AN ANALYSIS OF SOME OPERATIONAL PARAMETERS OF DI DIESEL UNDER SPEEDING-UP

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Deep investigations on the diesel operation under transient conditions have been carried out lately. Resent researches mostly concerned engine tests under acceleration conditions [3, 8] and engine start-up problems [7]. The exact knowledge about fuel combustion process in transient conditions could result in a better control process of the engine in real exploitation conditions [1, 2]. It is generally known that the vehicle engine operation under transient conditions takes most of its life time.

One of the research means is the inertial method of engine testing that realizes a test as an acceleration-retardation process [4, 5]. The testing of internal combustion engine by inertial method is based on the measurements of engine crankshaft speed. Engine speed is a general parameter carrying much information about engine operation and its actual technical condition as well. The information of general parameter could be modulated by different violating factors. Aiming at parameter comparison, the measurements of work parameters have been executed simultaneously in two ways. Two independent measurement systems determined the cylinder pressure and crankshaft angular acceleration. The measurements have been carried out during engine speeding-up without any external load and with full fuel dosing. This mode of test realization makes it possible to obtain engine operation conditions equal to the ones of full power characteristics [1].

PARAMETERS' DETERMINATION

The cylinder pressure p_c , injection pressure p_w , needle lift h_i have been obtained strictly from the measurement system. Mean indicated pressure has been calculated as pressure course integral (by the trapezoid method) in view of the sign of the cylinder volume V_s change, which gives the work of the cycle L_i

$$p_{i} = \frac{L_{i}}{V_{s}} = \frac{\sum 0.5 \cdot (p_{i} + p_{i+1}) \cdot (V_{i+1} - V_{i})}{V_{s}}$$
(1)

Engine speed adequate to the following work cycle has been determined as an average value for two succeeding revolutions and it was taken from data series registered during the test.

Engine speed *n* [rpm] and crankshaft angular acceleration ε [1/s²] are obtained directly from measurement system. The effective torque *M* [Nm] during engine speeding-up is calculated from crankshaft angular acceleration values ε [5]

$$M = 2 \cdot \pi \cdot \varepsilon \cdot J_z \tag{2}$$

where J_z [kgm²] is mass moment of engine inertia reduced to crankshaft axis.

Mean effective pressure p_e for *i*-cylinder four stroke ($\tau = 2$) engine could be determined on the basis of common equations as [1, 9]

$$p_e = \frac{2 \cdot \pi \cdot \tau \cdot M}{V_s \cdot i} \tag{3}$$

Therefore mean effective pressure during acceleration could be described as

$$p_e = \frac{4 \cdot \pi^2 \cdot \tau \cdot J_z \cdot \varepsilon_+}{V_s \cdot i} \tag{4}$$

and mean internal losses pressure during retardation could be determined as:

$$p_{sw} = \frac{4 \cdot \pi^2 \cdot \tau \cdot J_z \cdot \varepsilon_-}{V_s \cdot i}$$
(5)

For the comparison goal, the mean indicated pressure index p_{ix} has been made from crankshaft acceleration values registered during the test. The index is calculated from the sum of acceleration ε_+ and deceleration ε_- values existing at the same speed values

$$\varepsilon_i = \varepsilon_+ - \varepsilon_- \tag{6}$$

and then mean indicated pressure index

$$p_{ix} = \frac{4 \cdot \pi^2 \cdot \tau \cdot J_z \cdot \varepsilon_i}{V_s \cdot i} \tag{7}$$

The $p_i = f(n)$ and $p_{ix} = f(n)$ courses have been compared for three engines, all of direct injection type: S-4002, AD3.152, AD3.152UR.

EXPERIMENTAL TESTS

The experimental tests have been conducted on the test bench with detached brake and equipped with the quick actuator of injection pump control lever in order to carry out testing in transient conditions. The block diagram of the test set-up is shown in Figure 1.



Fig. 1. Block diagram of the test set-up: 1 - tested engine, 2 - cylinder pressure sensor AVL, 3 - crankshaft angle position transducer INTROLL, 4 - angular velocity sensor, 5 - computer PC 486/33 with transducer A/C AMBEX, 6 - measurement cassette ZEM, 7 - injection pressure sensor AVL, 8 -- needle lift sensor ZEM, 9 - notebook 486/33MHz, 10 - measurement interface

The test set-up was completed with two independent measurement systems. The one is the angular acceleration measurement system (parts 4, 9, 10 in Fig. 1), made in the Automotive Vehicle Department of The Lublin University of Technology [4, 5]. The angular acceleration measurement system controlled by laptop 486/33MHz enables the measurement and recording of instantaneous rotational speed and determination of instantaneous angular acceleration of the engine crank-shaft. This system is used to measure engine output parameters and to control engine running-up process. The second one is the quick-changing variables measurement system (parts 2, 3, 5, 6, 7, 8 in Fig. 1), made in The Vehicle Technical Exploitation Department of The Radom University of Technology [6]. It includes measurement channels of combustion chamber pressure, fuel line pressure and injector needle lift as well as crank angle transducer.

Measurements were done in series, which comprised 15 accelerationretardation cycles, performed in the same test start conditions: rotational speed (closely to idling speed) and constant temperature of the motor oil and the coolant (according to the manufacturer's specifications). Engine acceleration was caused by the step change of the dose up to maximal value. Slowing down the engine was caused by the quick switch off of the dosage. So transient conditions of engine work adequate to engine operational characteristics were achieved [1].

An average course obtained from 10 tests was recognised as the representative one for the tested engine. Averaged values were taken for calculating the mean indicated pressure index values p_{ix} . Real work cycle which is the closest to the averaged value of angular acceleration was recognized to be the representative one for the mean indicated pressure p_i calculation.

RESULTS AND DISCUSSION

The registered peak firing pressure p_z and the indicated pressure p_i calculated from the pressure courses mean for the tested engines are presented in Figures 2, 3 and 4. These values are typical and could be compared to the ones occurring in steady-state work. But they all are lower than the ones for new engines which may be connected with the actual technical condition of the tested engines.



Fig. 2. Peak firing pressure p_z and mean indicated pressure p_i of S-4002 diesel registered under speeding-up



Fig. 3. Peak firing pressure p_z and mean indicated pressure p_i of AD3.152 diesel registered under speeding-up



Fig. 4. Peak firing pressure p_z and mean indicated pressure p_i of AD3.152UR diesel registered under speeding-up

In order to compare the angular acceleration changes to the mean indicated pressure changes when the engine is quickly running up all the necessary variables have been presented in Figures 5, 6, and 7. The angular acceleration values have been recalculated to mean effective pressure values with the use of formulas (4), (5), (6) and (7). Mean effective pressure index has been compared to mean effective pressure by determining trends of changes. The equations characterising trends of changes are presented in the figures. Generally it may be stated that the dependencies occurring for all the tested engines are similar and are of about the same range.



Fig. 5. The comparison of mean indicated pressure index p_{ix} (crankshaft angular acceleration) and mean indicated pressure p_i of diesel S-4002 during free acceleration



n, rpm

Fig. 6. The comparison of mean indicated pressure index p_{ix} (crankshaft angular acceleration) and mean indicated pressure p_i of diesel AD3.152 during free acceleration



Fig. 7. The comparison of mean indicated pressure index p_{ix} (crankshaft angular acceleration) and mean indicated pressure p_i of diesel AD3.152UR during free acceleration

Although the diagram of p_i is nearly equidistant to the diagram of p_{ix} , there are differences in values level of these parameters for all the tested engines. It is possible to state that the change in shape of both the variables is similar but the difference is bigger for higher values of engine speed. Differences are generally higher for AD3.152UR engine which is the most exerted one. The mean indicated pressure index is higher than the mean indicated pressure for all the tested Direst Injection diesels. It may be relevant to the determination method of engine internal losses which makes possible to double take account of pressure work in the cycle. Generally simple sum of positive and negative acceleration could not be taken as the mean indicated pressure factor but only as the kind of index. It is necessary to find strict dependence between these parameters, which will be the goal of further investigations.

CONCLUSIONS

On the grounds of the obtained results it is possible to state that:

1. Phenomena and dependencies occurring during quick speeding-up are similar for all the tested direct injection diesels.

2. Quite good compatibility between mean indicated pressure and angular acceleration values changes has been stated.

3. The sum of acceleration values during speeding-up and slowing down may be regarded only as an index of mean indicated pressure because it does not result in the exact values of this parameter.

4. The mean indicated pressure index derived from acceleration values sum could be used in engine testing after its correlation to the mean indicated pressure has been determined.

5. The development of inertial method could result in a better instrument for engine testing under transient conditions.

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SUMMARY

The results of tests of three DI diesels under transient conditions have been presented in this paper. The transient conditions of engine work were achieved by free running acceleration caused by quick changes of injection pump control lever position. The tests were carried out on the dynamic test bench equipped with two measurement systems: angular acceleration measuring system and quick-changing variables measuring system. The mean indicated pressure determined by one measurement system has been compared to the mean indicated pressure index determined by the second one. On the grounds of the obtained results it is possible to state that in transient conditions both crankshaft angular acceleration values and mean indicated pressure values change together with quite good compatibility. The sum of acceleration values during speeding-up and slowing down may be regarded as an index of mean indicated pressure for further analysis and comparisons.