THERMAL AND ELECTRICAL ANALYSIS OF AUTOMOTIVE IGNITION SYSTEM

MILAN SEBOK[1], MATEJ KUCERA[2], MIROSLAV GUTTEN[3], DANIEL KORENCIAK[4]

Abstract

This article describes evaluation principles of individual parts of the ignition system, using conventional diagnostic systems, based on evaluation of current and voltage waveforms. By means of the practical test, diagnostics, measurements and subsequent analysis it was proved that thermovision plays an important role in diagnostics in on-line check automotive equipment. By comparing the non-standard warming behaviour of a part of the electrical system with combination with time high-voltage method, it is possible to diagnose a fault and also check the operating mode of the system. Sample thermogram of the temperature distribution of the ignition coils and analysis of high-voltage ignition curves with faulty spark plugs is given in the part of the paper of nondestructive diagnostics with a difference in temperature. Analysing the fault condition of ignition systems, using the method conventional diagnosis of high-voltage pulse waveforms and also the method of thermovision diagnostics, we can adequately evaluate the functionality of the electronic system and its individual components. In some cases, with one coil ignition systems, we cannot use the conventional method and therefore it is preferable to proceed to the analysis of temperature fields.

Keywords: thermovision, ignition systems, spark plug, high-voltage waveforms

1. Introduction

The ignition systems, even in their simplest form, represent an electrical system producing high voltage waveform in the form of complicated impulses. The diagnostic of these systems also requires diagnostic systems that allow record these processes for further analysis. The essence of the fully electronic ignition system is to distribute high voltages for individual spark plugs for created of ignition mixture. The current value of the jumping spark voltage in the individual cylinders must be determined by the separate switching control of the primary circuits of the high voltage transformers (spark ignition coils) [18].

The engine operating parameter signals are input to the control unit by means of which the control unit generates control pulses for the end stages of the individual ignition coils.

[1] Department of Measurement and Application Electrical Engineering, Faculty of Electrical Engineering and Information Technology, University of Zilina, Univerzitna 1, 010 26 Zilina, Slovakia, e-mail: milan.sebok@fel.uniza.sk

[2] Department of Measurement and Application Electrical Engineering, Faculty of Electrical Engineering and Information Technology, University of Zilina, Univerzitna 1, 010 26 Zilina, Slovakia, e-mail: matej.kucera@fel.uniza.sk

[3] Department of Measurement and Application Electrical Engineering, Faculty of Electrical Engineering and Information Technology, University of Zilina, Univerzitna 1, 010 26 Zilina, Slovakia, e-mail: gutten@fel.uniza.sk

[4] Department of Measurement and Application Electrical Engineering, Faculty of Electrical Engineering and Information Technology, University of Zilina, Univerzitna 1, 010 26 Zilina, Slovakia, e-mail: daniel.korenciak@fel.uniza.sk

Operational parameter signals are needed to calculate the exact moment in which the high-voltage pulse is occurred.

Fig. 1 is an example of voltage and current waveforms of the primary side of transformer. The ignition coil (high voltage transformer) produces high-voltage pulses on the spark plug electrodes for ignited mixture in the combustion chamber of the engine (Fig. 2) [16]. In practice, two solutions differing in the number of ignition coils are used.

The ignition system (DFS) with double secondary windings of transformer, where are the high voltage (or where high voltage is) supplied directly on two spark plugs, and at the same time are occurred the jumping spark voltage on two spark plug [13].

The EFS or COP ignition type (Coil on Plug), with one secondary winding of transformer, uses the coils to create only one high voltage impulse on the one spark plug, i.e. the number of ignition coils corresponds number of cylinders of the engine [10].

Conventional measurement diagnostic systems enable, based on the analysis of primary and secondary high voltage waveforms, evaluate the measurement of ignition systems for obtaining a more comprehensive overview of examined electric system [1].

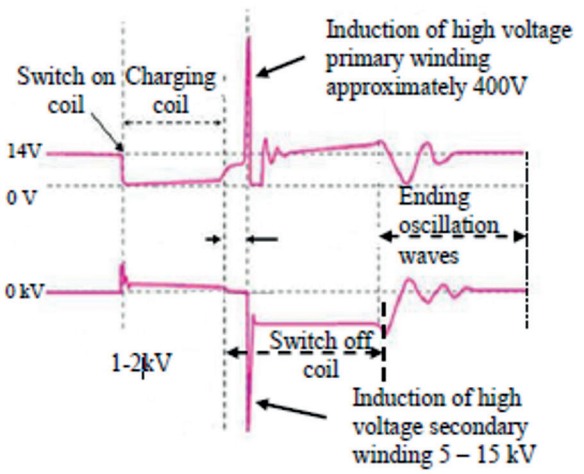

Fig. 1. Voltage waveforms of the primary side of the transformer winding

When locating fault states of electronic ignition systems, the possibilities for the non-destructive diagnostics of ignition systems are analyzed on the basis of thermal losses using thermovision [11], [2], [7].

Diagnostic of ignition systems using conventional diagnostic systems enables, based on analysis of primary and secondary high-voltage waveforms, to detect the failures in the diagnostic of measurement system under examination. [3], [4]. When locating fault states

of electronic ignition systems, the possibilities of non-destructive diagnostics of ignition systems based on heat losses using thermovision are analyzed too [5], [12].

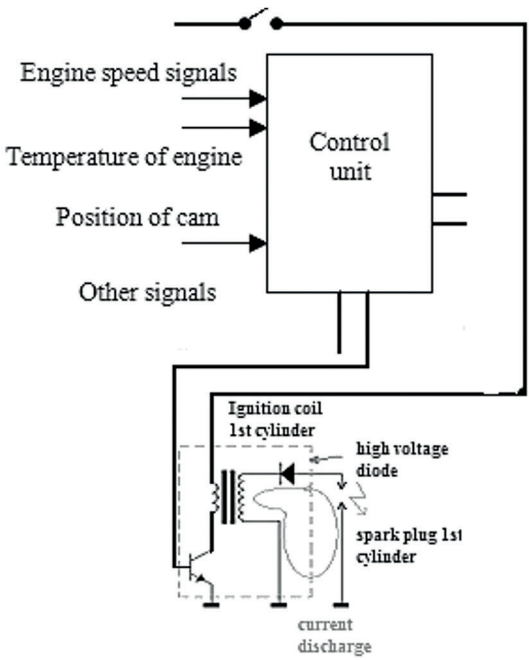

Fig. 2. Simplified EFS ignition scheme

2. Experimental diagnostics and analysis

One way to diagnose a fault state of an electrical ignition system is to use the analysis of the temperature distribution in the field.

By comparing the non-standard warming behavior of a part of the electrical system, it is possible to diagnose a fault and also check the operating mode of the system [8], [9].

Based on thermal field temperature measurements, we receive a color temperature distribution (thermogram).

By analyzing the temperature distribution it is possible to determine the functionality of the device.

An example of a thermogram of the temperature distribution (Fig. 3) of the ignition coils of the first and second cylinders is given, with a difference in temperature (increased warming on the first cylinder). As a result of the malfunction, the engine runs irregularly.

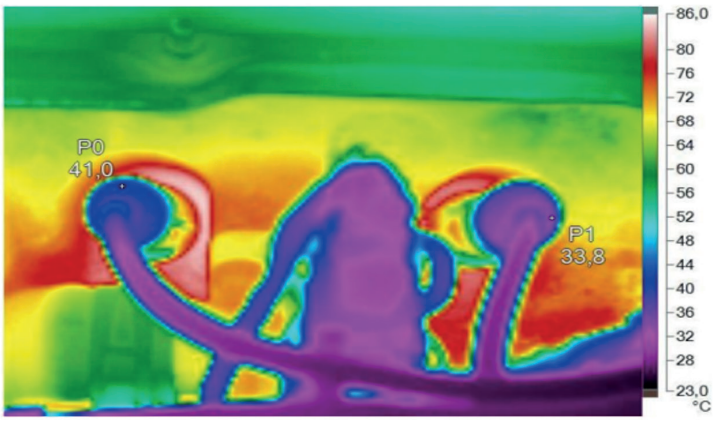

Fig. 3. Thermogram ignition coil 1st and 2nd cylinders

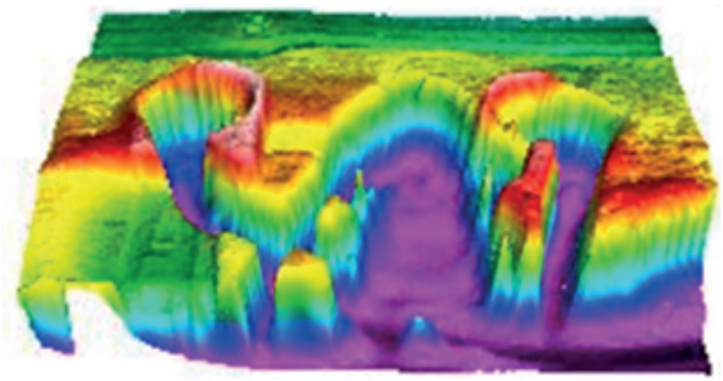

Fig. 4. 3D graph of temperature distribution

In practice, ignition individual coils are recessed into the cavity in the cylinder head and there are mounted directly on the spark plug with short cables. By implementing capacitive sensors on these wires waveforms of high-voltage discharges it can be obtained [17], [20].

We scan voltage on these coils just behind the high voltage diode which ultimately distorts the image resulting voltage. Diagnostic of high-voltage (secondary) circuit of ignition is affected by the presence of the high-voltage diode [14], [6].

After a more detailed analysis (Fig. 4) and using the diagnostic systems, the measured high-voltage waveforms (Fig. 5) were analysed, where determined failure of the first motor cylinder (short burning time) was confirmed.

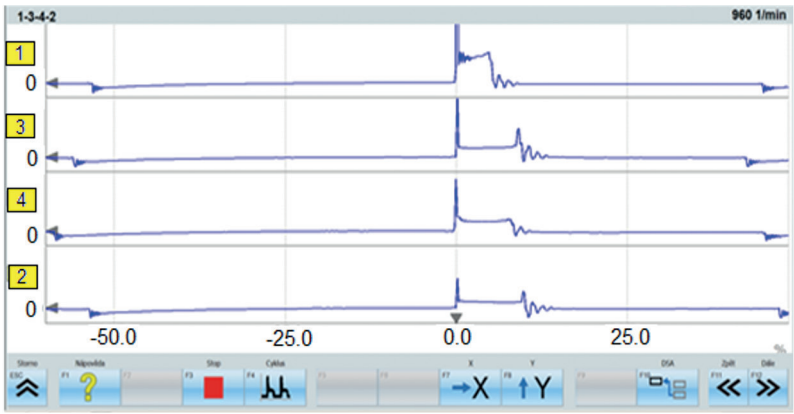

Fig. 5. Measured high-voltage spark curves - the primary side of ignition

From the results of measured process we can see, which the faulty ignition pulse is at the first cylinder in the ignition order (1-3-4-2). Short burning time of spark causes incomplete combustion of the mixture, resulting in an increase in the percentage of unwanted emissions.

Similarly, it is possible to analyze various failure states of the spark plugs. In (Fig. 6), high voltage curves of ignition coils with poor quality spark plugs are diagnosed.

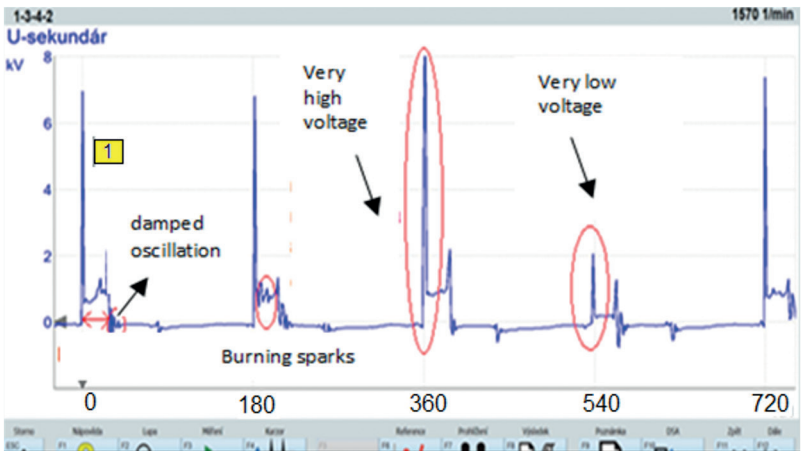

Fig. 6. Measured high-voltage ignition curves with faulty spark plugs

The result may be irregular running of the engine with incomplete combustion of the mixture. It is clear from the results that impulses do not have the desired shape.

On the other cylinder, the voltage is too low, which is caused by a degraded spark plug. The gap between the middle and the side electrode is too small. If this gap was larger than required, too high voltage would be generated.

Oxidation (pollution) of the spark plug results, for example, in poor quality oils, incorrectly set ignition angle, too much fuel mixture, dirty air filter and others [15], [19].

In Fig. 7 high voltage impulse of the second cylinder is missing at it is diagnosed due to the mistake ignition coil.

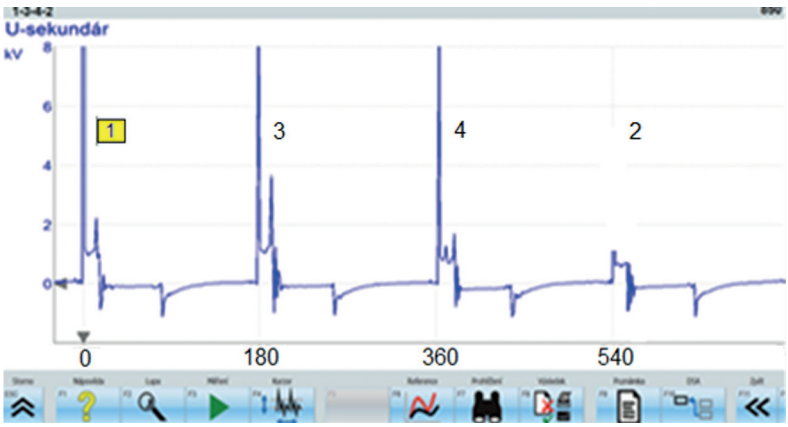

Fig. 7. Measured high-voltage ignition curves due to defective spark plug

By measuring the temperature distribution on the surface of the ignition coils, the anomaly was confirmed by the thermovision diagnosis (Fig. 8).

The thermogram shows a marked decrease in temperature of the spark plug of the second cylinder as a consequence of the spark ignition coil failure of one spark ignition (Fig. 9).

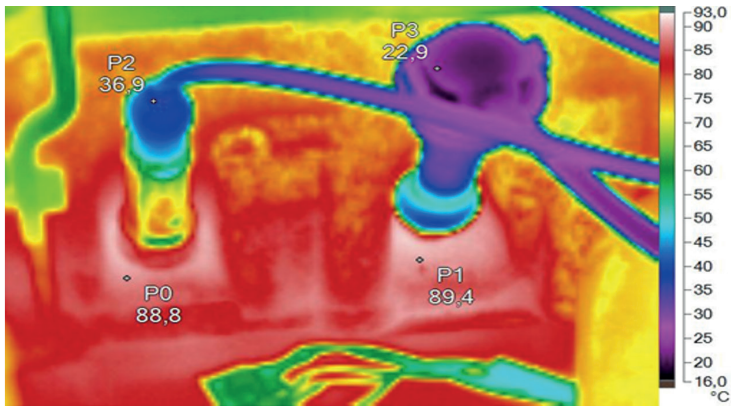

Fig. 8. Thermogram of ignition coils

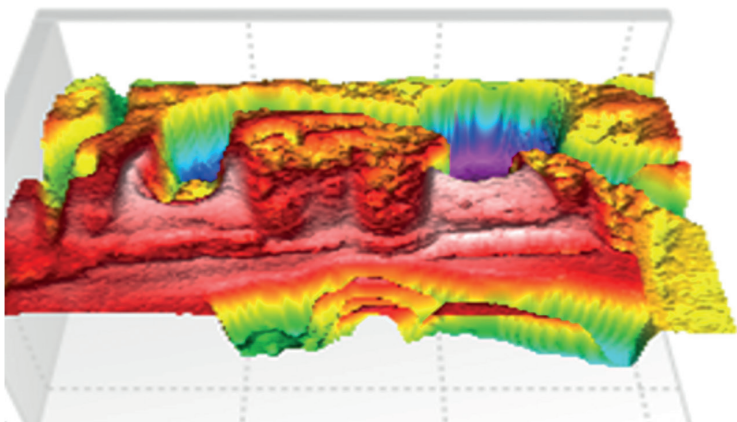

Fig. 9. 3D analysis of ignition coils for the first and second cylinder

By combining these two methods of diagnosing electrical components of the ignition system, we can more effectively analyze the fault states of the ignition coils themselves.

3. Conclusion

Analyzing fault condition of ignition systems, using the method conventional diagnosis of high-voltage pulse waveforms and also method of thermovision diagnostics, we can adequately evaluate the functionality of the electronic system and its individual components.

In some cases, with one coil ignition systems, we cannot use the conventional method and therefore it is preferable to proceed to the analysis of temperature fields. This method has limitations in coils encapsulated in a metal container.

At the non-contact temperature measurement method the possibilities of using more efficient measurement and diagnostics in locating fault states of electrical ignition systems were analysed.

By comparing the non-standard warming behaviour of a part of the electrical system with combination with time high-voltage method, it is possible to diagnose a fault and also check the operating mode of the system.

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