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EXPERIMENTAL ANALYSIS OF NOISE AND VIBRATION OF A DIESEL ENGINE

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Abstract

Noise and vibration of ignition compression engine is one of the most complicated fields to cope with since every mechanism that compose of the engine affect them separately. In this study, effect of diesel on engine noise and vibration has been studied on an unmodified compression ignition engine. Noise and vibration characteristic of a direct ignition engine, which was fuelled with diesel, were investigated. With the usage of equations obtained from regression analysis, estimation of engine characteristic fuelled with various biodiesels researches were carried out. Tests were conducted at fixed injection timing of diesel fuel. The first system is for diesel fuel injection; the second one is PFI (port-fuelled injection) and is used for injecting alcohol into the engine intake manifold. The engine applied to this study was a naturally aspirated, 3in-line, IVECO AIFO 8031 i06.05 diesel engine with direct injection. Experiments were conducted in a sound insulated room. For each experiment, vibration data gathered from the engine block with 3.2 kHz (for vibration) for 2 s and with 20 kHz sampling frequency for 0.320 s. All measurements were performed under conditions: angle 10; 4 different loads (4, 8, 12 and 20 kW).

Keywords: *biodiesel; compression ignition engine, engine vibration, sound pressure level*

1. Introduction

Vehicle comfort is a crucial point to satisfy customers. Automotive manufacturers have to develop their product due to high competition in sector and costumer demands [1, 2]. On the other hand, in last decades' alternative fuels have become popular due to environmental concerns and emission legislations of the countries [3, 4]. Therefore, effect of them on engine is undeniable. Biodiesel (fatty acid methyl esters) that derived from vegetable oil or animal fat, is one of the most popular alternative fuels basically due to its advantages such as, renewable, non-toxic, biodegradable and also it is able to use with little or no engine modifications [5-7].

In previous studies, it has been widely reported that by using various biodiesels leads to reduce of carbon monoxide (CO), hydrocarbon (HC) and particulate matter [8-10]. However, researchers were also reported higher NO_x emissions for biodiesel compared to diesel fuel [12-14].

In literature although there have been many studies about performance and emission characteristic of biodiesel from various feedstocks, few number of reports have been evaluated its acoustic and vibration characteristics. Taghizadeh-Alisaraei et al. studied on a six-cylinder diesel engine when the engine fuelled with biodiesel blends to observe its effect on engine vibration [15]. How et al. investigated vibration, performance and emission characteristic of a diesel engine that fuelled with coconut biodiesel blends [16]. Redel-Macías et al. fuelled a diesel engine with olive pomace oil methyl ester whereas Elshaib et al. used waste cooking oil up to pure biodiesel to investigate noise changes of diesel engines [17, 18]. Siavash et al. also analysed the noise parameter of a diesel engine for various diesel and biodiesel blends [19].

In literature, although it has been many studies about performance and exhaust emission characteristic of internal combustion engines operated with alternative fuels, there is deficiency about their noise and vibration characteristics, which are crucial issue for passenger comfort. With the usage of equations obtained from regression analysis, estimation of engine characteristic fuelled with various biodiesels can be possible without time consuming and costly experimental works. Therefore, in this study, noise and vibration characteristic of a direct ignition engine, which was fuelled with diesel, were investigated.

2. Experimental setup

The engine applied to this study was a naturally aspirated, 3in-line, IVECO AIFO 8031 i06.05 diesel engine with direct injection. The experimental setup is shown in Fig. 1. Detailed engine specifications are:

– number of cylinders 3 in line,
– displacement 2.9 dm^3,
– bore 104 mm,
– stroke 115 mm,
– compression ratio 19:1,
– rated power 24 kW,
– crankshaft revolution 1500 rpm.

Tests were conducted at fixed injection timing of diesel fuel. The first system is for diesel fuel injection; the second one is PFI (port-fuelled injection) and is used for injecting alcohol into the engine intake manifold.

The measurement system consists as follows:

– diesel fuel consumption – AVL 7031 gravimetric meter ±20 g/h,
– E85 consumption – digital scale elapsed time ±1 g,
– engine power – electrical power meter,
– exhaust emissions (NO_x, CO, HC) – Horiba Motor Exhaust Gas Analyser MEXA 8120F, Horiba Pre-Sampler ±1% of full scale for each analyser module,
– exhaust emissions (CO_2,O_2) – Sick Maihak S710 Gas Analyser 61% of selected output range,
– smoke meter AVL 415, ±3% of measured value,
– in-cylinder pressure sensor – Kistler 6001, sensitivity: ±0.5%,
– charge amplifiers – Kistler 5001,
– pilot injection timing – piezoelectric sensor attached to the high pressure fuel pipe – Kistler 6001 with adapter – Kistler 6501, sensitivity: ±0.5%,
– resolution for the data acquisition system – 0.35 CA deg.

The measurement points of vibration and sound show in Fig. 1b (1 and 2 points vibration measurement; 3 point sound measurement).

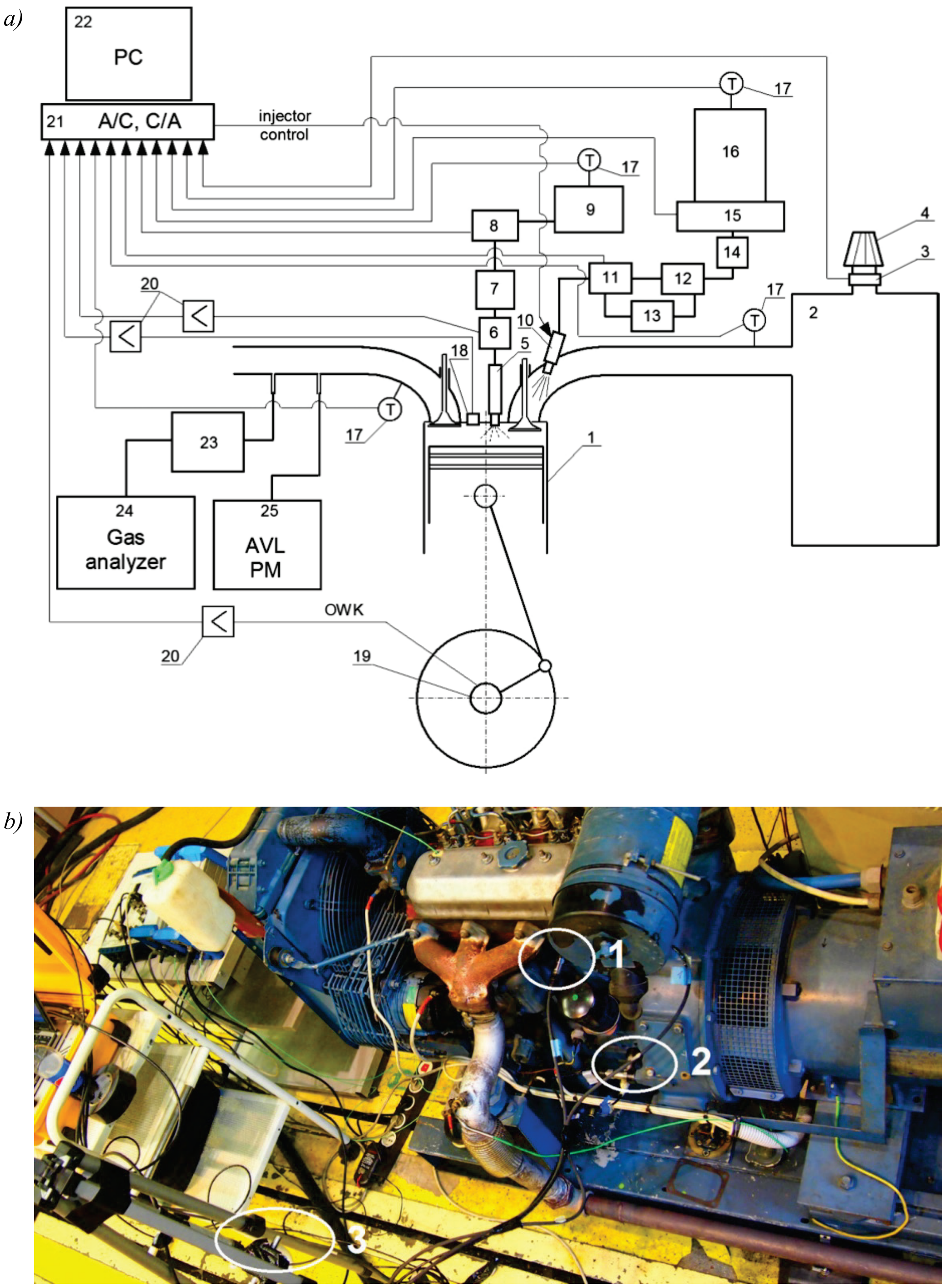
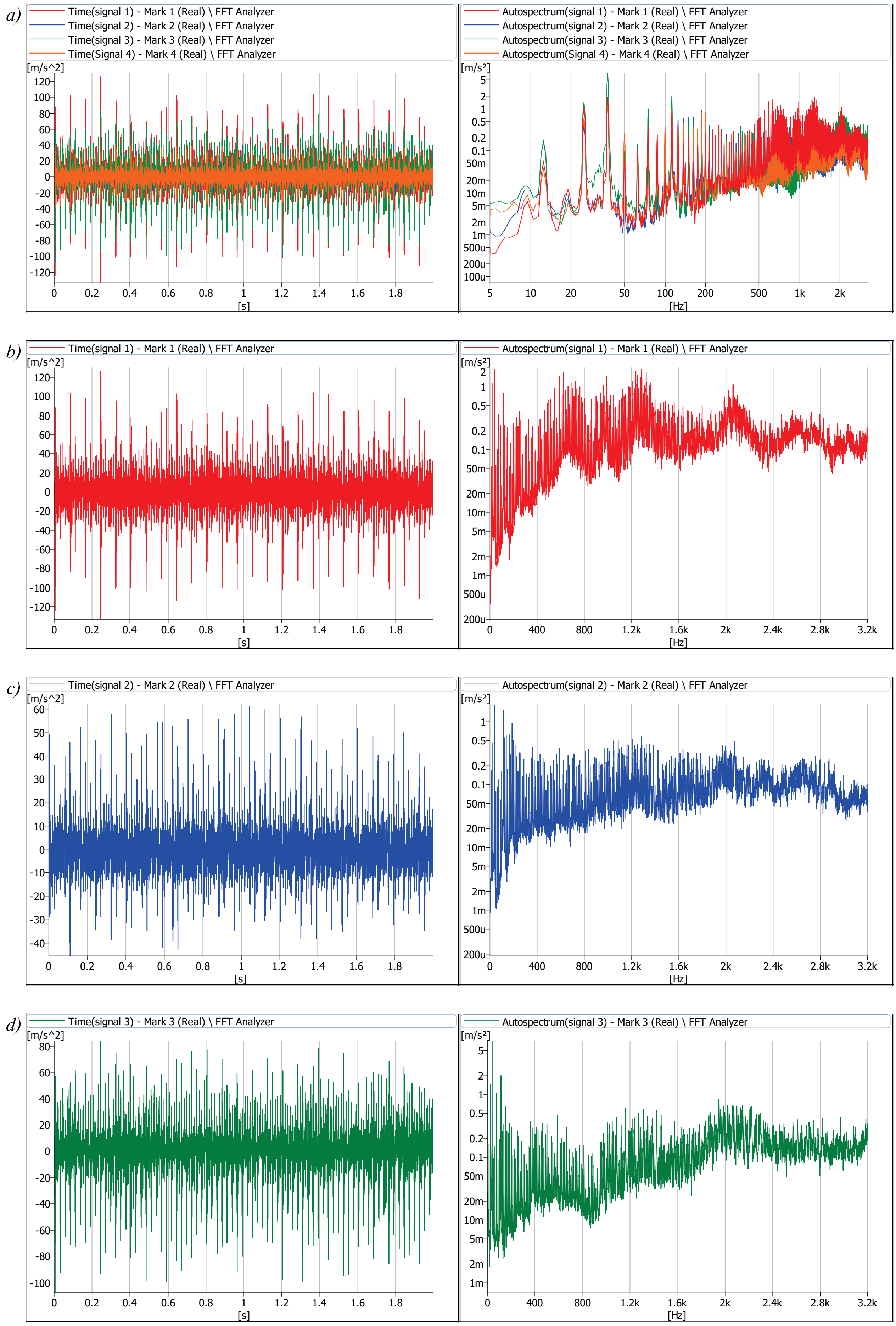


Fig. 1. Diagram of the experimental setup (a): 1 – engine, 2 – intake pulsation dumping tank, 3 – flowmeter, 4 – air filter, 5 – injector, 6 – fuel pressure sensor, 7 – fuel pump, 8 – fuel flowmeter, 9 – fuel tank, 10 – alcohol injector, 11 – pressure sensor, 12 – fuel pump, 13 – PID controller, 14 – filter, 15 – electronic scales, 16 – fuel tank, 17 – temperature sensor, 18 – pressure sensor, 19 – crank angle sensor, 20 – amplifier, 21 – A/D, D/A module, 22 – PC computer, 23 – pre-sampler, 24 – exhaust gas analyser, 25 – smoke meter; measurement points of engine vibration and sound (b)

3. Vibration of the engine

For each experiment, vibration data gathered from the engine block with 3.2 kHz (for vibration) for 2 s and with 20 kHz sampling frequency for 0.320 s.

Vibration acceleration and acceleration spectrum characteristic are presented in Figs. 2 and 3, respectively as examples.


a)
Time(signal 1) - Mark 1 (Real) \ FFT Analyzer
Time(signal 2) - Mark 2 (Real) \ FFT Analyzer
Time(signal 3) - Mark 3 (Real) \ FFT Analyzer
Time(Signal 4) - Mark 4 (Real) \ FFT Analyzer
[m/s^2]
[s]
Autospectrum(signal 1) - Mark 1 (Real) \ FFT Analyzer
Autospectrum(signal 2) - Mark 2 (Real) \ FFT Analyzer
Autospectrum(signal 3) - Mark 3 (Real) \ FFT Analyzer
Autospectrum(Signal 4) - Mark 4 (Real) \ FFT Analyzer
[m/s²]
[Hz]
b)
Time(signal 1) - Mark 1 (Real) \ FFT Analyzer
[m/s^2]
[s]
Autospectrum(signal 1) - Mark 1 (Real) \ FFT Analyzer
[m/s²]
[Hz]
c)
Time(signal 2) - Mark 2 (Real) \ FFT Analyzer
[m/s^2]
[s]
Autospectrum(signal 2) - Mark 2 (Real) \ FFT Analyzer
[m/s²]
[Hz]
d)
Time(signal 3) - Mark 3 (Real) \ FFT Analyzer
[m/s^2]
[s]
Autospectrum(signal 3) - Mark 3 (Real) \ FFT Analyzer
[m/s²]
[Hz]

e)

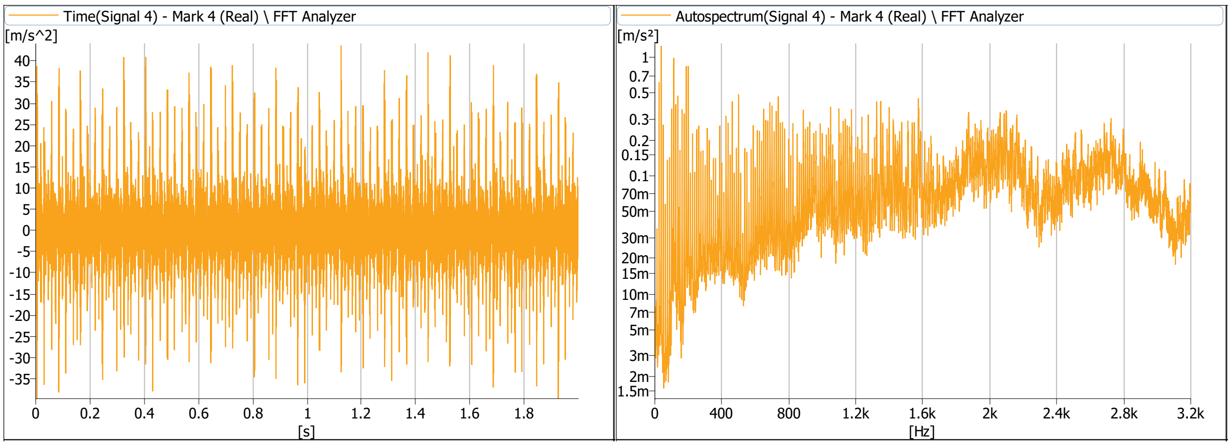


Fig. 2. Time and frequency domain signal of the engine vibration: a) total all for the 4 measurement signal (2 points and 2 directs), b) longitudinal direct of the 1 point, c) transverse direct of the 1 point, d) longitudinal direct of the 2 point, e) transverse direct of the 2 point

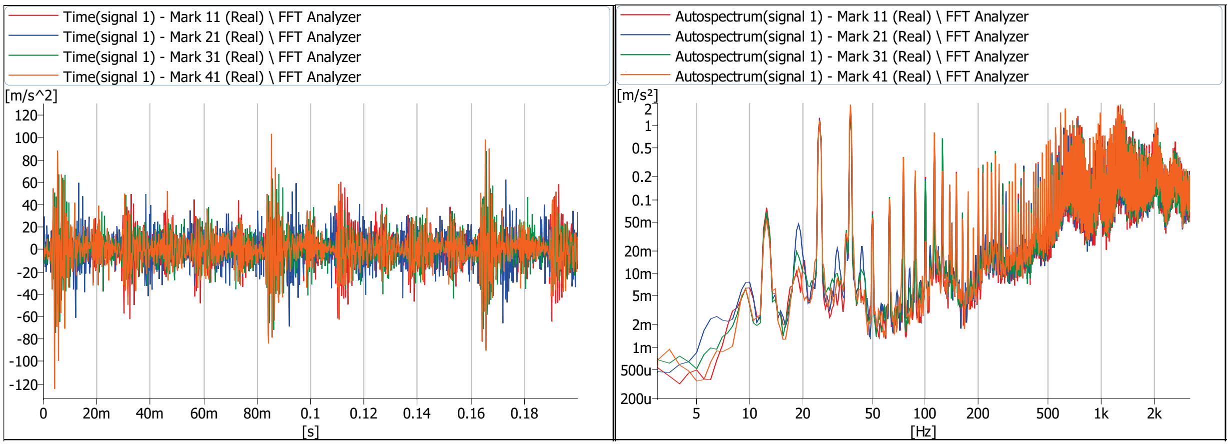


Fig. 3. Time and frequency domain signal of the engine vibration by the different engine torque (4, 8, 12 and 20 kW)

Figures 2 and 3 illustrate the vibration of the engine block. Since upward and downward piston movement is the primarily engine vibration source, the dominant frequency was found. Furthermore, other parameters such as burning pressure, input from the timing gear system, fittings of the engine, inputs transmitted from the motor body, flow of cooling factor, inlet and outlet gases, inlet and outlet of fuel through injector, inertia of cam unit's parts, impacts of head's parts may affect engine vibration [20-21].

All measurements considered in the article are performed under the following conditions: angle 10; 4 different loads (4, 8, 12 and 20 kW).

Fig. 2 shows that the greatest vibrations appear at 1 point in the longitudinal direction, further analysing the vibrations of the 1-point longitudinal direction at different engine loads (4, 8, 12 and 20 kW), which are shown in Fig. 3. Accordingly, Fig. 3 graphs in red indicate the vibration of 1-point longitudinal direction with a load of 4 kW, blue – 1-point longitudinal vibration at 8 kW load, green – 1-point longitudinal direction vibration at 12 kW load, orange – 1 point longitudinal direction vibration at a load of 20 kW.

Variations in fuel properties may explain the differences. Since biodiesel contains extra oxygen, combustion quality of biodiesel is better than combustion of conventional diesel fuel. That is why, many researchers have concluded on that, oxides of nitrogen exhaust emission generally increases with biodiesel addition by the same reason [12-14]. Enhancement of combustion with the usage of biodiesel means lowering vibration of the diesel engine block.

4. Sound pressure level of the engine

Experiments were conducted in a sound insulated room. Furthermore, periphery of dynamometer was covered by a wooden box with sound absorber panels.

A-weighted sound pressure level, which is similar to perceived by the human ear was used in order to processing of results. In Fig. 4-5, the results of noise measurement with diesel and biodiesel blend fuels are shown.

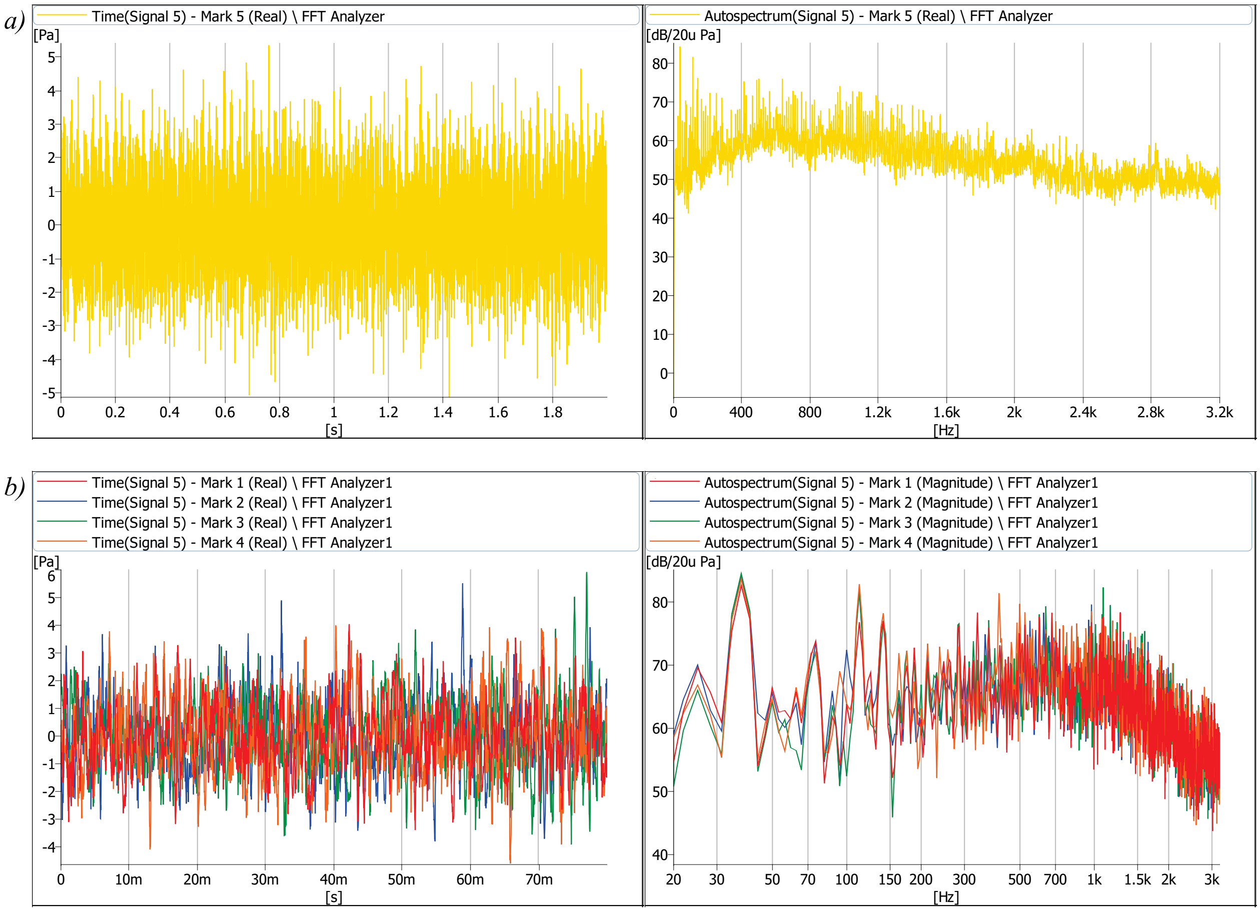


Fig. 4. Time and frequency domain signal of the engine that fuelled with SB20 (a) and SB40 (b) at 1500 rpm

Sound pressure level of the engine was also increased by increasing engine speed. Average sound pressure level found slightly lower than that of low sulphur diesel fuel with 0.6 dB[A], 0.3 dB[A], 0.2 dB[A], for SB20, CaB20, CoB20; 0.5 dB[A], 0.4 dB[A], 0.4 dB[A], for SB40, CaB40, CoB40; 0.7 dB[A], 0.7 dB[A], 0.7 dB[A], for SB60, CaB60, CoB60; 0.8 dB[A], 0.8 dB[A], 0.7 dB[A], for SB80, CaB80, CoB80; and 0.6 dB[A], 0.6 dB[A], 0.7 dB[A], for SB100, CaB100, CoB100, respectively. Decrement of sound pressure level may be related with the decrement of engine vibration. Therefore, parallel to decrement trend of engine block vibration, sound pressure level was also decreased by biodiesel addition.

5. Conclusions

Sound pressure level and vibration acceleration of the test engine increased with engine speed.

Averagely, compared to low sulphur diesel fuel, vibration and sound pressure level decrement was observed with biodiesel usage.

The dominant frequency was regardless of fuel type. It significantly affected by engine speed due to upward and downward piston movement.

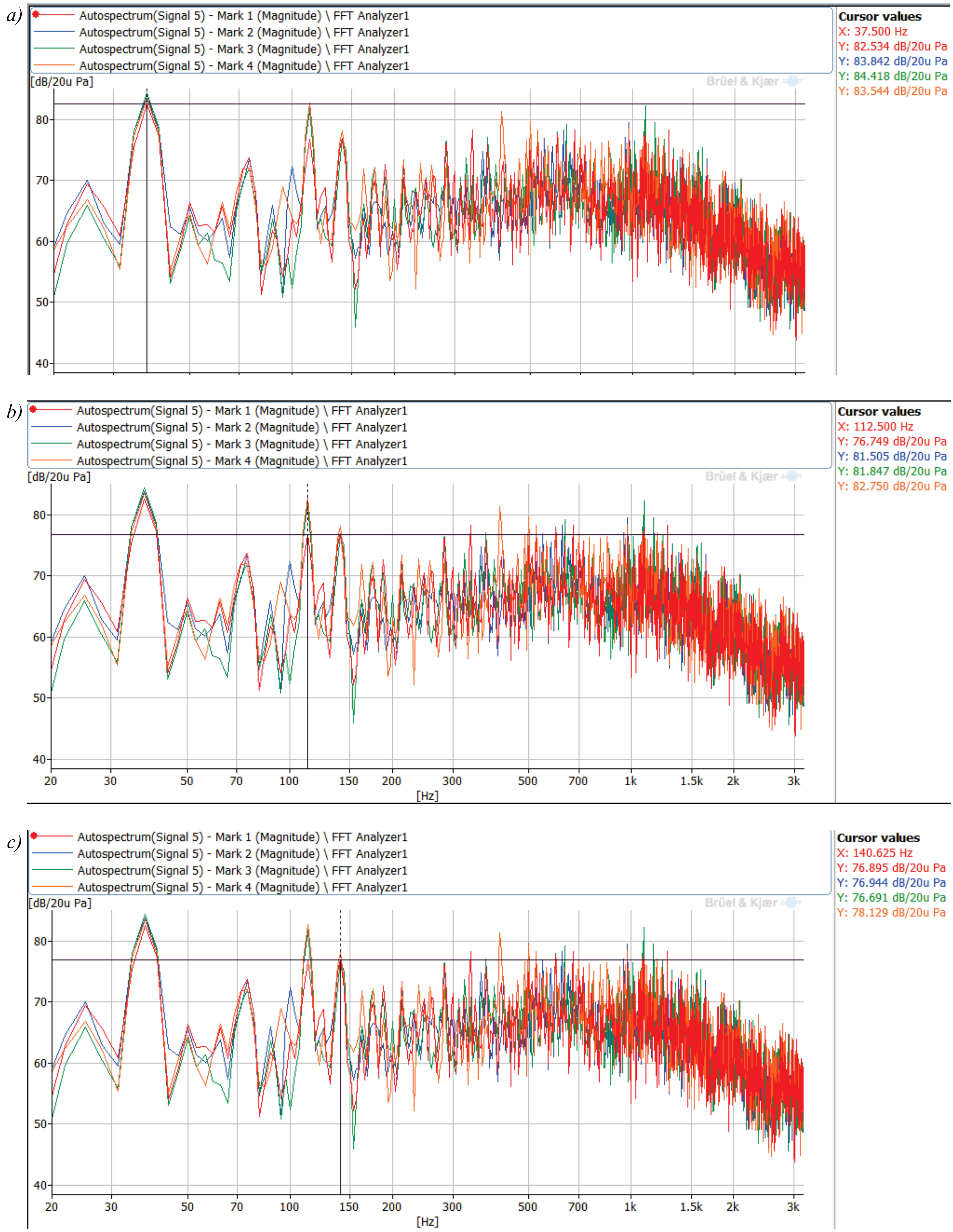


Fig. 5. Sound pressure level and frequency domain signal of the engine that fuelled with SB20 (a), SB40 (b) and SB100 (c) at 1500 rpm

Regression analysis was used to experimental data.

Vibration and sound pressure level can be predicted with an acceptable accuracy with the usage of linear and non-linear regression.

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