Research on HONDA NHX 110 fueled with biogas, CNG and E85

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Abstract. The work presents research on HONDA NHX 110 fueled with biogas, compressed natural gas – CNG, and the mixture of bioethanol with gasoline –E85. The experiment study was conducted on the author's test bench which contained: internal combustion engine ICE – HONDA NHX 110, electrical machine, electrical loading unit, control chain which contain NI cards and prepared application in LabVIEW software for data acquisition. In herein work, the influence of different angles of the ignition advance on value change of an indicated pressure diagram(for a single cycle and average value), the electric power value, vibration acceleration of internal combustion body for biogas have been presented. The results discussed in this work convey practical information about the vibroacoustic activity, maintenance of internal combustion engine as distribution generation source (electricity generation state) which have been powered by alternative fuels.

1. Introduction
The prospect of fossil fuels becoming fully consumed gives rise to a new approach to the functioning of Polish, European and global energy markets. Whilst looking at the European Union, the adopted climate package obligates European Union members to increase the share of renewable energy sources (RES) in the energy market (to 27% in the timeframe till 2030 [1-5]), improve the efficiency of processing of the primary fuels (27% in the timeframe till 2030) and reduce CO2 emission (by 40% till 2030 as compared to the 1990 levels) [1]. It should be stressed that the climatic package [1] offers a stimulus for the development of distributed generation devices [1–17]. Distributed generation devices include sources which produce energy from alternative fuels (e.g. LNG, CNG, biogas and other biofuels). These devices include gas engines. It is the low power combustion engines, which can be powered by alternative fuels to produce electrical energy, that are of particular importance.

The paper presents a study of a low –power Honda NHX combustion engine powered with gasoline RON95, CNG, biogas and E85.

2. Description of the testbed
The dynamometer test bench, which is presented in Figure 1a), consisted of a Honda NHX 110 four –stroke combustion engine with three-way catalytic converter, an electrical machine interworking with a load –applying system (a dynamometer), a programmable ECU MASTER EMU (EMU – Engine Management Unit) controlleras well as a measurement circuit and a controlling system. The main parameters of Honda NHX 110 engine is presented in Table 1.
Table 1. The main parameters of Honda NHX 110 engine

| Parameter                      | Value                                      |
|-------------------------------|--------------------------------------------|
| Nominal parameters of engine  |                                            |
| Maximum Power                 | 6.6 kW for 7500 rpm                       |
| Torque                        | 10.4 Nm for 4500 rpm (modified by authors) |
| Compression ratio             | 11                                         |
| Piston diameter               | 50 mm                                      |
| Piston stroke                 | 55 mm                                      |
| Throttle diameter             | 20 mm                                      |
| Timing system                 |                                            |
| Timing type                   | overhead camshaft                          |
| The opening of the intake valve / closing the intake valve | 10° BTDC / 25° ABDC |
| Opening the exhaust valve     | 25°                                        |
| Lubrication system            |                                            |
| Type                          | a forced pump                              |
| Fuel system                   |                                            |
| Type                          | electric pump with pressure regulator, Injector resistance = 9–12 Ω at 20°C (T=293 K) |
| Spark plug option             | CR8EH -9 NGK                               |
| Ignition advance angle (IAA)  | 14° BTDC - idle                            |

The torque generated by the examined combustion engine was conveyed to the electrical machine, which applied the load, by means belt transmission. The measuring circuit and the controlling system are discussed in detail in [7, 8, 13, 15-17].

The tests were conducted in an environmental chamber. Its photo is presented in Figure 1b). The tests were conducted at specified and recurring conditions: temperature: 295K, humidity 20%–conditions in an environmental chamber.

![Figure 1](image1.jpg) (a) ![Figure 1](image2.jpg) (b)

**Figure 1.** Photo of the test bench placed in an environmental chamber (a), photo of the environmental chamber (b).

Chapter 3 presents the results of the tests performed at the above discussed dynamometer test bench. for the engine powered with, among others, gasoline RON95, CNG, biogas and E85.

3. Research results

In the course of the research, the engine was located inside an environmental chamber. Constant environmental conditions were maintained inside the chamber – air temperature was 30°C ±1°C, relative humidity: 40% ±2%, air pressure was equal to atmospheric pressure: 1009 hPa. During all the measurements the temperature of the engine coolant was 93°C ±2°C, while engine oil temperature was 95°C ±2°C. Irrespective of which fuel was used to power the engine, a Lambda coefficient – \( \lambda = 1 ± 0.02 \) was maintained, which guaranteed proper operation of a three-way catalytic converter which was part of the engine. The tests were conducted for the rotational speed of 4500 rpm (in accordance with the
specification obtained from external sources, this is the rotational speed at which the engine achieves maximum torque) and with fully open throttle. Biogas contained 61% of methane.

3.1. Indicated mean effective pressure and electrical power graphs

Figure 2a presents the influence that the value of the ignition advance angle has on the average value of indicated pressure for the engine powered respectively with gasoline RON95, CNG, biogas and E85. The tests involving respective fuels were conducted with the following settings: gasoline RON95 – ignition advance angles from IAA=10 to IAA=40, with measurements taken at 10–degree intervals before the Top Dead Center (TDC); CNG – ignition advance angles from IAA=10 to IAA=40, with measurements taken at 10–degree intervals before TDC; biogas – ignition advance angles from IAA=20 to IAA=40, with measurements taken at 10–degree intervals before the TDC; and E85 – ignition advance angles IAA=20 and IAA=30 degree before TDC.

Based on [18-20], the efficiency of belt transmission was calculated – equal 89.5%, the efficiency of the electrical machine – equal 90.7% (for n=4500 rpm and gear ratio, between the combustion engine and the electrical machine, of i=1.42).

![Figure 2](image)

**Figure 2.** Influence of the ignition advance angle on: the average value of pressure for the entire cycle (a), electrical power in the case of the engine powered respectively with gasoline RON95, CNG, biogas and E85 (b).

Analysis of Figure 2a shows that the highest value of average pressure for the entire work cycle was obtained for ignition advance angle of IAA=40 (gasoline – 4.886 MPa, CNG – 4.739 MPa, biogas – 4.468 MPa). The highest value of electrical power (Figure 2b) was also obtained for the ignition advance angle of IAA=40 (gasoline – 4.151 kW, CNG – 2.97 kW, biogas – 3.028 kW).

Figure 3 presents the influence that ignition advance angle has on indicated mean effective pressure and average values of indicated pressure diagram, obtained in the case of the engine powered with gasoline RON95(Figure 3a), CNG (Figure 3b) and biogas (Figure 3c).
Figure 3. Influence of the ignition advance angle on the average values of pressure in range from 0 to 720 CA for the engine powered respectively with: gasoline RON95 (a), CNG (b), biogas (c).

Analysis of Figure 3 shows that the maximum average indicated pressure in a cylinder increases along with the growth of ignition advance angle. In the case of gasoline RON95 (Figure 3a), growth of the ignition advance angle led to the increase of the average maximum indicated pressure in a cylinder, with the pressure reaching the highest value of 6.01 MPa for IAA=40. The maximum values of indicated pressure in a cylinder (after calculating the average from several hundred work cycles) were as follows: for the ignition advance angle equal to IAA=20 – 3.821 MPa, for IAA=30 – 4.997 MPa, and for IAA=10 – 2.316 MPa.

In the case of CNG (Figure 3b), growth of the ignition advance angle led to the increase of the average maximum indicated pressure in a cylinder. The average indicated pressure in a cylinder, for the ignition advance angle of IAA=10 , was 2.408 MPa. For IAA=20 the average indicated pressure was 3.172 MPa, for IAA=30 it was 4.445 MPa, and for IAA=40 it reached the highest value: 5.392 MPa.

In the case of the biogas – powered engine (Figure 3c), growth of the ignition advance angle led to the growth of the maximum indicated pressure in a cylinder. The maximum values of indicated pressure in a cylinder (after calculating the average from several hundred work cycles) were as follows: for the ignition advance angle equal to IAA=20 – 3.249 MPa, for IAA=30 – 4.846 MPa, while for IAA=40 the pressure reached the highest value: 5.675 MPa.

3.2. Graphs of vibration acceleration

This sub–chapter presents the influence that ignition advance angle has on the acceleration of the engine’s body in directions x (perpendicular to the plane on which the piston’s axis lies) and y (parallel to the plane on which the piston’s axis lies). The acceleration measurements were conducted only for biogas. Due to scope of research extension, the authors will present the acceleration measurements results for other fuels in future publications.
Influence of the ignition advance angle on the vibration acceleration graph in respective directions: \(x\) (a), \(y\) for an engine powered with biogas (b).

Figure 4 presents the influence of the ignition acceleration angle on the shape of the vibration acceleration graph in respective directions \(x\) (Figure 4a) and \(y\) (Figure 4b) for a combustion engine powered with biogas.

The highest value of vibration acceleration was observed for the direction \(x\) (Figure 4a), for IAA=30 \(^\circ\), with the respective value being \(-59.97\, m/s^2\). The highest value of vibration acceleration for the angle range from 300 CA to 380 CA was equal \(31.7\, m/s^2\) at IAA=40 \(^\circ\). It was connected with combustion processes. For the direction \(y\) (Figure 4b), the highest value of vibration acceleration was observed for IAA=30 \(^\circ\), for which it amounted \(-59.97\, m/s^2\).

The highest value of vibration acceleration of the \(y\) direction was for IAA=40 \(^\circ\) (for the angle range from 300 CA to 380 CA) and it equated \(1.39\, m/s^2\). The growth of vibration acceleration value in this area was caused by combustion processes. The highest vibration acceleration values for the angle range from 0 CA to 720 CA was \(7.99\, m/s^2\) at IAA = 40 \(^\circ\).

3.3. \(CO_2\) and CO graphs

The sub–chapter presents the results of the research conducted to determine the impact that ignition advance angle on the combustion engine powered with gasoline RON95, CNG and biogas on the percentage content of CO and CO\(_2\) in exhaust gases.

Figure 5 presents the influence of the ignition advance angle on the percentage content of CO (Figure 5a) and CO\(_2\) (Figure 5b) in exhaust gases of the following fuels: gasoline RON95, CNG and biogas. In the case of gasoline RON95, the percentage share of CO did not exceed 0.4% while the share of CO\(_2\) was 15%. In the case of biogas, the percentage share of CO did not exceed 0.3% while the share of CO\(_2\) was 11.8%. For CNG the percentage share of CO did not exceed 0.16%, and it was the lowest value for all the tested fuels, while CO\(_2\) content was 11.9%.
4. Summary and conclusions
In this work a research study of Honda NHX 110 engine fuelled by gasoline RON95, CNG, biogas and E85 is presented. Based on conducted research it was concluded that with increase of ignition advance angle the indicated pressure value and Indicated mean effective pressure values increases. The highest value of indicated mean effective pressure was obtained for the ignition advance angle IAA=40° of gasoline RON95, it was equal 4.886 MPa. The highest value of electrical power was achieved for the ignition advance angle IAA=40° of gasoline RON95 it was equal 4.151 kW.

Furthermore, with increase of ignition advance angle the exhaust gas temperature decreased, which has a direct effect on the temperature of the three-way catalytic converter and higher emissions of hydrocarbons (HC) and other toxic substances.

The authors will continue the research on Honda NHX 110 engine fueled by, among others: M85 (mixture of 85% methanol and 15% gasoline RON95), M85B (mixture of 85% methanol and 15% butanol), hydrogen and gasoline RON95 (mixture of 15% H₂ and 85% gasoline RON95 as well as 30% H₂ and 70% gasoline RON95), hydrogen and methanol (mixture of 15% H₂ and 85% methanol as well as 30% H₂ and 70% methanol), hydrogen and butanol (mixture of 15% H₂ and 85% butanol as well as 30% H₂ and 70% butanol), hydrogen and ethanol (mixture of 15% H₂ and 85% ethanol as well as 30% H₂ and 70% ethanol) and pure hydrogen (100% H₂) at various λ factor values. At the same time, the authors are developing a one-dimensional combined model of the combustion process [21], which takes into account the dynamics of crankshaft-piston assembly.

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