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MECHANICAL TESTS FOR ACCELERATED TESTING OF MINERAL LUBRICANTS WITH RESPECT TO ITS DEGRADATION

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ABSTRACT
If the mineral hydraulic oil condition is monitored and correctly maintained, the hydraulic oil has a relatively long service-life – from 5 to 10 and even more years. Therefore, it is necessary to know the change mechanisms of physical-chemical properties based on different procedures of accelerated ageing – ageing tests. The analysis of the results acquired allows insight into the change mechanisms of the physical-chemical properties of mineral hydraulic oils, recognition of the influences of various operating parameters, determination of the more important values for the oil condition monitoring, and evaluation of an oil's current condition and remaining useful lifetime. This paper discusses the usability of mechanical tests for accelerated testing of mineral lubricants with respect to its degradation factors.
Keywords: mineral-oil-based lubricants, degradation mechanisms, mechanical tests

1. OIL DEGRADATION MECHANISMS

In general, oil ageing is understood to be the physical-chemical property changes taking place in oil degradation throughout its service-life. Due to the diversity of base oils and additives used today and the resulting number of ingredients present in oil, it is impossible to provide an accurate and universal statement about the general ageing mechanisms and chemical processes taking place. The excessive number of possible chemical reactions and the vast number of consequential chemical reactions can only be imagined. Already in dealing with base oils it is possible to observe the great chemical diversity of structures. Also the additives, though in very low amounts, may have different effects on the oil behavior, ageing process and oil degradation.
A further point preventing predictions of the processes of individual chemical reactions regarding ageing is that the chemical reactions depend on the current machine operating conditions, as shown in Figure 1. The more influencing factors are the temperature, oxygen and water presence.
Further values influencing the oil ageing are pressure, system volume, shear of long chain molecules, radiation and the influence of metal catalysts [48]. The influence of a combination of various present metal catalysts and the controlled degree of oil oxidation is shown Table 1. The oxidation degree is comparably shown in the form of the neutralization number value as an important parameter for evaluation of the oxidation and ageing process [19].
All the mentioned physical-chemical factors are additionally affected by the type of use, machine construction, maintenance, oil change intervals, oil quantity in tank, oil change interval, filtration, maintenance, …

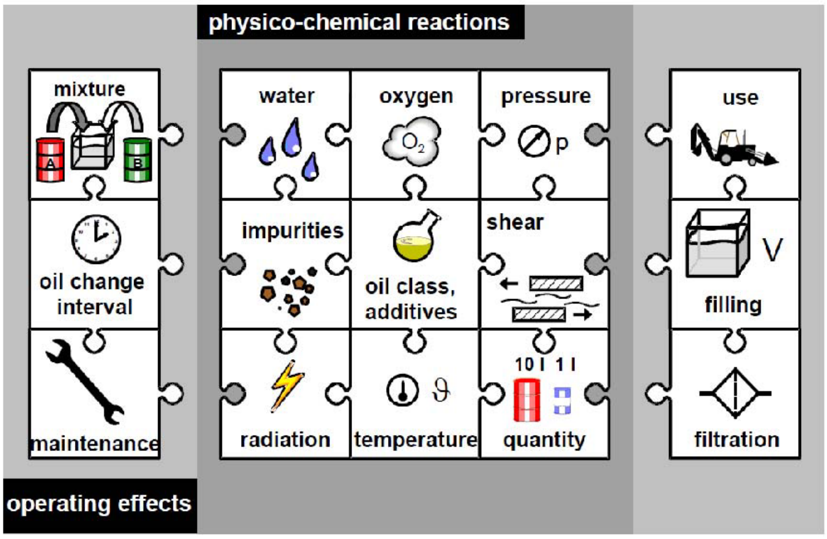

Figure 1. Various operating effects on mineral hydraulic oil ageing mechanisms [1].

On the basis of the reached operating hours in the presence of various catalysts it is evident that the worst combination is the presence of iron or copper and water. In all those cases the number of operating hours was drastically reduced in the presence of one of the catalysts, either iron or copper and, of course, water.

Table 1. Catalytic effect on oil oxidation [2].

Catalyst	Water	Test hours	Neutralization number
none	no	> 3500	0.17
none	yes	> 3500	0.90
Fe	no	> 3500	0.65
Fe	yes	400	8.10
Cu	no	> 3500	0.89
Cu	yes	100	11.20

The results in Table 1 show that the presence of water and metals with catalytic effect leads to a reduction in oil service-life. In the additional presence of alternating operating pressure, increased temperature and shear of hydrocarbon molecules it is possible to reach a combination of all influencing factors, thus allowing fast degradation of oil. After consideration of all such tests used for testing various lubricants, own, special tests for accelerated hydraulic fluid ageing is presented.

2. MECHANICAL ACCELERATED OIL-AGEING TEST

One of the more important tasks to be performed by lubricant is the ability to prevent direct contact of two metal parts. Producers of hydraulic components take this task very seriously and thus they pay significant attention to it. Inadequate lubricant's properties largely affect the component degradation and the machine operation reliability. Therefore, a great number of standardized tests have been developed and used in order to establish the relation between the oil condition and the lubricating properties, and its effect on the component wear. During testing the load is applied to the tested component (e.g. vane pump, …) under specifically prescribed conditions and at the end of the test the wear of certain component parts is measured e.g. by weighing or inspecting the wear traces (traces of wear, changed geometry due to wear etc.).

The tests concerned with lubricating properties and the service-lives of components usually use techniques and procedures similar to those occurring during the actual component usages. Testing is so performed in approximately identical environmental conditions as during actual use: the temperature conditions, presence of contamination, water, metals, alternating pressure, …

Usually is the time necessary for testing under actual operating conditions not available. Such testing would last too long (even several years). The results are wanted sooner than by testing in real and normal component use conditions, so various different procedures of faster component degradation under harsher conditions of use are used. The results can be gained in a reasonable time by retaining all characteristics of functioning conditions since the matters are only accelerated. The solution of the problem is the use of various methods of accelerated testing on purpose-made test beds.
The ***FZG – ASTM D5182 test*** [3] is commonly used for gearing power transmission, used on many automobile and industrial applications. The test is also reliable with respect to predicting steel-steel contact wear, when using hydraulic oils. For the **Eaton/Vickers 35VQ-25 – ASTM D6973 test** [4] a precisely determined type of Vickers vane pump, is used built-on to a 189 L tank. For the similar **Komatsu 500 hour test** [5], the piston pump is used. In distinction to other tests based on pump wear at constant loading and presence of increased temperature and pressure, the profile of applying pressure to the pump is alternating in this test. After the test's completion, the pump is disassembled and all internal parts are measured. Simultaneously, the oil analysis is executed for the presence and concentration of wear metals.

3. SPECIAL TEST UNIT FOR A MECHANICAL ACCELERATED OIL-AGEING-TESTS

The test is based on mentioned standardized tests and on other influencing factors having great influence on ageing and degradation regarding the physical-chemical properties of lubricants. The test and equipment used is adapted for accelerated ageing of hydraulic fluids and includes all influencing factors that have been proven to accelerate oil ageing. The complete test unit is shown in Figure 2.

Figure 2. Special test unit for mechanical oil-ageing testing (left) with the catalytic unit (right).

Real operating conditions – fluid flow through real hydraulic components on which fluid shear loads appear. **Increased temperature** ~93 °C generated by resistive fluid flow through hydraulic components. The temperature is generated by cyclical pressure changing and maintained to 93 ±1 °C by the use of the installed oil-water heat exchanger. **Shear loads** are generated by fluid flow over the control edges of the proportional pressure valve and two throttles. **Cyclic mechanical fluid loading** is executed by changing the pressure between 18 and 150 bar. The changes in pressure do not repeat in fixed time intervals (like in the Komatsu or Vickers tests) but is conditional on the temperature change. When temperature decreases the pressure abruptly increases to 150 bar and when the temperature increases over the desired value it abruptly decreases to 18 bar. The pressure changing is so non-periodically but rather depends on the current temperature conditions and represents the random pressure changes occurring within the real hydraulic system. **Dimensionally the test system is conceived in such a way so that the circulating number is much higher** than under real conditions. According to the tested sample quantity a 20 L tank was selected; the fluid flow was provided by a gear pump driven by an 18 kW three-phase induction motor assuring about 40 L/min flow at 1450 rev/min. With the use of a frequency converter the circulation number can be increased. While taking a sample of the fluid from the tank (about 1 L) the fluid quantity in the tank is reduced and the circulation number is changed. **The tank size** and all parameters related to test execution are specifically selected: required fluid quantity for execution of the entire set of tests on the basis of which it would be possible to recognize the pattern of physical-chemical changes, interdependence of parameters and to execute the tests on the basis of which the oil condition and remaining useful lifetime could be inferred. A **catalytic unit** was additionally built-on to the system on the return line. It consists of a set of copper-iron plates which, in the presence of water and increased temperature, have considerable influence on faster oil ageing.

4. RESULTS AND CONCLUSION

The presented conceived mechanical test for accelerated ageing of hydraulic fluid was implemented in duration of 787 hours without interruption by the use of the presented testing unit. The oil condition was monitored by periodical sampling and appropriate chemical analyses executed in the chemical laboratory as shown in Table 2.

Table 2. Hydraulic oil analysis results on accelerated oil ageing – important parameters.

Sample	Standard / Unit	0 h	192 h	787 h
Flash point	ASTM D 92 [°C]	232	230	228
Viscosity at 40 °C	ASTM D 445 [mm²/s]	46.42	46.27	47.16
Viscosity at 100 °C	ASTM D 445 [mm²/s]	6.89	6.87	6.93
Viscosity index	ASTM D 2270 [-]	104	103	102
Neutralization number	ASTM D 974 [mg KOH/g]	0.66	0.64	0.67
Water content	ISO 12937 [ppm]	63.23	59.13	103.65
Sulfur (S)	ASTM D-6481 [wt. %]	0.702	0.695	0.691
Calcium (Ca)	ASTM D-6481 [wt. %]	0.004	0.003	0.003
Zinc (Zn)	ASTM D-6481 [wt. %]	0.0452	0.0451	0.0446
Copper (Cu)	TXMS-06A [mg/kg]	< 3	155	167
Iron (Fe)	TXMS-06A [mg/kg]	< 3	< 3	< 3

The results indicate that the concerned test did not achieve evident oil degradation and that accelerated ageing of tested HLP ISO VG46 classical mineral hydraulic oil, as its physical-chemical properties during the test did not change as intended. The described test was very near the real operating conditions with respect to the use of components, like pump, valves, flow through pipes and gaps, oil pumping over etc., solely the operating conditions were harsher: increased operating temperature but limited to about 93 °C due to the adding of water the evaporation of which had already been accelerated at that temperature, presence of catalysts (Fe and Cu), higher pump circulation number, fluid flow over the control edges, accelerating the fluid shear stresses, and the presence of alternating pressure load.

Based on these findings it can be concluded, that the mechanical accelerated oil-ageing test are more appropriate for tribological investigation, than investigation regarding the degradation of physic-chemical changes of mineral based lubricants.

5. REFERENCES

[1] Meindorf T.: Sensoren für die Online-Zustandsüberwachung von Druckmedien und Strategien zur Signalauswertung. Shaker Verlag, Aachen, 2005,
[2] Booser E. R.: CRC Handbook of Lubrication (Theory and Practice of Tribiology), Volume I: Application and Maintenance, CRC Press, 1983,
[3] ASTM D5182 Standard Test Method for Evaluating the Scuffing Load Capacity of Oils (FZG Visual Method),
[4] ASTM D6973 Standard Test Method for Indicating Wear Characteristics of Petroleum Hydraulic Fluids in a High Pressure Constant Volume Vane Pump,
[5] Totten, E. G., Kling G. H., Smolenski D.J.:. Tribology of hydraulic pump testing. West Conshohocken : ASTM. 1997