PHYSICAL MODEL OF TRACTOR IMPLEMENT

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Abstract
In order to perceive the pressure oscillation in the hydraulic hitch-system of the tractor and oscillation of the whole tractor aggregate at different loads on the hitch-system, a physical model is used. Changing the position of weight on physical implement boom, different moments of inertia were obtained and the appropriate load on the hydraulic hitch-system hydro cylinder. Results of driving experiments on the artificial roughness road present the maximum pressure peak of 220 bar in the tractor hydraulic system when weight was placed on further position, and the driving speed was 8 km h^{-1} and tyre pressure was 1.2 bar. At the driving speed of 11.2 km h^{-1} and with the same tyre pressure, the hydraulic system pressures reached up to 212 bar. On the weight on the middle position of boom, pressure in the hydraulic hitch-system reached 172 bar at the driving speed of 7.8 km h^{-1} and tyre pressure of 1.2 bar, but at the driving speed of 11.2 km h^{-1} and at the same tyre pressure, the hydraulic system pressures reached 165 bar. If the weight was placed on nearest position, pressure in the hydraulic hitch-system reached only 85 bar at the driving speed of 7.8 km h^{-1} and tyre pressure - 1.2 bar, but at the driving speed of 11.2 km h^{-1} and at the same tyre pressure, it was 98 bar. The investigation of the physical tractor-implement model allows the determination of the conformity of the physical model with real harrow implement.
Key words: physical model, pressure peak, oscillation, physical implement.

Introduction

During tractor movement, with the working equipment (plough, harrow) attached to the hitch-system, over rough road surfaces oscillation of machine takes place. These oscillations are a reason of pressure pulsations in hydraulic hitch-system. The tractor hydraulic system is characterized by a pressure pulse effect, which reduces service life of the hydraulic system components, especially the lifetime of hydraulic hoses.

The previous experiments of (Laceklis-Bertmanis et al., 2010) present results of pressure oscillation investigation in hydraulic hitch-system of tractor Claas Ares ATX 557 with a harrow implement during the motion around an artificial roughness road. During experiments pressure oscillation at the different driving speed, tyre pressure and hitch-system oscillation damping (turned on/off) were investigated.

The pressure pulses in hydraulic hitch-system mostly depend on the mounted soil cultivating aggregate weight and mass moment of inertia. Different implements attached to the tractor's hitch-system cause different degrees of pressure pulsations. Changing the position of weight on implement physical model, the different moment of inertia was obtained and the appropriate load on the hydraulic hitch-system hydro cylinder. Therefore, the physical implement model for evaluation of the simplified mathematical model would be used. The main purpose of our experiments is to determine the physical model conformity to the real harrow implement.

Materials and Methods

The Experiments were performed in the NP Jelgava Business Park. In order to study the dynamic oscillation of the tractor hydraulic hitch-system, the physical implement model was used. Before measurements, the tractor was fitted with physical implement boom (Fig. 1). The physical implement boom consists of two parallel 2.5-meter-long mounted rolled metal consoles (120x120x6.3), connected together with two screws and a triangle knot. Physical implement was connected to the tractor's three-point hitch-system with knuckles. For hitch-system physical implement loading tractor balance weight (1400 kg) was used. The weight consists of two parts – 900 kg, and 500 kg. The balance weight corresponds to the implement of the previous experiments LMKEN short disk harrow and LEMKEN rubber rings roller (LEMKEN GmbH & Co.KG, 2012). In the experiments, the weight was placed in three positions (A, B, and C (Fig. 1)) and fixed with lanyard.

For data acquisition and processing, software offered by company Pico Technology was used. This software is provided for devices manufactured by different companies (Kaķītis, 2008). Using a universal data collection and processing device PicoLog, the hydraulic pressure oscillation in the tractor's hydraulic hitch-system were measured. In addition, the current tractor hydraulic hitch-system was equipped with displacement transmitter DTCH1000C (Fig. 2).

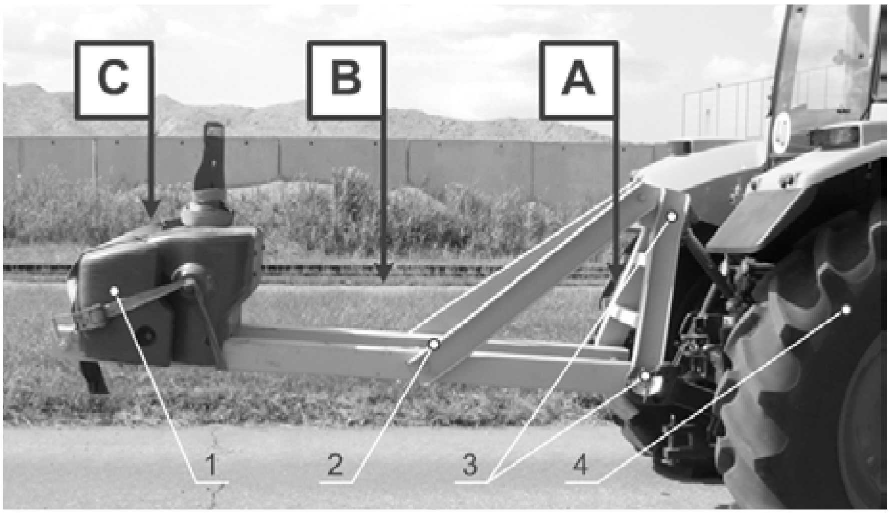

Figure 1. Physical Implement and Weight Position on Three Point Hitch-system of Tractor:
1 – weight; 2 – physical implement; 3 – three-point hydraulic hitch-system; 4 – traktor Claas Ares 557 ATX;
A, B and C – position of weight.

Pressure pulses and hydrocylinder displacement were measured with the pressure and displacement transmitters attached to the tractor's hydraulic hitch-system hydrocylinder. Displacement transmitter (RDP Group, 2012) was mounted on the hitch-system's hydrocylinder for measuring the displacement of hydrocylinder at different pressure peaks in the hydraulic system and the driving speed. One side of the displacement transmitter was attached to stationary position of the hydrocylinder, and another side - to the moving part. In order to protect the displacement transmitter from damage due to short range (±12.5 mm), one side was fitted with a magnetic clamp.

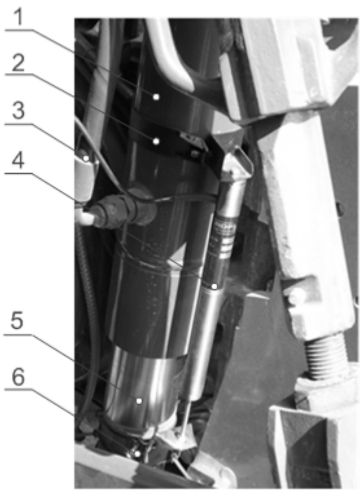

Figure 2. Position of the Diplacement Transmitter DTCH1000C on the Hidraulic Cylinder:
1 – hydrocilinder; 2 – mounting bracket; 3 – hose of oil supply; 4 – displacement transmitter;
5 – moving part of hydrocylinder; 6 –mounting bracket of magnet-type.

Using a universal data collection and processing device PicoLog, the hydraulic pressure hydrocylinder displacement oscillation in the tractor's hydraulic hitch-system was measured. The scheme of PicoLog gauge and transmitters connection is shown in Fig. 3. Artificial test road roughness, weight position, and the tractor's driving speed cause oscillation in the hydraulic hitch-system and the whole vehicle with different frequencies according to the driving speed. System oscillations were transferred to the hydrocylinder of the hydraulic system. Pressure pulses were immediate for a short time. A pressure and displacement converter receives and converts this process in a proportional electrical signal. The control unit was fed from the common network with voltage of 12 V. In the next step modified data were transmitted to the laptop. For data recording and processing, subprogram PLW Recorder is used. The acquired data values were saved in *.txt format for further processing. Data were processed by Microsoft Excel data analysis software.

Air pressures in tyres were selected from the tractor's manual, which provides different tyre pressures for different operating conditions. For example, for cultivation the 0.8 - 0.9 bar tyre pressure is provided, but for transportation it is 1.1 - 1.2 bar (Claas, 2007). Each measurement was repeated three times at certain gears and engine revolutions. From the acquired data, only the maximum values were taken into account, which characterized the greatest pressure peaks of the tractor's hydraulic hitch-system.

According to literature (Веденяпин, 1965), each experiment was repeated three times. Of each experiment, the nine maximum pressure value from resultant curves were used in further calculations, which is characterized by pressure changes in the

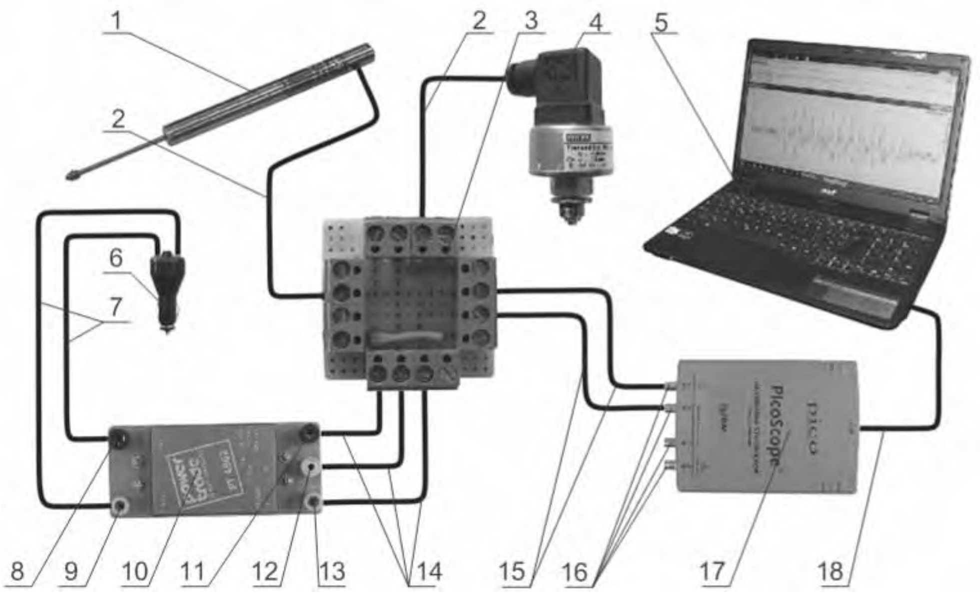

Figure 3. Installation Scheme of Transmitter and Measuring Device to PicoScope:
1 – diplacement transmitter *DTCH1000C*; 2 – data cable; 3 – alignement of transmitter and data; 4 – pressure transmtter ECO-1; 5 – computer with PicoTehnology software; 6 – plug box; 7 – cable of voltage; 8 – windrow „ – ”; 9 – windrow „ + ”; 10 – power trade (PT 4862); 11 – windrow of outlet with value „ – ”; 12 – ground bed; 13 windrow of outlet with value „ + ” ; 14 – cable of suppply voltage; 15 – data cable; 16 – inlet chanel BNC; 17 –PicoScope; 18 – data cable USB 2.0.

tractor's hydraulic hitch-system across the road roughness at different driving speeds. Average values were calculated from at least 27 values, and correlation between the series data points was at least 0.95, i.e., above 95%. After that, curves p=f (v) were constructed.

Results and Discussion

While changing the tractor hydraulic hitch-system oscillation damping position (switch on or off) that can be established on the tractor instrument panel, driving speed from 3 – 14 km h^{-1} and weight position on implement, various hydraulic hitch-system oscillation characteristics, which create the pressure pulse in hydraulic system were acquired.

Fig. 4 and Fig. 5 demonstrate how hydraulic pressure in the hydraulic hitch-system changes at all three weight positions and at tyre pressures 0.8 bar and 1.2 bar, and at driving speeds from 3 to 13.8 km h^{-1}. Initial operation pressures in the hydraulic hitch-system depend on weight position on the physical implement boom. In position A, initial pressure was 67 – 70 bar, but in position B it reached up to 120 – 125 bar and in position C up to 145 – 150 bar. The lower oscillation amplitude can be achieved if weight is placed near the hitch-system.

Fig. 4 describes changes in pressure at the tyre pressure of 1.2 bar and weight position A, B and C. If weight was placed in position C and the hydraulic hitch-system oscillation damping system was not used, then maximum average pressure of the hydraulic hitch-system reached 220 bar at the driving speed of 7.8 km h^{-1}, but when the hydraulic hitch-system oscillation damping system was used, the pressure pulse at the same driving speed reduced to 185 bar. If weight was placed on position B of boom and the hydraulic hitch-system oscillation damping system was not used, then maximum average pressure of the hydraulic hitch-system reached 170 bar at the driving speed of 7.8 km h^{-1} and tyre pressure 1.2 bar, but when the hydraulic hitch-system oscillation damping system was used, the pressure pulse at the driving speed of 11.2 km h^{-1} reduced to 165 bar. If weight was placed in position A of boom and the hydraulic hitch-system oscillation damping system was or was not used, the maximum average pressure of the hydraulic hitch-system reached 100 bar at the driving speed 11.2 km h^{-1} and tyre pressure 1.2 bar, but at the driving speed 7.8 km h^{-1} and at the same tyre pressure the hydraulic system pressures reached up to 88 bar.

Fig. 5 demonstrates changes in pressure at the tyre pressure of 0.8 bar and weight position C. If the hydraulic hitch-system oscillation damping system was not used, then maximum average pressure of the hydraulic hitch-system reached 210 bar at the driving speed of 6.4 km h^{-1}, but when the hydraulic hitch-system oscillation damping system was used, the pressure pulse at the same driving speed reduced to 185 bar. At the driving speed of 11.2 km h^{-1} and with the same tyre pressure, the hydraulic system pressures

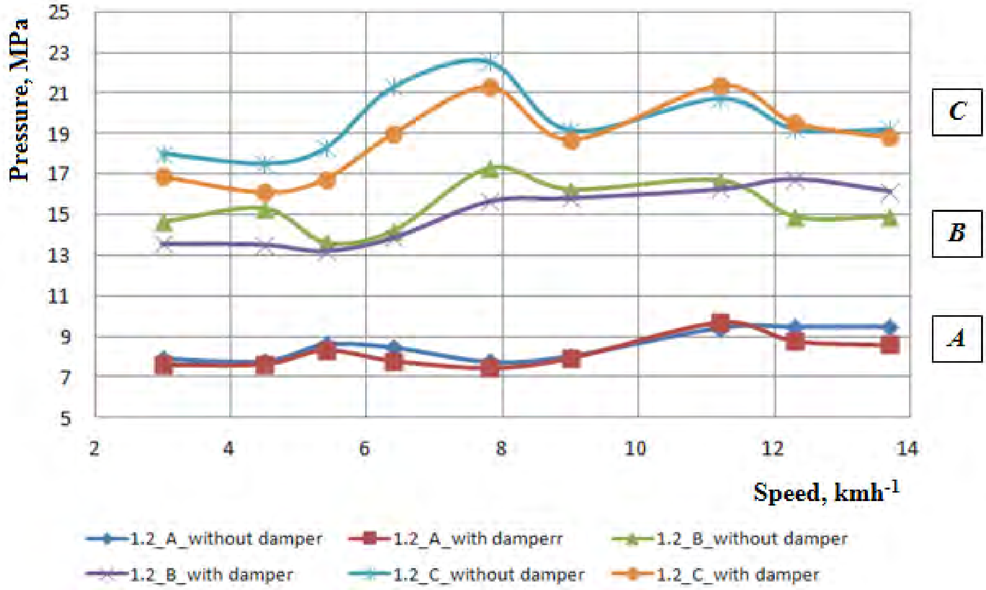

Figure 4. Pressure Peak in Tractor Hydraulic Hitch-System at Tyre Pressure 0.8 bar and Different Weight Positions A, B and C.

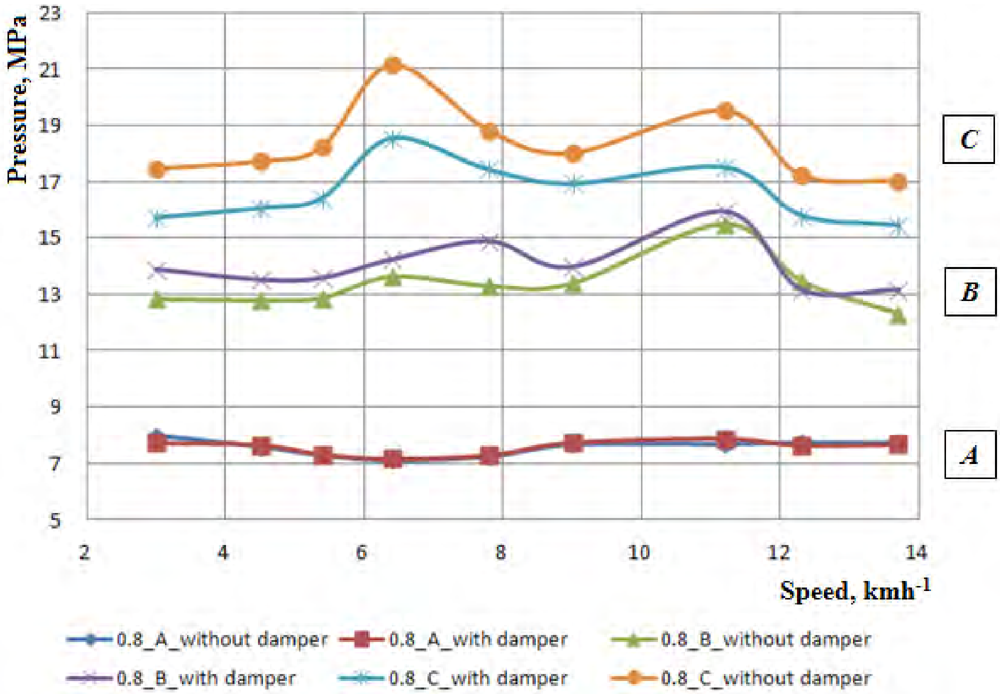

Figure 5. Pressure Peak in Tractor Hydraulic Hitch-System at Tyre Pressure 0.8 bar and Different Weight Positions A, B and C.

reached up to 195 bar. On the weight on position B of boom pressure in the hydraulic hitch-system reached 149 bar at the driving speed of 7.8 km h^{-1} and tyre pressure 0.8 bar, but at the driving speed of 11.2 km h^{-1} and at the same tyre pressure the hydraulic system pressures increased to 160 bar. If weight was placed in position A, the pressure in hydraulic hitch-system in the whole driving speed diapason reached approximately 70 – 80 bar.

Reducing the tractor tyre pressure from 1.2 to 0.8 bar, placed weight in position C and if the hydraulic hitch-system oscillation damping system was not used, then maximum average pressure of the hydraulic hitch-system decreased for 8.7% when the hydraulic hitch-system oscillation damping system was used, the pressure pulse at the same parameter decreased for 11.7%. Placed weight in position B and if the hydraulic hitch-system oscillation damping system

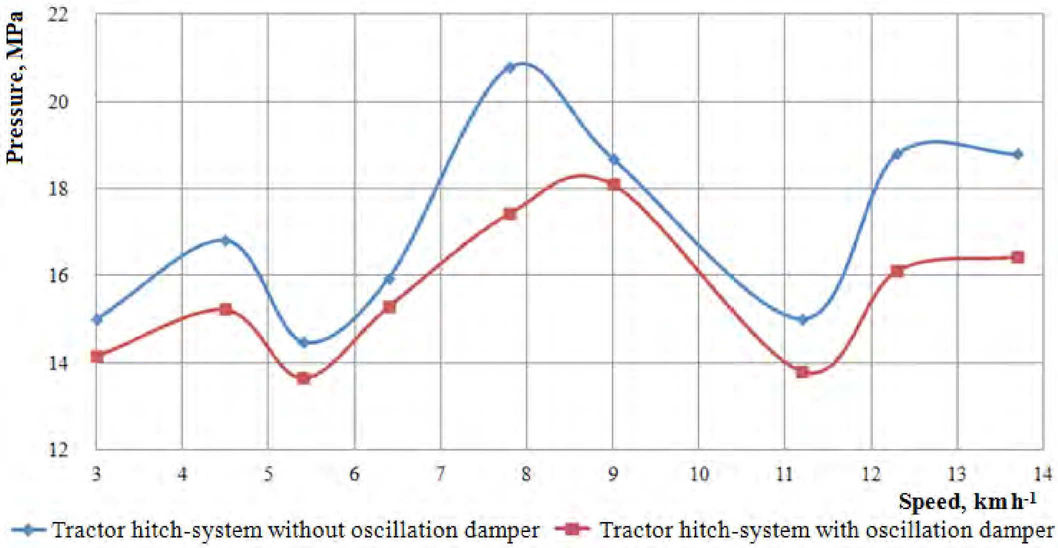

Figure 6. Tractor Hitch-System Oscillation at Different Speeds and tyre pressure of 1.2 bar.

was not used, then maximum average pressure of the hydraulic hitch-system decrease for 3% when the hydraulic hitch-system oscillation damping system is used, the pressure pulse at the same parameter decrease for 6.07%. Placed weight in position A of boom at the same parameters maximum average pressure of the hydraulic hitch-system decrease for 15.78%. The average displacement of the hydrocylinder in experiments amounted to 0.5 – 5 mm depending on the pressure in the hydraulic system hydrocylinder and weight position on the implement model.

Changing the position of weight on the physical implement boom, different moments of inertia and an appropriate load on the hydraulic hitch-system hydro cylinder was obtained. A lower oscillation amplitude can be achieved if weight is placed near the hitch-system.

Fig.6 shows maximal average values of the hitch-system pressure of the driving tractor with attached LMKEN short disk harrow and LEMKEN rubber rings roller (LEMKEN GmbH & Co.KG, 2012) at different motion speeds from previous investigations. Under way with tractor along artificial roughness test road, the air pressure in tyres of 1.2 bar was used.

Figures 5 and 6 suggest that the physical tractor implement model let it to arrange in correspondence with real - LMKEN short disk harrow and LEMKEN rubber rings roller, when tractor with implement oscillations on the artificial roughness test road is investigated.

For pressure peak values in graphs uncertainly was determined and for confidence level 0.95 it value do not exceed ± 0.194 MPa.

Conclusions

1. Decreasing the hydraulic hitch-system pressure impulse range is substantial for extending of service life of tractor metal constructions because a high leap of pressure in the hydraulic system corresponds to high forces and tension values in metal constructions.
2. The tractor implement physical model let it to arrange in correspondence with real - LEMKEN short disk harrow with rubber rings roller, when vertical oscillations on the artificial roughness test road is investigated.
3. For physical implement model, reducing the tractor tyre pressure from 1.2 to 0.8 bar, adjusting weight in position C and if the hydraulic hitch-system oscillation damping system was not used, then maximum average pressure of the hydraulic hitch-system decreased for 8.7%. When the hydraulic hitch-system oscillation damping system was used, the pressure pulse at the same parameter decreased for 11.7%.
4. Adjusting weight in position B and if the hydraulic hitch-system oscillation damping system was not used, then maximum average pressure of the hydraulic hitch-system decreased for 3%.W the hydraulic hitch-system oscillation damping system was used, the pressure pulse at the same parameters decreased for 6.07%.
5. Adjusting weight in position A of boom at the same parameters, the maximum average pressure of the hydraulic hitch-system decreased to 15.78%.

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