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ANALYSIS OF THE CHOSEN PARAMETERS OF COMBUSTION PROCESS FOR A 4C90 ENGINE RUNNING IN TRANSINT CONDITIONS WITH ADDITIONAL LOADING

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Summary. Results of tests consisting in indicating a 4C90 engine in conditions of running up are presented in the paper. The engine was additionally loaded with inert masses fastened to the flywheel. The influence of given load values on the chosen parameters of the combustion process, such as mean indicated pressure, combustion maximum pressure, pressure growing maximum velocity, combustion start occurrence angle, pressure maximum occurrence angle, has been analysed.

Key words: inert masses, chosen parameters, additional loading

INTRODUCTION

The research concerning Diesel engines of various uses running in the conditions of their operation proves that, apart from stationary engines, transient conditions are either basic conditions of diesel engine running or they are part and parcel of its running time [Wituszyński 1996]. Among engine transient running conditions of infinite number the most important ones are take – off, which makes about 54% of traction engine running in city conditions, and braking (about 30%) [Wituszyński 1996]. The analysis of combustion process chosen parameters in conditions of engine free running up caused by the step change of fuel dose control lever position was the subject of numerous papers [Żdanowskij 1974, Kovarik and Slavicek 1984, Szestuchin 1996, Lotko and Longwic 1999, Longwic *et al.* 2002]. It can be stated on the grounds of those papers that in conditions of engine free running up mean indicated pressure values p_i are slightly higher than values p_i obtained for the conditions of engine running, such as those on external characteristic – Fig. 1.

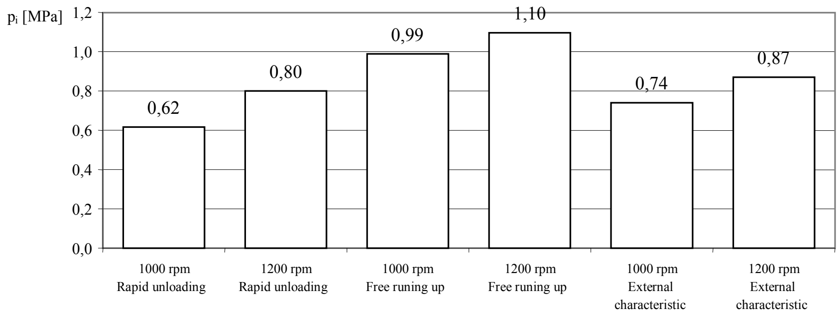

Fig. 1. Values of mean indicated pressure p_i for a 4C90 engine running in conditions of external type, free running up, rapid unloading for n = 1000 rpm and 1200 rpm [Longwic *et al.* 2002]

The reason for such a phenomenon is engine delayed thermal state in conditions of free running up as compared with (corresponding to it) running state on external characteristic [Longwic *et al.* 2002]. This results in a longer fuel self – ignition lag and thus the increase in engine running hardens. The course of combustion process is more rapid, which leads to an increase in combustion maximum pressures and consequently to the increase in mean indicated pressure. The test also proves that, for instance, together with an engine's rapid unloading mean indicated pressure values are similar to those of external type – Fig. 1 [Longwic *et al.* 2002]. Initial thermal state of the engine and rate of running up process should influence combustion process parameters in a self – ignition engine. In order to prove the thesis, inert masses fastened to the flywheel, used for an additional loading of the engine during its running up, were made. The present paper considers an analysis of the problem how loading an engine with an additional inert mass, and the resulting decrease in the running up process rate, influences the chosen parameters of the combustion process determined for the particular conditions of engine running.

AIM OF RESEARCH

The aim of tests was to assess how loading an engine running in conditions of running up with an additional inert mass influences the chosen parameters of a combustion process, such as mean indicated pressure, combustion maximum pressure, pressure growing maximum velocity, combustion start occurrence angle, pressure maximum occurrence angle.

TEST STAND

The research has been carried out in cooperation with the Institute of Vehicles and Machines Technical Operation at The Radom University of Technology. The measurement system [Różycki 1996] which 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, was used. Two inert masses, fastened to the flywheel, were made and used in tests. The scheme of the test stand is presented in Fig. 2.

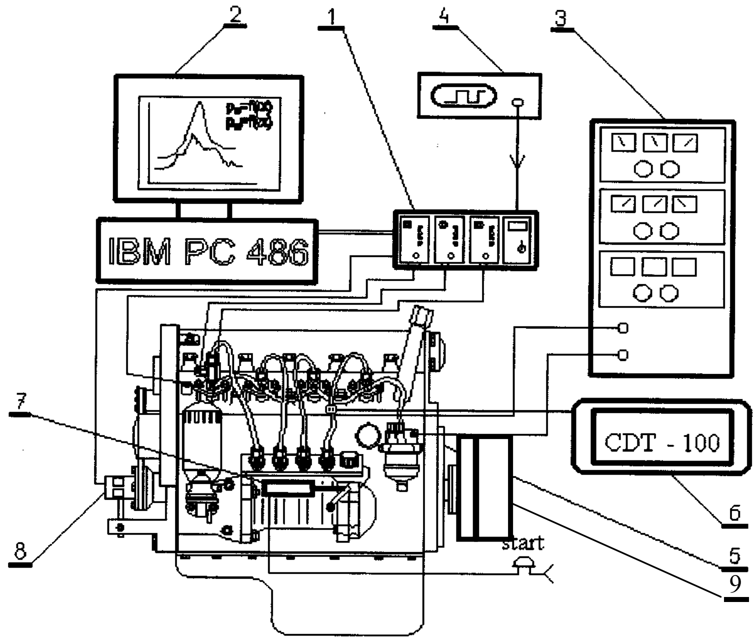

Fig. 2. Test stand with 4C90 engine: 1 – amplifiers assembly, 2 – computer PC, 3 – control and steer cubicle, 4 – time base generator, 5 – 4C90 engine, 6 – engine speed control system, 7 – stepper motor controlling injection pump toothed bar position, 8 – crank angle sender INTROL (measurement frequency 0,7 or 1,4°CA), 9 – inert masses

RESEARCH METHODOLOGY

Transient conditions were modeled 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 a 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 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. Tests were carried out for the following four cases of loading engine crankshaft with inert masses. Those cases were determined as: mass 1, mass 2, mass 3, mass 4, respectively.

Mass 1 – engine loaded only with its own moment of inertia.

Mass 2 – engine additionally loaded with inert mass with mass moment of inertia
$I_1 = 0.14625$ kgm^2.

Mass 3 – engine additionally loaded with inert mass with mass moment of inertia
$I_2 = 0.41625$ kgm^2.

Mass 4 – engine additionally loaded with inert mass with mass moment of inertia
$I_3 = 0.5625$ kgm^2.

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, $\varepsilon = 0$.

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

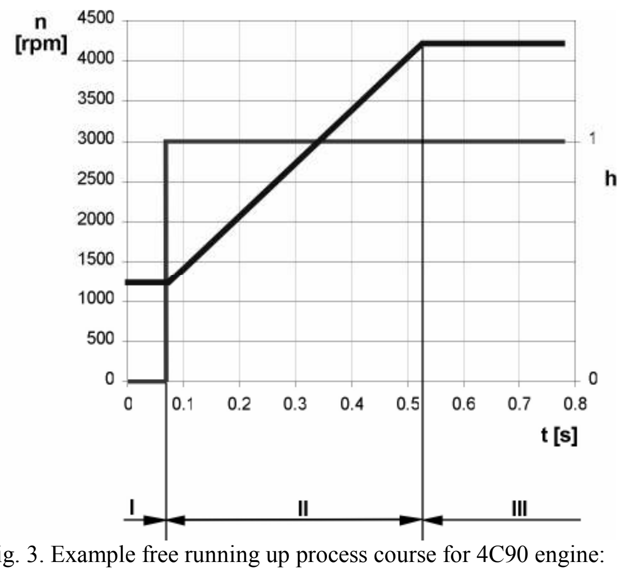

Fig. 3. Example free running up process course for 4C90 engine:
h – fuel dose control bar position,
I – period of engine idle running, II – period of engine free running up, III – period of engine idle running at maximum engine speed

ANALYSIS OF RESULTS

Values of the chosen parameters of the combustion process for a 4C90 engine loaded with additional inert masses running in running up conditions are presented in Fig. 4÷8. Models based on polynomial dependences were used to determine the regression function. Independent variable summands were left at 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 the significance level for the determined regression function was lower than 0.001.

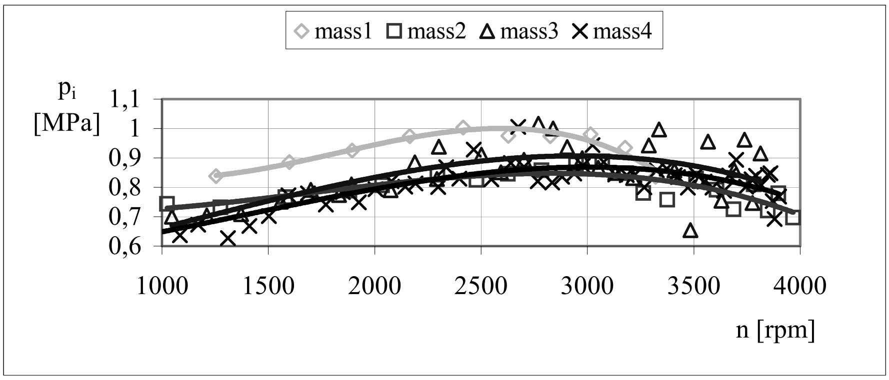

Fig. 4. Course of mean indicated pressure p_i [MPa] for 4C90 engine running in the conditions of running up for four cases of loading: mass 1 – engine loaded only with its own moment of inertia, mass 2 – engine additionally loaded with inert mass with mass moment of inertia I_1 = 0.14625 kgm^2, mass 3 – engine additionally loaded with inert mass with mass moment of inertia I_2 = 0.41625 kgm^2, mass 4 – engine additionally loaded with inert mass with mass moment of inertia I_3 = 0.5625kgm^2

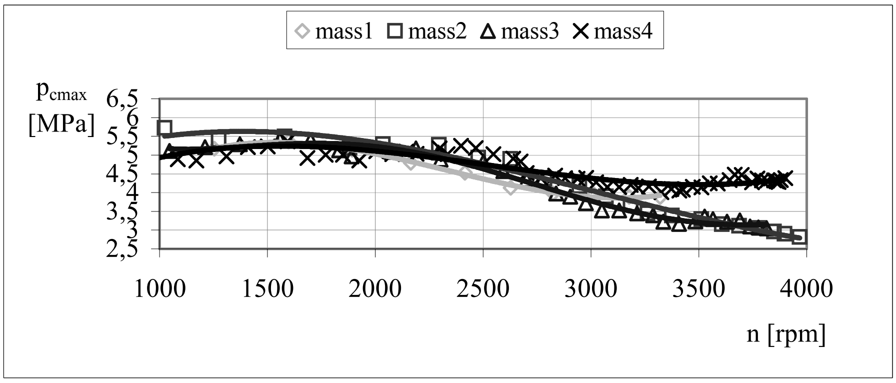

Fig. 5. Course of maximum combustion pressure p_{cmax} [MPa] for 4C90 engine running in the conditions of running up for four cases of loading: mass 1 – engine loaded only with its own moment of inertia, mass 2 – engine additionally loaded with inert mass with mass moment of inertia I_1 = 0.14625 kgm^2, mass 3 – engine additionally loaded with inert mass with mass moment of inertia I_2 = 0.41625 kgm^2, mass 4 – engine additionally loaded with inert mass with mass moment of inertia I_3 = 0.5625 kgm^2

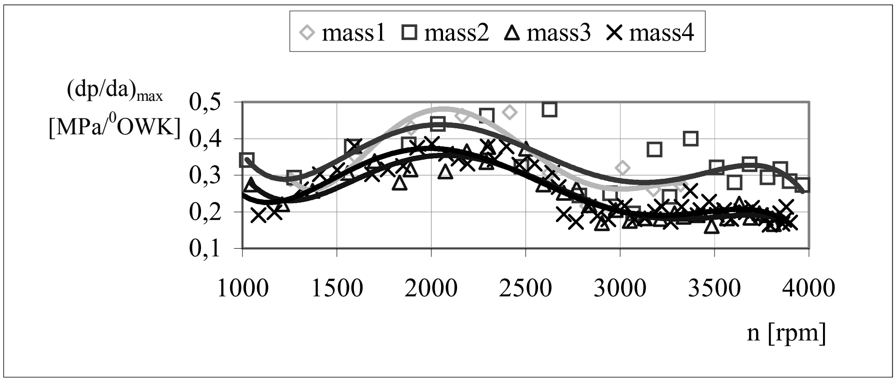

Fig. 6. Course of pressure growing maximum velocity $(dp/d\alpha)_{max}$ [MPa/°CA] for 4C90 engine running in the conditions of running up for four cases of loading: mass 1 – engine loaded only with its own moment of inertia, mass 2 – engine additionally loaded with inert mass with mass moment of inertia $I_1 = 0.14625$ kgm^2, mass 3 - engine additionally loaded with inert mass with mass moment of inertia $I_2 = 0.41625$ kgm^2, mass 4 – engine additionally loaded with inert mass with mass moment of inertia $I_3 = 0.5625$ kgm^2

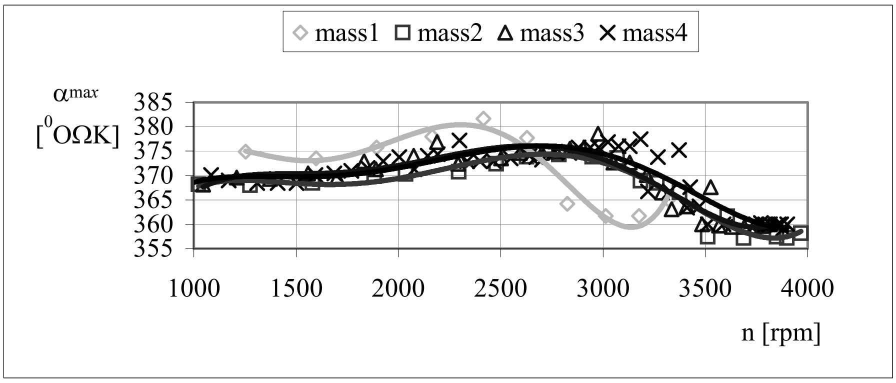

Fig. 7. Course of pressure maximum occurrence angle α_{max} [°CA] for 4C90 engine running in the conditions of running up for four cases of loading: mass 1 – engine loaded only with its own moment of inertia, mass 2 – engine additionally loaded with inert mass with mass moment of inertia $I_1 = 0.14625$ kgm^2, mass 3 – engine additionally loaded with inert mass with mass moment of inertia $I_2 = 0.41625$ kgm^2, mass 4 – engine additionally loaded with inert mass with mass moment of inertia $I_3 = 0.5625$ kgm^2

Values of mean indicated pressures were about 10% higher in the case of running up an engine without additional load (mass 1) as compared with the cases of loading with inert masses (mass 2, mass 3, mass4) – Fig 1. Values of mean indicated pressures were similar for all the three cases of loading an engine with inert masses. Values of maximum pressures were similar for all the four cases of loading an engine in the conditions of running up –Fig. 5. The reason for an increase in mean indicated pressure values in the case of engine free running up was an increase in the combustion start occurrence angle and pressure maximum occurrence angle, as compared with the cases of running up with inert masses – Fig 7, 8.

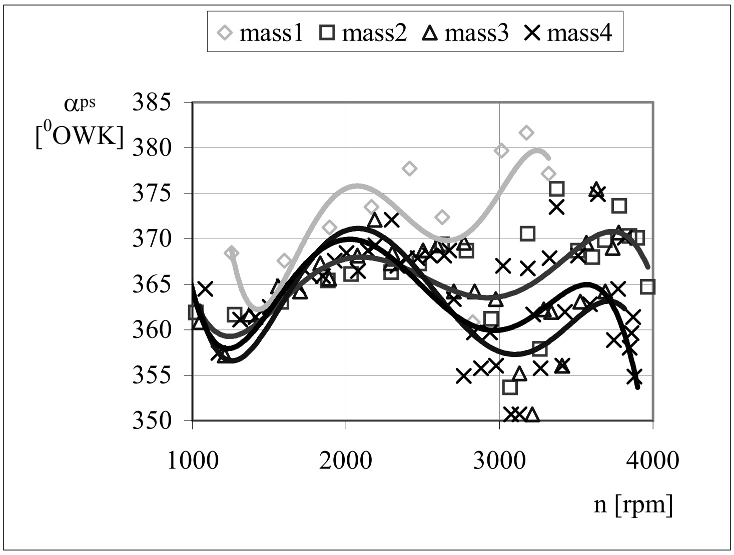

Fig. 8. Course of combustion start occurrence angle α_{ps} [°CA] for 4C90 engine running in the conditions of running up for four cases of loading: mass 1 – engine loaded only with its own moment of inertia, mass 2 – engine additionally loaded with inert mass with mass moment of inertia $I_1 = 0.14625$ kgm^2, mass 3 – engine additionally loaded with inert mass with mass moment of inertia $I_2 = 0.41625$ kgm^2, mass 4 – engine additionally loaded with an inert mass with the mass moment of inertia $I_3 = 0.5625$ kgm^2

The increase in those angles' values resulted in the increase in positive running field in indicator diagram. Changes in the cases of the above-mentioned angle must have been caused by longer self – ignition lag in the case of an engine free running up, which is reflected in an increase in the pressure growing maximum velocity – Fig. 6. Maximum relative differences in pressure growing maximum velocity values were as big as about 27% in case of mass 1 and mass 4.

CONCLUSIONS

The tests carried for an 4C90 engine in the conditions of running up prove that:

1. Additional loading caused by an inert mass significantly influences the chose parameters of the combustion process, such as: mean indicated pressure, combustion maximum pressure, pressure growing maximum velocity, combustion start occurrence angle, pressure maximum occurrence angle. The highest values of mean indicated pressure were obtained in the case of an engine's free running up. In the case of loading an engine's flywheel with an inert mass, mean indicated pressure values decrease, and for the tested masses increase the load hardly made any difference.

2. The reason for an increase in mean indicated pressure values was an increase in combustion start occurrence angle and pressure maximum occurrence angle in the case of engine free running up, as compared with the cases of running up with inert masses. An increase in those angles values resulted in an increase in positive running field in the indicator diagram. Changes in the course of the above-mentioned angles must have been caused by a longer self – ignition lag for the case of an engine's free running up, which is reflected in an increase in the pressure growing maximum velocity values.

3. The thesis concerning the delayed thermal state of an engine running in transient conditions, as compared with adequate steady – state conditions, seems to be true. A decrease in the running up process rate contributes to a decrease in mean indicated pressure but also causes a decrease in the pressure growing maximum velocity and thus a smaller mechanical loading of engine constructional pairs.

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