Technical Paper

Bypass Valve Sensor and Filter Condition Monitoring

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Filtration systems are closely related to the reliability and durability of hydraulic systems, which are the main power transmission method for construction machines such as hydraulic excavators. We have developed a bypass valve sensor that reliably detects functional deterioration of the filtration system. In addition, we will also introduce a part of the actual monitoring activity using the bypass valve sensor and the machine operation management system "KOMTRAX".

Key Words: *Hydraulic system, Filtration, Machine operation management*

1. Introduction

Hydraulic oil which transmits power in construction machinery has an influence on the performance and durability of such machinery, so that the management of the cleanness of hydraulic oil is significantly important. When the cleanness deteriorates, wear of the hydraulic parts causes inefficient power, pinching of foreign materials makes malfunction in the machine operation, and other problems may arise. To maintain the cleanness of hydraulic oil, the filtration system composed of the filter, the breather, etc. is structured in the hydraulic circuit, which aims to prevent foreign materials outside from entering and capture foreign materials inside of the circuit. (**Fig. 1**)

Komatsu has developed the bypass valve sensor which detects the deterioration of the function of the filtration system. In this paper, we introduce the filter condition monitoring with the machine operation management system "KOMTRAX" utilizing this bypass valve sensor, communication satellite connection and mobile phone lines.

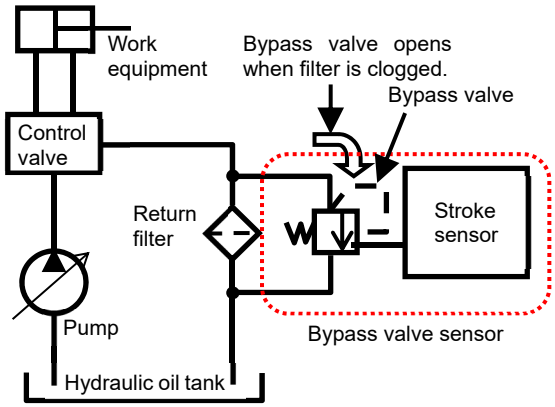

Fig. 1 Simple circuit diagram of construction machinery filtration system

2. Purpose of bypass valve

The return filter is located at the upstream of the hydraulic tank and filters the returning oil from the cylinder and the motor to the tank through the control valve with the best filtering capacity in the filtration system.

As the filter continues to capture particles in the returning oil, the flow of the oil becomes slower and increases the differential pressure between the front and the back of the filter. The returning flow rate of construction machinery changes depending on the operation status of the machine; when the flow rate is large, the differential pressure particularly increases. When the condition with an increased differential pressure is left as it is, the filter element as a filtering medium will get damaged. Therefore, the bypass valve is set to temporarily bypass the hydraulic oil when the differential pressure is large.

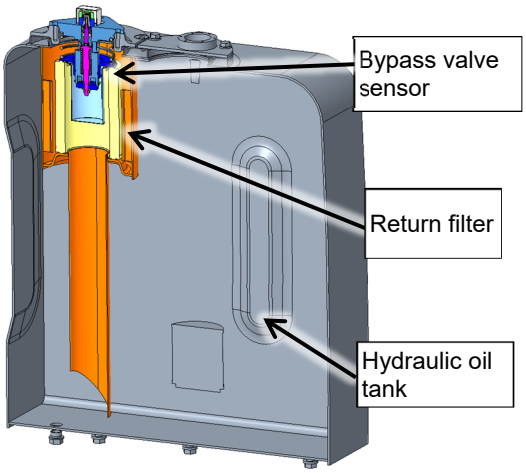

Fig. 2 Return filter and bypass valve sensor in a hydraulic oil tank

While the bypass valve operates, the filtration function does not work, which rapidly contaminates the hydraulic oil to increase the risk of failures of the hydraulic system. Usually, such clogging is prevented by periodic replacement of the filter, and maintenance is required to make the operation of the bypass valve unnecessary.

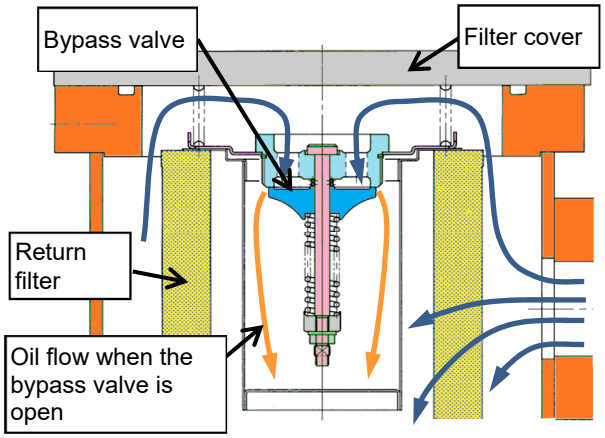

Fig.3 Structure of the bypass valve

3. Bypass valve sensor with differential pressure switch

The bypass valve sensor is used to detect clogging of the filter and find the deterioration of the filtration function before periodic replacement of the filter.

Conventionally, the differential pressure switch method in which the differential pressure between the front and the back of the filter triggers the sensor has been used to detect the operation of the bypass valve. With the differential pressure detecting method, the bypass valve is also operated by the differential pressure of the filter, so it has problems of variation of the pressure at which bypass valve the opens and closes and errors due to the accuracy of the pressure sensor. When the bypass valve opens first as shown in **Fig. 3**, the bypass valve is already open at the time when the sensor detects the clogging of the filter and the filtration function cannot be secured.

On the other hand, when the sensor detects the clogging of the filter before the bypass valve opens, it prompts the replacement of the filter still in good condition, resulting in the increase of the maintenance cost of the machine.

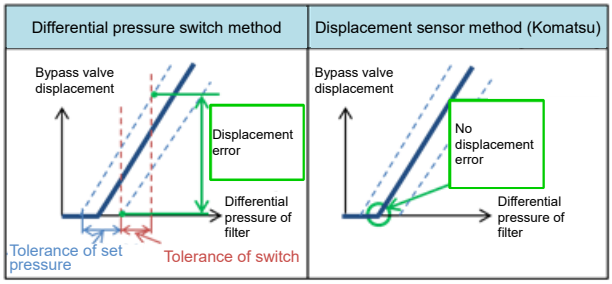

Fig. 4 Effect of detecting methods of bypass valve sensor on error

4. Characteristics of Komatsu bypass valve sensor

The Komatsu bypass valve sensor has solved this problem on accuracy by direct detection of the operation of the valve. The structure of the Komatsu bypass valve sensor is shown in **Fig. 5**.

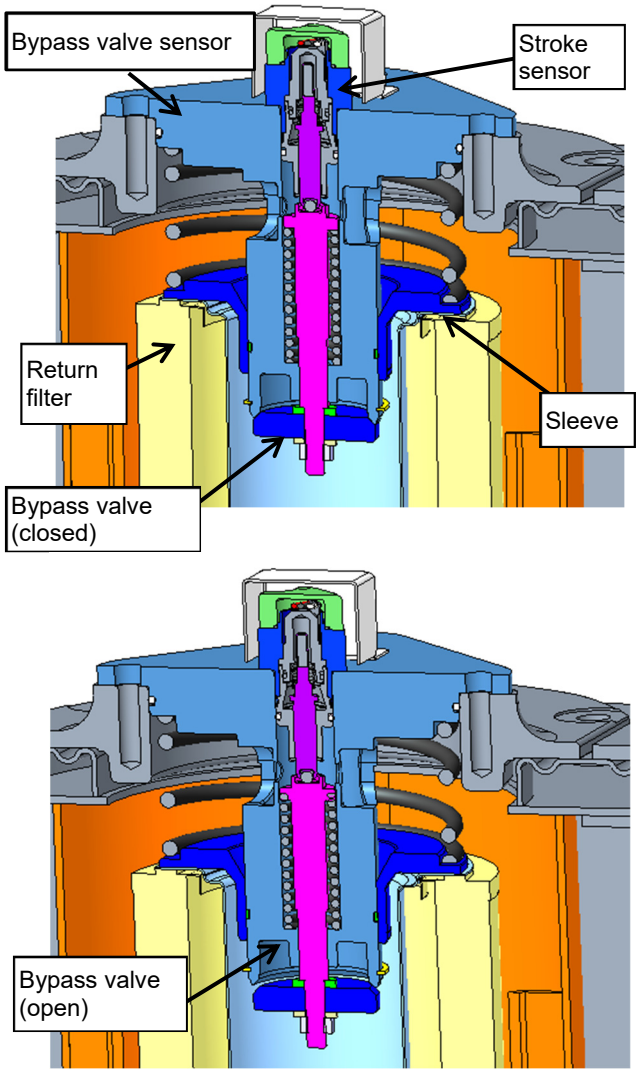

Fig. 5 Structure and operation of the Komatsu bypass valve sensor

The Komatsu bypass valve sensor has a structure in which the stroke sensor detects opening and closing of the bypass valve through the shaft interlocked with the valve, as shown in **Fig. 5**. At the sensor section, the stroke sensor with analog output detecting the displacement amount is utilized. The stroke sensor having performance of pressure resistance, vibration resistance, and heat resistance has been developed by Komatsu for construction machinery. It is mounted on many construction machines at present and has been operating for more than 10,000 hours without problem. The sensor is widely utilized as a swash plate angle sensor of pumps, a stroke sensor of valves, etc. as well.

It detects the stroke of the closed condition of the bypass valve before the hydraulic system operates just after the engine starts, and detects a change from that stroke, which enables the detection of opening and closing of the valve without detection errors. Even if an error is caused from the accuracy of the sensor or its attached position, such bad effect can be cancelled with the detection of a change from the initial state. This mechanism makes it possible to avoid the situations where an alarm is not output when the filtration function is lowered with clogging or otherwise the filter replacement is made despite a filter having good filtration function.

While many large-sized construction machines have a filter in an independent filter case out of the hydraulic tank, medium- to small-sized construction machines often have a return filter in the filter case built in the tank as shown in **Fig. 2** due to their limited package volume. This can minimize the package volume of the hydraulic system without setting extra piping or a case.

In this case, the bypass valve is fixed by the press force of spring, etc. as shown in **Fig. 3** not to make a gap between the filter element, the filter case and the bypass valve.

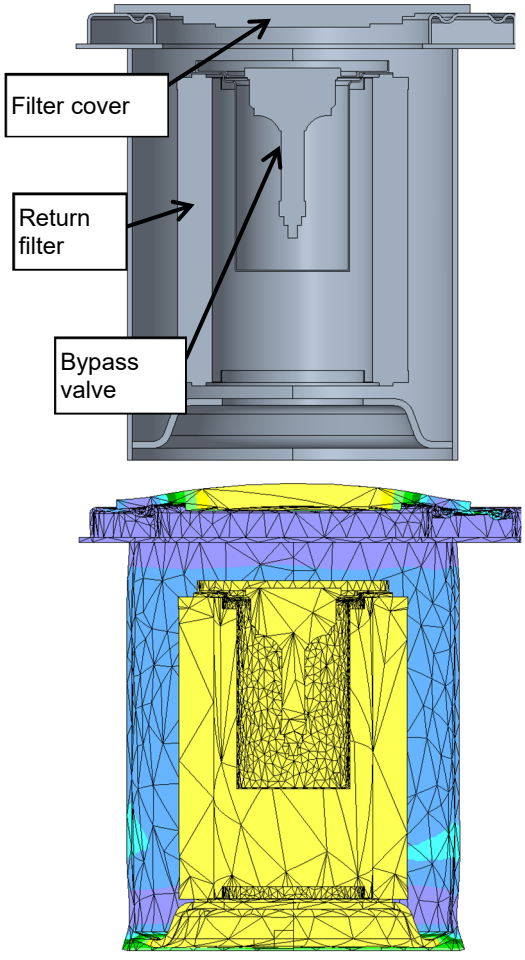

Fig. 6 Deformation of the filter case by pressure

As for the bypass valve of the hydraulic tank with the built-in filter case shown in **Fig. 2**, when the sensor is installed in the filter cover section to detect the operation of the bypass valve, a problem arises. Pressure is added to the filter case and the filter cover up to the set pressure of the bypass valve (0.2 to 0.4 MPa), causing deformation of the filter cover and the filter case. This means that the pressure of the returning oil changes the distance between the stroke sensor and the bypass valve even when the bypass valve is not open. This change of the distance is large enough to cause the stroke sensor to incorrectly detect that the bypass valve is open, so simply installing the sensor to the filter cover will result in a false alarm. The Komatsu bypass sensor has resolved this problem by introducing the structure which integrates the filter cover and the bypass valve as shown in **Fig. 5**. As a countermeasure for the deformation of the filter cover and the filter case, it has the structure with the sleeve following the deformation so that oil leakage is not caused from such deformation.

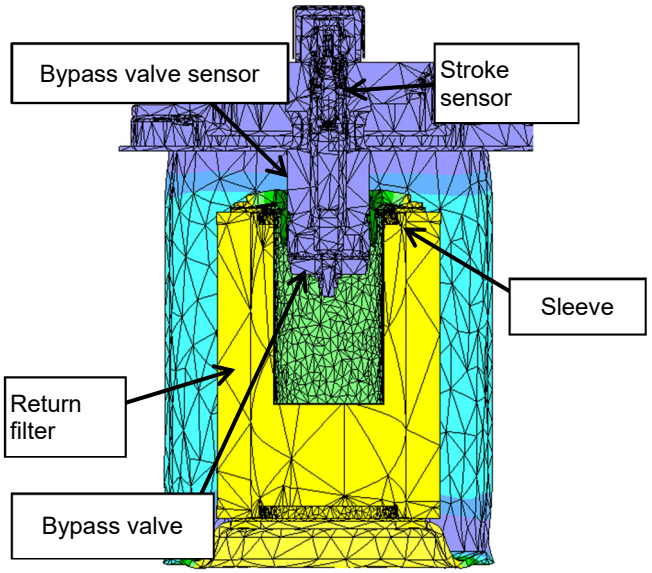

Fig. 7 Deformation of bypass valve sensor by pressure

5. Filter condition monitoring

With the developed bypass valve sensor described above and its outputs through Komatsu's machine operation management system called "KOMTRAX", the monitoring of the machines operating all over the world has been enabled. By continuously monitoring the information from KOMTRAX, the time for filter replacement can be grasped, which helps prevent fatal damages of the hydraulic component due to worsened contamination of the hydraulic oil in advance.

In addition, it is now possible to find when the return filter was replaced on each machine based on the output sent each time the bypass valve opens, as shown in **Fig. 9**.

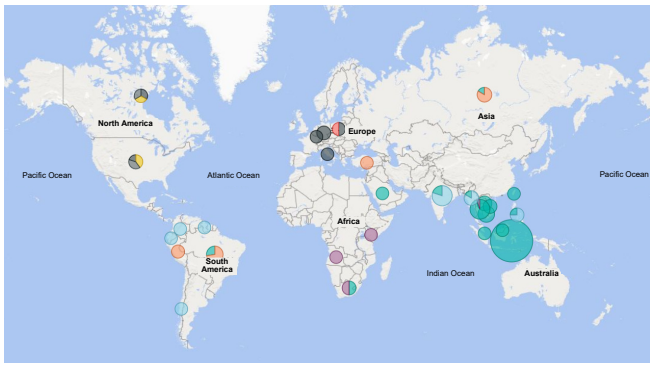

Fig. 8 Monitoring filter conditions of machines all over the world through KOMTRAX

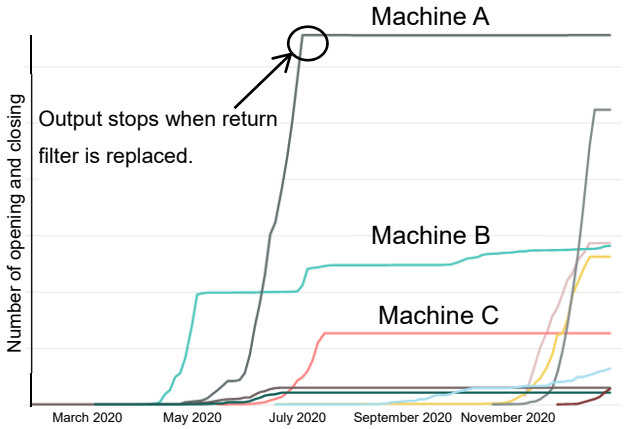

Fig. 9 Number of opening and closing of bypass valve of each machine

We conducted an investigation to see if the time for replacement of the return filter is properly given by collecting the replaced return filters which the bypass valve sensors had actually operated with. As a result, we found that the return filters captured dust that entered into the hydraulic circuits and that the pressure loss of the filters was approx. four times as much as that of a brand-new one (**Fig. 10**). This means that the filters have clogging, considering the set pressure of the bypass valve. We investigated the mounted hydraulic components as well as return filters, and found that the components had no problem in performance and wear. According to these results, we consider that the bypass valve sensor has given notices of the proper time for replacement of the return filter that is not too early or too late.

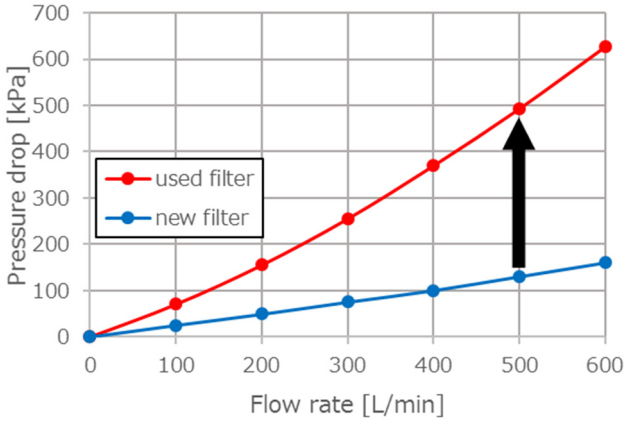

Fig. 10 Pressure loss of filters collected for investigation

Through this monitoring, it was found that while machines of most customers have been operating smoothly, some machines have a shorter life than usual. For such machines, we recommend early replacement of the return filter and, in addition, ask them to check the hydraulic components for any failures, usage environment and usage condition to see if special attachments are handled in such a way that causes more dust to enter in the hydraulic circuit than usual, in order to provide necessary services as required, in cooperation with our local service departments.

As an example of the above, we found that when an imitation product was used for the seal part instead of a Komatsu genuine product at the time of overhaul, the sealing performance significantly decreased, causing a lot of dust to enter into the hydraulic circuit, which enabled us to propose improvement plans to our customers.

By continuing the monitoring in the market, the causal relationship between the output data from the bypass valves and failures of hydraulic components will become clearer and we can provide more sophisticated services.

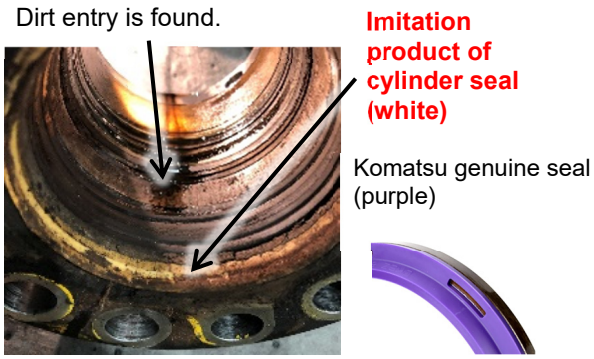

Fig. 11 Photo inside the cylinder which uses an imitation product

6. Conclusion

Improvement of reliability of hydraulic components will be more and more important to improve lifecycle cost for the users of the construction machines. For avoidance of sudden failures and preventive maintenance of hydraulic components, the management of the filtration is fundamental engineering that is essential to enhance the reliability.

We expect that this bypass valve sensor and the filter condition monitoring activity will lead to the improvement of filtration of construction machinery and eventually customers' profit.

Acknowledgments

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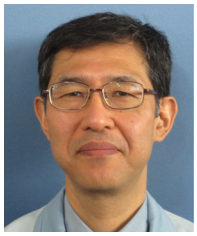
Introduction of the authors



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[A comment from the authors]

In construction machinery, the technologies for visualization of working conditions of machines, detection of failure symptoms of components, and preventive maintenance are a new field that has just begun. We will continue to introduce new technologies to contribute to the improvement of reliability of construction machinery.