The main types of vehicle engine diagnostics

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Abstract. The authors reviewed the types of diagnostics of internal combustion engines of vehicles, which showed that there are mainly three types of diagnostics of engines, which differ in the accuracy of the results, the time of its implementation and the cost of the service. The authors believe that diagnostics based on the parameters of the crankcase oil of an internal combustion engine, which is widespread in foreign countries, is beginning to be in demand in the Russian Federation. It allows, with minimal costs and with high accuracy, to analyze the state of the engine without taking the machine out of operation, because it is enough to send an oil sample to the laboratory or perform some simple express analyzes at the place of machine operation.

Keywords: engine diagnostics, engine oil, performance indicators, equipment, oil analysis, car malfunctions.

The main unit of the car, which is responsible for the dynamic characteristics of the car, its power and throttle response is the internal combustion engine (hereinafter referred to as the engine or ICE). ICE is a complex technical unit containing a number of systems and mechanisms. In order for its operation to be uninterrupted and reliable, it is necessary to regularly carry out maintenance of the car engine in accordance with the recommendations of the manufacturer.

One of the most important conditions for maintaining a high level of efficiency and reliability of engines is the timely detection and prevention of failures that occur during operation. It is carried out using technical diagnostic tools. Diagnostics allows you to detect hidden failures of the mechanism and determine the repair necessary to eliminate them, and in the absence of failures, identify the service life of the mechanism and the need for prevention.

Today there are three types of engine diagnostics:

1) **Mechanical diagnostics** – examination of the engine for mechanical damage. The main task of mechanical diagnostics — is to determine the need for repair of the main components of the ICE. It is carried out both outside the engine and inside. Internal diagnostics is carried out by

disassembling the engine, which is one of the most time-consuming jobs. This diagnostics allows with 100% probability to determine all malfunctions (wear of parts, carbon deposits, crankshaft condition, gasket defect, and so on). To carry out such a diagnosis, a disassembly is required: a universal and special tool (keys, socket heads, special pullers, and so on) and a measuring one (internal gauge, vernier caliper, micrometer). An area for a working post and an area for an aggregate section are required. Features of mechanical diagnostics are that the engine is diagnosed in accordance with the repair and maintenance manual for an engine of a particular brand and model.

2) **Computer diagnostics** – carried out using special computers equipped with software. It began to evolve with the advent of the electronic engine management system (EEMS). An electronic control unit (ECU) controls the operating parameters of such a system. This diagnostics evaluates the condition of the systems and mechanisms associated with the EEMS, such as the power supply system, the valve timing mechanism, the ignition system, the cooling system, the EGR, and so on. To carry it out, you need an autoscanner, software for it and a diagnostic cable. Diagnosing a car with a scanner or using a computer allows you to identify malfunctions in ICE, and also fairly accurately determine existing problems. Computer diagnostics of the machine makes it possible to comprehensively assess the technical condition of the engine, obtain information that displays the general condition of parts, mechanisms, components and assemblies of ICE, as well as identify weak points that can further lead to deterioration in performance or even to engine shutdown.

Computer diagnostics of a car engine is performed in several stages. Each stage ends with an error report that is displayed on the screen. The detected errors are decoded, and on the basis of the information received, a recommendation is made on the need to replace or repair certain assemblies, sensors or individual parts.

3) **Diagnostics by parameters of crankcase oil** – carried out by examining the engine oil. Years of experience accumulated in different countries (USA, Germany, France, etc.) shows that machine diagnostics based on the analysis of operating oil is a reliable way to identify malfunctions [1,2,3,4]. In the Russian Federation, such work is carried out by the diagnostic center of LLC "Himmotolog" [5]. When disassembling and repairing machines, predicted defects are confirmed in 95% of cases [6].

During the operation of engine oils, physical and chemical processes occur, accompanied by the actuation of additives, the accumulation of wear products, which leads to the premature depletion of the potential of the physicochemical properties of the oil and a decrease in the resource of the power unit [7]. Oil is the most efficient, variable and controllable element that determines the efficiency and reliability of the engine.

To analyze engine oil, the following equipment is required, as shown in table 1.

Table 1

Required equipment for analysis

Equipment	Functions
Viscometer	Designed to determine the dynamic and kinematic viscosity of oil
Infrared analyzer	Shows the degree of oil degradation (oxidation, nitration and base number) and oil contamination (soot, water, antifreeze and fuel)
Particle counter with magnetometer	Shows the content of metal particles in engine oil, wear products of engine parts
Multichannel photoelectric spectrograph	Determines the concentration of metals in used oils by the spectral method
Oil tester	Allows you to determine the presence of malfunctions in the car engine by changing the viscosity, density and other characteristics of the oil

Diagnostics of the oil operating in the engine has the following advantages [7,8]:

- performed without disassembly and visual inspection;
- the vehicle does not stop operating during the analysis;
- detecting faults at an early stage;
- minimal laboriousness of diagnostics;
- the ability to change the oil not by mileage, but by its actual performance.

To carry out the analysis, you will need about 130-150 cm^3 or 0.15 liters of motor. Groups of indicators are presented in table 2 [9,10].

Table 2

Indicators obtained in the analysis of engine oil

Analysis group	Indicators	Norm
Wear – indicators that correspond to the metal content of engine parts	Iron (Fe)	< 30 mg/kg
	Lead (Pb)	< 10 mg/kg
	Copper (Cu)	< 50 mg/kg
	Chromium (Cr)	< 5 mg/kg

	Aluminum (Al)	< 10 mg/kg
	Nickel (Ni)	< 15 mg/kg
	Silicon (Si)	< 20 mg/kg
Contamination – indicators indicating the presence of other fluids in the engine oil	Water (H_2O)	< 0 %
	Coolant	< 0 %
	Fuel	< 0 %
Chemical properties of oil	Alkaline number	< 8-9 mgKOH/g
	Acid number	< 6-7 mgKOH/g
	Kinematic viscosity	9,5-12,5 mm^2/s
Various additives	Zinc (Zn)	Standard indicators depend on the type of test oil and are indicated in the technical passport
	Phosphorus (P)	
	Magnesium (Mg)	
	Molybdenum (Mo)	
	Boron (B)	
	Barium (Ba)	

Thus, the analysis of engine oil provides a fairly large number of indicators by which it is possible to make a verdict on the engine's performance and its further maintenance.

Examples of various malfunctions that can be detected when diagnosing a working engine oil.

Mechanical wear of parts — these defects can be detected at the earliest stages when obtaining oil analysis results [11]:

- presence of lead and tin – bearing wear;
- presence of iron – wear of the camshaft;
- presence of iron, lead, tin and copper/aluminum – wear of the crankshaft;
- the presence of iron, chromium and aluminum – wear of the cylinder-piston group;
- chrome and fuel – piston ring wear.

Examples of diagnostics based on crankcase oil parameters.

Example 1. In the analysis of the oil sample, an increased amount of metals was found that make up the parts of the cylinder-piston group and the crankshaft bearings.

Conclusion - an abrasive got into the oil, road dust gets into the engine.

Possible malfunctions:

- defective air filter;
- damage to the gaskets between the engine intake manifold and the cylinder head.

Example 2. Decreased kinematic viscosity and sharply increased the flash point of the oil.

Conclusion – fuel gets into the oil.

Possible malfunctions:

- a leak in the fuel supply system;

- non-combustion of fuel in one of the cylinders;

- violation of fuel atomization by nozzles.

Example 3. The oil sample has an increased mass fraction of water, and intense bands of ethylene glycol are seen in the IR spectrum of the oil.

Conclusion – liquid enters the oil from the cooling system.

Possible malfunctions:

- damage to the cylinder head gasket [12].

In addition to malfunctions with the engine, you can determine the very quality of the used engine oil by comparing it with the technical data sheet.

Table 3 shows the comparative characteristics of the considered engine diagnostics for individual parameters.

Table 3

Comparison of types of engine diagnostics

Parameters	Crankcase oil diagnostics	Mechanical diagnostics	Computer diagnostics
Service cost	15$ - 30$	Over 135$	8$ - 15$
Time spent	1 to 24 hours (depending on the equipment used)	Full diagnostics takes from one day	20-30 minutes
Accuracy of the result	90%	100%	50%

As can be seen from the table, according to the price-time criterion, the most effective diagnostics is for used engine oil.

The combination of express analyzes with detailed analysis of engine oil samples makes it possible both to carry out an oil change on time and to identify many engine malfunctions at the earliest stage of their occurrence.

This type of diagnostics is widely used in the European Union and the USA when diagnosing engines, primarily trucks and road construction equipment. In Russia, car engine diagnostics based on the analysis of operating engine oil have not yet gained sufficient popularity compared to others.

It should be noted the effectiveness of this diagnostic method in relation to vehicles with diesel engines and off-road vehicles.

When carrying out diagnostics for engine oil, a number of conditions should be observed, failure to fulfill which leads to inaccurate results [8]:

– the engine must run on one brand of oil, only a change in viscosity classes is permissible when operating on seasonal oils;

– sampling frequency should be equal to a quarter of the recommended mileage according to the instruction manual.

Changing the oil according to the assigned resource without preliminary monitoring of its condition leads to the fact that in new engines the engine oil is drained while it is still fully functional, and in worn out engines it is too late, with a real loss of its performance [8].

Conclusion.

The review of the types of diagnostics of internal combustion engines of vehicles showed that the diagnostics of the engine by the parameters of crankcase oil has sufficient accuracy and is increasingly used among other types of diagnostics, especially in motor transport enterprises and enterprises operating road construction equipment.

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