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Comparison of Noise Emissions in the Interior of Passenger Cars

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***Abstract*—**The noise is one of the negative elements which affects the human health. This article presents the measurement of emitted noise by road vehicle and its parts during the operation. Measurement was done in the interior of common passenger cars with a digital sound meter. The results compare the noise value in different cars with different body shape, which influences the driver's health. Transport has considerable ecological effects; many of them are detrimental to environmental sustainability. Roads and traffic exert a variety of direct and mostly detrimental effects on nature.

***Keywords*—**Driver, noise measurement, passenger road vehicle, road transport.

I. Introduction

NOISE may be defined as a source or a vibration of a solid. Thus, the physical cause of the noise is quivering solid. Noise is therefore uncertain sound which has not a steady rate. If the vibration of the sound source is regular, we perceive tones, i.e. musical sound [1], [6]. If the sound is erratic from quivering body, we perceive it as a noise. This body can be air, water, wood or any other material.

The air is a mostly environment that spreads sound sensation from quivering body to your ear. Vacuum is the only environment that cannot spread the noise [2].

The unit bel (B) is used to express the sound intensity level, but mostly its tenth - decibel (dB). Examples of sound intensity:

- 20 dB whisper,
- 50 dB conversation,
- 60 dB rush street,
- 90 dB motorcycle,
- 110 dB rock concert,
- 120 dB jet airplane.

The noise would be also defined as "undesirable and harmful sound". Therefore, nowadays requirements of noise emissions in vehicles are imposed. Vehicle approving is based on the Economic Commission for Europe of the United Nations (UN ECE) 51. Measurement of noise emissions is carried out in accordance with Annex 10 Methods and instruments for measuring the noise made by motor vehicles [3], [9].

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II. Measuring Devices

A. Sound Level Meter Voltcraft Plus SL-300

This digital device was used to record sound. The measuring range is 30 -130 dB to within; ± 1.4%. The sound meter is connected to a 9V battery that lasts for 50 hours. It has internal memory that can be recorded and kept 32.600 values. This device consists of three parts:

- Measuring microphone with polyurethane cover,
- LCD display with resolution of 2000 points,
- controls, connectors, USB port.

Fig. 1 Sound level meter Voltcraft Plus SL-300

B. Video Car Recorder TX300

GPS Camera TX300 is a recording system of driving characteristics, which uses GPS, GPS/GPRS system and a 3D accelerometer. It is used to record the position, accelerations in 3 axles and instantaneous velocity [8]. The device is powered by 12-24V battery. It is necessary to insert the SD card for data recording. This device consists of five parts:

- Wind screen camera, resolution 640x480,
- Built-in microphone,
- GPS receiver with antenna,
- GSM-GPRS modem,
- 3G accelerometer.

The device enables to record:

- video and audio recording according to pre-set parameters,
- video recording from integrated camera,
- video recording from external camera,
- standard GPS data (position, speed, time),
- 3G integrated accelerometer data (accelerations in 3-axles).

Fig. 2 Video Car recorder TX 300

III. Measurement Procedure

A. Calibration of Sound Level Meter

Before the beginning and the end of the measuring, the device was checked with the sound calibrator that fulfils the requirements for the sound calibrators of accuracy Class 1 according to IEC 942:1988 [7]. Without any further adjustment, the difference between the readings of two consecutive checks shall be less or should equal the value of 0.5 dB [5]. If this value is exceeded, the results of the measurements obtained after the previous satisfactory check shall be discarded.

B. Measuring of Environmental Influences

It was also necessary to check the outdoor temperature and humidity. To determine these variables, we used a combined instrument for measuring of temperature and humidity (thermo – hygro meter) [4]. We have measured the temperature of 8.9°C and humidity of 54%. These values were constant during the whole measurement.

C. Sound Level Measuring in Interior of Moving Vehicle

The sound level measuring was done in-motion in three vehicles in the area of city Zilina (Slovakia) and in other neighbour parts of the city:

- every measurement was done twice in each vehicle,
- there were three types of measurements:
  - constant speed of 50 km/h,
  - full acceleration from 50 km/h to 90 km/h and deceleration to 50 km/h,
  - urban cycle (vehicle operation in urban area),
- vehicle was full loaded (5 person),
- navigator arranged the driver by using visual signals,
- person behind the driver manipulated with the sound level meter – the measuring position was next to the driver´s left ear (higher sound level than at the right ear) ,
- air temperature and humidity were measured all the time and used by calculating their influence on the normative sound level,
- measured values were evaluated in graphs and tables – the final value was as arithmetical average without the extreme values (max and min value) in chosen time interval.

1) Constant Speed of 50 km/h

We performed measurement on the vehicle that moved at a steady speed of 50 km/h. The actual gear was chosen according to the optimal engine rotation (3rd or 4th). The duration time of the measurement was in the range from 20 to 27 seconds, according to the actual traffic situation (the longest time interval of the constant speed driving). In the charts are recorded waveforms of sound level of chosen vehicles.

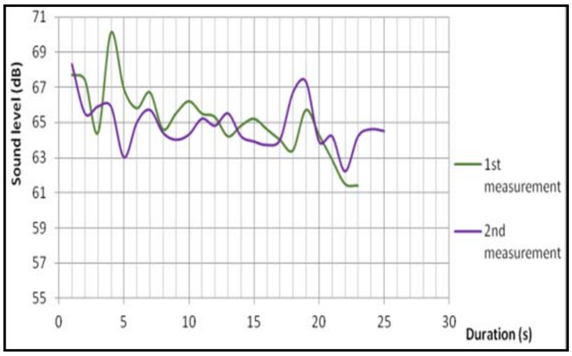

Fig. 3 Sound level in VW at constant speed of 50 km/h

Fig. 3 provides a graphical representation of sound measurement in the vehicle Volkswagen Polo at constant speed of 50 km/h. The sound level ranged from 61.3 to 70.1 dB in the vehicle.

2) Acceleration from 50 to 90 km/h

This measurement was done on a local road between city Zilina and village Rosina. The vehicle accelerated to the velocity of 90 km/h from the beginning velocity of 50 km/h on a straight part of the road.

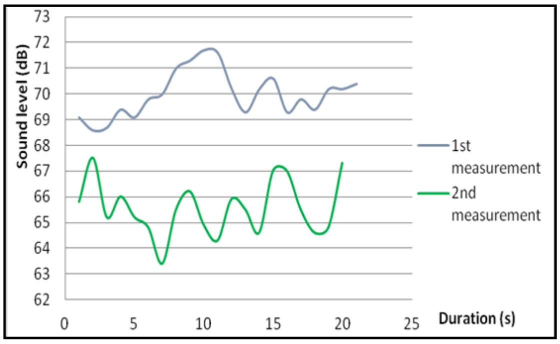

Fig. 4 Sound level in Citroen Berlingo during acceleration

At Fig. 4, there is the recording of the sound level measurement in the vehicle Citroen Berlingo, where the sound level ranged from 63.3 to 71.9 dB. The difference between individual measurements is relatively large because during the first measurement driver was shifting from the third to the fourth gear during the acceleration and at the second measurement the vehicle was accelerated to the desired speed only on the fourth gear. We also have done two measurements in the vehicle Jaguar X-type and its curves can be seen in Fig. 5. The sound level during acceleration of the vehicle ranged the interval from 63.4 to 71.2 dB.

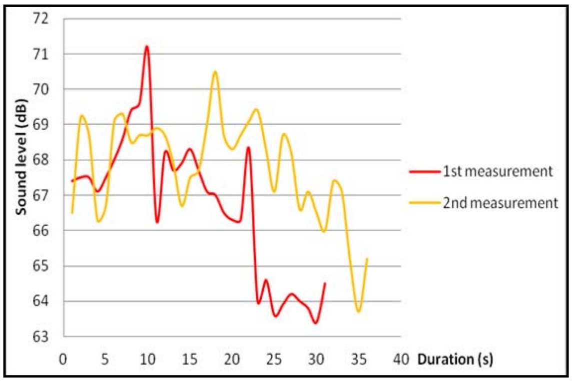

Fig. 5 Sound level in Jaguar X-type during acceleration

3) Urban Cycle

We used the GPS TX 300 camera that recorded the route, speed, distance, travel time, track elevation of the vehicle moving. Recorded track, which we simulated the urban cycle on, can be seen in Fig. 6. The speed profile with respect to measurement duration or a speed profile with respect to the travel distance is on Fig. 7.

In Fig. 7, there is recording during the measurement of sound level on three moving vehicles in the urban area. There can be seen that the highest sound level was in the vehicle Citroen Berlingo (76.1 dB). The sound level in vehicles Jaguar X-type and Volkswagen Polo is almost the same, but lower levels we measured for the vehicle Jaguar X-type (73 dB). The sound level in the vehicle Volkswagen Polo reached a value of 73.5 dB. This sound level was reached only in a short part of the track with higher velocity (up to 70 km/h) and higher lateral slope (elevation), so higher engine power was needed to move the vehicle. It is the reason of the sound level pick of the all vehicles. The average sound level values measured during the whole duration of the urban cycle are seen in Fig. 8.

Fig. 6 Recorded track during urban cycle measurement

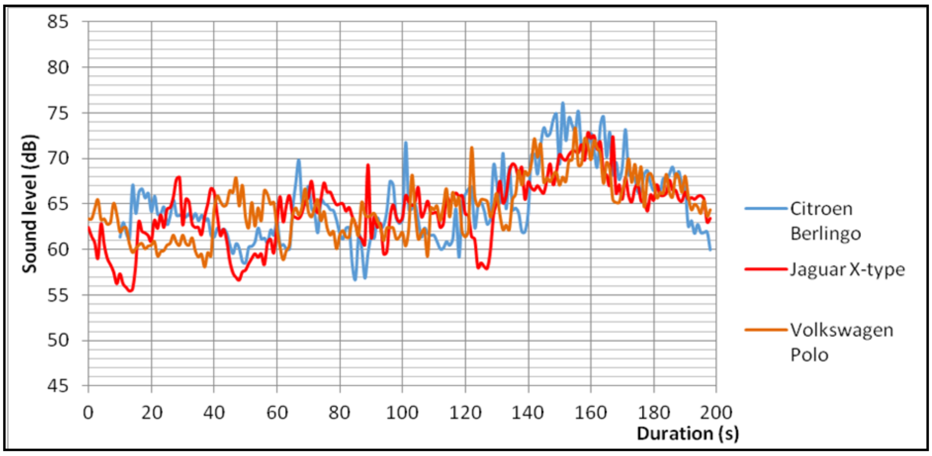

Fig. 7 Vehicle speed profile during urban cycle

D.Pick Values

The highest sound level measured during constant speed was in the vehicle Citroen Berlingo, value 69.8 dB. Conversely, vehicle Jaguar X-type reached the lowest sound level of 68.9 dB. VW was the noisiest vehicle during the acceleration test with value of 73 dB and at least noisy vehicle was Jaguar X-type with noise level of 71.2 dB. In the urban driving test Citroen reached the highest sound level once again, value of 76.1 dB and the lowest sound level vehicle Jaguar X-type with a value of 73 dB. But it is not properly to make conclusions from these values because they were reached only for 1 or 2 seconds. These values are important in the point of view to the human health, but evaluated average values are suitable to compare the sound levels in the vehicles.

IV. Evaluation

Table I shows evaluated values of measured sound level. These values are calculated as average numbers without extreme values. These results illustrate the comparison of all measured vehicles. Pick values of sound level are seen in the previous graphs.

TABLE I
FINAL EVALUATION

Vehicle	Constant Speed 50 km/h	Acceleration 50-90 km/h	Urban Cycle
Citroen Berlingo	66,7	67,8	65,0
Jaguar X-type	65,7	67,2	64,2
VW Polo	65,0	67,5	64,5

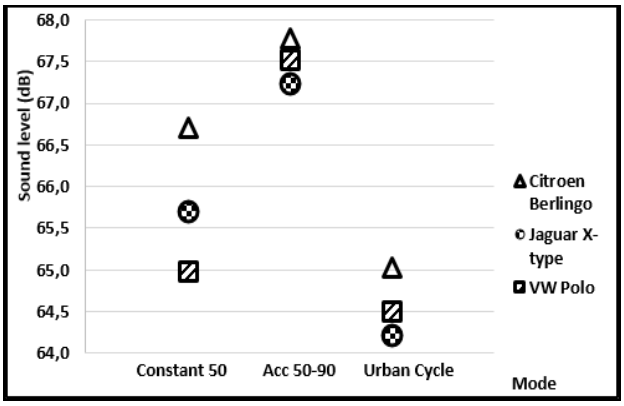

Fig. 8 The average sound level values of all measurements

V. Conclusion

Citroen Berlingo was the noisiest vehicle of the tested vehicles, which belongs to the light commercial vehicles which practical side is mainly used and it does not put the emphasis on driving comfort. In second place was Volkswagen Polo vehicle, which belongs to the family cars with a separate luggage compartment, which reduces the noise in the vehicle and then increases driving comfort. Quite noisy three-cylinder engine caused higher level of the noise during the speed increasing. You are able to enjoy the most of the driving sound comfort in the vehicle Jaguar X-type. As a luxury brand of vehicles, vehicle manufacturer Jaguar emphasizes the low noise level in the vehicle, because this aspect significantly contributes to the driving comfort of the vehicle.

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