Simulation of hydraulic pump load in laboratory conditions

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Abstract. The aim of the scientific contribution is simulating the load of gear hydraulic pump used in agricultural machinery in laboratory conditions, where the impact of ecological transmission-hydraulic fluid on life limit (flow and efficiency) of gear hydraulic pump GHD1-17R is monitored. Laboratory test equipment was used for the simulation. The equipment was used to perform life limit test of hydraulic pump and to monitor changes in physicochemical ecological energy carriers. The simulation in laboratory conditions took 500 hours. The Vickers test took 100 hours. Transmission-hydraulic fluid MOL Farm NH Ultra was used for simulation. The results were that fluid is appropriate to use in this type of hydraulic pump in agricultural machineries. According to the Vickers test, the fluid is characterized by an increased value of flow and efficiency after 50 working hours, thereby exceeding the specified test values.

1 Introduction

Transmission-hydraulic fluids are an essential part of the hydraulic mechanism. The main function of the fluid is energy transfer, as well as cooling, lubrication and dirt removal. The life limit of the hydraulic pump is affected by transmission-hydraulic fluid therefore, it is important to use fluid that will not only negatively affect its operation but also the individual elements of the hydraulic circuit. Laboratory test equipment is used to simulate the operating conditions of agricultural machineries, which allows researchers to perform accelerated test of hydrostatic converters and transmission-hydraulic fluids. By using accelerated test, the time of laboratory tests is optimized with the possibility of multiple repetitions without the influence of the external environment, which is not possible in operating conditions on the field [1]. By simulating the operating load of hydraulic pump in laboratory conditions the flow change in two laboratory tests was monitored. First of them was performed after 250 and 500 working hours at different rotation speed. The second test, according to Vickers, was performed after 50, 75 and 100 working hours. At the same time, the efficiency based on working hours at individual speed rotations was calculated. High requirements are placed on ecological transmission-hydraulic fluid, not only in terms of quality but also in terms of environmental impact. This is a natural consequence of efforts to increase the efficiency of production processes primarily due to a reduction in production cost, reduction in energy

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consumption with emphasis on reducing environmental impacts caused by production it- self, but also other dependent aspects [2].

2 Material and methods

The measurement was performed on a special laboratory test equipment at the Department of Transport and Handling at Slovak University of Agriculture in Nitra. Temperature, pressure, and flow were measured by a combined HMG 36010 sensor. A turbine flow meter was used to measure the flow. The flow characteristics of the hydraulic pump were measured after 250 and 500 working hours and based on Vickers test after 50, 75 and 100 working hours. The temperature of oil was in accordance with the standard ISO 8217, at the value 40 °C. During the measurement, the speed rotation of the hydraulic pump was gradually increased by 250 rpm in the interval from 500 rpm to 2,500 rpm. To measure the flow characteristics at specified pressure, the EVS 3100 sensor was used at a sampling frequency of 20 ms, with a recording time 10 s. The type of hydraulic pump is chosen regarding the technical data of the transmission-hydraulic circuit of the Zetor Fortera 114 41 tractor, specifically for the gear hydraulic pump with external gearing marked GHD1-17R-S2D1-SG05G04-N with geometrical volume of V_G=17.37 cm^3.

3 Results

Flow characteristics at a reference value of 0 hours and after 250 and 500 working hours at a speed rotation of 500 rpm to 2,500 rpm are shown in table 1.

Table 1. Flow efficiency and flow of the hydraulic pump.

Speed rotation, rpm	Flow efficiency, %			Flow, dm^3/min		
	0 h	250 h	500 h	0 h	250 h	500 h
500	88.36	89.96	86.05	7.68	7.82	7.48
750	92.33	93.56	88.04	12.04	10.20	11.48
1,000	94.56	95.19	89.32	16.44	16.55	15.53
1,250	95.92	96.48	90.24	20.85	20.97	19.62
1,500	96.83	97.28	90.85	25.26	25.38	23.70
1,750	97.47	97.83	91.20	29.66	29.77	27.75
2,000	97.77	98.11	91.35	34.01	34.12	31.77
2,250	98.03	98.29	91.09	38.36	38.46	35.64
2,500	98.17	98.33	91.14	42.68	42.75	39.62

The flow characteristics at the reference value at 0 hours and at a speed rotation of 500 rpm reached the value of 7.68 dm^3/min and at speed rotation of 2,500 rpm reached the value of 42.68 dm^3/min. The increased in the flow characteristic as a function of the speed rotation is between 500 rpm and 2,500 rpm (35 dm^3/min), wherein said characteristic has an almost linear course. The flow efficiency at the reference value at 0 hours and at a speed rotation of 500 rpm reached the value of 88.36 % and at speed rotation of 2,500 rpm reached the value

of 98.17 %. The largest increased in the flow efficiency as a function of the speed rotation is between 500 rpm to 1,500 rpm (8.47 %) after exceeding 1,500 rpm (nominal speed rotation) to 2,500 rpm there was an increase in flow efficiency (1.34 %). This course of flow efficiency found in our measurements corresponds to the authors [3] who found similar results. The authors state that the given course of flow efficiency is caused by fluid remaining in the tooth gaps of the gear hydraulic pump and with increasing speed the centrifugal force increases, which reduces the losses due to fluid remaining in the tooth gaps, thus increasing the flow efficiency. The influence of the centrifugal force on the fluid according to the mentioned authors is the greatest after the value of approx. 1,500 rpm, after reaching these speed rotations, the effect of the centrifugal force on the fluid has only a slightly increasing characteristic.

The flow characteristics after 250 working hours and at a speed rotation of 500 rpm reached the value of 7.82 dm^3/min and at speed rotation of 2,500 rpm reached the value of 42.75 dm^3/min. The increase in the flow characteristic has a linear course depending on the speed rotation, with the speed rotation 500 rpm to 2,500 rpm represent the value of 34.93 dm^3/min. The increased if flow efficiency as a function of speed rotation is highest between 500 rpm to 1,500 rpm (7.32 %), after exceeding the nominal speed rotation of 1,500 rpm to 2,500 rpm there was a slight increase in flow efficiency (1.05 %).

The flow characteristics after 500 working hours and at a speed rotation of 500 rpm reached the value of 7.48 dm^3/min and at speed rotation of 2,500 rpm reached the value of 39.62 dm^3/min. The flow efficiency at 500 working hours and at 500 rpm reached the value of 86.05% and at 2,500 rpm reached the value of 91.14 %. The largest increase in flow efficiency as a function of speed rotation is between 500 rpm to 1,500 rpm (4.8 %).

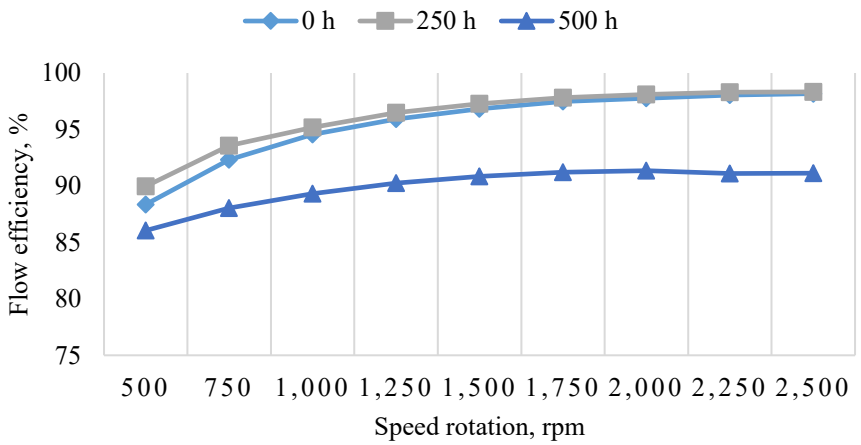

Fig. 1 Flow efficiency of hydraulic pump at reference value at 0 hours and after 250 and 500 working hours.

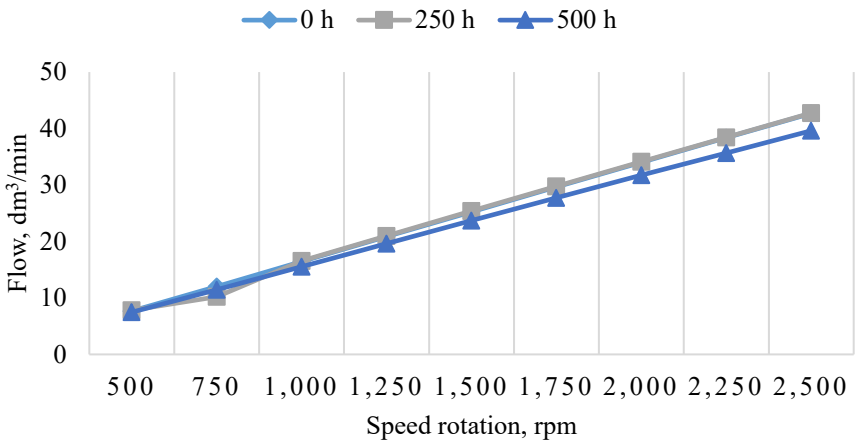

Fig. 2 Flow characteristics of hydraulic pump at reference value at 0 hours and after 250 and 500 working hours.

Table 2. Flow efficiency and flow of the hydraulic pump – test Vickers.

Speed rotation, rpm	Flow efficiency, %				Flow, dm^3/min			
	0 h	50 h	75 h	100 h	0 h	50 h	75 h	100 h
500	86.05	92.68	93.36	93.62	7.48	8.06	8.12	8.14
750	88.04	95.95	95.68	97.79	11.48	12.51	12.74	12.75
1,000	89.32	97.21	97.53	98.25	15.53	16.91	16.79	17.09
1,250	90.24	98.18	98.74	98.98	19.62	21.34	21.46	21.52
1,500	90.85	98.88	99.20	99.42	23.70	25.79	25.88	25.93
1,750	91.20	99.29	99.40	99.59	27.75	30.22	30.25	30.31
2,000	91.35	99.43	99.42	99.61	31.77	34.58	34.58	34.64
2,250	91.09	99.35	99.39	99.52	35.64	38.88	38.89	38.94
2,500	91.14	99.16	99.07	99.19	39.62	43.11	43.07	43.12

Flow characteristics at a reference value of 0 hours and after 50, 75 and 100 working hours at a speed rotation of 500 rpm to 2,500 rpm are shown in table 2 in accordance with the Vickers test method.

The flow characteristic at a reference value of 0 hours and at speed rotation of 500 rpm reached the value of 7.48 dm^3/min and at speed rotation of 2,500 rpm reached the value of 39.62 dm^3/min. The increase in the flow characteristic has a linear course depending on the speed rotation, while between the speed rotation of 500 rpm to 2,500 rpm it represents a value of 31.71 dm^3/min. The flow efficiency at the reference value of 0 hours and speed rotation of 500 rpm reached the value of 86.05 % and at speed rotation of 2,500 min^{-1} reached the value of 91.14 %. The largest increase in flow efficiency as a function of speed rotation is between 500 rpm to 1,500 rpm (4.8 %).

The flow characteristic after 50 working hours and at a speed rotation of 500 rpm reached the value of 8.06 dm^3/min and at speed rotation of 2,500 rpm reached the value of 43.11 dm^3/min. The increase in flow characteristic between 500 rpm to 2,500 rpm represent the value of 35.05 dm^3/min. The flow efficiency after 50 working hours and at 500 rpm reached the value of 92.68 % and at speed rotation of 2,500 rpm reached the value of 99.16 %. The largest increase in flow efficiency as a function of speed rotation is between 500 rpm to 1,500 rpm (6.2 %).

The flow characteristic after 75 working hours and at a speed rotation of 500 rpm reached the value of 8.12 dm^3/min and at speed rotation of 2,500 rpm reached the value of 43.07 dm^3/min. The increase in the flow characteristic has a linear course depending on the speed rotation, while between the speed rotation of 500 rpm to 2,500 rpm represents a value of 34.95 dm^3/min. The flow efficiency after 75 50 working hours and at 500 rpm reached the value of 93.36 % and at speed rotation of 2,500 rpm reached the value of 99.07 %. The largest increase in flow efficiency as a function of speed rotation is between 500 rpm to 1,500 rpm (6,03 %).

The flow characteristic after 100 working hours and at a speed rotation of 500 rpm reached the value of 8.14 dm^3/min and at speed rotation of 2,500 rpm reached the value of 43.12 dm^3/min. The increase in flow characteristic between 500 rpm to 2,500 rpm represent the value of 34.98 dm^3/min. The flow efficiency after 100 working hours and at 500 rpm reached the value of 93.62% and at speed rotation of 2,500 rpm reached the value of 99.91 %. The largest increase in flow efficiency as a function of speed rotation is between 500 rpm to 1,500 rpm (5.8 %).

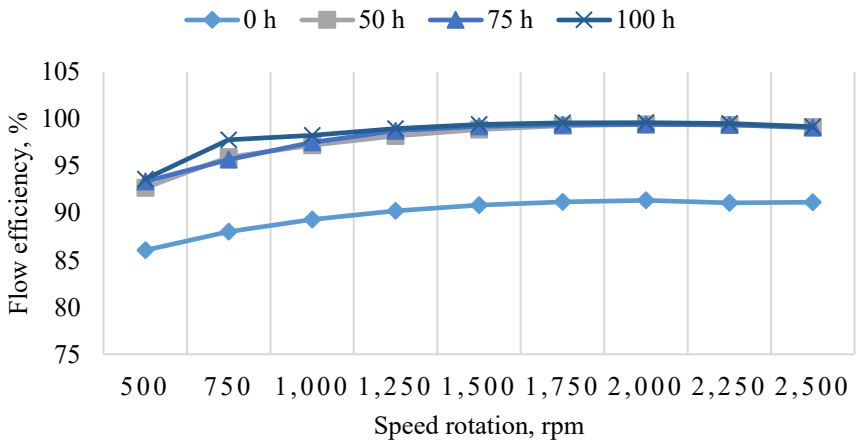

Fig. 3 Flow efficiency of hydraulic pump at reference value at 0 hours and after 40, 75 and 100 working hours – test Vickers.

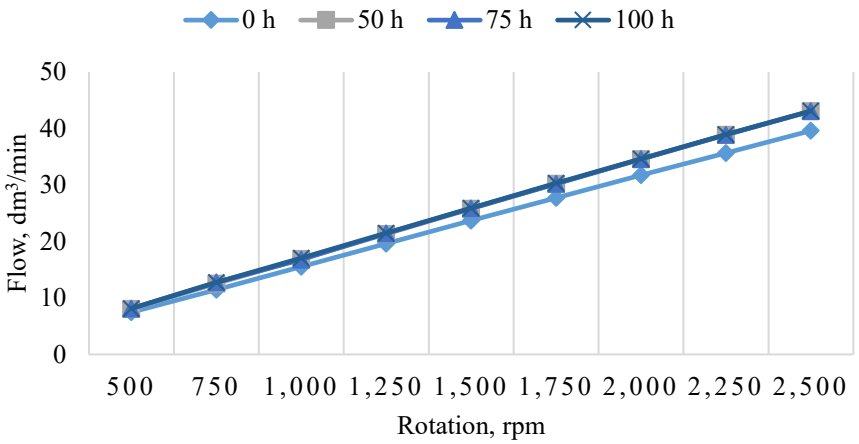

Fig. 4 Flow characteristics of hydraulic pump at reference value at 0 hours and after 50, 75 and 100 working hours – test Vickers.

4 Conclusion

The contribution is focused on the simulation of the operating load of the hydraulic pump of the agricultural tractor in laboratory conditions using the ecological transmission-hydraulic fluid. The aim of the simulation was monitoring changes in flow and flow efficiency of the hydraulic pump during operation, with predetermined operating fluid temperature conditions. We determined the flow efficiency by calculating based on the measured flow of the hydraulic pump at speed rotation 500 rpm to 2,500 rpm. Therefore, at the same time as monitoring the flow characteristic, it is necessary to monitor the change of the used fluid specifically the physicochemical properties of the operating fluid and the contamination of the fluid. According to [4] hydrodynamic principle requires a perfect medium; therefore the hydraulic fluid must meet all the conditions encountered in the operation of hydraulic systems. Several authors [5, 6, 7] have already dealt with the analysis of the influence of ecological fluids and their mixtures. The change in the properties of the physicochemical properties of the transmission-hydraulic fluid is the important indicator of the technical condition of the hydraulic pump and has a fundamental influence on the operation of individual elements of the hydraulic circuit. The evaluation of the oil level is carried out according to pre-planned intervals or [8, 9, 10]. We compared the measured and calculated values and found that the flow of the hydraulic pump together with its efficiency is gradually reduced due to wear and changes in the physicochemical properties of the working fluid. When comparing the flow characteristic of the Vickers test hydraulic pump with the reference value at 0 hours and the value after 50 working hours, according to the Vickers test method, an increase in the flow characteristic of 8.82% was recorded at a nominal speed rotation of 1500 rpm. Due to the established methodology and evaluation of the test according to the Vickers test method for gear hydraulic pumps, a change in flow rate of 3.75% is allowed, from which it can be stated that the biodegradable universal liquid does not pass the Vickers test after 50 working hours.

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