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DESIGN AND VERIFICATION OF ADDITIONAL FILTRATION FOR THE APPLICATION OF ECOLOGICAL TRANSMISSION AND HYDRAULIC FLUIDS IN TRACTORS

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Abstract

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This contribution presents the design and function verification of additional filtration. It is intended for the common transmission and hydraulic oil filling of tractors. The main role of this filtration concept is to ensure a high level of oil cleanness as a condition for the application of ecologic fluids in tractors. The next one is to decrease the wear of lubricated tractor components, the degradation of oil and eventually to extend the interval of oil change. The designed additional filtering is characterized by ease installation through the use of quick couplings and hoses to the external hydraulic circuit. Therefore, the filtration is suitable for various tractor types. Filter element has been designed with the filter ability 1micron and the ability to separate to 0.5 dm^3 of water from oil. Function of additional filtration was verified during the 150 engine hours of tractor operation. During this time period the oil contamination was evaluated on the basis of chemical elements content such as Fe, Cu, Si, Al, Ni, Mo and Cr. The additive concentration was evaluated on the basis of chemical elements content such as Ca, P and Zn. During the test operation of tractor the concentration decrease of chemical elements reached the values 25.53 % (Fe), 23.53 % (Si), 25 % (Al) and 5.5 % (Cu). The decrease of additive concentration reached only medium level (6.6 %). Therefore, the designed additional filtration doesn't remove additives from oil. Based on the evaluation of the content of chemical elements (that representing contamination and additives), we can say that the designed filtering method is suitable for use in agricultural tractors.

oil contamination, additives, biodegradable oil, spectroscopy, environmental protection

Fluids that are used in common transmission and hydraulic systems of tractors are exposed to specific conditions characteristic for agricultural production. These oils must perform all requires functions in the transmission and hydraulic system of tractor and they also must be resistant to oxidation and thermal degradation. Agricultural tractors often operate in dusty and humid environment which effects oil fill contamination. In addition, the oil fills are polluted by the amount of wear particles mainly from the transmission system, which carries the full power of the engine to the wheels of the tractor. Authors Sloboda *et al.* (2002), Jobbágy *et al.* (2003), Ileninová *et al.* (2008), and Toth *et al.* (2012) dealt in detail with the oil fill contamination in their contributions. Pollution causes a variety of adverse effects such as accelerated wear, corrosion of steel surfaces, oxidation of the oil and changes its physical and chemical properties. The pollution very harmfully affects manly on ecological fluid because accelerates the degradation processes.

Environmental protection requires the use of ecological lubricants, especially in terms of agricultural production. Tractors involve several hundred liters of various types of petroleum products, that causing contamination of soil and water by release into the environment. Alternative to petroleum oils are ecological liquids which present no risk to the environment. At present, ecological fluids are commercially available and there are also suitable for use in the tractors. The test results of such fluids were published in the contributions of authors Hujo *et al.* (2012), Kosiba *et al.* (2012b), Kučera *et al.* (2008), Majdan *et al.* (2011) and Tkáč *et al.* (2010). Ecological fluids are sensitive to contamination, such as metal wear particles, water or dirt from the environment. Therefore, the concept of additional filtration to raise cleanliness of tractor transmission and hydraulic oil fill was designed in Department of transport and handling. Findings published by Vitázek (2008), Kosiba *at al.* (2012a) and Kosiba *et al.* (2010) were used for design of additional filtration.

MATERIAL AND METHODS

The additional filtration of tractor transmission and hydraulic fluids was designed as the second stage of filtration on the tractor. Tractor manufacturer standardly mounts filters of first stage filtration. These have filter ability 15 micron to 20 micron depending on the tractor type. The filter housing type FT-B68 (Filtration technology s.r.o, Czech Republic) with filter element made from pulp was used for additional filtration. The filter ability of filter element is 1 micron and it is able to absorb 0.5 dm^3 of water, in contrast to the standard mounted filters. The maximum value of oil flow is 1.5 $dm^3.min^{-1}$.

Tractor worked 1,850 engine hours since the last oil change before installing filtration device. This value corresponds to a total number of 12,693 tractor engine hours. External filter device was mounted on a tractor after completing 1,850 engine hours thus shortly before the prescribed oil change (2,000 engine hours). Operating of tractor fitted with a filter device took time 150 engine hours. During this time, the function of filtration devices was verified in the operating conditions of tractor. Function of filtration system has been evaluated on the basis of a content of chemical elements representing contamination and additives in the oil. We used terminal of type mini-mess to sample fluids. Oil samples were taken before installing the filter and after completing 150 engine hours. There was collected representative sample of new oil before filling the transmission and hydraulic oil tractor. Oil samples were evaluated by ICP spectrometry (ASTM D 5185-05) at an accredited laboratory Wearcheck (Almásfüzitő, Hungary).

Decrease of chemical elements representing fluid contamination is calculated on the basis of data of contaminated oil and after operating the tractor with filter. Decrease of chemical elements representing the oil contamination is calculated according to the formula:

$$\Delta_Z = \frac{Z_U - Z_F}{Z_U}.100\,,\% \qquad (1)$$

where:

Δ_Z..... decrease in the concentration of chemical elements representing oil contamination, %

Z_U..... concentration of chemical elements representing contamination before the filtration, mg/kg

Z_F..... concentration of chemical elements representing contamination after the filtration, mg/kg.

Additives concentration was monitored on the basis of content of the chemical elements (Ca, P and Zn) in the oil. Decrease in the content of these elements in a sample of oil is calculated using the following formula:

$$\Delta_A = \frac{A_N - A_U}{A_N}.100\,,\% \qquad (2)$$

where:

Δ_A..... decrease in the content of chemical elements representing the additives, %

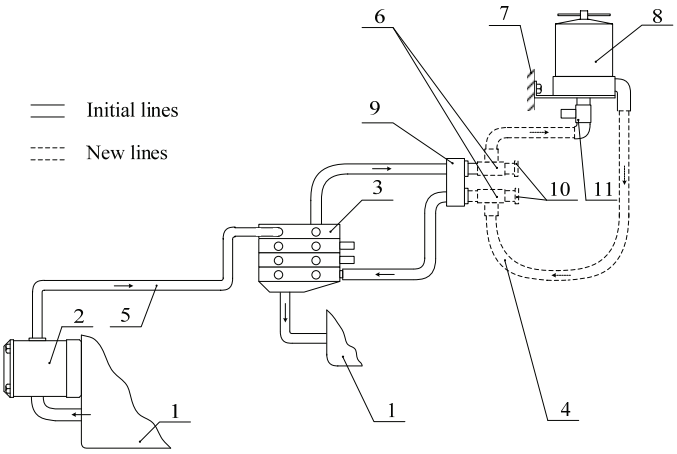
A_N ..... content of chemical elements representing the additives in the new oil, mg/kg

A_U..... content of chemical elements representing the additives after filtration, mg/kg.

RESULTS AND DISCUSSION

The scheme of designed additional filtration is shown in Fig. 1. The filter housing is connected to the external hydraulic circuit of tractor through hoses (4) and the quick couplings (9 and 10). Sockets terminate quick couplings which does not block the hydraulic circuit only for additional filtration. The filter housing (8) is sized for maximum flow rate 1.8 $dm^3.min^{-1}$, and therefore this filtering method is suitable only for tractors which allow to regulate the flow rate in external hydraulic circuit. The filter housing is placed in an area of the tractor three-point hitch so that it is easily accessible for replacement filter elements. Filtration is put into operation after the engine is started by setting the required flow of hydraulic oil. Filtering can also be operated at flow of hydraulic fluid through implements, because the filter is set up for maximum pressure of 30 MPa. Function of external hydraulic circuit is not limited by filtration because filtration system takes away only a small oil flow.

The designed filtration system is suitable for tractors which allow setting the flow rate in external hydraulic circuit. A tractor must be equipped with variable displacement hydraulic pump or throttle-valve which allows setting the specified flow rate through filter device (< 1.5 dm^3/min). The higher flow rate doesn't influences on a function of the



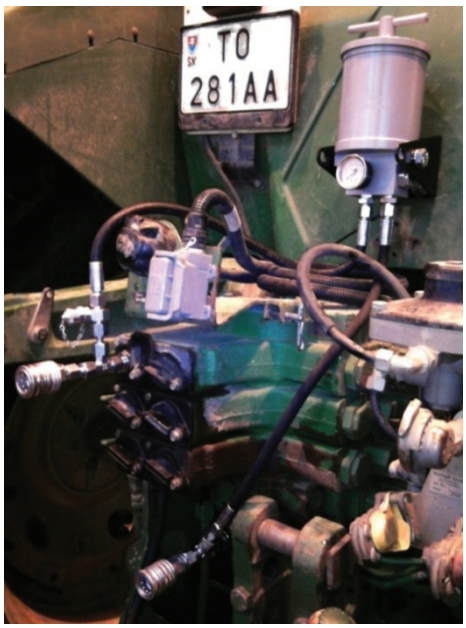
1: *Schematic diagram of additional filtration*
1 – tractor gearbox, 2 – hydraulic pump, 3 – hydraulic valve, 4 –hose, 5 – tube, 6 – T-tube, 7 – tractor frame, 8 – filter housing type FT-B68, 9, 10 – quick couplings of external hydraulic circuit of tractor 11 – terminal (minimess type) to sample fluids

filtration but uselessly loads the hydraulic system of tractor.

The connection of additional filtration in tractor is shown in Fig. 2.

Filtration device was designed for tractor type John Derry 8100. This tractor has a variable displacement hydraulic pump. Therefore, it allows mounting the filtration device to the external hydraulic circuit. This hydraulic pump allows setting the minimal flow rate (0.5 $dm^3 . min^{-1}$) through the filter system.

Fig. 3 shows the concentrations of chemical elements such as silicon, aluminum, chromium, copper, iron, molybdenum and nickel, which represent fluid contamination. In Fig. 3 is possible to see an increase in contamination after completing 1,850 engine hours compared with new oil. This pollution originates in the normal operation of the tractor. We can observe the decrease in the concentration of chemical elements (representing the oil pollution) after mounting additional filtration devices. For comparison, here are the values of the new oil.



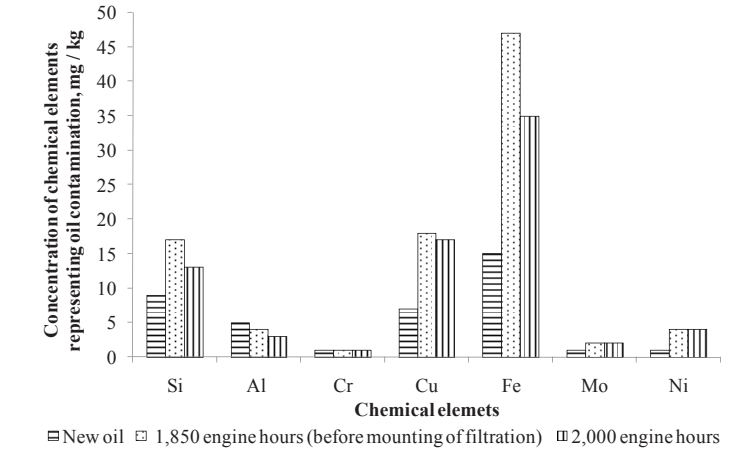
2: *Additional filtration system and its mounted on big tractors*

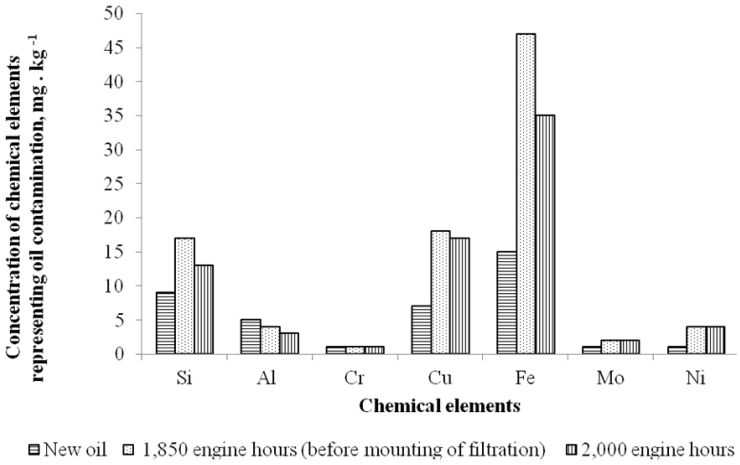
Decrease of concentration of chemical elements representing oil contamination (Tab. I) was calculated according to formula (1). Also, it was calculated on the basis of data before and after filtration. In the case of the most dangerous elements such as iron and silicon its decrease reached 25.53 % (Fe) and 23.53 % (Si).

As the machine is operated, the additive concentration in the oil decreases gradually. The additive is consumed in the machine primarily in neutralising acidic products and in dispersing contaminant particles. Other possibilities contributing factors are absorption of additives on the machine parts and removal of the additives by the oil filters (Nepogod'ev *et al.*, 1968).

Lubricants have different types of addtives. Some of them are suspended semisolid suspensions in the 5–10 micron range and are filterable. Efficient 1-micron filters can potentially remove EP (sulphur and phosphorus) additives that are not dissolved as well as suspended solid antiscuff additives (Mike Johnson, 2004).

In this case, a filter element with capability 1 micron was used. Therefore, it was necessary to verify that it doesn't remove oil additives. Fig. 4 shows the concentration of chemical elements representing the additive. These are mainly calcium, zinc and phosphorus. Fig. 4 and Tab. II show a gradual decrease in the concentration of additives, which is due to the normal operation of the tractor. Therefore, in this case filter doesn't remove additives.





3: *Concentration of chemical elements representing the oil contamination*

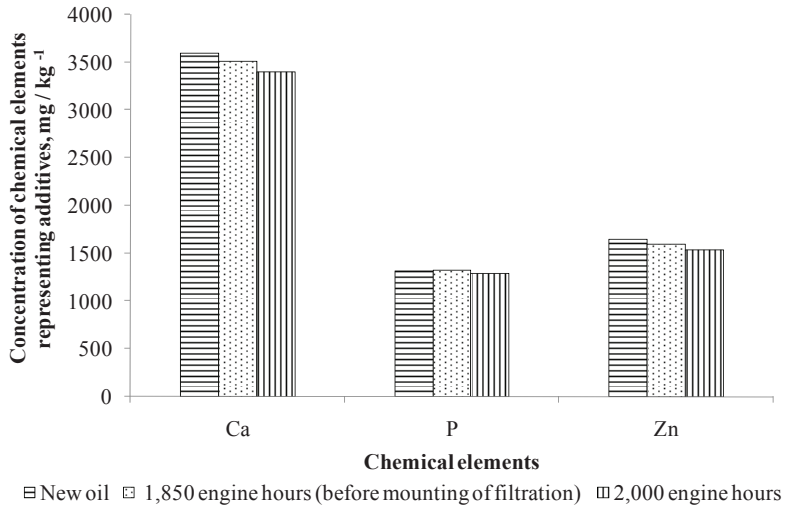
I: *Decrease in the concentration of chemical elements representing oil contamination*

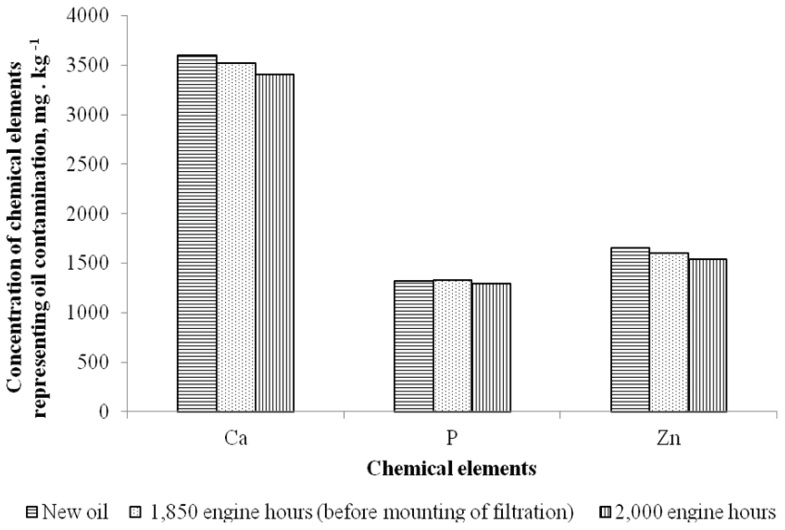
Chemical element	Unit	Tractor operation, Engine hours		$\Delta_{Z'}$ %
		1,850 (before filtration)	2,000 (after filtration)	
Fe	mg/kg	47	35	25.53
Cu		18	17	5.55
Si		17	13	23.53
Al		4	3	25.00
Ni		4	4	0
Mo		2	2	0
Cr		1	1	0

Tab. II shows a decrease in the concentration of additives, which is calculated according to formula (2). The largest decrease was recorded at zinc 6.55%. This value represents minimum decrease from view of oil operation in tractor during the exchange interval 2,000 engine hours.

CONCLUSION

The designed additional filtration of tractor transmission and hydraulic fluids take away contaminated oil from the external hydraulic circuit of tractor. The tractor owner can use different types of filtration devices from various manufacturers on the basis of chosen parameters of filtration. Filtration device is placed at the rear of the tractor above three-





4: *Concentration of chemical elements representing additives*

II: *Decrease in the concentration of chemical elements representing the additive*

Chemical elements	Unit	Tractor operation, engine hours		Δ_Z, %
		0 (new oil)	2,000 (after filtration)	
Ca	mg/kg	3,593	3,398	5.42
P		1,314	1,287	2.05
Zn		1,647	1,539	6.55

point hitch for easy installation and easy access. Oil is supplied into the filtration device through the hoses which are connected to the external hydraulic circuit of tractor through the quick coupling. Oil flow through the filtration device is provided turning on the given hydraulic circuit by the tractor operator. The designed filtration method is characterized by simple connection through the quick couplings, a high level of filtration, and continuous mode of operation. It removes contamination from the oil charge, which is not normally removed by the standard tractor filters. During the test operation of tractor (150 engine hours), there was a concentration decrease of iron at 25.53%, silicon at 23.53% and copper at 5.55% in oil. Designed filtration device does not capture additives. That is verified by a modest reduction of chemical elements such as calcium, phosphorus and zinc.

The use of ecological fluids requires a high cleanliness level of the oil fill and undetectable water concentration. Metal pollution particles act

as catalysts for unwanted chemical reactions and water causes hydrolytic degradation of base oils and additives. Additional filtration system is designed to ensure reliable operation of the tractor using ecological fluid type UTTO. This system eliminates the wear particles concentration, oxidation products and water, thus pollution which endangers the durability and performance properties of ecological fluids.

The designed filtration system creates the appropriate conditions for the extension of oil change interval. The high quality oils have superior oxidation resistance and thermal stability but the pollution is the reason for oil change also in case the physical and chemical parameters don't exceed limits.

SUMMARY

The ecological lubricating fluids are very sensitive to degradation due to metal particles and water contamination. Therefore, the application of ecological fluids in a tractor transmission and hydraulic system requires high cleanliness level of oil fill. The filters, which are standardly mounted by a tractor manufacturer don't provide high cleanliness level of oil in most cases. These filters are not able to remove water which causes the hydrolytic degradation of ecological base fluids and additives. From the reasons mentioned above the additional filtration system was designed to provide a second stage of filtration of transmission and hydraulic fluids in tractor. The first stage of filtration provides the filters standardly mounted by tractor manufacturer. The designed additional filtration system is easy connected to the external hydraulic circuit using the hoses and quick couplings. The filter housing is placed in an area of the tractor three-point hitch so that it is easily accessible for replacement filter elements. Filtration is put into operation after the engine is started by setting the required flow of hydraulic oil in external hydraulic circuit. Filtering can also be operated at flow of hydraulic fluid through implements, because the filter is set up for maximum pressure of 30 MPa. The filtration element disposes of filtration ability 1 micron and it is able to remove 0.5 dm^3 of water. The filter housing is sized for maximum flow rate 1.8 $dm^3 . min^{-1}$, and therefore this filtering method is suitable only for tractors which allow to regulate the flow rate in external hydraulic circuit. Operating of tractor fitted with a filter device took time 150 engine hours. During this test time, the function of filtration devices was verified in the operating conditions of tractor. Function of filtration system has been evaluated on the basis of a content of chemical elements representing contamination and additives in the oil. Oil samples were evaluated by ICP spectrometry. During the test operation of tractor the concentration decrease of chemical elements reached the values 25.53 % (Fe), 23.53 % (Si), 25 % (Al) and 5.5 % (Cu). The decrease of additive concentration reached only medium level (6.6 %). Therefore, the additional filtration increases the oil cleanliness, doesn't remove additives from oil and thus creates the necessary conditions for the application of ecological fluids in transmission and hydraulic systems of tractors, the reliable operation of tractor and extension of oil change interval.

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