Cleaning of technical oils by powder filter materials

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Abstract. The results of the study of powder filter materials (PFM) in comparison with the serial net and paper filter elements used for oil cleaning are given, as well as the effectiveness of their use for cleaning technical oil is substantiated. The possibility of promising use of powder filter material for cleaning engine oil is shown. As an example of the effective use of powder filter material, an example is given of oil cleaning in the process of engine running. A tangential filtration device for used engine oil is described. In the process of research, the range of fineness of cleaning motor oil with powder filter materials ranged from 5 to 70 microns.

1. Introduction

The operation of modern machines and mechanisms is unthinkable without the use of lubricants. Lubricants reduce friction losses, reduce parts wear, remove heat from friction zones, protect parts from corrosion, and remove wear products and other contaminants from friction surfaces in the operation process. A process of continuous accumulation of contaminants occurs in lubricants, leading to a gradual deterioration and loss of the required operational properties during operation under the influence of high temperatures and pressures, when contacted with metal surfaces, water, fuel and air. It is obvious that timely cleaning of lubricants increases the reliability and durability of equipment; it reduces the material costs for the purchase of additional petroleum products. Moreover, methods of cleaning make it possible to restore the required operational properties of used oils, thereby to re-use them secondary in operation [1, 2].

Paper, glass, ceramic, fabric, felt, and polymer filter materials are widely used nowadays. Powder filter materials (PFM) made of metal powders take a special place due to their advantages [3, 4]. They are more durable and resistant to corrosion; they can operate in a wide range of temperatures; they are subject to machine processing and welding; they have high thermal and electrical conductivity [5].

The main advantage of PFMs compared with other materials is the possibility of multiple regeneration compensating for their higher cost [6].

One of the main methods of cleaning is the filtering method based on the use of a wide range of filter materials [5, 7]. In references [1, 5] it is shown that powder filter materials from bronze powders, despite the intense competition of cheaper paper filters, can be successfully used for cleaning technical oils.
2. Results of experiments and their discussion

The performance studies of bronze filter elements of disc-shaped form in comparison with serial net and paper filter elements used for cleaning oil in the hydraulic system of YuMZ-6 tractors were carried out in references [1, 5]. Powder filter elements had a cleaning fineness of 25–30, 40, 50, and 70 μm and consisted of a set of rings (40 pieces) 2.5 mm thick of a disc-shaped form with an outer diameter of 61 mm, a hole diameter of 24 mm and a height of 5 mm. Paper filter elements (2 pieces) of the Regotmas type (with a double corrugated filtering surface) 601T-1-06 TU 112-04-86 had a cleaning fineness of 25–30 and 40 μm. Net filter elements 60-080 GOST 12242-78 (consisted of 18 rings of disc-shaped form) had a cleaning fineness of 80 μm.

Conducted comparative tests showed that all types of filter elements had a satisfactory performance in the hydraulic system of YuMZ-6 tractors at a different cleaning fineness. Paper filter elements had the highest dirt-holding capacity. Investigations of the intensity of clogging of various types of filter elements (dirt-holding capacity) before the actuation of the safety valve (0.28 MPa) depending on the amount of pollutant introduced into the hydraulic system were carried out by pollution with quartz sand. Portions of quartz sand weighing 20 and 40 g, thoroughly mixed with oil M10-B2 GOST 8581-78, were put every 3 minutes into the hole in the cover of the hydraulic tank housing.

Analysis of the data showed that the amount of quartz sand required for contamination for paper filter elements with a cleaning fineness of 40 μm makes 600 g, with a cleaning fineness of 25–30 μm, it is 440 g; for net filter with a cleaning fineness of 80 μm, it is 160 g and for powder filter with a cleaning fineness of 25–30, 40, 50 and 70 μm, it is 280, 180, 240 and 200 g, respectively. In other words, paper filter elements have 2-3 times more dirt-holding capacity than powder and net ones. This is explained by a more developed (due to corrugation) filtration surface. In turn, powder filter elements have 1.1–1.75 times more dirt-holding capacity compared with net ones due to the installation of a larger number (2 times) of the first ones in the filter housing. However, despite the fact that paper filter elements have the highest dirt-holding capacity, they are disposable products (single-use), while net and powder filter elements can be regenerated. Restoration of filter elements was carried out by blowing air.

Similar data was obtained at the Borisov Autohydrousilitel Plant when conducting comparative tests of the same powder filter elements with a cleaning fineness of 50 μm, assembled from ten disc-shaped rings, with serial net filter elements used for cleaning P oil (substitutional product of 22 turbine and M20A industrial oils) in the power steering pump system of a KamAZ vehicle [1, 5]. As a result of the tests, it was found that, firstly, powder filter elements provide high-quality oil cleaning; secondly, the dirt-holding capacity of the powder element is almost commensurate with the dirt-holding capacity of a serial filter element (on average, 65.8 and 62.8 g, respectively); thirdly, the hydraulic resistance of powder filter elements is 2–2.5 times higher.

Powder filter materials from tin-phosphor bronze powders are also a promising material for the mechanical cleaning of engine oil when running engines. It is known that the internal combustion engine (ICE) is one of the most complex and expensive aggregates for tractors, combine harvesters and other vehicles. While in operation, it serves out its motor potential, therefore, it is subjected to major repairs at the engine-repair enterprises in order to extend the service life, saving energy and financial resources. During such repair, replacement or restoration of worn parts and engine run-in are performed. Run-in of the internal combustion engine is the final operation, which largely determines its further post-repair resource. In the process of running, the engine wear rate is higher than under normal conditions of its operation. Figure 1 shows the dependence of the concentration of contaminants in the engine oil on the time of engine operation, during which the full alignment of mating parts occurs. Full alignment of mating parts occurs during the technological (bench) and primary operational running-in period [8]. As can be seen from Figure 2, during the technological run-in period, an increase in the concentration of contamination occurs most intensively. This is due to the fact that during the technological run-in, the engine oil of the engine receives the largest amount of wear products, as well as operational and repair-technological contaminants. At this stage,
contaminants from the air also get into the oil and products of incomplete combustion of fuel are generated.

**Figure 1.** The dependence of the concentration of contaminants in the engine oil on the time of engine run-in.

**Figure 2.** Contaminant particle size distribution during engine run-in.

The used engine oil is recycled or used for other needs after run-in. It should be noted that the used oil has a sufficient reserve of operational properties, but at the same time the content of mechanical impurities in it is 1.5–2 times higher than the limit value [8].

For cleaning the engine oil, it is proposed to use the equipment [7, 9] (Figure 3) with repeatedly regenerated filter elements [10].

**Figure 3.** Equipment for oil cleaning [9]: 1 - inlet pipe, 2 - outlet pipe, 3 - tank, 4 - control panel, 5 - cleaning unit, 6 - centrifuge, 7 - hydraulic pump, 8 - final cleaning tank, 9 - reserve tank, 10 - pre-cleaning tank, 11 - coarse filter, 12 - fine filter, 13 - connecting pipe, 14 - engine, 15 - distribution plate, 16–20 – valves.

The equipment works in the following way. Preliminary cleaned oil, which was previously used during the run-in, comes from the tank 8 and fills the engine oil crankcase; clean oil is filled from the
tank 9 to the required level. Pump 7 produced pre-start pumping of oil with closed 21 and open 22 valves. Engine run-in was performed according to a predetermined program with the valve 22 closed. After the run-in was completed, the hydraulic pump 7 was turned on, which sent used oil being in the crankcase through the nozzle to the centrifuge 6 fixed to the engine 14. The oil was poured into the crankcase bypassing the engine through the distribution plate 15 sump, and then again repeatedly passed through a centrifuge. Next, closing the valve 22 and opening the valve 21, the oil cleaned by the centrifuge using the hydraulic pump 7 was supplied from the engine crankcase to the tank 10. Applying excess air pressure, the oil from the tank 10 flowed to the coarse filter 11 and fine filter 12, from where it goes to the tank 8 for subsequent reuse.

Such design of the equipment makes it possible to produce oil without residue, without reducing the quality of reused engine oil, constantly adding fresh oil to it, as well as completely eliminate energy consumption necessary for oil heating, and eliminate the need to store and utilize used oil. This equipment can also be used for the prophylactic cleaning of fresh oils, in which the amount of contaminants is above the permissible limits. It can be used at the enterprises of repair and engineering service of the machine-tractor fleet. Figure 4 shows several variants of filter elements for oil cleaning. The developed filter elements provide for the fineness of cleaning from 5 to 70 microns.

![Filter elements for oil cleaning](image)

At the present time, the most preferable is the use of PFM products based on tin-phosphor bronze powders for cleaning engine oil during the major repair of diesel engines, as well as in stationary equipment for cleaning engine oil before pouring it into the corresponding equipment systems.

In principle, it is possible to use filter elements made of PFM for cleaning engine oil by direct installation in agricultural vehicles, but there are additional difficulties with the maintenance of equipment related to the need to regenerate filter elements, otherwise the use of relatively expensive material becomes impractical.

Used engine oil can be cleaned with a high degree of purity using a tangential filtration device. Figure 5 shows the appearance of a tangential filtration device for used engine oil. The fracture structure of a two-layer filter element is shown in Figure 6.

The device operates in the following way: used oil from the tank 1 by means of the oil pump 3, which circulates the oil in the system, is supplied to the coarse filter 2, and then to the tangential filter 5 with a filter element based on composite powder filter material. The cleaned oil goes through the pipeline 8 into the tank for cleaned oil (filtrate) 6. Ball valves 7 are installed in the device to adjust
the oil pressure. Manometers 4 are provided in the system to control the oil pressure. The connection of the component assemblies of the head sample of the device for tangential cleaning of used engine oil was made using a multilayer metal-plastic pipe. The working medium in the experiments was used motor oil. The device successfully passed full-scale tests in laboratory conditions.

Figure 5. Appearance of a tangential filtration device for used engine oil: 1 - tank with contaminated heated oil; 2 - coarse oil filter; 3 - oil pump; 4 - manometers; 5 - tangential filter; 6 - tank with cleaned oil; 7 - ball valves; 8 – pipeline.

Figure 6. The fracture structure of a two-layer filter element material based on bronze powder.

A study of the content of solids in the used and filtered oil was performed on an automatic image analyzer "Mini-Magiscan" of Joyce Loebl company (England). The appearance of the device for determining the particle size is shown in Figure 7. The results of the research are presented in Table 1. The diagrams of the particle size distribution of the contaminant are presented in Figures 8 and 9.

Figure 7. Laser diffraction analyzer of particle size distribution Malvern Mastersizer 2000 with automatic module of dispersion and supply of HydroS sample to determine the fineness of cleaning.

Table 1. Research results of used and filtered oil.

|                  | Used oil | Filtered oil |
|------------------|----------|--------------|
| **Particle size**|          |              |
| 0-5 µm           | 1427     | 853          |
| 5-10 µm          | 301      | 16           |
| 10-20 µm         | 117      | 0            |
| **Number of particles** | 3         | 175         |
According to the research results of filtered oil, it was found that the maximum particle size of the contaminant contained in the oil was 9 µm, and the content of the contaminant particles with a size more than 5 µm – less than 5%.

During the full-scale tests, the pressure drop has not changed on the filter element, indicating a high resource of the device for tangential cleaning of used engine oils, exceeding the service life of the known similar direct-flow devices at least twice.

3. Summary and conclusion
Comparative investigation of filtration by net, paper and powder filter materials confirmed the possibility of using PFM for cleaning technical oils. It has been found that a higher dirt capacity of paper filters is compensated by repeated regeneration of powder filter materials due to a more developed corrugated surface.

The possibility of promising use of powder filter material for cleaning engine oil is shown. The effective use of powder filtering material was given by the example of oil cleaning in the process of engine run-in. The possibility of using PFM in tangential filtration of used motor oils was confirmed. The tests made it possible to develop and introduce into production a number of products designed also for cleaning oil in stationary equipment.

In the process of research, the fineness range of cleaning engine oil by powder filter materials was from 5 to 70 µm.

References
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