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ENERGY-EFFICIENT TESTING DEVICE FOR NEW HYDRAULIC FLUIDS

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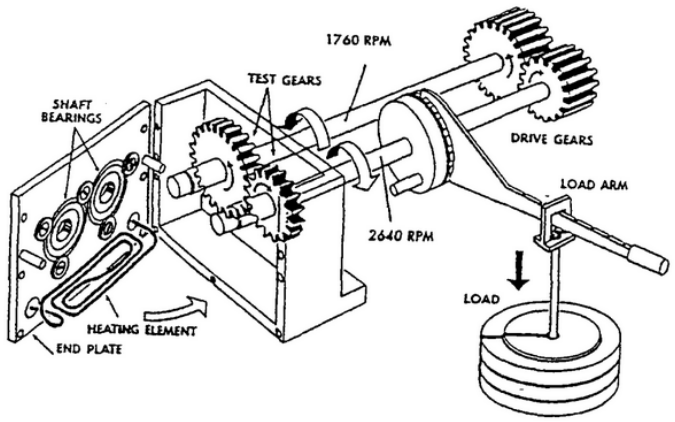
ABSTRACT
A large number of standardized tests have been developed and used in order to establish the lubricating properties of different hydraulic fluid in view of material wear and component degradation. In case of known hydraulic fluid type, e. g. mineral based hydraulic oil, this does not represent a major problem. In the case of completely new type of hydraulic fluid, e. g. ionic liquids, used as a lubricant, it is a completely different situation, closely linked to the test-costs. In these cases, we cannot rely directly on most of the known standards and known testing procedures. The major problem in this case is the energy consumption of testing device, especially because some standard tests are using very powerful drives, up to 90 kW, and last for several days or weeks, using a large quantity of testing fluid.
This paper discusses the different standard tests procedures, with respect to energy consumption. The proposed new testing device for testing new hydraulic fluids based on 5.5 kW drive system, a small testing fluid quantity, with the option of extending the flow capacity using hydraulic accumulators. A new testing device concept has been designed and constructed, and is appropriate for the combined testing of as many hydraulic components as possible, in market quality.
Keywords: hydraulic fluid, testing devices, energy aspect

1. INTRODUCTION
Tests related to lubricating ability of hydraulic fluid and hydraulic components as well, usually use techniques and procedures similar to those occurring during the actual component usages. Therefore testing should be performed in approximately identical operational conditions as during actual use: the temperature conditions, alternating pressure loading profile… In most cases, the operating conditions are tightened up e.g. higher fluid temperature, higher circulation number… [1]
The time required for testing a new hydraulic fluid under actual, real operating conditions is not specified. Such testing would last too long. We want to get the results much sooner than by testing under real and at normal component use conditions. So, various different procedures of faster component degradation are used under harsher conditions of use. The results can be gained in a reasonable time by retaining all the characteristics of functioning conditions since matters are only accelerated. The solution to the problem is the use of various methods of accelerated testing on purpose-made test devices.
In practice two types of tests are used: mechanical tests [2] and thermal tests [3]. Thermal tests are more appropriate when testing the durability of fluid and fluid degradation mechanism. When the wear of the hydraulic components is at the forefront, the mechanical tests are preferred.

2. MECHANICAL TESTS PROCEDURES AND DEVICES
Mechanical tests for determining the suitability of the lubricant can be divided into two groups: low-volume fluid tests, with a small volume of fluid required, and pump tests, with a much larger quantity. Some of them are standardized, the others designed for targeted testing or are adapted standard tests.

2.1. Small-volume tests

Small-volume mechanical testing procedures using laboratory testing devices, such as four-ball, pin-on V-block, Timken anti wear test... serving run for determination of anti-wear properties.
The *FZG-ASTM D5182 test* 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, usually a small amount, as in gear transmissions. The Lapotko s. c. "MP-1 test" uses fluid volume in amount of 0.7 L. In addition to lower volume, the MP-1 test is conducted for only 50 hours (and in some cases only 10 hours). Both test devices are shown in Figure 1.



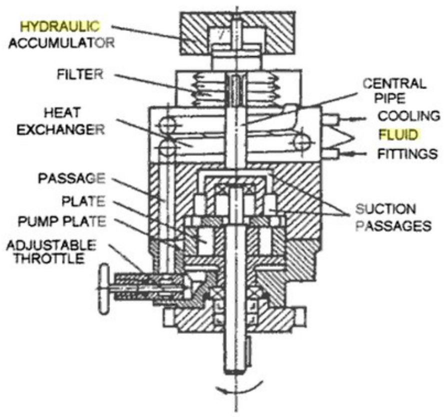


Figure 1. Schematic illustration of the FZG gear test (left) [1] and MP-1 test (right) [4]

MP-1 test is actually a small-volume pump test, using a vane pump type. The wear rate is based on the weight loss of the vanes, only after the test is completed. In view of the relatively same size, this test comes close to a "bench hydraulic pump test".
The Vickers V-100 vane pump is the most commonly utilized small volume hydraulic pump test. There are at least three national Standards based on the use of this pump: ASTM D-2882, DIN 51389, and BS 5096. The total loss of the vanes plus ring at the conclusion of the test is the quantitative value of wear [4], Additionally, such test is a 100-hour low-volume hydraulic pump test that utilizes only 1,3 L of fluid. This test utilizes a Vickers V10-1P3P1A20 vane pump with a 9,84 cm^3/rev displacement.

2.2. Large-volume pump test

Among the best known and most widely used pump test, is standard Eaton-Vickers vane pump test, using a standard industry pump type 35VQ-25 (ASTM D6973) built on to a 196 L tank and powered by 58 kW motor. Test rans for extended hours to determine the durability of the hydraulic fluid containing an anti-wear additive package. After 1,000 hours the pump was still below the weight loss limit for total ring and vane wear. [4]
Similar test are the Denison HF-O specification/test using a vane pump, or Sundstrand piston pump test and extended Sundstrand piston pump test, with the testing time of 450 hours. The Sundstrand pump test included 1 % water contamination to stress the fluid further. Another round of Sundstrand pump tests was run at an elevated temperature of 120 °C. Due to the higher temperature, no water was added to this test, and all other conditions remained the same.
A similar piston pump test is Komatsu 500 hour test. 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 constant, or is alternating within the 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.
All these mentioned and similar tests are based on large amounts of liquid under test, using a relatively high driving power, which in the long term testing represents a lot of energy. The most important testing parameters of mentioned pump test are summarized in Table 1.

Table 1. Testing parameters of different pump tests

	Eaton/Vickers test 35VQ-25	Denison Vane Pump Test	Sundstrand Piston Pump - Series 22
Fluid volume	196 L	189 L	45 L
Test temperature	93 °C	71 °C for 60 h 99 °C for 40 h	82 °C (1 % water) 120 °C (no water)
Test duration – standard Test duration – extended	50 h (2 days) 1,000 h (42 days); with inspections @ 300 h	100 h (4 days)	225 h (9 days) 450 h (19 days)
Pressure	cca. 207 bar	cca. 172 bar	cca. 345 bar
Pump speed	cca. 2400 rev/min	cca. 2400 rev/min	cca. 3100 rev/min
Flow rate	144 L/min	265 L/min	95 L/min
Power	58 kW	90 kW	64 kW

In the case of testing a completely new type of hydraulic fluid, these type tests are too energy consuming, a large amount of fluid is used and conclusions are made only in regard to specific pump type. No information is obtained regarding the impact of fluid to other components of hydraulic system. Therefore, we designed an alternative low-cost bench screening procedure, requiring a small quantity of test fluid, and using diverse hydraulic components, not only a pump - combined testing.

3. COMBINED TESTING DEVICE

In order to obtain a comprehensive insight into the influence of the hydraulic fluid on the various components that are characterized by different wear mechanisms (e.g. hydraulic valves, especially control valves), a more appropriate test should be used.

For hydraulic valves three different types of wear mechanisms are dominant (see Figure 2): erosion, three-body abrasion, and impact wear. The characteristics of these wear types and the factors governing wear behaviour are discussed as follows.

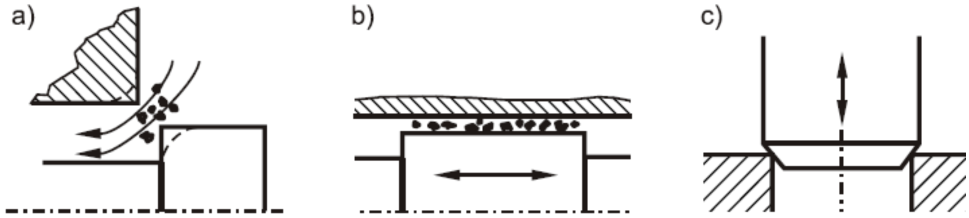


Figure 2. Valve wear mechanisms: a) erosion, b) three-body abrasion, c) impact wear

On the basis of the previously presented tests, which are limited to pump, as only one component in the hydraulic system, it is reasonable to design a different concept of testing for a comprehensive insight. New test rig design must provide the following aspects and demands: determine the suitability of new fluid under real operating conditions, usage the variety of hydraulic components, in industrial quality, commonly used within hydraulic systems, take into account the aspect of energy consumption, as well as the scale of the test rig, the duration of the test, the cost of testing, the possibility of on-line monitoring of all important data, at certain intervals, to check the changes in the characteristics of the tested components, to use the standard test procedures, where possible, the possibility of cost-optimal repetition of the test etc…

In accordance with the above mentioned requirements, a test rig for the integrated testing of the impact of a new hydraulic fluid on all components of the hydraulic system was developed. The hydraulic scheme and the appearance of the testing device show Figure 3.

The test rig allows insight into the pump wear, investigation of wear on vital parts of different valve types (control spool valve, poppet valve), the impact of the new fluid type on a variety of materials used within other hydraulic system components (filter material, paint coat, sealing…), as well as the on-line and off-line monitoring of the degradation process the components.

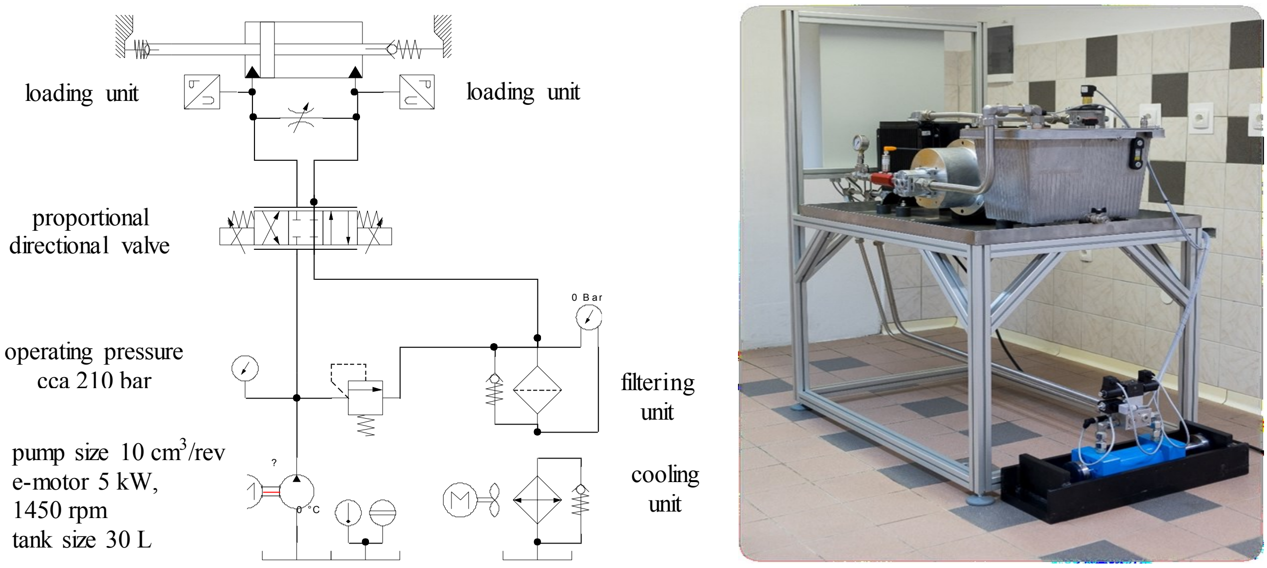


Figure 3. Hydraulic scheme and layout of combined testing device

4. CONCLUSION

Different methods are used for testing the wear resistance of individual hydraulic components, along with the known hydraulic fluid, as e. g. mineral based hydraulic oil. Some of them have become standardized; others are of internal nature, linked to a single manufacturer, either components or fluids. But, none of the represented methods allows a comprehensive insight into degradation mechanisms inside different hydraulic components when completely new hydraulic fluid type is tested.

An additional problem of used testing methods and procedures, especially those one with pumps, are usually very high costs of energy consumption (90 kW, several weeks), and testing under unrealistic conditions.

For the purpose of testing new hydraulic fluids, a new test device concept has been designed, appropriate for the combined testing of as many hydraulic components as possible, in market quality: pump, sensitive control valves, sealing materials, paint coats, filter material etc. The testing is carried out under demanding, but still normal operating conditions, and with low energy consumption.

5. REFERENCES

[1] Totten, G. E.: Handbook of Hydraulic Fluid Technology, Second edition, CRC Press, Taylor & Francis Group, 2012.,

[2] Lovrec, D.: Mechanical tests for accelerated testing of mineral lubricants with respect to its degradation. TMT 2016: proceedings, 20th International Research/Expert Conference "Trends in the Development of Machinery and Associated Technology", 24th September-1st October, 2016, TMT Proceedings, ISSN 1840-4944, Year 20, no. 1, Zenica, pp. 137-140, 2016.,

[3] Lovrec, D., Tič, V.: Thermal tests for testing of degradation behaviour of mineral based hydraulc oils. TMT 2016: proceedings, 20th International Research/Expert Conference "Trends in the Development of Machinery and Associated Technology", 24th September-1st October, 2016, TMT Proceedings, ISSN 1840-4944, Year 20, no. 1, Zenica, pp.141-144, 2016.,

[4] Totten, G. E., Kling, G. H., Smolenski, D. J.: Tribology of Hydraulic Pump Testing, Technology & Engineering, ASTM STP 1310, 1997.,

[5] Zhang, K., Yao, J., Jiang, T., Yin, X., Yu, X.: Degradation Behavior Analysis of Electro-Hydraulic Servo Valve under Erosion Wear, 978-1-4673-5723-4/13/ ©2013 IEEE, 2013.,

[6] Reinertz, O., Schlemmer, K., Schumacher, J., Murrenhoff, H.: Development of an Accelerated Ageing Test for Hydraulic Spool and Poppet Valves, 7th International Fluid Power Conference, Aachen 2010, 1-13, 2010.