TRIBOTECHNICAL DIAGNOSTICS OF AGRICULTURAL MACHINES

Zdenek Ales, Martin Pexa, Jindrich Pavlu
Czech University of Life Sciences Prague
ales@tf.czu.cz, pexa@tf.czu.cz, pavlu@tf.czu.cz

Abstract. The main objective for the present companies is to ensure reliability and operation of machines with minimal costs. These factors are associated with monitoring of the technical condition of machinery. The technical condition of machinery can be, for example, evaluated on the basis of analysis of used lubricants, within the tools of tribotechnical diagnostics. There are several tribotechnical methods how to assess the current technical state of the used lubricants (viscosity, water content, flash point, content of particles, acidity). One of the modern methods how to detect wear particles is LaserNet Fines which is a suitable technique for machine condition monitoring. In terms of condition monitoring it is necessary to find out extension and type of concrete wear. Even with simple methods it is possible to reveal serious problems which could cause damage of machines. Furthermore, in case of damage of machinery, lubricants have a negative influence on environment, especially in the context of soil, water and food chain contamination. Rigorous application of tools of tribotechnical diagnostics can properly ensure reliability and increase of maintenance efficiency. The objective of the paper is to show the description and examples of tribotechnical methods used for determination of the technical state of used lubricants utilized in agricultural machinery.

Keywords: wear, lubrication, diagnostics, maintenance.

Introduction

Quality product is dependent on reliable and serviceable manufacturing facility, which is influenced by effective and timely performed maintenance, including checking and refilling of lubricants and other vital fluids. Downtimes caused by failures of machinery operation are due to a number of external and internal influences and processes that occur directly in the machines. These influences result in changes in the properties of machine parts. Such changes are the primary causes of technical failures. A summary of these processes is called the failure mechanism. According to different combinations of factors that affect the damage of functional areas, there can be distinguished these categories: wear, corrosion, deformation, local surface deformation, cracks and fractures, other damages [1].

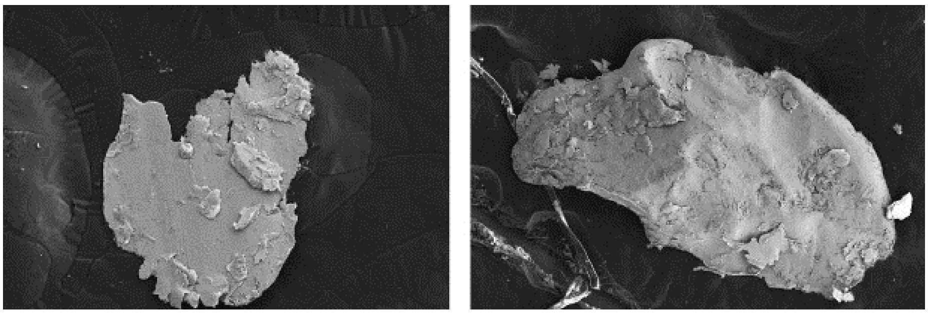

Fig. 1. **Shape of fatigue particle** [2]

Wear is a permanent adverse change on the surface or dimensions of rigid bodies, caused by the interaction of functional surfaces, or a functional surface and medium which causes wear. Wear occurs as a removal or relocation of particular matter from the surface by mechanical effects, sometimes accompanied by other factors, such as chemical or electrochemical [3]. Generally, there can be classified six basic types of wear: adhesive, abrasive, erosive, cavitation, vibration and fatigue.

Materials and methods

There are several methods how to assess the technical condition of lubricating oil. For the oil analysis in these experiments there were the following methodologies used:

- Determination of the level of contamination by solid particles;
- Determination of the flash point;
- Determination of the water content.

In order to determine the number and type of particles in lubricating oil there can be used the desktop particle counter and particle shape classifier LaserNet Fines-C. This analytical equipment can analyze the hydraulic fluids and other lubricating oils from different types of machinery and on the basis of the analysis to assess their current technical condition and suggest possible measures for their maintenance. The observation is based on evaluation of morphology and wear particles number generated during the operation of machinery and equipment. LaserNet Fines-C consists of two components. The first part is the analyzer which analyzes the taken samples, the second part is a personal computer, which is necessary to analyze and evaluate the data from the analyzer. Preparation of the oil sample for analysis is thorough agitation and removal of air bubbles in an ultrasonic bath. The analysis is carried out after removing the sample from the bath and entering the necessary data about the oil sample into computer. Then the oil is sucked into the LNF analyzer and the laser beam is radiating through the oil sample in the flow cell (Fig. 2). The formed picture is zoomed and captured on video camera. All captured pictures are processed in computer via software. The whole process of analysis takes about three minutes and the results of the analysis are displayed to the operator of the analyzer after the evaluation of the oil sample. One of the results of the analysis is cleanliness codes according to ČSN ISO 4406 [4] that describes the particle number in fluid – oil. According to this standard particles are divided into three categories: >4 μm, >6 μm a >14 μm. The standard describes the particle number per one milliliter of the oil sample. It is possible to obtain the cleanliness code by manual counting on appropriate microscope or using an automatic measurement device. The automatic measurement devices are commonly based on optical detection of particles, or based on flow/pressure rate measurements while the sample is flowing through the defined filter. LaserNet Fines-C was used for the carried out long-term stability test of biodegradable transmission oil and mineral transmission oil used in tractor end rear gear boxes dependent on operating time [5].

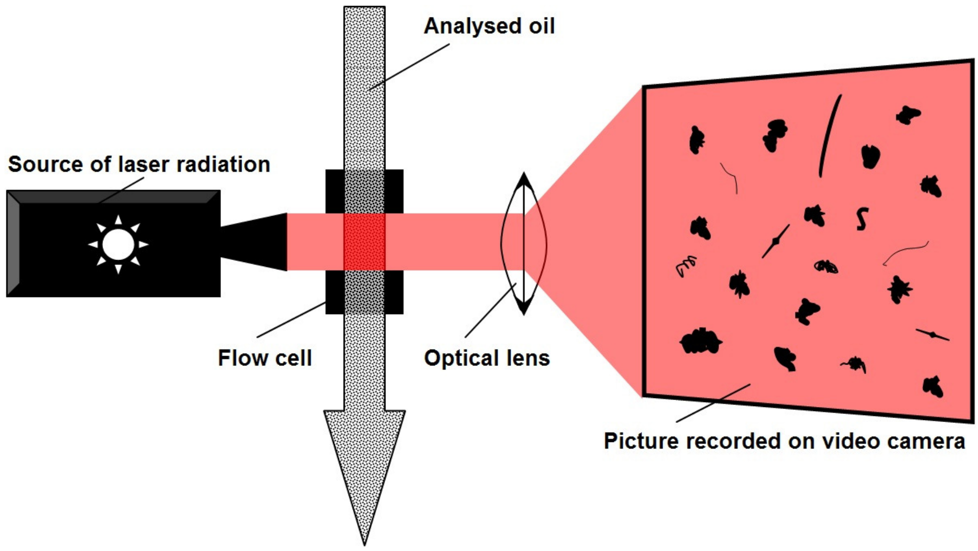

Fig. 2. **Principle of LNF analysis [6]**

The flash point is the lowest temperature at which there is enough flammable vapor to ignite when an ignition source is applied. Measuring of flash point requires a specified ignition source. At the flash point, the vapor may cease to burn when the source of ignition is removed [7]. The flash point of lubricating oils is carried out in an open cup. The exact procedure of testing is described in the ISO standard ČSN EN ISO 2592. The change (decrease) of the flash point is caused by permeation of foreign liquids and gases having a significantly lower flash point then lubricating oil itself. These foreign materials are commonly represented by other vital fluids used together with lubricating oil. Flash point temperature is an important parameter for motor oils. The second test describes the measured values of flash points of several motor oils.

Determination of the water content in lubricating oil is carried out with both, the qualitative and quantitative [8; 9] point of view. Presence of water in oil is unwanted because can affect or cause such as: corrosion, additives degradation, oil foaming, viscosity change, oxidation stability decrease, sediment increase etc. Water or moisture always deteriorate the quality of lubricating oil, but some trace amount of water is always presented and can not be fully inhibited. The exact procedure and type of tests are described in appropriate standards. The qualitative tests include visual examination and the crackle test according to the standard ČSN 65 6231 [10]. The crackle test is a simple test to identify the presence of free and emulsified water suspended in oil, provided a few simple rules are followed. The principle of the test is to raise the hot plate temperature to 160 ºC. Then using a clean dropper, place a drop of oil on the hot plate. According to the behavior of the oil droplet the approximate amount of the water content is determined. The last test shows how elementary tribotechnical method can detect water in the hydraulic system.

Results and discussion

During the first experiment the operating time was monitored and kept tracked almost a year and a half depending on calendar time. Seven oil samples (EP Gear Synth, Gyrogate PP 90) were taken from the gear boxes during this period. The realized analyses with the particle counter LaserNet Fines are very complex. According to the results mineral transmission oil Gyrogate PP 90 contained more particles in comparison with biodegradable transmission oil EP Gear Synth 150. A deeper analytical view in Figure 3 shows that mineral transmission oil Gyrogate PP 90 has lower ability to form a proper boundary oil layer compared to the other transmission oil. That is apparent due to higher increase of fatigue particle fraction during the experiment. It is necessary to mention that transmission oil Gyrogate PP 90 was filled into the gear box which was only rinsed out with clean oil. Nevertheless, the experience from agricultural companies shows that there is not time to proper disassembling and cleaning before each oil change.

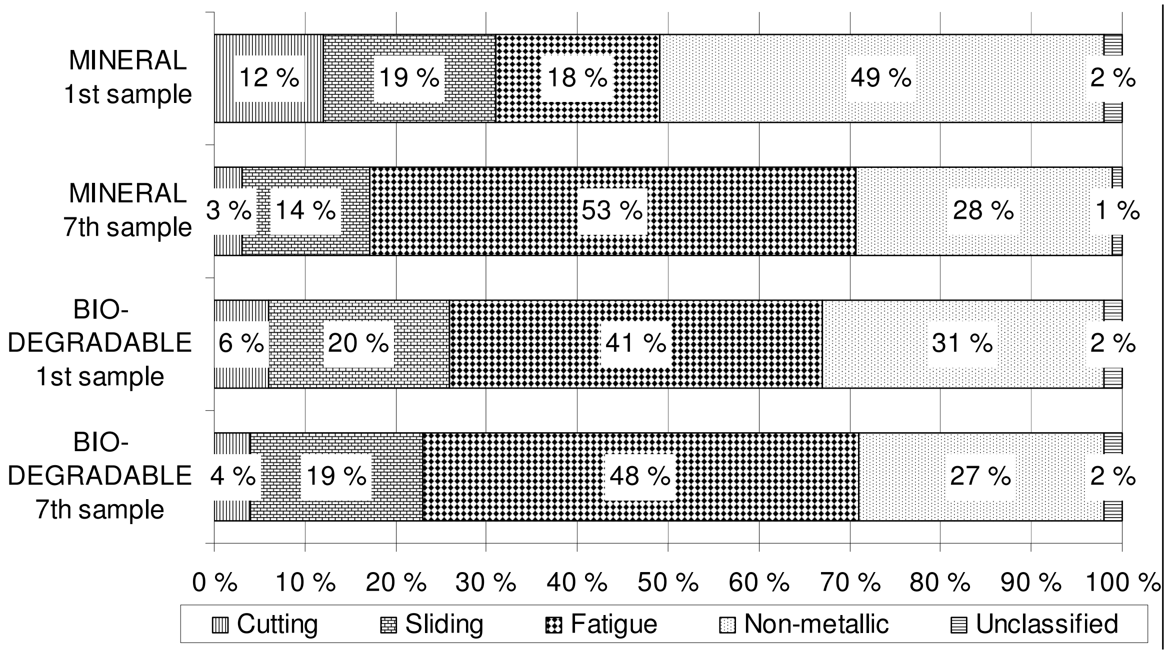

Fig. 3. **Percentage fraction of different particles in transmission oil samples**

The second experiment was focused on determination of the flash point of the used oils in the automobiles. Table 1 represents the results of the analyses. The values of the flash point for compression ignition (CI) engines meet the requirements for motor oils. The opposite situation is in all measured spark ignition (SI) engines. Low flash point of spark ignition engines can cause a poorly adjusted fuel system, which is supplied with more fuel than necessary. This possibility is excluded because modern engines are controlled with lambda regulation which maintains an appropriate balance of fuel-air mixture. A more likely possibility is inappropriate operation of the vehicles, which are operated only for short drives, the engine is not operated within proper temperature and thus more fuel condenses on the walls of the combustion chamber and flows into the crankcase.

Table 1

Flash point of used motor oils

Nr.	Automobile	Viscosity classification	Engine type	Engine operating time (km)	Oil operating time (km)	Flash point (ºC)
1	Fabia	SAE 10W-40	SI	119 282	2 759	65,58
2	Octavia I	SAE 5W-40	SI	81 465	14 784	70,48
3	VW CADDY	SAE 5W-30 LL	SI	41 481	20 300	76,53
4	Renault Clio	SAE 10W-40	SI	186 650	16 550	83,48
5	Peugot 106	SAE 10W-40	SI	123 034	14 928	85,60
6	Fabia	SAE 10W-40	SI	77 900	14 400	95,70
7	Fabia	SAE 5W-40	SI	116 327	14 583	111,60
8	Octavia I	SAE 5W-30	CI	185 346	10 891	193,53
9	Citroen Jumby	SAE 5W-30 LL	CI	120 960	30 774	196,58
10	Octavia I	SAE 5W-40	CI	401 542	15 386	204,58
11	Octavia II	SAE 5W-40	CI	221 026	12 300	205,70
12	Octavia I	SAE 5W-40	CI	159 179	15 482	207,53
13	Ford Transit	SAE 10W-40	CI	423 745	13 488	207,70
14	Renault Megan Scenic	SAE 5W-40	CI	99 853	19 697	209,58
15	Ford Mondeo	SAE 5W-30	CI	170 240	30 088	210,58

The third experiment revealed water in the hydraulic system of the ALPHA HARDI self-propelled sprayer. The task of the experiment was to detect the cause of inappropriate color of the hydraulic fluid. Figure 4 represents 4 samples – the owner of the sprayer tried to dilute the whole content of the hydraulic fluid with new one. During dilution he took 5 samples of the hydraulic fluid for analyses. The first assumption led to suspicion that it might be a chemical reaction. The simple crackle test showed that over 2 % content of water was presented in the hydraulic fluid. Such a contamination was caused by not properly trained operator of the machinery.

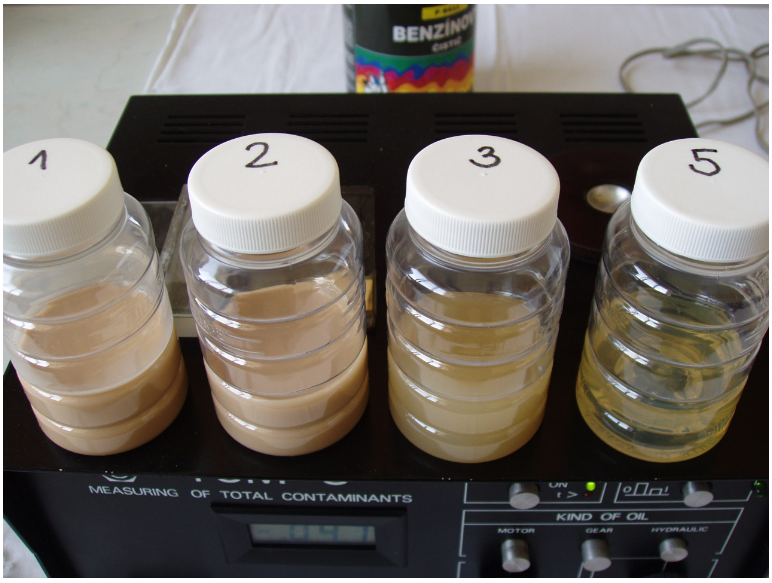

Fig. 4. **Hydraulic fluid samples contaminated with water**

Conclusions

The given methods of monitoring of the technical state of lubricating oils are sufficiently accurate and besides that provide additional information about the technical state of machinery.

In spite of the fact that mineral transmission oil Gyrogate PP 90 has lower ability to form a proper boundary oil layer, this lubricant is more than seven times cheaper compared to biodegradable oil. This is the main issue why most companies prefer to purchase mineral oil. The question is if it is wise to give the priority to economic factors only. The current trend indicates that the entrepreneurs are compelled by legislation to use biodegradable fillings in their machinery. Thus, such a trend is commonsensible in order to achieve sustainable growth.

The presented results also show the influence of fuel and water contamination of lubricating oil. Nevertheless, it is necessary to conclude that for effective operation of machines it is crucial to ensure proper diagnostic tools in order to determine their technical state.

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