist-type motorcycle showed a much lower sound emission level (above 71 dB(A)). In this case, the maximum sound level was similar to the sound level generated by the tested personal cars.

The maximum sound level generated by personal cars was the lowest among the investigated means of transport and reached values above 72 dB(A). When comparing the test results for the different types of personal cars, it can be noted that the compact van generated a higher sound level than the medium-class estate car, whose sound level value slightly exceeded 1 dB(A).

When analysing the recorded values of the maximum sound level, it can be noted that they assumed the permissible values [24,27] or exceeded them already at a traffic speed of 50 km/h.

Analysis of the results of tests conducted to determine the influence of the vehicle speed on the maximum traffic noise level leads to the conclusion that an increase in the vehicle speed from 50 to 70 km/h induces an increase in the sound level by about 3-4 dB(A), and by about 2-5 dB(A) from 70 to 90 km/h, depending on the means of transport under consideration.

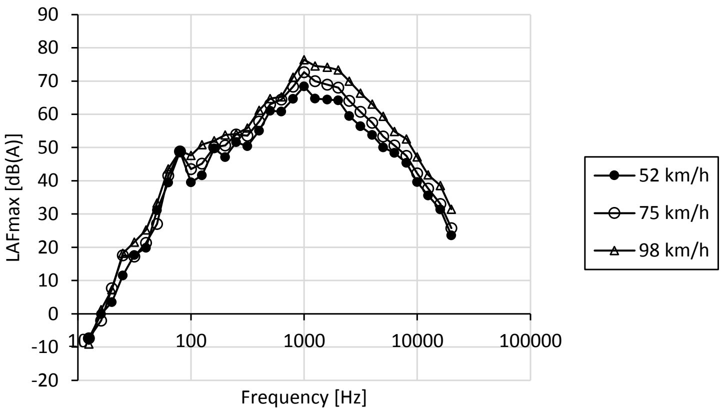
When analysing the influence of sound levels on the environment, the equivalent sound levels generated by the vehicles, L_{Aeq}, were compared within the range of their movement in the vicinity of the noise analyser (Fig. 4b). The tests show that, similar to the maximum sound level, the highest noise emission was characteristic of the truck with a semi-trailer. The recorded values of L_{Aeq} were above 72 dB(A). For personal cars and motorcycles, the recorded values were similar in a majority of cases; however, they were even lower than for the truck, reaching more than 66 dB(A). Only for the tourist motorcycle were the observed values of the equivalent sound level much lower, i.e., above 62 dB(A). Comparing the recorded equivalent sound levels during a single driving event involving the vehicle with permissible levels, which may occur in selected points of the environment, and with the influence of noise on people [24], it can be concluded that the sound levels recorded in the immediate vicinity of the road considerably exceeded the accepted standards, regardless of the means of transport under consideration. By referring the recorded sound level values to an 8- or 16-h exposure time, it can be noted that the actual exposure to traffic noise depends on the intensity of traffic, its structure type and its speed.

Further analyses involved frequency distributions of noise generated by the tested means of transport. Figs. 5 and 6 show the characteristics of the maximum sound level, L_{AFmax}, recorded in 1/3 octave bands.

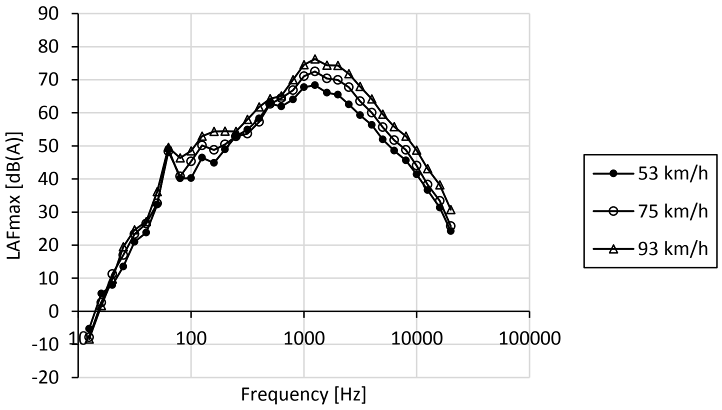
The noise generated by the personal cars and the truck was the highest in the frequency range of about 1 kHz. Above and below this frequency, a considerable decrease in the noise level can be observed. There is a second maximum visible in the characteristic curves, in the frequency range of 50, 63 and 80Hz, which corresponds to the frequencies of combustion processes in the engines of the tested vehicles (rotational speeds of personal car engines: 2,000-2,200 min^{-1}; those of the truck engine: 1,100-1,300 min^{-1}).

In the case of the frequency characteristics recorded for the motorcycles, it can be noted that the maximum levels of the generated noise occurred in a wider frequency range, i.e., from the combustion frequency to the frequency range in the order of several kilohertz (combustion frequencies increased with an increasing traffic speed, since the tested motorcycles allowed us to take measurements at the considered traffic speeds in one gear only).

a)



b)



c)

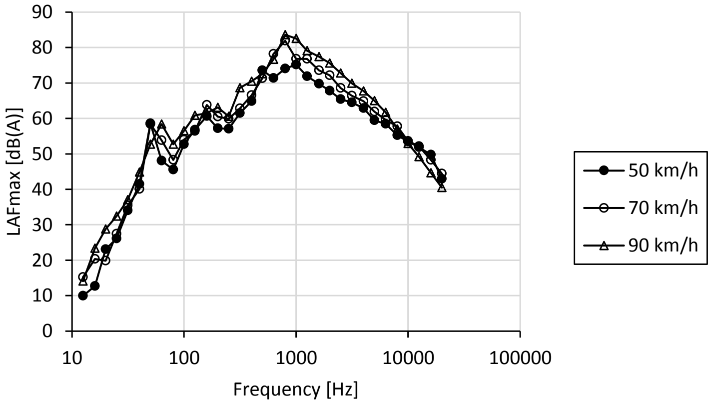
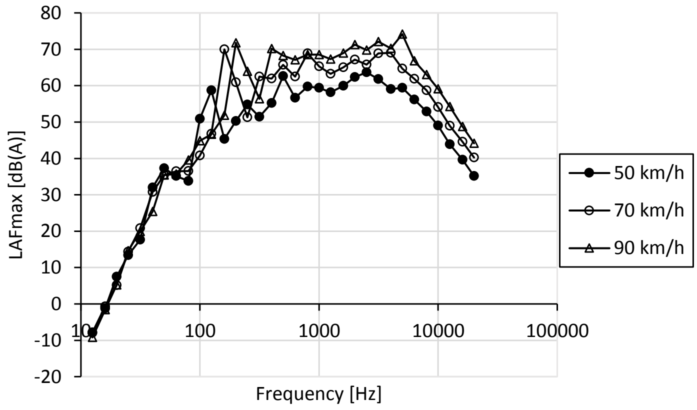
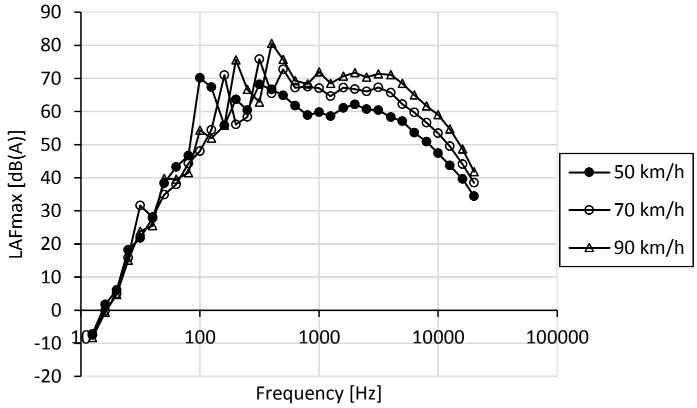


Fig. 5. Measurement results of the maximum sound level, L_{AFmax}, in 1/3 octave bands for personal cars I (a) and II (b), and for the truck with a semi-trailer (c)

a)



b)



c)

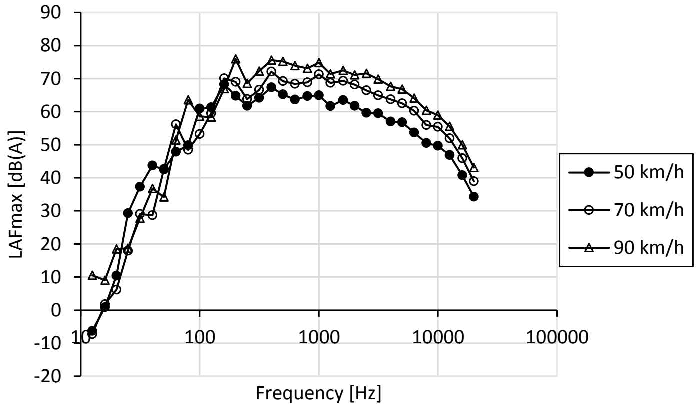


Fig. 6. Measurement results of the maximum sound level, L_{AFmax}, in 1/3 octave bands for the tourist motorcycle (a), sports motorcycle (b), and cruiser (c)

The 1/3 octave band characteristics of the sound level presented in Figs. 5 and 6 also allow us to assess the influence of changes in the speed of the tested vehicles throughout the frequency range. Thus, a conclusion can be drawn from these results whereby, for the tested personal cars and the truck, an increase in speed induced an increase in noise in a range above the frequency of the combustion processes taking place in their engines. However, the highest increase in the generated noise was observed in the frequency range above 0.8-1.0 kHz, depending on the type of tested vehicle. In the case of the tested motorcycles, a clear increase in noise was observed along with an increasing vehicle speed in the frequency range above the combustion frequency.

4. CONCLUSION

As part of the study, an evaluation was made of the influence of different means of transport on the level of traffic noise recorded in the immediate vicinity of a road. The obtained test results confirm that noise generated by trucks was the highest among the analysed vehicles, reaching the following values: L_{AFmax}>80 dB(A) and L_{Aeq}>72 dB(A). Motorcycles, in particular, the sports and cruiser types, also generated considerable traffic noise, reaching values of L_{AFmax}>75 dB(A) and L_{Aeq}>66 dB(A), i.e., higher than for the personal cars. The performed tests lead to the conclusion that, for the personal cars and the truck with a semi-trailer, the maximum traffic noise occurred in the frequency range of about 1 kHz, while a local maximum of a lower value was observed, corresponding to the frequency of combustion processes. In the case of the motorcycles, the frequency distribution of the generated noise was more uniform, with the recorded noise showing higher values in a wider frequency range. Sound level maxima were also visible, which could be observed in the frequency distributions, corresponding to the frequency of combustion processes in the motorcycle engines.

The test results allow us to conclude that an increase in the vehicle speed by 20 km/h causes an increase in traffic noise by 2-5 dB(A), depending on the characteristics of traffic streams. An increase in the speed, in the case of cars, induces an increase in noise, first of all, in the range of higher frequencies, i.e., above 1 kHz, while, in the case of motorcycles, such an increase is observed in frequency bands above the frequency of combustion processes in the engines.

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