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RESEARCH ANALYSIS OF APPLYING THE CATALYTIC CONVERTER FOR FLEXIBLE FUEL ENGINE

ANALIZA BADAWCZA ZASTOSOWANIA KONWERTERA KATALITYCZNEGO W WIELOPALIWOWYM SILNIKU SPALINOWYM

Abstract

In order to transform the chemical energy of vegetable oil or alternative, vegetable oil-alcohol blends, in SI engines, one should properly modify system of combustion. The author worked out a system of pneumatic fuel injection by means of hot exhaust gases drawn from one cylinder during the working stroke and, following the addition of fuel, forced into another cylinder during the compression stage [3]. On the present stage of this combustion system development, it seems the possibility in small SI engines the renewable fuels combined with an emission control of toxic components of the exhaust gasses to implementation. This enables optimisation of whole exhaust system at conservation of high temperature in the monolith TWC. In the paper catalytic conversion of toxic components in exhaust gas as dependence of alternative fuels mixture preparation obtained from experiment is presented. Research works were conducted on a low cost flexible fuel, 250 cc two-stroke two-cylinder spark ignition engine, based on pneumatic fuel injection by means of hot exhaust gases. In the paper results of experiment in comparison to petrol fueled engine were given. The paper includes several figures obtained from experiments. Petrol, rape oil, ethyl alcohol and their mixtures were used to examinations. The engine was started on petrol or alcohol, and after switching to the alternative fuel, the load setting took place. Below in the form of the collective balance sheet, the effect of flexible fuel engine fueling on working parameters were shown.

Keywords: flexible fuel engine

Streszczenie

Zamiana energii chemicznej oleju roślinnego i jego mieszanin z etanolem i/lub benzyną na pracę użyteczną w silniku o zapłonie iskrowym wymaga odpowiedniego zmodyfikowania systemu spalania. Autor opracował system pneumatycznego wtrysku paliwa za pomocą gorących gazów spalinowych [3]. Na obecnym etapie rozwoju tego systemu spalania uzyskano możliwość zasilania małych silników ZI paliwem bazującym na paliwach odnawialnych z jednoczesną kontrolą emisji toksycznych składników gazów spalinowych. Koncepcja ta umożliwiła kontrolę całego systemu spalania w celu utrzymania stabilnej temperatury w monolicie złoża konwertera katalitycznego. W artykule zostały zaprezentowane wyniki eksperymentów z zakresu konwersji toksycznych składników gazów spalinowych w zależności od rodzaju zastosowanego paliwa. Badania zostały przeprowadzone na niskobudżetowym wielopaliwowym dwusuwowym silniku ZI. Wyniki eksperymentów zamieszczone w artykule uzyskano podczas badań silnika zasilanego benzyną, alkoholem etylowym i ich mieszaninami z olejem rzepakowym.

Słowa kluczowe: silnik wielopaliwowy

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1. Introduction

Control of the fuel dosage in flexible-fuel two-stroke spark ignition engine should consider from one side, the energetic requirement of the receiver forcing into load into straining this engine, on the other the minimization of emission of toxic components of the exhaust gases. These issues will be examined on the engine equipped with the system of the homogeneous fuel-air mixtures combustion with the application of catalytic converter of the exhaust gases. With novelty in suggested functional model of the supply and combustion system of the flexible-fuel engine will be connecting the regulation of the dose of fuel with getting the stability of the rotational speed of the crankshaft for value 3000 1/min in the changeable operation points of load and with the stabilization of the rate of lambda coefficient in the range 0.97 to 1.03 based on the composition of the exhaust gases measured behind catalytic converter.

The configuration of the supply and combustion system is extorting the different guidance's towards applied normally approach with dosage of fuel issue at the quantitative adjustment of the engine power control. Usually the verification of the current composition of air to fuel mixture is based because on the composition of the exhaust gases takes place through the measurement of the oxygen content in front of the catalytic converter. The measurement behind the converter in this case carried out is simultaneous exclusively for exploitation-diagnostic purposes. However in the suggested solution on account of the specificity of the process of the charge exchange in a 2-stroke engine (there is current oxygen in the exhaust gases in front of the catalytic converter because charge of air which in the process of loading the cylinder before the fuel injection is getting to the exhaust port) on the current composition of the exhaust gases in front of the catalytic converter it isn't possible to obtain information for lambda coefficient values.

However on account of the fact that the inspected engine will be allocated to the work in the cogeneration unit, it is possible to apply the proposed method of the regulation of the dose of fuel, because the efficiency of the exchange of the chemical energy of fuel for the useful work isn't an operational research criterion in this case. It is possible to get the precise manner of the regulation of the dose of fuels thanks to that about the changeable chemical composition and the calorific value, including on one hand the receiver forcing into load of this engine, on the other the minimization of emission of toxic components of the exhaust gases, which are a main carrier in this case of energy exploited in the process of the recycling of the waste heat in cogeneration units.

It is creating the possibility of using oxygen in the exhaust gases for oxidizing hydrocarbon elements of the outlet loss and products of the incomplete combustion of fuel in the exothermic reaction in the engine cylinder. Next, for providing the maximum fitness of the reduction in nitric oxides in the scheme for the power regulation of engine in appropriately narrow range, a quality regulation will be used. It is of course associated with the requirement of the presence in the exhaust gases in front of the catalytic converter of the carbon monoxide in the right concentration (for the initiation of reaction of the reduction).

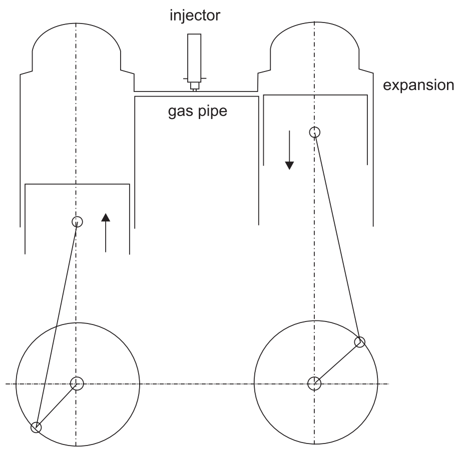

Fig. 1. Prof. Stanislaw Jarnuszkiewicz idea [7] of the injection arrangement

Rys. 1. Układ zasilania według koncepcji prof. Stanisława Jarnuszkiewicza [7]

2. Investigation object

A two cylinder, two stroke, air-cooled engine 155.1 Dezamet[1] make of displacement volume 246 cm^3 was the investigation object. In its manufactory version the engine is equipped with a carburetor feeding system. The basic technical dates of the engine are listed in Table 1. Adaptation of the engine for investigation purposes made introduction of some changes necessary. The main modification consisted in application of pneumatic injection system into the cylinder. The engine was also equipped with a mass air flow meter, Kistler system of pressure measurement, and a DiGas 4000 light emission analyzer.

Table 1

Model and producer of engine	155.1 Dezamet
Type	Two stroke, spark ignition, air-cooled
Cylinder number	2
Bore mm	52
Stroke mm	58
Displacement ccm	246
Compression ratio	8
Ignition system	electronics
Spark plug number	2
Fuel	petrol, vegetable oil, alcohol
Rating kW/RPM	4,9/3000
Brake specific fuel consumption g/kWh	364

[1] Dezamet – Zakłady Metalowe “DEZAMET” S.A., Bumar Group Company.

3. Combustion engine control

Combustion engine power control should, on the one hand, take into regard the power demand of the electric generator, and on the other hand – minimization of emission of toxic exhaust gases components. For engine control a low pressure fuel dosing controller based on micro-processor technique was applied. The controller indicated the fuel dose basing on the table conditioning the injection time on engine temperature and (value) of air mass flow. During the work under load the controller maintained the indicated rotational speed value by regulating the fuel dose determined by actual load. Work of the engine in the presented system is characterized by loading variability at constant rotational speed of the crankshaft. So it was necessary to create proper laboratory conditions enabling effective investigations of the combustion engine control algorithm in variable loading conditions. Time of injector opening at constant fuel pressure before the injector is directly proportional to the required fuel dose. Fuel dosing was synchronized with the phase of the constant pressure in a gas pipe by use of a hallotronic sensor. Air mass flow was determined by measurement of the value of signal tension change of the flow meter in the inlet system before throttle, synchronized with fuel dosing. In consequence it may be stated that two control quantities were at disposal: injection time and air mass flow. Quantities of these two controls depend generally on a number of factors (actual rotational speed, load, kind of fuel, inlet air temperature, engine temperature etc.). For respective investigations which permit engine control with a working equipment (for example: electrical generator, CHP) a test bed permitting determination of injection time in real time had to be prepared. Choosing the equipment for the laboratory test bed one focused on making determination of dynamic changes control possibly easy and system handling simple and clear for the user. Fig. 2 presents in rough outlines the lay-out of the test bed.

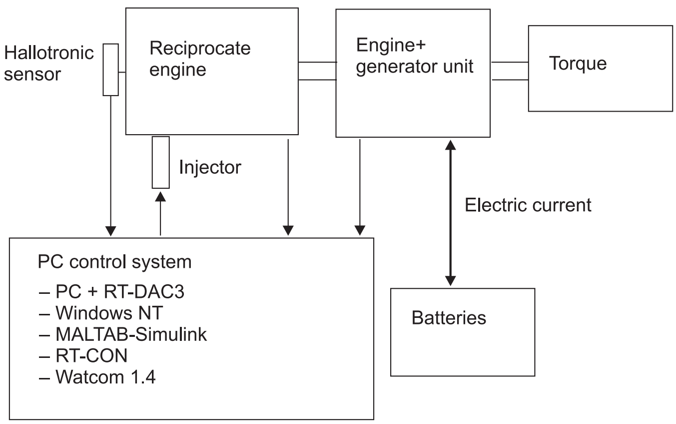

Fig. 2. Scheme of test bed

Rys. 2. Schemat stanowiska badawczego

As stabilization of the rotational speed, PID controller is concerned. Typical stages of loading changes were chosen and projected on the test bed as experiments stabilizing the rotational speed of the combustion engine. The following diagram (Fig. 3) traces of injector time opening and rotational speeds for passing from starting to working under load of engine.

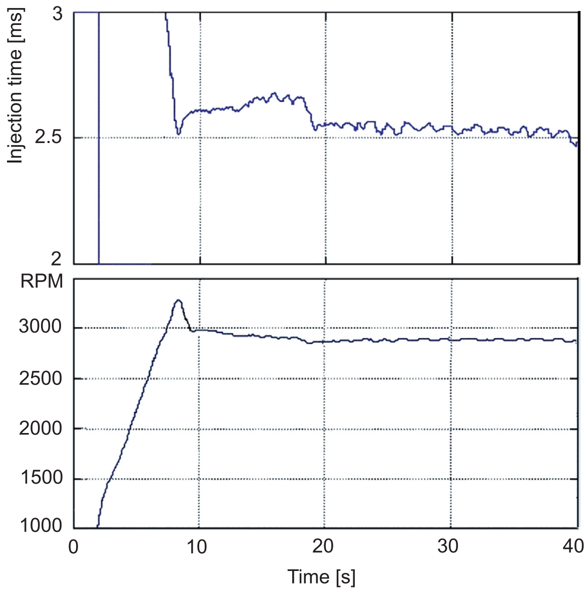

Fig. 3. Passing from starting in to working under load

Rys. 3. Praca silnika przy przejściu od fazy rozruchu do obciążenia

4. Engine investigations

From the performed experimental investigations of the control system some information is obtained concerning possibility of fuel dose control within the range of useful load of the engine. Moreover, what is really significant, some information was also obtained in what a ange of useful load of the flexible fuel engine there existed a possibility of practical realization of power control by means of a system based on pneumatic injection. In the following diagram the results of investigations of the engine with the above mentioned system were presented. These were confronted with working parameters on this engine using alternative fuels and petrol. Petrol, rape oil, ethyl alcohol and their mixtures were used to examinations. In Table 2 a list of applied fuels was compiled. Letter symbols mean: *A* – alcohol, *B* – mean 95 RON petrol, *R* – the rape oil, but numbers mass concentration. The engine was started on petrol or alcohol, and after switching to the alternative fuel, the load setting took place.

Below in the form of the collective balance sheet, the effect of flexible fuel engine fueling on working parameters and emission were shown.

Table 2

Symbol of fuel	Density [g/cm³]
B100	0.74
R100	0.91
B60R40	0.80
A100	0.80
A33B33R33	0.80

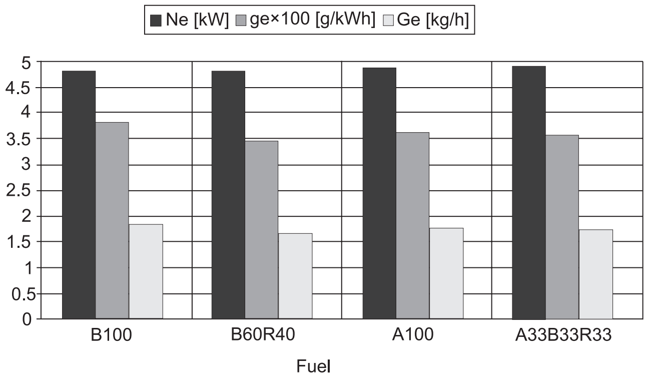

Fig. 4. Effect of engine fueling on brake power, brake specific fuel consumption and on fuel consumption per hour

Rys. 4. Wskaźniki pracy silnika przy zasilaniu paliwami badawczymi

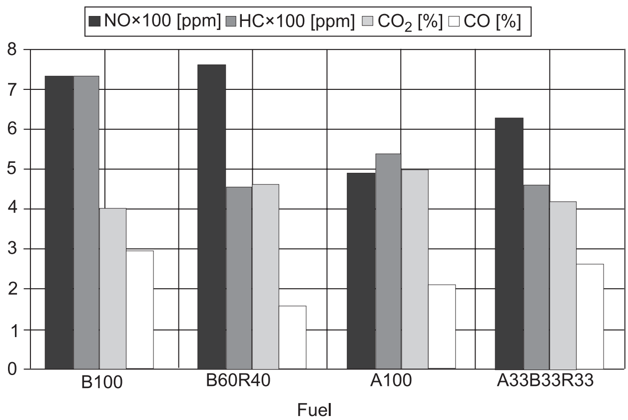

Fig. 5. Effect of engine fueling on NO, HC, CO_2 and CO measured in front of the catalytic converter

Rys. 5. Stężenia składników spalin NO, HC, CO_2 i CO w punkcie pomiarowym przed konwerterem katalitycznym

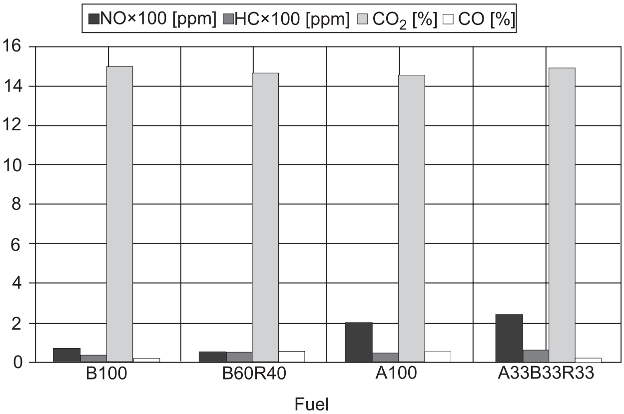

Fig. 6. Effect of engine fueling on NO, HC, CO_2 and CO measured behind the catalytic converter

Rys. 6. Stężenia składników spalin NO, HC, CO_2 i CO w punkcie pomiarowym za konwerterem katalitycznym

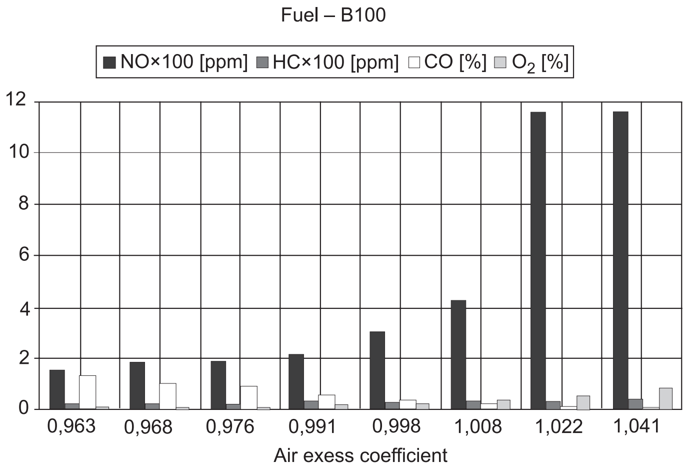

Fig. 7. Effect of air excess coefficient regulation on NO, HC, CO_2 and CO measured behind the catalytic converter

Rys. 7. Wpływ regulacji współczynnika nadmiaru powietrza na stężenie składników spalin NO, HC, CO_2 i CO za konwerterem katalitycznym

5. Analysis of investigation results

diagram 4 show loading characteristics and diagrams 5 and 6 present characteristic of CO_2 and toxic component concentration as function of fuels at the application marked out, in front and behind the catalytic converter. Next diagram 7 show effect of air excess coefficient regulation on the composition of exhaust gases behind the catalytic converter. Experiment was conducted for permanent and unchanging opening the throttling valve at the rotation speed 3000 1/min. The value of the torque and the power was made conditional on the dose of fuel which was established in the process of the measurement according to the criterion of the minimization values of the time of the injection and contents of HC in the exhaust gases. For such accepted conditioning during tests of mentioned above fuels the disposable range of the power was included in the range of 4.78 kW to 4.92 kW. The greatest value was achieved for fuel A33B33R33, however smallest for commercial petrol. Values of the brake specific fuel consumption were included in the range from 342 g/kWh to 379 g/kWh. The smallest value was achieved for fuel marked B60R40. As regards the content of the constituents of the exhaust gases, low concentration of CO on the level 1,5% was achieved also for this fuel. In the case of HC minimal emission on the level 456 ppm was achieved also for this fuel. Next low concentration of NO on level of 491 ppm for fuel A100. How already one mentioned, in presented system of combustion will be off-distributor system of pneumatic injection by means of hot exhaust gas used. This solution characterizes with simplicity of construction, however for the price of potential possibilities of pronouncement of occurrence of scavenge – loss, as injection of exhaust gas-fuel mixture begins in moment when exhaust port is yet open. For minimizing this effect in the flexible fuel engine, system which makes possible obtainment proportional to rotational speed frequencies of natural oscillations of complicated system composted from resonance chamber and parts of exhaust system was used. In this manner is defined period of natural oscillations the stream of gases filling the exhaust system. Profitable from the point of view charge exchange course of pressure in exhaust system is attained then, when period of natural oscillations of exhaust gases is approximately equal to period of scavenge process. Is occurring then as in final phase of this process, height of pressure before closing exhaust port. This occurrence makes difficult outflow of charge from cylinder. It is also possible withdrawing parts of recent charge from exhaust system to cylinder, what yet more improves filling. Hence low CO_2 emission and relatively high like to the SI two-stroke engine NO emission because the cylinder was scavenged out with the clean air. Small value of rest of the exhaust gases in in-cylinder charge resulted in increased of NO emission.

In spite of applying these treatments the scavenge – loss is an inevitable occurrence in the described system therefore how already was recalled, applying the adjusted catalytic converter lets considerably lower the emission of toxic ingredients. As the additional advantage in this case, is possibility of the application the process of the waste heat recycling from cogeneration units. Potential effect of purifying the exhaust gases is shown in diagram 6. As regards the content of the constituents of the exhaust gases, low concentration of CO on the level 0,1%, it was achieved for petrol fuel. In the case of HC minimal emission on level 8 ppm it was achieved for A100 fuel. Next low concentration of NO on the level 46 ppm it was achieved for B60R40 fuel. During this process the temperature of the exhaust gases increased from level 550 to 950 C. Diagram 7 depicts the “sensitivity of the catalytic converter” to the oxygen content in the exhaust gases feeding it. Issue of using information about the presence in the quality and quantitative meaning of oxygen in the exhaust gases behind the catalytic converter in the form of the decision-making parameter for setting the dose of fuel in the set point of the engine load, will be an object of future works.

6. Conclusions

This is a low cost in-cylinder fuel injection system. Research experiments were oriented mainly for using not-standardized mixtures of engine commercial petrol with rape oil and ethyl alcohol. Spraying and injection of fuel, give additional possibilities of complete evaporation of light fuels, alternative fuels with extended fraction and heavier fuels, such as diesel oil, kerosene and vegetable oil, which may be very beneficial from the viewpoint of practical realization of utilization processes. Analysis of obtained findings doesn't authorize changes of indicators to take ultimate conclusions out as for the influence of the mutual composition of studied components of fuels on the course of the work of an flexible fuel engine. With a view to achieving more clear-cut results one should conduct further research. All the not less even in the reduced scope it is possible to notice the influence of the allowance of so-called biocomponents especially of lowering elements of the toxic exhaust gases and what is very essential for lowering the brake specific fuel consumption. In the process of engine examinations, a conception of controlling dosing of fuel proved correct. In spite of the tendency of stratifying of mixtures petrol – alcohol with the addition of the rape oil was get continuity of dosing with fuel in laboratory tests and disruptions weren't taken note at the work of fuel apparatus. Results achieved in the process of these examinations are encouraging continuing works in the possibility of applying in the internal-combustion engine with the pneumatic fuel injection by means of hot exhaust gases, not-standardized fuels on the basis of biocomponents. It is playing a significant role in the practical realization of recycling processes (for example a worked vegetable oil) and of diversification of energy supplies. Energy self-sufficient house, perhaps to be an interesting field of application [6].

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