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Newly developed rapidly biodegradable hydraulic oil in test

A newly developed rapidly biodegradable hydraulic oil including additives with the same property was subject to practical tests over several years whereby stresses and chemical alterations in the liquid were investigated. The saturated synthetic ester based liquid showed no alterations in composition necessitating its replacement during the three-year test period even under heightened thermal stress. With sufficient topping up a complete replacement is not necessary in that the average period hydraulic fluid is in the system is less than the official liquid working lifetime.

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Keywords

Hydraulic fluid, stability, degrading behaviour

The Curatorium for Forestry Work and Technology (KWF) together with partners from forestry and industry tested a new type of rapidly biodegradable hydraulic oil from the company Bechem in a project supported by the FNR.

Rapidly biodegradable hydraulic oil, also known as HE fluid (E = ecological or environment) has been steadily improved in the last years and by now has proved its suitability many times over although doubts and thus acceptance problems still remain. The principle existing argument between comparative environmental compatibility and technical suitability for demanding work situations has led to products offering a wide range in environmental characteristics, technical suitability and price, a situation that also contributes to the still existing uncertainty. Additionally there is the problem that the basic hydraulic liquid is a rapidly biodegradable product whereas the necessary additives are not. The partner in the cooperative project described here, Carl Bechem GmbH has therefore joined with the KWF in taking up the challenge of developing a hydraulic liquid with new additives which are environmentally safe under present rulings and which fulfils the environment label standards. The additives should also be biodegradable and ecologically non-toxic. The liquid should further lead to no colour metal corrosion and remain stable in the machinery over long periods.

Project target was the achievement of a measurement method and evaluation system for assessing the technical suitability of rapidly biodegradable hydraulic oils and to apply these in the long term tests wherein a newly developed pressure liquid should on the one hand be taken to the limit of its performance capabilities and on the other prove its suitability for practical use out in the field.

Material and methods

Three machines were selected for the test: a combined tree harvester and a timber forwarder as typical forestry equipment in which the newly developed hydraulic oil should be used under working conditions and a backhoe tractor used in forestry which would be able to test the liquid to the limits of its performance. For this reason a switch was integrated into the circuit which allowed the hydraulic oil cooler to be bypassed until a temperature of 80 °C was reached in the tank. The aim here was to create conditions where hydraulic fluid would change its characteristics about double so fast as in the other machines.

A measurement system integrated in the machines collected data for evaluating the stresses on the liquid. Measuring oil temperature in the tank was considered sufficient in this context. All other hydraulic oil temperatures follow the tank one during stress phases while in resting phases the temperatures on the periphery of the hydraulic system drop very quickly but only slowly in the tank.

Figure 1 shows results. From original insertion of the hydraulic oil to be tested through until end of project in September 2001 the backhoe carried out 1510, the forwarder 1030 and the combined harvester 1491 working hours.

Table 1: Changes in viscosity, neutralisation number (NZ), foam and density of the hydraulic fluid during the project period in the excavator

Working hours h	Viscosity mm^2/s	NZ mg KOH/g	Water ppm	Foam Ml	Density g/cm^3
Test liquid	41.8	0.6	260	0	0.952
0	40.9	0.8	460	180	0.952
126	41.2	0.7	420	250	0.947
207	41.9	0.6	560	500	0.949
1000	42.9	0.8	280	310	0.9525
1180	43.6	0.9	240	50	0.953
1260	43.9	0.8	260	0	0.952
1390	44.4	0.95	300	40	0.9526
1510	44.3	1.4	800	20	0.9526

Results

In normal work the pressures in the hydraulic systems of all three machines were altered by the second whereby usual pressure range was from around 0 bar to maximum. The frequency distribution of the measured pressures on all machines showed a peak with very low pressures coming from the resting phases of the machines. The maximum for working pressure frequency distributions was in the backhoe with 180 to 200 bars, in the working hydraulics of the forwarder and combined harvester this was 240 bar in each case.

Main interest was paid to the chemical and physical alterations in the newly formulated liquid. The parameters recorded from the three test machines are shown in *tables 1 to 3*. Main indicators for liquid changes are the viscosity and neutralisation number (NZ). Maximum viscosity reached was never more than 46.6 mm^2/s and is thus still a long way from the maximum permitted value of 52 mm^2/s. Maximum NZ was 1.4 mg KOH/g whereby the limit for a notable reduction of neutralisation capability can be seen as 2.6 mg KOH/g. Even under the conditions of accelerating aging in the test backhoe, the performance limits of the hydraulic oil were not reached.

Only the limit value for water content in rapidly biodegradable hydraulic oil (according to VDMA guideline 24568) of 1000 ppm was reached by the forwarder. This seemed to be connected to the temperature level in the tank. Apparently, a higher tank temperature level – as in the backloader – correlated with a low water content in the hydraulic oil and conversely a low temperature level with a high water content. In the first place dissolved water is not damaging to the machine so long as the water does encourage precipitation of acids, alcohol and further by-products in the oil. This effect, which would have led to a rise in NZ and viscosity, was not observed.

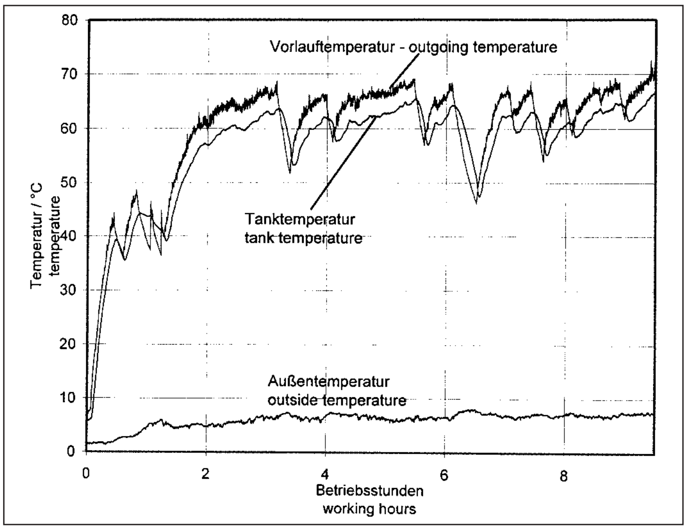

Fig 1: Typical development of measured temperatures for the hydraulic fluid in the tank and in the inflow of investigated excavators during one shift compared to ambient temperature

The DIN 51524 foam limit was exceeded over short periods in some samples taken from the backhoe and forwarder and this led to a change in the additives. But this was seen as of little importance with regard to the operating capabilities of the liquid as any foam created in the laboratory very quickly subsided. Although the same hydraulic oil was used in each case, sometimes there was high foam production created in the backhoe's oil whilst foam creation was only to a limited extent in the forwarder and almost no foam was formed in the combined harvester system. No explanation for these differences could be found but it is possible that constructional characteristics (seals, material selection of system components) or small contaminations not able to be identified with the test methods, led to the differences – or even mixing phenomenon affecting the originally filled hydraulic oil.

In no case did wear metal appear in significant amounts.

Liquid losses

Hydraulic fluid losses during work and the required topping up meant the fluid was continuously refreshed. In this way the proportion of original liquid in the total amount assumed a relationship which could be taken as analogous to the lifetime laws for radioactivity. Through the continuous topping up the length of time spent in the system by the added proportion of the liquid was less than for the original liquid. This allows one to calculate an average duration time for liquid in the system and the relationships in the investigation meant this average value was close to an asymptotic maximum value representing around 2000 hours for the backhoe, ~ 1830 hours for the forwarder and, because of the large amount of topping up in the combined harvester system, only 880 hours for this machine.

Oil change not required

Thus one can conclude that for the trial machines where more than 2000 working hours is the period accepted as time between hydraulic oil changes where no topping up takes place, the average time in the system where topping up does take place means no complete changes would be required with the refreshing from topping up sufficing.

Working hours h	Viscosity mm^2/s	NZ mg KOH/g	Water ppm	Foam Ml	Density g/cm^3
Test liquid	41,8	0,6	260	0	0,952
0	45,9	0,6	400	10	0,9501
100	45,2	0,5	680	200	0,9502
791	46,6	0,7	1020	260	0,952
1030	42,5	0,8	1000	340	0,9523

Table 2: Changes in viscosity, neutralisation number (NZ), foam and density of the hydraulic fluid during the project period in the forwarder

Working hours h	Viscosity mm^2/s	NZ mg KOH/g	Water ppm	Foam Ml	Density g/cm^3
Test liquid	41,8	0,6	260	0	0,952
0	44,9	0,75	390	0	0,9504
921	45,9	0,8	521	0	0,9538
1491	44,3	0,9	600	20	0,9526

Table 3: Changes in viscosity, neutralisation number (NZ), foam and density of the hydraulic fluid during the project period in the harvester