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THE OPTICAL-ELECTRONIC DEVICE FOR QUALITY CONTROL OF ENGINE OIL

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ABSTRACT

The mode and the device for the analysis of engine oil impurity of the internal combustion engine disperse particles are given in this paper. Also theoretical justification of development of the device realizing the offered opto-electronic method of engine oils analysis is given. Optical and ultrasonic methods of the analysis of engine oils impurity in the device for increase in informational content of data are used.

Keywords: lubricant, optical-electronic device, internal combustion engine, engine oil, pollution analysis method, optical control method, ultrasound analysis method.

INTRODUCTION

The engine oil which is used in the internal combustion engine (ICE) is a carrier of information about the thermodynamic, chemical and tribological processes occurring in the cylinder-piston group, and throughout the lubrication system to a certain extent. Changing the technical condition of the engine structural elements which occurs during the operation or emergence of a problem in its work is reflected in physical and chemical characteristics of engine oil considerably [1-2].

It is necessary to control for monitoring of pollution of oil in ICE the following parameters:

- level of products of the greased frictional surfaces wear;
- fuel pollution (dissolution);
- pollution due to coolant leak;
- pollution due to excessive accumulation of soot;
- penetration of pollution from the outside which is defined by the increased silicon level in the used oil;
- amount of the water which is condensed in oil system;
- change of the main characteristics of oil due to oxidation, aging, interactions with water and other factors [1].

Content of mechanical impurity in net engine oils shall be not higher than 0,015% according to the state standard specification 10541-78 standard. Limit indicator of content of mechanical impurity in the working oils are values from 1 to 3% depending on engine type.

It is known [1] that with increase in useful life of oil, in it the amount of mechanical impurity, including the weighed particles metal (products of depreciation of details of barrel-engine piston group) and charcoal increases (insoluble products of oxidation) character. Particles of the charcoal nature at the same time are distributed in a butter layer evenly, and particles of the metal nature as particles with a bigger density, distributed generally in the lower butter layers in a case at the switched-off engine.

Controlling the main indicators which characterize properties of oils, it is possible to determine suitability of oil to operation. Oil can lose a quality inventory in case of operation of the defective or overloaded engine. And on the contrary, can be in good shape by the time of replacement.

The ways of the analysis of pollution of oils can be based on various methods: vibroacoustic, electric, optical, spectral, etc. [3-10]. However these ways and devices which realize them possess certain shortcomings, in particular, insufficient informational content.

Development of the devices realizing optical-electronic methods which give the chance of implementation of the continuous automated control, increases in accuracy, efficiency and reliability of measurements is the perspective direction [11-13].

Authors offer the mode of the analysis of impurity of engine oil of the internal combustion engine disperse particles including sounding of the studied disperse environment a bunch of low-power laser and ultrasonic radiation, registration of the radiation dissipated and reflected by disperse particles. At the same time, according to the images received through CCD dissipated from the studied environments of a light bunch and on ratios between parameters of images for the reference port and the port of control of metal particles, and also between parameters of images of the reference port and port of control of charcoal particles judge degree and the nature of impurity of engine oil, the sizes and a form of disperse particles [14].

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THEORETICAL JUSTIFICATION OF DEVELOPMENT OF THE DEVICE WHICH REALIZES THE OFFERED OPTICAL ELECTRONIC METHOD OF ENGINE OILS ANALYSIS

It is necessary to choose and to mathematically describe their key parameters of the weighed particles for their effective analysis.

It is possible to determine the size of the weighed particles proceeding from a way of the analysis of the weighed particles which is based on radiation of the studied object electromagnetic and acoustic by radiations and registration of the electromagnetic radiation disseminated by particles [15]. Radiation at the same time is carried out at the same time by both types of radiations, change of frequency of monofrequency electromagnetic radiation is registered.

The size of the weighed particles is determined by a formula:

$$R = \sqrt{\frac{9 \cdot \eta \cdot \sqrt{V_0^2 - (\Delta f \cdot \lambda)^2}}{4 \cdot \pi \cdot \rho \cdot F \cdot \Delta f \cdot \lambda}},$$

where

η - coefficient of viscosity of the environment;
V_0 - amplitude of particle velocity under the influence of acoustic oscillations;
Δf - maximum frequency variation of repelled monofrequency electromagnetic radiation;
λ - wavelength of monofrequency electromagnetic radiation;
ρ - particle density;
F - frequency of acoustic vibrations.

Coefficient of hobby of particles in the sound field is defined for determination of weight and particle density. The particle weighed in the environment under the influence of linear forces of the sound field is involved in oscillating motion [15]. Depending on properties of the environment, the sizes and particle density the last can be fond by environment completely, partially or to remain motionless.

Drag coefficient k_{dr}, which is understood as the ratio amplitude of suspended particle velocity U_p to amplitude of gas particle velocity U_0 or amplitude of particle displacement A_p to amplitude of displacement of particle environment A_0, which has been calculated by König:

$$k_{dr} = \frac{U_p}{U_0} = \frac{A_p}{A_0} = \sqrt{\frac{1 + 3m + \frac{9}{2}m^2 + \frac{9}{2}m^3 + \frac{9}{4}m^4}{l^2 + 3l \cdot m + \frac{9}{2}m^2 + \frac{9}{2}m^3 + \frac{9}{4}m^4}}, \quad (1)$$

where $l = (2\varepsilon + 1)/3$;

$$m = \left(\frac{1}{\alpha}\right)\sqrt{\frac{\eta \cdot T}{\rho_0 \cdot \pi}},$$

T - period of oscillation;
α - particle radius;
η - dynamic coefficient of viscosity of the environment;
ρ_0 - environment density;

$$\varepsilon = \frac{\rho_0}{\rho_ч};$$

$\rho_ч$ - particle density.

According to Brandt, Freund and Hideman more evident expression for coefficient of hobby of a particle Wednesday provided that between the weighed particle and the fluctuating environment Stokes's strength for small numbers of Reynolds Re<1 and moderate levels of pressure works (<150 dB):

$$k_{dr} = \frac{1}{\sqrt{1 + \left(\frac{4\pi \cdot \rho_ч \cdot \alpha \cdot f}{9\eta}\right)^2}} = \frac{1}{\sqrt{1 + \varpi^2 \cdot \tau^2}}, \quad (2)$$

where $\tau = \frac{2}{9}\left(\frac{\rho_ч \cdot \alpha^2}{\eta}\right)$ - particle relaxation time,

f - frequency of acoustic vibrations,
$\varpi = 2\pi \cdot f$.

In inertial force, the particle not only fluctuates with amplitude, smaller, than amplitude of oscillations of the environment, but also differs from oscillations of the environment on a phase. The phase displacement angle φ is defined by a ratio:

$$tg\varphi = \frac{4\pi \cdot \rho_ч \cdot \alpha^2 \cdot f}{9\eta} = \varpi \cdot f. \quad (3)$$

From expression (2) it is visible that the vibration amplitude of particles the more differs from environment vibration amplitude, than the size and particle density are more, than sound frequency less viscosity is higher.

Dependence of coefficient of hobby on particle radius for the discrete frequencies of a sound is given in a Figure-1.

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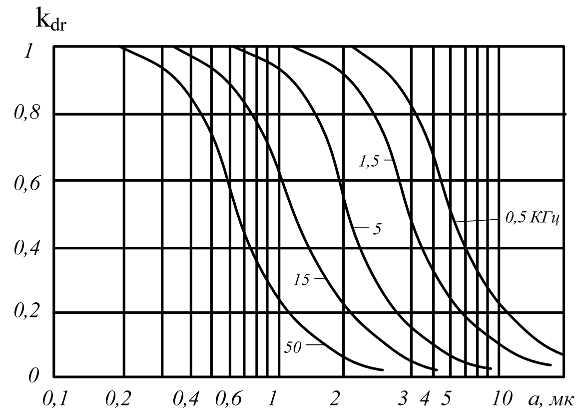

Figure-1. The dependence of the drag coefficient of the particle radius for discrete sound frequencies.

At increase in level of a sound up to 160 dB above for particles with radius 1-10 μm the number Re accepts values 1-10 and then drag coefficient k_{dr}:

$$k_{\mathrm{dr}} = \frac{1}{\sqrt{1+\left(\dfrac{\varpi \cdot \tau}{1+3/8 \cdot \mathrm{Re}}\right)^2}}, \tag{4}$$

where $\mathrm{Re} = \dfrac{\alpha \cdot U}{\nu}$,

ν - kinematic coefficient of viscosity of the environment;

U - speed of the movement of the environment or particles.

From a formula (4) it is visible, in case of the big sound level the level of hobby is function of amplitude of sound pressure, and it grows with increase in last.

Dynamic η and kinematic ν coefficients of viscosity of the environment (gas or liquid) depend on environment temperature and increase with increase in temperature (at liquids decrease at increase in temperature) and can be taken from help these dependences of viscosity of environments on temperature.

THE COMBINED OPTICAL-ELECTRONIC DEVICE FOR DETERMINATION OF PARAMETERS OF DISPERSE PARTICLES

The developed mode of the analysis of engine oils allowing to carry out integrated assessment of whether pollution of oil is result of wear of details of the engine with education in oil of metal particles or it has character of aging of oil with education in it charcoal particles is implemented in the device for determination of parameters of disperse particles [16].

The block diagram of the device for determinations of parameters of disperse particles is submitted to in Figure-2.

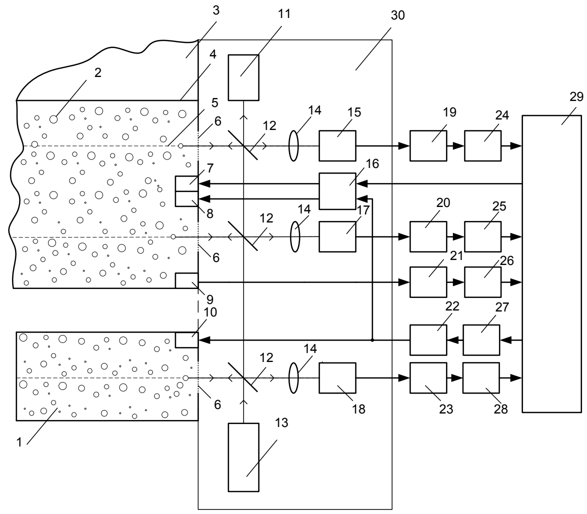

Figure-2. The block diagram of the device for determination of parameters of disperse particles.

The device realizing the offered method contains a reference basin with pure oil 1; the optical measuring link of monitoring of charcoal particles located below the top level of oil 4 at height of the minimum level of oil 5 in an engine 3 case; the optical measuring link of monitoring of metal particles located in the bottom of the oily underpan of a case of the engine; the laser 13 as a source of probing radiation; observation ports 6; beam splitters (translucent mirrors) 12; luminous trap 11; lenses 14; CCD arrays 15, 17, 18; temperature sensor 9; ultrasonic radiator of the channel of determination of charcoal particles 7; ultrasonic radiator of the channel of determination of metal particles 8; ultrasonic radiator of reference channel 10; amplifier 21; analog-to-digital converters 19, 20, 23; DSP processors 24, 25, 28; digital/analog transformer 27; generator of ultrasonic oscillations 22; switch 16; electronic computer 29. Optical part of the device is placed in the casing 30 protected from an outside flare and from hit of dust and moisture [16].

The device functions as follows. The researched disperse system 2 contacts to probing radiation with wavelength λ, which is generated by the laser 13 and ultrasonic oscillations created by radiators of ultrasonic oscillations 7, 8, 10, respectively, in channels of the analysis: charcoal particles, metal particles and in reference. Through beam splitters the 12th probing radiation through observation ports 6 is brought to the dispersing environment (a continuous phase) 2. When passing this wave through the researched disperse system there is a dispersion, reflection and absorption of radiation. Scattered and the reflected (under small angles concerning a traveling direction) from dispersible particles the 2nd radiation passes through observation ports 6 and gets on beam splitters 12 which direct it to lenses 14. Lenses 14 project radiation directly on CCD arrays 15, 17, 18, respectively, channels of charcoal particles, metal particles and reference. Further the received image from CCD arrays 15, 17, 18 will be transformed from the analog form

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in digital by means of analog-to-digital converters 19, 20, 23 and comes to DSP processors 24, 25, 28 and further in the form of the digital signal characterizing key parameters of oil arrives for later processing and registration for a computer 29. For the accounting of change of temperature of oil in a case of the internal combustion engine the temperature sensor 9 from information through which amplifier 21 and ATsP 26 also comes to a computer 29 is entered. The computer coordinates operation of all nodes of system, namely, controls process of digitization of a signal from CCD arrays and the temperature sensor, by means of analog-to-digital converters 19, 20, 23; controls operation of the ultrasonic oscillator 22 via the digital/analog transformer 27 and the switch 16; processes and registers results of measurements. With an ippolzovaniye of mathematical model of optimum interaction of ultrasonic fluctuations with disperse particles, expect parameters of the influencing impulses the PC so that fluctuations of a surface of a disperse particle happened under the harmonious law to own frequency f_n. At the same time consider temperature of disperse system and characteristic time of attenuation of fluctuations of disperse particles at the expense of viscous forces.

The device begins to function at the time of inclusion of ignition, and his work is divided into three stages: the start moment, the engine warming up moment, the moment of normal operation of the engine at a working temperature.

The algorithm of the PC (microcontroller) of the developed device has provided assessment of coefficients of hobby of particles according to the received images of the fluctuating particles on the expressions and help data which are written down in memory of the microcontroller, and determination of density and mass of these particles in the studied stream described earlier.

As a result of operation of the microcontroller on the set algorithm by means of registration not less than two images of particles are defined parameters of the movement of a stream - the field of speeds of particles, the size, a form of particles, and, by means of registration of series of images within at least two periods of sound vibrations taking into account a relaxation of particles in a stream of the fluctuating particles in the acoustic field values of density and mass of substances of the particles weighed in a stream are defined with all the data obtained earlier.

At the first stage at the time of switching on of ignition, first, depending on temperature of oil the frequency of ultrasonic radiators is selected, secondly, survey of two channels alternately is conducted: the reference channel - the channel of metal particles and the reference channel - the channel of charcoal particles for detection of percentage of charcoal and metal particles.

At the second stage of heat-up of the engine, first, depending on heating the frequency of ultrasonic oscillations changes, secondly, as well as at the first stage, survey of two channels alternately is conducted: the reference channel - the channel of metal particles and the reference channel - the channel of charcoal particles for detection of percentage of charcoal and metal particles.

At the third stage according to the received images in channels of the analysis receive distribution curves of the sizes of particles. Besides, at all stages monitoring of ratios between averaged data of the reference channel and channel of the analysis of metal particles and data of the reference channel and channel of the analysis of charcoal particles for determination of an integral index of impurity of engine oil and their comparing with the existing standards is carried out.

Thus, the considered optical-electronic device allows to increase significantly informational content of data for assessment of concentration, the size and a form of the weighed metal and charcoal disperse particles which are in oil, and in particular gives the chance to control quality of operation of the engine, the remained resource of work of oil before his replacement.

CONCLUSIONS

a) Opto-electronic method of engine oils analysis and optical-electronic device for monitoring the quality engine oils was developed.

b) The offered device for quality control of engine oils allows to increase informational content of the weighed metal and charcoal disperse particles this for assessment of concentration which are in oil, and in particular, it's gives the chance to control the remained resource of work of oil before its replacement.

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