Performance parameters monitoring of the hydraulic system with bio-oil

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Abstract

Janoško I., Polonec T., Lindák S., 2014. **Performance parameters monitoring of the hydraulic system with bio-oil**. Res. Agr. Eng., *60* (Special Issue): S37–S43.

In environmental terms, hydraulic fluids used in the hydraulic system of municipal vehicles represent problems related to a potential leakage from the system into the environment and the subsequent contamination of groundwater and soil. More environment-friendly way is to use green hydraulic fluids that are biodegradable in accidents. This paper aims to investigate the possibilities of biodegradable oil application and its adaptation in the hydraulic systems of municipal vehicles by monitoring the impact of the bio-oil Mobil EAL 46 ESSO on the performance parameters as flow, efficiency, durability, etc. Hydraulic pump revolutions were measured using a non-contact sensor based on the principle of magnetic induction change. Method of tightness monitoring was used to achieve results for functionality and wear of the hydraulic system. During 600 h of the test period no significant deterioration of performance parameters was detected. Results are useful for companies involved in waste collection.

Keywords: Variopress 518; bio-fluid; working hydraulics; power parameters

Developments in the area of municipal engineering hydraulic systems bring a number of benefits associated with facilitating the work during handling the solid municipal waste and, in addition to comfort and control, also the speed of individual working operations during the activity of hydraulic circuits of municipal vehicles.

With growing demands on the construction of hydraulic systems and improving their power parameters, the complexity of requirements for hydraulic fluids in terms of their biodegradability in the environment increases (Jablonický et al. 2012; Kosiba et al. 2012). It is a good reason because demands of an urban vehicle design increase the risk of disorders associated with hydraulic systems, and thus the risk of hydraulic fluid leakage into the environment increases (Janoško et al. 2004, 2008, 2010, 2012; Tkáč et al. 2008).

The hydraulic fluid Mobil EAL 46 ESSO is one of the fluids that are biodegradable and its content does not pollute the environment. It is a liquid that belongs to modern liquids with its appropriate additives improving the operational as well as functional and lubricating properties. It is therefore necessary to analyse the fluid, particularly in terms of its power parameters in the hydraulic system, but also its properties which the manufacturer states in its data sheet.

MATERIAL AND METHODS

Bio-hydraulic fluid Mobil EAL 46 ESSO. The selected hydraulic fluid Mobil EAL 46 ESSO (Exxon Mobil, Port Jerome du Gravenchon, France) is a high-quality and high-power lubricant that is de-

Supported by the Scientific Grant Agency KEGA of the Ministry of Education of the Slovak Republic and Slovak Academy of Sciences, Grant No. 044SPU-4/2014.

Table 1. Characteristics of the hydraulic oil Mobil EAL 46 ESSO

Properties of Mobil EAL 46 ESSO	Benefits of Mobil EAL 46 ESSO
Readily biodegradable hydraulic oil, very low level of water hazard – NGW (not hazardous to water)	reduces the possibility of environmental damage; reduces the potential costs of remediation and cleaning the spillage or leakage; it is becoming an integral part of the ecological environment in the enterprise
High viscosity index and low pour point	wide range of operating temperature
Excellent water separability	prevents formation of deposits and filter plugging, thereby increasing reliability machine devices
Exceptional corrosion protection and compatibility with many metals	limited corrosion of components and actuator systems within the hydraulic system, responding to steel and copper alloys
Excellent wear resistance properties and high-pressure properties	protects hydraulic groups and subgroups from wear and abrasion, extending the life of the hydraulic system
Quick air release properties	optimum efficiency of circulation and suitability for systems with small scoops of dirt
Good compatibility with sealing materials and communications	works equally well with elastomers which are used for petroleum oils

signed to meet requirements of environmentally friendly hydraulic fluids. The hydraulic fluid used in the hydraulic system Variopress 518 (FAUN Umwelttechnik GmbH & Co KG, Osterholz, Germany) is based on synthetic esters that are easily degradable. A high-performance complex of carefully selected ingredients enables this type of oil an excellent wear resistance, excellent high-pressure properties, thermal stability and also protection from corrosive agents.

Of course, a high oxidation resistance helps to protect the oil from increasing density and from the formation of sediments under high temperatures. Due to the high viscosity index of the base oil and low pour point, this type of oil can be used in a very broad range of operating temperatures. Unlike oils based on vegetable oils (HETG), environmentally friendly hydraulic oils based on synthetic esters (HESS), as this class of hydraulic oils is, can increase the overall performance of the hydraulic system Variopress 518 also during operation at higher temperatures, and they can offer improved thermal and oxidative stability. Table 1 presents the basic characteristics of the selected experimental oil.

Hydraulic system Variopress 518. Municipal vehicles have been selected for the experimental measurement of hydraulic system power parameters. In our case, we chose the hydraulic system Variopress 518 constructed on the platform of a Mercedes Benz chassis. Power parameters were established on the basis of the applied experimental methods, with monitoring the following variables: hydraulic fluid pressure, hydraulic pump revolutions, hydraulic fluid temperature, hydraulic arm lifting time and especially hydraulic pump power and the flow of hydraulic fluid. Fig. 1 shows the hydraulic system Variopress 518, which consists of two main hydraulic circuits. The front section of the circuit controls the peak discharge in the process of emptying of municipal solid waste, and the back section, which is the subject of the experimental measurement, is divided into two hydraulic circuits, of which one controls the container´s lifting hydraulics, and

Table 2. Measurement of hydraulic system tightness after 600 operating hours

Experiment No.	HGP state	Temperature (°C)	Ejection of piston rod (mm)		
			at the beginning	after 10 min	difference
1	ON	48.4	245	257.5	12.5
	OFF	48.6	245	258.3	13.3
2	ON	48.9	245	257.9	12.9
	OFF	49.5	245	258.7	13.7
3	ON	49.7	245	258.8	13.8
	OFF	49.8	245	259.8	14.8
4	ON	49.9	245	260.3	15.3
	OFF	50.0	245	261.2	16.2

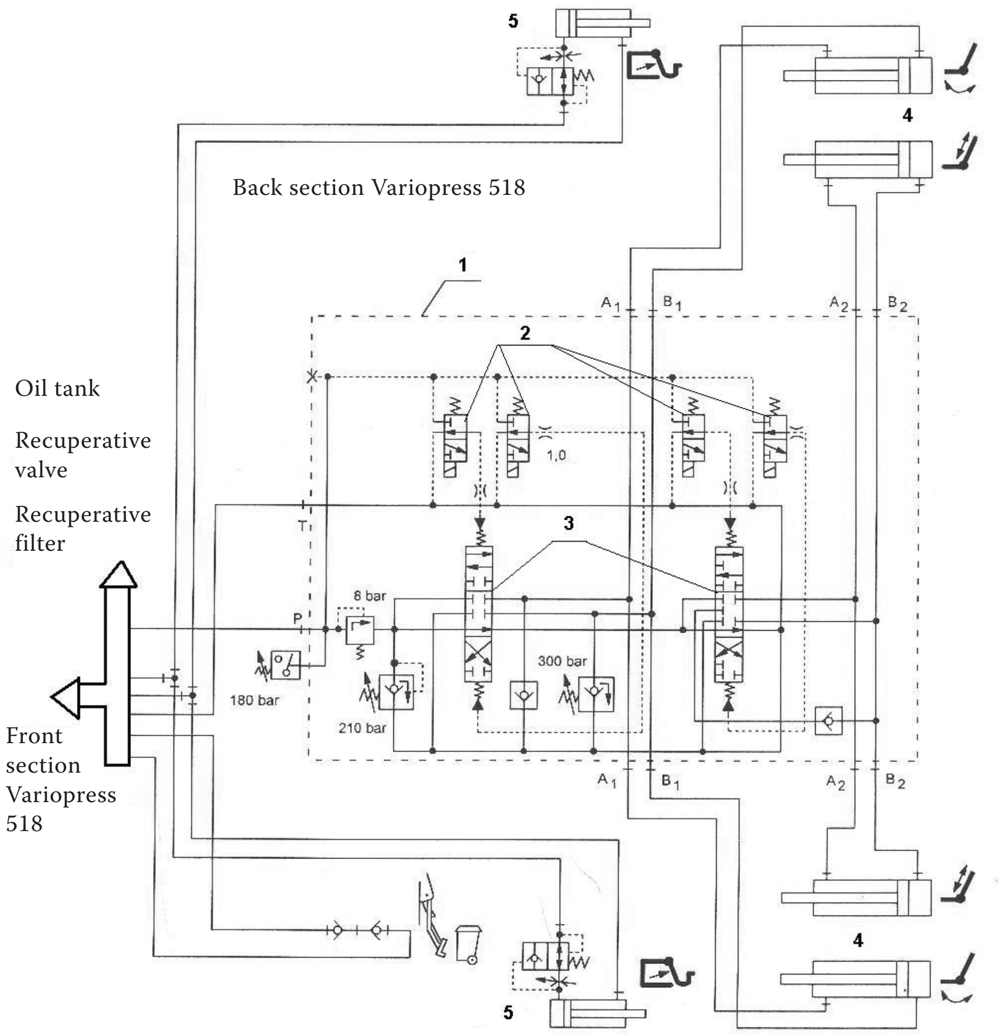

Fig. 1. Partial hydraulic system Variopress 518

1 – hydraulic distributors of pressing system; 2 – control hydraulic distributors; 3 – power hydraulic distributors; 4 – linear motor of hydraulic pressing plates; 5 – lifting mechanism containers; A1, A2, B1, B2 – inlet/outlet of linear power motors; P – main oil supply, T – return pipe in the tank

the second circuit provides partial processing of municipal solid waste by pressing and sliding board.

In the hydraulic system of the municipal vehicle, a hydraulic gear pump was used. We needed to know what the theoretic flow Q_{gt} of this system is. The theoretic flow supplied with the hydraulic pump which has two wheels is given by the size and count of gear gaps and revolutions:

$$Q_{gt} = V_{01} \times n \quad (1)$$

where:

Q_{gt} – theoretic flow (m³/s)
V_{01} – geometric capacity (m³)
n – revolutions (s^{-1})

The geometric capacity can be calculated only approximately. For gearing without correction with an angle of meshing 20°, it is given by the following relation:

$$V_{01} = 2\pi \times D_t \times m \times b \quad (2)$$

where:

V_{01} – geometric capacity (m³)
D_t – thread effective diameter (m)
m – module (m)
b – wheπel width (m)

Due to the effect of flow efficiency, the real flow is lower and is given by the following relation:

$$Q_v = V_{01} \times n \times \eta_{vg} \quad (3)$$

where:

Q_v – real volume flow (m³/s)
V_{01} – geometric capacity (m³)

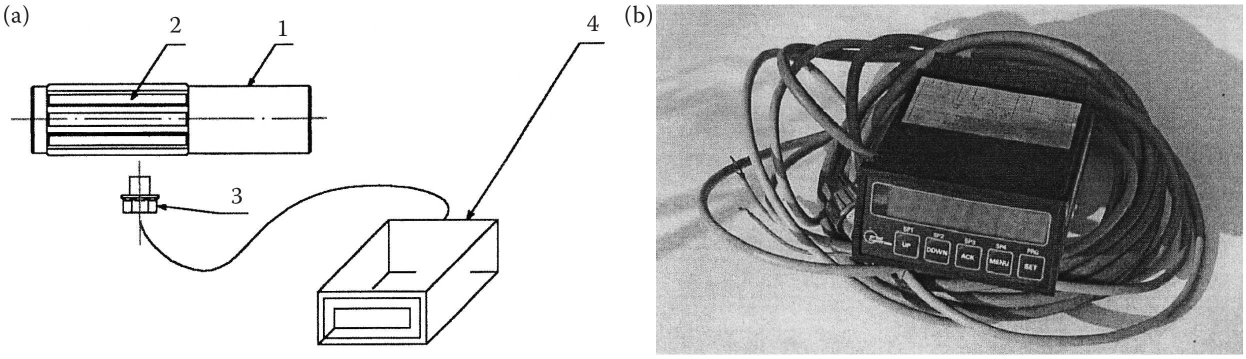

Fig. 2. Measured principle of hydraulic pump revolutions (a) and real view on display of Orbit Controls DC 7111 (b)

1 – mortise shaft; 2 – teeth; 3 – inductive sensor of revolutions; 4 – display Orbit Controls DC 7111

n – revolutions (1/s)
η_{vg} – flow rate recovery (–)

Gear pumps are made for flows from 1 dm^3/min to 400 dm^3/min. Working pressures normally and permanently reach the value of 12, at the top of 14–16 MPa. The flow rate recovery for the hydraulic gear pump is given by the following relationship:

$$\eta_G = \eta_{vg} \times \eta_{mg} \quad (4)$$

where:
η_G – total rate recovery (–)
η_{vg} – flow rate recovery (–)
η_{mg} – mechanic-hydraulic recovery (–)

For the flow of researched fluid, we need to know the flow of the hydraulic pump, which can be seen in Fig. 2:

$$Q_G = V_G \times n_G \times \eta_{vg} \quad (5)$$

where:
Q_G – flow rate of hydraulic pump (m^3/s)
V_G – capacity of hydraulic pump (m^3)
n_G – revolutions (1/s)
η_{vg} – flow rate efficiency of hydraulic pump (–)

There is a hydraulic motor that can be seen in Fig. 2, the role of which is the transmission of energy in the hydraulic system. So there is a need to know relations given for the flow of the hydraulic motor. Therefore, the flow of the hydraulic motor is given by the relation:

$$Q_M = V_M \times n_M \times \frac{1}{\eta_{vM}} \quad (6)$$

where:
Q_M – flow rate of direct motor (m^3/s)
V_M – capacity of direct motor (m^3)
n_M – revolutions (s^{-1})
η_{vM} – flow rate efficiency of motor (–)

Measuring methods. Under experimental methodology for obtaining objective information on the condition of the municipal vehicle with Variopress 518 in practice, we have designed and completed the required technical equipment which is necessary for assessing the power measurement of the hydraulic system.

Monitoring of hydraulic gear pump revolutions. For the measurement of hydraulic pump revolutions, we used a non-contact sensor (type of induction; SUA, own production, Nitra, Slovak Republic) based on the principle of magnetic induction change (Fig. 2). On the circumference of the hydraulic pump's shaft, two magnets are attached. The sensor was attached above the rotating magnets. The sensor responds to the movement of magnets and after hydraulic pump's rotation from the magnetic field influence, the sensor brought an output induced electrical signal to the electronic circuitry reader of a device Orbit Controls DC 7111 (Orbit Controls, Prague, Czech Republic), where the signal was further amplified and shaped

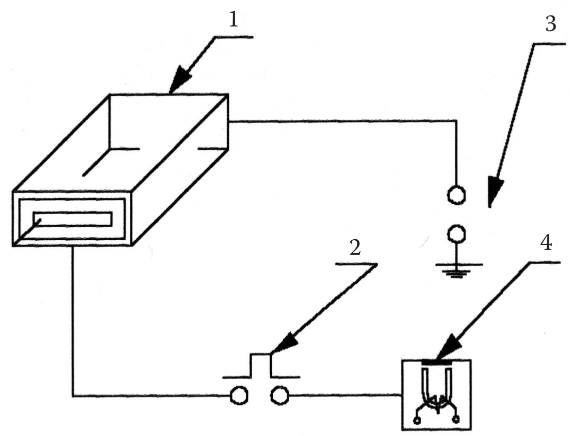

Fig. 3. Recording device of working time

1 – display; 2 – switch; 3 – power supply; 4 – electromagnet of hydraulic pump's shaft

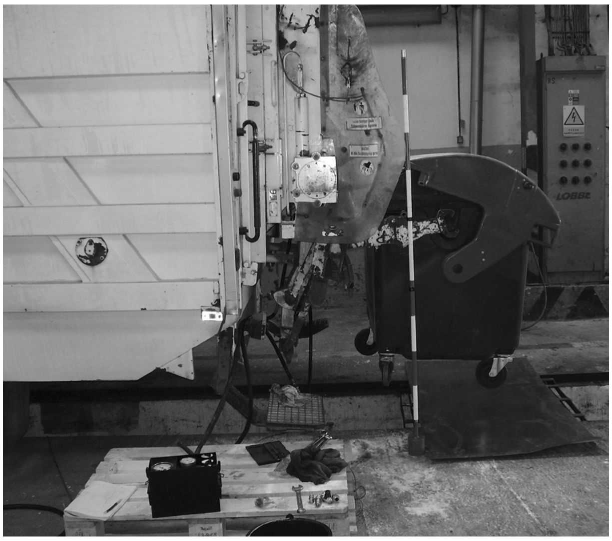

Fig. 4. Measurement of arms decrease

Fig. 5. Measurement of oil temperature and pressure in the system, (in-line hydraulic tester HT50A model C; SPX Corporation, Owantona, USA)

to the desired level of TTL (Compatible signal Transistor-Transistor Logic must have a minimum pulse width, an output voltage and current specification for any given hardware).

Measurement of hydraulic system operating time. The actually working time of the municipal vehicle hydraulic system was determined by a device that we was designed and produced at the Department of Transport and Handling (SUA in Nitra, Slovak Republic). The device is used for monitoring the operating time of the municipal vehicle hydraulic system with the hydraulic extension Variopress 518, continuously without any operator's intervention during one year.

Measurement of hydraulic system tightness. To assess the functionality and wear of the hydraulic system in view of the hydraulic fluid 46 ESSO Mobil EAL, a method of tightness monitoring used with load (540 kg) was applied. The load acted as resistance to the hydraulic system during working operations (Figs 4 and 5).

The aim of this method was to monitor the tightness elements (pressure valves, distributors) of the system in the given time after applying the experimental oil into the hydraulic system. Measurements were performed with the mentioned strain, though the exact position of the arms was exactly stabilized in a horizontal position, and after 10 min, a decrease of arms from their horizontal position and the length of the extended piston rod were recorded. The tightness assessment of the hydraulic system had a significant impact on the overall assessment and recommendation of the type of bio-oil for its use in the municipal vehicle hydraulic system.

RESULTS AND DISCUSSION

Evaluation of hydraulic system power parameters

The said performance indicators were assessed after 200, 400 and 600 operating hours of the municipal vehicle hydraulic system. Firstly, a default measurement of the hydraulic system was performed, and then the hydraulic system was examined periodically after 200 h of operation (Fig. 6).

According to the methodology of measurement, based on the measured values of power P in relation to flow Q, and after completing 200, 400 and 600 operating hours in the hydraulic system, we can note that the hydraulic fluid used in the hydraulic system has no influence on the reduction, modification or loss of hydraulic system performance. In the hydraulic system, there was no wear during the experimental measurements of the hydraulic pump, switchgear, and valves due to hydraulic fluid flowing in the system, which then would be reflected in a significant decline in the power of the system.

Tightness evaluation of the hydraulic system Variopress 518

The assessment of hydraulic system tightness was performed at each test measurement. Table 2 shows the measured values of arm's fall, or back section's ejected piston rod of the hydraulic system after 600 h of operation.

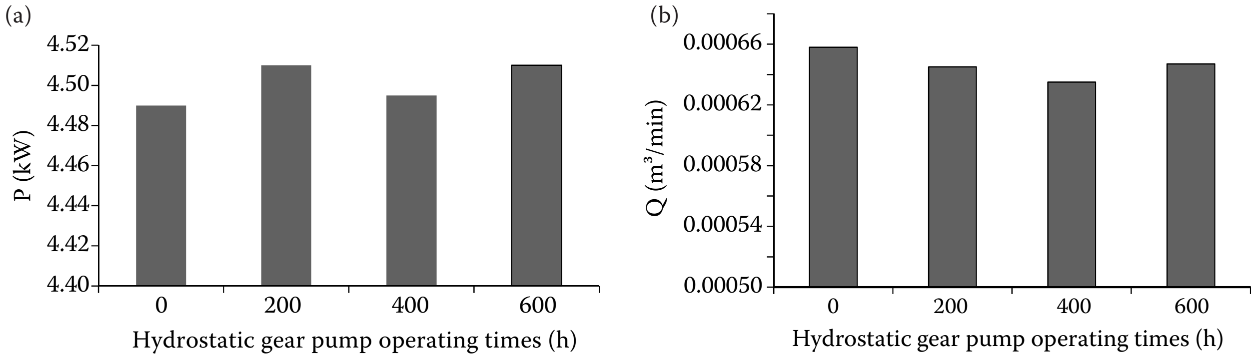

Fig. 6. Graphic view of measured (a) power data and (b) flow data
P – power of hydraulic gear pump; Q – flow of hydraulic gear pump at tested pressure

According to the methodology, it can be concluded that the resulting leakage did not show a significant effect of experimental hydraulic fluid on tightness elements of the system.

Standard analysis of hydraulic oil properties

The hydraulic oil was subjected to physical and chemical analysis such as kinematic viscosity, acid number of oil, the percentage content of water and polluting elements, Fe content and other. After initial measurement and subsequently after 200, 400 and 600 operating hours, the monitored parameters of bio-oil in the hydraulic system Vario-ress 518 were analysed. Final results were recorded in Table 3.

On the basis of experimentally observed properties of the hydraulic fluid ESSO Mobil EAL 46, it can be concluded that the hydraulic oil does not affect the hydraulic system components significantly with its properties. On the basis of findings, in terms of the pollutant content of elements in the hydraulic fluid, its application in a new hydraulic system may be advisable. The hydraulic fluid contains additives that improve the functional properties of the hydraulic system (antifoam ingredients, additives to improve corrosion properties), phosphoric acid contained in hydraulic fluid, but on the other hand, these agents are not suitable for certain types of sealants. Finally, it can be concluded that impurities contained elements moving within the prescribed tolerance limits.

CONCLUSION

This paper presents the results of monitoring the impact of the bio-oil Mobil EAL 46 ESSO on performance parameters of the municipal vehicle hydraulic system. The results are useful for transport companies involved in waste collection and farms operating similar hydraulic system.

The experimental organic liquid Mobil EAL 46 ESSO used in the hydraulic system of municipal vehicles based on esters and together with other additives is preferred to petroleum products that are biologically decomposed in the environment. The objective of the experiment was to investigate the possibility of biodegradable oil application and its adaptation to the hydraulic system of municipal vehicles. After an overall assessment of the results, it can be concluded that the experimental hydraulic fluid ESSO Mobil EAL 46 is suitable for use in hydraulic systems of municipal vehicles. Based on the findings, it can be stated that the hydraulic fluid maintains its properties without adversely affecting the performance parameters of the hydraulic system.

Table 3. Chosen parameters of the hydraulic bio-oil Mobil EAL 46 ESSO

Operating time (h)	Kinematic viscosity (mm^2/s)	Acid number (mg/g)	Mechanical impurities (% wt.)	Flashpoint (°C)	Water content (% wt.)	Iron content AAS (mg/kg)
0	39.61	0.69	0.012	300	< 0.025	7.25
200	42.12	0.63	0.012	300	0.025	7.25
400	45.32	0.62	0.014	240	0.035	7.45
600	53.31	0.67	0.015	220	0.050	8.00

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Received for publication April 15, 2013
Accepted after corrections October 14, 2013

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