MINISTERUL EDUCAŢIEI NAŢIONALE
ROMÂNIA
UNIVERSITATEA DE MEDICINĂ, FARMACIE, ŞTIINŢE ŞI TEHNOLOGIE „GEORGE EMIL PALADE" DIN TÂRGU MUREŞ

Acta Marisiensis. Seria Technologica
Vol. 20 (XXXIV) no. 2, 2023
ISSN 2668-4217, ISSN-L 2668-4217

sciendo

10.2478/amset-2023-0012

ASSESSMENT ON THE ACOUSTIC COMFORT INSIDE THE HEAVY VEHICLE CABIN

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Abstract

Noise, vibration, and harshness (NVH) researchers spend inexhaustible resources of materials, time and money in determining the objective factors that are important in ensuring acoustic comfort in vehicles. In this paper, the factors that directly influence the interior acoustic pressure level in a heavy-duty vehicle were investigated. It was determined using specific descriptors and different units of measurement in assessment of sound levels and the impact generated by noise, the level of interior acoustic pressure and particular values of some prominent sources of noise in the operation of vehicles (engine, HVAC system), taking into account the factors of insurance and thermal comfort, with the aim of determining the cumulative impact at the board of heavy vehicles due to noise.

Key words: acoustic comfort, engine noise, HVAC system sound, sound levels, heavy vehicle, prominent source of noise.

1. Introduction

Nowadays, people spend more and more time in transport systems. In terms of vehicular transport systems, there is an upward search trend in growth for comfort, ergonomics and safety in both private and public transport, as well as in special purpose vehicles. Thus, comfort has become one of the performance requirements of vehicles and an indicator on the market [1].

Noise and vibration directly influence customer perception of vehicle quality and interior. Noise levels in the cabin has become a key factor [2].

Furthermore, the HVAC (Heating, Ventilation, and Air Conditioning) system is one of the most important adnexal systems of the motor that directly influence the interior thermal comfort of a vehicle's cabin [3]. On the one hand this system is a prominent source of noise, besides the engine, the interaction of the propulsion system with the roadway, the interaction of the vehicle body with the external environment in motion [4, 5].

The ventilation and air conditioning system consists of fan, a mixing unit (consisting of various equipment) and air ducts through which air enters the cabin, including the front grills, grills from lower/leg area for both front and rear passengers [6]. Researchers have recently been concerned with defining a relationship between objective measures and subjective sensation that allows a virtual prediction of comfort-discomfort in vehicles. In the specialized literature, there are studies according to which the objective factors are evaluated, each being represented by specific descriptors and different units of measure in assessment of (dis)comfort [7, 8, 9].

Fig. 1: Positioning of the HVAC system on board the vehicle

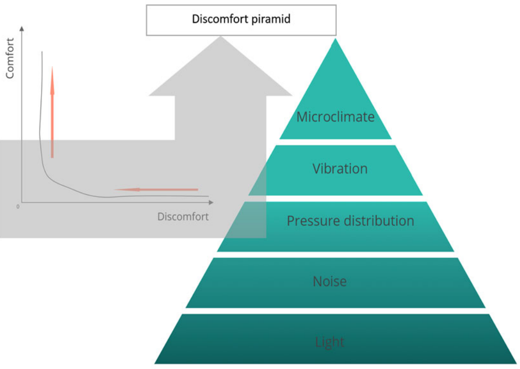


Fig. 2: Discomfort pyramid Zhang and Helander (1996) [9]

In the study, two factors positioned in the pyramid of discomfort were taken into account: microclimate and indoor noise.

In the present study, objective influencing factors of acoustic comfort inside a heavy-duty vehicle are presented with the aim of determining the cumulative impact due to noise on passengers during their operation.

2. Experimental set-up

The experimental unit consists of heavy vehicle, N3 category, high mobility, 6x6, with standard cab with 2 seats and manual ventilation/conditioning system.

Fig. 3: The vehicle on which the tests were carried out

In order to keep the external factors constant, during the tests with the engine stationary, the vehicle was kept inside a shed. Also, the tests were carried out during two similar sessions over 2 days external conditions. The fan has four different stages through which the air flow introduced into the cabin can be changed, shown in Fig. 4, both for the hot and cold sensor. Considering the fact that the tests were carried out during the summer, with an ambient temperature of 30 degrees Celsius, the air conditioner was tested by switching the indicator to the blue zone.

Fig. 4: Methods for adjusting the H.V.A.C. system

a) b) c)

Fig. 5: Vehicle HVAC system operations

The noise produced in the passenger compartment of the vehicle under study is measured with the vehicle in motion and with the vehicle stationary in accordance with ISO 5128: 1980 on the measurement of noise inside vehicles. Starting from various theoretical models present in the specialized literature, it was possible to determine the level of sound pressure inside motor vehicles, to ensure thermal and acoustic comfort inside the passenger compartment of a vehicle of category N3 classified in accordance with the Regulations and technical norms in road transport from 2001 / RNTR 2.

Sound pressure levels were determined using a precision sound level meter class 1, B&K 2245, with 50 mV/Pa (corresponding to –26 dB re 1 V/Pa) ±1.5 dB nominal open-circuit sensitivity of the microphone. The equipment required for the measurements is represented by a laptop, a sound analysis software - Noise Partner and a sound level meter. The position of the sound level meter has a horizontal coordinate of 0.7 ± 0.04 m, and a vertical level of 0.2 ± 0.02 m, with the seat of the seat as the point of origin, so that the sound level meter can be located in the area next to the driver's ear. First, the background noise was measured, then the sound pressure level with ventilation the HVAC system was measured off, then the measurements were driven for each fan gear, for each air position admitted. The sound pressure level was recorded for 60 seconds in each case mentioned. The results were downloaded to the computer by means of the software and the data have been imported in an Excel document and constituted in a database. The next step is to identify the environmental conditions, the ambient temperature must be between + 5 °C and + 40 °C. No tests shall be performed if, when measuring noise, the wind speed, including gusts, at the height of the microphone exceeds 5 m/s. The background noise is also measured, in an interval of 10 seconds before and after each measurement. The next step is the calibration of the measuring devices, this step is repetitive and will be performed before each measurement. Afterwards, the sound level meter is positioned inside the vehicle and the measurements are made while stationary and while driving for different operating speeds of the engine.

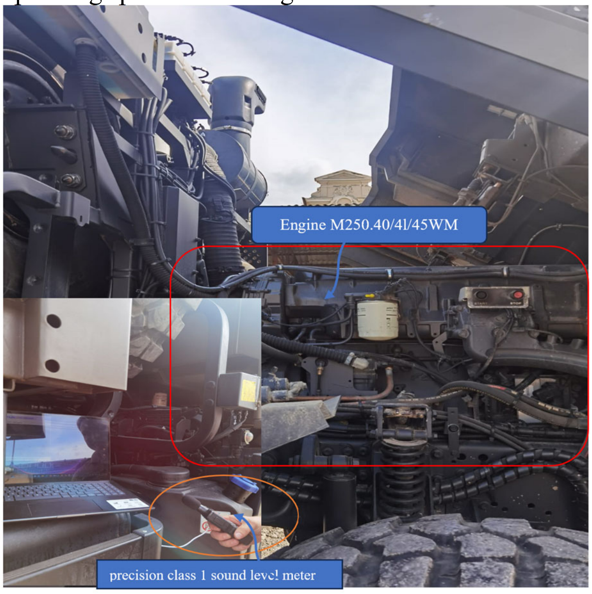


Fig. 5: Measuring the engine noise level

The average associated measured font noise was 30 dBA. The average noise level of the engine in operation is 89.62 dBA.

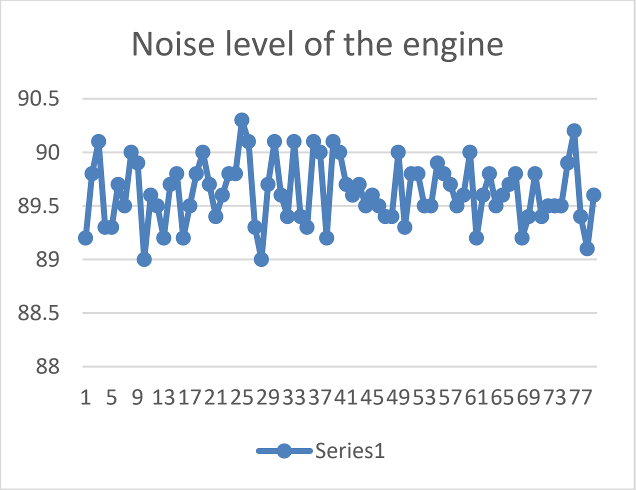
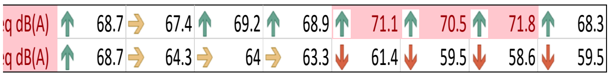


Fig. 6: The noise level of the engine in operation



q dB(A)	↑ 68.7	→ 67.4	↑ 69.2	↑ 68.9	↑ 71.1	↑ 70.5	↑ 71.8	↑ 68.3
q dB(A)	↑ 68.7	→ 64.3	→ 64	→ 63.3	↓ 61.4	↓ 59.5	↓ 58.6	↓ 59.5

Fig. 7: Values of the interior sound pressure level while driving without the air conditioning on.

Analyzing the values obtained for the vehicle in motion but with the air conditioning off, it can be seen that there are areas marked in red where the sound pressure level exceeds 70 dBA.

The interior sound pressure level while driving without the air conditioning in operation has an average value of 65.95 dBA. The interior noise level was determined with the air conditioner on, for step c) according to figure 5.

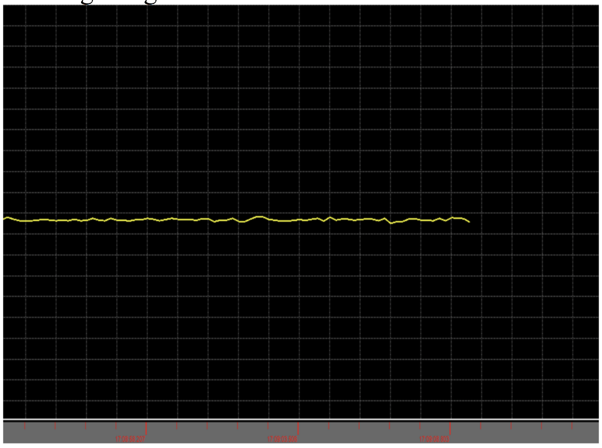


Fig. 8: Determining the indoor noise level when stationary with the air conditioning on

The average level of acoustic pressure in the cabin is 67.82 dBA. The interior acoustic pressure level while driving with the air conditioning on in the same conditions as when stationary is 68.67 dBA.

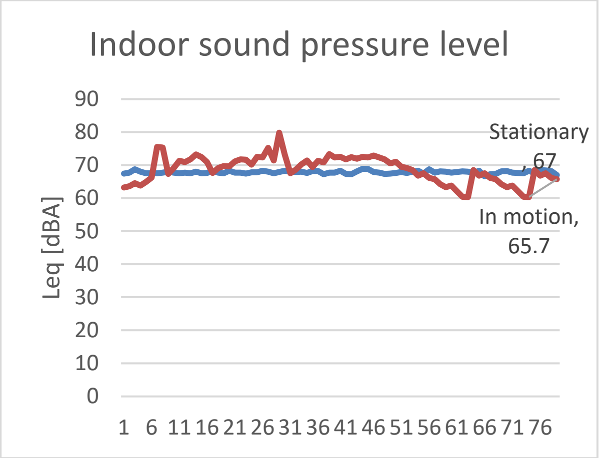


Fig. 8: Interior noise level when stationary and moving, with air conditioning, to ensure thermal comfort.

Analyzing the graph of the dependence of the internal acoustic pressure level, stationary, depending on the speed, it can be stated that the values are different, being higher and falling within the values allowed by the standards in force. Also, the values obtained while driving for the level of acoustic pressure in the vehicle cabin are below the reference line of the values imposed by the standard. The sound level of the vehicle in motion according to approval certificate: 81dB(A). The sound level of the stationary vehicle acc approval certificate: 86dB(A).

3. Discussions

Synthesizing predictive theoretical studies through computational methods as well as the analyzed experimental results, the following conclusions are presented:

- On a national level, the issue of indoor noise modeling in heavy vehicles, is not yet sufficiently developed, showing the need designing new solutions to combat noise in their passenger compartment;
- The acoustic background associated with the passenger compartment of the vehicle both while driving and stationary, under test conditions, continuously contribute to the profile of noise perceived by passengers.
- The level of noise from the engine in operation reaches values of over 90 dBA in certain sections, this being one of the most present sources, whose sound waves propagate in the passenger compartment, leading to variations in the waves of different amplitudes and frequencies, in consequence to noises.
- In the operation of the heavy vehicle on public roads, the sources with character transient (such as traffic or other industrial areas generating prominent sound emissions), ca contribute significantly by bringing to the noise profile in the cabin perceived by the passengers, leading to values that exceed the permissible limits.
- The impact created by the contribution of noise associated with traffic, in a transient manner, to the values determined in the passenger compartment of motor vehicles creates over time passenger discomfort, although by turning on the air conditioning, the aim is to ensure thermal comfort at the expense of ensuring acoustic comfort.
- Analyzing the values obtained in motion with the air conditioning on and off, it can be stated that they vary by up to 3 dB, being higher when the air conditioning is on.
- Based on the analysis of the values obtained in stationary and in motion, the difference between the internal acoustic pressure being higher when driving than when stationary, it was determined that the noise coming from engine dominates the other acoustic emissions of which it tends to be more important that of the exhaust, followed by the intake and the mechanical (of the parts structural). Other secondary sources of noise considered are the transmission mechanics, drive systems, engine cooling fan, and HVAC system both on and off during thermal comfort tests.
- The noise variations determined following the measurements experimental, in the passenger compartment of the vehicle lead to the appearance of discomfort and bring harmful effects on the passengers. A noise level between 35-70 dB, for a long time, to which the driver can be subjected to vehicle leads to the appearance of fatigue, weakening of vision, difficulty in understanding talking even causing headaches for a noise level that exceeds the value of 70 dB.

4. Conclusions

The paper presents a strategy for the objective determination of important data regarding the acoustic comfort of the vehicle cabin, by presenting experimental data and interpreting them to bring improvements in terms of comfort together with the selection of the best available techniques, with the aim of contributing to the improvement current vehicle performance requirements.

It was determined that by ensuring the microclimate (air temperature, solar radiation, air humidity) which includes the provision of local and global thermal comfort, the responsibility of the air conditioner, leads to a small proportion of acoustic discomfort, the HVAC system being one from prominent sources of noise on board vehicles.

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