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ANALYSIS OF SYNTHETIC OIL SAMPLES DURING AN OPERATING TEST

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This paper presents the results of analyses of ecological synthetic oil samples during an operating test. The operating test of oil was performed within cooperation of the Department of Transport and Handling and Slovnaft, a. s. (joint stock company). The analysis of ferrographic samples was performed in the laboratory of the department, and other analyses were done in an accredited Wearcheck Laboratory at Almásfüzitő, Hungary.

Keywords: kinematic viscosity, total acid number, viscosity index, ferrography

The operating test of the MOL Farm UTTO Synt oil followed after laboratory tests conducted at the Department of Transport and Handling. The laboratory test was used to investigate the effect of oil on flow characteristics of the UD 25 hydraulic pump, and samples of oil were simultaneously analysed.

The UD 25 hydraulic pump is used on the Zetor Forterra 114 41 tractors. The MOL Farm UTTO Synt oil was used in the tractor transmission hydraulic circuit. The oil was sampled from the tractor in the working range of 450 engine hours (EH) and 900 engine hours. These samples were subsequently analysed in the accredited Wearcheck Laboratory at Almásfüzitő and in the laboratory for analysing ferrographic samples at the Department of Transport and Handling.

At the present time, hydrostatic systems are widely dispersed in industry. They provide various types of motion. Power transmission is performed by means of hydraulic fluid. Hydraulic fluid needs service and the monitoring of operating parameters (Majdan et al., 2008). Therefore, it is extremely important to replace mineral oils with plant-based oils or synthetic oils (Tkáč et al., 2010).

From the viewpoint of hydraulic fluid utilisation in a machine, it is important to know the operating characteristics of a fluid, i.e. to know the effect of fluid on the technical condition of hydraulic system components (Tkáč et al., 2008; Jablonický et al., 2007).

Material and methods

We have used a newly developed ecological fluid, which is made of a synthetic base fluid based on polyalphaolefins. We used this fluid because it has a high chemical stability and miscibility with mineral oils that are currently used in tractors in Slovakia. During the test, we used a new ecological fluid MOL Farm UTTO Synt produced by MOL Group, Hungary. This fluid belongs to universal transmission hydraulic fluids for tractors. The technical parameters of oil are specified as follows: kinematics viscosity at 40 °C = 58.14 mm².s⁻¹; kinematic viscosity at 100 °C = 10.22 mm².s⁻¹; viscosity index = 165; pour point = -42 °C.

Ferrographic analysis of oil

The aim of a ferrographic study is to identify the quantity and size of wear particles in oil samples. The following oil samples were studied: samples of a new oil, and oil samples after completing 450 engine hours and after completing 900 engine hours. Wear particles have a significant effect on the abrasive wear of friction pairs in transmission hydraulic circuits of tractors. These contaminants degrade the hydraulic oil used.

Figure 1a MA 1 magnetic analyser

Figure 1b KAPA 6000 microscope

Pollution particles, despite oil filters located in the tractor transmission hydraulic circuit, should continue to grow during the operating test. These particles tend to agglutinate during the test and aggregate into larger particles. The technological procedure of ferrographic analysis was carried out in the laboratory of the Department of Transport and Handling (Faculty of Engineering, Slovak University of Agriculture in Nitra).

The MA 1 magnetic analyser and KAPA 6000 microscope were used for the ferrographic analysis of oil samples. The MOL Farm UTTO Synt oil was diluted before ferrographic analysis in proportion of 2 : 1 with tetrachlorethylene to better highlight the pollution particles in the oil.

Physical and chemical properties of the ecological fluid

For measuring the total acid number (TAN), we have used a test by which acids were neutralised in the oil by adding potassium hydroxide (KOH). The volume of alkali reagent, which is required to achieve the neutralisation point, is a function of acid concentration in the oil.

When the oil oxidises, organic acids are produced. They are concentrated in the oil and cause TAN increasing. Like the kinematic viscosity, also the total acid number reveals a degraded fluid in which degradation processes occurred and antioxidant additives were more or less depleted, if the parameters were not changed otherwise, e.g. by an admixture of foreign acid substances with a lower or higher viscosity than the tested fluid (Majdan, 2012).

Kinematic viscosity is one of the parameters of fluids the value of which can rise and fall during operation. In some cases, the viscosity of oil can decrease during oil ageing at first, and as oxidation products increase, viscosity can change to grow. When assessing the kinematic viscosity of fluid, we therefore consider lower and upper limits that are or are not exceeded during operation. Limit values are determined by percentage, depending on the fluid type. For example, if the kinematic viscosity of a hydraulic fluid changes by more than 20 % as compared to the value of a new oil, the oil has to be replaced (Majdan, 2011).

Fluid viscosity varies with temperature. The rate of viscosity change with temperature is referred to by viscosity index (VI). Viscosity index is an empirical value used to quantify changes in viscosity in respect of temperature. The viscosity of a fluid with high viscosity index does not change so quickly with temperature as a fluid with low viscosity index (Exxon, 2009).

Figure 2 Wear particles in the sample of a new oil

Water content was determined by a coulometric method, which is one of the most advanced and accurate measurements of water from 5 ppm. Water is undesirable in oil; it can penetrate into it only as an external substance, e.g. by leakage through cooling circuits, an improper sealing of fluid systems, poor storage (rain), but also by condensation during a longer shutdown of a device (Intertribodia, 2010).

Water can be characterised as a catalyst of degradation – oil ageing; it can cause that some additives are washed out of the oil, the acid number increases, and thus the opportunity for corrosion in the device increases, too. When found that the amount of water is exceeded, measures may be taken, e.g. water can be removed by filtration (Majdan, 2011).

FTIR spectroscopy

The abbreviation FTIR stands for Fourier Transform Infrared, the preferred method of infrared spectroscopy. In infrared spectroscopy, infrared radiation is passed through a sample. Some of the infrared radiation is absorbed by the sample, and some of it is passed through (transmitted). The resulting spectrum represents the molecular absorption and transmission, creating a molecular fingerprint of the sample. Like a fingerprint no two unique molecular structures produce the same infrared spectrum. This makes infrared spectroscopy useful for several types of analysis (Thermonicolet, 2008).

The basis of FTIR spectroscopy is in the interaction of infrared radiation with the analysed material, where photons can be emitted from the material or absorbed into it. FTIR spectroscopy can be used to measure the content of soft impurities (water, glycol, etc.) as well as certain types of solid impurities (fibre, seal, etc.).

Results and discussion

In the samples of unused MOL Farm UTTO Synt oil, there were practically found no pollution particles. After completing 450 engine hours, oil samples contained wear particles of no more than 10 µm. At the same time, there were also clusters of small wear particles that have no negative impact on the transmission hydraulic circuit of the Zetor Forterra 114 41 tractor. After completing 900 engine hours, oil samples contained large clusters of small wear particles and large wear particles, too.

The ferrographic images of the synthetic oil were compared with a catalogue of wear particles. By comparing

Figure 3 Wear particles in the oil sample after completing 450 engine hours

Figure 4 Wear particles in the oil sample after completing 900 engine hours

with the images in the catalogue of wear particles, we found that they are particles of adhesive wear.

During the test, there were evaluated the main physical and chemical properties of the tested ecological fluid. Samples were evaluated in the accredited Wearcheck Laboratory at Almásfüzitő.

The evaluation of kinematic viscosity is based on the manufacturer's requirement stating that the value of kinematic viscosity must not exceed the tolerance of $\pm 10\%$. The values obtained during the test of ecological fluid are within the required tolerance, meaning that the fluid is in a good condition in terms of viscosity (Figure 5). The evaluation of fluid's TAN is important because of an

Figure 5 Kinematic viscosity at 100 °C

Figure 6 Total acid number

Figure 7 Viscosity index

Figure 8 Infrared spectrum of ecological fluid

increasing amount of acids in the fluid, which is characteristic for the ageing process and directly determines the degree of fluid degradation. The measured values of TAN (Figure 6) had a slightly increasing trend up to 450 engine hours, and TAN has not changed subsequently. Limit values were not exceeded; the fluid thus meets the requirements. Water content in the ecological synthetic fluid was so low that it could not be measured by instruments. During the test, the value of viscosity index (Figure 7) was within the limits specified by the manufacturer and is not a reason for changing the ecological fluid.

Fluid samples were submitted to FTIR spectroscopy. The infrared spectrum represents an imprint with absorption peaks that correspond to the frequency of vibrations between bonds of atoms.

In Figure 8, we can see a part of the infrared spectrum of the studied ecological synthetic fluid. In the field of around 1,600 cm⁻¹, it is possible to see an increasing peak with the rise of engine hours. A change in the peak size in this area is characteristic for the identity change of fluid. It follows that during the operating test there were foreign substance leaks in the fluid, causing mixing with other fluid. This peak change was caused by the mineral fluid being present in additional devices of the tractor. The fluid also contains resins, which are degradation products of the mineral oil.

Conclusion

This paper is focused on the analysis of a new ecological synthetic fluid MOL Farm UTTO Synt. The fluid was used in the Zetor Forterra 114 41 tractor.

Based on the analysis of ferrographic images and comparing with the catalogue of wear particles, it was found that the transmission hydraulic circuit of the Zetor Forterra 114 41 tractor is in the process of wear. Based on the increasing of peaks in the area characteristic for fluid identity, we discovered by FTIR spectroscopy that the ecological fluid is mixed with the mineral fluid through the additional device of the tractor. That was confirmed by the presence of resins as a typical product of mineral fluid degradation. Based on the evaluation of physical and chemical properties during the operating test, it is possible to see that the limits specified by the manufacturer were not exceeded, and the ecological synthetic fluid has good physical and chemical properties after 900 engine hours. In terms of ferrography, we recommended the fluid to be filtered in order to extend its technical life. At the present time, a new filtration device is therefore being designed at the Department of Transport and Handling.

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