HYDROPNEUMATIC SUSPENSION FOR TRACTOR IMPLEMENT

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Abstract. In order to reduce the pressure oscillation in the hydraulic hitch-system of the tractor and oscillation of all tractor aggregate the correction of the hydraulic system parameters is used. The lower oscillation amplitudes can be achieved using the tractor implement as oscillation reducer. Equipment of hydraulic hitch-system with hydropneumatic accumulators let adjust the stiffness and damping characteristics of the hydraulic cylinder, limiting the pressure oscillation amplitude. In order to create major changes in the level of stiffness, extra accumulators can be used. Improvement of the hydraulic hitch-system with different charged hydropneumatic accumulators, reduce pressure peaks in the hydraulic system till 8.76 %, at the driving speed 11.2 km·h^{-1} and tire pressure 0.12 MPa, but at the driving speed 7.8 km h^{-1} and the same tire pressure till 8.17 %.

Key words: hydropneumatic suspension, tractor hitch-system.

Introduction

During the tractor movement, with being attached to the hitch-system working equipment over rough road surfaces oscillation of the machine take place. These oscillations are a reason of pressure pulsations in the hydraulic hitch-system. The pressure pulse reduction in the tractor hitch-system is important for increasing of the system components lifetime. Pressure oscillation damping in the tractor hydraulic hitch-system can reduce overall system oscillations and improve the driving control.

The modern tractor linkage system is fitted with the oscillation damper that reduces the hydraulic hitch-system pressure oscillations. Equipped hydraulic hitch-system with hydropneumatic accumulators allows adjusting the stiffness and damping characteristics of the hydraulic cylinder, limiting the pressure oscillation amplitude. In order to create major changes in the level of stiffness, extra accumulators can be used.

The purpose of the investigation is to determine the pressure pulse reduction possibility in the tractor hitch-system adjusting the stiffness and damping the characteristics of the hydraulic cylinder.

The experiments present the results of pressure oscillation investigation in the hydraulic hitch-system of the tractor Claas Ares ATX 557 during the motion around artificial roughness test road. During the experiments oscillations at different driving speed, tire pressure, weight position on the implement boom and hitch-system oscillation damping (turned on/off) were investigated. The investigation of the physical tractor implement model allowed simplifying simulation of the implement oscillation during transportation.

Materials and methods

The experiments were performed in the NP Jelgava Business Park. In the experiment the tractor Claas Area 557 ATX was used. In order to reduce the pressure oscillation in the hydraulic hitch-system of the tractor and oscillation of all tractor aggregate the correction of the hydraulic system parameters are used. To make the correction in the hydraulic hitch-system different charged hydraulic accumulators were included. For the tractor hydraulic hitch-system loading the implement boom physical model and loading weight were used [1].

Before the measurements the tractor was fitted with the implement boom physical model, loading weight and connecting module of hydraulic accumulators (Fig. 1). The test road, movement speed, tire pressure and experimental methods are the same as in the previous experiments [1; 2].

Using the hydropneumatic accumulator as pressure oscillation damper it is necessary to determinate for further calculation the hydraulic system pressure in the tractor hitch-system hydraulic cylinder depending on the attached equipment weight, road roughness and tractor driving speed. In the experiments two different charged bladder type hydraulic accumulators were used. Two of them charged to the pressure of 15 MPa and three to 13 MPa. The position of the hydraulic accumulators on the tractor three point hitch-system and the view of the diaphragm type hydraulic accumulator are shown in Fig. 2.

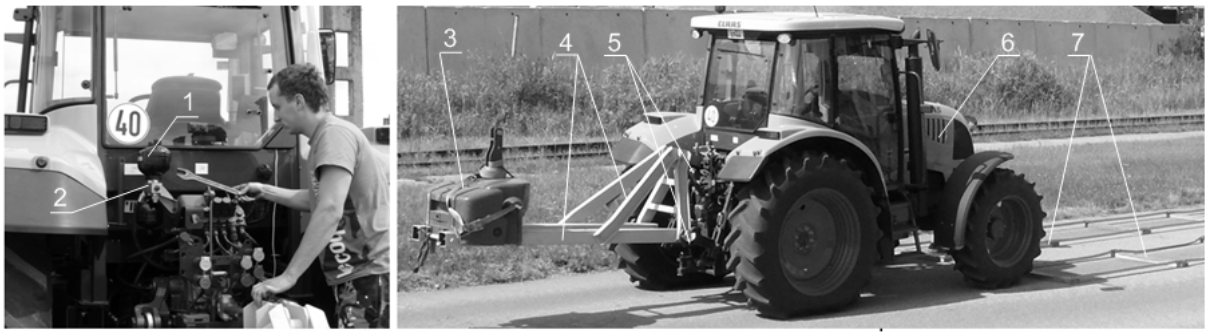

Fig. 1. **Tractor preparation for experiments:** 1 – diaphragm type hydraulic accumulators; 2 – hydroaccumulator connecting module; 3 – loading weight; 4 – physical implement of boom; 5 – tractor three point hitch-system; 6 – tractor Class Ares 557 ATX; 7 – test road

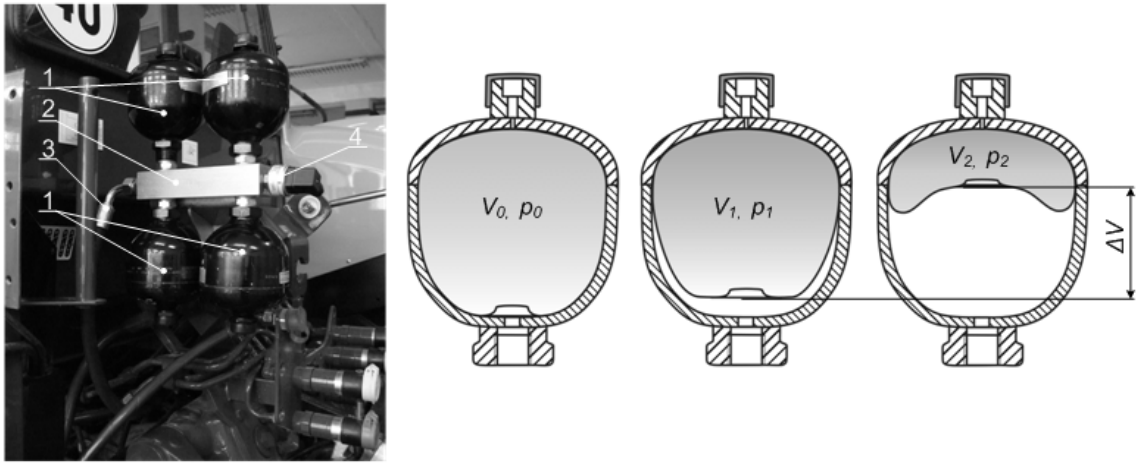

Fig. 2. **Position of hydraulic accumulators on tractor three point hitch-system:** 1 – diaphragm type hydraulic accumulator; 2 – hydraulic accumulator connecting module; 3 – hose of oil supply; 4 – pressure sensor Wika Transmitter ECO-1

The selection of the gas pre-charge pressure defines the accumulator capacity. The accumulator is pre-charged with nitrogen. The gas pre-charge pressure should be lower than the minimum pressure in the hydraulic system. Once the maximum operating pressure is reached, the effective volume ΔV is available in the accumulator.

The pressure p in the diaphragm accumulator increases according to the Boyle-Marriot law [3; 4]:

$$V_g^{1/k} p = const\ , \tag{1}$$

where V_g – gas volume, cm^3;
k – polytrop rate.

If the accumulator is charged slowly, then $k = 1$, and $pV_g = constant$ but if it is charged fast $k = 1.2$. The useful volume of liquid is conditional on the permissible pressure difference [3]:

$$\frac{V_d}{V_p} = \left(\frac{p_s}{p_{\min}}\right)^{\frac{1}{k}} - \left(\frac{p_s}{p_{\max}}\right)^{\frac{1}{k}}, \tag{2}$$

where V_p – nominal volume of accumulator, cm^3;
V_d – useful volume of accumulator, cm^3;
p_{min} un p_{max} – minimal and maximal working pressure, MPa;
p_s – gas preload pressure, MPa.

In order to obtain optimum utilization of the accumulator volume the following gas pre-charge pressures are recommended:

- for energy storage:

$$p_{0,t\max} = 0.9 \cdot p_1 \tag{3}$$

where p_1 – minimum operating pressure

- for shock absorption:

$$p_{0,t\max} = 0.6 to 0.9 \cdot p_m \tag{4}$$

where p_m – average operating pressure for free flow

- for pulsation damping:

$$p_{0,t\max} = 0.6 \cdot p_m \quad or \quad p_{0,t\max} = 0.8 \cdot p_1 \tag{5}$$

During the operation the diaphragm must not touch the fluid-side connection. Since the volume of the gas increases as the temperature increases, the gas pre-charge must be determined at the maximum operating temperature using the recommended value.

Each tractor drive experiment was repeated three times for every driving speed [5]. The nine maximum pressure values from the resultant curves are used in further calculations. They characterize pressure changes in the tractor hydraulic hitch-system moving on the test road at the driving speed 7.8 km·h^{-1} and 11.2 km·h^{-1} and with a determinate weight position. Average values were calculated from at least pressure 27 values and the confidence level 0.95 was used for mean value uncertainty evaluation.

Results and discussion

Changing the tractor hydraulic hitch-system (stiffness and damping) parameters and speeds different pressure values in the linkage cylinder are obtained. The experimentally obtained hydraulic hitch-system pressure values are shown in Fig. 3. The experiments were performed at two driving speeds 7.8 km·h^{-1} and 11.2 km·h^{-1}, at which previously the maximum pressure peaks were observed [1].

Fig. 3. describes changes of the hydraulic hitch-system hydraulic cylinder pressure oscillation at the tire pressure 0.08 MPa. The maximum average pressure of the hydraulic hitch-system reaches 17.26 MPa at the driving speed 7.8 km·h^{-1}, but at the driving speed 11.2 km·h^{-1} it reduces to 16.67 MPa, if diaphragm accumulators are not used. Using one on 13 MPa charged diaphragm accumulator average pressure of the hydraulic hitch-system reaches 15.93 MPa at the driving speed 7.8 km·h^{-1}, but at the driving speed 11.2 km·h^{-1} it reduces to 15.71 MPa. Using two on 13 MPa charged diaphragm accumulators average pressure of the hydraulic hitch-system reaches 15.85 MPa at the driving speed 7.8 km·h^{-1}, but at the driving speed 11.2 km·h^{-1} it reduces to 15.71 MPa. Using three on 13 MPa charged diaphragm accumulators average pressure of the hydraulic hitch-system reduces till 15.85 MPa at the driving speed 7.8 km·h^{-1}, but at the driving speed 11.2 km·h^{-1} it reduces to 15.63 MPa. Using two different charged (13 MPa and 15 MPa) diaphragm accumulators average pressure of the hydraulic hitch-system reaches to 16.78 MPa at the driving speed 7.8 km h^{-1}, but at the driving speed 11.2 km h^{-1} it reduces to 15.71 MPa. Using two different charged (one 13 MPa and two 15 MPa) diaphragm accumulators average pressure of the hydraulic hitch-system reaches to 16.05 MPa at the driving speed 7.8 km·h^{-1}, but at the driving speed 11.2 km·h^{-1} it reduces to 15.21 MPa.

Fig. 4. Describes the changes of the hydraulic hitch-system hydrocylinder pressure oscillation at the tire pressure 0.12 MPa: if diaphragm accumulators are not used, then the maximum average pressure of the hydraulic hitch-system reaches 15.97 MPa at the driving speed 11.2 km·h^{-1}, but at the driving speed 7.8 km·h^{-1} it reduces to 14.89 MPa.

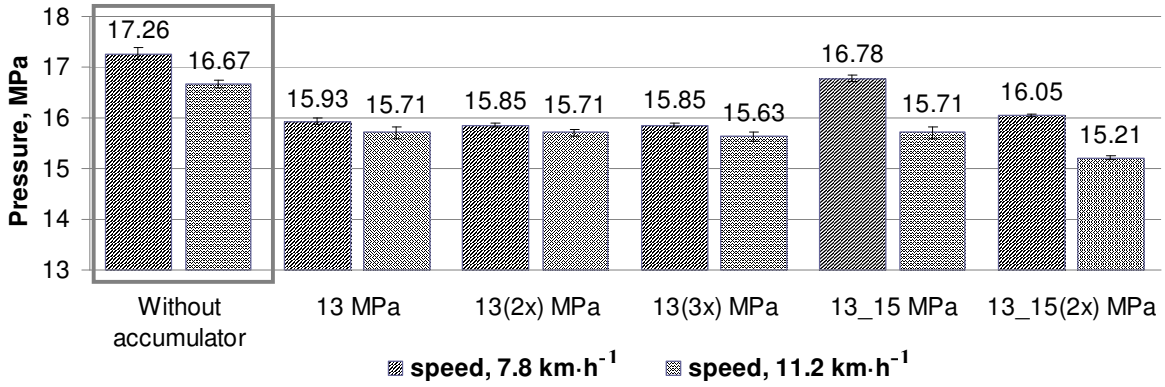

Fig. 3. **Pressure in tractor hydraulic hitch-system of hydraulic cylinder at tire pressure 0.08 MPa and different charged hydropneumatic accumulators**

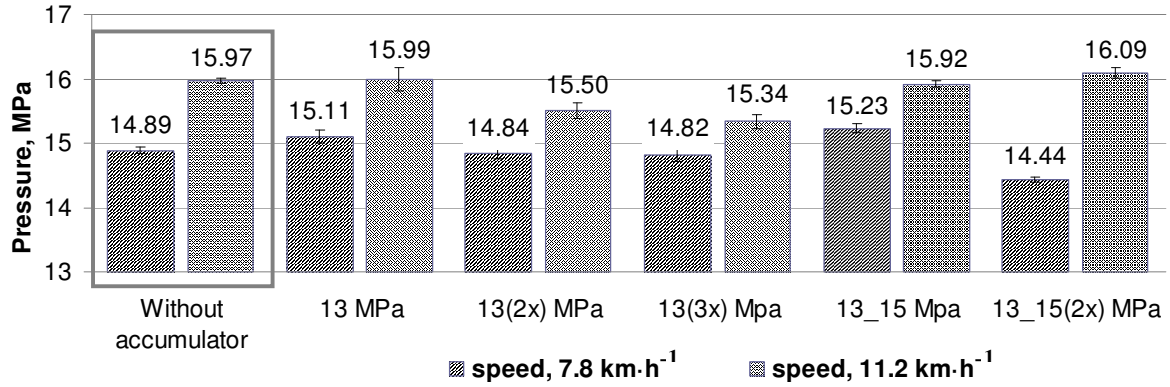

Fig. 4. **Pressure in tractor hydraulic hitch-system of hydraulic cylinder at tire pressure 0.12 MPa and different charged hydraulic accumulators**

Using one on 13 MPa charged diaphragm accumulator average pressure of the hydraulic hitch-system reaches 15.11 MPa at the driving speed 7.8 km·h^{-1}, but at the driving speed 11.2 km·h^{-1} reduces to 15.99 MPa. Using two on 13 MPa charged diaphragm accumulators average pressure of the hydraulic hitch-system reaches 14.84 MPa at the driving speed 7.8 kmh^{-1}, but at the driving speed 11.2 km·h^{-1} reduces to 15.50 MPa. Using three on 13 MPa charged diaphragm accumulators average pressure of the hydraulic hitch-system reduces till 14.82 MPa at the driving speed 7.8 km·h^{-1}, but at the driving speed 11.2 km·h^{-1} reduces to 15.34 MPa. Using two different charged (13 MPa and 15 MPa) diaphragm accumulators average pressure of the hydraulic hitch-system reaches to 15.23 MPa at the driving speed 7.8 km·h^{-1}, but at the driving speed 11.2 kmh^{-1} reduces to 15.92 MPa. Using two different charged (one 13 MPa and two 15 MPa) diaphragm accumulators average pressure of the hydraulic hitch-system reaches to 14.44 MPa at the driving speed 7.8 km·h^{-1}, but at the driving speed 11.2 km·h^{-1} reduces to 16.09 MPa.

The maximum average reduction at the driving speed 7.8 h^{-1} of the hydraulic system pressure oscillation was obtained, if the hitch-system fitted with one 13 MPa and two 15 MPa charged diaphragm accumulator and reached 3.02 % at the tire pressure 0.08 MPa. But at the driving speed 11.2 km h^{-1} was obtained, if the hitch-system fitted with three 13 MPa charged diaphragm accumulator and reached 3.94 % at the same tire pressure. Increasing the tire pressure till 0.12 MPa the maximum average reduction at the driving speed 7.8 h^{-1} of the hydraulic system pressure oscillation was obtained, if the hitch-system fitted with three or two 13 MPa charged diaphragm accumulator and reached 8.17 %. But at the same tire pressure and at the driving speed 11.2 km·h^{-1} was obtained, if the hitch-system fitted one 13 MPa and two 15 MPa charged diaphragm accumulator and reached 8.76 %.

All the above-mentioned test mode results are summarized in Table 1.

Table 1

Summary of experiment parameters in all test modes

Pressure in hydraulic system at tire pressure 0.12 MPa						
Speed, km·h^{-1}	Without accumulator	Different charged hydraulic accumulators, MPa				
		13	13(2x)	13(3x)	13_15	13_15(2x)
7.8	17.26 ± 0.12	15.93 ± 0.13	15.85 ± 0.08	15.85 ± 0.08	16.78 ± 0.08	16.05 ± 0.12
11.2	16.67 ± 0.09	15.71 ± 0.25	15.71 ± 0.12	15.63 ± 0.17	15.71 ± 0.25	15.21 ± 0.17
Pressure in hydraulic system at tire pressure 0.08 MPa						
Speed, km·h^{-1}	Without accumulator	Different charged hydraulic accumulators, MPa				
		13	13(2x)	13(3x)	13_15	13_15(2x)
7.8	14.89 ± 0.05	15.11 ± 0.11	14.84 ± 0.08	14.82 ± 0.10	15.23 ± 0.14	14.44 ± 0.10
11.2	15.97 ± 0.04	15.99 ± 0.19	15.50 ± 0.12	15.34 ± 0.11	15.92 ± 0.12	16.09 ± 0.20

Conclusions

1. Equipment of the hydraulic hitch-system with hydropneumatic accumulators allows adjusting the stiffness and damping characteristics of the hydraulic cylinder, limiting the pressure oscillation amplitude.
2. The maximum average amplitude of the pressure peaks is reduced till 16.34 %, driving at the tire pressure 0.12 MPa, but driving at the tire pressure 0.08 MPa till 9.58 %, when different charged hydropneumatic accumulators are used.
3. The maximum average reduction at the driving speed 7.8 km·h^{-1} of the hydraulic system pressure oscillation was obtained, if the hitch-system fitted with one 13 MPa and two 15 MPa charged diaphragm accumulators and reached 3.02 % at the tire pressure 0.08 MPa. But at the driving speed 11.2 km·h^{-1} was obtained, if hitch-system fitted with three 13 MPa charged diaphragm accumulators and reached 3.94 % at the tire pressure 0.08 MPa.
4. Increasing the tire pressure till 0.12 MPa the maximum hydraulic pressure average reduction 8.17 % at the driving speed 7.8 km·h^{-1} was obtained, if the hitch-system was fitted with three or two 13 MPa charged diaphragm accumulators. But at the same tire pressure and at the driving speed 11.2 km·h^{-1} hydraulic pressure average reduction was obtained 8.76 %, if the hitch-system was fitted with one 13 MPa and two 15 MPa charged diaphragm accumulators.

Acknowledgements

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References

1. Laceklis-Bertmanis J., Pirs V., Kronbergs E., Metla-Rozentals A., Metla M. Physical Model of Tractor Implement. Proceedings of the 18th International Scientific Conference „Research for Rural Development". Jelgava: LUA, 2012. (Article in press)
2. Laceklis-Bertmanis J., Pirs V., Jesko. Investigation of Pressure Oscillation in Hydraulic Hitch-System. Proceedings of the 16th International Scientific Conference „Research for Rural Development". Jelgava: LUA, 2010.
3. Radziņš Z., Zars V. (1964) Hidrauliskās mašīnas un mehānismi. (Hydraulic Machines and Mechanisms) *Rīga*, 510. lpp. (In Latvian)
4. Dirba V., Uiska J., Zars V. (1980) Hidraulika un hidrauliskās mašīnas. (Hydraulic and Hydraulic Machines.) *Rīga „Zvaigzne",* 451. lpp. (In Latvian)
5. Веденяпин Г.В. (1965) Общая методика экспериментального исследования и обработки опытных данных. (The General Methodology of Experimental Investigation and Processing of Experimental Data.) *Москва: издательство Колос*. 135 с. (In Russian).