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MEASUREMENT OF ACOUSTIC PRESSURE IN THE VEHICLE

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Abstract: The article deals with measuring the sound pressure level in a selected type of car in order to assess its sound properties and detect possible noise sources. The study describes in detail the methodology used, including the choice of measurement equipment and the placement of the acoustic head in the vehicle interior. The measurements were taken while driving on the route between the Košice city districts of Pereš and Šaca. The obtained data offer an insight into the distribution of sound pressure in the cabin and help determine the noisiest areas. The final evaluation includes suggestions for improving acoustic comfort in the vehicle, as well as recommendations regarding design and construction modifications of cars
Keywords: noise sources, acoustic comfort, measurement technology, acoustic head

INTRODUCTION

ACOUSTICS is the science that deals with the propagation of sound [12]. Overall, acoustics is a dynamic and constantly evolving field that has a fundamental impact on many aspects of modern society. [3] From improving acoustic comfort in buildings and automobiles to advanced medical diagnostic methods, acoustics plays a key role in improving our quality of life and technological progress. [4]

SOUND is a mechanical wave of an elastic medium that is perceived by the ear. The definition of sound has two parts [6]:

- physical "mechanical wave of an elastic medium",
- physiological "is perceived by the ear".

NOISE is unwanted sound that causes an unpleasant or disturbing sensation, feeling, and can also have other harmful effects on the human body. [14]

ACOUSTIC PRESSURE p (Pa) is a manifestation of acoustic energy at the point of action. It expresses positive and negative deviations from the barometric pressure value caused by a traveling sound wave. [1]

ACOUSTIC PRESSURE LEVEL A L_A (dB) in calculations and measurements, only the octave spectrum of 125 to 4 000 Hz is often used. [15] In terms of the adverse effects of common sound sources, other bands are generally of lesser importance. [7] Low–frequency sound of 16 to 63 Hz is perceived by the ear with relatively low sensitivity. [8] High–frequency sound of 8 000 to 16 000 Hz is usually relatively well damped by the environment. Faults most often occur in the mid–frequency range of 125 to 4 000 Hz. [2]

THE SOUND PRESSURE LEVEL A is calculated according to the relationship:

$$L_A = 10 \cdot \log\left[\sum_{i=1}^{n}\left(10^{\frac{(L_i+K_{Ai})}{10}}\right)\right](\text{dB}) \quad (1)$$

ACOUSTIC INTENSITY I (W.m⁻²) – is the areal density of acoustic power (power per unit area). [4]

$$I = \frac{P}{S}(\text{W.m}^{-2}) \quad (2)$$

ACOUSTIC POWER P (W) – is the amount of acoustic energy that a source radiates into the surrounding space per unit time. [5] Acoustic power is the power of an acoustic sound source (sound equipment, siren, traffic, industry, municipal noise, etc.). [12]

MOTOR VEHICLE OF SELECTION

In the first step, it was necessary to select a suitable motor vehicle. For measuring the acoustic pressure in the interiors, a Škoda Superb III generation motor vehicle (Figure 2) with a 1,4 TSI engine (Figure 1), a six–speed automatic transmission and a Plug–in hybrid drive was selected. The combination of a petrol and electric engine provides a maximum power of 160 kW and a torque of up to 400 Nm.

Figure 1. View of Engine 1.4 TSI 160 KW [21]

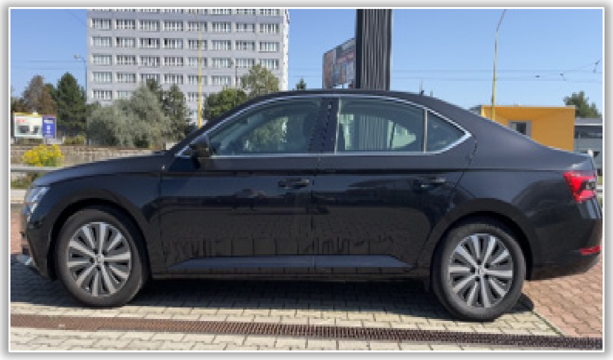

Figure 2. A real look at the exterior of a selected vehicle Škoda Superb III.

With a 100 % charge of the iV battery (Figure 3), the car was able to travel approximately 55 kilometers on pure electric power. The Superb iV battery could be charged from the mains using a 3,6–kW charging station in approximately 3 hours and 30 minutes. [20]

Figure 3 View of the charging of the Škoda Superb III. [20]

The technical parameters of the 1.4 TSI engine are listed in the following Table 1.

Table 1. Engine technical parameters [21]

Combined consumption (petrol):	1,0 – 1,3/100 km
CO_2 emissions:	23 – 29 g/km
Top Speed:	225 km/h
Acceleration:	8 s at 100 km/h
Combined consumption (electricity):	142 – 157 kWh/100 km
CO_2 emissions:	0 g/km
Gearbox::	6° automatic
Fuel type:	Plug–in Hybrid

The technical parameters of the Škoda Superb III generation are described in the following Figure 4. The dimensions in the picture are given in millimeters. The overall view of the vehicle's drive system is shown in the following Figure 5.

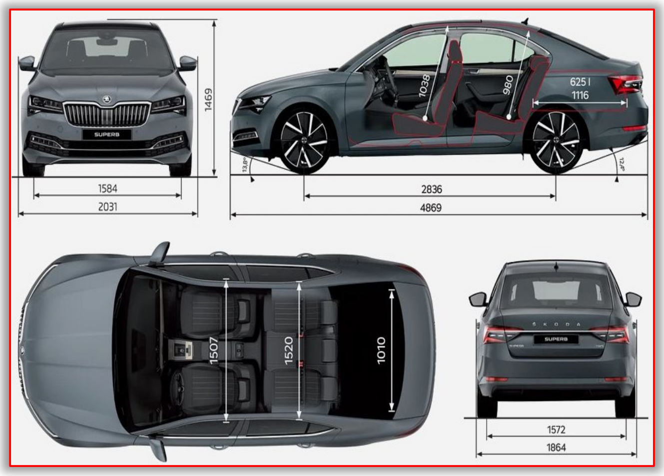

Figure 4. Technical parameters of the Škoda Superb III. vehicle [21]

Figure 5. The drive system of the Škoda Superb III. [21]

SELECTED MEASUREMENT LOCATION

In the second step, it was necessary to select a selected section with the best possible road surface on which the individual measurements would be carried out.

The selected measurement section was the E58 and E571 roads between the urban district urban district Pereš and the urban district of Šaca. The total length of the section in one direction was 6,093 km. There were 9 speed limits in the direction from urban district Pereš to urban district Šaca, and therefore it was necessary to determine at what speeds the measurements would be carried out. In the opposite direction from urban district Šaca to urban district Pereš, there were no speed limits. [16]

The following Figure 6 and Figure 7 show views of the road on which the measurements were taken.

Figure 6. View of the road from the Pereš municipal district [13]

Figure 7. View of the road from the Šaca Municipality [13]

The measurements were carried out at steady vehicle speeds on a selected section of the road for motor vehicles. On the marked section, measurements were carried out in both directions at acceleration and speeds of 30, 50, 90 and 130 km/h. Acceleration measurements from 0 to 100 km/h were also carried out. In the following Figure 8, the section on which the measurements were carried out is shown in orange. [16]

Figure 8 Selected measurement site (Košice city district Pereš – Košice city district Šaca) [13]

SELECTED MEASUREMENT TECHNIQUE

The following measurement technique was chosen for the experimental measurements:

- psychoacoustic head (HEAD acoustics HMS V) (Figure 9),
- binaural digital equalizer with 24–bit technology and USB interface (HEAD Acoustics BEQ II) (Figure 10),
- programmable digital equalizer (HEAD acoustics PEQ V) (Figure 10),
- headphones (Sennheiser HD600) (Figure 11),
- metal stand (Figure 12),
- multifunctional starting power supply with inverter (RING REPP265) (Figure 13),
- notebook ACER (Figure 14), with software (Artemis) (Figure 15).

Figure 9. Psychoacoustic head – HEAD acoustics HMS V

Figure 10. Binaural digital equalizer with 24–bit technology and USB interface – HEAD Acoustics BEQ II and programmable digital equalizer – HEAD acoustics PEQ V

Figure 11. Headphones – Sennheiser HD600

Figure 12. Metal stand

Figure 13. Multifunctional starting power supply with inverter – RING REPP265

Figure 14. Notebook ACER

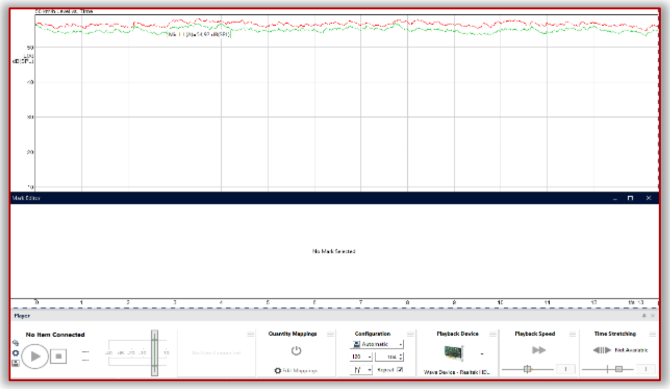

Figure 15 Software Artemis [18]

The following Figure 16 shows the connection diagram of the individual mentioned components.

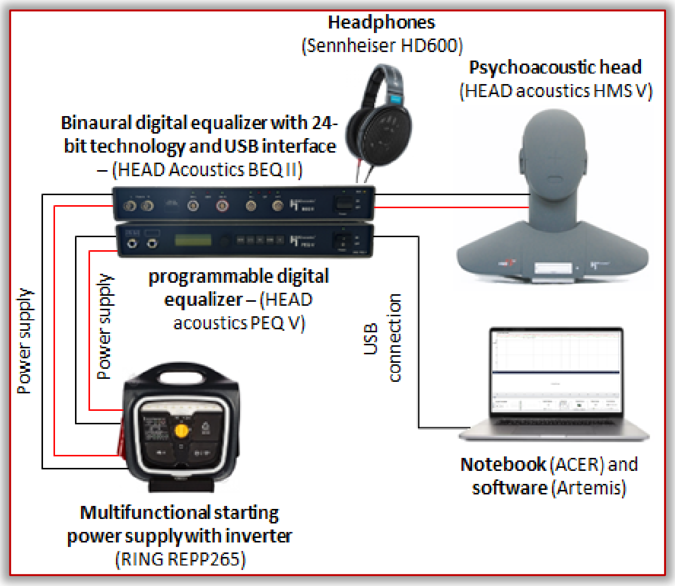

Figure 16. Connection diagram of individual components

EXPERIMENTS

Measurement procedure

A Škoda Superb III generation car was used for the measurement purposes, while the artificial psychoacoustic head together with a metal stand was placed in the interior of the car on the passenger seat and secured against movement with a seat belt.

The installed artificial psychoacoustic head in the tested car is shown in Figure 17. A notebook with a binaural digital equalizer and a programmable digital equalizer were placed on the back seat and secured against movement. The starting sources that power the aforementioned devices were stored in the trunk of the car.

Figure 17. Real view of an installed artificial head with a metal stand in the interior of a vehicle

After installing the individual components, it was possible to start individual experimental measurements on the selected section. After making the sound recordings, these recordings were processed, removing unwanted and random ambient sounds (such as: driving over bumps, sounds of surrounding vehicles, etc.). From these filtered recordings, individual psycho–acoustic parameters were determined using the Artemis evaluation software.

Measurement results

The following tables and graphs present the results of measurements of equivalent A–weighted sound pressure levels in the interior of cars recorded by a pair of microphones of binaural measurement technology (artificial head) Table 2 and Figure 18.

Table 2. Sound pressure values at selected speeds in the left and right microphones

Microphone	Speeds	L [A]
Acceleration	left	63,08 dB
Acceleration	right	65,75 dB
30 km/h	left	56,49 dB
30 km/h	right	58,02 dB
50 km/h	left	54,92 dB
50 km/h	right	56,6 dB
90 km/h	left	65,39 dB
90 km/h	right	66,95 dB
130 km/h	left	67,22 dB
130 km/h	right	69,07 dB

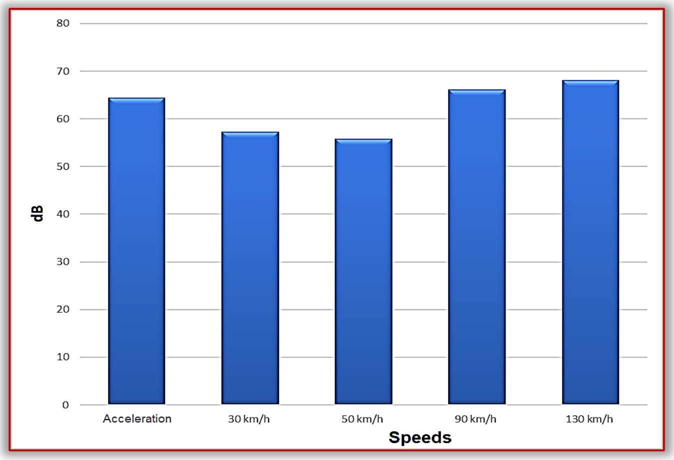

Figure 18. Sound pressure values at selected speeds

CONCLUSIONS

Measuring the sound pressure level in a selected car has provided valuable insights into the acoustic environment in the vehicle cabin. Based on the measurements, the authors of the article identified key noise sources and areas with the highest sound pressure levels. This information is invaluable for improving the acoustic comfort of passengers and can be used in the design and development of new car models.

The study confirmed that the highest noise levels occur at higher speeds and near the engine compartment. The authors also found that the quality of materials and insulation in the interior significantly affects the overall sound pressure level.

Based on these findings, the authors recommend that car manufacturers consider using better insulation materials and implementing design modifications aimed at reducing noise. Future research should focus on long–term monitoring of the acoustic properties of vehicles in real conditions and on the development of new technologies for noise reduction.

This study contributes to a better understanding of the acoustic properties of cars and provides valuable information for car manufacturers and acoustic experts.

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