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APPLICATION OF A NEW TEST PROCEDURE FOR MECHANICAL TESTING OF HYDRAULIC FLUIDS

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Abstract: This paper describes a friction and wear test in a newly developed test machine, which was developed at the TU Hamburg-Harburg to investigate the lubricating capability of hydraulic fluids. The aim of the development of the new test procedure is a better representation of the tribological contacts and effects in fluid power machinery. The investigation of the lubrication capabilities of hydraulic fluids using a line contact showed, that a distinction between different fluids regarding their lubrication capabilities can be made, using friction-, wear- and erosion tests (galling). The high reproducibility of the boundary conditions during different tests was achieved by steady design modifications of the test rig and the development of a computer program for fully-automatic control of the test procedure. The developed test machine fulfils the requirements of a simple test procedure and simply shape of test specimen, which could be produced from principally every type of material and production machines, existing in every company that produce fluid power components.

Keywords: Hydraulic, fluid, lubrication, testing

1. INTRODUCTION

A very important feature of a hydraulic fluid is its potential to separate the surfaces of a loaded tribo-contact and by this to reduce friction and wear in this contact. The most reliable test to investigate the lubricating capability of a hydraulic fluid is the field test, i.e. the application of the fluid under typical operating conditions and for typical operating periods. For many reasons field tests are time consuming and costly, and the operating condition of different applications typically will be very different so that results from one application might not be transferable to another application. This situation leads to the necessity for fluid producers as well as for the producers of hydrostatic machinery to test their product in a laboratory test before they go for a field test. It should be clear that laboratory tests are only helpful if they reproduce the situation in the tribo-contact of the real machine to a high extend.
The Institute for Product Development and Mechanical Engineering Design at the Hamburg University of Technology has developed a new test procedure and a test machine to investigate the lubricating capability of hydraulic fluids [1]. In future this test possibly can replace the vane pump test according to DIN 51389 [2]. The aim of the project was to find a test procedure which reproduces the totality of wear relevant tribological effects in hydrostatic machinery as good as possible, using simply shaped test specimen and a test machine, which allows an easy measurement of the mechanical parameters to derive from these friction and wear. The load conditions of the tribo-systems within a hydrostatic machine (contact pressure, type of relative movement) and – velocity and destructor and the properties of the contact partners define the parameters in the contact zone (temperature and geometry) which have the main impact on friction coefficient, critical load and wear performance of the tribo-system. The test procedure and test machine was developed by a systematic approach in research projects DGMK 514 [3], 514-1 [4] and 610 [5].

2. PRINCIPAL ARANGEMENT OF THE TEST APPARATUS

The aim of the development of a new test procedure was to achieve
- reproducible quantitative test results with high accuracy,
- simple test specimen, which do not require special manufacturing technologies,
- a test procedure which can be automated and
- low energy consumption, small volume of test fluid and short test time.

A detailed analysis of the tribo-contacts in hydrostatic machines was the base for a specification for this new test procedure and machine. Using design methodology and systematic design approach a test principal was found, which is shown in Fig. 1. The arrangement of the test apparatus allows the investigation of line contact and area contact. During the research project it was found, that the line contact is the more interesting one and generates data which allow to classify lubricating capabilities of different fluids; this is the reason why the majority of the tests was only using data from the line contact.

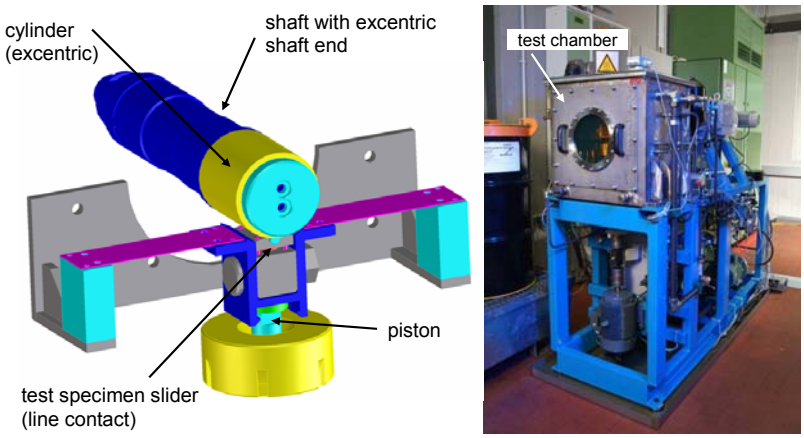

Figure 1. MPH test rig - principal arrangement of the test apparatus

To quantify the lubricating capability of a hydraulic fluid the following parameters are used:

- $p_{HD,crit}$ critical pressure which leads to adhesive material removal ("galling"),
- $\mu_{Ex,average}$ average friction coefficient in the line contact,
- V_{line} wear volume of the test specimen slider.

The accuracy and the reproducibility of these parameters define to a high extend how good the tested fluids can be classified as low, medium and high lubricating fluids. Exact measurements of the mechanical parameters as speed, torque and pressure, the possibility to calculate contact forces having friction in guiding devices and bearings in the calculation and a sophisticated method to measure and calculate the wear volume at the slider are the basis to achieve adequate results.
During the research project a number of design changes have been made with the test machine to improve the accuracy and reproducibility of the measurements.

3. TEST CONDITIONS

To define the optimal test conditions for the short term and long term test (short term test is the test for critical load, long term test is the test for friction coefficient and wear volume) a great number of tests were done. During these tests it was found that the starting process for the test is of significant influence on the results of the tests.

3.1 Start procedure

The parameters of the starting procedure have to be such that initial damages of the test specimen are avoided and a controlled running in of the line contact is achieved. An automation of this starting procedure lead to a significant improvement of the following tests.

3.2 Short term test procedure

Short term tests are used to find the critical pressure $p_{HD,crit}$, which is the pressure when spontaneous and intensive adhesive material transfer between the sliding contacts starts galling. The pressure on the piston produces a critical pressure within the tribo-contact at which the lubricating film between the contacting services disappears and mixed friction changes to friction of solids. Figure 2 shows the developing of the test parameters versus time for a typical short term test.

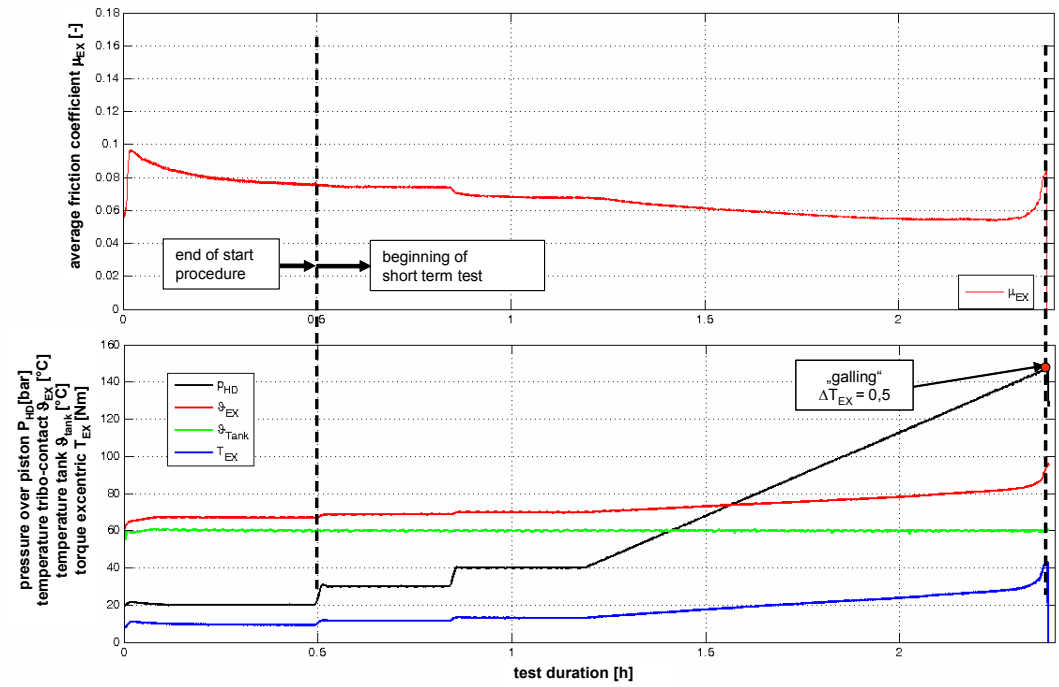

Figure 2. Typical developing of the test parameters within a short term test

3.3 Endurance test procedure

The endurance test is used to find the fluids specific work friction coefficient of the line contact and the volume loss of the test specimen slider. The load of the tribo-contact is constant for all tests; load means the average pressure on the piston which is held constant during the hole test to produce a constant force in the line contact between slider and cylinder (excentric). Figure 3 shows the developing of the test parameters within the endurance test.

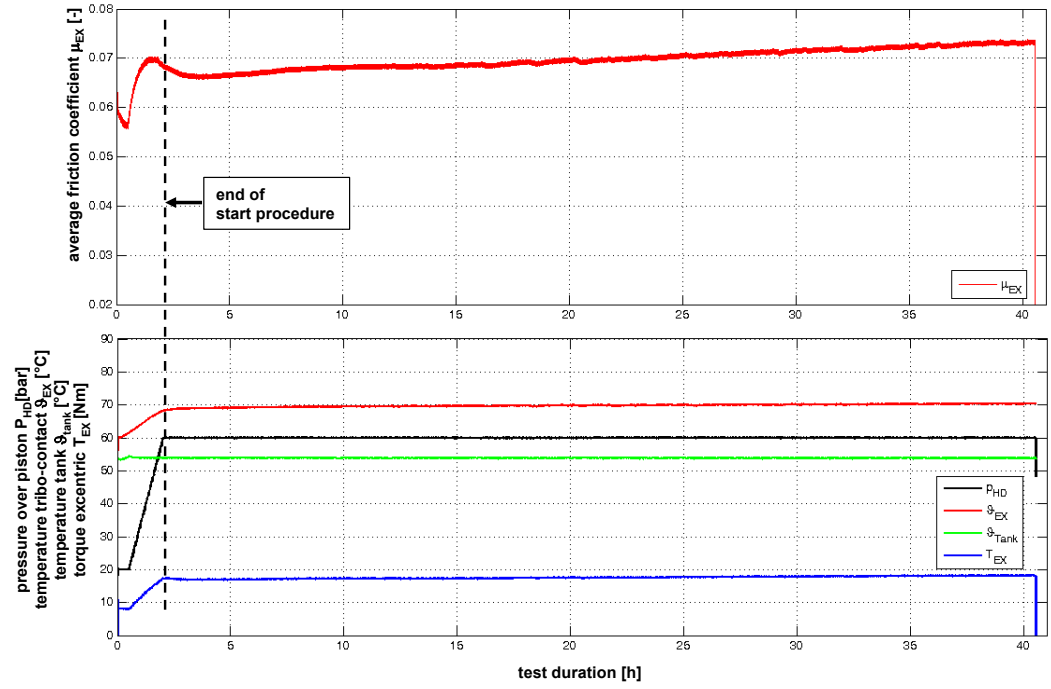

Figure 3. Typical developing of the test parameters within a endurance test

4. RESULTS FROM COMPLETET TEST SERIES

Within the project mineral oil based hydraulic fluids of HL- and HLP-type and synthetic esters of HEES-types were tested; at this time the tests are extended to mineral and ester based multigrade motor oils and gear oils. Main task of the by now completed tests was to demonstrate different lubricating capabilities of these types of fluids as they should be expected for the different types. The most important point was to demonstrate that the results of multiple tests with the same fluid are in a narrow range, i.e. show small deviations from an average value. This paper reports about the test results for six different types of hydraulic fluids, one fluid of HEES-type, three fluids of type HLP and two fluids of type HL. All fluids had corrosion and anti-aging additives, the HEES-type and the HLP-type fluids were equipped with ep- and aw-additive packages in different concentrations.

The table in Fig. 4 gives information about the absolute values of the tests of a typical test range. It is important to see that the critical pressure and the average friction coefficient of three test runs are more or less close to an average value while the volume loss of the slider shows bigger deviations for different tests with the same fluid under the exact same conditions. It can also be seen that there is a certain correspondence between critical load, average friction coefficient and volume loss. On the other hand the table shows, that a relative comparison of the fluids lubricating capabilities is not very easy, because a great number of test results have to be taken into account. Therefore a different presentation of the results has been developed, which is also shown in Fig. 4. The diagram shows the isometric presentation of a results base. In this figure the ellipsoids represent the limits of the measured values for the different fluids; all values are referred to the HF-1 fluid as a reference.

Hydraulic fluid	Class	$p_{HD,krit}[bar]$	$\mu_{Ezz,mittel}[-]$	$V_{Linie}[mm^3]$
HF-1	HL	60	0,060	0,0589
		60	0,056	0,0620
		57	0,062	0,0419
HF-2	HL	47	0,055	0,0155
		42	0,055	0,0225
		41	0,058	0,0400
HF-3	HLP	62	0,063	0,0176
		67	0,058	0,0202
		61	0,063	0,0245
HF-4	HLP	86	0,070	0,0409
		88	0,064	0,0230
HF-5	HLP	73	0,074	0,099
		77	0,068	0,0837
HF-6	HEES	120	0,037	0.0092
		106	0,038	0.0022

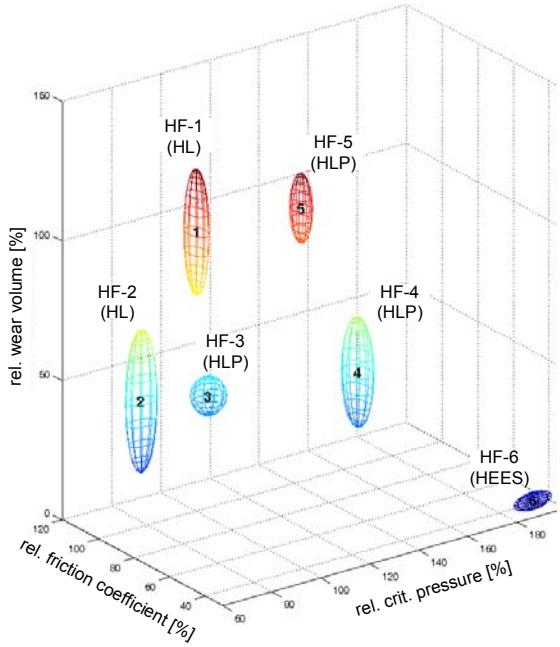

Figure 4. Absolute values and isometric representation of the test results

Figure 5 shows the projections of the three dimensional diagram of figure 4 and demonstrate clearly that the measurement with the MPH test rig allow a clear differentiation of not only fluids of different classes but also of fluids within one class.

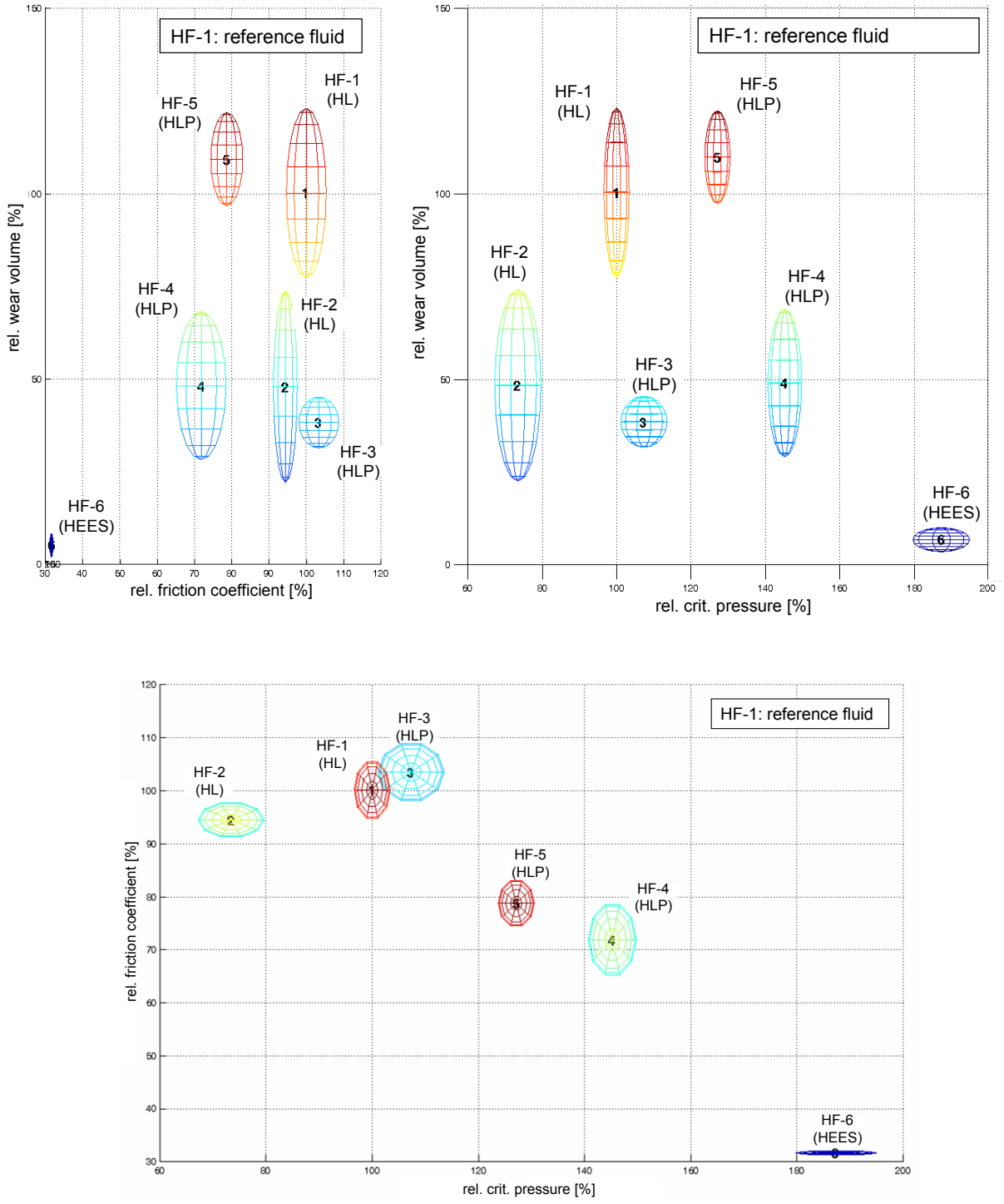

Figure 5. Projections of the three dimensional diagram (see fig. 4) of the result parameters

CONCLUSION

The results of a high number of tests within the MPH-project have shown that it is possible to differentiate the lubricating capability of hydraulic fluids with the MPH test rig. With the design improvement of the test rig and the development of a fully automatic test rig control the reproducibility of test results could be improved. Looking to recent tests with the actual test rig it could be seen, that the values for friction coefficient and critical pressure do not differ more than ± 10% from the average. The wear volume shows bigger deviations within a test sample with a maximum of ± 15 % which possibly can be reduced by more accurate measurement techniques [6], [7].

Reproducibility of test results was a major point for the MPH-project. The achieved accuracies must be seen in comparison to accuracies requirements of other tests which are used to test hydraulic fluids. The vane pump tests and also the FZG-test [8] do not define a minimum number of test runs and no accuracies in the test results. According to the standards in both tests only one test run is necessary for a classification of a fluid. This leads to the conclusion that test results with the MPH test rig and – procedure may give better reliable data about the lubrication capability than other test procedures used assuming at minimum 3 test runs per fluid.

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