Design of the measuring device of the agricultural tractor´s external hydraulic circuit

Juraj Jablonický[1], *Peter* Kožuch[1*], *Jozef* Nosian[1], *Juraj* Tulík[1], *Jerzy* Kaszkowiak[2] and *Marcin* Zastempowski[2]

[1]Slovak University of Agriculture in Nitra, Department of Transport and Handling, 94976 Nitra, Slovakia
[2]University of Technologies and Life Sciences in Bydgoszcz, Department of Machinery, Al. prof. S. Kaliskiego 7, 85-796 Bydgoszcz, Poland

Abstract. The main goal of the presented paper was to design the measuring device of the external hydraulic circuit of the agricultural tractor, with the implementation of verification measurement and functionality of the device. At the same time, based on the device itself, which was verified in practice, a simulation was created in the FluidSim simulation program using the results of operational verification measurements. At the beginning of the structural design, the requirements for the electro-mechanical device were determined. This device is used for loading of the external hydraulic circuit, determination of the measuring object and flow calculation of the hydraulic pump. The verification measurement itself takes place at rated speed, constant and overpressure pressure in the tractor´s hydraulic system.

1 Introduction

Quality and rapid research and development plays an important role in the introduction of new agricultural, forestry and handling equipment into operation, even in the field of new elements that are applied in their working hydraulics. The importance of testing the mentioned technology, its aggregates or components, within the development stage is constantly growing and represents a significant guarantee of the service life and reliability of these products. The authors [1, 2] focuses on the design of laboratory test equipment with a focus on hydraulic systems, where he states that high demands are placed on hydraulic fluids as a carrier of energy in hydraulic systems, while the test equipment should simulate the operating load of the tractor´s hydraulic system. By monitoring the change in the flow of the hydraulic pump at precisely determined intervals, it is possible to assess the influence of the working fluid´s physical properties on the flow properties of the hydraulic pump [3]. With an experimental set of pressure measurements with numerical simulation in case of the engines in laboratory conditions, we reduce the time required to perform operational measurements [4]. Some, especially long-term tests, cannot be performed directly on machines and equipment, as this would disproportionately prolong and increase the cost of the development process. However, operational tests of agricultural, forestry and handling

---

[*] Corresponding author: xkozuchp@uniag.sk

equipment, which are focused on testing the impacts of used hydraulic fluids on hydraulic elements in working hydraulics systems, it is advantageous to test not only in laboratory but also in real operating conditions. The advantage of in-service tests is that the measured data can be used as input data for long-term tests under laboratory conditions. In this way, it is possible to obtain objective information on the possible ecological impacts of the used hydraulic fluids, on the environment in which the mentioned machinery will work [5, 6]. For this reason, the precise engineering production of individual elements of the hydraulic circuit is important, because it is important to monitor the accuracy of CNC machine tools using new methods and trends in product development and planning. Multiriterial diagnostics of CNC machines is equally important [7, 8, 9].

2 Material and Methods

The proposed electro-mechanical device for testing the external circuit of working hydraulics of machines, the diagram of which is shown in Fig. 1 consists of measuring circuit A, control and evaluation circuit B and supply circuit C. The measuring circuit A consists of an input quick coupling 1 and an output quick coupling 14, which serve to connect to the hydraulic circuit of the tractor's working hydraulics, and with a quick coupling 4, which serves to connect to the measuring circuit A. The measuring circuit A consists of an input quick coupling 1 and an output quick coupling 14, which serve to connect to the hydraulic circuit of the tractor's working hydraulics, and with a quick coupling 4, which serves to connect to the measuring circuit A. A connection point 2 is located between the quick couplings 1 and 4, which allows connection to a device for measuring the purity code of the hydraulic fluid. Between mentioned couplings is also located a pressure filter 3, which can ensure the flow value of 95 $dm^3.min^{-1}$, and it is resistant to a maximum working pressure of 31.5 MPa. Between the quick coupling 4 and the three-way valve 8 is located a combined temperature sensor 5, a pressure sensor 6 and a flow sensor 7. The temperature sensor can operates in the temperature range from -25 °C to 100 °C, with a response time of 4 s^{-1}. The pressure sensor is selected to be able to withstand pressures up to 25 MPa. The designed flow sensor can operate from a flow value of 6 $dm^3.min^{-1}$ to 60 $dm^3.min^{-1}$. These values sufficiently cover the entire measuring range when testing the working tractor´s hydraulics. An important part of the designed loading device are the electrohydraulic proportional valve 9 and throttle valve 10, which are connected to the three-way valve 8. To maintain the safety of the designed device, a safety valve 11 is placed in the circuit, operating at a maximum pressure of 30 MPa, and providing flow value of 45 $dm^3.min^{-1}$. The valve 8 is located between the flow sensor 7 and the three-way valve 8.
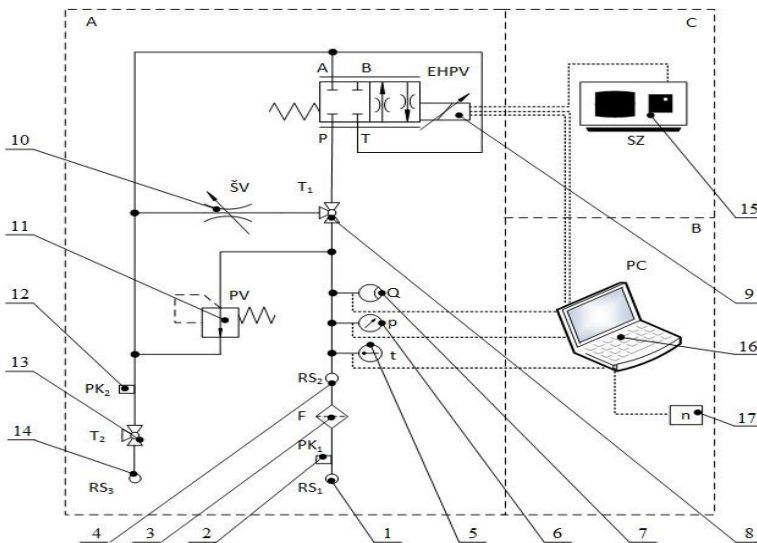
Fig. 1. The set of pressures in the hydraulic circuit of the tractor used in the simulation of the operation load.

A - measuring circuit, B - control and evaluation circuit, C - supply circuit, 1 - input quick coupling, 2 - first connection point to the device for recording the purity code of the hydraulic fluid, 3 - pressure filter, 4 - quick coupling, 5 - sensor temperature, 6 - pressure sensor, 7 - flow sensor, 8 - first three-way valve, 9 - electrohydraulic proportional valve, 10 - throttle valve, 11 - safety valve, 12 - second connection point to the device for recording the of hydraulic fluid purity code, 13 - second three-way valve, 14 - outlet quick coupler, 15 - stabilized source, 16 - computer, 17 - speed sensor

Measurements on this electro-mechanical device can take place after switching the three-way valve either in automated mode, via electrohydraulic proportional valve supplied from a stabilized source and controlled by a computer, or in manual mode via throttle valve.

3 Results

The proposed electro-hydraulic equipment for testing the external circuit of the tractor's working hydraulics was connected to the external circuit of the ZETOR SUPER 5321 tractor, equipped with a UD 20 hydraulic pump, during verification tests in operating conditions. During the verification tests, the electro-hydraulic device in an automatic mode in which the load of the hydraulic pump was realized via electrohydraulic proportional valve in the form of increasing pressure. With increasing pressure in the range of 0-18 MPa, hydraulic pump flow values were recorded at a nominal speed of 1500 min-1. Subsequently, the average values of the hydraulic pump flow were generated from measured values at individual pressures. These average values were compared with the flow values from the FluidSim simulation program. In this program the same hydraulic pump loading was simulated using an electro-hydraulic device. Processing and evaluation of measured flow values in operating conditions on the ZETOR SUPER 5321 tractor was performed in the statistical program. Table 1 shows these evaluated data.

Table 1. Ensemble of measured evaluation of the UD 20 hydraulic pump´s flow at a nominal speed of 1500 min^{-1} and a changing load.

| Statistical evaluation ensemble of measured values						Flow FluidSim
Pressure, MPa	Average	Variance	Standard Deviation	Coeff. of Variation	Reliability, %	
0	30,54	0,08	0,022	0,0005		29,72
2	30,06	0,42	0,113	0,0128		29,61
4	29,71	1,19	0,182	0,0329		29,07
6	29,11	0,38	0,115	0,0133		28,51
8	28,49	1,05	0,165	0,0273		27,96
10	27,82	2,71	0,174	0,4169	95	27,46
12	27,05	0,14	0,051	0,0026		26,87
14	26,92	0,15	0,056	0,0031		26,35
16	25,42	0,18	0,651	0,0042		25,81
18	25,39	0,48	0,178	0,0317		25,31
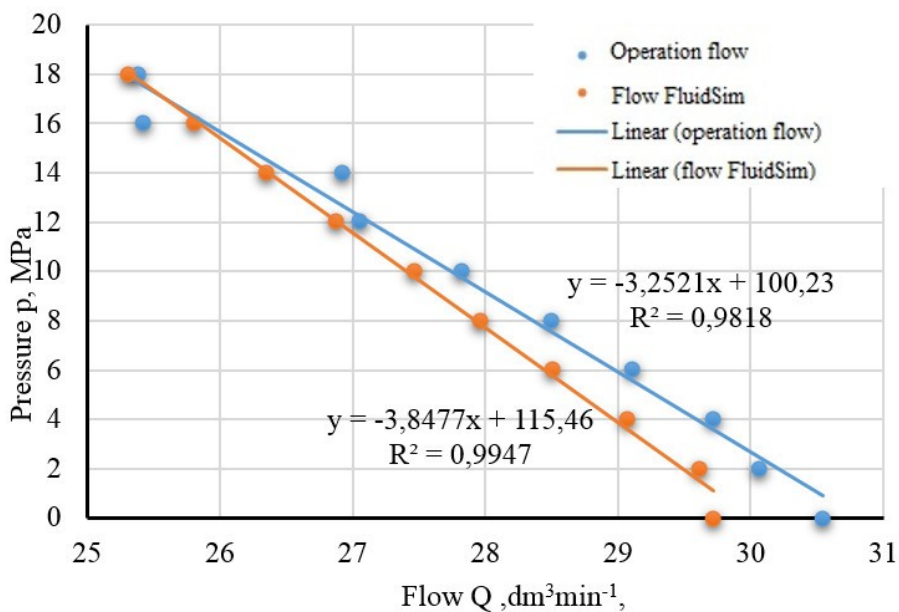
Fig. 2. Recorded dependence of flow on pressure in operation and simulation at nominal speed of hydraulic pump UD 20, n = 1500 min^{-1}

4 Conclusion

Authors [10, 11] states in their work, the functionality of the proposed test equipment must be verified by practical experiments with verification measurement and assessment of the suitability of hydraulic circuit elements and designed sensing devices. From the graphical dependence of the flow values as a function of pressure at a constant hydraulic pump speed of 1500 min-1, it can be seen that the differences in flow values from operating measurements compared to the simulation are smaller the higher the pressure is, at which the tractor's external working hydraulics are loaded. The differences between the flows recorded from the operational measurements and the flows from the FlidSim simulation program were at range from 0.32% to 2.69%. This inaccuracy is caused by the fact that in the simulation program the constant speed of the hydraulic pump is maintained even when it is loaded with pressure. During operational measurements, the operating speed of the hydraulic pump slightly fluctuates, which is related to the derived load in the form of increasing pressure. Based on this comparison of values, it follows that the device is designed correctly and that measurements can be made with sufficient accuracy. The verification test of the electromechanical device was performed in the simulation program FluidSim. First it was necessary to create a simulation model of the tractor´s external working hydraulics and then create a simulation model of the electromechanical device for loading tractor´s external working hydraulics and the electric control circuit of the electrohydraulic proportional valve. The measured values of flow and power of the hydraulic pump with the correct function of the safety valve were compared with the calculated values of flow and power of the hydraulic pump UD 20. The second verification test of the electro-mechanical device for loading the tractor´s external working hydraulics, was the verification test in operating conditions in which the measuring device was connected to external circuit of the working hydraulics of the ZETOR SUPER 5321 tractor. Verification measurements were performed at nominal speed 1500 min^{-1} and pressure in the interval from 0 to 18 MPa. Authors [12, 13] dealt with similar experiment, where they try to verify the measurement of proposed laboratory device vie flow characteristic of the hydraulic pump, while in one case was used biodegradable hydraulic fluid. A comprehensive analysis of the effect of biological fluids and mixtures thereof has been performed by author [14]. Unfortunately operating this kind of machinery in those places has lots of negative impacts. One of those negative impact is power delivery efficiency on soft or loose type of soil. This problem was dealt by author [15]. The biggest advantage of designed measuring device is, that thanks to proposed software it can record measurement values via of which it is possible to repeat measurements. This represents a significant shift in measuring technology in hydraulic systems of tractors, forestry and handling machines while it is registered at the Industrial Property Office of the Slovak Republic under number 288693.

References

1. Ľ. Hujo, Š. Čorňák, Z. Tkáč, M. Jánošová, TAE, **9**, 183 (2019)

2. M. Zastempowski, BazTech, **58**, 188 (2013)

3. Ľ. Hujo, J. Jablonický, R. Janoušková, J. Kosiba, Z. Tkáč, J. Tulík, NT20, **128**, 403 (2020)

4. M. Puškár, T. Brestovič, N. Jasminská, Int. J. Veh. Des., **67**, 63 (2015)

5. Z. Tkáč, Š. Čorňák, V. Cviklovič, J. Kosiba, J. Jablonický, R. Bernát, Acta technol. agric. **20**, 42 (2017)

6. M. Majdan, Z. Tkáč, R. Abrahám, K. Kollárová, I. Vitázek, M. Halenár, Tribol. ind. **39**, 547 (2017)

7. M. Košinár, I. Kuric, Adv. Sci. Technol., 6, 115 (2011)

8. I. Kuric, I. Zajačko, M. Cisár, Adv. Sci. Technol. Res. J., 10, 59 (2016)

9. I. Kuric, ICQEM, **9**, 453 (2011)

10. Ľ. Hujo, J. Jablonický, J. Markovič, J. Tulík, M. Simikič, M. Zastempowski, R. Janoušková, Appl. Sci., **11**, 483 (2021)

11. J. Nosian, Ľ. Hujo, M. Zastempowski, R. Janoušková, Acta technol. agric. **24**, 35 (2021)

12. J. Nosian, M. Halenár, P. Kuchar, J. Tulík, A. Furstenzeller, M. Kučera, Acta Facult. Tech., **24**, 89 (2019)

13. M. Halenár, P. Kuchár, Mendel. Brun., **24**, 784 (2017)

14. M. Puškár, A. Jahnátek, I. Kuric, J. Kádárová, M. Kopas, M. Šoltésová, Air Qual. Atmos. Health , **12**, 855 (2019)

15. M. Simikč, N. Dedović, L. Savin. M. Tomić, O. Ponjičan, SOIL TILL RES., **141**, 34 (2014)