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The Analysis of Wear Metals in Oils

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***Abstract*—A platform for analyzing wear metals in oils was developed. It can be used to analyze lubricating oil for the presence of metal chips. The unit is based on the Ohm's law. The results of laboratory tests confirmed the efficiency of this unit for analyzing oils used in engines of construction and road machines and automobiles for the presence of metals.**

***Keywords*— engine diagnostics, electrical conductivity, amperage, oil contamination, multimeter, electrical resistance, wear products**

I. INTRODUCTION

Improvement of the design of road-building machines involves improvement of their reliability and durability. Gradual deterioration of parts and assemblies of road construction equipment is a natural phenomenon caused by temperature and dynamic stresses which change the geometry of parts, increase friction forces and reduce the wear life.

The loss of national income due to friction and wear is 4.5%, and the cost of frictional force elimination is 20-25% of the total energy volume produced [1].

In 2010, in Russia, the accounted share of costs of premature wear of machines amounted to 2% of the national income [2]. At present, the share of these costs is higher. In order to reduce the costs of parts wear, it is necessary to meet the following conditions:

- compliance with the specifications of lubricating oils;

- the use of oils of reliable brands and timely oil replacement;

- compliance with maintenance rules and regular technical monitoring of parts wear;

- run of new mechanisms while commissioning to reduce the rate of parts wear and friction of surfaces.

II. METHODS

One of the ways to solve these problems is to assess the current state of machine aggregates by determining the content of wear products in the oil and justifying measures aimed at restoring the performance of parts and assemblies at early stages. One of the main theoretical and practical problems is development of an effective method for assessing the technical state of internal combustion engines which would reflect the engine state and meet the following requirements:

1. Minimum time to assess the technical condition of the engine.

2. Maximum information about the state of engine components and parts.

3. Information reliability.

4. Availability for enterprises.

Assessment and analysis of the technical condition of engine mechanisms are a difficult practical task. The rate of distribution mechanism parts wear is tenths or even hundredths of a millimeter. In order to measure the wear rate, it is necessary to demount the engine. However, each disassembly causes an inevitable breakdown in the running-in of the working pairs and accelerates the wear. In practice, the engine wear is assessed without disassembly [3].

III. RESULTS AND DISCUSSION

The authors developed a platform for analyzing engine oils for the presence of wear products. The article presents calculations and justifies applicability of the platform for determining the volume of metal chips in oils.

Fig. 1. The ZMZ-511 engine

The recommended operating time to overhaul is 140,000 km. The dimensions of the connecting rod-piston group will change by 0.3 mm, and the dimensions of gas distribution mechanism parts will change by 0.2 mm. The calculated values of the volume of metal chips for the entire period of operation before the overhaul are presented below.

The volume of metal chips is determined by formula:

$$V = 3.14 \cdot \left(\frac{(D_{nom} \pm t)^2 \pm D_{nom}{}^2}{4} \right) \cdot L_w \cdot n$$

where D_{nom} – nominal part diameter, mm;

t - maximum deviation from the nominal size (for the CRPG, t = 0.3 mm, for the GDM, t = 0.2 mm);

L_W – working surface length, mm;

n – the number of rubbing pairs.

TABLE I. SPECIFICATIONS OF THE ZMZ-511 ENGINE

Parameter	**Value**
Configuration	V
Number of cylinders	8
Volume, l	4,254
Diameter of cylinders, mm	92
Piston stroke, mm	80
Compression ratio	7,6
The number of valves per cylinder	2
Gas distribution mechanism	OHV
Cylinder operation	1-5-4-2-6-3-7-8
Engine rated power / crankshaft speed	92 kW (125 hp) / 3400 rpm
Maximum torque / crankshaft speed	294 N * m / 2000-2500 rpm
Supply system	Carburetor K135
Recommended Minimum Octane Gasoline	76-80
Environmental standards	Euro 0
Weight, kg	262

TABLE II. THE VOLUME OF METAL CHIPS FOR THE ENTIRE PERIOD OF OPERATION

Name of the part	**Number of parts in the engine, pcs.**	**Volume of metal chips, mm^3**
Crankshaft neck	5	4933.5
Crankshaft crank pin	8	5861.44
Connecting rod liner	16	5898.88
Crankshaft main bearing	10	4960.5
Piston pin	8	1876.32
Bushing upper rod head	8	1891.54
Bushing	8	27782.4
Piston	8	31839.36
Compression ring	16	1875.31
Camshaft bearing journal	5	1566
Camshaft bearing journal bushing	5	1575
Camshaft cams	16	2644.48
Guiding axel of levers	16	3188.61
Lever	16	3222.94
Pusher	16	1004.8
Pusher bore	16	4039.3

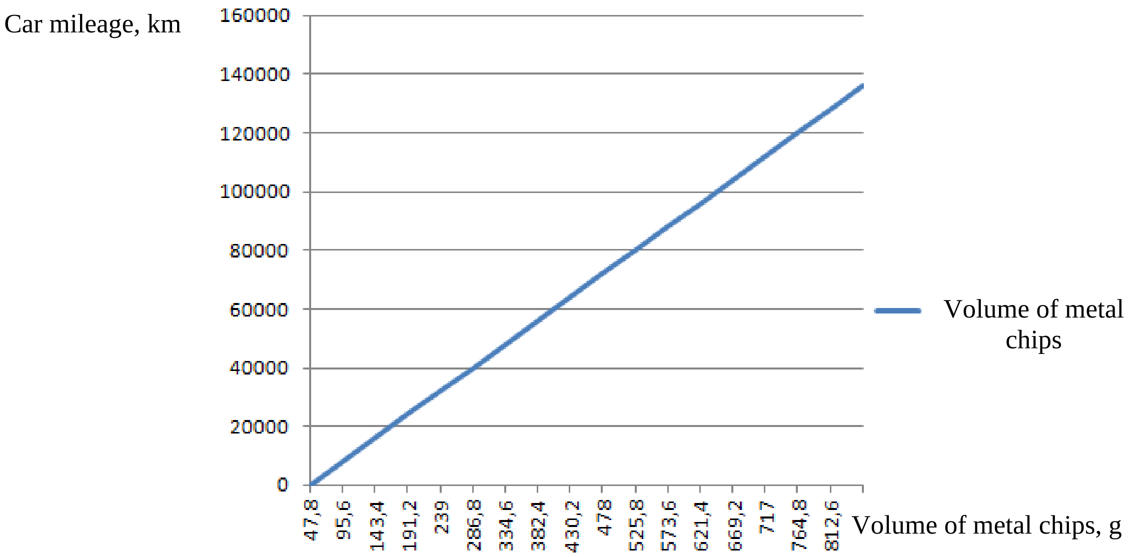

Fig. 2. The dependence of the volume of metal chips on the car mileage

The total volume of metal chips for the entire period of engine operation before overhaul is equal to:

$$V_{max} = \sum V_i = 104157.38\ mm^3.$$

If the machine is maintained every 8,000 km, there will be 17 oil changes. If the average metal density is 7800 kg/m3, for the period before the overhaul, 812 grams of metal chips will be produced. Figure 2 shows the dependence of the volume of chips on the operating time. Dividing the total mass of chips by the number of replacements, one can determine the maximum permissible rate of metal chips in the oil (4.78 g/l).

To determine the volume of metal chips in the oil, we developed a platform (Figure 3). It is based on the Ohm's law. The more the volume of metal chips in the oil, the less its electrical resistance, the greater the current in the circuit.

The Ohm's law states that the current through a conductor between two points is directly proportional to the voltage across the two points:

$$I = U/R \tag{1}$$

where

U – voltage [V];

R – resistance in the circuit [Ohm].

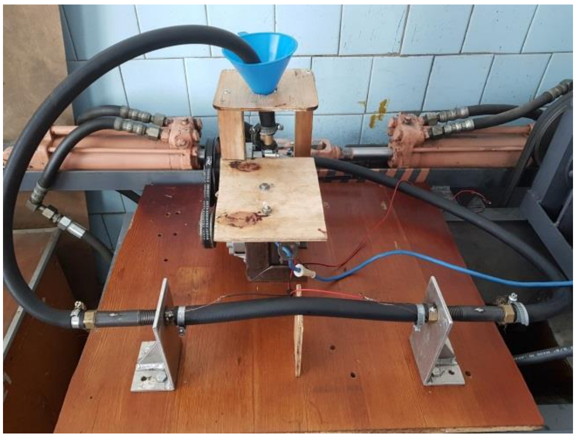

Fig. 3. The general view of the platform

TABLE III. THE RESULTS OF ANALYSIS OF OILS FOR THE PRESENCE OF METALS USING THE DESIGNED PLATFORM

No of the experiment	Mass of metal chips, g	Current, mA	Oil resistance, kOhm
1	0	4.45	2.9
2	0.5	4.49	
3	1.0	4.54	
4	1.5	4.58	
5	2.0	4.61	
6	2.5	4.64	
7	3.0	4.67	
8	3.5	4.7	
9	4.0	4.74	
10	4.5	4.78	
11	5.0	4.82	2.67

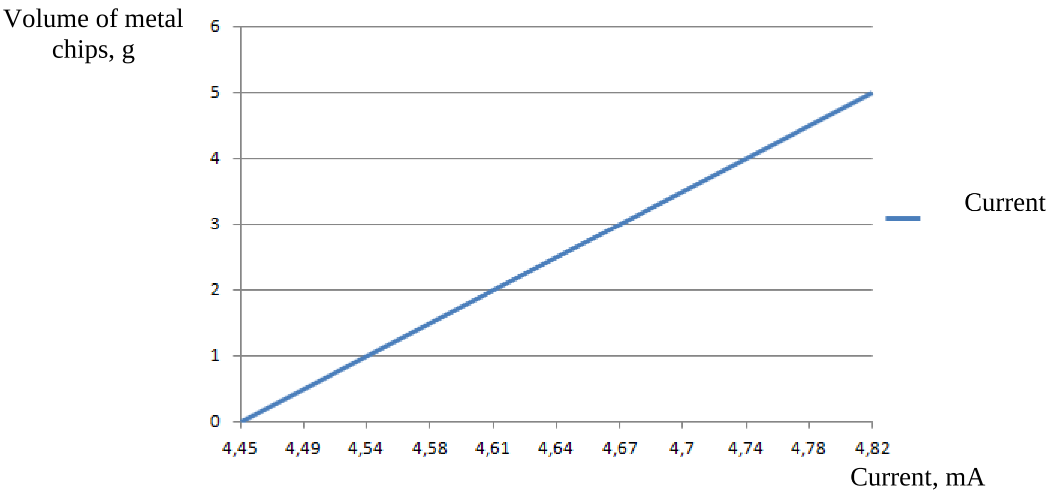

Fig. 4. The dependence of the current on the volume of metal chips in oils

TABLE IV. THE RESULTS OF CORRELATION COEFFICIENT CALCULATION

No of the experiment	Correlation coefficient value
1	0
2	12.5
3	11.11
4	11.58
5	12.5
6	13.15
7	13.64
8	14
9	13.8
10	13.6
11	13.9

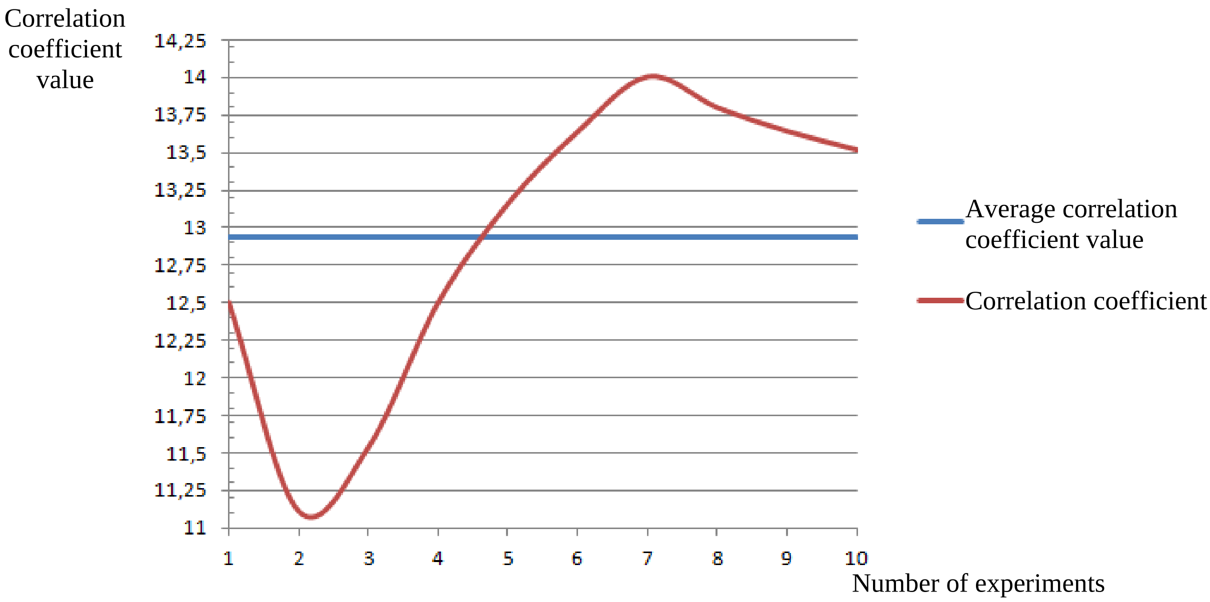

Fig. 5. Correlation coefficient value

The platform can analyze the hydraulic oil. It consists of a filler funnel, a NSh-10 gear pump, a 220V/120W electric motor, conductive contacts, rubber hoses, a 12V battery, electrical wires, and a microammeter.

The direct current passes through the oil line determining conductive properties of the oil. Oils have a high electrical resistance equal to 2.9 kOhm (measurements were taken on a platform with a pure semi-synthetic motor oil viscosity equal to 10W40). Metal chips increase electrical conductivity of oils. To measure electrical conductivity, a microammeter was used.

The results are presented in Table 2. All the measurements were made at a constant voltage of 12.41V, the distance between the contacts was 320 mm, the volume of oil was 0.5 l.

Metal chips increase electrical conductivity of oil. Based on the resistance measurements for pure oils and oils containing metal chips at a concentration of 2.5 g/l, one can say that metal particles reduce electrical resistance of oils (Fig. 4).

To determine the volume of metal chips, the following formula can be used:

$$y = \delta \cdot (x_i - x_{nom})$$

where y – the volume of metal chips, g;

δ – correlation coefficient;

x_i - microammeter readings, mA;

x_{nom} - microammeter readings for pure oil, mA.

It is necessary to calculate an average correlation coefficient by formula:

$$\delta = \frac{y}{(x_i - x_{nom})}.$$

Calculation of the correlation coefficients is shown in Table 4.

Due to possible correlation coefficient calculation errors, an average coefficient value was calculated. Figure 5 shows the correlation coefficient values and the average coefficient value equal to 12.9.

IV. Conclusion

The formula is used to determine deviations, i.e. it shows an increase in the wear rate. It is used to determine the maximum concentration of metal chips in the oil. After each oil change, it is possible to monitor the rate of engine parts wear.

The method for analyzing oils for the presence of metals was developed. The designed platform can be used to determine the degree of contamination of the working fluid, monitor the rate of engine parts wear during each scheduled maintenance. By monitoring the state of oils, one can reduce engine failures and enhance engine performance.

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