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TRANSMISSION OF VIBRATIONS FROM THE ENGINE TO THE CAR BODY

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Abstract

Vibrations have become an important factor of vehicles. Vibration tests help identify, and then tune the automotive vehicle to improve the structural strength. Due to the increasing development of vehicles and machines and their widespread use. Increased research-using vibrations due to their low or zero interference with the vehicle under test. Vibration testing is often carried out using Laser Doppler Vibrometry (LDV), a device that is used for contactless measurement of vibration on the surface. The laser beam is directed from the device to the surface of interest, and the amplitude and frequency of vibration are extracted from the Doppler shift frequency of the reflected laser beam due to the movement surface. High values of vibration transmitted from the engine, and the way significantly affect the body of the vehicle and the driver.

Article presents results of research carried out on vehicles powered by three different engines and rpm. Tests were carried out on an engine dynamometer in the same environmental conditions. Two of engines were with spark ignition, including one with a supercharged engine and compression ignition engine.

The measurements were made using the Laser Doppler Vibrometry using Fast Fourier Transform. The spectrum obtained is used for further analysis to determine the acceleration level at various frequencies. Obtained from Fast Fourier Transform readings used for drawing graphs of frequency V acceleration.

The results of the study are interesting and promising, as they show a significant difference in the velocity for spark ignition engines and compression-ignition.

Keywords: *LDV (Laser Doppler Vibrometry), car body, car suspension*

1. Introduction

Car suspension systems affect the results of measurements unless these measurements are comparative ones for the purpose of which the vibroacoustic signal of a fully functioning vehicle is taken as a point of reference. The Laser Doppler Vibrometry allows for direct measurement of velocity (displacements and phase shifts) [1, 2]. Moreover, no contact with the surface under investigation is required (it may be sometimes necessary to use a system of mirrors and a retroreflective tape that helps reflect the laser beam without losses). One of the most essential issues is the place of the measurement; in order to ensure the repeatability of the measurements, in particular the comparative measurements, the laser beam should be aimed at one target. The objective of this research is to determine how the vibrations of the engine are transmitted to the car body.

2. Scope of research

The pictures below demonstrate the targets of the vibroacoustic laser beam: the wheel arch and the passenger's door (Fig. 1).

Fig. 1. LDV targets on the wheel arch (left side) and passenger's door

This study made use of three cars, of the same make but with different driving units: apart from the supercharged 1.4 L spark ignition engine and 1.6 L compression ignition engine that were presented above, the third car is also Fiat Bravo Model 198, Version 54A, with 1.4BZ 90CV CD engine [3], which is very similar to the petrol-fuelled 1.4 L engine, but it is not supercharged.

3. Results of measurements

The first vehicle under investigation was that with 1.4 L spark ignition engine (90 KM). Fig. 2 presents the absolute vibration velocity levels on the engine mount bracket, wheel arch and passenger's door.

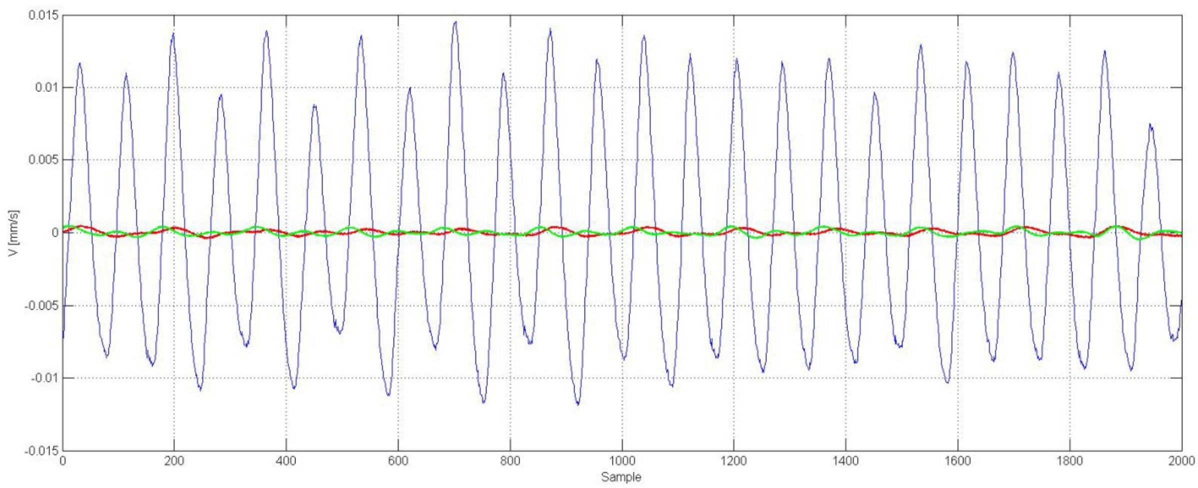

Fig. 2. Absolute vibration velocity levels for a vehicle with 1.4 L spark ignition engine (90 KM), idle speed (800 rpm); blue – on the engine mount bracket, red – on the wheel arch, green – on the passenger's door

The differences in the vibration levels are clearly seen. A similar analysis has been carried out at an excitation of 2000 rpm. In this case, apart from an obvious change in the length of the period, it is possible to observe a significant increase in the vibration amplitude measured on the engine mount bracket. Tab. 1 includes both absolute maximum and medium values of the vibroacoustic signal in order to help compare the values and draw conclusions.

Tab. 1. Absolute vibration velocity values measured on the engine, wheel arch body and passenger's door; 1.4 L spark ignition engine

Measurement target	Rotational speed of engine crankshaft 800 rpm		Rotational speed of engine crankshaft 2000 rpm	
	V_{max} [mm/s]	V_{mean}*10^{-5} [mm/s]	V_{max} [mm/s]	V_{mean}*10^{-5} [mm/s]
Engine mount bracket	0.0155	1.74	0.0265	7.36
Wheel arch body	0.0005	0.02	0.0003	0.15
Passenger's door	0.0005	0.31	0.0004	0.46

It seems particularly interesting to notice that the vibrations measured on the passenger's door are greater that those measured on the wheel arch.

Figure 3 and 4 demonstrate the normalised frequency response of a relative vibration velocity. Both for the discrete time response and in this case, the blue colour indicates the measurement taken on the engine mount bracket; the red colour indicates the measurement taken on the wheel arch body, and the green one on the passenger's door.

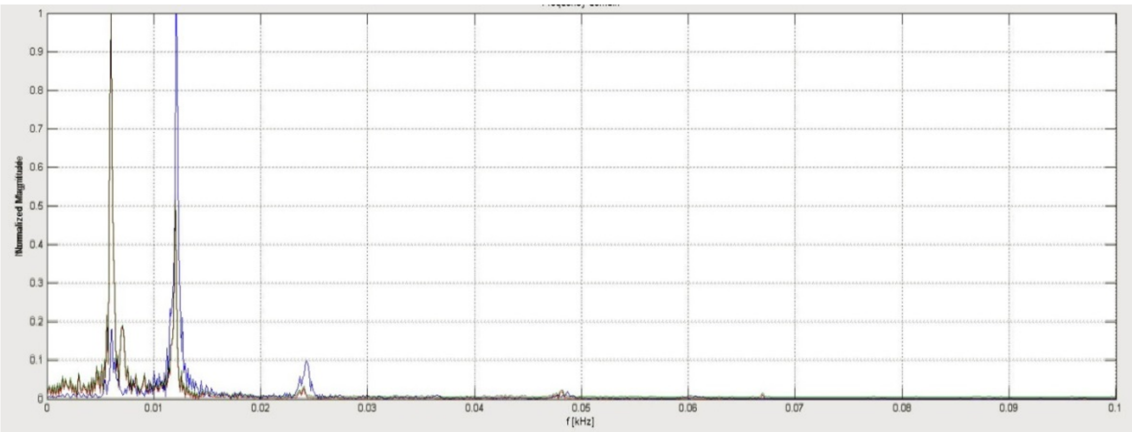

Fig. 3. Relative vibration velocity levels (frequency response) for a vehicle with 1.4 L spark ignition engine (90 KM), idle speed (800 rpm); blue – on the engine mount bracket, red – on the wheel arch, green – on the passenger's door

The normalised frequency response demonstrates that all the measurements include two dominant harmonics: the first one of 12 Hz and the other of 6 Hz. The fact that the second harmonic is dominant in terms of magnitude is particularly visible for measurements taken on the passenger's door.

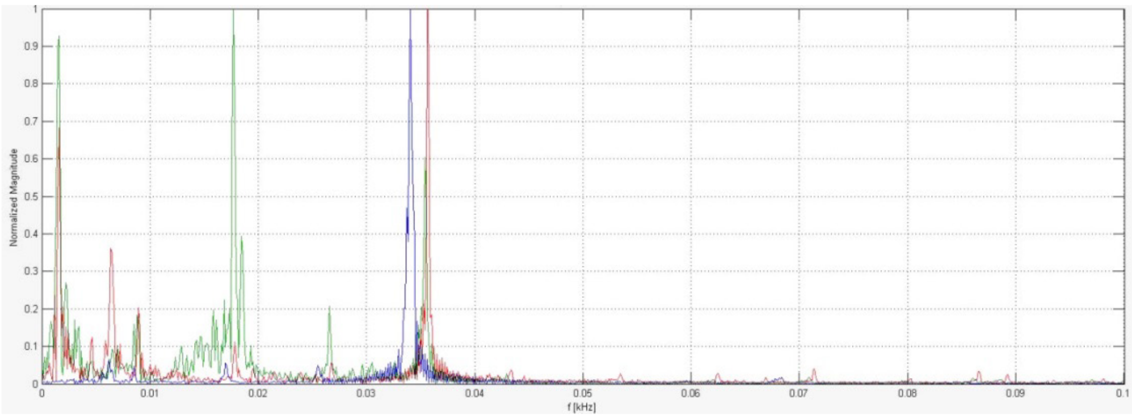

Fig. 4. Relative vibration velocity levels (frequency response) for a vehicle with 1.4 L spark ignition engine (90 KM), idle speed (2000 rpm); blue – on the engine mount bracket, red – on the wheel arch, green – on the passenger's door

The experiment carried out for the value of 2000 rpm shows significant changes in the frequency response. A significant number of harmonics is transferred to the area below 40 Hz. The spectrum for the target on the passenger's door is particularly interesting: here the spectrum density is the largest and three dominant harmonics occur.

The second vehicle under investigation was of the same model, but with a supercharged engine. A comparative analysis of the discrete time response of the vibroacoustic signal was also carried out for this vehicle at the values of the crankshaft speed of 800 and 2000 rpm.

For a vehicle with supercharged spark ignition engine, a significant damping is observable for the signal measured on the wheel arch body and passenger's door; however, it is lower than for the non-supercharged engine. Tab. 2 demonstrates the comparison of particular values for this type of vehicle.

Tab. 2. Absolute vibration velocity values measured on the engine, wheel arch body and passenger's door; 1.4 L supercharged spark ignition engine (120 KM)

Measurement target	Rotational speed of engine crankshaft 800 rpm		Rotational speed of engine crankshaft 2000 rpm	
	V_{max} [mm/s]	$V_{mean}*10^{-5}$ [mm/s]	V_{max} [mm/s]	$V_{mean}*10^{-5}$ [mm/s]
Engine mount bracket	0.0172	1.68	0.0276	1.67
Wheel arch body	0.0005	2.20	0.0003	2.96
Passenger's door	0.0006	1.68	0.0006	1.97

Unlike in the case of the previous model, here the vibrations transmitted to the wheel arch have greater values. The reason behind it is the system damping. Maximum amplitudes reveal small differences in comparison to the previous model. Significant differences are noticeable for the mean value. This value may be a variable of a smooth running of this particular driving unit; in this case, it is lower because the mean values are greater and results from the supercharging system of this unit.

The normalised spectrum for idling, without excitation, shows a greater divergence between harmonics. It also confirms the hypothesis concerning a negative impact on the unit's ergonomics.

The excitation resulted in this case in amplifying the harmonics and increasing their number. The additional values are a result of a simple supercharging system. Additional harmonics are also seen for ranges greater than 40 Hz.

The last object under investigation was the same car model, but equipped with a 1.6 L compression ignition engine. As before, a comparative analysis of the discrete time response of the vibroacoustic signal was carried out at the value of the speed of crankshaft.

The results confirm previous conclusions. An apparent change in the length of the period and an increase in the vibration amplitude following an increase in the rotational speed of the crankshaft can be observed. Maximum and mean values are presented in Tab. 3.

For a vehicle with a compression ignition engine the damping of mean values of vibrations is particularly noticeable, which directly results in better ergonomics (however, maximum values are greater than in previous analyses).

Comparing maximum and mean values of vibrations measured on the car body, is not possible to infer how the engine suspension affects the transmission of vibrations. The analysis of vibration amplitudes on the wheel arch and passenger's door demonstrates that the vibration amplitudes decrease as the rotational speed of the crankshaft increases (we can see a reverse phenomenon on the engine mount bracket). In the case of this model, the increase in the mean values of vibrations transmitted on the passenger's door should be treated as a negative effect, because this value increases.

As in the previous cases, apart from an apparent change of the dominant harmonic, a change of excitation results in additional harmonics when the excitation increases. However, these harmonics, in opposition to the previous case, overlap to a large extent. It confirms a better ergonomics of this unit.

Tab. 3. Absolute vibration velocity values measured on the engine, wheel arch body and passenger's door; 1.4 L supercharged spark ignition engine (120 KM)

Measurement target	Rotational speed of engine crankshaft 800 rpm		Rotational speed of engine crankshaft 2000 rpm	
	V_{max} [mm/s]	V_{mean}*10^{-5} [mm/s]	V_{max} [mm/s]	V_{mean}*10^{-5} [mm/s]
Engine mount bracket	0.0168	0.462	0.0338	0.499
Wheel arch body	0.0011	0.216	0.0008	0.155
Passenger's door	0.0016	0.116	0.0015	0.209

The comparison of all three models reveals that the vehicle with compression ignition engine is more ergonomic, but the amplitudes of maximum relative vibration velocity increase (Fig. 6 and 7).

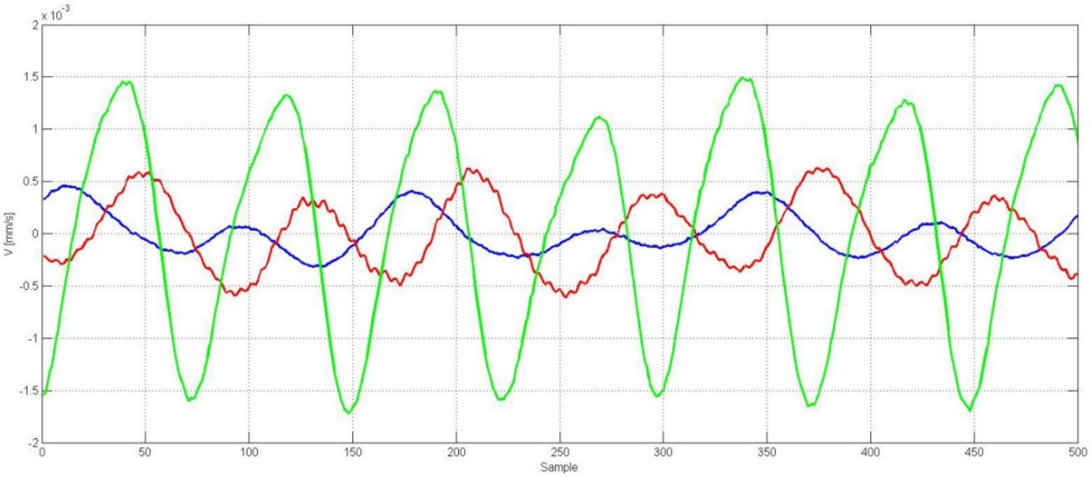

Fig. 5. Discrete relative vibration levels for three vehicles: blue – non-supercharged 1.4 L spark ignition engine, red – 1.4 L supercharged engine, green – 1.6 L compression ignition engine; the measurement taken on the passenger's door, idle speed 800 rpm

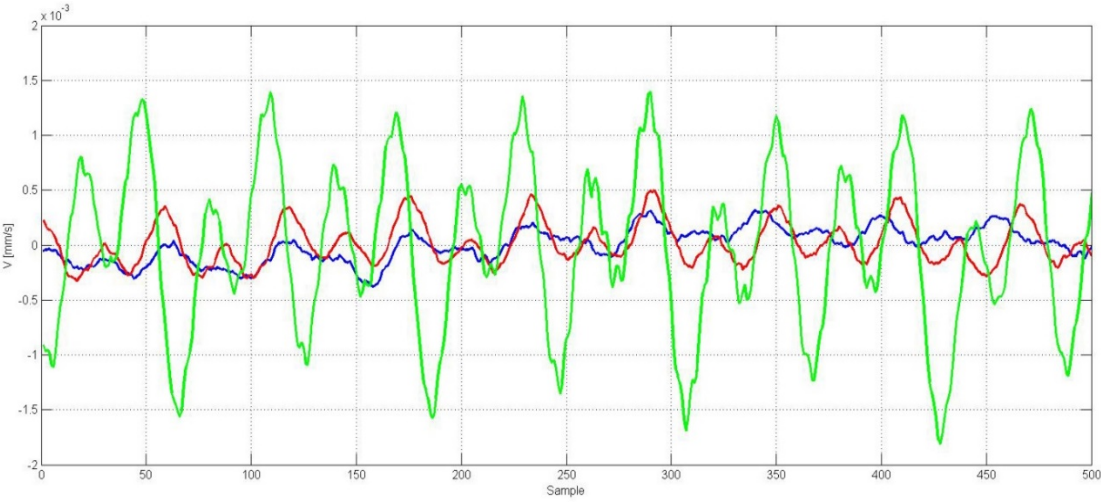

Fig. 6. Discrete relative vibration levels for three vehicles: blue – non-supercharged 1.4 L spark ignition engine, red – supercharged 1.4 L engine, green – 1.6 L compression ignition engine; the measurement taken on the passenger's door, idle speed 2000 rpm

4. Conclusions

As the rotational speed of the crankshaft increases (and the length of the period decreases), additional fluctuations occur in all types of vehicles (they were clearly seen even for the lowest velocity of the supercharged engine), but the vibration signal is of stationary character.

The diagrams (Fig. 8-10) show unambiguously that the amplitude of the relative vibration velocity notwithstanding the measurement target is the greatest for the vehicle with compression ignition engine and the lowest for the vehicle with spark ignition engine (non-supercharged). Simultaneously, the fluctuations and mean values of the signals indicate that the vehicle with diesel engine that is most ergonomic, whereas the vehicle with supercharged spark ignition engine is least ergonomic.

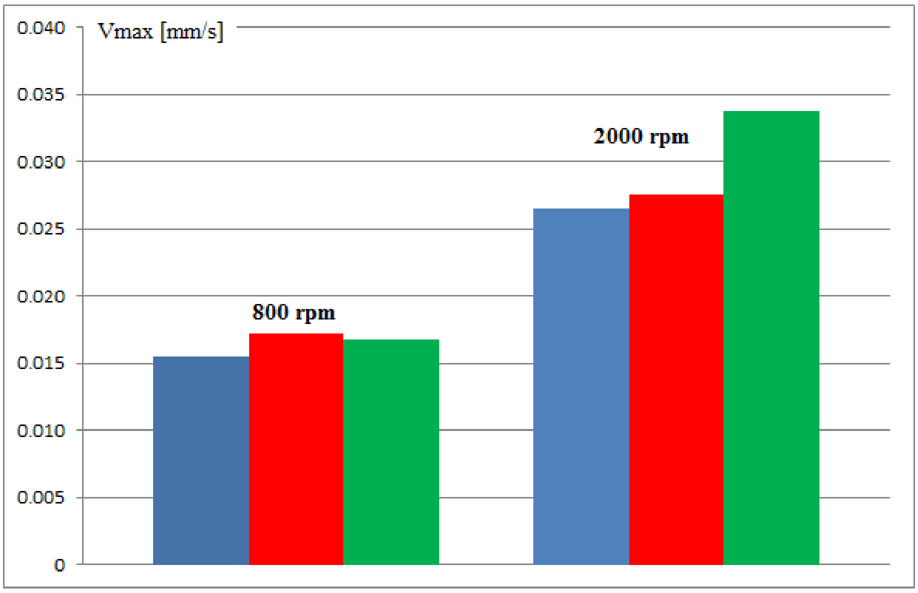

Fig. 7. Comparison of maximum relative vibration velocity measured on the engine mount bracket for a car model equipped with 3 different engines; blue – 1.4 L spark ignition engine (90 KM), red – supercharged spark ignition engine (120 KM), green – 1.6 L compression ignition engine (105 KM)

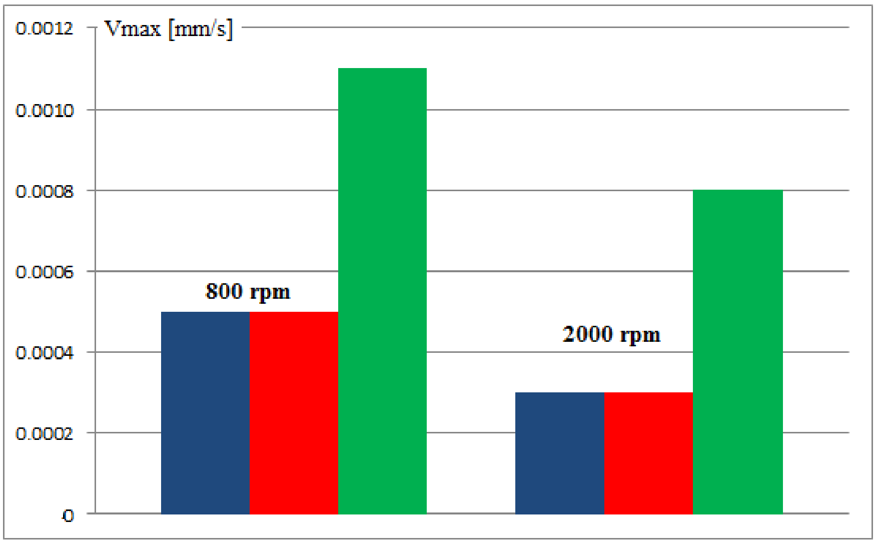

Fig. 8. Comparison of maximum relative vibration velocity measured on the wheel arch body for a car model equipped with 3 different engines; blue – 1.4 L spark ignition engine (90 KM), red – supercharged spark ignition engine (120 KM), green – 1.6 L compression ignition engine (105 KM)

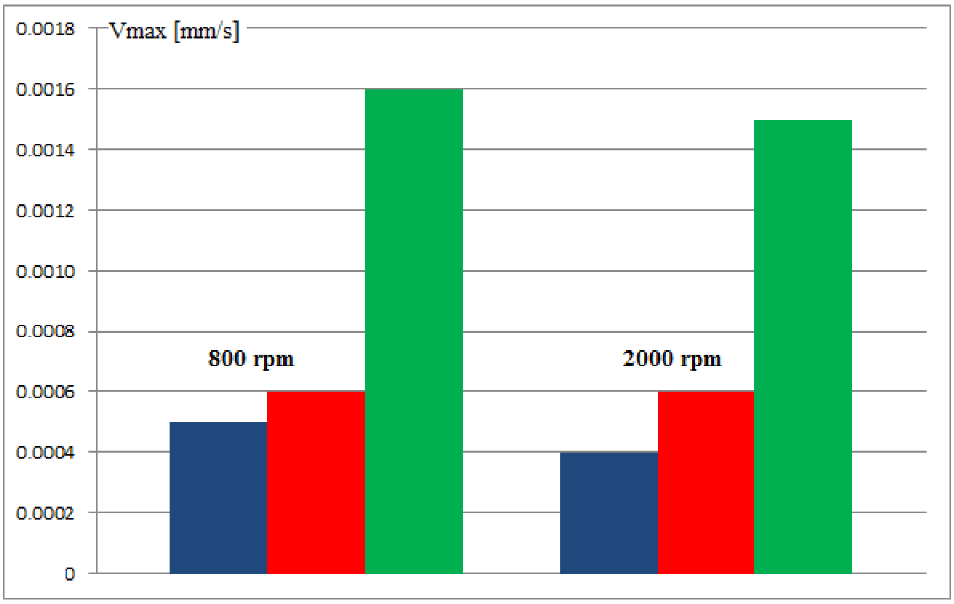

Fig. 9. Comparison of maximum relative vibration velocity measured on the passenger's door for a car model equipped with 3 different engines; blue – 1.4 L spark ignition engine (90 KM), red – supercharged spark ignition engine (120 KM), green – 1.6 L compression ignition engine (105 KM)

References

[1] Acoustic and vibration lab. http://soundmasters.kaist.ac.kr.
[2] Automotoserwis, diesel diagnostics. www.automotoserwis.com.pl/porad/diesel.htm.
[3] Fiat Polska. www.fiat.pl.