Engine combustion chamber tightness diagnostics

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ABSTRACT: The modern combustion engines and their systems are getting more complicated and sophisticated nowadays. It is no more possible to verify their function or actual technical state directly. Thus various methods of indirect diagnostics are being developed more and more rapidly. The on-board diagnostics is being increasingly applied to monitor and measure suitable diagnostic signals during operation, deviations from required or expected values are then recorded. This trend requires the application of completely disassembly-free techniques of measurements and the real-time analyzing of measured figures. This paper presents the results of the research on relation between the starter's starting current and the engine combustion chamber tightness. The experiments were carried out for common four-cylinder engine.

Keywords: combustion chamber tightness; instantaneous starting current; compression pressure; on-board diagnostics

The energy transformation efficiency of piston combustion engines depends, among others, on each cylinder's combustion chamber tightness. The combustion chamber tightness measurement is therefore one of the most frequent diagnostic tasks (Balog 1999). The compression pressure is a common indicator of the combustion chamber tightness. The compression pressure is an important complementary indicator of the vehicle engine's technical state and together with the engine's output composes the main set of parameters characterizing the engine technical state. The common technique of direct compression pressure measurements is very suitable for maintenance, however, for periodical or continual diagnostics or for so called on-board diagnostics is inappropriate. For these purposes, the completely disassembly-free diagnostic technique, detecting the combustion chamber tightness by means of measuring the instantaneous starter current during the engine's cranking, seems to be very suitable. This method is based on the fact, that the instantaneous cranking current is proportional to instantaneous mechanical resistance of the cranked engine and that the engine's mechanical resistance is proportional to individual cylinders' combustion chamber tightness (Balog 1999). Periodical variations of the cranked engine mechanical resistances then determine the basic (characteristic) frequency of starting current variations (Pošta, Pavlíček 2002).

Besides this basic characteristic frequency, other variations of various frequencies participate on the measured signal waveform, these frequencies superpose on the basic waveform and thus participate on the resulting signal (Havlík 2002). The measured signal waveform can be affected, for instance, by the variable mechanical resistance of engaging individual starter pinion teeth to mesh with flywheel gear ring, the starter shaft runout, the brushes passing the commutator bars or by the electrical failures of armature windings (Pošta et al. 2002). The display of the measured waveform can be also affected by the selected sample rate. It is necessary to eliminate these disruptive factors or to distinguish their influence to the diagnostic signal (Pošta et al. 2000).

For the chosen indicator "instantaneous starting current", the dependence of variations and the sensitivity on the variations of the single cylinder's combustion chamber tightness of four-cylinder engine was examined experimentally.

MATERIAL AND METHODS

The measurements were carried out with the ŠKODA 781 136B Monomotronic, 50 kW four-cylinder in-line ignition engine and the MAGNETON 12 V 0.8 kW starter, type 443115142350. The engine is an OHV type, equipped with mechanical adjusting of the valve clearance. Each cylinder is equipped with one intake valve and one exhaust valve. The mechanical condition of the measured engine was good.

The controlled leakage was achieved by setting the first cylinder's exhaust valve permanently slight open by means of adjusting the valve clearance. The starter was powered by the AKUMA, 12 V, 55 Ah lead accumulator. The accumulator was fully recharged by external power supply after every series of measurements. During the measuring, the engine was prevented from starting by disconnecting the high-voltage spark-plug cables.

The combustion chamber tightness was measured and represented by means of the compression pressure measurement. For this purpose the BAZ KN 1124 recording compression pressure meter was used.

The instantaneous values of the starting current were measured using the ATAL 100 A measuring probe, which is a part of the ATAL 520M tester equipment, and recorded by a digital oscilloscope. As the oscilloscope the PCX-1230 oscilloscopic converting computer card was used, the card was installed in a PC.

The converting card PCX-1230 is a component of the Precision Series kit, which is used especially for laboratory and industrial measurements with very high requirements for accuracy and sample rate (POŠTA, PAVLÍČEK 2002). The device is based on Analog Devices A/D converters and thanks to its circuits' construction reaches required parameters. The PCX-1230 card features:

– 3 separated input channels (amplifier + A/D converter + data memory)
– programmable synchronization logic for detecting external events
– control logic with recording before and after event
– multicard master/slave logic for synchronizing all PC cards in the system
– enables using 3 data inputs on the same time base
– analog inputs:
  – number of inputs 3
  – input impedance 100 kW
  – input voltage range ±1 V
–A/D converter:
  – type AD9220 (Analog Devices)
  – resolution 12 bit
  – working frequency 10 MHz (internal oscillator)
– data memory:
  – memory capacity 3 × 56 kB.

The measuring and recording of the measured values was triggered manually after 4 s of starting, every starting lasted 7 s. These precautions ensured that the measurement is performed while the engine regime is stabilized. The sample rate was 620 Hz or 744 Hz. The reason of using two different sample rates was to verify, if the recorded waveform is not distorted due to phase interferences between the measured and sampling frequencies.

The time base was triggered by the first cylinder's ignition voltage pulses.

1,024 samples were recorded during every measurement. That represents 7.25 revolutions of the engine crankshaft while the sample rate is set to 620 Hz, and 6.25 revolutions for sample rate of 744 Hz. The data was stored on the computer hard drive in a text format. The data was then exported to Excel and presented graphically.

RESULTS

The results of direct compression pressure measurements are presented in Table 1. Fig. 1 shows the results of instantaneous starting current time course measurements. The current values on the vertical axes are presented in A, the time values on the horizontal axes are represented as a number of samples. Measurements No. 851, 881 and 8b1 were performed on the faultless, correctly adjusted engine, measurements No. 861, 871, 891 and 8a1 were carried out with the engine with artificially prepared leakage in one of the cylinders.

DISCUSSION

Basing on the measurements No. 851, 881 and 8b1 performed on the engine with equal compression pressures in individual cylinders it is obvious, that after not any later then four seconds of the starter working the values of the instantaneous starting current are stabilized.

The first cylinder's combustion chamber tightness was artificially decreased for measurements No. 861, 871, 891 and 8a1. The values are presented in Table 2.

Looking at the waveforms presented in Fig. 1 it is evident, that the decreased tightness of a single combustion chamber of the four-cylinder engine appears significantly and unambiguously: the worse tightness decreases the values of instantaneous current during the leaking cylinder's compression stroke comparing to the faultless cylinder. Together with that the instantaneous current during the compression stroke of the next cylinder increases. The fluctuations are significant and occur periodically.

The decrease in starting current of the leaking cylinder is obviously caused by the decreased compression pressure. The amount of work necessary to achieve this

Table 1. Cylinder compression pressures (kPa)

Measurement number	Cylinder number			
	1	2	3	4
851	14.5	14.6	14.5	14.6
861	9.5	14.6	14.5	14.6
871	11.2	14.6	14.5	14.6
881	14.5	14.6	14.5	14.6
891	11.6	14.6	14.5	14.6
8a1	10.0	14.6	14.5	14.6
8b1	14.5	14.6	14.5	14.6

Table 2. First cylinder's combustion chamber tightness decreased

Measurement number	851	861	871	881	891	8a1	8b1
Tightness (%)	100	65.5	77.2	100	80.0	69.0	100

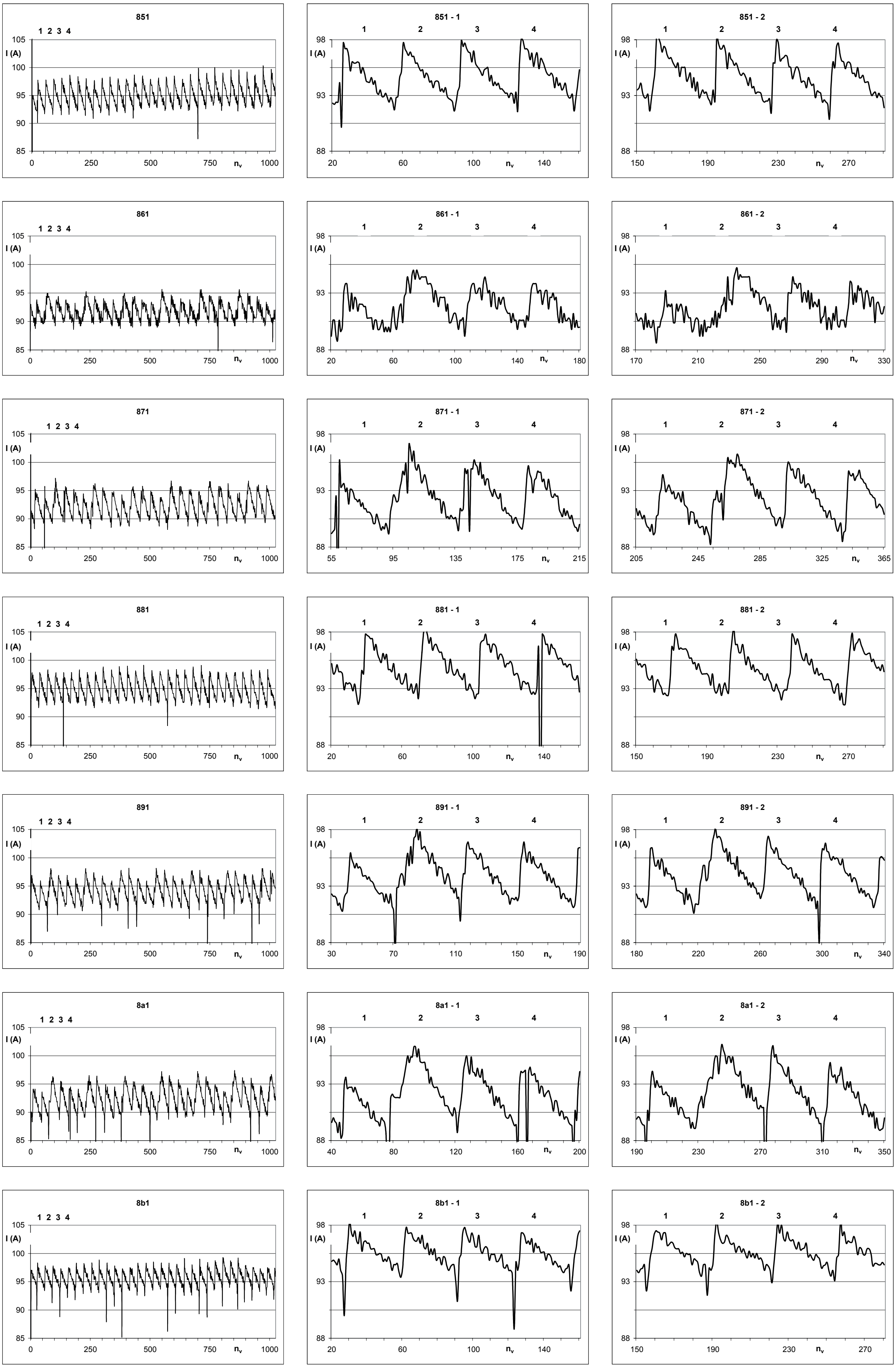

Fig. 1. Instantaneous starting current vs. time

decreased compression pressure is lower, so the lower starting current is necessary. The full amount of work is needed for reaching the compression pressure in the next, faultless, cylinder. This amount of work is supplied both by the starter itself and to certain extent by the expansion of gases in the previous cylinder. As the previous cylinder provides decreased amount of work, the starter must provide increased performance. This turns to an increase of the instantaneous starting current.

If the starting current waveform appears to be distorted by the above described irregularities, it is evident, that one of the engine's cylinders' tightness is decreased. This knowledge can be utilized for external diagnostics. However, also the continual monitoring of combustion chambers' tightness can be based on this, for example as a part of on-board diagnostic system.

CONCLUSIONS

Basing on the performed experimental measurements the hypothesis, that instantaneous value of starting current is one of the indirect indicators of the combustion chambers' tightness, can be considered as proved. This indicator can be utilized for external diagnostics. It can be also applied as a part of on-board diagnostics.

In the field of external diagnostics, a suitable technique of recording the "instantaneous starting current" diagnostic signal is the use of a memory oscilloscope.

The application of the "instantaneous starting current" diagnostic signal for on-board diagnostics requires the installation of a current sensor into the starters' power circuit and adding of a suitable evaluating program module into the on-board computer system.

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Diagnostika těsnosti spalovacího prostoru motoru

ABSTRAKT: Moderní spalovací motory a jejich soustavy jsou stále komplikovanější a propracovanější. Ověřit správnost jejich funkce nebo jejich okamžitý technický stav již nelze přímo, proto se stále rychleji rozvíjejí metody nepřímé diagnostiky. Stále více se také zvětšuje podíl palubní diagnostiky, při které jsou přímo za provozu sledovány vhodné diagnostické signály a zaznamenávají se odchylky od předepsaných nebo očekávaných hodnot. Tento trend si vynucuje využívání zcela bezdemontážních způsobů měření a vyhodnocování naměřených hodnot v reálném čase. Příspěvek přináší výsledky zjištění závislosti okamžitého startovacího proudu spouštěče na těsnosti spalovacích prostorů motoru. Experimenty byly provedeny na běžném čtyřválcovém řadovém čtyřtaktním zážehovém motoru.

Klíčová slova: těsnost spalovacího prostoru; okamžitý startovací proud; kompresní tlak; palubní diagnostika

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