Pressure in the hydraulic system of three point hitch of tractor equiped with electrical and mechanical control

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ABSTRACT: The goal of the measurement of the tractor ZTS 164 45 equipped with digital electrohydraulical control EHR-D BOSCH during ploughing with ploughs KUHN (4 bottoms) and 5 PHX 35 (5 bottoms) was to obtain time dependent states of pressure in the hydraulic system of the three point hitch of tractor. From the point of view of comparison of obtained results testing conditions were determinated with respect to physical and mechanical properties of soil such as soil volume mass, soil humidity, penetration resistance and shear resistance of soil. Beyond these measurements also measurements of operation parameters as a ploughing depth, ploughing width, working speed and fuel consumption were accomplished. The measured results of physical and mechanical properties of soil show big content of loam elements and stones in the soil. Simultaneously the measured results of the operation parameters of the ploughing sets confirmed that the ploughs KUHN and 5 PHX 35 are suitable for tractor ZTS 164 45. Based on the measured results there is a possibility to infer following conclusions: Control system of the three point hitch offers a reliable function. Hydraulic circuit is equipped by an improper distributor which causes pressure peaks which are corresponding with safety valve adjustment. Hydraulic circuit has a low conductive resistance. Loading of tractor body is higher when using mounted plough than with semi mounted plough.

Keywords: press; hydraulic system; three point hitch; electrohydraulical control; mounted plough; semi mounted plough

Producers of agricultural tractors currently make efforts to improve their machines implementing new technologies. Challenging demands are put not only on single machines but also on properties and behaviour of machinery systems.

One of fixed areas of research and development activity consists in solution of exploatation and operating systems. This project cannot be fulfilled without research and methodical process, without necessary equipment, fundamental knowledge, and experiences. A lot of deficiencies are caused by insufficient measurement activities.

In this paper a possibility of measurement of time dependent states of pressures in the hydraulic system of tractor is presented. Research in the field of exploatation system also consists of a dynamic solution which is very suitable to be accomplished by means of computer and to be utilized it as a model of monitoring system. In this case there is a possibility to monitor influence of changes of individual parameters on the system (TURZA 1996). This is a very complicated problem and its solution requires some simplification assumptions. Although we can estimate properties of the designed hydraulic system by computer there is a necessity to pay attention to the experimental research in the laboratory and operation conditions (BAUER et al. 2001). Laboratory measurements would be concentrated on the dynamic loading and operation measurement of the typical heavy duty working operations.

For the successful design of some system knowledge of operating conditions is needed. We have implemented experimental measurements of operating performance, which includes external environment and internal function of the system during specific conditions and operating modes. The knowledge of operating conditions is desirable not only for design but also for evaluation of operation properties driver comfort, criteria of dynamic and stability, reliability and additional specific properties which are directly or indirectly influenced by operating load, pressures, deformations, speeds, acceleration and alike. So operating conditions present a source of operating modes which are inputting in alls theoretical and experimental methods to estimate and evaluate operation properties of the systems (DRABANT, PETRANSKÝ 1999).

Research workers of Department of Vehicle and Heat Devices, Faculty of Agricultural Engineering, Slovak University of Agriculture in Nitra have aimed research to real design of tractors with respect to operation conditions. Because lot of operating processes has a stochastic character and monitoring time periods are relatively long a suitable measuring and operative system must be developed. Permanently we have attended to obtain the operating load of individual nodes and systems of tractors. This paper contains results of experimental measuring of pressures in the hydraulic system of tractor when ploughing performed at the Co-operative Farm Bátovce.

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Fig. 1. Ploughing set of tractor ZTS164 45 + KHUN

MATERIAL AND METHODS

Two sets were arranged according to technical documentation. The first set consisted of tractor ZTS 164 45 + plough 5 PHX 35 and the second one of tractor ZTS 164 45 + plough KUHN (Fig. 1). The tractor is made by ZTS TEES Corp. Martin, Slovak Republic.

The tested tractor was equipped by electrohydraulical control EHR-D BOSCH.

During the test we implemented following research activities:

– Measurement of land conditions with respect to physical and mechanical properties of soil.
– Measurement of selected operating parameters of ploughing set.

Following physical and mechanical properties of soil were investigated:

– Volume mass of soil
– Soil moisture
– Penetrometric resistance of soil
– Shear strength of soil.

Samples of soil were taken by means of Kopecký's rollers and their volume mass and soil moisture was determined after drying them at the temperature of 105°C during the time of 6 hours. Penetrometric resistance of soil was measured by means of registration penetrometer. For measurement of the shear soil strength handle screwed device PILCON-EDECO with direct readout of values was used. The measurements were accomplished in three values of depth with diameter of the propeller 19 mm. Measurement method and evaluation of the measured values was performed according to the Standard STN 71 1026 *Laboratory determination of soil shear strength by propeller test.*

Following parameters were measured to determinate operation parameters of the ploughing set:

– Operating width of set
– Ploughing depth
– Operating speed of set
– Fuel consumption.

The testing land was divided into two parts with the length of 100 m. One part was divided and marked by stakes after each 10 m length. Operating width of the ploughing set was measured after each running in the

Fig. 2. Transmission of measuring data from recording units HMG 2020 to PC MicroBook 825D

place against the mark by means of steel measuring tape with accuracy ±5 mm. Similarly the ploughing depth was measured by means of a depth-gauge. Operating speed of the ploughing set was calculated according to the measured length and the time. For measurement of fuel consumption a measuring tank was built in the fuel system of engine.

Following pressures were measured in the hydraulic system of the tractor ZTS 164 45:

– Output pressure of hydraulic pump
– Input pressure of hydraulic cylinder.

Fig. 3. Placement of the pressure tested transducers in the cabin of the tested tractor

A measurement of pressures in the hydraulic system was accomplished by means of the handle measuring instrument HMG 2020. The measuring instrument HMG 2020 is able to measure and record four values in digital form at the same time continually. Each measured value may by activated or inactivated as need. For each transducer the measuring range may by determined and automatic reset of all measuring channels is also possible. A suitable sampling frequency was determined with respect to presumed of maximum frequency before measurement. The total number of samples taken also was determined according to the Shannon-Kotelnik theorem to eliminate a loss of information. After finishing of measurement or filling of memory the measuring instrument HMG 2020 was connected to the MicroBook 825 D (Fig. 2) to record the measured values on the hard disc of the computer. Pressure transducers HDA 3444-A-400-009 HYDAC (product of Germany) of rated measured range 40 MPa (Fig. 3) were used. The pressures mentioned above were measured during ploughing of the track of 50 m and also during returning of the ploughing set and sinking of the plough and ploughing again. Position, draught and mixed control of three point hitch was used for measurement of pressures in the hydraulic system of tractor for both types of ploughs mentioned above.

RESULTS AND DISCUSSION

By measurements and calculation the physical and mechanical properties of soil as volume mass, soil moisture, penetrometric resistance of soil and shear slide strength of soil were determinated. These values are presented in Table 1.

The selected penetrometric record inside of track and outside of track of tractor wheels is shown in Fig. 4. Penetrometric record shows that the measured tension outside of track increases from the depth of 5 cm and in the depth of 20 cm its value is 2.4 MPa. The maximum value 3.35 MPa was obtained in the depth of 57 cm. The measured tension inside of track increases from the depth of 5 cm and in the depth of 20 cm its value is 3.7 MPa. The results of soil shear strength are presented in Table 2.

Table 2. Measuring soil shear strength – wheat stubble

Number of measurement	Depth 10 cm	Depth 20 cm	Depth 30 cm
1	17	26	86
2	42	94	87
3	31	88	90
4	27	–	–
5	15	118	–
6	53	90	105
7	26	120	–
8	33	81	84
9	28	93	96
10	10	56	73
11	31	75	93
12	22	84	–
Arithmetic average	**25.42**	**84.09**	**89.25**
Standard deviation	**13.41**	**25.09**	**8.77**

Based on measured results we can state that the plot contains heavy soil with high content of loam elements and stones. In some cases the measurement of penetrometric resistance of soil was not possible due to stones located in the measured depth. The measured and calculated operation parameters of ploughing set of tractor ZTS 164 45 + plough KUHN are presented in Table 3. The same operation parameters of ploughing set of tractor ZTS 164 45 + plough 5 PHX 35 are presented in Table 4. The measured results presented in Tables 3 and 4 relate to position control of the three point hitch.

Based on the results of measurement we can state very high values of fuel consumption per hectare due to high humidity of soil (average humidity of soil was 34.37%) and also high volume mass of soil (average volume mass of soil was 1.807 g/cm^3). For this reason the average volume of slip was 19.7%.

The time dependence states of output pressure of the hydraulic pump and pressure in the hydraulic cylinder of the three point hitch of tractor ZTS 164 45 with plough 5 PHX 35 during ploughing, returning and follow up ploughing for position control are shown in Fig. 8. These dependence states for draft and mixed control are similarly shown in Figs. 9 and 10.

Table 1. Volume and mass soil moisture – wheat stubble

Variant	Number of roller	Depth (cm)	Mass of wet soil + roller (g)	Mass of dried soil + roller (g)	Mass of roller (g)	Volume mass of wet soil (g/cm^3)	Volume mass of dried soil (g/cm^3)	Volume soil moisture (%)	Mass soil moisture (%)
I.	99	10	282.1	231.9	88.1	1.780	1.319	46.06	34.91
	133	20	290.4	252.1	86.9	1.867	1.516	35.14	23.18
	5	30	292.2	253.1	85.9	1.893	1.634	35.87	23.39
II.	18	10	247.2	208.6	86.9	1.471	1.117	35.41	31.72
	4	20	290.4	253.1	85.5	1.880	1.538	34.22	22.26
	59	30	296.2	261.3	87.7	1.913	1.593	32.02	20.10
III.	124	10	267.9	229.6	86.7	1.662	1.311	35.14	26.80
	120	20	301.1	377.3	89.7	1.939	1.721	21.83	12.69
	30	30	290.4	253.7	88.2	1.855	1.518	33.67	22.18
Arithmetic average of measured soil properties						1.807	1.463	34.37	24.12

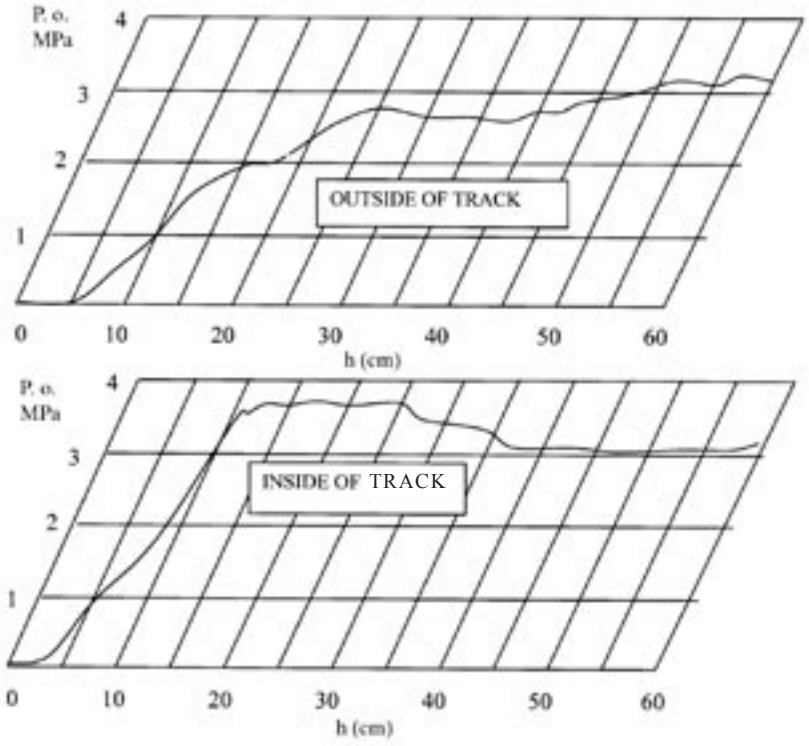

Fig. 4. Record of penetration resistance inside the track and outside of track

Pressure of the hydraulic pump during returning of ploughing set (tractor ZTS 164 45 with plough 5 PHX 35) for position control is 19 MPa. This pressure was reached with mixed control (Fig. 9) and draught control (Fig. 10). Time differences of 13 s (Fig. 8) and 8 s (Figs. 9 and 10) was caused by returning of tractor set.

Measurements of pressure in the output of hydraulic pump and in input of hydraulic cylinder of tractor ZTS 164 45 have shown that the electrohydraulic control has a low conductive resistance. This fact is confirmed by time dependent states of pressure in output of hydraulic pump as shown in Fig. 5 and Fig. 8 for position control. During ploughing with plough KUHN in the time of 50s hydraulic circuit was refilled 22-times and with plough 5 PHX 35 13-times at the same time.

When mounted plough KUHN is used pressure in the hydraulic cylinder varies from 3 to 8 MPa in working position and from 8 to 16 MPa in transporting position.

Table 3. Operating parameters – wheat stubble

Tested ploughing set: Tractor ZTS 164 45 + plough KUHN, 4-bottoms, position control

Parameter	Symbol	Measure	Value
Number of running	n	–	2
Length of running	L_p	m	460
Average operating width of plough	B	m	1.6725
Average ploughing depth	h	cm	19.50
Average speed of ploughing set	v_p	m/s km/h	2.0621 7.423
Width of ploughed field	B_p	m	3.345
Ploughed area	S	m^2	1,538.70
Ploughed soil volume	V	m^3	300.0465
Ploughed soil mass	G	t	542.184
Total measuring time	t	s	1,035.0
Area performance	W_p	m^2/s ha/h	1.4867 0.5352
Volume performance	W_o	m^3/s m^3/h	0.2899 1,043.64
Mass performance	W_g	t/h	1,885.857
Fuel consumption	M	dm^3	8.10
Fuel consumption per hour	M_h	dm^3/h	28.1739
Fuel consumption per hectare	M_{ha}	dm^3/ha	52.6418
Fuel consumption per 1 m^3 ploughed soil	Mo	dm^3/m^3	0.02699
Fuel consumption per 1 t ploughed soil	m_g	dm^3/t	0.01494

Table 4. Operating parameters – wheat stubble

Tested ploughing set: Tractor ZTS 164 45 + plough 5PHX, 5-bottoms: land – wheat stubble

Parameter	Symbol	Measure	Value
Number of running	n	–	2
Length of running	L_p	m	460
Average operating with of plough	B	m	1.8475
Average ploughing depth	h	cm	27.167
Average speed of ploughing set	v_p	m/s km/h	1.9819 7.1348
Width of ploughed field	B_p	m	3.695
Ploughed area	S	m^2	1,699.70
Ploughed soil volume	V	m^3	461.757
Ploughed soil mass	G	t	834.3958
Total measuring time	t	s	975
Area performance	W_p	m^2/s ha/h	1.743 0.6276
Volume performance	W_o	m^3/s m^3/h	0.4736 1,704.949
Mass performance	W_g	t/h	3,080.843
Fuel consumption	M	dm^3	8.40
Fuel consumption per hour	M_h	dm^3/h	31.0154
Fuel consumption per hectare	M_{ha}	dm^3/ha	49.419
Fuel consumption per 1 m^3 ploughed soil	Mo	dm^3/m^3	0.01819
Fuel consumption per 1 t ploughed soil	m_g	dm^3/t	0.01007

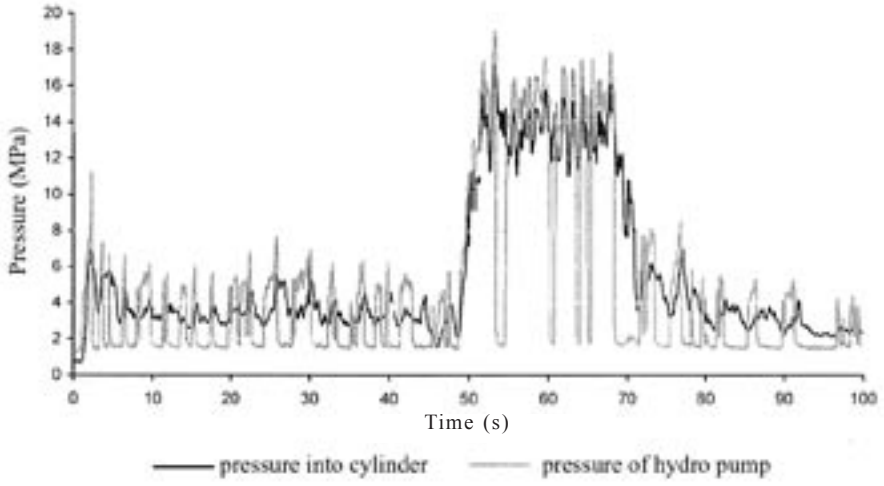

Fig. 5. Time dependent state of output pressure of hydraulic pump and of input pressure of hydraulic cylinder during ploughing with plough KUHN – position control

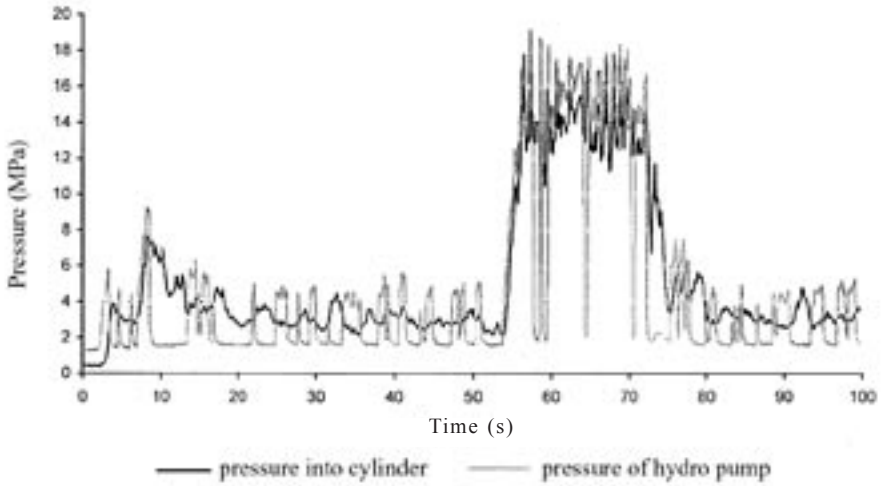

Fig. 6. Time dependent state of output pressure of hydraulic pump and of input pressure of hydraulic cylinder during ploughing with plough KUHN – mixed control

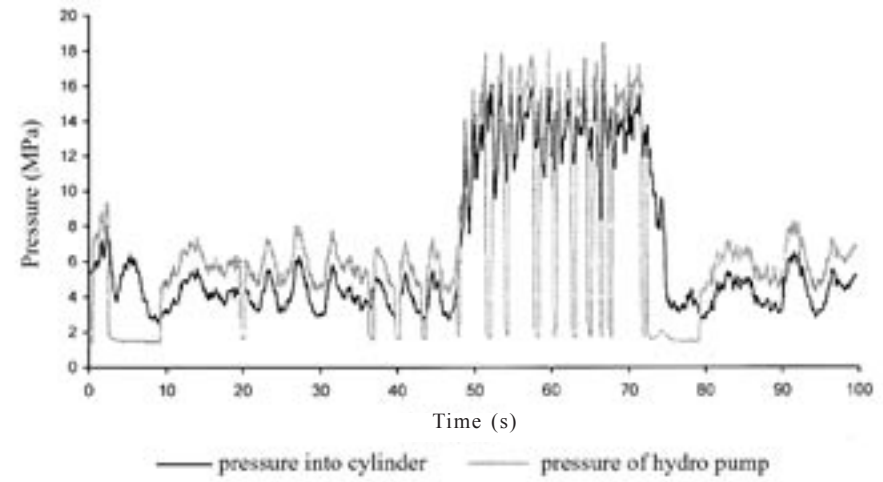

Fig. 7. Time dependent state of output pressure of hydraulic pump and of input pressure of hydraulic cylinder during ploughing with plough KUHN – draght control

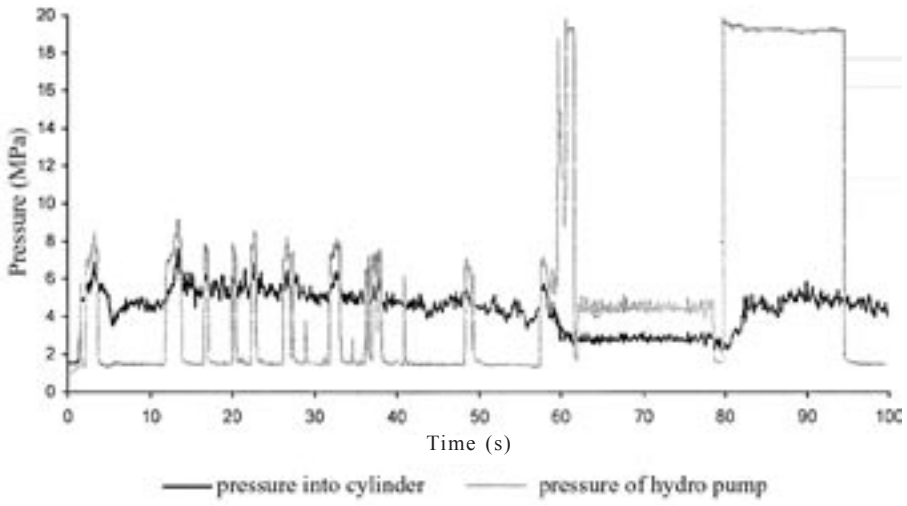

Fig. 8. Time dependent state of output pressure of hydraulic pump and of input pressure of hydraulic cylinder during ploughing with plough 5 PHX 35 – position control

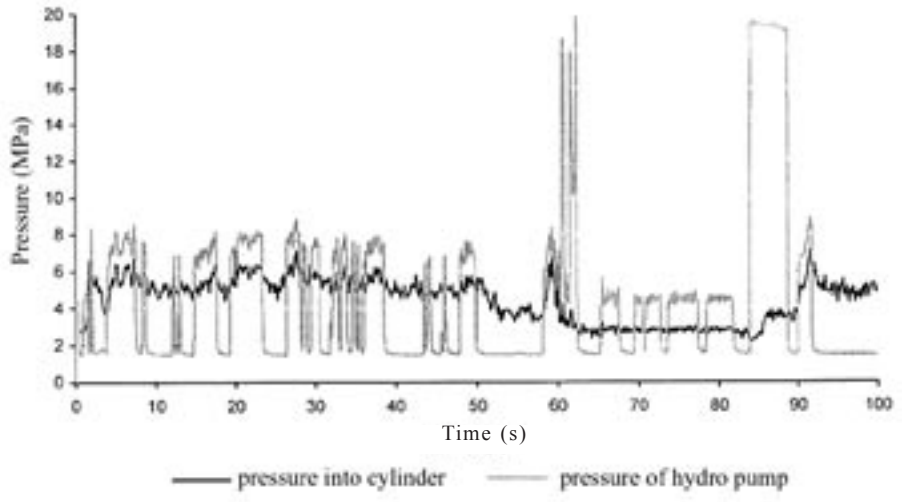

Fig. 9. Time dependent state of output pressure of hydraulic pump and of input pressure of hydraulic cylinder during ploughing with plough 5 PHX 35 – mixed control

Very unfavourable values of pressure in the output of hydraulic pump during the ploughing were obtained which oscillate from 1.5 to 9 MPa and from 1.5 to 18 MPa in transporting position.

When semi mounted plough 5 PHX 35 is used pressure in the hydraulic cylinder varies from 4 to 7.5 MPa and about 3 MPa in transporting position. Thus the load of tires and tractor body is lower in comparison with mounted plough KUHN in this case.

All the measured results of time dependent states of pressure confirmed that each resetting of hydraulic distributor causes creation of pressure peaks in the output of hydraulic pump. These pressure peaks are corresponding with safety valve adjustment. Duration of these

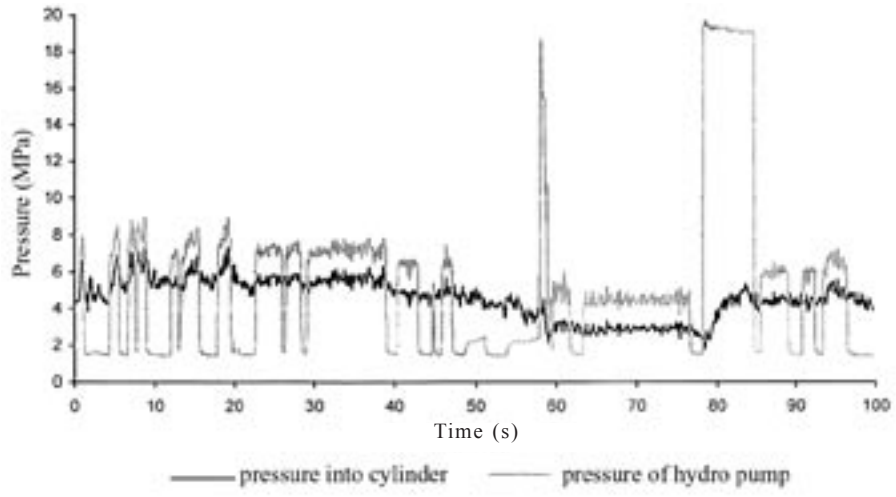

Fig. 10. Time dependent state of output pressure of hydraulic pump and of input pressure of hydraulic cylinder during ploughing with plough 5 PHX 35 – draght control

pressure peaks depends on the velocity of movement of control lever. Hence the hydraulic circuit is equipped with improper distributor from the point of view of interconnection of channels in the intermediate stage.

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Tlaky v hydraulickom systéme trojbodového závesu traktora s elektromechanickou reguláciou

ABSTRAKT: Predmetom uskutočnených meraní bolo získanie časových priebehov tlakov v hydraulickom systéme trojbodového závesu traktora ZTS 164 45 s digitálnou elektrohydraulickou reguláciou EHR-D od firmy BOSCH pri orbe s pluhmi KUHN (4 radlice) a 5 PHX 35 (5 radlíc). Z hľadiska objektívneho porovnania dosiahnutých výsledkov v rámci skúšok sme určili charakteristiky podmienok skúšok so zameraním na fyzikálno-mechanické vlastnosti pôdy spracovávaného pozemku – objemovú hmotnosť a vlhkosť pôdy, penetrometrický odpor a šmykovú pevnosť pôdy. Pri vlastnom meraní tlakov pri orbe sme vykonali aj meranie prevádzkových ukazovateľov orbovej súpravy: pracovná šírka záberu súpravy, hĺbka spracovania pôdy, pracovná rýchlosť súpravy a spotreba paliva. Z výsledkov merania fyzikálno-mechanických vlastností pôdy vyplynulo, že išlo o pozemok s ťažkou pôdou s veľkým obsahom ílovitých častíc a kameňov. Výsledky dosiahnuté pri meraniach prevádzkových ukazovateľov orbových súprav potvrdili, že pluhy KUHN i 5 PHX 35 sú konštrukcie vykazujúce vyhovujúce parametre a sú vhodné do orbovej súpravy s traktorom ZTS 164 45. Z nameraných priebehov tlakov možno vyvodiť nasledovné závery: Regulačný systém trojbodového závesu vykazuje spoľahlivú činnosť. Hydraulický obvod má zaradený nevhodný rozvádzač, ktorý spôsobil pri prepínaní tlakové špice v hodnote nastavenia poistného ventilu. Hydraulický obvod má malý zvodový odpor. Nesené pluhy oproti pluhom návesným nepriaznivejšie namáhajú hydraulický systém, pneumatiky a telo traktora.

Kľúčové slová: tlak; hydraulický systém; trojbodový záves; elektrohydraulická regulácia; nesený pluh; návesný pluh

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