Promising algorithm for diagnosing vehicle ignition coils

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Abstract. The principle of performance of all elements, and their interconnection are described. A failure in one element causes a failure in the entire system and impossibility of movement. The analysis of key processes was carried out. Conclusions about responsible elements were drawn. An ignition coil that generates high voltage during the spark formation is one of the elements. Its technical state was studied; its regular monitoring was suggested.

1. Introduction

In a vehicle (car), all nodes are interconnected; a failure in one of them causes failures in other ones. One of the key and critical elements responsible for the vehicle movement is an ignition coil that generates high voltage to create sparks. Its operation is similar to the functions of a transformer. It involves conversion of the low tension voltage from the vehicle battery (starter) to the high-tension voltage generated for the spark plugs as a result of which the air-fuel mixture ignites. Without its normal operation, complete combustion of the fuel mixture "squeezing" the maximum efficiency of the motor is impossible. Its technical condition should be controlled.

While the breaker is closed (the engine works at low revs), electricity flows through the primary coil, heating it. The resistor is included in the coil circuit which reduces the amperage (by increasing the resistance). When the breaker is in the open position (at high speed), the heating is very small. When you start the engine, to increase the spark energy, the resistor is blocked by the chopper (reducing the resistance and increasing the amperage).

Automakers use three types of coils:

Traditional coils. They are two windings connected by negative ends, and the positive wire of the secondary one is connected to the terminal of the cover which ensures the waste of high-voltage electricity. A magnetizing core is in the middle. Oil can be poured into the structure to insulate the coils and protect them against heat.

Individual coils are used in cars with an electronic type of ignition. Each candle has its own coil. A diode is introduced into the secondary circuit to block the current (the coil overheat is suppressed). This directs high voltage to the spark plugs to exclude the distributor from the circuit. The device has a spring and an insulating body.

Tow-ended models supply voltage from two cylinders. They are combined into a kit serving all four cylinders.
It is necessary to know general characteristics of the coils. These parameters are listed in the technical manuals.

- Resistance in different windings
- Spark length in time
- Spark power, its energy
- Current
- Induction of the primary winding

The values of all the parameters listed in the technical documentation of the car. They are required during the selection of a new part for replacement and comparison of measured indications during the diagnosis.

Normal operation of this part is influenced by constant heating and vibration. They cause various damages, insulation failures, breaks, short circuits. Starting the engine is difficult, the rhythm of ignition is disturbed.

Due to various problems in the spark plugs and high-voltage wires, there is a large overload. Faulty distributive ignition causes failures in the engine.

![Oscillogram of primary voltage of the ignition coil](image)

**Figure 1.** Oscillogram of primary voltage of the ignition coil

2. Methods and materials

In accordance with GOST R52230, the control of coils is carried out in normal climatic conditions, unless other conditions are indicated in the presentation of specific control methods. The lower limit of relative humidity may differ from the one specified GOST R52230.

GOST 28827 determines the load of high-voltage coil terminals (capacity 50 pF, 100MOhm, 1MOhm, 0.18MOhm resistors).

When there are no specific instructions, the voltage should be $U_k = 14.0\text{V}$, the accumulation time $- I_i = 3.2\text{ms}$, and the length of the spark gap between the main electrodes - 6.0 mm.

Total resistance of supply wires and the transient resistance of the connector in the supply circuits of the windings should be 100-200mOhm.

In accordance with customer requirements, the device includes semiconductor switches whose function is to switch the ignition coil windings to a stabilized voltage source (14V) for a certain measured time until the primary current reaches 9A.
When the current reaches this value, the key opens, and the energy accumulated in the coil creates an arc discharge on the plugs connected to its secondary winding. The process is recorded by an external memory.

The operation principle. Figure 2 shows a block diagram of the device controlling the quality of ignition coils.

![Figure 2. The block diagram of the device](image)

The power switch (S1, S2) switches the ignition coil to the source (E) when the control signal from the microcontroller (MC) is applied [1, 2, 4, 7]. The nominal current value is fixed by measuring shunt R; the time of current growth from zero to the nominal value is also fixed. Since the power switch S1 or S2 is turned off, the voltage $u_1(t)$ or $u_2(t)$ scaled by a resistor divider is digitized within 10 milliseconds by the MC’s ADC module and transmitted to the SD card. The measurement results are analyzed by the microcontroller [3], and the conclusion about the quality of the ignition coil is transmitted to the LCD and duplicated in the SD card file.

The test process is set from the input device - the keyboard (KB). Intermediate and final results are displayed on a liquid crystal display (LCD). The information is recorded [5, 6].

3. Results

Figure 3 shows the oscillogram of the signal, the primary voltage of an ignition coil.

![Figure 3. The oscillogram of primary voltages of an ignition coil](image)

- time 0… 5ms – charging of the ignition module coil;
- in the range of 5 … 5 ms, voltage surges until the arc discharge appears;
- in the period of 5 … 6.3ms - the arc discharge is in the spark gap;
- in the interval 6.3 … 8.5ms, free oscillations are fading;
- to 8.5 ... 10ms - the result is in a steady state.

The oscillogram records changes in parameter values of the coil and the entire group of engine systems. Distortion of the schedule occurs under the influence of certain characteristics:

- Advanced ignition (angle);
- Revolutions per minute (crankshaft rotation);
- Throttle position (displacement angle);
- Pressure;
- Proportions of the fuel mixture (depleted or enriched);
- Other.

Using a digital oscilloscope-based motor tester, the following problems are fixed:

- Breaking of the high voltage circuit connecting the sensor and the candles. There may be a reduction in the sparking period which will adversely affects the transistor and isolation;
- Increased resistance in accompanied by a voltage drop when too long wires are oxidized. The graph shows that at the beginning of the spark, the voltage value is greater than at the end of the spark;
- An open wire between the sensor and the coil. The additional sparking gap (between the ends of the broken wire) increases voltage, and damages the winding;
- The inter-turn breakdown takes some of the energy, especially when the load on the engine increases. The engine loses power during acceleration and increases speed;
- Electrode gap of the candle. Changes in its value cause a drop in the voltage and misfire;
- Reduced compression in the cylinders due to a drop of voltage of sparking and pressure of the pistons in the cylinder chambers.

Let us analyze Figure 3. In the charge area, the coil is connected to a stabilized voltage source 14V until the current value is 9A.

The absence of short-circuited turns of the coil is characterized by the presence of a voltage pulse in the next area and a sufficient quality factor. An insufficient pulse voltage may not be sufficient to ignite the arc in the spark gap. Rejection of ignition coils is based on a similar criterion.

The duration of the arc discharge in the region of 5 ... 6.3ms shown in Figure 3 characterizes the energy supply of the ignition coil. As a rule, the duration of arc ignition is approximately 1 ... 2ms.

Damped free oscillations indicate a sufficient quality factor of the circuit formed by the inductance of the coil, the interturn capacity of the winding and the active resistance of the winding wire which confirms operability of the ignition module coil.

Figure 4 shows that the damping of free oscillations is followed by an area corresponding to the steady state. Figure 4 shows an oscillogram of primary voltages of the ignition coil when the spark circuit is broken.

![Figure 4](image-url)

**Figure 4.** The oscillogram of primary voltages of the ignition coil when the spark circuit is broken

When de-energizing the primary winding of the coil, we can observe a voltage surge above the threshold for the switching transistor.

The energy stored in the coil is released in the form of heat, but arcing in the spark gap is not observed. The ignition system consisting of the module, the switch and the spark plugs is faulty, and the main cause of its malfunction is an increased distance of the spark gap.
Figure 5 shows an oscillogram of primary voltages of the ignition coil in the presence of short-circuited coils.

![Oscillogram of primary voltages](image)

**Figure 5.** The oscillogram of primary voltages of the ignition coil if there are short-circuited coils in the second channel

### 4. Conclusion

The surge of the primary voltage is due to the presence of leakage inductances in the ignition module. A gradual voltage drop after de-energization of the primary winding is determined by the law of aperiodic discharge of an inductance coil with active resistance. The absence of free oscillations indicates a low quality of the oscillating circuit formed by the winding inductance, the interturn capacitance and the active resistance of the winding wire.

The ratio of inductance to active resistance is determined by a voltage drop rate.

Using a microcontroller, a device supplied from the 9V DC source can control the compliance of the ignition coils with the requirements.

A specific feature of this device is its stationary ignition coil diagnosis function.

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