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ENTRANCE RESEARCH ON PRESSURE DISTRIBUTION IN COMBUSTION CHAMBER OF GASOLINE ENGINE APPLIED IN ELECTRIC GENERATOR, FUELLED BY SYNGAS, FOR DIFFERENT IGNITION TIMING

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Abstract

Synthetic gas (syngas) produced form waste organic matter may be used as a fuel for internal combustion engines. Possibilities of syngas application as an independent IC engine energy carrier are limited. Designed system of energy conversion from waste to electricity is expected to produce gas consists mainly carbon monoxide, methane, hydrogen and carbon dioxide. Based on theoretical study and own research, as the main factors which impact on floating syngas composition the quality of input substance, process temperature and gasifying medium application were identified. The fluctuation of syngas composition contributes important challenge in aspect of energetic efficiency and mechanical durability of generator system. The researches were provided on research test bed, which enables pressure distribution measurement in the combustion chamber (for various mixture of synthetic gases) and correction of ignition timing. The results of the researches indicate that proper correction of the ignition advance allows syngas mixtures combustion in wide range of their composition.

***Keyword**: spark-ignition engine, biomass, syngas, gasification, cogeneration*

1. Introduction

Limited resources and high prices of fossil fuels are reasons for alternative Energy sources development. Nowadays people are able to generate unconventional energy from almost all compounds of the environment like wind, sun, water and biomass. Waste organic matter (waste biomass) contributes interesting and prospective substitute of fossil fuels [1, 2]. A synthetic gas, product of gasification process, maybe applied for IC engine suppling. It contributes thermal and mechanical energy source in cogeneration systems. Despite this fact, the possibilities of syngas application as an independent fuel are limited. Designed system of energy conversion (from waste to electricity) is expected to produce gas consists mainly carbon monoxide, methane, hydrogen and carbon dioxide. Those gases are characterized by extremely different thermodynamical and chemical properties.

According to present studies and researches, [1-7] strong fluctuation in syngas quality may be observed (Tab. 1) what is strongly correlated with heating and caloric values or methane number.

Tab. 1. Syngas fluctuation according to different researchers and studies [1-7]

	min. [% vol.]	max. [% vol.]
H_2	5	56
CO	10	52
CO_2	9	36
CH_4	2	12

This situation contributes great challenge for engine combustion parameters optimization. Current researches in this field are focused on optimal ignition time for particular mixture of synthetic gas.

2. Research workstand

A special test bed was prepared for the researches. The test stand was equipped in PRAMAC S12000 generation system and Honda GX 630 gasoline engine. Basic parameters of the internal combustion engine are presented in Tab. 2.

Tab. 2. Technical parameters of Honda GX630 gasoline engine

Parameter	Value
Model	GX 630 20.8 KM
Engine type	four-stroke, two-cylinder, cooled with air
Type of cylinder	Steel made, V 90, OHV
Type of crankshaft	Horizontal
Cylinder capacity	688 cm^3
Diameter x stroke	78 x 72 mm
Compression ratio	9.3:1
Maximum power	15.5 kW (20.8 HP)/3500 rpm
Power handling	10.5 kW (14.1 HP)/3000 rpm
Maximum torque	48.3 Nm / 4.93 Kgm / 2500 rpm

The generator system, primary fuelled by gasoline, was modified and equipped in necessary accessories enable syngas fuelling. The test stand scheme is presented in Fig. 1.

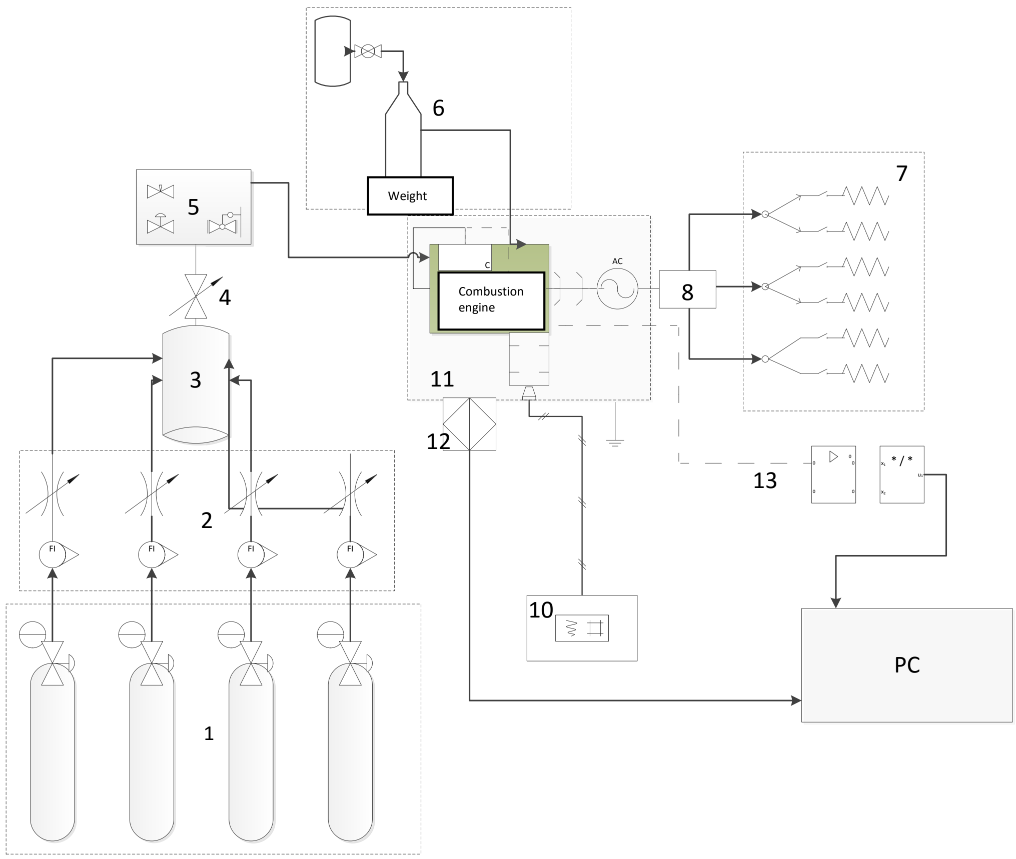

Fig. 2. Scheme of engine test stand

The engine test stand is equipped in IC engine connected with electricity generator (11). Fuelling system was modified in a way, which enables fuel consumption measurement. Gasoline consumption measurement system (6) is constructed by fuel reservoir, cut-off valve and measurement bulb mounted on RADWAG WPE 4000 weighing machine. The solution enables fuel consumption measurement by weighing method.

Syngas consumption measurement system (1) is constructed by four gas containers (50 dm^3 of water capacity), each filled by different technical gases: hydrogen – 5.0 purity, methane – 5.0 purity 2.5, carbon dioxide – 4.5 purity and carbon monoxide – 1.8 purity.

Each container is equipped in two-step gas regulator (0-4 bar) and rotameter (2) for gas consumption measurement. After the rotameter gas flows to the mixture (3) and then, through cut-off valve (4), to evaporator (5). The third generation evaporator for LPG applications was applied (with regulation of gas expenditure in function of under pressure in inlet collector and regulation of evaporator spring tension). The gas from evaporator, through the mixture, finally reaches outlet system.

As the generator loading (7) system of electric heaters was applied. The heaters were connected to generator by parameters net measure system Eastron 630 (8) which enables to read real load of electric generator. The loading system (heaters) was configured for full range of unit work with 1 kW resolution.

For ignition timing, set EMU controller (ECU Master) was applied instead basic ignition system. The controller enables any configuration of ignition with individual ignition inductors. In case of predicted problems with some syngas mixtures, high-energy spark inductors were applied.

The system for pressure measurement inside of the combustion chamber (13) is composed from ROD 426 3600 01 Heidenhain encoder with 7200 points resolution on rotation, placed coaxial on crankshaft (form timing gear system side), which conduce to define temporary crankshaft placement and 6117BFD16 Kistler in-chamber pressure sensor which is integrated with spark plug. Pressure sensor is connected to 5064C12 Kistler amplifier, and then with encoder connected through measurement platform (SMETec Combi) to PC for data acquisition.

The testing stand was also equipped with exhaust analyser MEXA 584L (10). The analyser was also applied for air-fuel mixture set (excess air coefficient, Lambda, from 1-1.1 depending on the gas mixture).

3. Results and discussion

Based on, graphically presented (Fig. 3) shares of particular gases, 27 synthetic mixtures was set. All of the mixtures were put into the test and investigated in aspect of their application possibilities for engine fuelling and the most prospective ignition timing for 6 kW load.

In measurement algorithm 5 points of ignition was choose (8.5, 11.5, 14.5 17.5, 20.5 deg. crank angle, before TDC), entrance measurements for 4 kW and then for 6 kW load.

The pilot tests were provided for four gas mixtures: two for 4 kW and two for 6 kW and as the result, the indicator charts was obtained. The pressures measurement was provided after thermal stability achievement on tested engine (2 minutes in one work point) according to the standards and bibliography [7, 8].

The thirty following work cycles was saved for analysis of maximum pressures fluctuation for particular ignition timing. In the effect the average pressures distribution was defined. The results were presented in Tab. 3.

The illustration of pressure distribution chart for 30 cycles of engine work, on example of mixture no. 21, is presented in Fig. 4.

The illustration of pressure displacement chart for 30 cycles of engine work, on example of mixture no. 21, is presented in Fig. 5.

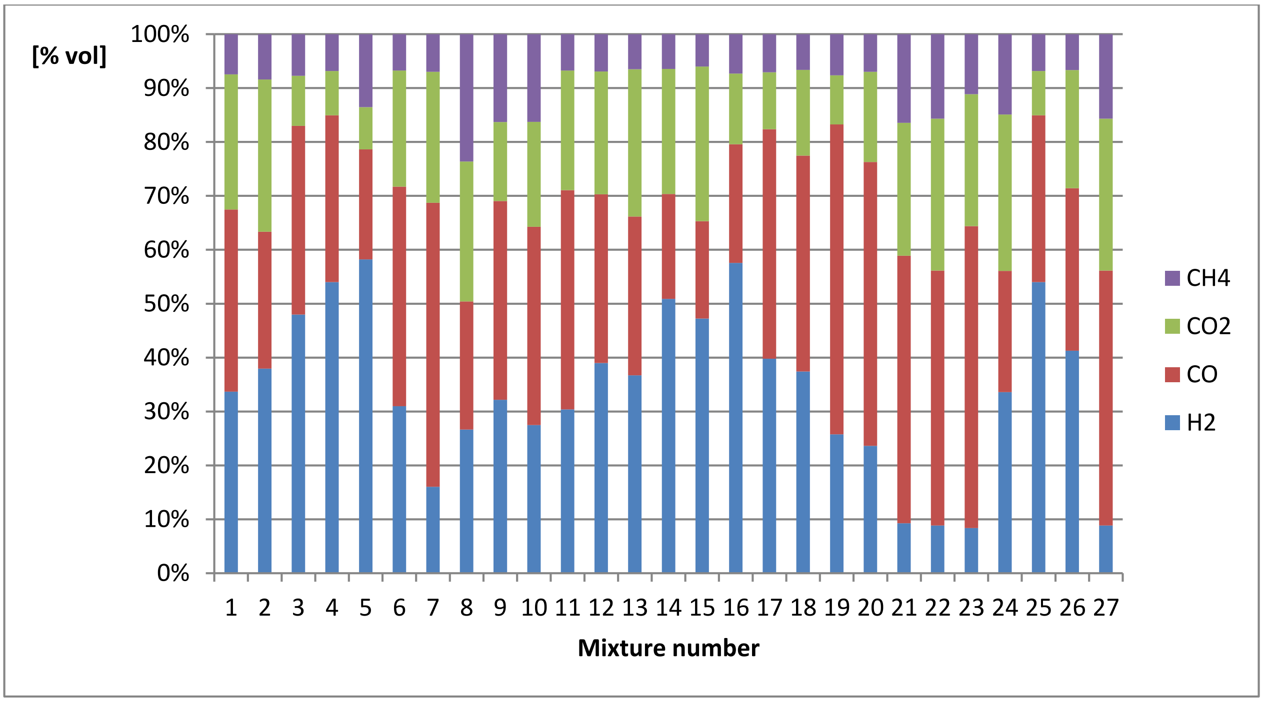

Fig. 3. Mixtures composition set for the tests

Tab. 3. Maximum pressures of the combustion for various ignition timing

Mixture number	Ignition timing	Average maximum pressure [bar]	SD	deg.CA	SD
19	8.5	42.37	3.83	22.27	5.48
	11.5	48.35	3.26	17.88	4.74
	14.5	50.63	2.86	16.48	4.62
	17.5	55.74	2.72	12.27	2.35
	20.5	59.47	2.14	10.45	2.22
20	8.5	34.88	1.9	10.72	12.56
	11.5	31.89	2.56	16.23	12.11
	14.5	36.87	4.93	20.44	9.8
	17.5	37.33	4.75	17.9	9.6
	20.5	43.65	4.23	14.89	6.36
21	8.5	27.06	2.47	24.81	5.1
	11.5	28.8	2.28	22.92	5.6
	14.5	33	2.4	21.82	3.59
	17.5	30.75	2.34	20.24	5.64
	20.5	33.23	2.36	18.5	3.44
22	8.5	26.16	2.11	24.74	10.9
	11.5	28.79	2.54	23.56	8.34
	14.5	30.92	2.98	24.58	7.11
	17.5	33.92	2.73	21.65	4.4
	20.5	35.68	3.29	17.4	5.68

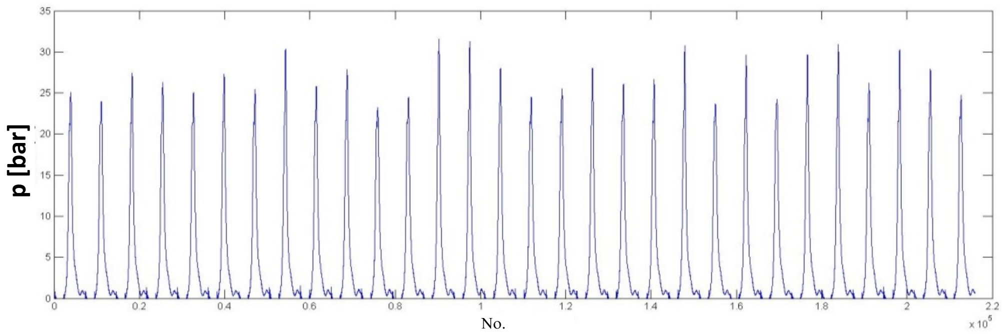

Fig. 4. Pressure distribution chart for 30 cycles (mixture no. 21)

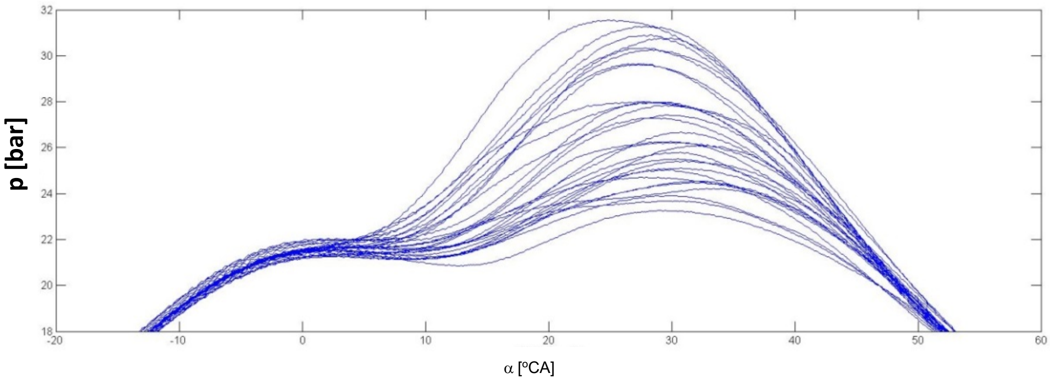

Fig. 5. Pressure displacement chart for 30 cycles (mixture no. 21)

The illustration of average pressure displacement chart (30 cycles of engine work), on example of mixture no. 19, is presented in Fig. 6-10.

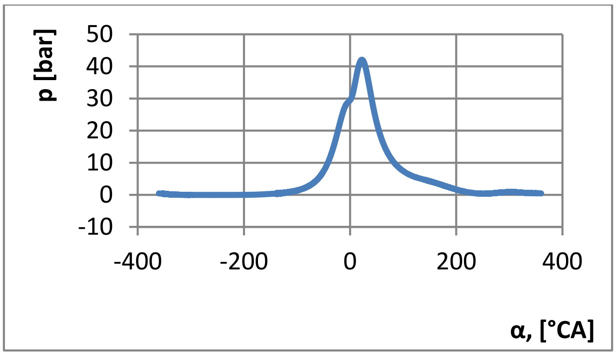

Fig. 6. Average pressure displacement chart (30 cycles of engine work), ignition timing: 8.5° before TDC

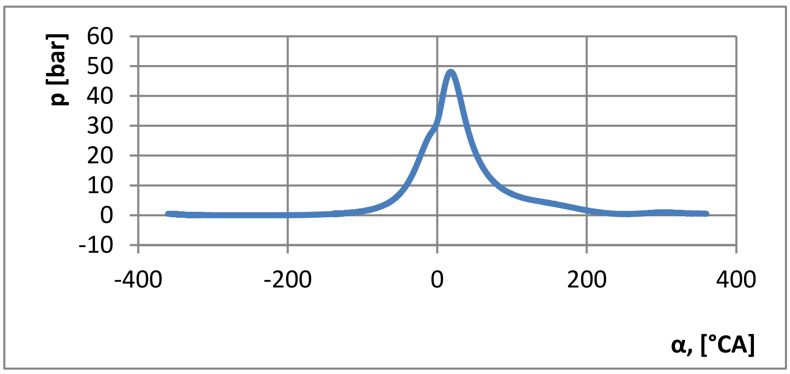

Fig. 7. Average pressure displacement chart (30 cycles of engine work), ignition timing: 110 before TDC

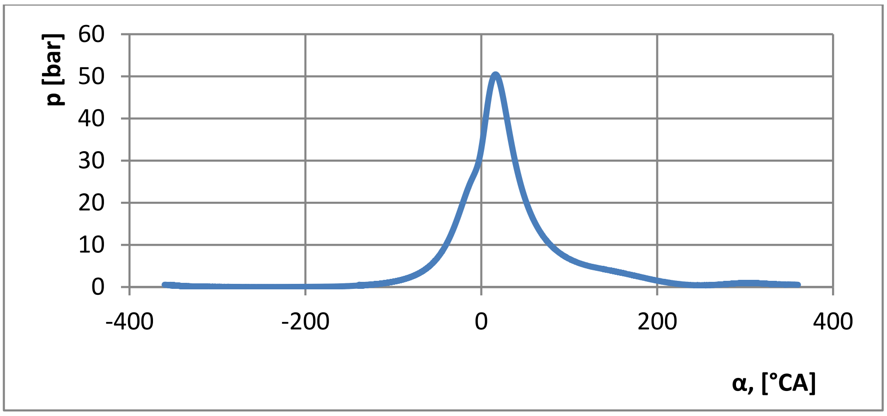

Fig. 8. Average pressure displacement chart (30 cycles of engine work), ignition timing: 14.5° before TDC

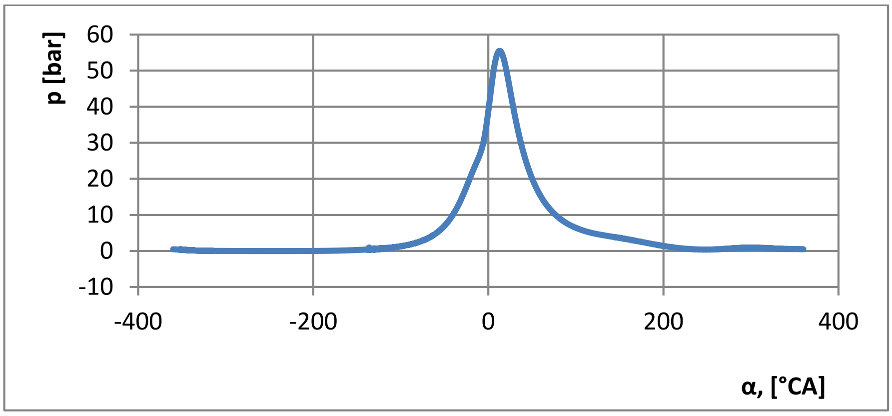

Fig. 9. Average pressure displacement chart (30 cycles of engine work), ignition timing: 17.5° before TDC

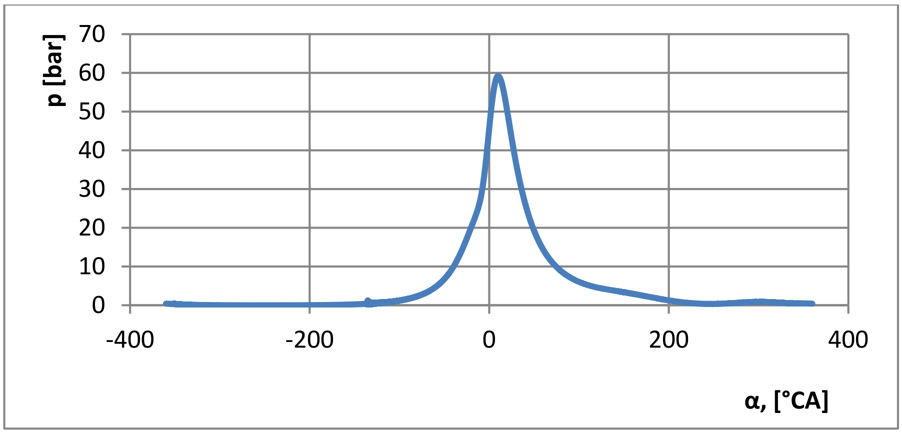

Fig. 10. Average pressure displacement chart (30 cycles of engine work), ignition timing: 20° before TDC

4. Conclusions

Based on the results of the entrance research work, following conclusions were specified:

- application of syngas as an engine fuel needs ignition timing correction (in relation to basic sets) for adjustment to a syngas composition. This fact indicates that future investigation requires also measurements in aspect of noise and vibrations emission,
- according to the researches, for most prospective ignition timing, the maximum pressure of the combustion, was observed near 20 deg of crank angle,
- based on the researches observation, for hydrogen-composed fuels it may be necessary to apply additional systems for crankcase venting, especially upper spaces of the engine. GX630 Honda

engine (test engine) is equipped in ventilation spaces on side of the engine only. This fact causes hydrogen generation in vales covers, what effect uncontrolled gas explosion in crankcase. When hydrogen share in the mixture was above 20%, the phenomena wasn't observed,
- the researches indicates that it is possible to combust over 50% CO-consisting mixture (as so as over 50% H_2-consisting) applying fuel direct injection into inlet collector,
- near optimum ignition timing, pressure distribution diagram is characterized by inflexion point placement close to TDC. This fact as so as relatively late ignition timing indicates on significant higher combustion rate in comparison to conventional fuel,
- increasing CO share in the syngas mixture limit maximum pressure value in the combustion chamber,
- cold-engine start problems must be consider as an important issue in syngas application discussions. Dual-fuel system may be consider as a solution with conventional fuel mode during a cold-engine start. This solution will be also prospective for increasing of generator work stabilization in extreme situations (high fluctuation of syngas composition),
- future research should be focused on defining of function between gas composition, ignition timing and optimal engine performance.

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