ANALYSIS OF CHOSEN PARAMETERS OF COMBUSTION PROCESS FOR 4C90 ENGINE FUELLED WITH EKO DIESL AND ONM IN TRANSIENT CONDITIONS

Rafał Longwic

The Technical University of Lublin, Poland

INTRODUCTION

The research concerning Diesel engines for various uses running in the conditions of their operation has proved that, apart from stationary engines, transient conditions are either basic conditions of a diesel engine running or they are an inherent part of its running time [7]. The course of self-ignition engine working processes, particularly the combustion process, is different in transient conditions than in steady-state conditions, mainly because of a shorter self-ignition lag and the phenomenon of thermal inertia [4]. The problem of combustion process course in transient conditions for the self-ignition engine has been described in the author's previous papers [3, 4]. It has to be mentioned that this subject has not been thoroughly discussed recently due to considerable difficulties in carrying out experimental tests. Available scientific papers were published in the 70's and 80's [2, 6, 8] and include experimental tests results obtained with the use of less precise measuring devices (those, which made it impossible to measure some engine operation quickly changing parameters simultaneously). In the present paper an attempt to assess how the use of various kinds of diesel oil influences the course of combustion process in a self ignition engine in transient conditions has also been made. This is crucial for stating how the kind of used fuel influences the vehicle's dynamic properties, e.g. during acceleration.

At present there are two main kinds of diesel oil available in the market:

- standard diesel oil – light Eko diesel with three types: summer (EDL), transitory (EDP) and winter (EDZ);
- reformed diesel oil, also called city diesel oil (ONM).

Crude oil fraction with the final boiling point 300°C was used as a base for ONM fuel production. Such a restriction eliminated hydrocarbons with a large number of carbon in a molecule from the fuel contents. The lack of such a group of hydrocarbons in the fuel caused the reduction of its density, viscosity and a distinct improvement in its low-temperature properties when compared to standard diesel oil Eko Diesel. In the final stage of both ONM and diesel oil Eko diesel production, the process of deep hydrofining in hydrogen sulfur removal process, which leads to a considerable reduction of sulfur contents (below 200 mg/kg), is realized.

The results of indicating the engine with turbulence chamber 4C90, fuelled with ONM and Eko Diesel of summer and winter types, in transient conditions, have been presented in the paper. Conditions of engine transient operation were mapped by the method of active experiment consisting in engine free engine up caused by the step change of fuel dose control element position. The course of combustion process chosen parameters, i. e. mean indicated pressure, pressure growing maximum velocity, maximum combustion pressure, pressure maximum occurrence angle and combustion start occurrence angle has been presented. An attempt at explaining the observed differences in the course of tested fuels combustion process in transient conditions has been made.

RESEARCH AIM

The aim of research was to state how the use of various kinds of diesel oil (EDL, EDZ and ONM) influences the values of chosen parameters of combustion process in an engine with turbulence chamber 4C90 in transient conditions.

FUELS USED IN TESTS

ONM, EDL and EDZ were used for fuelling the 4C90 engine. Basic physical-chemical parameters of the tested fuels have been determined and they are presented in Table 1. Eko Diesel of summer type (EDL) had he highest values of cetane index and ONM – the lowest (relative difference was about 7%). The greatest relative differences occurred for the kinematics viscosity index at 40°C, which was about 37% lower for ONM compared with EDL.

Table 1. Chosen physical-chemical properties of the tested fuels

Properties	Diesel oil kind		
	EDZ	ONM	EDL
Cetane index	52,7	50,9	54,5
Density at 20 ºC (g/cm^3)	0,834	0,819	0,835
Kinematic viscosity at 40, ºC mm^2/s	2,91	2,07	3,27
Sulfur contents, % (m/m)	0,043	0,043	0,025
Cloud point, ºC	-	-32	-8
Ignition temperature, ºC	66	66	64,5
Temperature of cold filter blocking, ºC	-21	-35	-15
Water contents, mg/kg	169	165	120

OBJECT OF STUDIES

The object of studies was the 4C90 engine. Its basic technical data are presented in Table 2. Control measurement of compression pressure in particular engine cylinders was carried out. Compression pressure values checked with the SPCS-50 tester at engine crankshaft rotational speed 250 rpm were not lower than 2.45 MPa. The obtained results prove that the object of studies was technical data.

Table 2. Chosen 4C90 engine technical data

Maximum power	51.5 KW at 4200 rpm
Maximum torque	145 Nm at 2500 rpm
Idle running rotational speed	800±20 rpm
Engine cubic capacity	2417 cm^3
Number of cylinders	4
Compression ratio	21.1:1
Cylinder diameter	90.0 mm
Unitary fuel consumption	299 g/kWh
Fuel supply system	line pump MOTORPAL, injection sprayer of BDNOSPC 6389 (Pintaux) type
Fuel pumping dynamic start angle	15°CA
Injectors opening working pressure	15 MPa

TEST STAND

The research has been carried out in cooperation with the Institute of Vehicles and Machines Technical Operation at the Technical University of Radom. The measurement system used [5] made it possible to measure and register simultaneously: pressure in combustion chamber, pressure in turbulence chamber, pressure before the injector, injector needle lift and engine crankshaft rotational speed with frequency 1.4°CA. The scheme of the test stand is presented in Fig. 1.

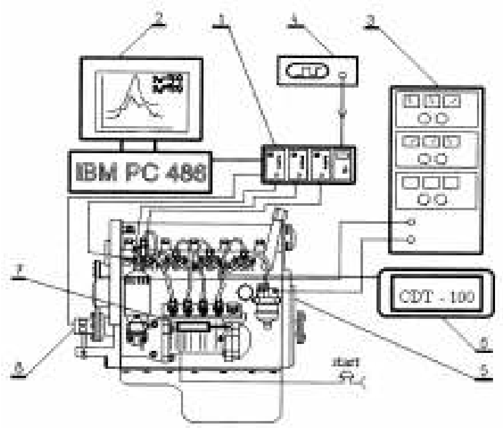

Fig. 1. Test stand with 4C90 engine: 1 – amplifiers assembly, 2 – computer PC, 3 – control and steer cubicle, 4 – time base generator, 5 – 4C90 engine, 6 – engine speed control system, 7 – stepper motor controlling injection pump toothed bar position, 8 – crank angle sender INTROL (measurement frequency 0.7 or 1.4°CA)

RESEARCH METHODOLOGY

Transient conditions were modelled by unloaded engine rapid running up caused by the step change of fuel dose control element position. Unitary travel of fuel dose control lever was forced by solenoid actuator at the moment chosen by the operator.

Measurement initial conditions were characterized by:

– constant engine crankshaft initial rotational speed,

– steady engine thermal state, whose measure was the temperature of lubricating oil.

At the moment when crankshaft rotational speed and oil temperature in the running engine were equal to the values assumed for initial conditions, the operator triggered the measurement start. The measurement system began the measurement of pressure in the combustion chamber, pressure in turbulence chamber, pressure before the injector and injector needle lift from the point determined by piston upper reversible position (beginning of suction). After about 4-8 engine running cycles, the shift of fuel dose control bar was activated. The measurement system registered combustion chamber pressures for 30 successive running cycles. In the registered measurement cycle (30 successive engine running cycles) three engine running periods can be distinguished:

I. crankshaft rotational speed and running engine oil temperature are equal to values assumed for initial conditions, fuel dose control bar position $h \approx$ const, engine crankshaft angular acceleration $\varepsilon = 0$;

II. this period can be divided into 2 subperiods: 1 – $n \neq$ const, engine transient thermal state, $h = h_{max}$, $\varepsilon \neq 0$; 2 – beginning at the moment of injection pump regulator start $n \neq$ const, engine transient thermal state, $h \neq$ const, $\varepsilon \neq 0$. The first of discussed subperiods was subject to further analysis.

III. $n = n_{max}$, engine quasi steady thermal state, $h \approx$ const, $\varepsilon = 0$.

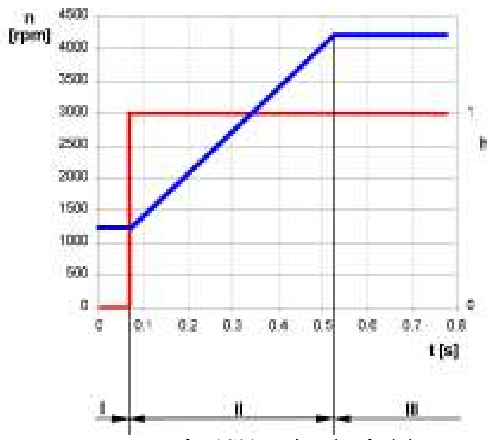

Fig. 2. Examplary free running up process course for 4C90 engine: h – fuel dose control bar position, I – period of engine idle running, II – period of engine free running up, III – period of engine idle running at maximum engine speed

The measurement was repeated 10 times with the above above initial conditions strictly kept. Engine running cycles falling into the period II-1 of engine free running up process were subject to analysis. An examplary course of 4C90 engine running up process is presented in Fig. 2. Three distinguished above engine running periods have also been shown in the figure.

RESULTS AND ANALYSIS

Courses of chosen combustion process parameters for 4C90 engine, running in free running up conditions fuelled with ONM and Eko Diesel of summer and winter types, are presented in Fig. 3-7. Models based on polynomial dependencies were used to determine the regression function. Independent variable summands were left at the significance level α = 0.05. Significance level for independent variables was tested with t-Student test. Significance level for the determined regression function was tested with F-Snedecor test. Matching measurement data with the model was regarded as satisfactory if significance level for determined regression function was lower than 0.001.

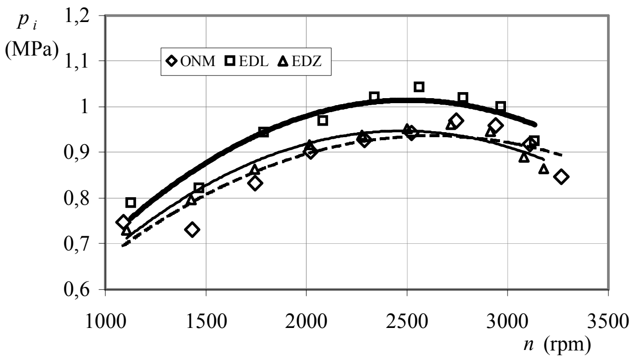

Fig. 3. Course of mean indicated pressure p_i (MPa) for 4C90 engine running in free running up conditions, fuelled with ONM, EDL and EDZ

Mean indicated pressure values p_i were about 15% higher for Eko diesel of summer type compared with the other fuels (Fig. 3). The lowest mean indicated pressure values were obtained for ONM fuel. The reason for the observed differences in values p_i was the up to about 20% rise of maximum combustion pressure pcmax for EDL compared with EDZ and ONM (Fig. 4). Values of the combustion start occurrence angle α_{ps} and pressure maximum occurrence angle αmax were similar for all the tested fuels (Fig. 6, 7). Only for engine speeds higher than 2500 rpm, a rapid decrease in combustion start occurrence angle value occurred in case of EDL fuel compared with the other fuels. This phenomenon can be associated with the running of the tested engine injection system – the increase in the injection start angle value. The values of pressure growing maximum velocity

$(dp/d\alpha)_{max}$ were the highest for ONM fuel (Fig. 5), whose value of cetane index was the lowest compared with the other fuels used in the tests (Table 1).

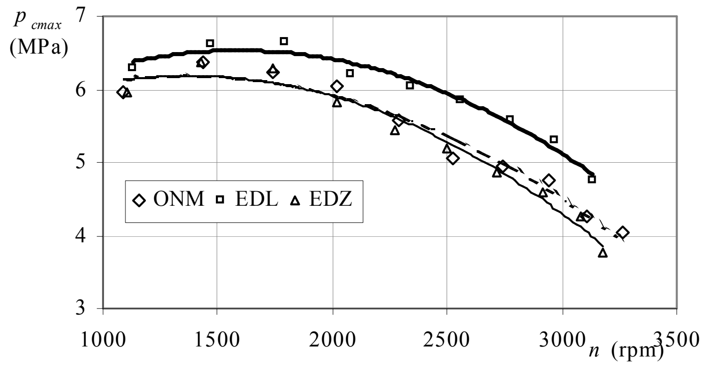

Fig. 4. Course of maximum combustion pressure p_{cmax} (MPa) for 4C90 engine running in free running up conditions, fuelled with ONM, EDL and EDZ

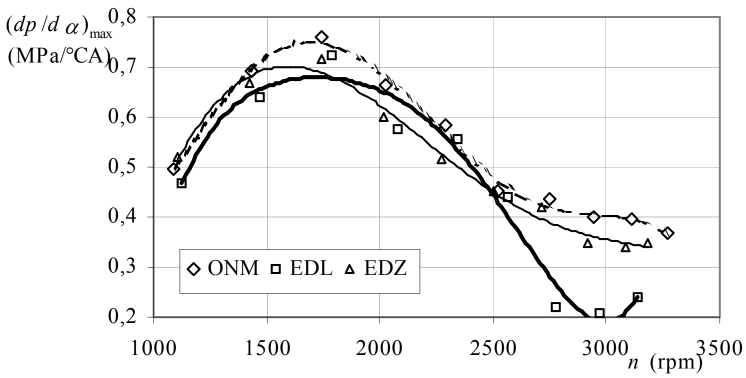

Fig. 5. Course of pressure growing maximum velocity $(dp/d\alpha)_{max}$ (MPa/°CA) for 4C90 engine running in free running up conditions, fuelled with ONM, EDL and EDZ

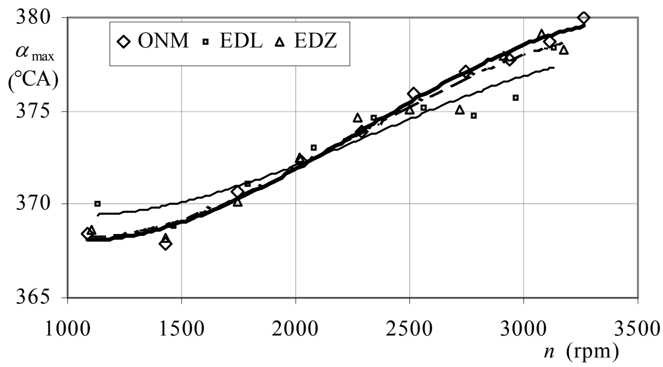

Fig. 6. Course of pressure maximum occurrence angle α_{max} (°CA) for 4C90 engine running in free running up conditions, fuelled with ONM, EDL and EDZ

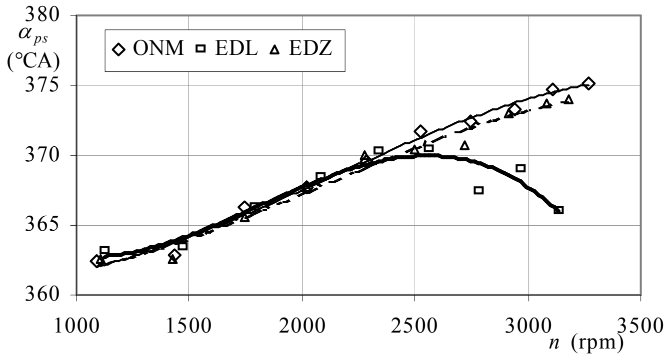

Fig. 7. Course of combustion start occurrence angle α_{ps} (°CA) for 4C90 engine running in free running up conditions, fuelled with ONM, EDL and EDZ

CONCLUSIONS

An attempt to assess how the use of various kinds of diesel oil (EDL, EDZ, ONM) influences chosen parameters of combustion process in an engine with turbulence chamber (4C90) in transient conditions has been made in the paper. The obtained results have proved that that there tends to be a similar growth of mean indicated pressures for EDL against ONM and EDZ as in an engine steady running conditions [1]. This phenomenon is caused by higher values of maximum combustion pressure for EDL. The increase in maximum combustion pressures follows the increase in fuel dose for EDL, caused by the highest viscosity of this fuel compared with the other tested fuels. Higher values of fuel viscosity cause its impeded reverse flow and thus the increase in residual pressures in high pressure conduits. This phenomenon is responsible for an increase in the injection start angle and injection duration angle and causes an increase in fuel dose. The increase in EDL fuel dose at higher cetane index, as compared with ONM and EDZ, results in similar values of combustion start occurrence angle for tested fuels. Values of pressure growing maximum velocity are nearly two times higher in 4C90 engine running up conditions compared with engine running in steady-state conditions. The highest values $(dp/d\alpha)_{max}$ were obtained for ONM, which was caused by its lowest viscosity (the smallest injection start angle) and the lowest cetane index value compared with the other tested fuels. The determined values of cetane indices are higher than those stated in standards ZN-94/MPiH/NF-213 and ZN-93/MPiH/NF-209 but as far as tested fuels are concerned, the cetane index was highest for EDL, not for ONM. The values of mean indicated pressure, about 15% higher for EDL against ONM and EDZ, determined in 4C90 engine free running up conditions, should contribute to the improvement of dynamic properties of vehicles equipped with this engine. However, some research into the process of actual vehicle acceleration should verify this thesis.

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SUMMARY

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