Computer Science Journal of Moldova, vol.**7**, no.2(20), 1999

An algorithm for testing of gas distribution phases in the internal combustion engines

T. Nicu

Abstract

A method and algorithm for testing the gas distribution phases of internal combustion engines are proposed. This method allows a way of testing the gas distribution phases, based on direct and continuous measurements of pressure in cylinders and negative pressure in the intake manifold for using in the real time.

1 Introduction

The compression pressure is an important factor for determining a large range of faults, due to the fact that a lot of factors influence the cylinder compression, for example, the state of the piston segments, the state and fatigue of the cylinder, state and degree of adjustment of the valves, engine temperature etc. [1, 2, 3]. In this paper a method, including original algorithms and computerized procedures, that substantially improves the testing of the cylinder-piston couple is presented. The method is contained in the following explanation. The measured compression pressure, both directly and indirectly, allow, us to state if the pressure is in the acceptable limits [3, 4, 5]. Pressure deviations could be caused by two groups of parts: a) the cylinder, the piston and its segments, b) head of cylinder block, camshaft and the valves. In order to determine the group that caused the fault a simultaneous testing of the pressure in all cylinders, of the negative pressure (absolute pressure) in the intake manifold with the running engine, the analysis of the measured data together with the gas distribution phases is recommended. The analyzed data is used to identify the broken valves.

In order to apply this method, means of direct pressure measurement, based on electronic sensors of absolute pressure in the cylinders and negative pressure in the intake manifold are needed. Also some adjustments in the engine are necessary to unplug the spark or injectors (for diesel engines), to insert the sensor and to start the engine. The quality of the measured data is directly related to the precision of the sensor. Usually the electronic sensor doesn't have precision problems, its error does not exceed $0,1-0,01\%$ and its reactivity $10-15\mu s$. The main advantage of this method is in the effective determination of the valve state without taking off the engine, although it needs interventions into the functioning of the engine. The current paper deals with algorithms that use the acquisition data in correlation with the engine distribution phases.

2 Mathematical model

The determination of the state of the cylinder-engine couple is based on measuring the negative pressure in the intake manifold and the cylinder compression. The proposed algorithm contains two new parts a) the simultaneous determination of the compression and negative pressure in the intake manifold is achieved by filtering the data that correspond to the active cylinder zone at stabilized revolutions; b) the adjustability of the algorithm – synchronizing with the position of the crank shaft and the continuous measuring of revolutions.

The mathematical model of the algorithm is:

a) The acquired data are presented in the following way:

$$R = \{S_j, t_{jk}, < P_{ij} >, < D_{ij} >\}, \quad (1)$$
$$j = 1, \dots, M; i = 1, \dots, N; k = 1, \dots, K,$$

where S_j – is the signal synchronized with the first cylinder;

t_{jk} – the active period of the cylinder at each revolution of the crank shaft;

$< P_{ij} >$ – the set of pressure values during the active period of the current cylinder at each revolution of the crank shaft;

$< D_{ij} >$ – the set of absolute pressure values in the intake manifold during the active period of the current cylinder at each revolution of the crank shaft;

M, N, K – respectively the number of total measurements, measurements at one cylinder rotation and the number of cylinders in the engine.

b) The maximum values of the pressure in the active zone of the current cylinder:

$$D_{jmax} = \max\{D_j\}, Nt = const, \tag{2}$$

c) The negative pressure is calculated by averaging the maximum values that correspond to the active zone of the cylinder at constant revolutions.

$$D_{jmed} = \{\sum D_{jmax}/n\}, Nt = const, \tag{3}$$

where D_{jmax} – the maximum values of the pressure in the active zone of the current cylinder;

n – number of active zones of the cylinder at constant revolutions;

Nt – the revolutions of the engine generated by the starter.

d) The pressure difference between the manifold and the cylinders is determined:

$$\begin{aligned} D_{jmin} &= \min\{D_{kmed}\}, j = 1, \dots, K, \\ D_{jmax} &= \max\{D_{jmed}\}, j = 1, \dots, K, \\ \Delta D &= D_{jmax} - D_{jmin}. \end{aligned} \tag{4}$$

3 The algorithm

Step 1. Data acquisition is performed: $R = \{S_j, t_{jk}, < P_{ij} >, < D_{ij} > \}$, $j = 1, \ldots, M$; $i = 1, \ldots, N$; $k = 1, \ldots, K$.

Step 2. The value of engine revolutions is calculated $Nt = \frac{120}{\sum t_{jk}}$ is calculated for each rotation of crankshaft S_j.

Step 3. The segment of constant revolution is defined: $S_l, \ldots, S_h$, where $Nt = const$.

Step 4. The maximum values of negative pressure in the active zone of each cylinder is calculated: $D_{jmax} = \max\{D_j\}$,
$Nt = const$.

Step 5. The negative pressure is calculated by averaging the maximum values that correspond to the active zone of the cylinder at constant revolutions: $D_{jmed} = \{\sum D_{jmax}/n\}, Nt = const$.

Step 6. The minimal negative pressure in the manifold between the cylinders is determined: $D_{jmin} = \min\{D_{kmed}\}, j = 1, \ldots, K$.

Step 7. The maximal negative pressure in the manifold between the cylinders is determined: $D_{jmax} = \max\{D_{kmed}\}, j = 1, \ldots, K$.

Step 8. The negative pressure difference between the cylinders is determined: $\Delta D = D_{jmax} - D_{jmin}$.

Step 9. The mean rezults $D_{jmin}, D_{jmax}, \Delta D$ are printed.

Step 10. The graphics of negative pressure in the manifold and compression in cylinders are drawn: $\{S_j, t_{jk}, < P_{ij} >, < D_{ij} >\}, j = 1, \ldots, M; i = 1, \ldots, N; k = 1, \ldots, K$.

Preliminary conditions for running of this algorithm: the ignition sparks are taken off one by one and the respective sensors are plugged in; the engine starts and the idle revolutions stabilize; measurements are taken during 15-20 sec. Initial data and means for the execution of the algorithm:

– the number of cylinders and the ignition order;

– the sensor of synchronization with the first cylinder (on board or external);

– pressure sensor for the cylinder (on board or external);

– external pressure sensor;

– crankshaft position sensor (on board).

The algorithm was verified from two points of view a) its stability, taking into consideration the fluctuation of the revolutions because of multiple factors; b) complexity (execution time). The verification was made experimentally with the multiplicity of conditions, for instance, the engine has two defected cylinders, which conducts to: for the first cylinder a $4 - 5mbar$ deviation, for the third cylinder a $6 - 7mbar$ deviation of the negative pressure. The respective results are presented in Figures 1 – 3. In the Fig. 1 a fragment of data simultaneously measured is presented: a) first cylinder pressure; b) negative pressure in the intake manifold; c) the signal of synchronization with the crankshaft. Periodic deviations in the intake and compressions phases are observed. Such deviations are possible when both valves of the 4^{th} cylinder have serious faults or are broken. The data processed according to the algorithm is presented in Fig. 2 and Fig. 3, they reflect the state of the valves of the 3 and 4^{th} cylinder (according to the engine formula).

4 Complexity of algorithm

The polynomial that characterizes the efficiency of the algorithm was determined according to known methods [6]. The factors that influence the most the efficiency of the algorithm are the number of measurements for one cylinder and the number of cylinders. The polynomial is of the first degree:

$$O(N) \cong C_1 \cdot N_{cld} \cdot N_{mas} + C_0 \tag{5}$$

From the polynomial we see that the algorithm depends linearly from the number of measurements and number of cylinders. The linear dependence is at the analysis of the measured data phase, but the real number of cylinders stays between 2÷24, that's why the efficiency of the algorithm remains high. The simulation results confirm the algorithm's efficiency.

Conclusion

Judging by the results of the research one can conclude that the algorithm has a high efficiency, that's why a number of 30–35 thousand measurements for any number of cylinders can be performed. It is recommended to use the algorithm both in testing systems and in experimentation of internal combustion engines.

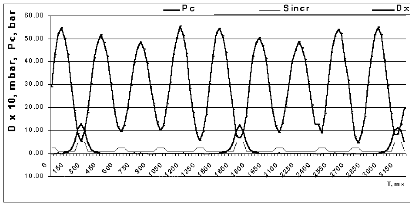

Figure 1. Fragment of simultaneous measurement of the cylinder pressure and the negative pressure in the intake manifold, synchronized with crankshaft position.

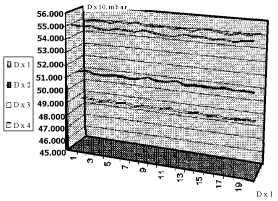

Figure 2. Average of negative pressure in the intake manifold for each cylinders phase.

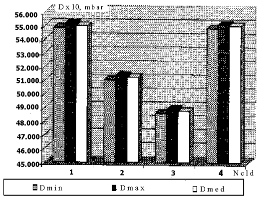

Figure 3. Evaluation of the negative pressure in the intake manifold for each cylinders.

References

[1] Hilohi C., Untaru M., Soare I., Druta Gh. Automobile testing methods and means. – Bucharest, Ed. Tehnica, 1989 (in Roumanian).

[2] Flexible PC-Software für Motorenprufung. – In: Maschinenwelt Electrotechnick. – 1992, v.47, No.10, p.271.

[3] Gusakov N.V., Peshkilev A.G. Methodologic bases for development of automatic science investigation systems for automobiles. – in Increasing of automobile efficiency and ecology. – Moscow, VTUZ-ZIL, 1990, pp.115–123 (in Russian).

[4] Gromov A.A.,Hatkevici L.A. Automatic testing system for automobile carburation engines. – in Engine Development 1991, No.7, pp.36–37 (in Russian).

[5] Hiromitsu K., Makoto N., Junichi M., Katsuyuki O. Inrestgation of air flux in collector of engine. – Transport Japan Society Mech. Engeneering. B. 1992, 58, pp.965–971.

[6] Aho A., Hopcroft J., Ulman J. The design and analysis of computer algorithms. – London: Adison Wesley Publishing Company, 1978.

T. Nicu,
Technical University of Moldova,
AFN Ltd.,
Alexandru cel Bun str., 51a
Chişinău, 2012, Moldova,
Phone: (373)–2–241–188
E-mail: afn@afn.moldnet.com

Received 28 July, 1999