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USING OF SOUND VISUALISATION TECHNIQUES FOR IDENTIFICATION AND ANALYSIS OF VEHICLE NOISE SOURCES

Urgency of the research. *The use of continuous measurement on the roads and highways with noise visualization techniques can in the future lead to increasing road safety. Central computer system could for example, evaluate the information continuously and the feedback would have warned drivers, through their mobile phones or GPS, to replace tires in the nearest dealer or car service. Vehicles fault diagnosis is currently carried out by different devices in car services. In terms of increasing the efficiency, diagnostic methods can be extended for noise visualization techniques.*

Target setting. *Using of measuring devices (for noise visualization) in car services for faster detection of faults and damaged parts as well as based on the measured values of noise pressure level, could be evaluated, if the tires are still safe or not.*

Actual scientific researches and issues analysis. *Acoustic cameras and various noise visualization techniques are implemented to manufacturing process of passenger car manufacturers. Their use is for detecting errors and for reduction of engine noise and its parts as well as car interior.*

Uninvestigated parts of general matters defining. *This article provides only partial research and conclusions. Philosophy, to use this noise visualization technique in many cases is different.*

The research objective. *The aim of this study was to demonstrate the differences in sound levels between two vehicles Skoda Octavia at different speeds at the same road. Partial output is a frequency analysis and identification of dominant sound sources in the engine space of VW Golf 1.4 vehicle.*

The statement of basic materials. *The methods of dynamic visualization of noise are used all around the world. In our case, we used the acoustic camera to visualize and identify the sound sources of moving vehicle as well sources of noise in the engine space.*

Conclusions. *It has been found that vibration from the engine are transmit by chassis to the interior of vehicle and cause uncomfortable noise. In the future, we expect the use of such measuring devices in car services for faster detection of faults and damaged parts. When passing vehicles and higher speeds, the biggest noise, the pressure wave in the contact tire-road is causing. Differences in noise pressure levels are mainly due to weight, quality of tires, aerodynamics and the shape and size of the tread.*

Key words: *vehicle; identification; frequency; measurements, noise.*

Introduction. The main task of the sound engineering is optimal adaptation of vehicle noise on subjective needs of its users. Although most vehicle transmission noises relate to internal parts and cannot be seen, their behavior and sound frequency always deal with a moving part according to engine rpm or pressure. Other worn vehicle parts can mimic the noise or feel of faulty transmission parts, so it becomes important how to identify noises specific to certain problems [1]. Vibration is the variation or displacement of a body with respect to specific reference position with time when displacement is alternatively greater or smaller than reference. Harshness is defined as vibration perceived actually and audibly produced by interaction of the tyre with road irregularities and vibrations of the structure and components [2]. Vibrations in engine are generated due to the reciprocating mechanism used for converting the energy into rotary motion. The engine vibrations produce combustion and reciprocating and rotational forces. Noise and vibration in driveline are a consequence power transmission from engine to wheels. The various sources are transmission gear noise, drive and propeller shaft, axle noise, tyre noise, aerodynamic noise, wind noise and interior noise. Tyre noise is due to tribology between tyre and road. Tire is excited by several means, which include non-uniform wear, radial or lateral run-out, road roughness, road surface irregularities, road surface discontinuities that induces impacts, bumps etc, which contribute to noise and vibration of automobiles [3].

1. Experimental part

To measure and visualize vehicle noise, we used acoustic camera. Used acoustic camera is based on beamforming method and conventional delay-and-sum beamforming in the time domain (see Fig. 1). Time domain delay-and-sum is done by separately delaying each microphone signal, making them align before summation and normalization. Acoustic camera currently uses the time domain delay-and-sum mainly because of the faster processing speed and new signal processing algorithms [4; 5].

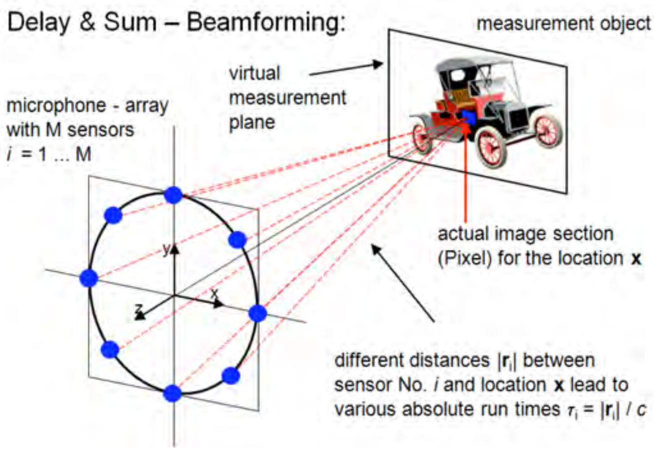

Fig. 1. Delay-sum beamforming method of the acoustic camera [4;5]

Measurement of passing vehicles

Measurement was realized for two passenger vehicles, directly Škoda Octavia 1.4 (Fig. 2) and Škoda Octavia 1.6i (Fig. 3). Speed of the vehicle in the measurement position was 30, 40 and 50 km/h. Passing vehicles was measured in the perpendicular to the microphone array. Measurement was carried out under relatively favourable conditions, air temperature 11°C, sunny, no wind. We used ring antenna, which consists of 48 microphones and one web camera. Distance of measured object and the antenna was 10 m. Measurement time record was set at 8 seconds. NoiseImage program is designed for process and analysis of measured data. In this program can be calculate outputs as time sound record (Fig. 4), frequency spectrum, spectrogram (Fig. 5) and sound images and movies.

Fig. 2. Noise emissions of Škoda Octavia 1.4 (gear engaged 4, speed 50 km/h)

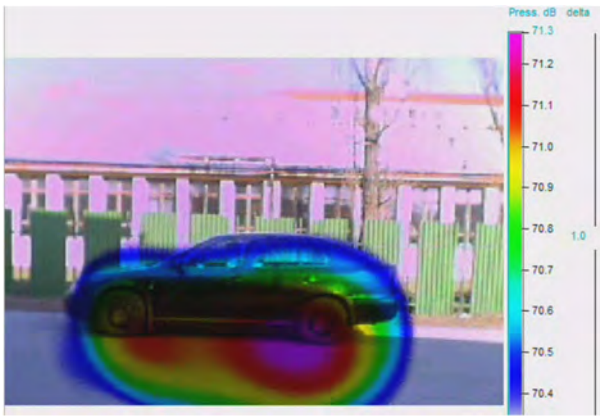

Fig. 3. Noise emissions of Škoda Octavia 1.6i (gear engaged 4, speed 50 km/h)

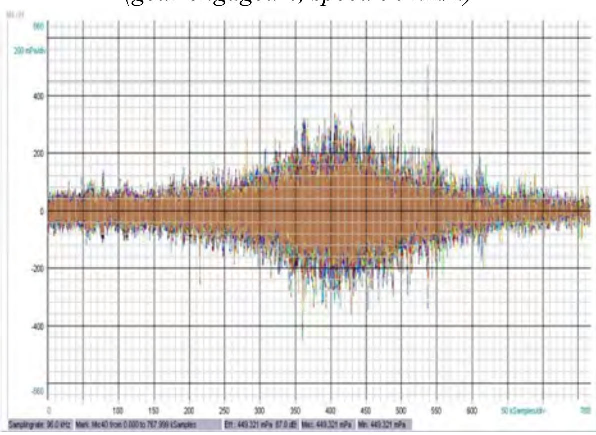

Fig. 4. Time sound record of passing vehicle

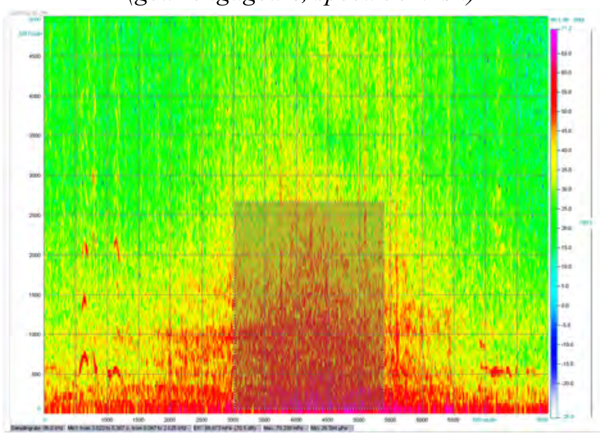

Fig. 5. Spectrogram of passing vehicle

Measurement in the engine space

Measurement was realized on passenger vehicle Volkswagen Golf 1390 cm^3, 55 kW. Location of ring antenna was 1 m from the engine, see Fig. 6. Measuring time was set to 8 seconds. The measurements were performed in three variations, specifically:

– at engine idling speed,

– at 2000 rpm of idling speed,

– at variables rpm of idling speed (from idling speed to 2000 rpm idling speed).

Fig. 6. Location of ring antenna from the engine space

2. Results and discussion

When moving the vehicles it is evident from Fig. 2 and Fig.3 that the greatest noise of passing car is emitted on contact of the tire with the road. This is caused by the pressure wave which is generated by the contact of the road and the tires. Similarly results describes also by the authors v [6]. Acting forces on the road when passing a vehicle are vertical, horizontal and dynamic. The results and the comparison of sound pressure levels of passing vehicles Škoda Octavia 1.4 (Auto 1) and Škoda Octavia 1.6i (Auto 2) are stated in the Table and Fig. 7.

Table

Sound pressure levels of the comparison vehicles

Sound pressure level [dB]			
Gear selected	**Speed of passing vehicles [km/h]**	**Auto 1**	**Auto 2**
2	30	67.6	66.6
3	40	75.0	69.8
4	50	75.7	70.3

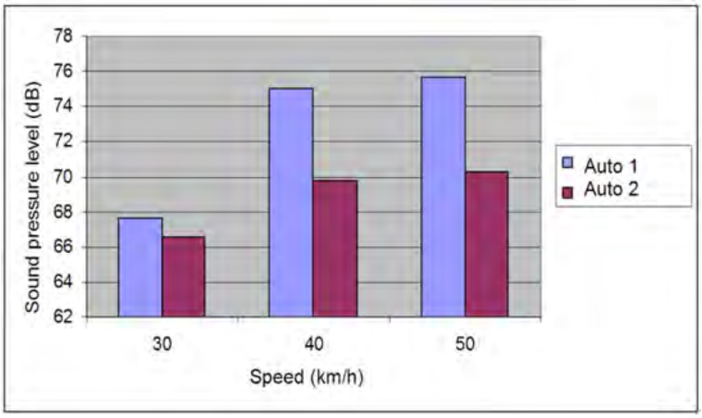

Fig. 7. Sound pressure levels depending on the speed of passing vehicles

The quality of the road had the same properties and the differences in sound pressure levels are associated primarily with the quality of the tires, different composition and age.

The results of measurements in the engine space is primarily for identify of dominant frequency bands and frequencies. With analyzing the frequency spectrum (Fig. 8) were selected the most dominant frequency bands for identifying of problematic noise sources. Acoustic images were processed for frequency bands from 195 Hz to 207 Hz, see Fig. 9, from 718 Hz to 746 Hz, see Fig. 10, from 990 Hz to 1000 Hz, see Fig. 11 and from 2900 Hz to 3100 Hz, see Fig. 12. The resulting acoustic images were processed only for variant at 2000 rpm of idling speed.

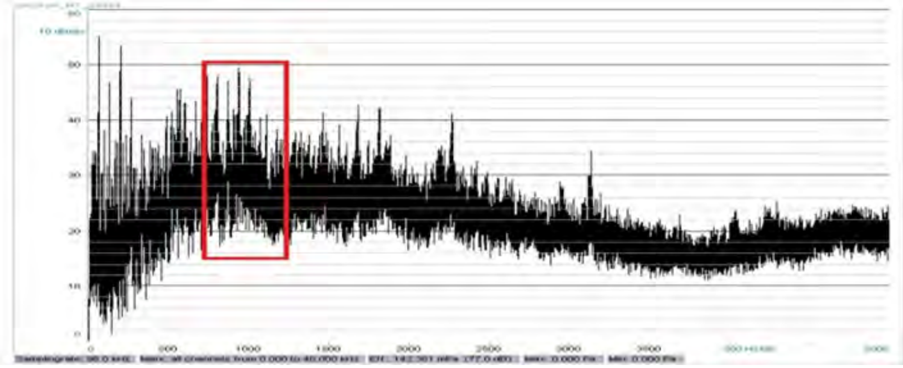

Fig. 8. Frequency spectrum of the variant - 2000 rpm of idling speed

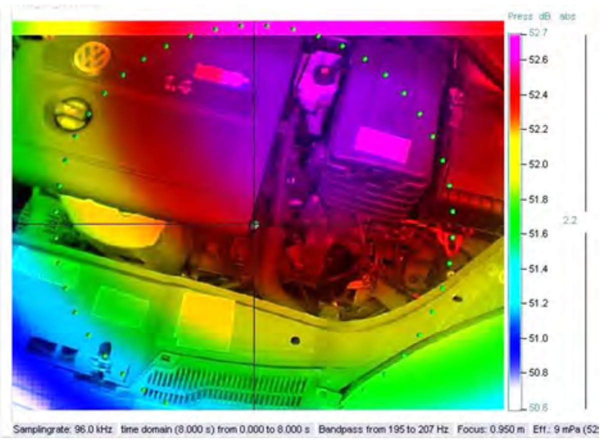

Fig. 9. Acoustic image from 195 to 207 Hz

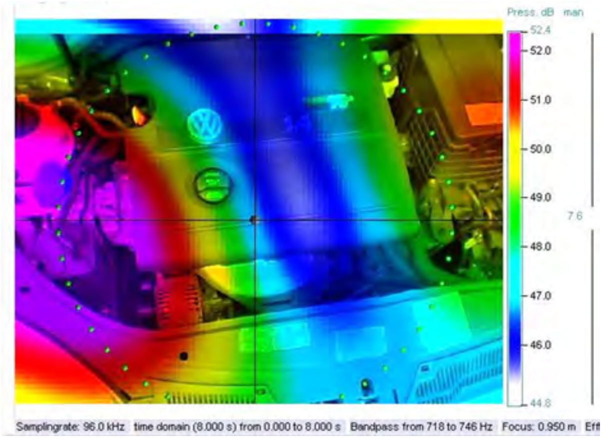

Fig. 10. Acoustic image from 718 to 746 Hz

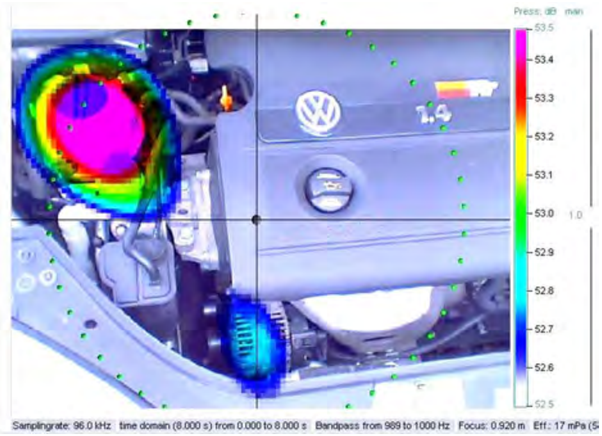

Fig. 11. Acoustic image from 989 to 1000 Hz

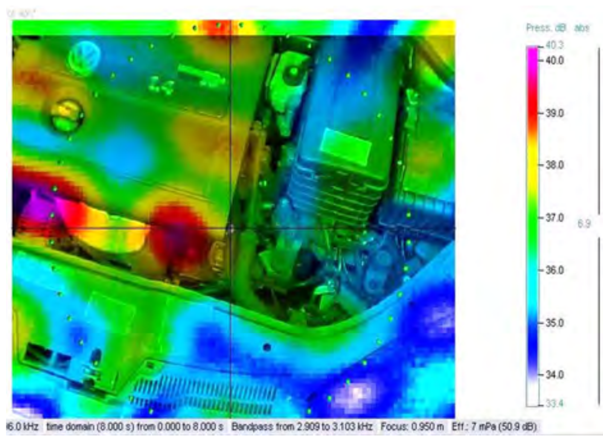

Fig. 12. Acoustic image from 2900 to 3100 Hz

From the presented acoustic images can be visually identified the noise sources, such as vibration of the engine block, aerodynamic noise of the air intake, belt drive system which are not in one plane, pulleys are strongly stretched, alternatively various resonance effects.

The noise pressure level at 2000 rpm idling speed amounted to 71.2 dB compared to 48.5 dB at idling speed. These calculated values are valid for the frequency range 0-24 kHz. All noise pressure levels are presented as unweighted, ie without weighting filter A.

The results of measurements at variables rpm, showed the occurrence of tonal component in the vicinity of 120 Hz frequency (see Fig. 13).

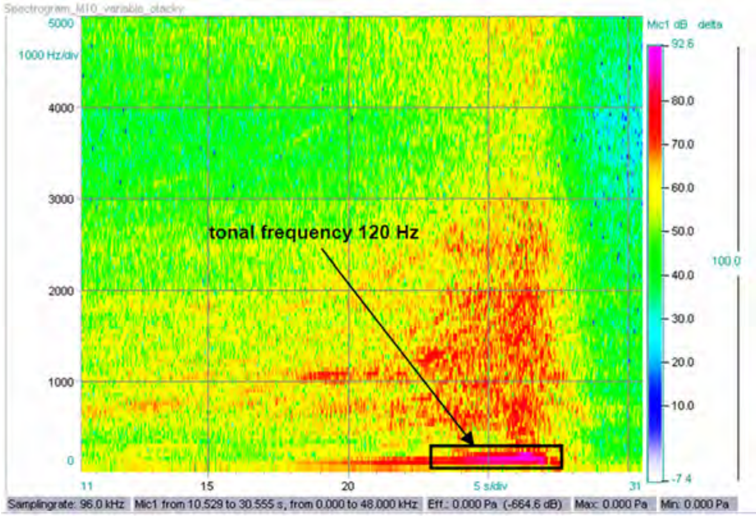

Fig. 13. Spectrogram with selected tonal frequency

Conclusion. It is possible used of visualisation techniques to localize a sound source of engine parts. Then can determine the sources of defects and take measures to eliminate them. It has been found that vibration from the engine are transmit by chassis to the interior of vehicle and cause uncomfortable noise. Currently, acoustic cameras and various noise visualization techniques are implemented to manufacturing process of passenger car manufacturers. Their use is for detecting errors and for reduction of engine noise and its parts as well as car interior. In the future, we expect the use of such measuring devices in car services for faster detection of faults and damaged parts.

When passing vehicles and higher speeds, the biggest noise, the pressure wave in the contact tire-road is causing. Differences in noise pressure levels are mainly due to weight, quality of tires, aerodynamics and the shape and size of the tread. The use of continuous measurement on the roads and highways with noise visualization techniques can in the future lead to increasing road safety. Based on the measured values of noise pressure level, could be evaluated, if the tires are still safe or not. Central computer system could for example, evaluate the information continuously and the feedback would have warned drivers, through their mobile phones or GPS, to replace tires in the nearest dealer or car service.

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ВИКОРИСТАННЯ ТЕХНІКИ ВІЗУАЛІЗАЦІЇ ЗВУКУ ДЛЯ ВИЯВЛЕННЯ ТА АНАЛІЗУ ДЖЕРЕЛ ШУМУ ТРАНСПОРТНОГО ЗАСОБУ

У цій статті розглянуто метод динамічної візуалізації шуму, використовуючи акустичну камеру. Використання акустичної камери дає можливість візуалізувати й ідентифікувати джерела звуку рухомої техніки, а так само джерела шуму в моторному відсіку. Для того щоб краще діагностувати дефекти, можна дані вимірювання поєднувати з вимірами вібраційних сенсорів. Результат дослідження показав різницю у рівні звуків між двома машинами Skoda Octavia на тій самій дорозі при різних швидкостях. Частковий висновок – це аналіз частоти та ідентифікація домінуючих джерел звуку в моторному відсіку VW Golf з об'ємом двигуна 1,4 л.

Ключові слова: *автомобіль; ідентифікація; частота; вимірювання; шум.*

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ИСПОЛЬЗОВАНИЕ ТЕХНИКИ ВИЗУАЛИЗАЦИИ ЗВУКА ДЛЯ ОПРЕДЕЛЕНИЯ И АНАЛИЗА ИСТОЧНИКОВ ШУМА ТРАНСПОРТНОГО СРЕДСТВА

В данной статье рассматривается метод динамической визуализации шума, используя акустическую камеру. Использование акустической камеры дает возможность визуализировать и идентифицировать источники звука движущейся техники, а так же источники шума в моторном отсеке. Для того чтобы лучше диагностировать дефекты, можно данные измерения совмещать с измерениями вибрационных сенсоров. Результат исследования показал разницу в уровне звуков между двумя машинами Skoda Octavia на одной и той же дороге при разных скоростях. Частичный вывод – это анализ частоты и идентификация доминирующих источников звука в моторном отсеке VW Golf с объемом двигателя 1,4 л.

Ключевые слова: *автомобиль; идентификация; частота; измерение; шум.*

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