Jari RINKINEN, Petteri MULTANEN

THE EFFECT OF VARIABLE FLOW ON HYDRAULIC FILTER – THE RESEARCH IN TUT/IHA SINCE 1993

1. Multi-Pass Test

The filtration efficiency of hydraulic filters is generally rated using the standardised Multi-pass test method and test equipment (figure 1). In order to achieve a high reproducibility and reliability of the test results the test values of the Multi-pass test are very stable. This is however inconsistent with the real-life working conditions which can cause a substantial decrease of the filter performance. That is why there is need for new types of test procedures for the testing of hydraulic filters.

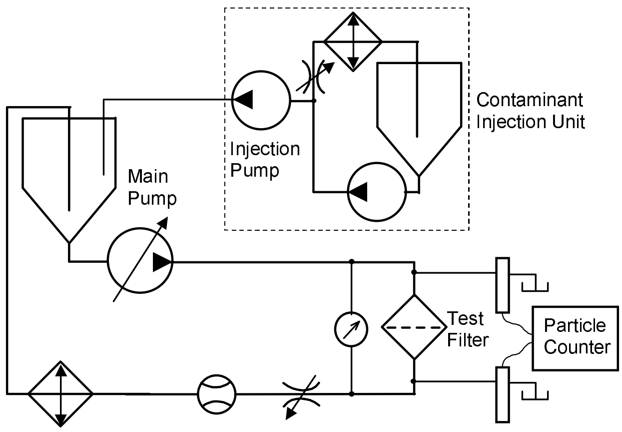

Fig. 1. The Multi-pass test unit (simplified).

2. Test Results of Filters in PARANA Project

In the Institute of Hydraulics and Automation (IHA) was carried out a particle analysing project (PARANA 1993-95) in co-operation with 22 project participants from Finnish industry. In the project the function of hydraulic filters ($\beta_{10} \geq 75$, four manufacturers of filter) was studied under variable flow in laboratory test rig that was constructed for these measurements. Three different flow forms were used during tests. These were steady flow, square flow and cyclic flow form (figure 2).

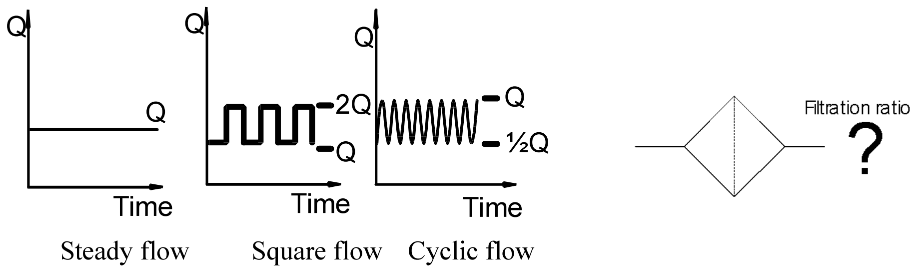

Fig. 2. The used variable flow forms with basic question of current filtration ratio [1]

The steady flow form in figure 2 simulates by-pass circuit flow condition. Square flow simulates the flow condition in a return line filter and The cyclic flow test simulates the flow condition in pressure line filter. In square flow the used period between the changes in square flow was one minute. In cyclic flow the used frequencies was 1 Hz and 2,5 Hz.

The injection of ACFTD test dust was done once in the beginning of each laboratory test. So, these could be called batch type tests. That is why in the results the term "filtration ratio" is used instead of β_x-value. The ACFTD concentration in the beginning of each test was 1 mg/l. During the test the oil was circulated through the test filter until the upstream particle concentration was dropped to 0,03 mg/l. The values 0,03...1 mg/l was simulating the cleanliness of industrial systems (ISO 14/12 or better) in this project.

The tested four filters was manufactured in four different companies. The sizes and other catalogue data were about the same. The customer could have chosen anyone of these to the same place in his system. Main results of these flow form tests with filter C are shown in figure 3.

In figure 3 is shown very strong changes in filtration ratio with different flow forms. Naturally the best results are reached with steady flow. Filtration ratio is much lower with square flow and the worst results are got with cyclic flow. On the other hand the changes in cyclic flow results between 1...2,5 Hz are minor.

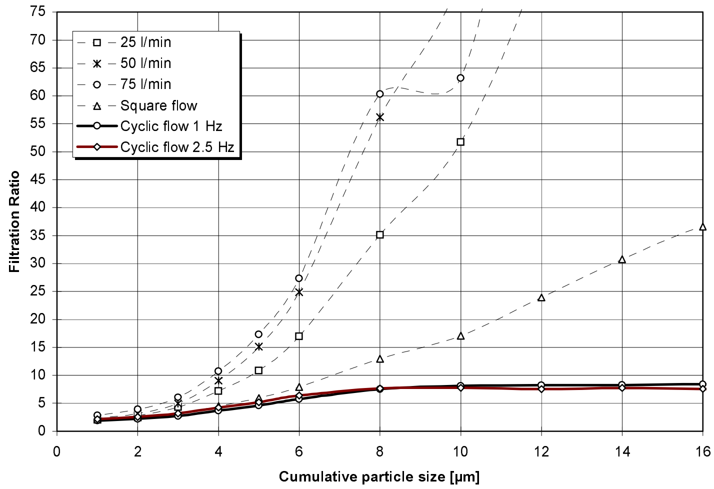

Fig. 3. The average filtration ratio in laboratory tests of pressure line filter C (β_{10} >75) [1]

Some results from field tests of filters in Finnish metal industry are shown in figure 4. In figure 4 is shown that the measuring results of the filter can vary a lot during the normal working cycle of the system. Pressure levels and pressure differences will have a strong influence to number of particles and of course to the measuring event itself. This is how the filtration ratio will also vary significantly between the measurement rounds 2 and 4.

3. SUOTU Project

Since 1996 IHA has co-operated in SUOTU projects with Parker Filtration/Finn-Filter on this research area. In SUOTU projects hydraulic filters were tested using a further developed filter test unit. A simplified illustration of the hydraulic circuits of the new test unit is presented in Figure 5.

The test unit is in principle as a Multi-pass test unit but in addition it enables the produce of accurate flow variations and the control of particle concentration in filter upstream. The test unit and the test procedures used makes it possible to test hydraulic filters under different conditions, which are near to the actual working conditions of filters. In Multi-pass tests ISO Medium Test Dust (ISO MTD) was used. The test procedure included a peak flow pattern. The main parameter of it was the flow amplitude.

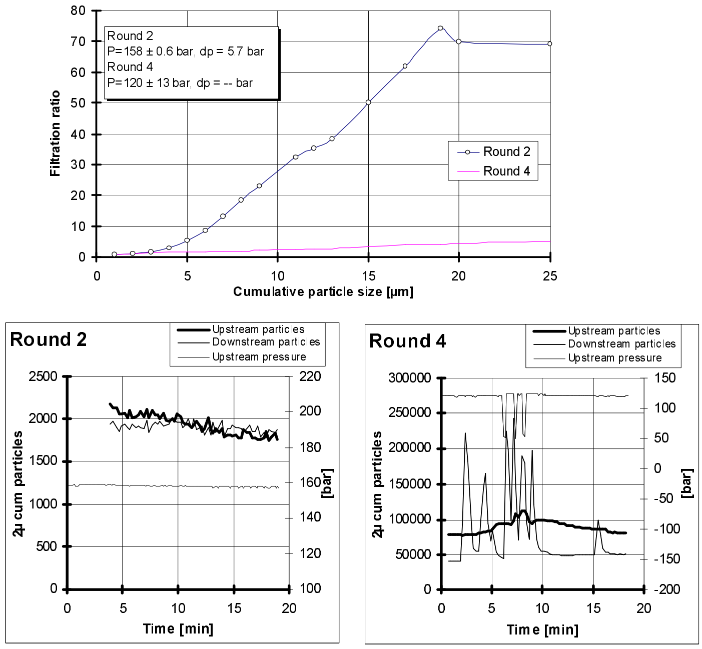

Fig. 4. Results from field tests in pressure line filter 2 (type F, b10 >75) in Finnish metal industry (ME1)

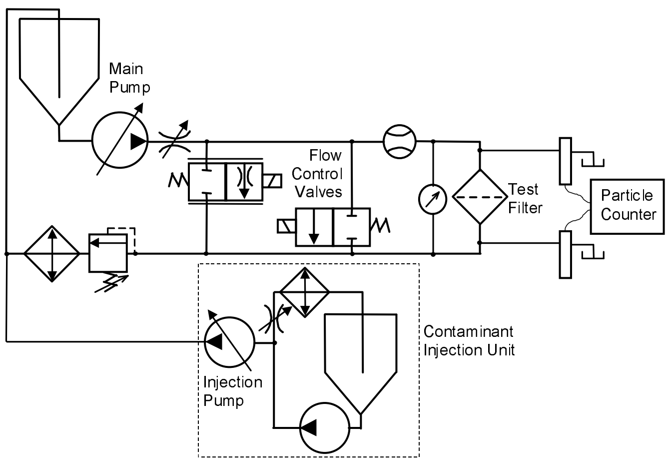

Fig. 5. The hydraulic circuits of the variable flow Multi-pass filter test unit (simplified) [2]

4. Peak Flow Pattern

All measurement and control tasks, which were needed during filter tests, were performed using a single LabView based application. The main features that were special for Multi-pass filter testing were the producing of variable flow and the control of contaminant injection on the basis of the measured particle concentration in the main unit.

Flow variations are generally easy to produce with any signal generator. In Multi-pass test the problem arises from the particle counting. In order to maintain the reliability of particle counting the flow rates of sensors must be constant, which limits the usable range of flow variations. This problem was solved using so-called "peak flow" pattern. The form of the pattern is presented in figure 6 for two flow amplitudes.

In peak flow pattern the flow changes from one level to another only for a short period of time (peak time). Even though the flow variation has the maximum influence on the filter it has a minimum disturbing influence on the particle sensors.

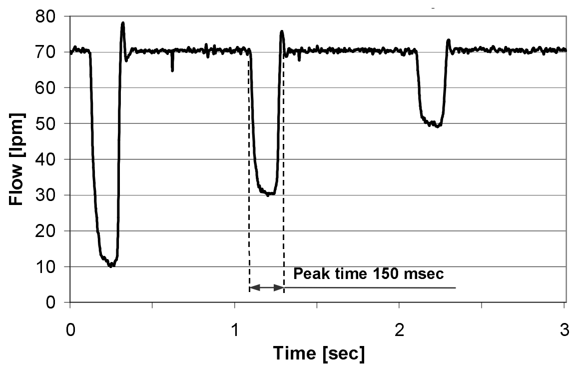

Fig. 6. Actual peak flow patterns 70..10, 70..30 and 70..50 lpm with peak time of 150 msec [4]

5. Controlled Injection Flow

Injection flow was controlled in all presented tests to maintain a constant particle concentration in the upstream of filter. In reference tests the control was based on one base injection level, which was adjusted if needed. In combined tests there were two different base injection levels, which were changed along with flow type. This was needed because the flow rate going through the filter was different in constant and cyclic flow phases.

The effect of controlled injection flow can be seen in figure 7. The upstream concentration in the main unit is presented there for particle sizes ł1µm and ł5µm as they were measured in two separate tests. Both tests were performed using the combination of constant flow 70 lpm and variable flow 70…50 lpm, but the injection flow was constant in one test and controlled in the other.

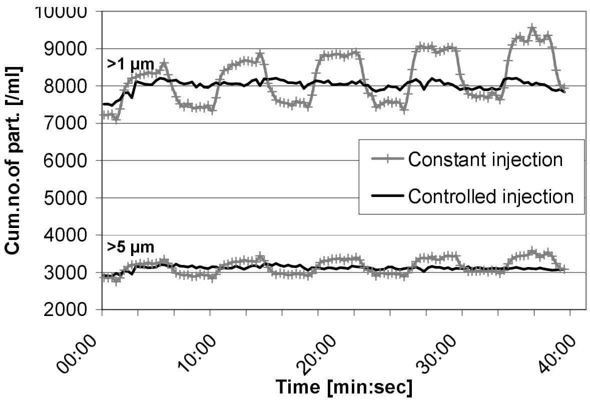

Fig. 7. The effect of controlled injection flow on the upstream particle concentration [3]

The constant injection flow caused the increase in particle concentration during cyclic flow phases when compared to the constant flow phases. In addition the concentration increased steadily during the test because the efficiency of filter decreased. The curves in figure 8 show that constant injection can not assure constant concentration if combined flows are used or the filter efficiency is substantially low.

The controlled injection flow resulted in a very stable concentration. The curves for particle sizes ≥1µm and ≥5µm are examples of this. The injection was actually controlled on the basis of particles ≥2µm, but the levels of all measured particles up to ≥40µm remained stable during control.

6. Efficiency Curves for Filter Selection

Total of sixteen 5µm elements and six 10µm elements were tested using the following flow profiles:
- Constant flow 70 lpm

- Combined constant and peak flow 70..50 lpm
- Combined constant and peak flow 70..30 lpm
- Combined constant and peak flow 70..10 lpm

In the combined tests constant flow and peak flow phases were changed and repeated after each four minutes. The cycle rate was 1 Hz in all peak flow phases and the peak time was 150 msec.

The average b-values of both element types are presented in figure 8 as a function of cumulative particle size.

The curves in figure 9 show clearly how the flow amplitude affects the filtration efficiency. The bigger is the amplitude; the lower is the efficiency. It is also evident that the efficiency is affected in all particle sizes. The spread of curves indicates that a coarse filter is more affected by variable flow than a finer filter. This can be seen also in figure 8, where particle sizes x for the definition β_X=100 are presented for both elements as a function of flow amplitude.

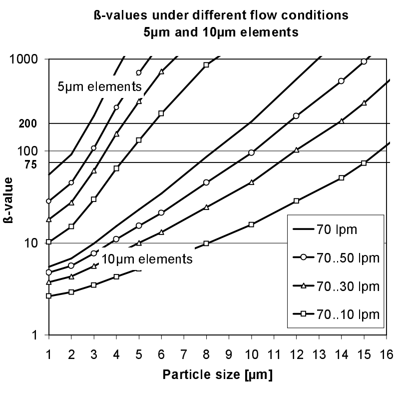

Fig. 8. The β-values of 5µm and 10µm elements tested with different flow amplitudes [4]

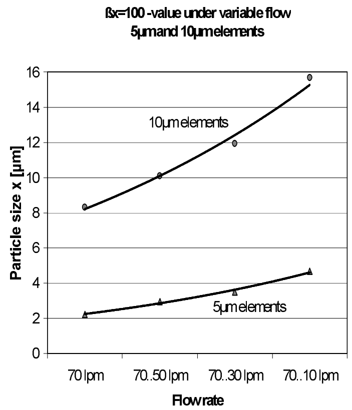

Fig. 9. Particle sizes of 5µm and 10µm elements for the definition of β_X=100

According to figure 9 the 5µm element has a value of β_2=100 when tested under constant flow. The variable flow tests resulted in particle sizes 3µm, 3,5µm and 5µm. The values show that this element type performs as expected also under highly variable flow.

The results of 10µm elements show the importance of testing under variable flow. The element has a value of b8=100 with constant flow. With variable flow the particle sizes were 10µm, 12µm and 16µm. If this element should be used under highly variable flow conditions, it should be considered as 16µm element.

7. Conclusion

The laboratory tests of filters with different constant and variable flow show that variable flow affects greatly the efficiency of hydraulic filter. Similar kind of results were got also from field tests in Finnish industry.

A series of 5µm and 10µm elements were tested using four different flow amplitudes. The presented efficiency curves serve the selection of filter and the evaluation of filtration efficiency under variable flow conditions. The test results show also that the definition of filter efficiency cannot be based purely on traditional Multi-pass test.

References

1. Kiiso T., Järvinen M., Rinkinen J.. Behaviour of Hydraulic Filters under Different Flow Conditions, The Forth Scandinavian International Conference on Fluid Power, Tampere, Finland, September 26-29, 1995. TUT/IHA. ISBN 951-722-374-9. Vol. 2, p 786-799.

2. Multanen, P., Rinkinen, J., Kangasniemi, H. & Häppölä, K. Testing of Hydraulic Filters for Real Use. The Sixth International Conference on Fluid Power, Tampere, Finland. May 26-28. 1999. TUT/IHA. 14 p.

3. Multanen, P., Rinkinen, J., Kangasniemi, H. & Häppölä, K. Modified Multi-pass Filter Test for Mobile Hydraulic Applications. 2nd International Conference Filtration in Transportation, Stuttgart, Germany, October 12-13. 1999. Filter Media Consulting Inc. 5 p.

4. Multanen, P., Rinkinen, J., Kangasniemi, H. & Häppölä, K. Filtration Efficiency under Variable Flow Conditions – Test series with different flow amplitudes. IFPE 2000 Techical Conference for Power Transmission, Chicago, USA. April 4-6,. 2000. National Fluid Power Association. p. 233-239.