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MULTIPASS HYDRAULIC FILTER TESTS

Franc MAJDIČ[1]

[1] University of Ljubljana, Faculty of Mechanical Engineering, franc.majdic@fs.uni-lj.si

Abstract: *Engineers in industry meet daily with various machines; their operation depends on hydraulic systems. In order to operate the machines smoothly it is necessary to pay special attention to the hydraulic liquid. By selecting the appropriate filter elements, we improve the filtration process and thus the condition of the hydraulic liquid, which in the long term helps to extend the useful life of hydraulic components and reliability of hydraulic systems. In order to select the most suitable filter cartridge, various methods of their evaluation and testing have been developed, including the Multiple Transition Test according to ISO 16889:2008 standard. Work will present development and validation of multipass filter test rig. Some results of the filter tests with standard MTD dust will be shown. ß valve and filter capability will be introduced on the end.*

Keywords*: Multi−pass test, filter element, hydraulic fluid, filtration ratio, cleanliness*

1. Introduction

Cleanliness of hydraulic fluid is extremely important for useful life of hydraulic components and the whole system. Filtering quality is very important [1]. The ISO 16889 [2] is in use to evaluate the quality of filters. Mentioned standard describe test rig and procedure to do appropriate and comparable filter tests. The standard also specifies a calculation procedure for determining the tested parameters and for evaluating the obtained experimental results. Standard test dust MTD by ISO 12103-1-A3 should be used [3-5].

First we calculate predicted test time of the tested filter element (equation 1). Desired upstream gravimetric level (c'_b) should user choose from the table in standard. There are three possibilities: 3 mg/L, 10 mg/L or 15 mg/L. Estimated filter element contaminant capacity (m_e) is a parameter of tested filter which should be known by the producer. Test flow rate (q) should be chosen by user.

$$\boldsymbol{t_{pr}} = \frac{\mathbf{1000} \times \boldsymbol{m_e}}{\boldsymbol{c_b}' \times \boldsymbol{q}} \qquad (1)$$

Minimum required operating injection system volume is calculated by equation (2).

$$\boldsymbol{V_{min}} = (\mathbf{1,2} \times \boldsymbol{t} \times \boldsymbol{q'_i}) + \boldsymbol{V_v} \qquad (2)$$

Desired gravimetric level is calculated by equation (3).

$$c'_i = \frac{c'_b \cdot q}{q'_i} \qquad (3)$$

Quantity of contaminant is calculated by equation (4).

$$m = \frac{c'_i \cdot V_{ii}}{q'_i} \qquad (4)$$

After test of filter element, it is necessary to calculate upstream (equation 5) and downstream (equation 6) particle counts.

$$\overline{\boldsymbol{N}}_{\boldsymbol{u,x,t}} = \frac{\sum_{j=1}^{n} \boldsymbol{N_{u,x,j}}}{\boldsymbol{n}} \qquad (5)$$

$$\overline{\boldsymbol{N}}_{\boldsymbol{d,x,t}} = \frac{\sum_{j=1}^{n} \boldsymbol{N_{d,x,j}}}{\boldsymbol{n}} \qquad (6)$$

Using equation (7), filtration ratios $ß_{x,t}$ can be determined for each of 10 reporting times of the test.

$$\bar{\boldsymbol{\beta}}_{\mathbf{x(c)}} = \frac{\bar{N}_{u,x,t}}{\bar{N}_{d,x,t}} \qquad (7)$$

2. Test rig

Standard ISO 16889 describe test rig and protocol how to test hydraulic filters. Figure 1 shows hydraulic circuit of recommended test rig. It contains two subcircuits, A and B. Subcircuit **A is contamination injection system**. It consists of conical (60°) reservoir (a), injection pump (b), shut-off valves (c), clean-up filter (g) for preparing system before entering the test dust, check valve (m), particle counting system (e), flow meter (h) and oil cooler (j). **Filter test system (B)** consists conical (60°) reservoir (a), positive displacement system pump with drive (n), tested filter (d), differential pressure sensor, shut-off valves (c), two (one on input and one at output of tested filter) particle counting system (e), pressure sensor (l), back pressure valve (f), clean-up filter (g) for preparing system before entering the test dust, check valve (m), flow meter (h) and oil cooler (j).

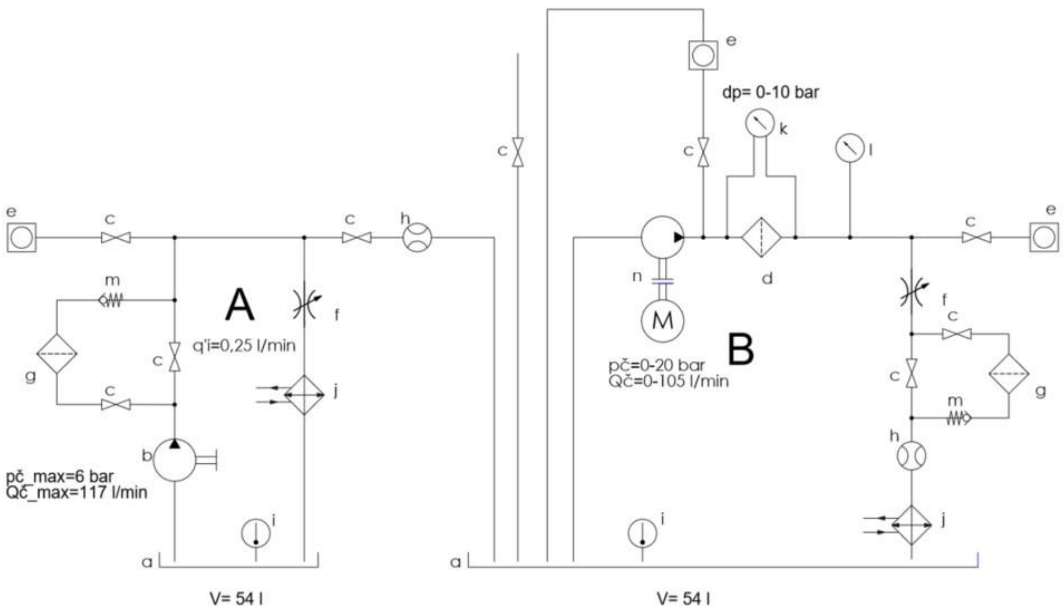

Fig. 1. Hydraulic circuit of multi-pass test rig [VIR = ISO 16889]

Figure 2 shows frame of new multipass filter test rig in development phase. We tested different construction type of pumps (Fig. 1, pos. b and n). Problem is with wear and cavitation, so in this way is very important to find correct construction of the pump.

Figure 3 shows two on-market accessible filters tested in the context of this research. Both filters have nominal filterability 20 µm.

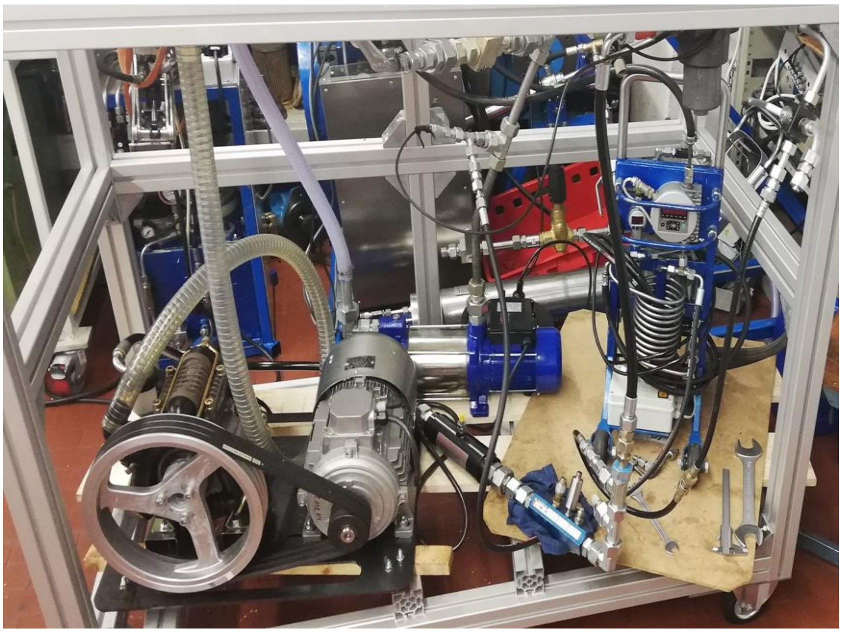

Fig. 2. Hydraulic test rig (in development phase)

Fig. 3. Tested hydraulic filters

3. Results and discussion

Two different standards, on market accessible filter element have been tested (Fig. 3).
Figure 4 shows results of filtration ratio ß for the first filter element. It is obvious that the smallest changes are seen in the particle size of 4 µm. Cleanliness in size of 4 µm was better just on start for 1 class of ß filtration ratio. At particle size of 6 µm was ß ratio 4 on the start, on the end it has fallen on ratio 2. The best result with the first filter element was for particle size of 14 µm. The best ß ratio, 9 was at the second period. On the end of the test was ß ratio 4 for particle size of 14 µm and more.
Figure 5 shows results of filtration ratio ß for the second filter element. It is also obvious, that the smallest changes are seen in the particle size of 4 µm. ß ratio for particle size of 4 µm was 2 just in third and fourth measurement in other measurement it was 1. At particle size of 6 µm was ß ratio 4 in six measurements, on the end it has also fallen on ratio 2. The best result with the second filter

element was for particle size of 14 µm. The best ß ratio, 11 was at the eight period. On the end of the test was ß ratio 10 for particle size of 14 µm and more. The second tested filter element (Fig. 5) was better than the first one (Fig. 4) in the way of filtration ration ß.

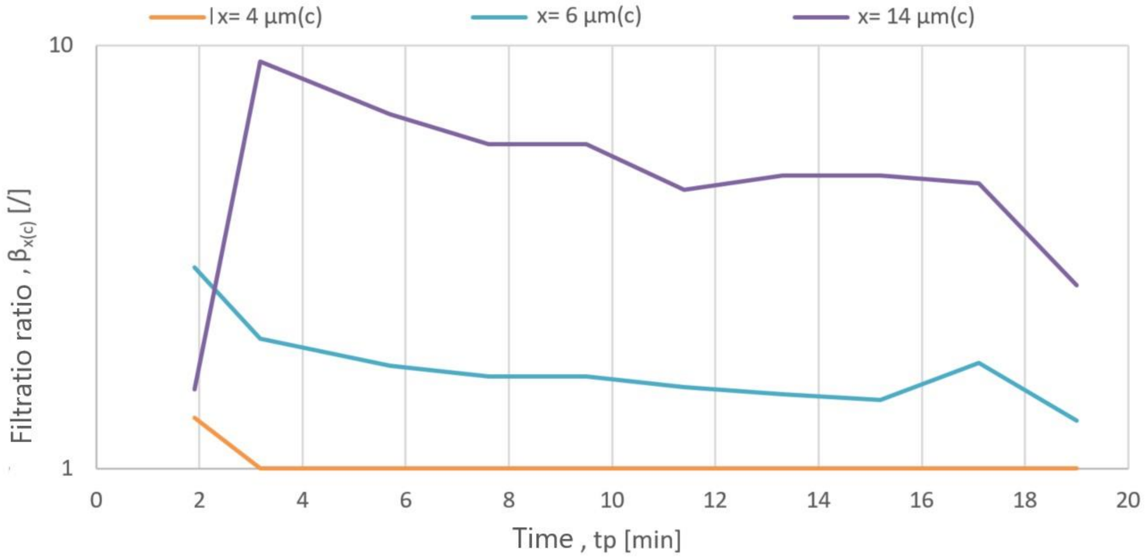

Fig. 4. Measuring results of the first tested filter

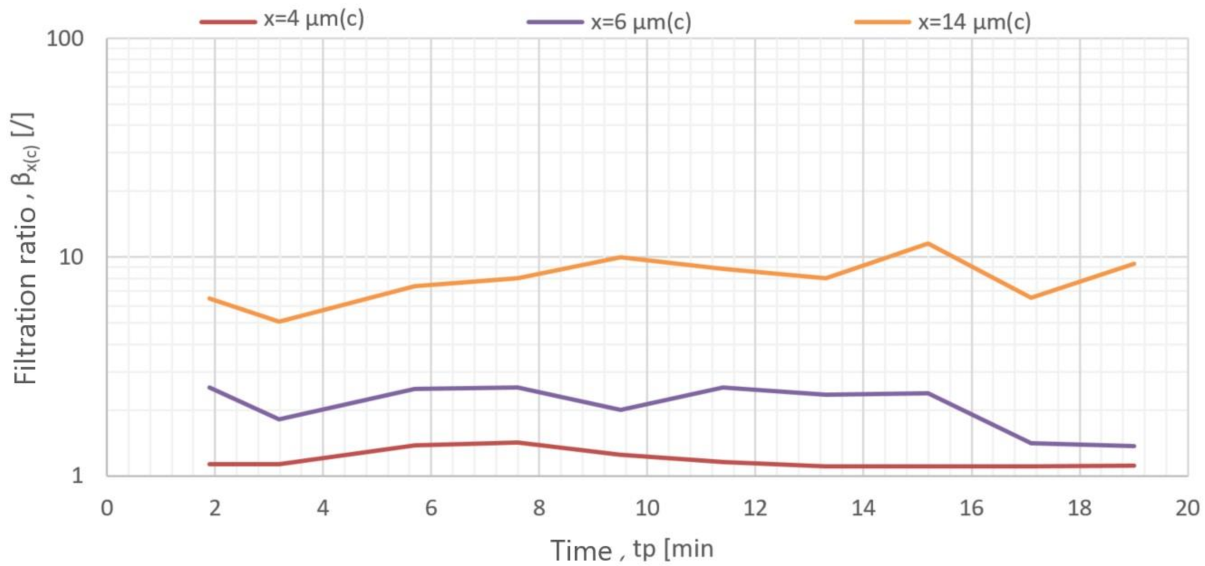

Fig. 5. Measuring results of the second tested filter

In addition to the filtration ratio, the quantitative absorption of the filter is also very important. Both filter elements have been weighed very carefully before and after the test. Results are shown in table 1.

Table 1: Results of weighing filters before and after the test

	Mass before test [g]	**Mass after test [g]**	**Difference [g]**	**Calculated mass, m_R [g]**
Filter element 1	189.807	193.527	3.720	5.02
Filter element 2	245.072	246.73	1.658	4.85

4. Conclusion

The ISO 16889 multi-pass test were examined and found out all the requirements for successful testing of hydraulic filter elements.

We designed and built a test rig with all the appropriate hydraulic components and measuring instruments that made it possible to test hydraulic filter elements.

We have found that, despite the recommendations of the standard, some hydraulic components are not available or are not suitable for testing under the conditions prescribed by the standard.

We successfully implemented configurations that improved the test conditions and did not affect the distribution of the test dust in the hydraulic fluid. The hydraulic pump pressure oscillations were reduced to the tolerable limit, ± 10%.

Testing of hydraulic filter cartridges was performed and the results obtained were analyzed according to the procedure prescribed by the standard. The measured final pressure drops on the filter elements were 2.57 bar in the first case and 3.55 bar in the second case. We have filled in all the necessary tables and plotted all the corresponding graphs.

We have found that hydraulic fluid must be handled carefully to prevent foaming, as air bubbles in the liquid affect the measured number of particles in the liquid. The average filtration ratio β had a value of 1 for the first test, for particles larger than or equal to 4 μm, due to the air bubbles in the hydraulic fluid resulting from foaming.

The results show that the test rig is suitable for testing according to ISO 16889. The average filtration ratio β for particles larger than or equal to 6 μm in the first test was 1.63 and 2.09 in the second. For particles larger than or equal to 14 μm, it was 4.65 in the first test and 7.4 in the second test, which makes sense given the nominal permeability of the filter cartridge.

We have identified the shortcomings of the test facility, especially in measuring equipment, which in some cases does not meet the requirements of the standard. Better measuring equipment would provide more accurate results, especially results related to filtration efficiency.

The multi-pass test can effectively evaluate the hydraulic filter elements. The test is suitable for testing all types and sizes of filter elements and shows us enough data to select the hydraulic element properly. A properly performed test gives a better idea of the effectiveness of the filter elements, and consequently it is easier to select the appropriate filter element that will ensure proper filtration of the hydraulic fluid and thus contribute to a better functioning of the hydraulic system.

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