INVESTIGATION OF PRESSURE OSCILLATION IN HYDRAULIC HITCH-SYSTEM

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Abstract. This paper presents results of pressure oscillation investigation in hydraulic hitch-system of a tractor Claas Ares ATX 557 during the motion during artificial roughness road test. During experiments oscillation at different driving speed, tyre pressure and hitch-system oscillation damping (turned on/off) were investigated. Tractor hydraulic hitch-system was equipped with a pressure sensor Wika Transmitter ECO-1 and data processing software PicoLog. Results of experiments present maximum pressure peak of 210 bar in the tractor hydraulic system when hydraulic hitch-system oscillation damping system at driving speed 8 km·h^{-1} is not used and system pressure peak reduces to value of 180 bar if the hydraulic hitch-system oscillation damping is used.

Key words: pressure peak, pressure sensor, oscillation, tractor hydraulic hitch-system.

Introduction

The tractor hydraulic system is characterized by a pressure pulse effect, which reduces the hydraulic system components service life, especially the lifetime of hydraulic hoses. The pressure pulse in hydraulic hoses arises when the tractor moves along a rough terrain with mounted soil cultivation tools on hydraulic hitch-system. Hose durability (number of cycles T until the break-up) can be determined by formula (OST 23.I.82-82):

$$T = 43\alpha \cdot \left(\frac{p_f}{p_s} \right)^{-7.7},$$

where T - number of cycles until the break-up;
α - hose characteristic coefficient; α ≈ 1;
p_f - maximum actual pressure in pulse, MPa;
p_s - failure pressure, MPa.

Therefore, a tractor hydraulic hitch-system pressure pulse amplitude reduction is important to extend metal construction life time, because high-pressure pulse values in hydraulic hitch-system causes high power and tension values in metal constructions. Pressure oscillations damping in hydraulic systems can reduce overall system oscillation and improve the implement steering ability. The main task of experiment is to determine changes of the tractor Claas Area 557 ATX hitch-system hydraulic pressure pulse operating with a hitch-system oscillation damper or without it at various driving speeds and tyre pressure.

Materials and Methods

Experiments have been performed in the Faculty of Engineering of Latvia University of Agriculture. In the experiment the tractor Claas Area 557 ATX with engine power of 102 hp was used. Before measurements the tractor - was fitted with LEMKEN short disk harrow and LEMKEN rubber rings roller (specifications are given in Table 1).

Table 1
Main Specifications of the Mounted Implements

LEMKEN short disk harrow 8/300	
discs number/ Ø (mm)	24/465
working width, cm	300
weight without roller, kg	805
LEMKEN rubber rings roller GRW 600	
diameter, mm	600
weight (3m large), kg	623

In order to study the dynamic oscillation of the tractor hydraulic hitch-system, in experiments-artificial road roughness was used (see Fig.1). Road roughness is established according to rural conditions. Total road length is 24 meters which is divided into 12 equal parts by 2 meters each, respectively. Road roughness is constructed from wood planks with dimensions 150 x 50 x 1000 mm. Planks are connected with steel angle shaped bars 40 x 40 x 3 mm by screw-bolts M10 x 1.5. Roughness columns are placed in two parallel rows with 1.8 m distance on asphalt road surface.

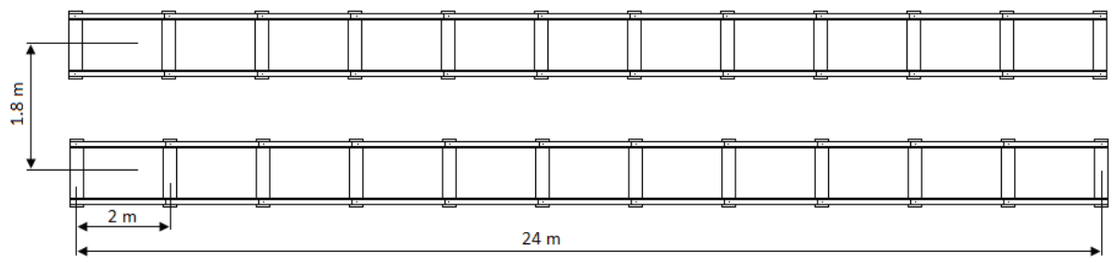


Figure 1. Artificial Roughness Test Road.

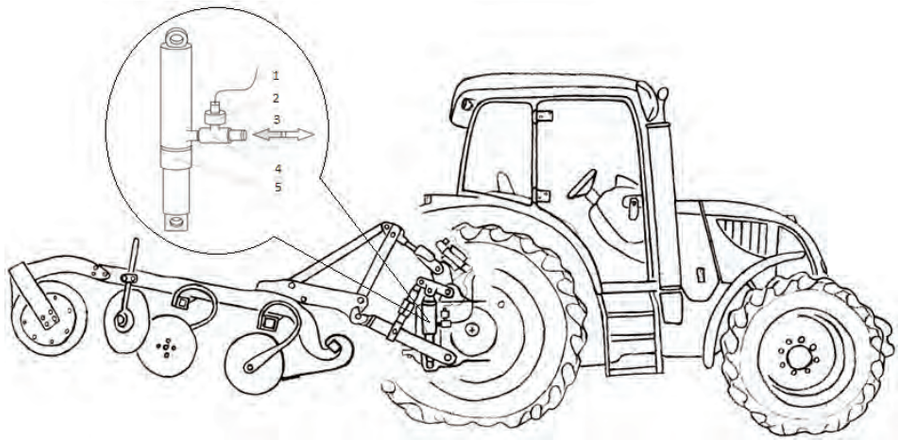


Figure 2. Pressure Sensor Wika Transmitter ECO-1 Mounted on Tractor Hydraulic Hitch-System:
1– data cable; 2 – pressure sensor Wika Transmitter ECO-1; 3 – hydraulic flow direction;
4 – T-piece (reducer); 5 – hydraulic cylinder.

The current tractor hydraulic hitch-system is equipped with pressure oscillation sensor Wika Transmitter ECO-1 (Fig.2). The sensor is chosen such that its own oscillation frequency is 10 times higher than the frequency of measured pressure changes (Kaķītis et al., 2008). The sensor parameters are given in Table 2.

Table 2

Main Specification of the Mounted Pressure Sensor Wika Transmitter ECO-1

Parameter	Values
pressure range	0 ... 400 bar
operating temperature	- 60 ... + 100 °C
output current	4 ... 20 mA
inlet intensity	DC 10 ... 30 V

For data acquisition and processing software offered by the company PicoTechnology is used, provided for devices manufactured by different companies Kaķītis A. (2008). Using a universal data collection and processing device PicoLog, the hydraulic pressure oscillation in the tractor hydraulic hitch-system is measured. PicoLog gauge connection scheme in Fig.3 is shown.

Because of influence of road roughness, the tractor and its hydraulic hitch-system are oscillated with the determined frequency according to driving speed. System oscillations are transferred to the hydro cylinder 8 (Fig.3) of hydraulic system. Pressure pulses are immediate and for a short time. Pressure pulses are measured with a pressure sensor 6 attached to the tractor hydraulic hitch-system hydro cylinder 8. In order to conect it to the pipes, it is needed to create a T-piece (reducer), in which an appropriate pressure sensor could be screwed in. A pressure converter receives and converts liquid (oil) pressure in proportional electrical signal. Data obtained by the pressure sensor are transmitted to the central processing unit 3. The control unit is fed from the common network with voltage of 12 V. In the next step modified data are transmitted to the laptop 1. For data recording and processing subprogram PLW Recorder is used. The acquired data values are saved in *.txt format for further processing. Data are processed by Microsoft Excel data analysis software.



Figure 3. Installation Scheme of Measuring Device PicoLog:
1 – computer with PicoTehnology software; 2 – data cable; 3 – Pico transducer; 4 – DC (12V);
5 – data cabel (4...20 mA); 6 – pressure sensor; 7 – connection tube to hydraulic cylinder; 8 – hydraulic cylinder; 9 – hydraulic hitch-system; 10 – hydraulic oil flow.

Air pressures in tyres are selected from the tractor manual which provides different tyre pressures for different operating conditions. For example, for cultivation tyre pressure is provided 0.8 - 0.9 bar, but for transportation it is 1.1 - 1.2 bar Claas (2007).

Each measurement is repeated three times at certain gears and engine revs. From the acquired data only the maximum value is taken into account, which characterizing the greatest pressure of the tractor hydraulic hitch-system.

Results and Discussion

While changing the tractor hydraulic hitch-system oscillation damping position (switch on or off) and driving speed from 3 – 14 km·h^{-1}, various hydraulic hitch-system oscillation characteristics are acquired, which may create the pressure pulse in hydraulic system.

Hydraulic pressure curve is divided into three stages (Fig.4 a, b):

1. beginning of oscillation (beginning of movement);
2. oscillation in stationary regime (during which the maximum hydraulic hitch-system pressure occurs);
3. ending of oscillation (phase in which oscillations are terminated).

Fig.4 (a and b) demonstrate how hydraulic pressure in the hydraulic hitch-system changes in at all three stages at driving speed of 7.8 km·h^{-1}. Initial operation pressures in the hydraulic hitch-system is 100 - 120 bar, which is achieved from mounted implement total load on hydro cylinder.

The maximum pressure oscillation amplitude is observed at driving speed of 7.8 km·h^{-1} and pressure in tyres of 1.2 bar.

Position b in Fig.4 describes changes of pressure curves at the tyre pressure of 1.2 bar: if the the hydraulic hitch-system oscillation damping system is not used, then maximum average pressure of the hydraulic hitch-system reaches 210 bar, but, when the hydraulic hitch-system oscillation damping system is used, the pressure pulse reduces to 180 bar.

Reducing the tractor tyre pressure from 1.2 to 0.8 bar, the maximum mean value of pressure in the hydraulic hitch-system reaches 180 bar, but, when the additional pressure oscillation damper system is used, then the system pressure does not exceed 150 bar (Fig.4 a).

Looking at two graphs in Fig. 4, it can be concluded that reducing tire pressure from 1.2 to 0.8 bar and in addition using the tractor hydraulic hitch-system oscillation damping option, the hydraulic pressures about 60 bar can be reduced. Due to the influence of hydraulic pressure, pulse controllability of aggregate deteriorates. By reducing the hydraulic pressure pulse it is possible to prolong the service life of the common system and to improve steering ability of aggregate.

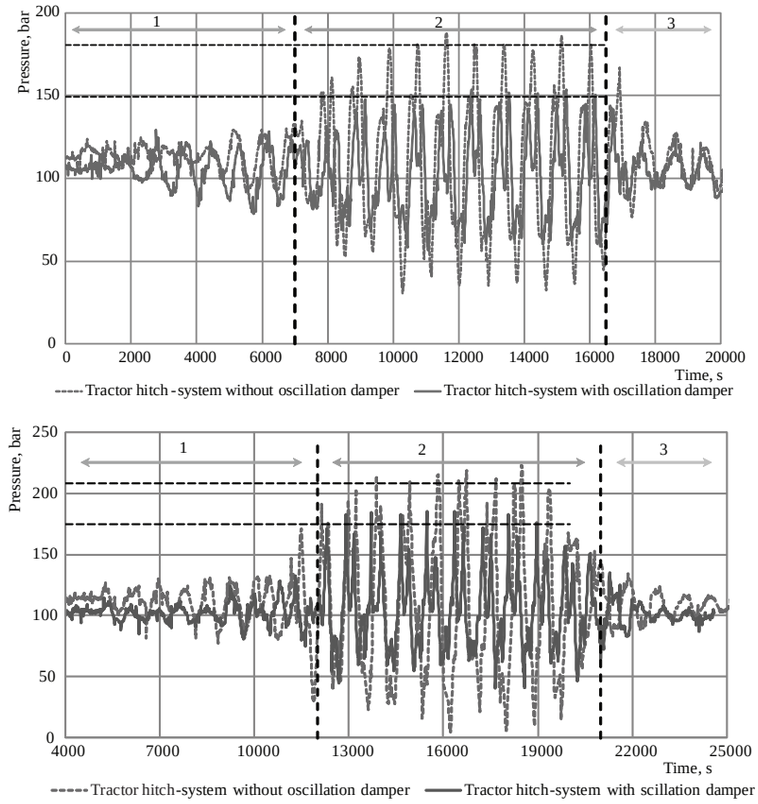


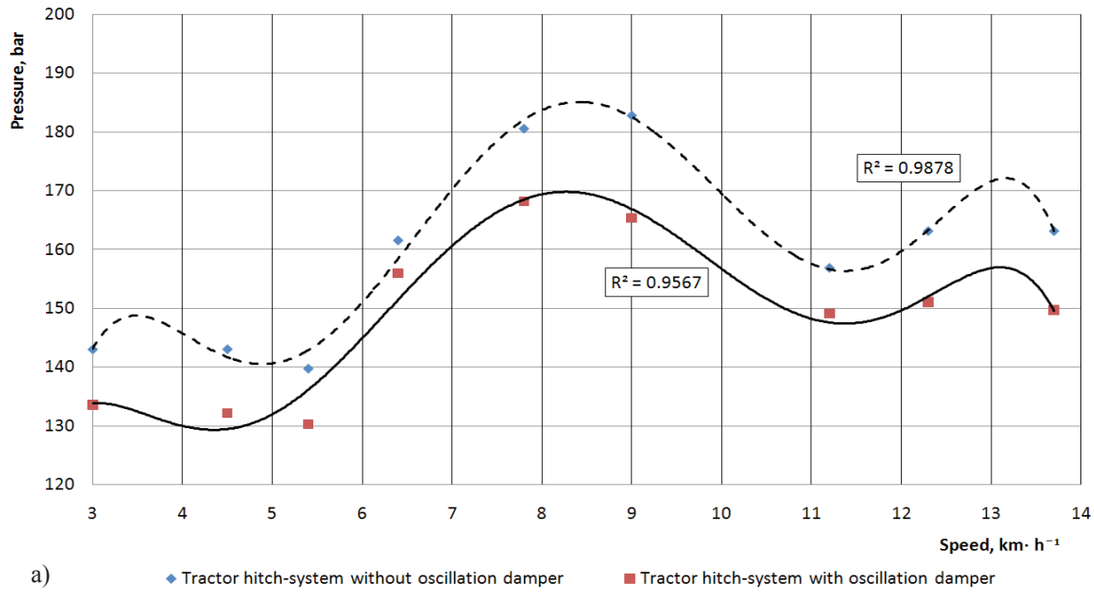
Figure 4. Pressure Peak in Tractor Hydraulic Hitch-System at Different Tyre Pressures:
a – measurement at tyre pressure 0.8 bar; b – measurement at tyre pressure 1.2 bar; 1– oscillation begins; 2 – oscillation in stationary regime; 3 – finishing oscillation.

In Fig.5 (a, b) common average values of the system pressure at different motion speeds and tyre pressures are described. Testing the- tractor on artificial roughness test road with air pressure in tyres of 1.2 bar, confirms that to transportation regime of aggregate at, and driving speed of 5 km·h^{-1} (see Fig.5 b), and steering ability of the tractor were good, and pressure in the hydraulic hitch-system was in limits 140 – 170 bar.

By gradual increase of driving speed from 5 to 8 km·h^{-1} - pressure of hydraulic hitch-system increased as well and achieved 210 bar. Steering ability of the tractor worsened, and it was observed that front wheels were torn by the road surface. At driving speed of 8 km·h^{-1} the tractor was impossible to steer.

Bu gradual increase of driving speed from 8 to 11 km·h^{-1} - pressure in hydraulic hitch-system decreased to 140 – 150 bar and steering ability of the tractor improved, but by exceeding driving speed over 13 km·h^{-1}, steering ability has become worsened.

Exploiting damping option of the tractor hydraulic hitch-system, common pressure oscillation in the tractor hydraulic hitch-system has decreased for approximately 20 bar, but steering ability of the tractor has not been substantially improved.



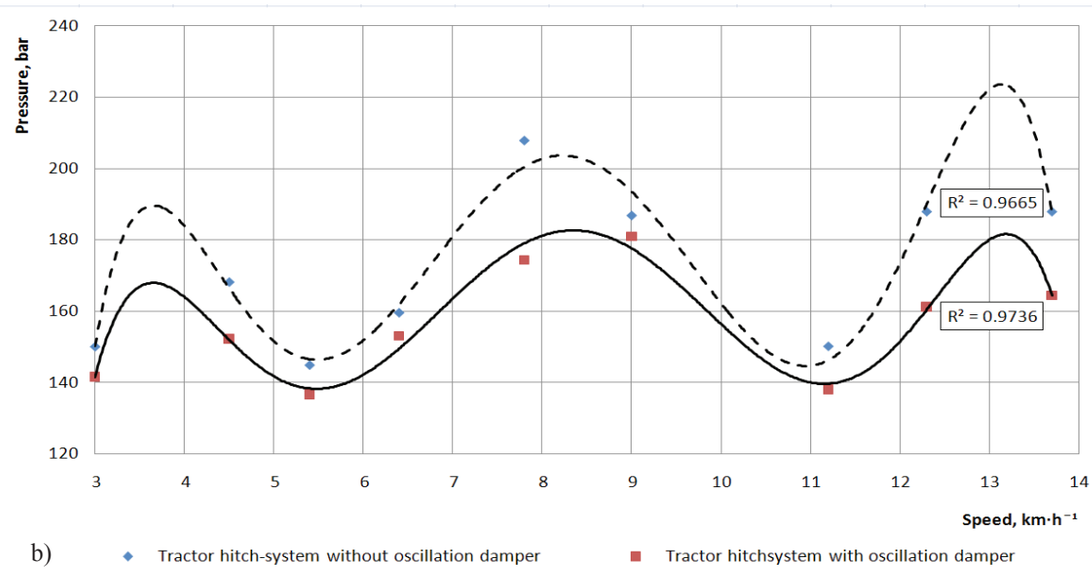


Figure 5. Tractor Hitch-System Oscillation at Different Speed:
a – measurement at tyre pressure 0.8 bar; b – measurement at tyre pressure 1.2 bar.

Reducing the tyre pressure from 1.2 to 0.8 bar that, corresponds to the required soil processing pressure, and additionally employing damping option of the tractor hydraulic hitch-system, the steering ability of the tractor substantially increases and during movement at maximum pressure of hydraulic hitch-system it corresponds to 170 bar (Fig.5 a), front wheel tearing from the road surface has not been observed. When driving speed exceeds over 13 $km \cdot h^{-1}$, the steering ability worsens.

Conclusions

1. Decreasing the hydraulic hitch-system pressure impulse range is substantial for amplification of service life of metal constructions because a high leap of pressure in the hydraulic system corresponds to high forces and tension values in metal constructions.
2. Maximum range of pressure oscillation is observed at driving speed of 7.8 $km \cdot h^{-1}$ and tyre pressure of 1.2 bar.
3. Oscillation of pressure can be reduced by exploitation of oscillation damper that can be established on the tractor instrument panel. If the oscillation damper is not used, then at driving speed of 7.8 $km \cdot h^{-1}$ the pressure oscillation in hydraulic system reaches 210 bar but, when the oscillation damper is used, the pressure in hydraulic system decreases to 180 bar (at tyre pressure 1.2 bar).
4. Decreasing tyre pressure from 1.2 to 0.8 bar, the maximum average values of pressure in hydraulic hitch-system reach 180 bar but, if an additional oscillation damper is used, pressure in the hydraulic system does not exceed 150 bar.
5. By decreasing tyre pressure of aggregate and exploiting the option of oscillation damper of the tractor hydraulic hitch-system, it is possible to decrease the pressure of hydraulic hitch-system for 50 bar and improve steering ability of tractor.
6. For hydraulic hitch-system longer service it would be necessary to reduce the hydraulic pressure oscillation to a greater range.

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