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RAPIDLY BIODEGRADABLE HYDRAULIC FLUIDS ON THE BASIS OF RAPESEED OIL

Abstract

Hydraulic fluids based on mineral oils have 83% on the market today. The vegetable oils have only 2%, but the prognosis for the year 2000 foresees that hydraulic fluids based on vegetable oils could reach about 8% of shares on the market. On the other hand some industrialized and small countries, like Slovenia, have considered legislative measures to prevent environmental pollution and protection of the natural resources. The rapeseed oils can offer significant environmental advantages with respect to resource renewability, biodegradability and toxicity when compared to mineral oils.

The laboratory test results for one vegetable and one mineral base hydraulic fluid are described in this paper. The results of their physical, chemical and mechanical properties have been obtained by the standard tests for hydraulic fluids. Through simulated real working parameters of dredger on a model laboratory hydraulic system, the behaviour of rapeseed and mineral hydraulic fluids has been studied. After the laboratory tests, the rapeseed base fluids testing was proceeded on the hydraulic system on the dredger in praxis. During these tests operating temperature, fluid pressure, neutralization number (TAN), viscosity, number of particles and water content were simultaneously analysed. The contact surface roughness of hydraulic elements before an after the tests were measured. The ageing of the test oils was analysed by the Fourier transform infrared (FTIR) spectroscopy.

INTRODUCTION

Today's technology of high pressure and high performance hydraulic power systems is closely connected with the high developmental level of hydraulic fluids. However, hydraulic fluids based on mineral oils assure an optimum performance and technical requirements specified in the standards for hydraulic oils except requirements for toxicity and biodegradability (1-3). The rapeseed oil is the so-called triglycerides, which contains fatty acids with mono, double and triple bonds in their chains. The double and triple bonds make the base rapeseed oil sensitive to temperature and cause thermal and oxidative instability (4). Therefore some suitable additives are used to improve the properties of base oil, especially thermal and oxidative stability and EP characteristics.

Rapid biodegradability, non-toxicity and good lubricity are the basic advantages of hydraulic fluids based on rapeseed oil. Hydraulic fluids are biodegradable if they decompose under the microbiological degradation conditions into products as water, CO_2 and bio-mud. The rapidity of degradation depends on the distribution of the substance in the ground, quantity of the sort of bacteria, quantity of oxygen, temperature, humidity, sunlight and other conditions. The common used test for testing the biodegradability of hydraulic fluids is the CEC-L-33-A-93 test.

The second important characteristic of biodegradable hydraulic fluids is their low toxicity. The toxicity of chemical substances is determined with the laboratory test methods according to the standard DIN 38 412/8,9,11 and 15. The environmental legislation variously depends on the country. The German water legislation defines the water pollution potential of substances (5). The soil protection legislation is partly included in the water protection legislation.

Up to now in Slovenia we have developed a lubricant for forestry chainsaws based on rapeseed oils, which is sold on the market (6). In this paper the properties, the results of the tests on the laboratory hydraulic system and field tests of the developed hydraulic fluid based on rapeseed oil are presented.

EXPERIMENTAL

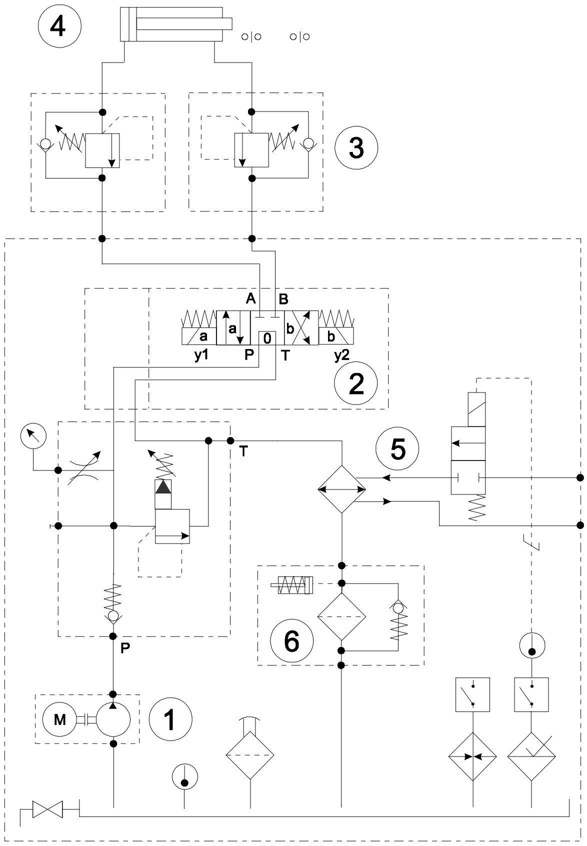
Hydraulic test oil and test procedures. The test fluids used in this study are:

- Fluid B - constituents of rapeseed base oil spiked with standard package of additives, which are used for mineral hydraulic oils and
- Fluid M - mineral hydraulic oil taken from the Slovenian market.

The main properties of the developed Fluid B and mineral test oil Fluid M are shown in Table 1.

In order to be sure that the properties of the rapeseed oil Fluid B comply with the properties of the mineral oil Fluid M the laboratory tests were running simultaneously on two laboratory hydraulic test systems under the same conditions. The oil samples had been taken at the front of the filter from both laboratory hydraulic systems simultaneously every 100 hours. By the laboratory tests TAN, viscosity, number of particles and water content in hydraulic fluid were measured.

Slika 1: Laboratorijski hidraulički sustav - dijagram tijeka
Figure 1: Laboratory hydraulic system - circuit diagram



1. Gear pump... 2l/min. at 1500 r.p.m., 2. Directional valve, 3. Pressure relief valve, 4. Cylinder, 5. Water cooler, 6. Filter 10 μm., max.system pressure 27 MPa
1. Zupčanička crpka... 21/min na 1500 okretaja u minuti. 2. Usmjerni ventil. 3. Ventil za oslobađanje tlaka. 4. Cilindar. 5. Hladnjak za vodu. 6. Filtar od 10 mm., maks. tlak sustava 27 MPa.

The contact surface roughness of the main hydraulic component before and after tests was measured. For testing the biodegradability of oils the test CEC-L-33-A-93 was used.

The field test on the dredger has been performed for the repeseed oil Fluid B. From the dredger hydraulic system samples had been taken at the front of filter every 50 hours. All samples were taken during the operation of the dredger. Before the analyses samples were homogenised in ultrasonic bath. TAN, viscosity, number of particles and water content in all oil samples were measured. When the laboratory and field tests were run the environmental temperature and humidity were measured.

The ageing of the repeseed oil during the laboratory and field tests was also monitored by the Fourier transform infrared (FTIR) spectroscopy. FTIR provides a reliable method for the determination of the oil condition, i.e. degradation products.

Slika 2: Bager O&K MH5 PMS
Figure 2: Dredger O&K MH5 PMS

The infrared spectrum of oil contains information on various frequencies that can be correlated to the presence or absence of particular components showing the condition of oil. The primary oxidation products of repeseed oils are mainly hydroperoxides, secondary products including alcohols, aldehydes, esters and others.

Equipment and test parameters

The physical and chemical properties of both test oils were tested in accordance with different standardized test methods for mineral oils.

For the mechanical properties of the rapeseed and mineral oils the FZG test rig, Vickers V-104 pump test, High Frequency machine and Seal test procedure were used. The laboratory tests of the rapeseed and mineral oils have been performed on two laboratory hydraulic systems, Figure 1.

On the laboratory hydraulic system the steady state and two cyclic test I and II have been performed.

The test parameters for all three tests are shown in Table 2.

Figure 2 shows the dredger, which was used for the field test of the Fluid B test oil.

The main parameters of the dredger hydraulic system are shown in Table 3.

The FT-IR instrument used for the study was a Perkin Elmer 1720 X.

The instrument details and scan parameters are shown in the Table 4.

RESULTS

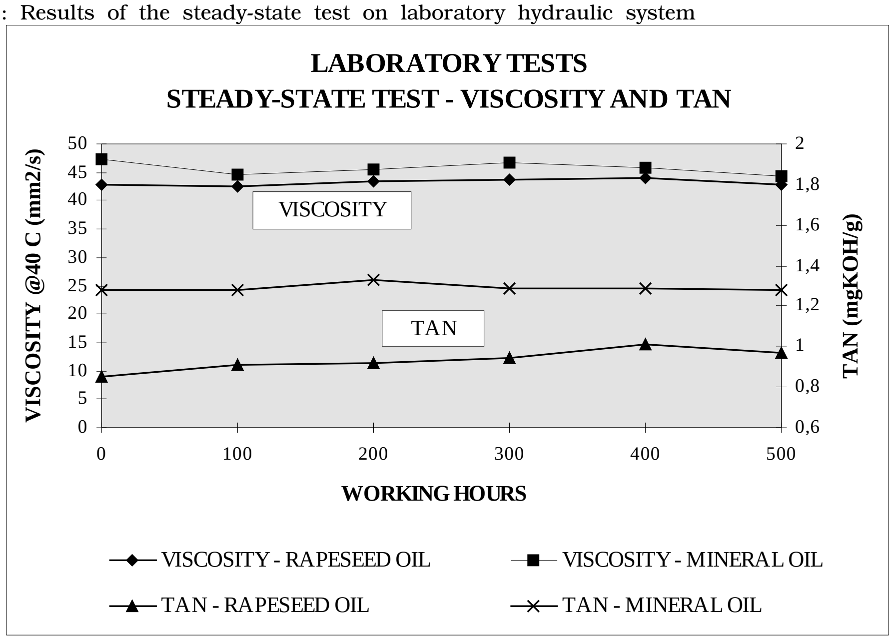
Table 5 shows the comparative analysis data for Fluid B and Fluid M obtained by standard test methods.

Results of the laboratory hydraulic system tests

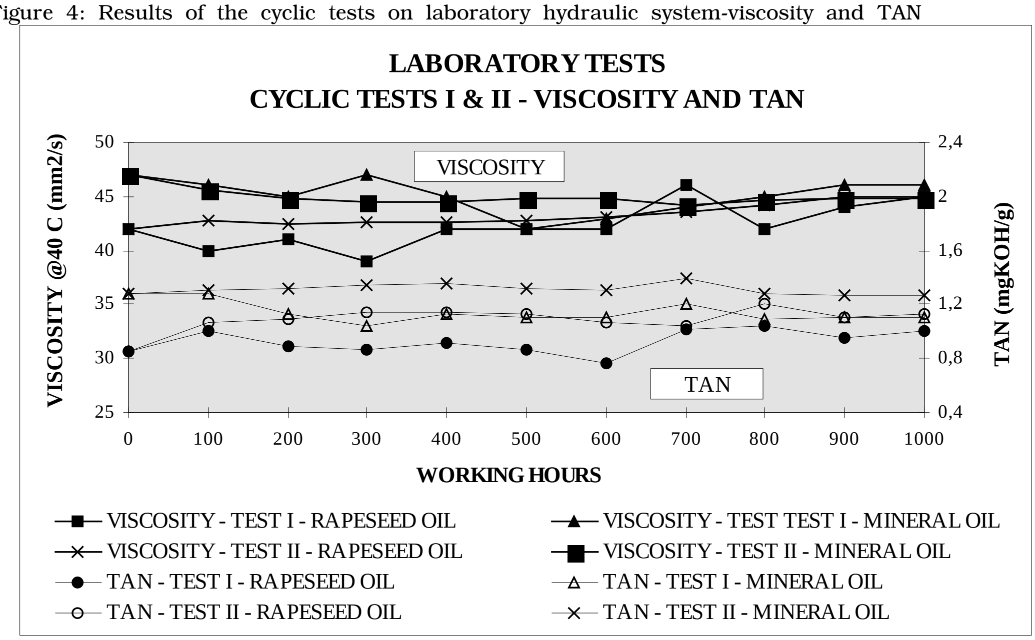
The viscosity and neutralization number of samples from the steady-state test for hydraulic fluid based on rapeseed oil and hydraulic fluid based on mineral oil are shown on Figure 3.

All parameters were constant, except TAN of repeseed oil Fluid B which slightly increased during the 500 hours test.

Slika 3: Rezultati ispitivanja u mirovanju na laboratorijskom hidrauličkom sustavu
Figure 3: Results of the steady-state test on laboratory hydraulic system



Slika 4: Rezultati cikličnih ispitivanja na laboratorijskom hidrauličkom sustavu - viskoznost i TAN
Figure 4: Results of the cyclic tests on laboratory hydraulic system-viscosity and TAN



From the results it can be observed that both viscosity and TAN for the rapeseed and mineral hydraulic fluids were nearly constant during the cyclic tests I and test II.

Field tests results

Since the results for the viscosity and TAN of oil in the 1000 hour field test didn't change substantialy, it was prolonged to 2100 hours, Figure 5. The comparison of the laboratory results and field test shows that all results are nearly the same.

Slika 5: Viskoznost i TAN uzoraka iz praktičnog i cikličnog ispitivanja
Figure 5: Viscosity and TAN of samples from field and cyclic tests

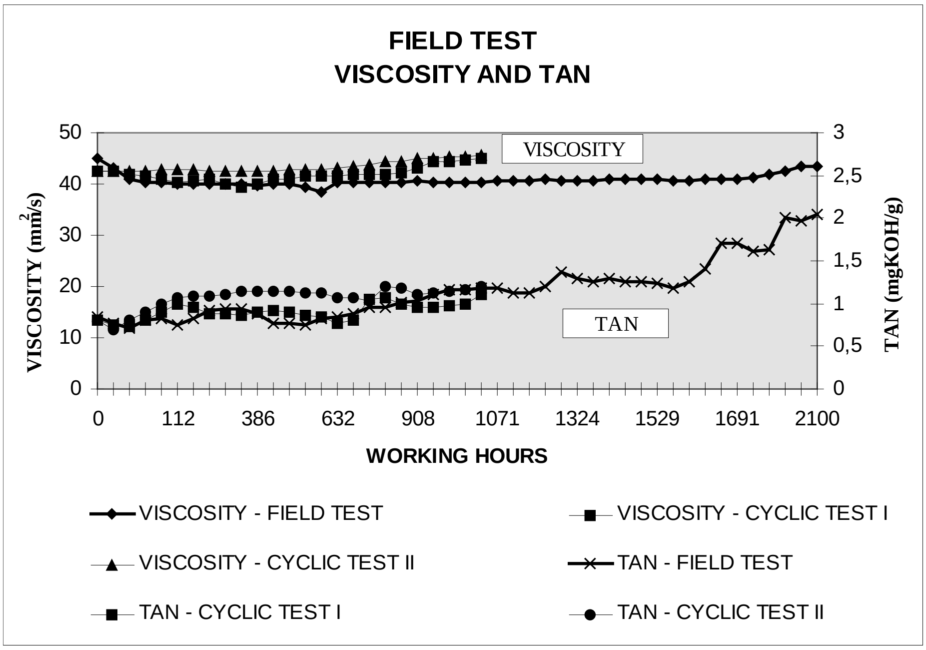
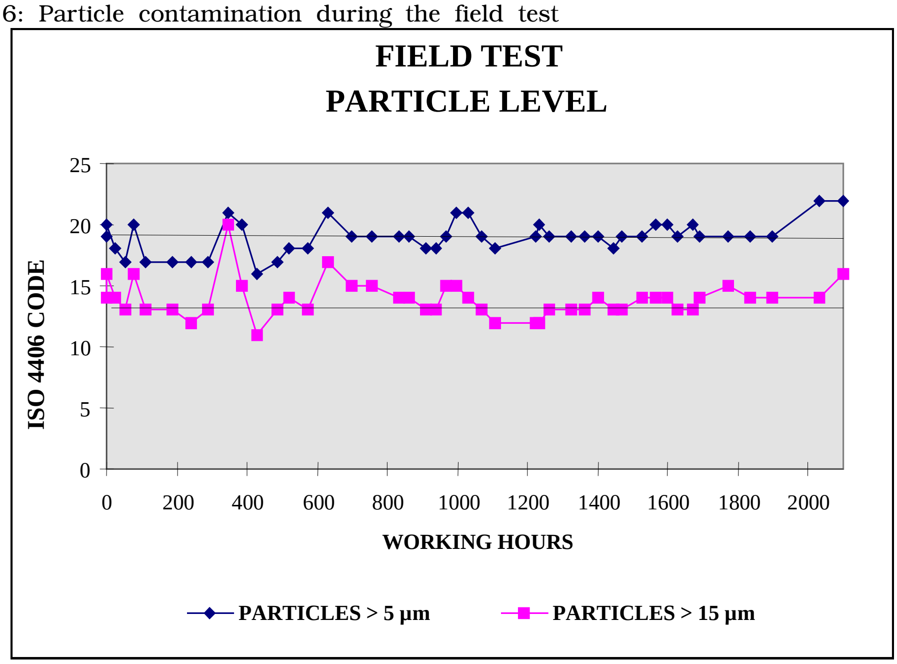
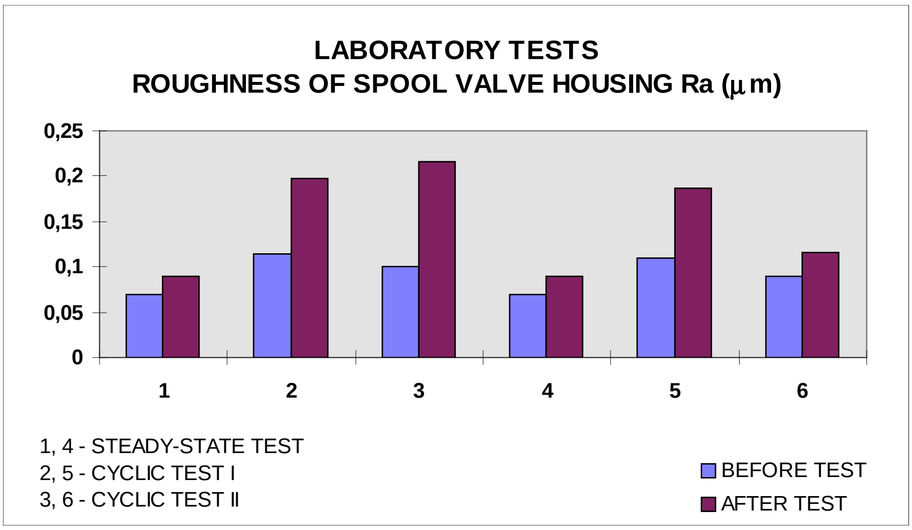


Figure 6 shows the results of the particle contamination analyses by the particles counter in accordance to the standard ISO 4406.

Slika 6: Onečišćenje česticama za vrijeme praktičnog ispitivanja
Figure 6: Particle contamination during the field test



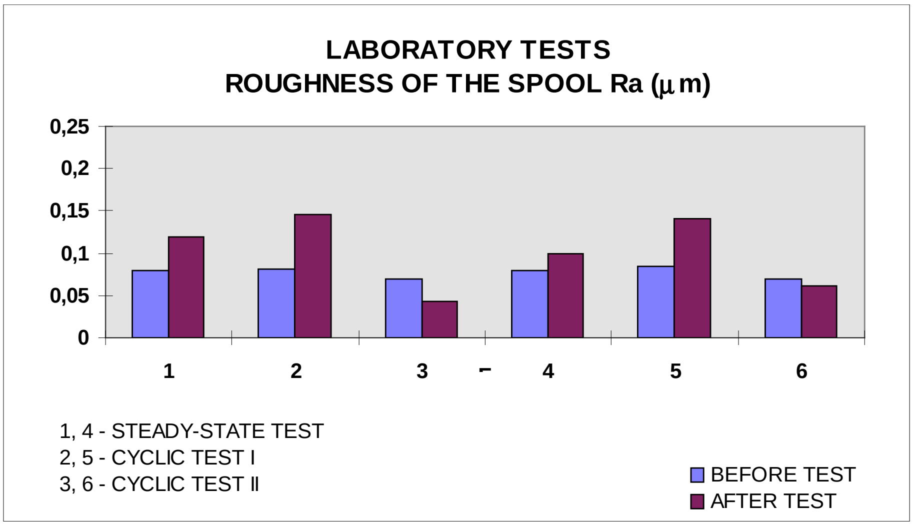
Slika 7: Hrapavost površina kućišta razvodnog ventila prije i poslije laboratorijskih ispitivanja
Figure 7: Roughness of surfaces of the spool valves housings before and after laboratory tests



Surface roughness measurement

Figures 7 and 8 provide a graphic representation of roughness of the spool valve housings and spool surface before and after the test on laboratory hydraulic systems.

Slika 8: Hrapavost površina ventila prije i poslije laboratorijskih ispitivanja
Figure 8: Roughness of the spool surfaces before and after laboratory tests

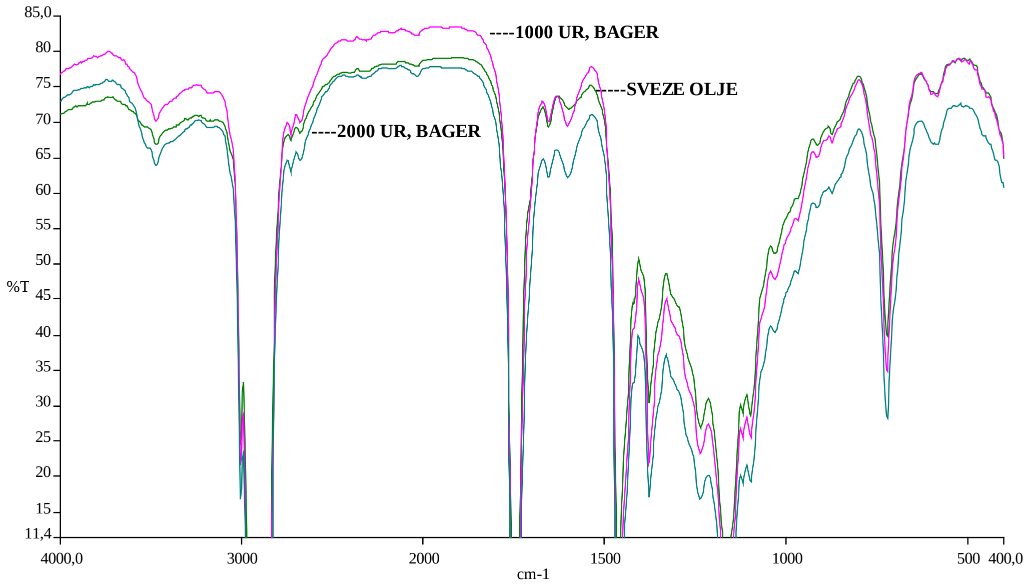


From the results we can conclude that the roughness of the surfaces of spool valves after all tests on laboratory hydraulic systems was increased. Changes are greater when the hydraulic fluid based on rapeseed oil was used.

FTIR spectroscopy for the analysis of rapeseed oil

The infrared spectra of new and used oil after 1000 and 2000 hours are shown in Figure 9. In thise spectra, it is difficult to detect and explain changes by simple inspection.

Slika 9: Infracrveni spektri svježeg i rabljenog ulja nakon 1000, odnosno, 2000 sati
Figure 9: The infrared spectra of new oil and used oil after 1000 and 2000 hours.



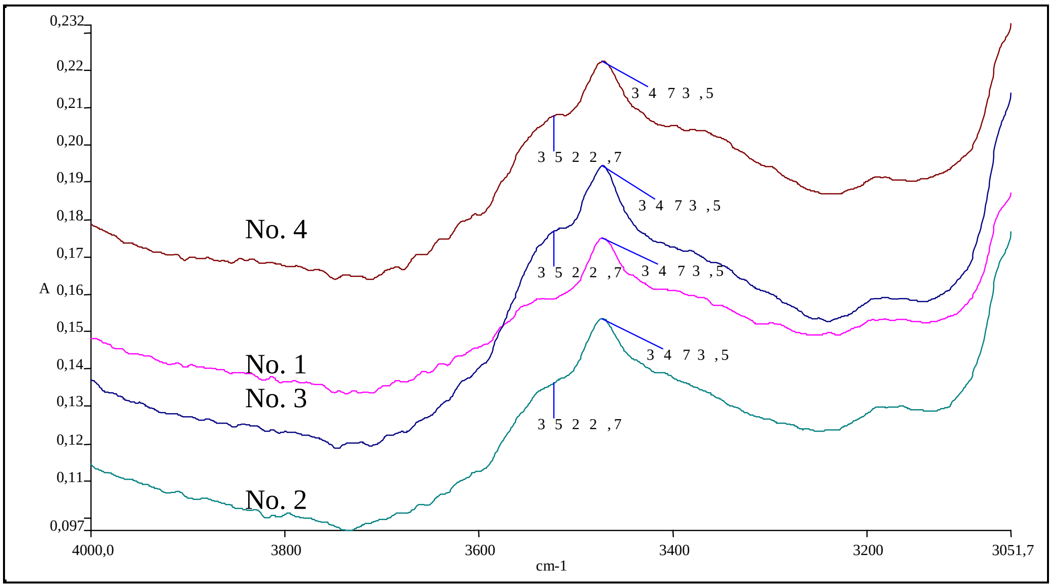
The biggest changes in structure of the oil samples are observed in the region of the wavelengths between 3800 and 3100 cm^{-1} (hydroperoxides, water, acids, alcohols), in the region between 1800 and 1700 cm^{-1} (acids, ketons, aldehids) and between 1660 in 1550 cm^{-1} (vibrations of compounds with double bonds). Figure 10 shows the spectral changes in the region of OH stretching vibrations. The samples tested on FTIR presented on following figure 10 are:

No. 1: New oil
No 2: Oil from Dredger after 1000 hours
No. 3: Oil from Dredger after 2000 hours
No. 4: Oil after the cyclic test (1000 hours)

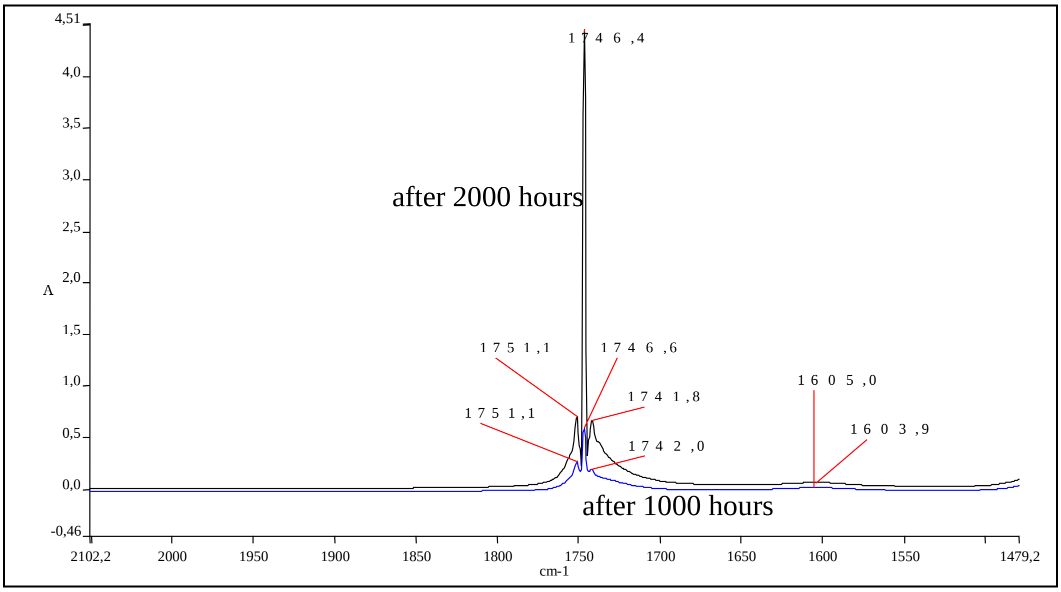
The changes of absorbtion band around 3530 cm^{-1} were increased due to extended use of oil in dredger.

The differential spectra of test oils from the dredger are shown in Figure 11. From the spectra we can see the presence of new components in the region of carbonyl vibrations (1760–1730 cm^{-1}). The quantity of oxidation products increased with time, but the structure of product remained unchanged.

Slika 10: Povećanje apsorpcijskog pojasa oko 3525 cm^{-1}
Figure 10: The increasing of absorbtion band around 3525 cm^{-1}



Slika 11: Diferencijalni spektri uzoraka ulja iz bagera nakon 1000 i 2000 sati
Figure 11: Differential spectra of oil samples from dredger after the 1000 and 2000



DISCUSSION

The developed rapeseed oil Fluid B has lower viscosity and higher viscosity index than mineral oil Fluid M (Hydolubric 46), Table 1. All results of the standard tests, shown in table 3, are in the reference values for rapeseed and mineral test oils. This confirms that the properties of the rapeseed oil Fluid B completely correspond to the properties of the mineral oil Fluid M. The basic advantages of the rapeseed oil are 99% biodegradability, non-toxicity and good lubricity.

The steady state test results and the results of the cyclic test I were constant during the tests, Figure 3 and 4. TAN of the rapeseed oil increased from 0.85 to 1.2 after 1000 hours in the cyclic test II. The results of the cyclic test are equal to the results of the field test until 1000 hours of test duration. The viscosity and TAN were substantially increased from 1000 to 2100 hours in the field test. According to these results we can conclude that TAN and viscosity of the hydraulic fluid based on rapeseed oil increased with test duration in the field test. The hard particles in the hydraulic fluid based on rapeseed oil did not increase with time of the test duration. Laboratory tests show a greater increase in the surface roughness of spool valves and spool valve housings, when the hydraulic fluid based on rapeseed oil was used.

The analysis of the spectra of oil samples from the laboratory hydraulic systems and from dredger shows that the amount of oxidative products increased with the test duration but only slightly influenced the physical properties of the oil.

CONCLUSIONS

FLUID B corresponds to the specification for hydraulic fluids, and meets the requirements of modern hydraulic systems. Results show that the hydraulic systems satisfactorily operate with FLUID B based on rapeseed oil. The hydraulic system of the dredger operated without problem for over 2000 hours. It is necessary to consider some restrictions of working parameters. The working temperatures have to be within a certain interval, below 80^{0}C.

Tests on laboratory hydraulic systems are suitable for testing the properties of hydraulic fluids and their influence on hydraulic components at the controlled working conditions. Up to now known results of the laboratory and field tests have shown that the standard components satisfactorily operate with the hydraulic fluid based on rapeseed oil.

According to this we suppose that biodegradable hydraulic fluids can replace hydraulic fluids based on mineral oils in some fields of use.

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621.892-82 hidraulične tekućine	hydraulic fluids
.004.14 gledište svojstava u primjeni	application properties viewpoint
620.1 ispitivanje u eksploatacijskim uvjetima	field testing
576.343 biorazgradljivost	biodegradability
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