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POLLUTION ANALYSIS OF NEW SYNTHETIC BIODEGRADABLE FLUID DURING DURABILITY TEST OF HYDROSTATIC PUMP

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This paper deals with the pollution evaluation of a biodegradable fluid, which was used as a working medium during the laboratory durability test of a hydrostatic pump. There was used a new synthetic biodegradable fluid MOL Farm UTTO Synt., developed and produced by MOL Group, Hungary. The fluid should have been practically used as a universal, common gear-hydraulic filling in agricultural machines. During the test, the pollution of used fluid was evaluated on the basis of cleanliness code, filtration of solid particles and ferrography. Based on results of cleanliness code, we could monitor the course of hydrostatic pump wear. After test completion, the fluid was subjected to filtration of solid particles and ferrography, where clusters of small particles and larger particles were detected. On the basis of their surface and shape, they were included in particles of adhesive wear. By the comparison method it was found that they are bronze particles located in the bearings of the hydrostatic pump used.

Keywords: pollution, synthetic fluid, ferrography, cleanliness code, filtration

At present, the European Commission more and more tightens the requirements for environmental protection, which in agriculture may result in a gradual replacement of conventionally produced fluids by biodegradable fluids. These fluids are expensive; therefore, it is important to monitor the properties directly affecting their service life.

The pollution evaluation of fluids belongs to important analyses because the presence of metal pollution particles in fluids acts as a degradation process catalyst, shortens their service live, and negatively affects individual parts of the hydraulic circuit (Majdan et al., 2012; Jablonický et at., 2012). The evaluation of new fluids can be carried out under operational or laboratory conditions. The advantage of laboratory tests is in the fact that they are less expensive and less time consuming. The fluid can be analysed using a laboratory device designed at the Department of Transport and Handling. This laboratory device serves for an accelerated durability test of hydrostatic pumps, monitoring the effect of the fluid used on the technical condition of the hydrostatic pump and other parts of the hydraulic circuit (Tkáč et al., 2008; Majdan et al., 2012).

Material and methods

The fluid was subjected to the laboratory accelerated durability test of the hydrostatic pump. The test was performed using the hydrostatic pump UD 25 used in the tractor Zetor Forterra. The durability test consisted in its cyclic pressure loading the parameters of which were determined under operating conditions and subsequently simulated on the laboratory test device. The test lasted for 106 of pressure cycles, and the effect of new biodegradable fluid on the technical condition of the hydrostatic pump was monitored (Tkáč, 2010). The fluid used is a newly developed ecological fluid made on the basis of polyalphaolefins. We have chosen this fluid because of its high chemical stability and miscibility with mineral fluids, which are currently used in tractors in Slovakia. It is the new ecological fluid MOL Farm UTTO Synt. produced by MOL Group, Hungary, belonging to the group of universal transmission hydraulic fluids designed for tractors. The main specifications of this fluid are listed in Table 1.

Table 1 Specification of new synthetic-based biodegradable fluid MOL Farm UTTO Synt

Parameters	Test method	Evaluation	Unit
Appearance	Visual	light, bright	–
Consistency at 15 °C	EN ISO 3675:2000	0.8681	$g.cm^{-3}$
Kinematic viscosity at 40 °C	EN ISO 3104:1996	58.14	$mm^2.s^{-1}$
Kinematic viscosity at 100 °C	EN ISO 3104:1996	10.22	$mm^2.s^{-1}$
Viscosity index	ISO 2903:1999	165	–
Pour point	EN ISO 3016:1999	-42	°C
Flash point	EN ISO 2592:2002	232	°C
Content of calcium	ASTM D 6481-99(2004)	0.318	%

Cleanliness code

The analysis of the biodegradable fluid in terms of the content of solid pollution particles is made using the CS 1000 device by Hydac (Figure 1). The principle of this device is based on optical detection of particles and based on that, the quantity and size of particles in the fluid used is evaluated. The test device analyses all pollution particles and they are at the same time grouped according to size 4 μm, 6 μm and 14 μm.

Filtration of solid particles

The filtration of solid particles was performed using the measuring kit FAS M2. The principle of filtration of solid particles (Figure 2) consists in fluid filtering (150 ml), the fluid being diluted by perchlorethylene (50 ml) before filtration, by an electrical vacuum pump through the filter unit. Part of the filter unit is a membrane filter disk on which

Figure 3 Ferrograph MA-1

pollution particles are captured. Thus obtained filter disks are subjected to microscopic analysis using the microscope Kappa 6000.

Ferrographic analysis

The aim of ferrographic analysis is to identify the quantity and size of wear particles in fluid samples. Wear particles have a significant effect on the abrasive wear of friction pairs in hydraulic circuits and also on technical life of hydraulic fluid. These contaminants degrade the hydraulic fluid used. During the test, pollution particles tend to agglutinate and aggregate into larger particles (Kohli et al., 2011; Shizu et al., 2012). The ferrographic analysis was performed in the laboratory of the Department of Transport and Handling. MOL Farm UTTO Synt. was diluted before the ferrographic analysis in proportion 2 : 1 with tetrachlorethylene to better highlight the pollution particles in the fluid.

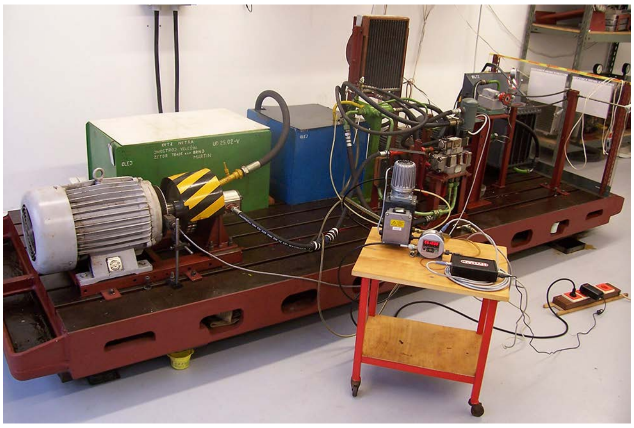


Figure 1 Measurement of cleanliness code during the laboratory durability test of the hydrostatic pump UD 25

Figure 2 Filter kit FAS M2

Results and discussion

One of the evaluation methods of fluid pollution is an evaluation according the standard ISO 4406 – 'Cleanliness code'. Fluid samples were evaluated every 250,000 cycles of

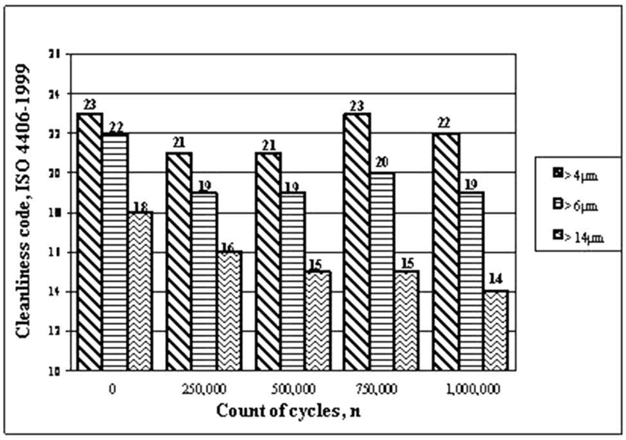
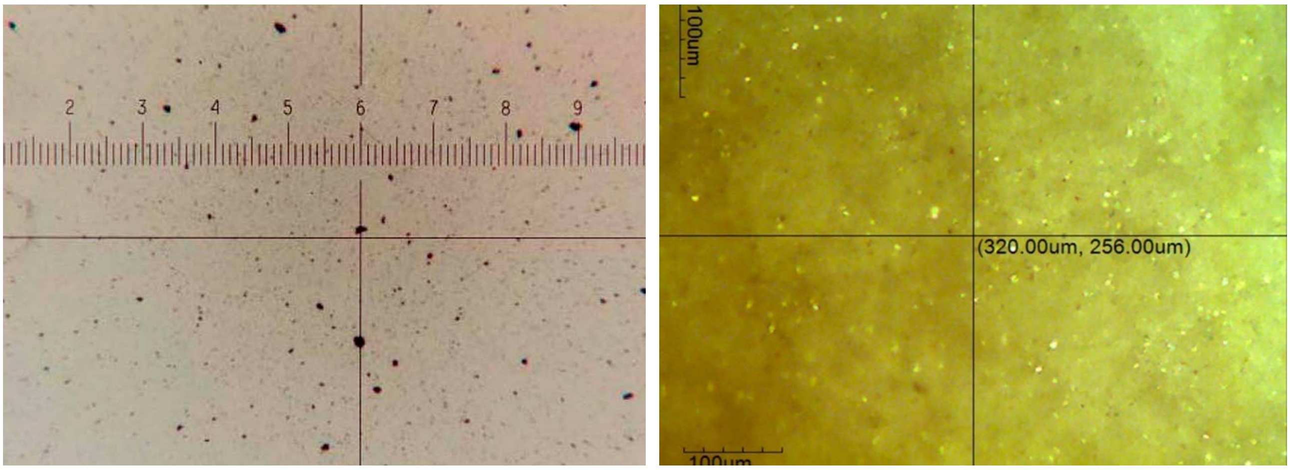
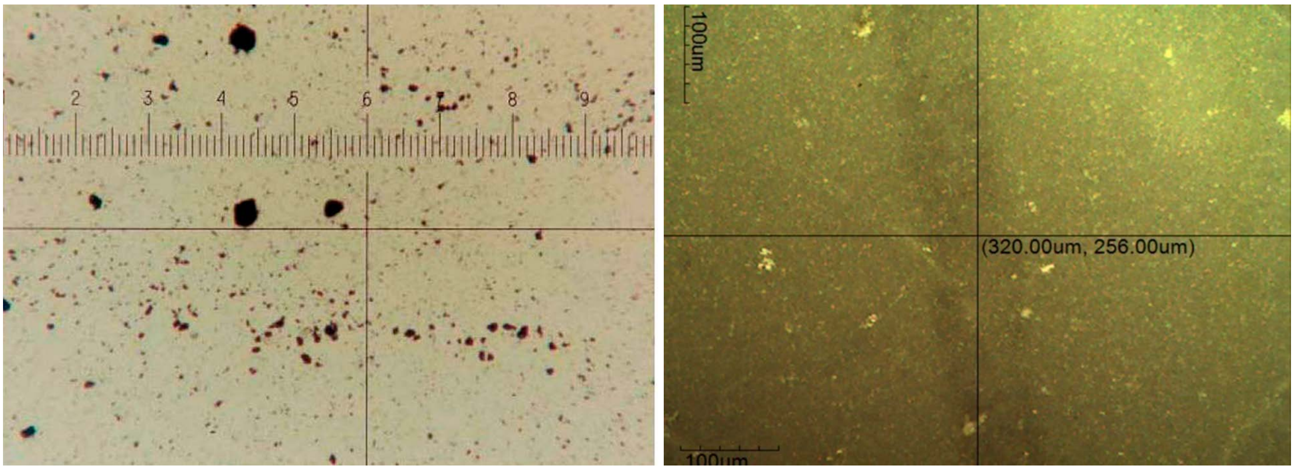


Figure 4 Result of cleanliness code measurement



a) b)

Figure 5 Filtration of solid particles of synthetic biodegradable fluid; a) reference (21/19/16); b) sample after 250,000 cycles



a) b)

Figure 6 Filtration of solid particles of synthetic biodegradable fluid; a) reference (22/20/17), b) sample after test completion (10^6 cycles)

pressure load. Figure 4 contains the results of fluid pollution based on the quantity and size of particles, which are classified into groups according to size.

On the basis of results of biodegradable fluid pollution measurements, it is possible to monitor the overall decrease of pollution particles compared to values of new fluid. A common case in operation is that the new fluid is usually polluted either by production products or by poor storage. Consequently, decreasing of the total number of solid pollution particles (up to 500,000 cycles) from values 23/22/18 (from 40.10^3 to 80.10^3 particles per 1 ml of fluid corresponding to class 23) to value 21/19/15 (from 10.10^3 to 20.10^3 particles per 1 ml of fluid corresponding to class 21) occurred due to filtration in the laboratory test device. Increasing of pollution particles occurred after 500,000 cycles, which can be attributed to the continuing running-in process of the hydrostatic pump. After 750,000 cycles, the production of pollution particles slowed down, meaning that the running-in process of the hydrostatic pump UD 25 was completing.

Filtration of solid particles

The filtration of solid particles can also be used to determine the pollution level of biodegradable fluid. Figures 5a and 6a show the images obtained from filtration of solid particles. They were subsequently compared with the images contained in the catalogue of pollution particles, Figure 5b and 6b (Jihostroj, 2011).

From the results of filtration of solid particles, the pollution level was determined and verified on the basis of comparing the samples with catalogue reference samples. Because the fluid reached before the test the greatest pollution levels (determined from the results of pollution measurements according to ISO 4406), pollution was evaluated only at 250,000 cycles when the fluid was filtered through the laboratory device. With images of solid particles filtration after 250,000 cycles, the best match was reached for the reference sample with pollution level 21/19/16. Images contain small wear particles characteristic during the running-in. The largest wear particle found did not exceed 10 μm. These results correspond with results measured during the evaluation of pollution according to ISO 4406-1999.

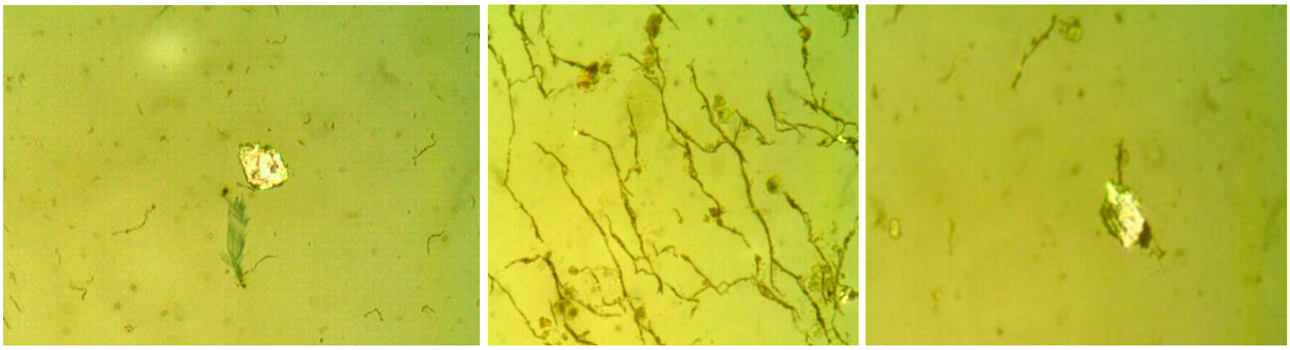


Figure 7 Wear particles in biodegradable fluid after 250,000 cycles

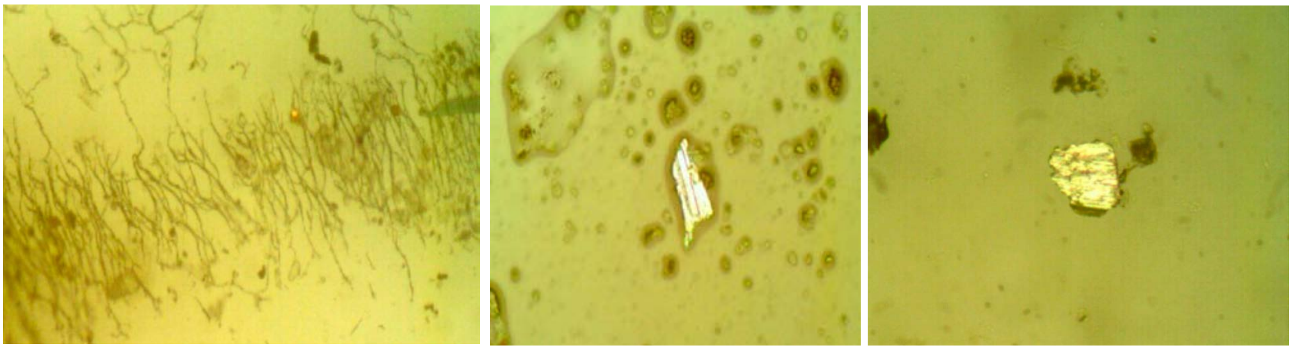


Figure 8 Wear particles in biodegradable fluid at test completion

When comparing the pollution images obtained after test completion (Figure 6a) with reference images, the smallest difference was found with the reference image (Figure 6b) with pollution level 22/20/17. There could be seen that the obtained image is characterised by less wear particles larger than 6 μm and 14 μm, which confirms the correctness of measured results according to ISO 4406, when the pollution level was 22/19/14. The reference images catalogue did not contain an image with pollution level 22/19/14. The pollution image (Figure 6a) contains small wear particles being a result of completed running-in and also larger wear particles that may indicate the continuing initial phase of operational wear. The largest wear particle found after test completion reached the length of 21.5 μm.

Ferrography

During the ferrographic analysis, wear particles contained in the fluid were obtained by the magnetic analyser MA-1 (Figure 3). The device produces the magnetic field through which wear particles are collected on a sloping glass plane. Subsequently, samples were subjected to microscopic analysis with the microscope Kappa 6000, using the zoom 200x and 400x. Samples are evaluated after 250,000 cycles and at test completion.

The images of ferrographic analysis (Figures 7 and 8) show the presence of particle clusters, ferromagnetic wear particles chains coming from the hydrostatic pump UD 25. The presence of these small wear particles points to the running-in process when there was unevenness compensation of the surface functional areas. The fluid contained larger wear particles, too. The morphology of found wear particles was of a scaled nature with a smooth surface, which is typical for adhesive wear particles of soft materials. Comparing with the catalogue of wear particles it was found that it is a typical shape and coloration of bronze particles located in the snap rings of bearings of the hydrostatic pump UD 25.

Conclusion

When assessing the new biodegradable synthetic fluid during the laboratory durability test of the hydrostatic pump UD 25, we focused on its pollution evaluation. There was used ferrography, filtration of solid particles and cleanliness code according to ISO 4406. The results of cleanliness code indicate that the highest pollution was reached before test initiation. Subsequently, pollution was reducing due to fluid filtration in the laboratory device (250,000 pressure load cycles). The subsequent rise of pollution was attributed to running-in. The pollution level was determined from filtration of solid particles by comparative method, and it was also possible to monitor the size of present wear particles. The results of filtration of solid particles confirmed the results obtained by measuring the cleanliness code. The ferrographic analysis enabled obtaining the images of wear particles in the fluid. Based on the results and subsequent comparison of particles with the catalogue of particles, it is possible to state that the fluid contains bronze particles from the snap rings of bearings of the hydrostatic pump UD 25.

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