Diagnosis and reliability improvement of internal combustion engine ignition coil

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Abstract. It is shown that the work of all elements of engine is interrelated, and often the failure of one of them leads to the impossibility of further movement. Conclusions are made regarding the critical components, which include the ignition coil, which forms a high voltage for the formation of a spark. Its technical condition is considered and its regular control is offered. In the car all nodes are interconnected, and often the breakdown of the one leads to impossibility of further movement. One such responsible node is the ignition coil, generating high voltage sparks. Its technical condition should be the subject of a regular monitoring.

1. Introduction
In the car all nodes are interconnected, and often the breakdown of the one leads to impossibility of further movement. One such responsible node is the ignition coil, generating high voltage sparks. Its technical condition should be the subject of a regular monitoring.

If other conditions are not mentioned in the specific control methods, coils control is carried out in normal climatic conditions according to GOST R52230. A relative humidity lower limit is vary from the specified in GOST [1, 2].

High voltage coil lead load (capacity 50 pF, resistors, 100MOhm 1MOhm, 0.18 MOhm) must comply with the requirements of GOST 28827.

In all cases, unless otherwise is specified, the supply voltage at the controller must be \( U_{k} = 14.0V \), storage times \( t_{s} = 3.2ms \), and the length between the main spark plug electrodes arresters - 6.0 mm.

2. Problem definition
The total resistance of connecting wires and connector contact resistance in windings power circuits must be between 100 and 200 mOhm.

According to the customer's request, the device has semiconductor keys that perform a cascade ignition coil winding switch to a stable voltage source (14V) for some measurable amount of time to achieve primary current preset value (9A). After reaching the current set value, the key is opened and remains open. Further, the energy stored in the coil creates an arc discharge on the spark plug connected to its secondary winding. This process is fixed to the external storage since start until the end of the transitional process.
3. Theory
The block diagram of ignition coils quality control devices is presented in Fig.1.

![Diagram](image)

**Figure 1.** Device block diagram

The power key (S1, S2) commutes an ignition coil (E) to a source during a microcontroller (MC) control signal [1, 2, 4, 7]. Measuring shunt R fixes the nominal current value achievement, time growing from zero to the rated value is also fixed. Since power key S1 or S2 disabled voltage \( u_1(t) \) or \( u_2(t) \) was scaled by the resistor divider and digitized by the ADC module of the MC microcontroller within ten milliseconds and then transferred to the SD card.

The measurement results are analyzed by the microcontroller [3, 4], then ignition coil quality finding is passed to the LCD and is duplicated in the SD card file. The testing process is specified by the keyboard (KB). The intermediate and final results are displayed on the liquid crystal display (LCD), which is powered by a 9V and 5W power source. Received and processed information is written to an external flash drive, which is a SD card [5, 6].

The control device, a two winding ignition coil (at the center bottom), a spark plug gap (at the right bottom), the control keyboard (above) are shown in Fig.2.

4. Experimental results
Fig.3 shows the oscilloscope trace of the working ignition coil primary voltage.

The following areas can be identified on the resulting oscilloscope trace:

0...5 ms - the charge of ignition module coil; 5...5ms - voltage (leap) impulse before the arc advent; 5...6.3 ms - arc discharge in the spark gap; 6.3...8.5 ms - damped free oscillations; 8.5...10 ms - steady mode.

In the charge, the field coil is connected to a stable 14v voltage supply before current achievement of a 9A level.

The presence of a voltage pulse in the next area characterizes the absence of short-circuited turns of the coil and sufficient quality. Small voltage values impulse may not be enough for the ignition spark arcs gap, so the rejection of coils is also by this criterion.

Length of arc discharge in the 5...6.3 ms area in Figure 3 describes the energy of the ignition coil. As a general rule, the duration of the arcing is 1...2 ms.

The presence of decaying free vibrations in the next area testifies the sufficient goodness of circuit, which is formed by coil inductance, inter turn winding capacity and the wire resistance. This is another criterion of the ignition coil module correctness.

After the free vibrations decay, there is an area corresponding to the stabilized regime.
Figure 2. The test system

Figure 3. The oscilloscope trace of the working ignition coil primary voltage
The oscilloscope trace of the ignition coil primary voltage while spark circuit opening is shown in Fig.4.

**Figure 4.** The oscilloscope trace of the ignition coil primary voltage while spark circuit opening

**Figure 5.** The oscilloscope trace of the ignition coil primary voltage while there is short-circuit turn (second channel)
5. Discussion of results

There is a power surge above the threshold for a switching transistor while the primary winding is cut off. The energy stored in the coil for the first 5 ms of charging is almost entirely allocated to the transistor in the form of heat, and the arc ignition in the spark gap does not occur. In this case, the ignition system, consisting of a module, commutator and spark plug, is defective, and it is caused by an excessively longer spark plug gap while the switching circuit and the ignition module are working [7].

The oscilloscope trace of the ignition coil primary voltage while there is short-circuit turn shown in Fig.5

6. Conclusion

The presence of primary voltage jump is due to the inductances dispersion in the ignition module. A slow voltage decline after the primary winding failures is a subject to the law of coils aperiodic discharge with active resistance. The absence of free vibrations indicates a small oscillating circuit goodness, which is formed by winding inductance, inter turn capacity and wire resistance. The speed of the voltage decline is determined by the ratio of inductivity to active resistance.

The designed and built device based on the microcontroller with the possibility of autonomous 9V power supply can perform control in compliance with the ignition coils. The feature of the device is the ability to diagnose the ignition coil removing together with the high voltage circuit and spark plug.

References

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