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POSSIBILITIES OF MONITORING THE TECHNICAL CONDITION OF THE COMBUSTION ENGINE WITH STARTER LOAD CURRENT

Michal Jukl[1], Adam Polcar[1], Jiří Čupera[1]

[1] Department of Technology and Automobile Transport, Faculty of Agronomy, Mendel University in Brno, 613 00 Brno, Czech Republic

Abstract

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This article deals with the verification of relations between the electric current of engine starter and tightness of the combustion chamber and the possibility of its use for the evaluation of the state in terms of engine wear. Engine wear is closely related to the quality of fuel combustion and also with the amount of produced harmful emissions. On this basis, it would be possible to extend the technical requirements of the protocol OBD to include the indirect control of engine wear. To meet the objectives set out above measurement was carried out by a petrol engine, which was located in the vehicle Škoda Felicia Combi GLX 1.3 The whole measurement was divided into several parts. The first measurement was carried out on the abovementioned motor without simulating leakage. The second measurement was performed when the leakage of one cylinder was simulated. Simulated leakage was conducted at removing the spark plugs. Other measurements simulated "mild" leak of the whole engine – all cylinders. Leakage was implemented by loosing all the spark plugs about 8 turns against full tightening with the appropriate torque. The last, fourth measurement simulates a "large" leaks of engine cylinders. This leakage was induced by removing all the spark plugs from all cylinders. As the measurement results showed leakage of one cylinder, and also the whole engine is reflected not only in the individual amplitude of the starter current, but also the shape of the entire curve.

Keywords: starter current, compression pressure, engine wear

INTRODUCTION

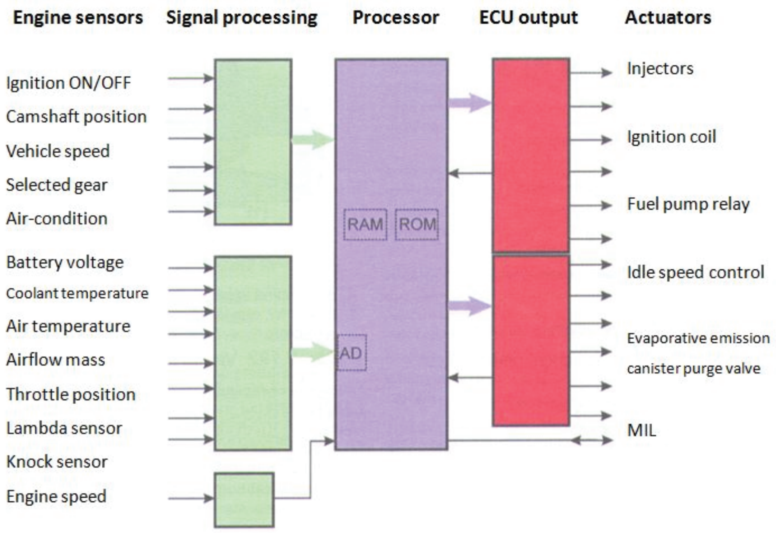
The proper function of the various systems of a motor vehicle is given next to the operational reliability of parts by their appropriate regulation. The primary control systems were based on simple rules of elementary physics. However, this regulation is technically limited with itself principle of operation and may not reflect other conditions. These factors may significantly change control action, e.g. using of fuel with lower octane number.

For these reasons control devices with feedback began to be preferred. Control of individual vehicle systems began to be exclusively a matter of electrical control units (Bauer *et al.*, 2013).

Vehicles are thus gradually equipped with sensors for measuring physical, chemical and biological parameters. Parameters are then transferred to another physical value. The electronic control unit receives signals from these sensors. With using the internal algorithm is proceeded to regulatory intervention in the system (see Fig. 1).

Several input values can influence setting of one output parameter in real time.

The regulatory function of the control units is conducted in closed loop, in which the actual value of parameter is compared with the prescribed value. If there is a discrepancy between these values, ECU (Electronic Control Unit) will react and adjust



1: *Signal processing inside ECU (Electric Control Unit)*

prescribed value with the actuator. Beside regulatory function, ECU's have also other functions:

- Control function – evaluate and process information about the controlled process or object, information about actions outside of this process and according to this information the appropriate control devices are controlled to achieve certain specified objectives,
- Diagnostic function – selected parameters (that affect the operational reliability of functional unit) are controlled by ECU. Than it is decided whether the parameter is within the prescribed range (Bauer *et al.*, 2006).

The main reasons that have contributed to the implementation of the diagnostic functions of these control systems was the increase of harmful emissions of vehicles with internal combustion engines. Motor vehicle manufacturers was forced to meet the relevant technical regulations based on the system adopted standards known as OBD (On Board Diagnostic) (Papoušek *et al.*, 2007).

This was especially systems that significantly affect the composition of exhaust gases and give feedback when it detects a fault signal. Emission relevant faults are reported to the driver by indicator lamp on the dashboard named as "MIL" (Malfunction Indicator Lamp). The fault is also stored in code memory faults.

With the gradual development of electronics in the automotive industry in the early 90's, it was necessary to build the new standards which are no longer just focus on electrical and electronic circuits of the vehicle, but will check all passive components, which significantly affect the composition of exhaust gases (e.g. catalytic converter). The basic diagnostic functions, which were set this new standard known as OBD II include monitoring the efficiency of the catalytic converter, engine misfire detection, crankcase ventilation, etc.

At present is under development another version of OBD, respectively OBD III. The difference with OBD II lies in the integration of wireless transmitters in the vehicle, whose task is to facilitate the information stored in the error memory (Štěrba *et al.*, 2011).

Engine wear is closely related to the quality of fuel combustion and also with the amount of produced harmful emissions (Pošta, 2002; Stodola, 2003). On this basis, it would be possible to extend the technical requirements of the protocol OBD to include the indirect control of engine wear.

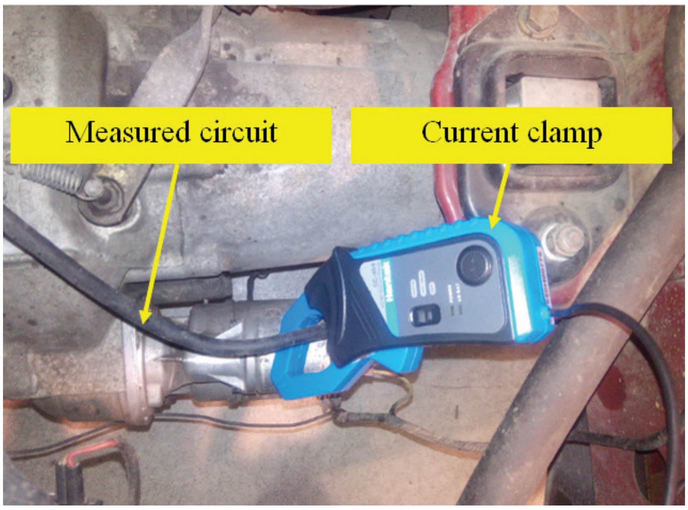
MATERIALS AND METHODS

To determine the direct relationship between the load current and the leakage of the combustion chamber was made oscilloscope measurements of petrol engine which was fitted in the car Škoda Felicia Combi GLX 1.3. The vehicle to the test was loaned from Institute of Technology and Automobile Transport, Mendel University in Brno. Technical parameters of the engine are given in Tab. I.

To measure the load current was used handheld digital storage oscilloscope Hantek DSO 1202B.

I: *Technical parameters of engine*

Škoda Felicia 1.3 GLX – Engine Parameters	
Engine type	4-stroke, spark ignitioned
Number of cylinders	4 in-line
Displacement	1289.0 cm^3
Bore x Stroke	75.5 × 72.0 mm
Compression ratio	9.7
Max. power	50.0 kW (5000 min^{-1})
Max. torque	106.0 N.m (2600 min^{-1})
Injection	SPI, Bosch Mono-Motronic
Recomanded fuel	Natural 95



2: *Connected current clamp*

II: *Hantek DSO 1202B parameters*

Hantek DSO 1202B oscilloscope	
Bandwidth	200 MHz
Maximal sampling	1 GS/s
Display resolution	640 × 480

Basic parameters of Hantek DSO 1202B are situated in Tab. II. The current was measured with current clamp Hantek CC-650. This device can measure direct current without circuit disconnection. Connecting to measured circuit is shown in the Fig. 2.

Fuel injector was disconnected to prevent engine running. The whole experiment was divided into several parts. The first measurement was carried out at the mentioned engine without any leakage simulating. The second measurement was performed during the simulation leakage of one cylinder. The simulation of compression pressure leakage was performed by removing the spark plugs. Other measurements simulated "mild" leak of all cylinders. This situation was carried by losing of all the spark plugs about 8 revolutions against full tightening. The last, a fourth measurement simulated high leakage of all engine cylinders (all the spark plugs was removed).

Repeatedly engine starting (with disconnected injector) can cause that the battery voltage will start gradually to decline. This phenomenon could cause measurement errors. For this reason it was connected starting generator to the battery. Basic technical parameters of the starting generator are given in the Tab. III.

All measurements of the load current during start-up was performed at idle throttle and disconnected clutch.

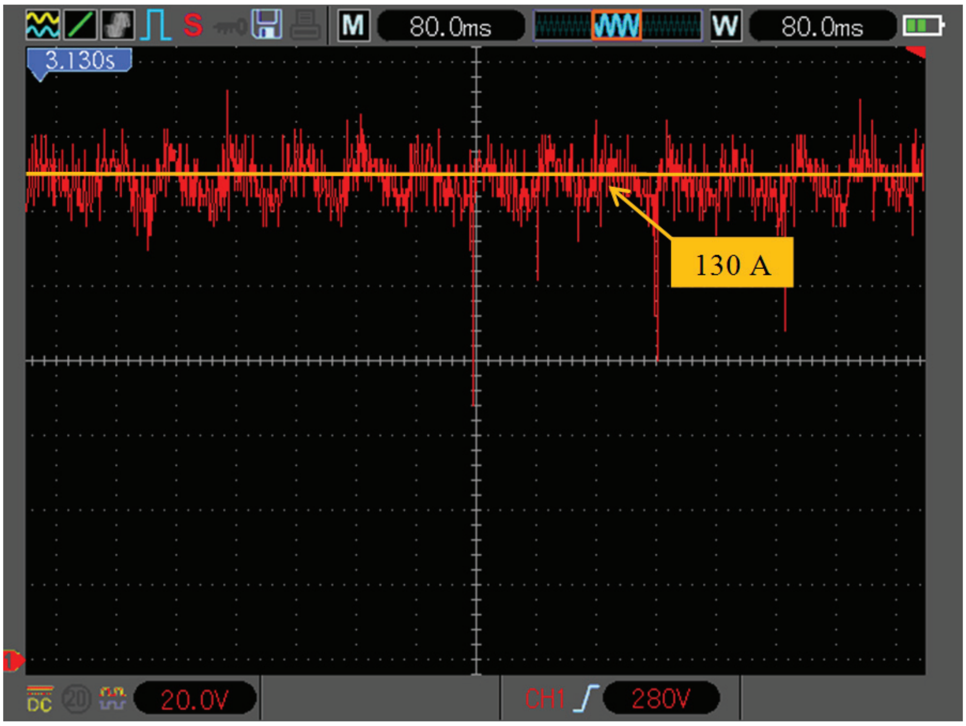
III: *Basic technical parameters of used starting generator*

Manufacturer	RUKOV RUMBURK
Type	CARSTAR
Input	3 × 380 V/25 V
Output	12 V/24 V 200 A

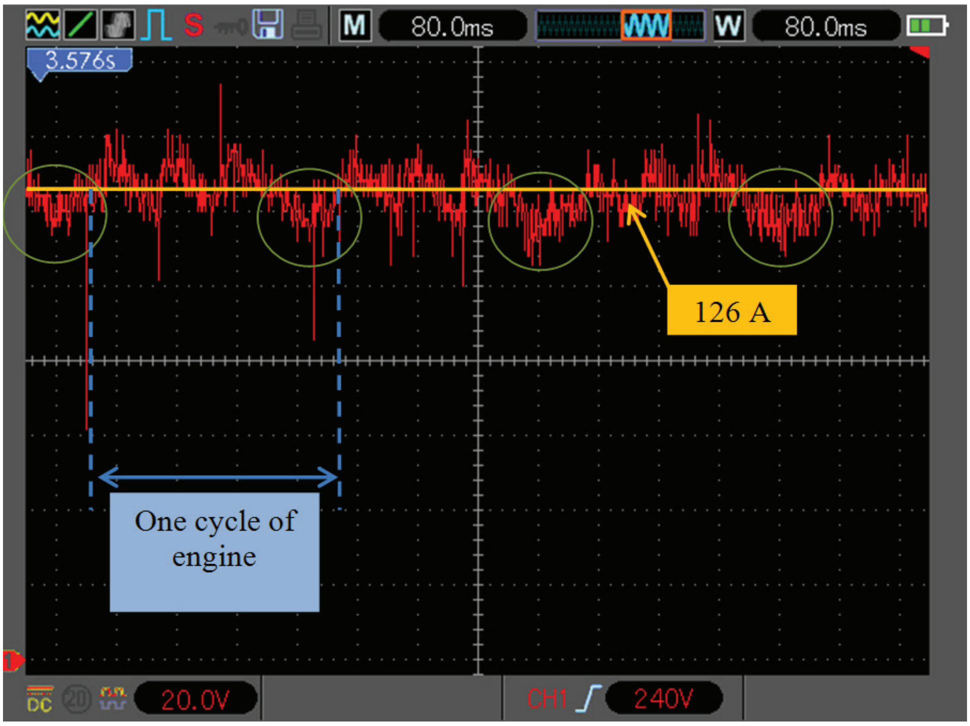
RESULTS AND DISCUSSION

Oscilloscope measurements were performed for the certification check the connection of the starter load current and leak of combustion engine. As is mentioned above, the tightness of the combustion engine may not be related only to wear, but also to failure of the engine, or cylinder.

The record of the oscilloscope measurement of the load starter current at the starting of test engine is shown in Fig. 3. The results of the measurements were used to obtain reference values. The waveform of load current is shown by the red line. The measured waveform of current is identical to the periodic function (for example to goniometric function sine). Maximum current amplitudes represent the current consumption at the highest resistance to rotation of the crank mechanism at starting. As we can also see from Fig. 3, maximum amplitudes of current have the same values during the record. Maximum values of the load current are approximately 140 A, a minimum values are approximately 120 A. Same values of maximum current is possible to explain by same maximum compression pressure in all cylinders at starting of engine. This assertion was confirmed by measurements of maximum compression pressures of individual cylinders using pressure gauge with the registration manometer (type: KB 1126). The results of the maximum compression pressures showed only minimal differences among cylinders. The highest difference has been achieved between the second and the fourth cylinder. This difference was only 4%. The mean value of the load current during starting was approximately 130 A (see yellow line Fig. 3).



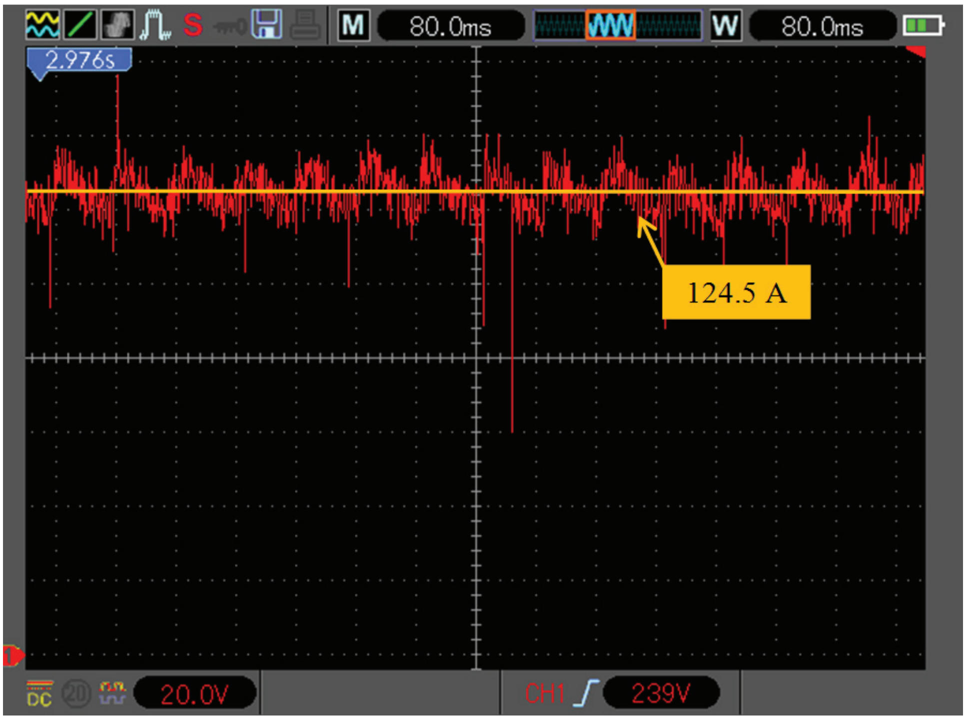
3: *Waveform of load current at idle position of throttle – Škoda engine*



4: *Waveform of load current at leak simulation of the fourth cylinder*

To simulate a leak among cylinders, the spark plug was removed (from the fourth cylinder). The measured waveform of current is shown in Fig. 4.

As is evident from Fig. 4, deformation of waveform arise (compare with reference waveform, see Fig. 3). One revolution of the crank shaf tis characterized by only three maximum of current amplitude in other words by three increases of resistance against rotation crank shaft, by three increases of pressure. After the last increase of current, gradual decline of current follows. This decline is evident up to time, when the pressure starts to increase again in the first cylinder in the next revolution of crankshaft.



5: *The waveform of load current during simulated leaks of all cylinders (spark plugs loosed about 8 revolutions against full tightening)*

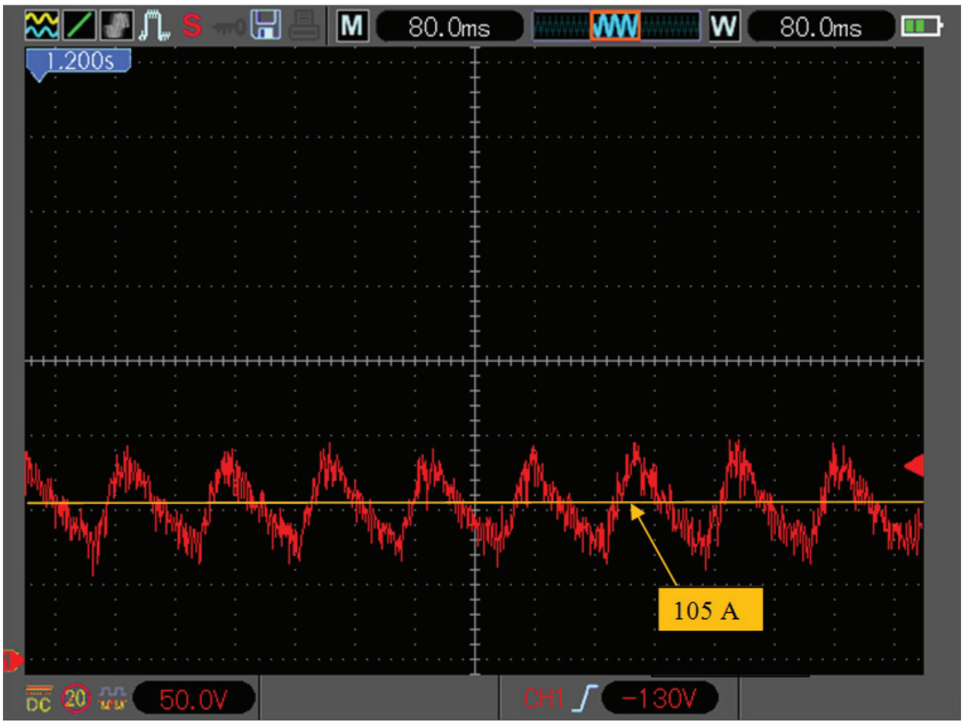
6: *The waveform of load current during simulation of leaks of all cylinders (spark plugs removed from the engine)*

Missing peak (with value 136 A) is replaced by the current down turn (approximately to value 115 A, marked in green in Fig. 4). Simultaneously, there is a slight decrease of mean value of current to value 126 A, which is about 3% less compared with the previous measurement.

Evaluation of the maximum current variances among the cylinders is carried out by equation for petrol engines (Štěrba *et al.*, 2011):

$$\text{number of cylinders} \times 2.5\ \text{A}.$$

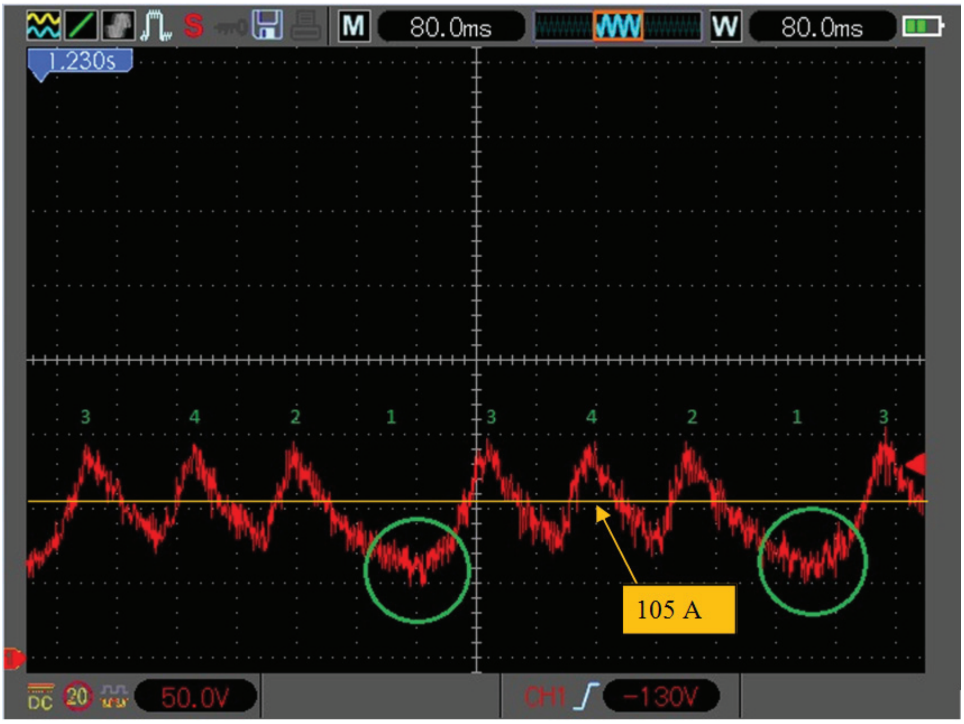
7: *Peugeot engine 1.8i 16V LFY XU JP4*



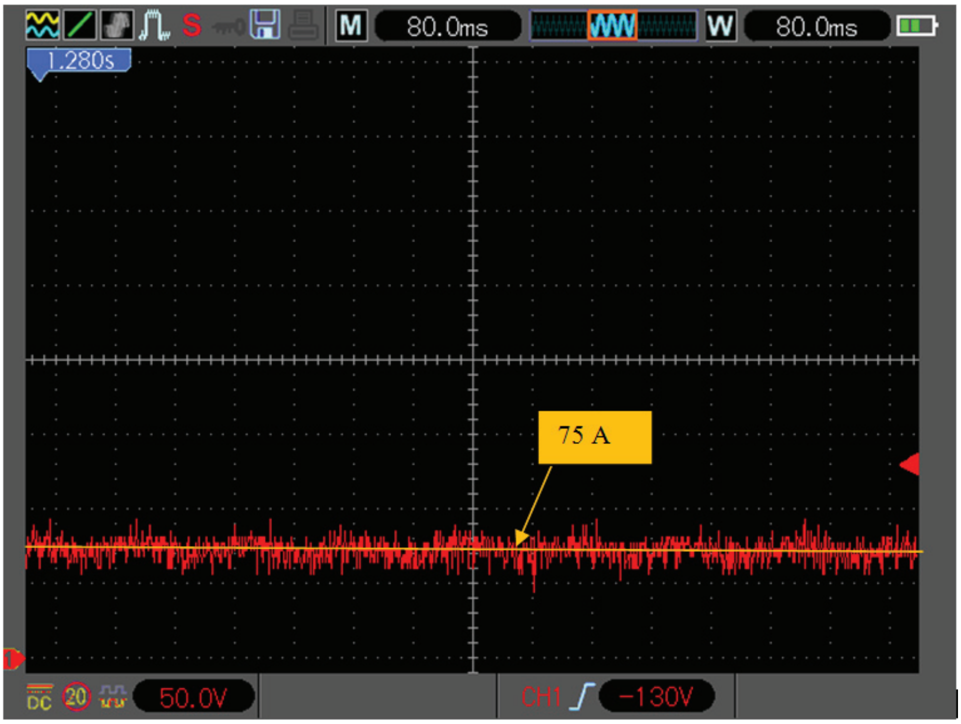
8: *Waveform of load current at idle position of throttle – Peugeot engine*

At diesel engines, it is 20 A (for a cold compression or rather for a cold start). For diesel engines, it is not dependent on number of cylinders. For our engines, the maximal permissible variance is 10 A. Based on results, when the spark plug was removed, the current decreased about 21 A. These results indicate in admissible difference of current in other words results show high leak of cylinder.

In the next step was simulated leak of all cylinders. In the first phase, the smaller leaks were simulated by loosing of all spark plugs about 8 revolutions against full tightening. The measured waveform of load current is shown in Fig. 6.



9: *Waveform of load current at leak simulation of the first cylinder – Peugeot engine*



10: *Waveform of load current without sparkplugs*

As is evident from Fig. 6, the starting current slightly decreased. The mean value of current was 124.5 A. The load current decreased about 4% (compared with reference values of current). When all spark plugs were removed from the engine, the mean load current decreased to value 111 A, in other words about 15% (see Fig. 7).

As also Fig. 7 shown, simultaneously with a decrease of current, which is needed for a spin of the engine, the higher frequency of current is recorded. Due to it is not possible to distinguish of individual current peaks among cylinders. Better resolution could be achieved by setting of time base (when all spark plugs are removed, crankshaft has a higher angular velocity) and by filtration of current signal. The load current is affected by interference of starter commutator.

To verify the preceding contention measurements were taken at another engine. It is a petrol engine Peugeot 1.8 16V LFY XUJP4. For measurement were used the same equipment as in the previous case – see Fig. 8.

Current clamp connecting and the oscilloscope settings is identical to the previous case. Even in this case, measurements were made without a simulation of leakage, then with the creation of leakage (disassembled spark plug).

CONCLUSION

As is evident from the measurement result, the load current can be used for objective evaluation of engine wear, respectively for dynamic test of combustion chamber tightness. During the engine starting the starter is loaded variably – when the piston moves up starter is loaded much more than the piston moves down. This loading is directly proportional to the current consumption of the starter.

The higher pressure increase occurs in the cylinder, the greater amplitude of the pulsating current will be. To assess the degree of engine wear is therefore necessary to take account of the size of the load current for each current peaks and its overall course respectively its shape. When implementing a system that will include measuring the load current is also necessary take account that the disadvantage of this indirect measurement of engine wear can lead to biased results due to defects electric starter circuit.

At present modern cars with a high proportion of electronics are equipped with systems known as BEM (Battery Energy Management). These systems automatically ensure sufficient battery power to start the engine, based on the battery charge state and the temperature. If the charge level of battery becomes critical, the system can gradually shuts down non-operative appliance. This system is also necessary to all the vehicles with the start-stop system. At a certain modification of the system could be used for monitoring the start current of vehicles for monitoring of engine condition. The electric line to the starter would have to be equipped with a current sensor which should be active during the vehicle starting. Error status would be indicated by the signal lamp on the dashboard. This test can be performed on modern engines with the help of OEM diagnostic tool (often known as the compression test).

The system would be a type of on-line diagnostics that can detect the state of the internal combustion engine operation.

SUMMARY

This article aims to verify the relationship between load current of engine starter and tightness of the combustion chamber and the possibility of its use for assessing the state of the engine in terms of wear. To determine the direct relationship between the load current and the leakage of the combustion chamber was made oscilloscope measurements of petrol engine which was fitted in the car Škoda Felicia Combi GLX 1.3. The vehicle to the test was loaned from Department of Technology and Automobile Transport, Mendel University in Brno.

The whole experiment was divided into several parts. The first measurement was carried out at the mentioned engine without any leakage simulating. The second measurement was performed during the simulation leakage of one cylinder. The simulation of compression pressure leakage was performed by removing the spark plugs. Other measurements simulated "mild" leak of all cylinders. This situation was carried by losing of all the spark plugs about 8 revolutions against full tightening. The last, a fourth measurement simulated high leakage of all engine cylinders (all the spark plugs was removed).

Results of the first measurements were used to obtain reference values. As the results showed, the measured current waveform is identical to the periodic function. Maximum current amplitudes represent the power consumption at the highest resistance against rotation of the crank mechanism at startup. As the measured waveforms also shows the maximum current amplitude reaches almost the same value in the whole range of recording. This phenomenon is explained by the same compression pressure in the cylinders of engine during startup (verified with measuring of compression pressure).

To simulate a higher leaks was subsequently removed the spark plug from the fourth cylinder. The results of this measurement showed that the original waveform is deformed (in comparison with original curve). One rotation of the crankshaft is characterized by only three maximum current amplitude (versus original four). Missing peak (approximately 136 A) is replaced by the current drop of 21 A to 115 A. The maximum permissible current difference between individual measured cylinder for our type of engine is but a maximum of 10 A. The measured values refer to the inadmissible current difference, respectively. a large leak. During simulation a leak the entire engine through either loosing or the full removing the spark plugs from all cylinders there is also a decrease in load current. The measurement results therefore confirm strong relationship between the tightness

of the combustion chamber of engine and current of the starter. Leakage of one cylinder as well as the whole engine is reflected not only in the individual amplitudes of the starter current, but also in the shape of the entire curve.

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Contact information

Michal Jukl: michal.jukl@mendelu.cz
Adam Polcar: adam.polcar@mendelu.cz
Jiří Čupera: jiri.cupera@mendelu.cz