Maintenance of Hydraulic Systems based on Optical Monitoring of Contamination

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ABSTRACT

Fluid contamination in the hydraulic system of tractors and other self-propelled agricultural machinery influences seriously the hydraulic system, components and hydraulic oil. This paper introduces what fluid contamination means, the significance of deriving fluid cleanliness level according to NAS and ISO standards and the importance of monitoring contamination for technicians engaged in servicing and maintenance. The procedure includes the determination of total contamination in hydraulic fluid by means of the HYDAC apparatus (filtration unit OF 5 and fluid control unit FCU 2010). The counting of particles is performed by a very sensitive optical instrument, which registers the number of particles in various size ranges in a measured fluid sample. These results are reported as the number of particles greater than a certain size found in a specified volume of fluid.

Key words: agricultural machinery, hydraulic system, fluid contamination, servicing and maintenance reliability.

INTRODUCTION

The development of technology and gradual introduction of modern ideas for an effective development of contemporary farming implies increased requirements for the technical standards of equipment and machines and for reliability and effectiveness of operation. Hydraulic system as an important part of tractors and other self-propelled agricultural machinery plays an utmost role. However, with the extensive application of hydraulic systems, its fault rate increases rapidly and highly and more than 50 % of faults of agricultural machinery are related with their hydraulic systems (Goering and Hansen, 2004).

The most frequent causes of breakdowns in hydraulic components such as pumps, cylinders, and valves are due to contamination of the operating medium including phenomena associated with friction and wear (Daqing, 1993). The contaminants circulating in the system damage the surfaces of the components and break off particles from these, which, when filtration is inadequate, continue circulating in the oil and attack different component surfaces in a recurrent fashion (Hanawa, 1998). Types of contaminants of hydraulic oils can be distinguished in solid, liquid and gaseous. Solid contaminants, also known as particles, consist of wide variety of materials (iron, steel, brass, etc). Liquid contamination is most often water and gaseous contamination is almost always air. According to their origin, the sources of contamination can be distinguished: a) contamination introduced by components, b) contamination produced during manufacture, c) contamination produced during operation (wear, corrosion), d) contamination entering from outside during operation (tank, piston rod seals), and e) contamination entering during maintenance. Recent trends are characterized by efforts to use methods that enable the determination not only of the number of particles in the hydraulic medium but also their shape, size, origin and thus to study the involved tribotechnical phenomena (Downs, 1997). Two standards, NAS 1638 and ISO 4406 have become accepted for the classification of particle contamination of the hydraulic medium. According to the NAS 1638 classification system, all particles from a sample volume of 100
ml are counted and divided into different size classes. In contrast to NAS 1638, the classification according to ISO 4406, instead of the particles being divided into classes, a code is determined from the total number of particles greater than 2 µm, 5 µm and 15 µm (ISO/DIS 4406, 1980), (Bensch, 1999).

Today’s sophisticated hydraulic systems require a high quality hydraulic fluid in a clean and closed circulation system in order to operate efficiently. Replacement and cleaning of fluids in use should account for approximately 75% of the typical hydraulic system maintenance costs. Careful monitoring of hydraulic fluid cleanliness, coupled with a proactive approach to cleaning the fluid, extends the life of the fluid almost indefinitely. Knowing the cleanliness level of the fluid in a hydraulic system is the basis for fluid contamination monitoring. Particle counting is the most common method of determining cleanliness level and deriving the appropriate standards. Very sensitive optical instruments count the number of particles in various size ranges in a measured fluid sample. These counts are reported as the number of particles greater than a certain size found in a specified volume of fluid (Jiagen and Qiang, 1993), (Harwick et al., 1995). Taking into consideration the technical possibilities of recording the contamination under different conditions, two realistic sampling and investigation techniques appear: a) sampling and investigation in laboratory conditions (special tribotechnical investigation) and b) on-line sampling and investigation (current tribotechnical investigation). The first investigation way can only be performed in special laboratories equipped with analytic apparatuses and facilities applying various technical achievements. The establishment of such laboratory within a region should be based on thorough economic analysis respecting mainly a high return rate of the investment. In contrast, the on-line sampling and investigation is practiced under the conditions of current operation and is adjusted to its possibilities. During on-line investigation, the results are available immediately and appropriate action can be based on it (Kovář and Otto, 1979).

This paper introduces what fluid contamination means, the significance of deriving fluid cleanliness level according to current NAS and ISO standards and the importance of contamination monitoring for technicians engaged in servicing and maintenance. The procedure includes the determination of total contamination level in the hydraulic fluid by means of the HYDAC apparatus (filtration unit OF 5 and fluid control unit FCU 2010). The counting of particles is performed by a very sensitive optical instrument, which registers the number of particles in various size ranges in a measured fluid sample. These results are reported as the number of particles greater than a certain size found in a specified volume of fluid.

**MATERIALS AND METHODS**

For hydraulic systems to operate reliably, it is imperative that the operating hydraulic medium (oil) stays in perfect condition. If the contamination condition is systematically monitored, a considerable increase in reliability, service life and economy of the hydraulic systems can be achieved. Therefore, the key to preventive maintenance and comprehensive quality assurance procedures is to record the actual solid particles’ contamination in the hydraulic oil.

The HYDAC filtration unit, type OF 5, is used as a mobile unit for servicing and maintenance, but also for off-line filtration on hydraulic or lubricating oil units. Combining it with a fluid control unit, type FCU 2010, greatly increases the level of efficiency of the filtration unit. The FCU 2010 constantly measures the level of contamination of the oil which, at the same time, is pumped by the filtration unit. Figure 1 shows the HYDAC filtration unit OF 5 combining with fluid control unit FCU 2010.

The HYDAC filtration unit is a compact unit consisting of a motor-pump unit together with a size 1300 filter housing. Furthermore, the unit is equipped with two transparent hoses and everything is ready-assembled on a mobile trolley. The oil flow to be measured is fed to the FCU 2010 by means of a pump KE 1310 mounted on a mobile trolley. The pump sucks a partial flow out of the suction tract of the filtration unit and feeds this directly to the FCU 2010. The partial flow is then fed into the drain line of the filtration unit.
The FCU 2010 is installed in a separate housing which is also mounted on the mobile trolley. The principle of the determination of total contamination in the hydraulic medium by means of the FCU 2010 apparatus is based on detecting optical light blockage. The heart of this apparatus is a fibre-optic sensor (semi-conductor infra-red diode together with electronic compensation). This sensor was designed specially for rough industrial applications and is resistant to interference and vibrations, and it is practically independent of the colour of the fluid or the basic turbidity. Finally, the electronics register the measured values with the aid of a microcomputer and display the measurement results via an easy-to-read display.

The FCU 2010 has the following features: a) measuring procedure in accordance with international standards NAS 1638 and ISO 4406, b) average value display of the last 10 measurements, c) measured value is displayed every 40 ÷ 120 s, d) permissible sensor flow rate 50 ÷ 150 ml/min, e) maximal total flow rate 800 ml/min at 350 bar, f) permissible viscosity range 5 ÷ 1000 mm²/s, g) permissible pressure range 1 ÷ 350 bar, and h) permissible fluid temperature range 0 ÷ 70 ºC.

The oil sample was collected from the hydraulic and hydrostatic system oil reservoir of a New Holland combine. Both systems draw their oil from the same reservoir but the oil for each circuit goes through a separate filtering system. A filter element is installed at the oil cooler outlet, to prevent contamination in the hydrostatic system after start up. The used hydraulic/hydrostatic oil has to meet the following specification: DIN 51524 PART 2 HV46, ISO VG-46. Oil quality and cleanliness is of utmost importance for the reliability and life of the hydraulic and hydrostatic system.

The content of the oil reservoir is circulating and passes filtration seven times in total (tests) in order to determine if the oil is suitable for further use. At the same time, the current contamination class is constantly displayed. It can establish a normality of wear condition of internal oil wetted components in order to recognize abnormality sufficiently early in the failure cycle to minimize catastrophic failures.

RESULTS AND DISCUSSION

The results obtained during hydraulic and hydrostatic oil filtration and monitoring, are discussed as follows.

A classification of the particle sizes of the hydraulic and hydrostatic system oil sample has been made following the standard code NAS 1638, in order to obtain a quick assessment of system cleanliness. The curves in figures 2 ÷ 8 present the contamination dynamics of hydraulic and hydrostatic oil after seven times of filtration. The particle sizes data have been
plotted according to contamination classes at four specific sizes, 5-15, 15-25, 25-50 and 50-100 microns, interpolated and quoted. The NAS 1638 and ISO 4406 solid contamination standards consider these two sizes, i.e. 5 and 15 microns, to be important because the critical and the maximum size limit of contamination particles tolerable by the lubricant film in hydraulic and hydrostatic system is between 5-15 microns. The cleanliness level with respect to the particulate matter in the oil of a hydraulic and hydrostatic system is of utmost importance to diagnose the impending distress of the lubricating system. The best cleanliness levels were obtained in classes NAS 15-25, NAS 25-50 and NAS 50-100.

Fig. 2. Oil contamination monitoring data for test 1

Fig. 3. Oil contamination monitoring data for test 2
Fig. 4. Oil contamination monitoring data for test 3

Fig. 5. Oil contamination monitoring data for test 4

Fig. 6. Oil contamination monitoring data for test 5
Figures 9, 10 & 11 show the contamination reduction after 24 min of filtration during test 1. The particles counts are provided on bars and they have been taken from samples with a volume of 100 ml. The recommended level of cleanliness for mobile hydraulic systems according to NAS 1638 corresponds to the maximum permissible limit of 8 microns, which for classes NAS 5 – 15 µm is 32,000 – 64,000, NAS 15 – 25 µm is 5,700 – 11,400 and NAS 25 – 50 µm is 1,012 – 2,025 particles per 100 ml. By observing Figures 9, 10 & 11 an obvious conclusion is that the NAS 1638 levels of contamination fall in the sensitive zone of cleanliness after 24 min of filtration.
Fig. 9. Contamination reduction after 24 min of filtration during test 1 (particles 5-15 µm)

Fig. 10. Contamination reduction after 24 min of filtration during test 1 (particles 15-25 µm)

Fig. 11. Contamination reduction after 24 min of filtration during test 1 (particles 25-50 µm)
The particulate contamination in the hydraulic and hydrostatic system of a combine is mainly due to the presence of foreign particles entering into the system because of various reasons such as ingress of dust and dirt from the environment, poor sealing of the tank, blocked air filters and wear of seals. The blocked or damaged filter element on the bypass filtration system may also aggravate the contamination problem. Particulate count data can be used for trend monitoring of the hydraulic and hydrostatic system of a combine in order to ascertain the required cleanliness levels and diagnose any impending defects originating from particulate contamination. The particle counts will not remain at a constant level but will be subject to variation, depending upon the efficiency of the oil filtration system (filters etc.), environmental factors and changes in maintenance activity. If all these factors are favourably managed, the particle counts could be held at a level which is considered appropriate by the manufacturers of the system.

CONCLUSIONS
In this paper, the authors describe the significance of hydraulic fluids contamination monitoring for technicians engaged in servicing and maintenance. Seven tests were conducted to observe the hydraulic fluid cleanliness. Oil cleanliness before filtration was higher compared to normal operating level and after filtration with HYDAC OF 5 the oil cleanliness condition approximated that of newly used oil. Further analysis of the results indicates the following: a) fluid condition monitoring is needed at low levels of contamination in order to detect the onset and progress of contamination, b) during onset of fluid contamination the response of the monitoring system was instantaneous, and c) continuous cleaning of the fluid can restore the initial level of cleanliness.

REFERENCES