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THE CONCEPT OF MEASURING VIBRATION IN PRAMAC S12000 GENERATING SET

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Abstract

Vibration measurements are now widely applied and developed field of science. The article is an example of the application of that field diagnostic using the accelerometer. The study was conducted at Honda GX630 combustion engine in a current generator system. The generator is characterized in that it can be powered by either liquid fuel, or which gas. The results of vibration measurements is presented for (both) gas mixtures containing varying concentrations, as well as for gasoline. The paper presents the results of the vibration, based on an analysis of the time and frequency domain, using Fast Fourier Transform. In the analysis analogue filters, and digital filters (windowing) was used. The analysis includes proposals concerning vibrations difference for individual substances in comparison to vibrations of engine powered a classic, liquid fuel. To simplify the analysis, and thus the discussion on the results, the data presented in the charts with honours major changes in the received, digitized results. Measurements and results presented in the article were carried out as part of a pilot project to support research and development in scale demonstration DEMONSTRATOR+ (WND-DEM-1-527 / 001).

Keywords: *engine vibrations, gas supplied engine, FFT*

1. Introduction: Honda GX630 engine & measurement system

The object under consideration is PRAMAC S12000 generating set consisting of Honda GX630 ignition engine (Fig. 1) [1] coupled with MECCALTE ET20F three-phase AC generator.

Air cooled Honda GX630 is a drive of generating set (Fig. 1). It is supplied in two ways (gasoline and gas mixture) Due to compact construction of the engine and high temperature of its elements during work, position of placing the sensor is the head of first cylinder in the area not exceeding 120 degrees Celsius. The exact place of mounting the sensor is presented in Fig. 2 with mark [1].

The cylinder head is made of aluminium, which does not allow mounting the sensor with magnets. Nevertheless, a method not allowing surface damage was chosen. Accelerometer was glued in the place using Loctite 454 cyanoacrylic glue. The method of mounting the sensor is presented by draft in Fig. 3.

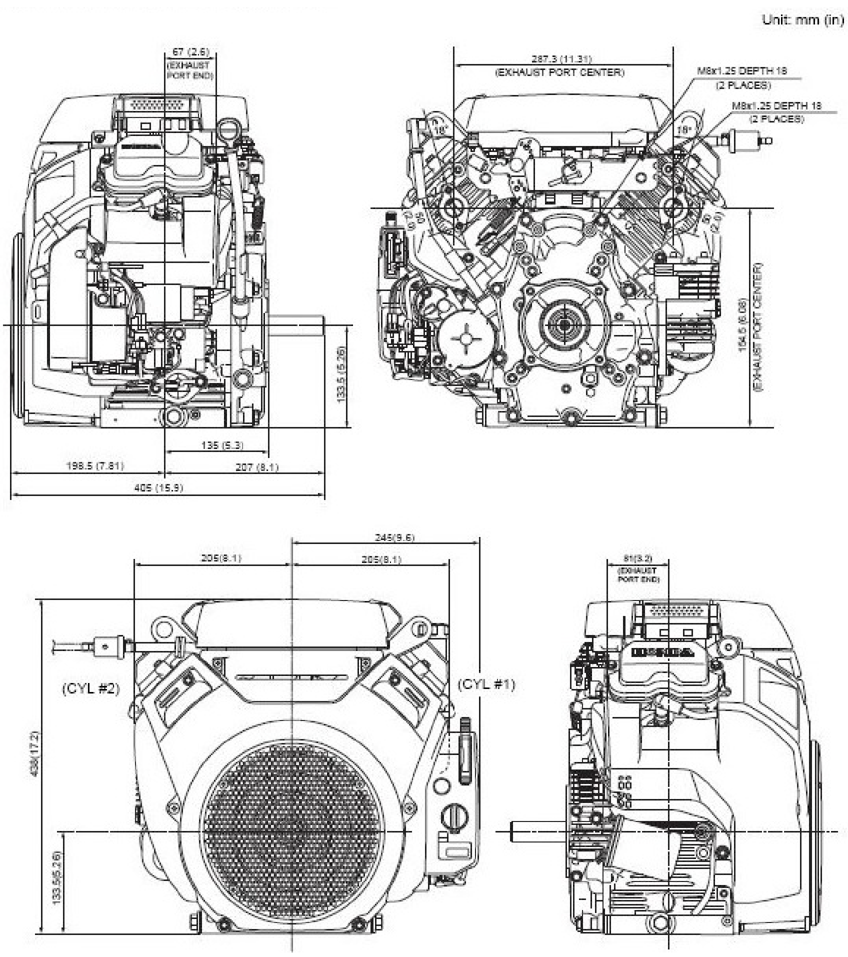

Fig. 1. Honda GX630 Combustion engine [1]

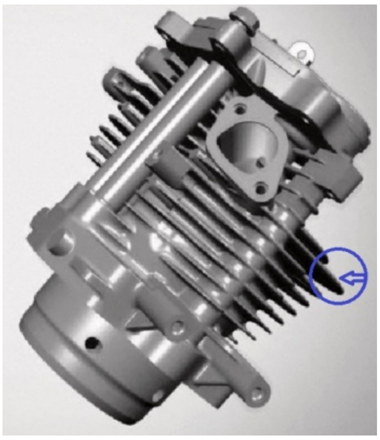

Fig. 2. The exact place of mounting the sensor on cylinder head

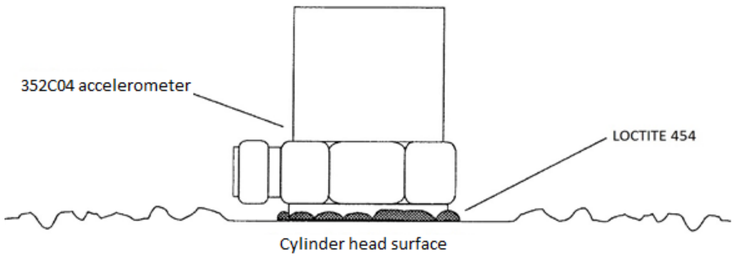

Fig. 3. Sensor mounting method [2]

The data acquisition system consists of an analogue AC/AC converter, incremental encoder and Smetec Combi device with data acquisition software. The sensor is plugged to the amplifier with screw connector and coaxial cable. The accelerometer sensitivity was adjusted to the examined object in analogue converter. The converter output is connected to Smetec COMBI acquisition system by coaxial cable finished with BNC joint. COMBI is connected to PC through IEEE1394 bus and cooperates with software supplied by producer.

2. Sensor characteristics

During the research, one-axial accelerometer 352C04 by PCB was used [2]. Sensor was mounted non-destructively on the head by Loctite 454 glue. The physical construction of used sensor is presented in Fig. 3. Characteristics of used sensor are presented in Tab. 1.

Tab. 1. 352C04 accelerometer parameters [2]

Performance	ENGLISH	SI
Sensitivity (± 10 %)	10 mV/g	1.02 mV/(m/s²)
Measurement Range	± 500 g pk	± 4900 m/s² pk
Frequency Range (± 5 %)	0.5 to 10,000 Hz	0.5 to 10,000 Hz
Frequency Range (± 10 %)	0.3 to 15,000 Hz	0.3 to 15,000 Hz
Resonant Frequency	≥ 50 kHz	≥ 50 kHz
Broadband Resolution (1 to 10,000 Hz)	0.0005 g rms	0.005 m/s² rms
Non-Linearity	≤ 1 %	≤ 1 %
Transverse Sensitivity	≤ 5 %	≤ 5 %
Environmental		
Overload Limit (Shock)	± 5000 g pk	± 49,000 m/s² pk
Temperature Range (Operating)	-65 to +250 °F	-54 to +121 °C
Temperature Response	See Graph	See Graph
Base Strain Sensitivity	0.003 g/με	0.029 (m/s²)/με
Electrical		
Excitation Voltage	18 to 30 VDC	18 to 30 VDC
Constant Current Excitation	2 to 20 mA	2 to 20 mA
Output Impedance	≤ 100 ohm	≤ 100 ohm
Output Bias Voltage	7 to 12 VDC	7 to 12 VDC
Discharge Time Constant	1.0 to 2.5 sec	1.0 to 2.5 sec
Settling Time (within 10% of bias)	<10 sec	<10 sec
Spectral Noise (1 Hz)	110 μg/√Hz	1080 (μm/s²)/√Hz
Spectral Noise (10 Hz)	25 μg/√Hz	245 (μm/s²)/√Hz
Spectral Noise (100 Hz)	8 μg/√Hz	78 (μm/s²)/√Hz
Spectral Noise (1 kHz)	4 μg/√Hz	39 (μm/s²)/√Hz
Physical		
Sensing Element	Ceramic	Ceramic
Sensing Geometry	Shear	Shear
Housing Material	Titanium	Titanium
Sealing	Hermetic	Hermetic
Size (Hex x Height)	0.44 in x 0.88 in	11.2 mm x 22.4 m
Weight	0.20 oz	5.8 gm

Smetec COMBI data acquisition device is used in A/C converter system [3]. The main feature of this device is 2 MB of cache memory for each measuring channel. It allows registering around 30 measurement cycles for each channel with frequency of shaft position equal 0.1° rotation of crankshaft [3].

The analogue signal is given to A/C converter and registered in cache memory cache after the measurement command is executed. When the cache is full, data is transferred to PC. Measurement channels are controlled through equipment by separate controller of serial bus. This solution ensures identical time base for each measuring channel. Tab. 2 presents basic parameters of the system.

Tab. 2. Smetec COMBI data acquisition device parameters [3]

Number of Analog Channels	8 (galvanically separated)
Sampling Rate each Channel	1 MHz
Accuracy/ Dynamic	14 Bit
Memory each Channel	2 MByte up to 16 MByte
Interface	IEEE1394
WINDOWS System	WINDOWS 2000/XP/7
Variable Input Ranges	Up to +/- 10 V
Integrated Encoder Device	yes
Data Acquisition	Crank Angle or Time
Power Supply	12 V DC (8,5 V – 15 V)
Field of Application	Test Bench and Vehicle Application

3. Base of measuring the vibration of Honda GX630 combustion engine

The main measurement assumptions used in the process are:

a) The sensor is connected with the engine through dedicated glue.
b) The sensor is stuck on the engine first cylinder (Fig. 3).
c) 5 gas mixtures (Tab. 3) and gasoline were examined.
d) Top limit of frequency was set to 10 kHz.
e) Niquist frequency was calculated from Shannon-Katielnikow theorem to be 20 kHz [4-6].
f) The analysis was made in MATLAB using following scripts.

Tab. 3 Examined gas mixtures

No.	CH_4	H_2	CO
1.	15%	73%	11%
2.	15%	63%	22%
3.	15%	53%	33%
4.	14%	43%	43%
5.	14%	34%	52%

4. Preliminary measurement

The first measurement trial was made to confirm the calculation assumptions (i.e. the number of registered cycles) and to make a measurement series for gasoline as a reference object. Fig. 4 presents the results of gasoline measurement registered for high amount of cycles.

It was tested which frequency has a reduction of measurement cycle amount (Fig. 5 and 6).

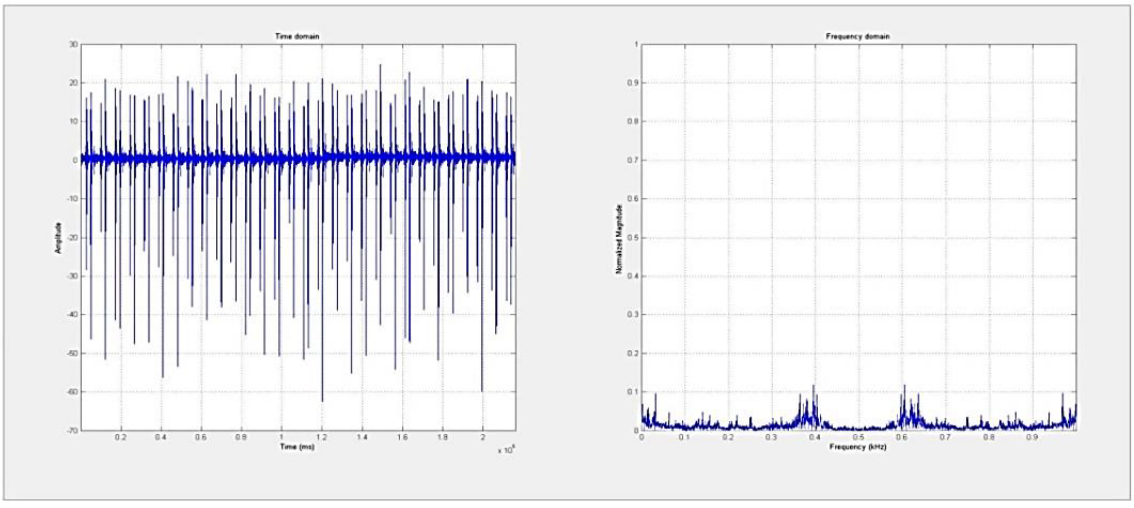

Fig. 4. Measurement of gasoline for high amount of cycles (left – waveform, right – frequency spectrum)

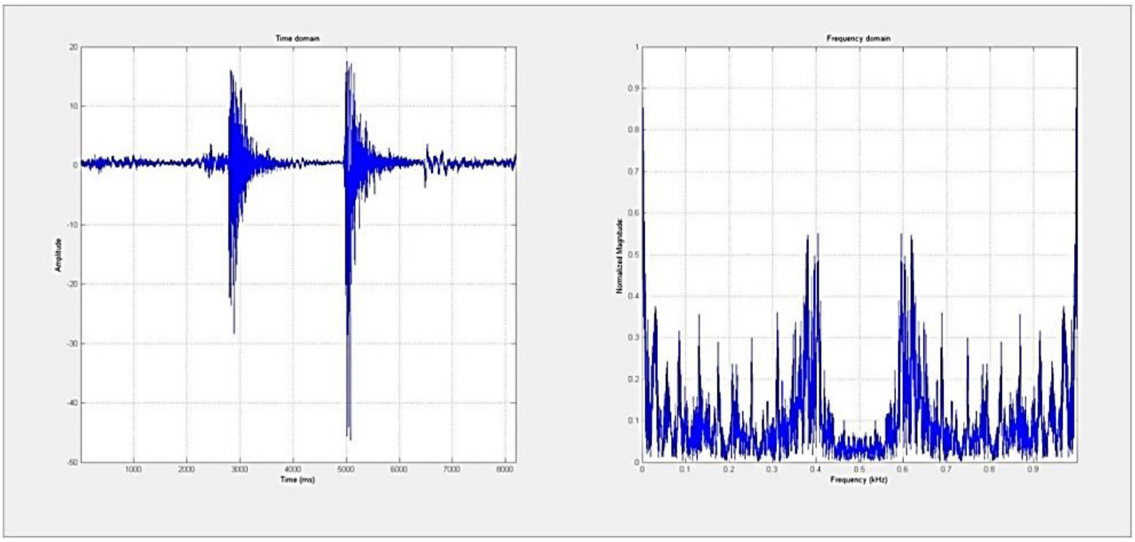

Fig. 5. Measurement of gasoline for 2 cycles (left – time, right – frequency spectrum)

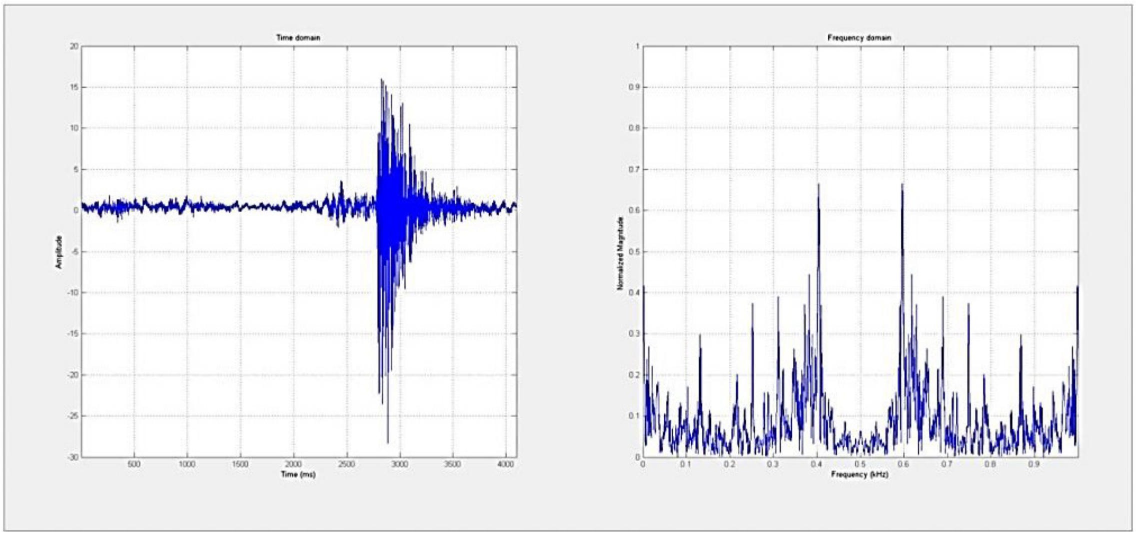

Fig. 6. Measurement of gasoline for 1 cycle (left – waveform, right – frequency spectrum)

During the preliminary measurement windowing influence (made by multiplication in the time domain, or by weave in frequency domain) on the spectrum, and therefore the comparative analysis possibility was evaluated [4-6]. Fig. 7 presents the result of windowing operation on the spectrum by Blackman window.

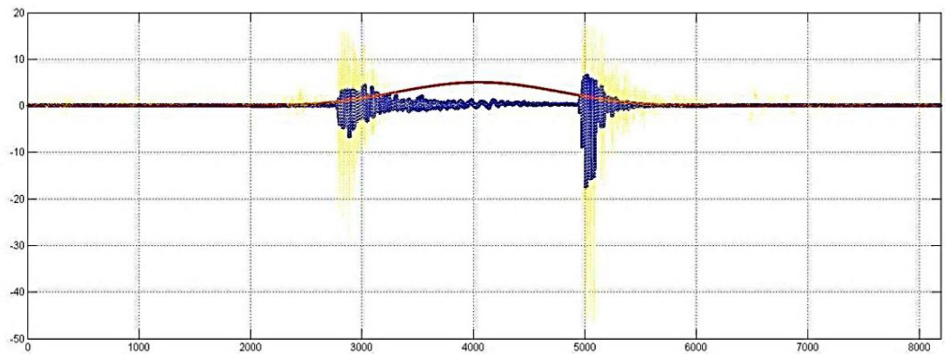

Fig. 7. Frequency waveform (gasoline) after the windowing (blue) and before (yellow). The red colour represents applied Blackman window

Figure 8 represents the frequency spectrum of original signal (blue) and after the windowing operation (red).

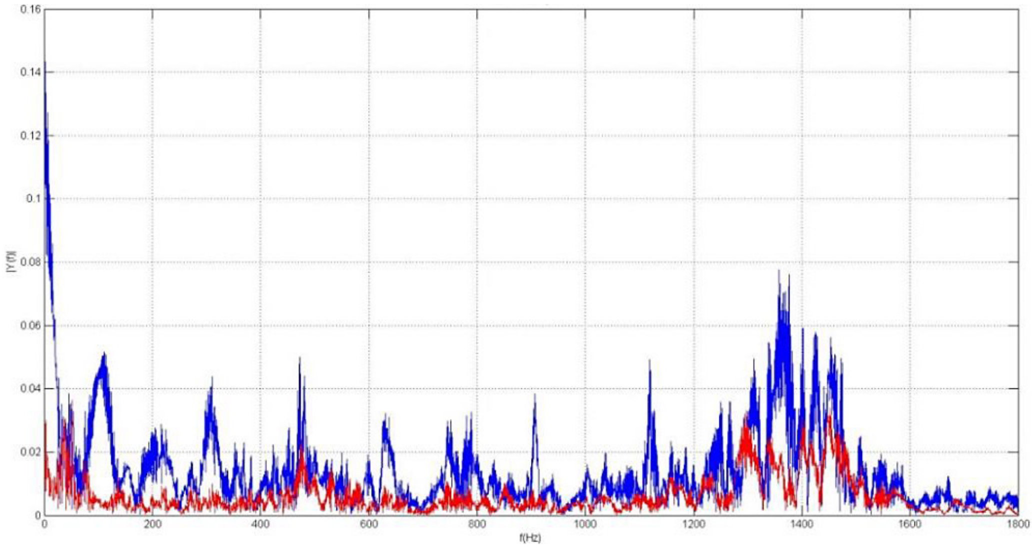

Fig. 8. Frequency spectrum (gasoline) after windowing (red) and before (blue)

5. Essential measurement

Five kinds of gas mixtures where tested during the measurement (Tab. 3). The main research assumption was evaluating how the gas composition influences the system vibration in order to have a possibility of evaluating the mixture composition and system quality by vibration measurement. Fig. 9 presents the comparison for gas number 5 (14% CH_4, 34% H_2, 52% CO) and gasoline (blue).

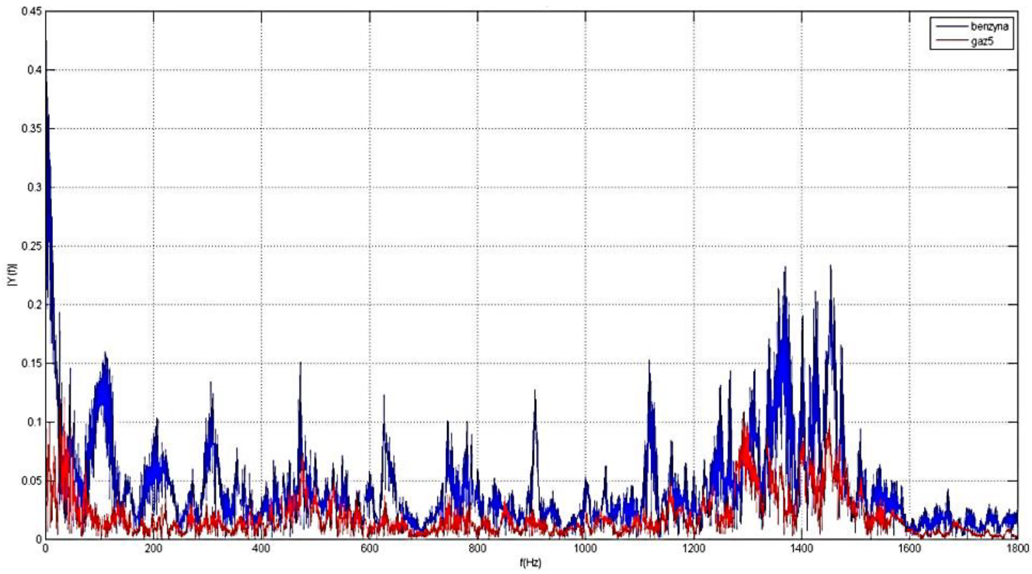

Fig. 9. Frequency spectrum of system supplied with gasoline (blue) and gas number 5 (red)

Similar comparison was made for all the other gases to have possibility to apply comparative analysis in order to indicate the direction of vibration change. Fig. 10 presents general conclusion from observed changes. Additionally, top limit of individual variables attempts, both for waveform (direct method) and for frequency spectrum (in this case maximal value of modules was designated). The results are presented in Tab. 4.

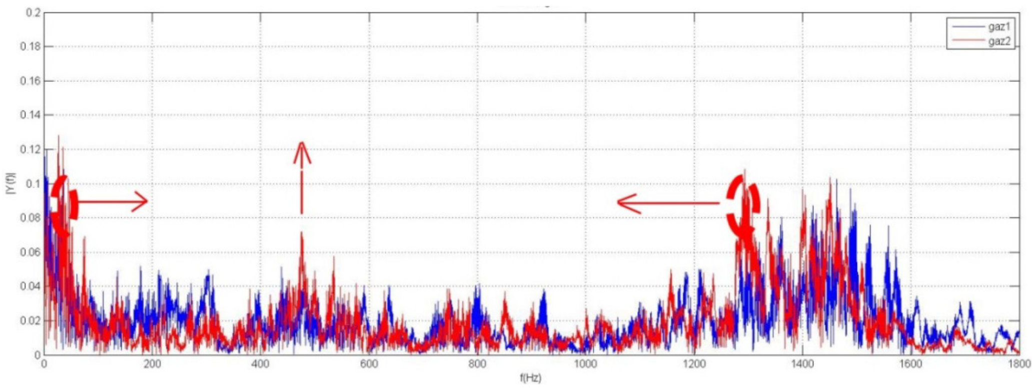

Fig. 10. Spectrum change characteristics for different mixtures (blue – gas 1, red – gas 2)

Tab. 4. Maximal values of acceleration and dominant frequencies for each gas compositions and gasoline

Type	Value	
	max (type)	max (abs(FFTtype))
Gasoline	17.49	0.2127
Gas 1	8.45	0.2242
Gas 2	11.63	0.0737
Gas 3	16.13	0.0769
Gas 4	10.21	0.0702
Gas 5	13.31	0.0685

6. Conclusions

a) Accelerometers are a good, but not perfect selective sensors, which can be used in analysis of vibration frequency of engine supplied with difference gas mixtures.
b) The influence of gas mixture on vibration can be noticed: increase of CO and H_2 reduction results with spectrum shrinkage – bringing harmonic dominants closer to each other (Fig. 10).
c) Gasoline is a fuel generating more turbulent combustion by the term of increased amplitudes (for both, waveform and frequency spectrum module) – Tab. 4.
d) Increase of CO, with parallel decrease of H_2 reduces maximal accelerations, but directly has to influence the (energetic) quality of the process.
e) The measurement should be repeated using multiaxial accelerometers, mounted in different ways and Laser Scanning Vibrometry.

Acknowledgements

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