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Development of portable filtration unit with self-diagnostics for industrial use

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Abstract It is well known that contamination of fluids shortens the life of hydraulic systems. Sometimes the necessary operating conditions (high pressures and high flow rates) make adequate filtration in the suction, working, or return lines through the filter difficult because it would interfere with the work process. A high cleanliness of the oil can be achieved with a so-called "bypass" filtration, which is part of the whole hydraulic device with its own circuit. Another way to ensure fluid cleanliness is to filter the hydraulic fluid with a portable filtration unit, which is the main topic of this paper. The fluid is pumped from the reservoir of the main hydraulic device, through the portable filtration unit and returned to the reservoir. In this way it is possible to clean the hydraulic oil without the need for costly and unnecessary "bypass" hydraulic components for filtration.

Keywords: • portable filtration unit • self-diagnostics • filters • wear particles • hydraulic oil •

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1 Introduction

Hydraulic filtration is a physical separation process in which solid particles are separated from the fluid using a filter medium. The process improves the cleanliness of hydraulic oil and also reduces miniature damage (wear) to pumps, valves, motors and other hydraulic components that are more sensitive to high levels of fluid contamination. Researchers at the University of Valencia describe the importance of "oil analysis used for reducing maintenance costs, improving reliability and productivity and providing peace of mind in different industry areas" and invested in an analytical approach to relate wear rate and oil analysis results [1]. T. M. Hunt emphasizes the importance of wear particle analysis and detection of particles in fluids to improve system life [2]. A recent study shows the importance of in-line monitoring of hydraulic oil contamination to improve the performance of hydraulic excavators [3]. Another study considers diagnostics and prognostics as the two main aspects to efficiently maintaining a machine in "good shape". This is a so-called Condition Based Maintenance (CBM) [4]. K. F. Martin in his paper discusses necessity for planned maintenance, condition-based maintenance and condition monitoring [5]. Scientists at the University of Novi Sad investigated how to increase the efficiency of hydraulic systems through reliability theory and monitoring of the system's operating parameters [6].

It is obvious that monitoring of parameters is important throughout the life of the machine and the need for it is growing daily. But there are setbacks for machines with self-diagnostic systems, because they are more expansive.

In our laboratory we have developed a portable filtration unit with self-diagnostics for the filtration of larger quantities of oil in hydraulic machines, such as hydraulic presses. This allows us to filter hydraulic oil while monitoring the properties of the oil in the current system. The unit can then be easily relocated to another hydraulic system where we can filter and monitor the oil of another hydraulic system. This service reduces the cost of installing a filtering and monitoring system on any hydraulic system, we are about to filter. The main function of the portable filtration unit is to filter hydraulic oil with a flow rate of up to 100 l/min or simply to pump used oil from the reservoir into other canisters for recycling. Self-diagnostics are integrated into the unit and measure oil temperature, dielectric constant, viscosity, oil cleanliness and oil relative humidity.

2 Portable filtration unit and filtering process

The portable hydraulic unit has two basic functions. The first is to filter oil and the second is to pump the used oil from the reservoir into waste canisters for further recycling. There are five different sensors to monitor the condition of the hydraulic oil, which are displayed on the HMI and stored on the controller for later use.

Figure 1: Portable filtration unit.

Unit is driven by two electric motors with pumps responsible for pumping the oil and passing it through the filters and sensors. A Siemens controller is used for data acquisition, data processing and control of the unit (Figure 1).

2.1 Filtering procedure

The portable filtration unit has a suction line and a return line. The inlet of the suction line is located just above the bottom of the reservoir, so any larger particles will not be filtered, as they often remain on the bottom throughout the life of the machine (Figure 2). Some of the newest reservoirs have a port for bypass filtration located at the very bottom of the reservoir so that all particles are filtered. The return line is located below the surface of the fluid, so that minimal air is injected into the fluid.

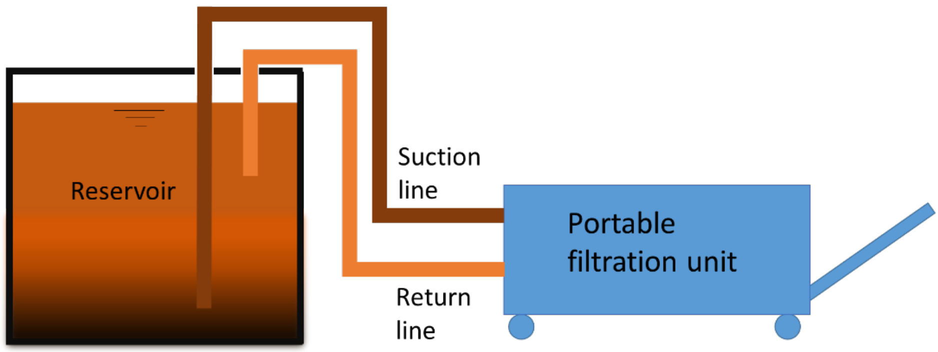

Figure 2: Schematic showcase of filtering hydraulic oil in reservoir.

The portable filtration unit has two magnetic filters at the beginning, which separate ferromagnetic particles (Figure 3). This is followed by two pre-filters and six fine filters that filter particles of all shapes and sizes. The two pre-filters remove larger particles and also extract water from the oil. Six fine filters remove fine particles. The filters were developed and manufactured in cooperation with TRM PRO d.o.o.

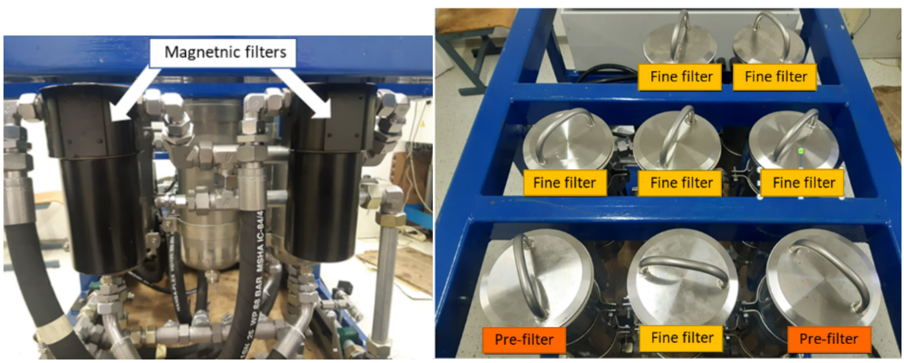

Figure 3: Magnetic filters (left) and pre-filters and fine filters (right).

2.2 Hydraulics

The main function of the unit is to filter hydraulic oil located in larger reservoirs through suction and return lines. Figure 4 shows quick couplings for the inlet and outlet of the oil. The unit has two pumps (main pump and auxiliary pump). The main pump is used to push the oil through the filters. Pressure sensors are located upstream and downstream of the filters to measure the pressure drop.

An electrically operated 4/2 valve is used to switch between the filter function and the function of pumping used oil into canisters for further recycling. The auxiliary pump is used to provide sufficient pressure and flow rate of the oil for the sensors to measure temperature, relative humidity, viscosity, dielectric constant and cleanliness.

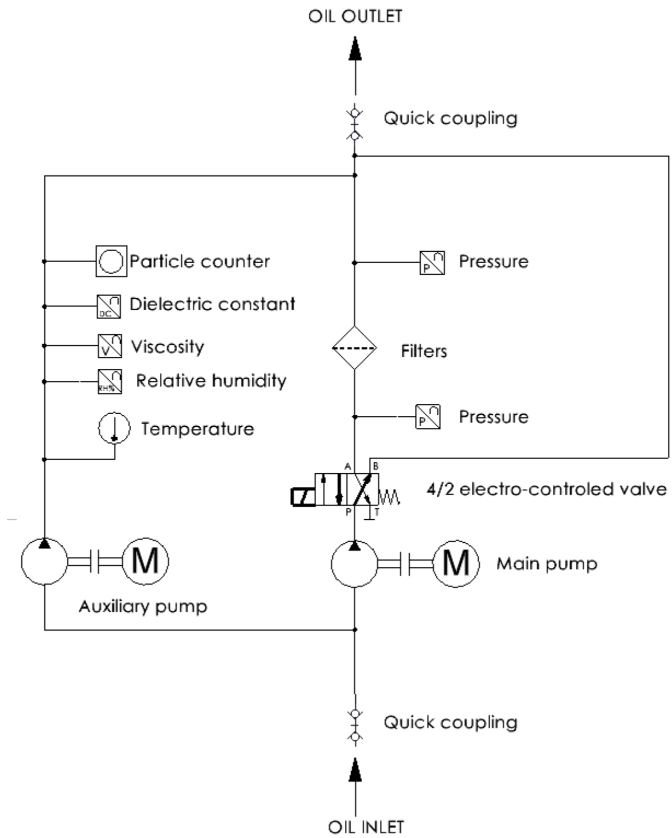

Figure 4: Simplified hydraulic block scheme.

2.3 Electrical-controlling part

In cooperation with Trecon d.o.o. we have developed an automated filtering procedure which is controlled by the SIMATIC S7-1200, CPU121C controller. SIMATIC-HMI KTP700 Basic Panel is used as a human-machine interface. The first function is that we can set the desired cleanliness and once it is reached, the unit stops. The second function is that we can set the allowable differential pressure of the filters and once the limit is exceeded, the unit will stop. The third function is that we can set the desired time period for filtration and once it expires, the unit stops. It has also built-in self-diagnostics, which allows us to monitor the main fluid parameters (Figure 5), such as the elapsed time (pos. 1), the cleanliness of the fluid (pos. 2), the inlet pressure (inlet of the filters) (pos. 3), the outlet pressure (outlet of the filters) (pos. 3), the temperature (pos. 4), the relative humidity of the fluid (pos. 5), the dielectric constant (pos. 6) and the viscosity (pos. 7). It is possible to display the described parameters in time-dependent diagrams on the HMI display or to download the data to the USB stick as a .txt or .xlsx file.

Figure 5: Display of key fluid parameters.

The unit has a built-in, electrically controlled 4/2 valve. When it is in the first position, the unit is filtering oil. When the valve is in the second position, the unit can pump used oil into canisters for further recycling. The duration of oil pumping before the unit stops can also be set here.

2.4 Robust design and transportation options

The portable filtration unit (Figure 6) is located in a Slovenian company. It has a robust design to withstand accidental collisions that could severely damage the unit. The unit stands on oil-resistant wheels and has a carrier bar to clamp to the trailer hitch for easy transportation with an electric vehicle. Another option for transport is with a forklift. The unit has two steel beams that attach to the bottom of the unit for this type of transport. The last option for transportation is with an overhead crane, as the unit has anchors at the corners of the metal structure. Figure 7 also shows a support for the hoses for the return and suction lines, which are connected to the unit via hydraulic couplings.

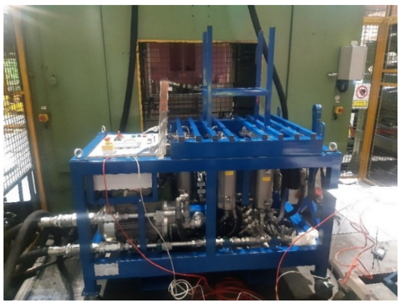

Figure 6: Portable filtration unit with self-diagnostics in industrial environment.

Figure 7: Carrier for hoses and hoses for suction and return line attached to the chain lift for easier transportation.

2.5 Measurements

In a Slovenian company we have in parallel measured the cleanliness of hydraulic oil, using a UCC20 bottle sampler according to SIST ISO 4406. Table 1 shows ISO code numbers or the number of particles per milliliter of fluid. Table 2 presents the corresponding cleanliness for different types of hydraulic systems.

Table 1: ISO 4406 code number meaning [7].

ISO code number	Number of particles per ml	
	More than	Up to and including
22	20 000	40 000
21	10 000	20 000
20	5 000	10 000
19	2 500	5 000
18	1 300	2 500
17	640	1 300
16	320	640
15	160	320
14	80	160
13	40	80
12	20	40
11	10	20
10	5	10
09	2.5	5
08	1.3	2.5
07	0.64	1.3

Table 2: Suggested accepTable contamination codes for various types of systems [7].

ISO code numbers	Type of system	Typical components	Sensitivity
23 / 21 / 17	Low pressure systems with large clearances	Ram pumps	Low
20 / 18 / 15	Typical cleanliness of new hydraulic oil straight from the manufacturer. Low pressure heavy industrial systems or applications where long-life is not critical	Flow control valves Cylinders	Average
19 / 17 / 14	General machinery and mobile systems Medium pressure, medium capacity	Gear pumps/motors	Important
18 / 16 / 13	World Wide Fuel Charter cleanliness standard for diesel fuel delivered from the filling station nozzle. High quality reliable systems General machine requirements	Injector valve and high pressure pumps/ motors Directional and pressure control valves	Critical
17 / 15 / 12	Highly sophisticated systems and hydrostatic transmissions	Proportional valves	Critical
16 / 14 / 11	Performance servo and high Pressure long-life systems e.g. Aircraft machine tools, etc.	Industrial servovalves	Critical
15 / 13 / 09	Silt sensitive control system with very high reliability Laboratory or aerospace	High performance servovalves	Super critical

NOTE: The three figures of the ISO code numbers represent ISO level contamination grades for particles of >4μm(c), >6μm(c) and >14μm(c) respectively.

Table 3 shows various measurements of cleanliness on hydraulic press 1, depending on where we took the sample. We vacuum the sample to remove air from the oil. Table 4 shows the results of hydraulic press 2, where all samples were also vaccumed before the measurements. Table 5 shows the results of the ON -LINE measurements of cleanliness.

Table 3: Cleanliness of oil on hydraulic press 1 according to ISO measured with UCC20 bottle sampler and vacuuming

Test number	Return line	Reservoir
1	20/17/12	20/16/11
2	21/19/15	21/20/16
3	20/17/12	20/16/11
4	20/17/13	20/16/10
5	20/17/12	20/16/11
6	20/17/13	20/16/11

Table 4: Cleanliness of oil on hydraulic press 2 according to ISO measured with UCC20 and vacuuming

Test number	Control line
1	21/19/15
2	21/19/15
3	21/19/15
4	21/19/15

Table 5: Cleanliness of oil on hydraulic press 1-ON-LINE measured with UCC20

Test number	ON-LINE-filter pressure port
1	20/13/08
2	20/13/09
3	20/12/07

3 Conclusion

We filtered the hydraulic press 1 with a capacity of 2000 l for 48 h. We measured the cleanliness of the press only after the 48 h filtration with the UCC20 bottle sampler (Table 3). The cleanliness was 20/17/13. Hydraulic press 2 had not yet been filtered and had a cleanliness of approximately 21/19/15 (Table 4). Table 1 shows that each increase in grade means that the number of particles doubles. Particles of size 4 μm(c) and above are present for 1 increment in grade more in hydraulic press 2 than in hydraulic press 1. Particles of size 6 μm(c) and above are present for 2 increments more in hydraulic press 2 than in hydraulic press 1, and the same is true for particles of size 14 μm(c) and above.

There are some disadvantages in dealing with cleanliness. Temperature, oil viscosity, relative humidity and air bubbles, sampling location and other factors affect the measurement of cleanliness. The factor of location is clearly seen in Table 4 where the same oil is measured in the return line and in the reservoir and it is surprisingly better in the reservoir than in the return line. Another example is the measurement with the Bottle Sampler (Table 3) and ON -LINE (Table 5). Again, there are different measurement locations and one cannot say with certainty whether the different results are due to the measurement method or the measurement location. The first grade is the same, but the other two are significantly lower. Further research is advisable to fully assess all factors affecting cleanliness.

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