# ANALYSIS OF COMBUSTION PROCESS OF A CHARGE OF NATURAL GAS IN LABORATORY COMBUSTION CHAMBER

**Bronisław Sendyka**[1]

**Marcin Noga**[2]

*Cracow University of Technology*

*Institute of Automobiles and Internal Combustion Engines*

*31-864 Kraków al. Jana Pawła II 37*

*tel.: +48 12 628 36 88*

*fax: +48 12 628 36 90*

*e-mail: bsendyka@usk.pk.edu.pl; noga@pk.edu.pl*

***Abstract***

*The article contains an analysis of investigation results of the combustion process of a charge of natural gas mixture with air. Investigations were carried for charges of stoichiometric composition and lean ones for various initial pressures in the combustion chamber. Ignition of the mixture was indicated by an ignition plug supplied from a direct ignition device. Measurements comprise a digital record of the pressure course in the chamber.*

*Values of pressure increment in the chamber during the combustion process were analyzed. A diagram of pressure increment values dependent on charge composition and initial pressure in the combustion chamber was elaborated. Evaluation of particular results permits to determine potential possibilities of gas - air charge combustion.*

## 1. Introduction

The aim of the described investigation was, among others, to determine combustibility of gas- air mixtures of relatively high value of the air excess coefficient $\lambda$ reaching up to 1,6 at high pressure in the combustion chamber, verification of usability in these conditions of direct ignition devices recently applied in engines of high performance supplied with gasoline and, as described subsequently, recognition of effects of natural gas combustion in static conditions.

## 2. Investigation methods

The carried out investigations consisted in combustion of gas - air charges of excess coefficients respectively: $\lambda$ = 1,0; 1,2; 1,4; and 1,6 in a static chamber at various initial pressures in the chamber with digital recording of the pressure course. For a complete series of tests a direct ignition device of properties permitting to obtain increased energy of spark discharge was applied.

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[1] Prof. Bronisław Sendyka D.Sc., Ph.D. Eng.

[2] M. Sc. Eng. Marcin Noga

## 3. Test stand

A test stand presented in fig. 1 was prepared for investigations.

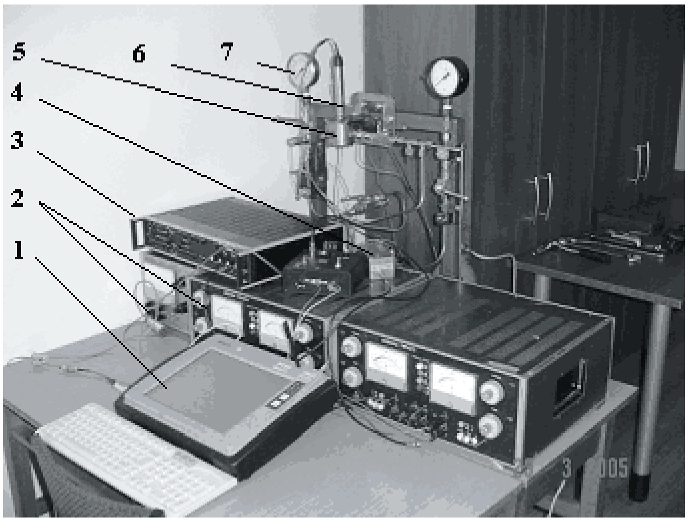


*Fig. 1. General view of the test stand for performance investigations of the process of natural gas - air charge combustion: 1 - Diagnoscope, 2 - Power supply, 3 - Impulse generator, 4 - Coil controller, 5 - Combustion chamber, 6 – Coil, 7 – Manometer*

During test performance the combustion chamber was filled with previously prepared combustible mixtures of adequate compositions. These were stored in bottles under pressure of about 8 [MPa] (Fig.2.).

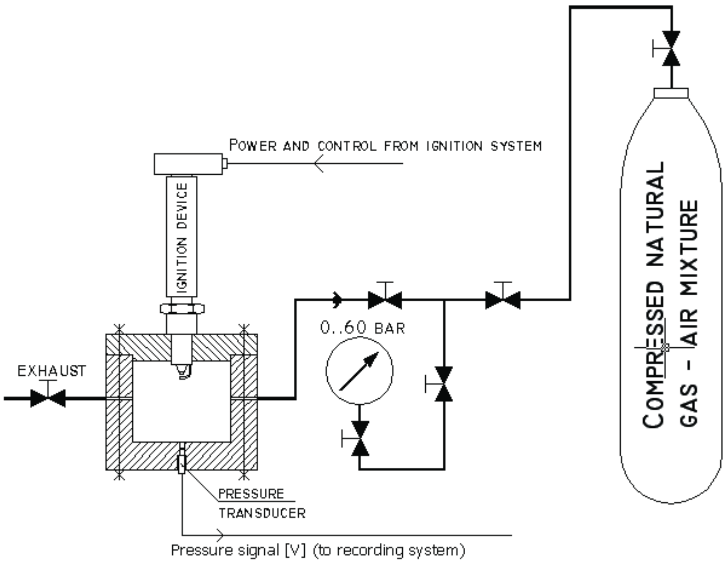


*Fig. 2. Scheme of the investigation chamber with its feeding system with combustible mixture*

Single ignition impulse was released be means of a impulse generator. A rectangular signal of 5 [V] amplitude controlling the ignition circuit (Fig. 3.), its width was established so as to make the ignition device, not exceeding its nominal parameters, cause on the plug a spark discharge of adequately high energy. Its level is determined, at constant value of other parameters, by the value of the primary current $i_1$ at the moment of its cutoff. It was established on the level $i_{max}$ = 12 [A] (Fig. 4.). The gap between the plug electrodes was established on the level 0,3 [mm] so that the spark (ignition) could take place even for the most extreme conditions encountered during the investigations carried out - it means for lean mixtures stored in the chamber under high pressure.

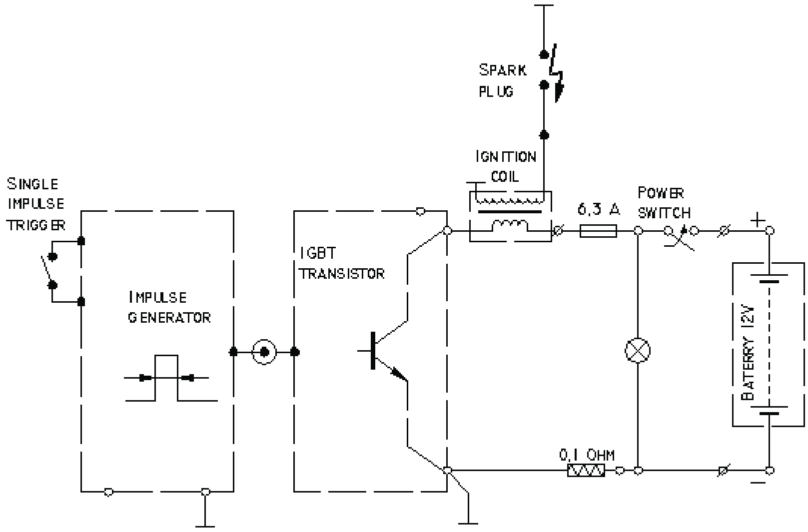


*Fig. 3. Scheme of the ignition system used in investigation*

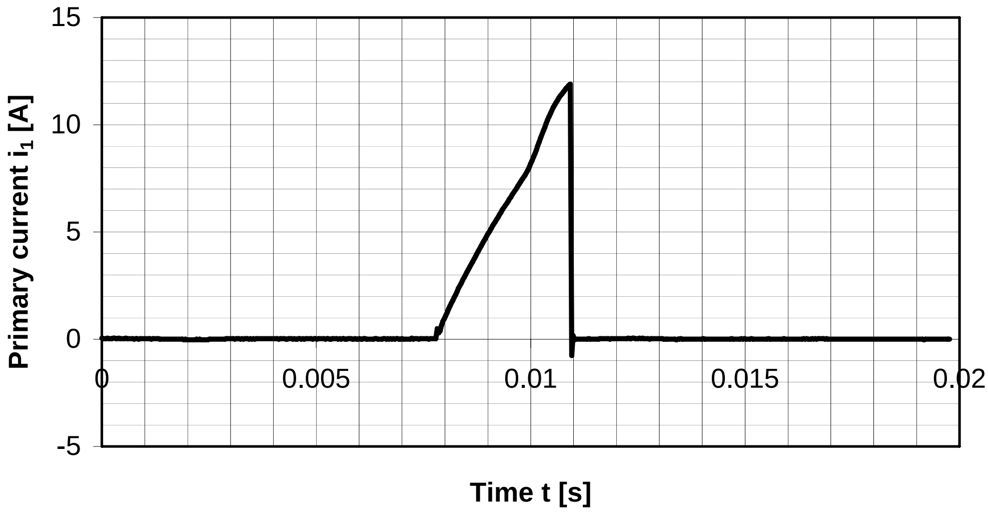


*Fig. 4. Oscillograph record of current flow in primary circuit*

Voltage pressure signal was read from the optoelectronic converter of calibration described with equation (1). It was recorded by use of a data acquisition card of an automobile diagnoscope. Such a choice of the recording system was imposed by its reliability of functioning even in conditions of occurrence of intensive disturbances generated by the ignition system. Exemplary traces of the signal from the sensor recorded during one of the tests shown in fig. 5.

$$p = 2{,}301 \cdot U - 1{,}295, \tag{1}$$

where:

p - value of pressure [MPa],

U - signal of voltage recorded from the sensor [V].


*Fig. 5. Traces of changes of voltage from the pressure sensor recorded by use of a diagnoscope mixture of composition λ = 1,2; initial pressure: $p_1$ = 3,250 [MPa]; maximal combustion pressure $p_{max}$ = 14.792 [MPa]*

## 4. Results of performed tests

The results obtained during investigations was presented in fig. 6. These are values of pressure increment in the combustion chamber Δp [MPa] (2) for combustible mixtures of various initial pressures of charge.

$$\Delta p = p_{max} - p_1 , \tag{2}$$

where:

Δp - pressure increment [MPa],

$p_{max}$ - maximal combustion pressure [MPa],

$p_1$ - initial pressure in the combustion chamber [MPa],

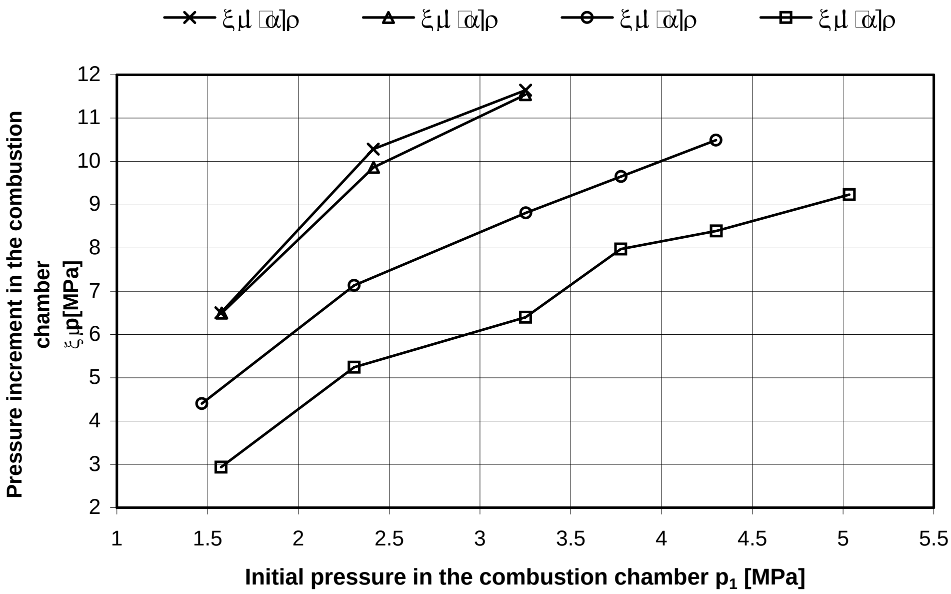


*Fig. 6. Values of pressure increment in the combustion chamber Δp [MPa] obtained or combustible mixtures of various coefficient of air excess λ and various initial pressures of the charge p[1]*

## 5. Conclusions

Analyzing the investigation results it should be noticed that:

1. Values of pressure increment for a mixture of determined composition depends, with certain approximation in a linear way, on the value of initial pressure of the chamber charge.
2. Biggest departures from the linear increase in the value of pressure increment during combustion with increase in initial pressure in the chamber occur for mixtures of an air excess coefficient $\lambda = 1{,}0$ and 1,2.
3. Combustion of mixtures of a coefficient of air excess $\lambda = 1{,}0$ and 1,2 generated very similar values of pressure increment in the chamber; this might indicate to a higher efficiency of leaner mixture combustion.
4. The act of occurrence of a great difference between initial conditions occurring in the chamber ( for example: lack of charge movement, its low temperature close to room temperature, and lack of pollution with exhaust gases as well as constant chamber capacity) and those encountered in piston combustion engines should be stressed.

## 6. Remarks concerning investigations

During the performed investigations the following was noticed:

- Two ignition plugs got destroyed due to loss of tightness in consequence of influence exhaust gas under exceptionally high pressure.
- Combustion of mixture of stoichiometric composition generated such a great amount of humidity in the chamber that after 1 - 2 tests the plug had to be removed, and its electrodes and the inner part of the insulator had to be dried with compressed air; in case this was not done no ignition of the recharged mixture took place.

## References


[1] Alizon F., Guibert P., Dumont P., DuPont A., “Convective Heat Transfers in the Combustion Chamber of an Internal Combustion Engine Influence of In-Cylinder Aerodynamics”, SAE, Warrendale 2004.

[2] Catania A. E., Spessa E., Misul D., Martorana G., “Conversion of a Multivalve Gasoline Engine to Run on CNG”, SAE, Warrendale 2000.

[3] Gilaber P., Pinchon P., “Measurements and Multidimensional Modeling of Gas-Wall Heat Transfer in a S.I. Engine”, SAE, Warrendale1988.

[4] Karkoszka P., "Samochodowe niekonwencjonalne systemy zapłonowe", WKiŁ, Warszawa 1988.

[5] Kordziński C., "Zapłon elektryczny trakcyjnych silników spalinowych", WKiŁ, Warszawa 1969.

[6] Kowalewicz A., "Tworzenie mieszanki i spalanie w silnikach o zapłonie iskrowym", WKiŁ, Warszawa 1984.

[7] Misul D., Mittica A., Spessa E., Catania A.E., “Refined Two-Zone Heat Release Model for Combustion Analysis in SI Engines”, The Fifth International Symposium on Diagnostics and Modeling of Combustion in Internal Combustion Engines, Nagoya 2001.

[8] Rychter T., Teodorczyk A., "Modelowanie matematyczne roboczego cyklu silnika tłokowego", PWN Warszawa 1990.

[9] Spessa E., Catania A.E., Misul D., Vassallo A., “Analysis of Combustion Parameters and Their Relation to Operating Variables and Exhaust Emissions in An Upgraded Multivalve Bi-Fuel CNG SI Engine”, SAE, Warrendale 2004.
[10] Szargurt J., "Termodynamika techniczna", Wydawnictwo Politechniki Śląskiej, Gliwice 1997.
[11] Yamamoto Y., Sato K., Matsumoto S., Tsuzuki S., “Study of Combustion Characteristics of Compressed Natural Gas as Automotive Fuel”, SAE, Warrendale 2004.