STIFFNESS AND DAMPING CONSTANT ADJUSTMENT FOR TRACTOR HYDRAULIC HITCH – SYSTEM MODEL

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Abstract. During tractor movement, with attached to the hitch-system working equipment (plough, harrow), over rough road surfaces oscillation of the machine takes place. These oscillations are a reason of pressure pulsations in the hydraulic hitch-system. Pressure pulse reduction in the tractor hitch-system is important for increasing of the system components lifetime. Pressure oscillations damping in the tractor hydraulic hitch-system can reduce the overall system oscillations and improve the driving control. On basis of the investigation of simulations in Working Model software, when the tractor is moving over rough road surface with attached soil cultivation implement, pressure oscillation can be decreased by changing the hydraulic hitch – system stiffness and damping parameters. The maximum pressure oscillation amplitude is observed at the speed 7.8 km·h^{-1}, and reaches 210 bar in the experiments, but at the same speed it reaches 212 bar in the simulation results. According to the experimental investigation results a simplified hydraulic hitch-system is developed.

Key word: tractor hitch-system, simplified model, oscillation.

Introduction

Pressure oscillations damping in the tractor hydraulic hitch-system can reduce the overall system oscillations and improve the driving control.

The previous experiment [1] presents the results of pressure oscillation investigation in the hydraulic hitch-system of the tractor Claas Ares ATX 557 during the motion around artificial roughness road test. During the experiments oscillation at different driving speed, tire pressure and hitch-system oscillation damping (turned on/off) was investigated. The tractor hydraulic hitch-system was equipped with a pressure sensor Wika Transmitter ECO-1 and data processing software PicoLog. The results of the experiments present the maximum pressure peak of 210 bar in the tractor hydraulic system when the hydraulic hitch-system oscillation damping system at the driving speed 7.8 km·h^{-1} is not used and the system pressure peak reduces to the value of 180 bar if the hydraulic hitch-system oscillation active damping is used.

The investigation of simulations [2] in Working Model software, when the tractor moved over rough road surface with attached soil cultivation implement, let to conclude that pressure oscillation can be decreased by changing the hydraulic hitch – system stiffness and the damping parameters were described. The maximum pressure oscillation amplitude was observed at the speed 7.8 km·h^{-1} and it reaches 212 bar in the simulation results. The differences between the simulation and experimental investigation results vary within 2-10 %.

In order to develop an analytical model it is necessary to make a simplified oscillation model and determine its compliance with the previous model in Working Model.

Materials and methods

Using Working Model software [3] it was necessary to determinate the hydraulic system pressure in the tractor (Class Ares 557 ATX) hydraulic hitch-system hydro cylinder depending on the attached equipment weight, road roughness and tractor speed.

In Working Model software a dynamic model the same parameters of the tractor and attached equipment [4-6] weight, road roughness and movement speed as in the experimental investigation had been used. The simulation model in the previous experiment (see Fig. 1) was used in the side-view. The parameters of the hydraulic cylinder and tyres are entered two times larger in the simulation model.

The three-point hitch mechanism was considered as planar system. The system was modelled in two dimensions to represent the force in the original geometrical configuration between the tractor and the implement. In order to evaluate the vertical force of the tillage tools a two dimensional study of the tractor linkage mechanism is needed. The mechanisms consist of seven articulated beams.

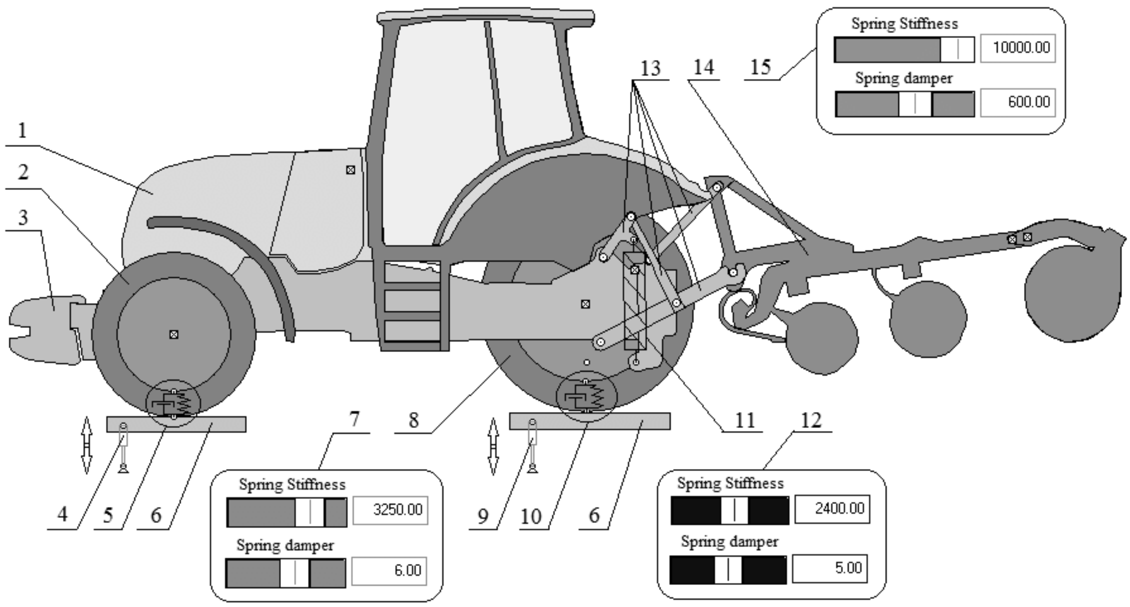

Fig. 1. **Tractor model in Working Model software:**
1 – tractor Class Ares 557 ATX; 2 – tractor front tyres; 3 – front weight; 4 – front actuator; 5 – front tyres; 6 – road roughness platform; 7 – front tyres control units; 8 – tractor rear tyres; 9 – rear actuator; 10 – rear tyres; 11 – hydraulic cylinder; 12 – rear tyres control units; 13 – tractor hitch-system; 14 – soil cultivator implements; 15 – hitch-system control units

To make the force calculation simpler, the three-point hitch-system mechanism was described by ties and pin joints. The coordinates of each joint are calculated in the coordinate system x_o and z_o. The point I_o is the centre of the rear wheel, as the point of origin, and the side view of the three–point hitch mechanism is shown in (Fig. 2).

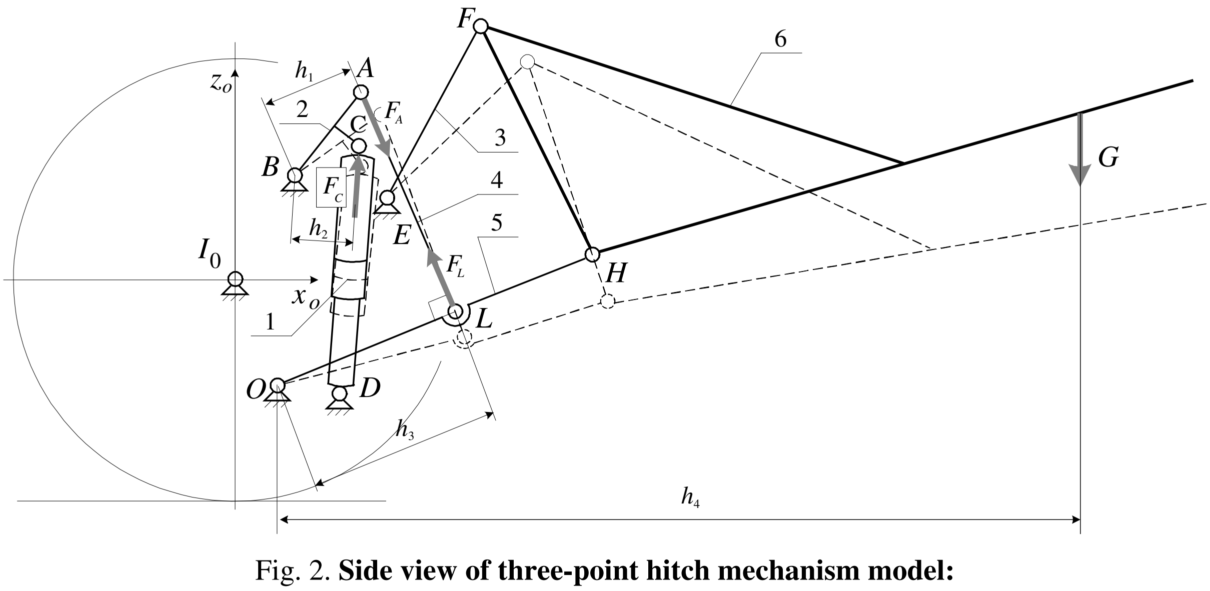

Fig. 2. **Side view of three-point hitch mechanism model:**
1 – tractor hydraulic hitch-system hydrocylinder; 2 – lift arm (changeable); 3 – upper link (changeable); 4 – lift rod; 5 – the lower link; 6 – tool triangle chassis

This side view of the three-point hitch mechanism model was created and described on transportation position. The implement displacement and oscillations are depending on the tractor driving speed, road roughness and tractor hitch-system stiffness and damping parameters.

The equilibrium of the tractor hitch-system link arm gives the following system of equations:

$$\begin{cases} F_L \cdot h_3 - G \cdot h_4 = 0 \\ F_C \cdot h_2 - F_A \cdot h_1 = 0 \end{cases} \tag{1}$$

Here, F_L and F_A is the lift rod reaction force at the points L and A, but G is the implement weight. The length h_1, h_2 and h_3 values were obtained graphically ($h_1 = 0.266$ m, $h_2 = 0.176$ m, $h_3 = 0.55$ m). Theses values depend on the tractor hydraulic hitch-system position.

The hitch-system hydraulic cylinder force reaction F_C was calculated in stationary position when the tractor implement was in transportation position.

$$F_c = p \cdot A, \tag{2}$$

where p – pressure, Pa;
A – area of hydraulic cylinder, m^2.

From the equilibrium (1) the coordinate h_4 of the tractor implement mass centre is calculated:

$$h_4 = \frac{F_L \cdot h_3}{G}, \tag{3}$$

where F_L – force or lift rod, N;
G – implement weight, N;
h_3 – distance from force reaction F_L to pivot point O, m.

Creating a simplified model of the hitch-system oscillations (see. Fig. 3) it is necessary to determine the hydraulic cylinder coordinate, h_5 on condition if $h_6 = h_4$ and $F_L = F_A = F_N$, then:

$$h_5 = \frac{G \cdot h_6}{F_N}, \tag{4}$$

where F_N – reaction of hitch-system hydraulic cylinder, N;
h_6 – distance from implement centre of mass to pivot point O, m;
h_5 – distance from force reaction of hitch-system hydrocylinder to pivot point O, m.

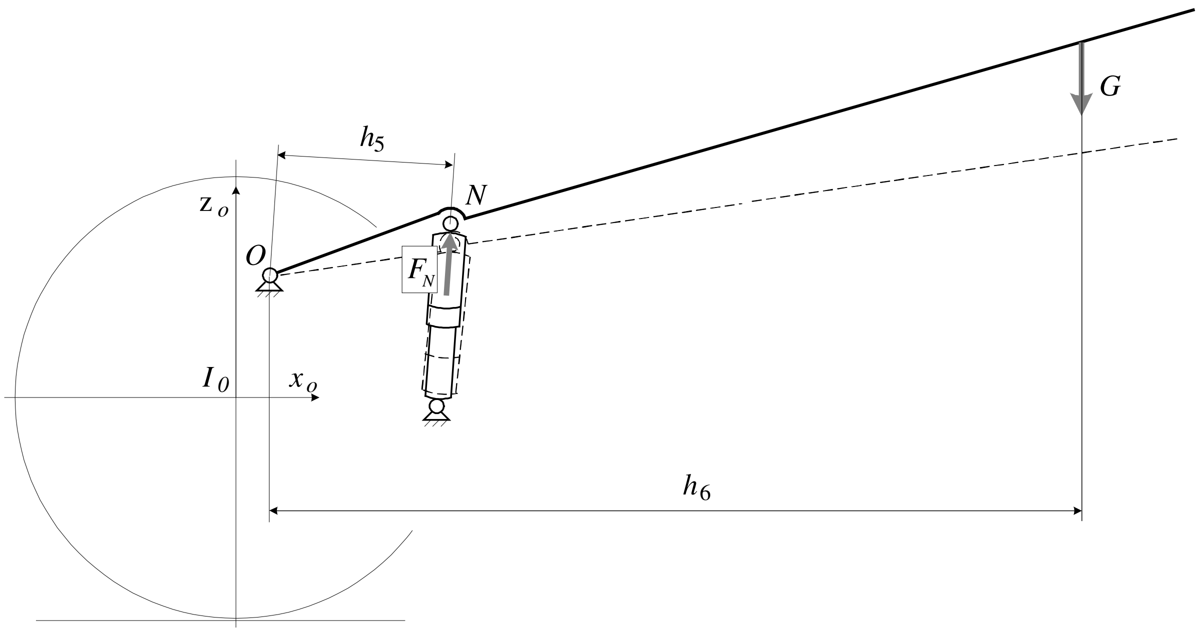

Fig. 3. **Simplified side view of three-point hitch mechanism**

In the simplified model of the tractor-implement (Fig. 4) the hitch-system hydraulic cylinder characteristic is the same as in the previous model [2] and described by the stiffness and damping coefficients. The tractor hitch-system hydraulic cylinder parameters were changed by the control button during simulation. Changing the hydrocylinder stiffness and damping coefficients it is possible to obtain different oscillation characteristic of the tractor hitch-system. The function of the road roughness surface in Working Model program is assured with actuators [2].

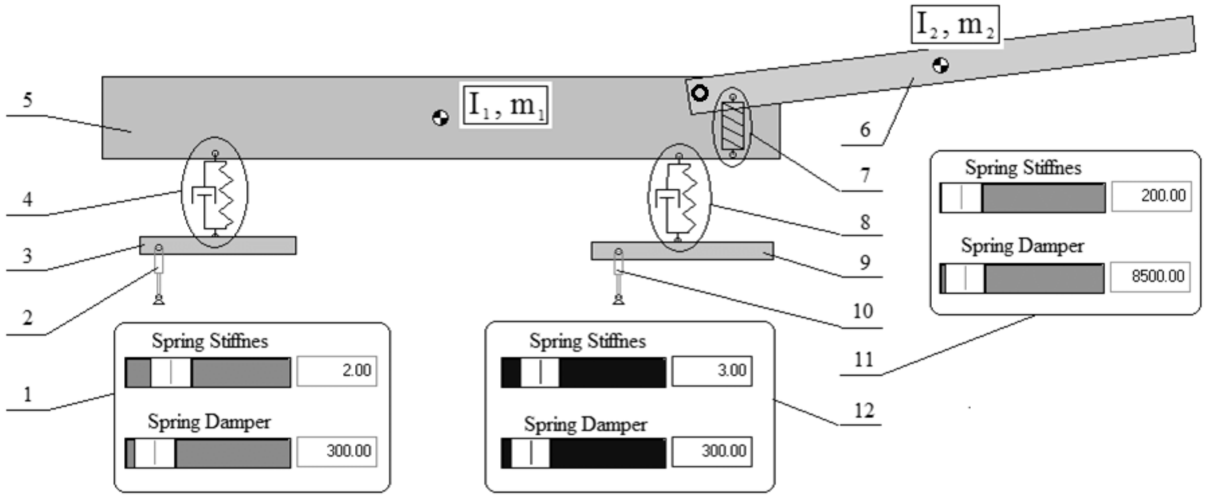

Fig. 4. **Simplified model of tractor-implement in Working Model software:**
1 – front tyres control units; 2 – front actuator; 3 and 9 – road roughness platform; 4 – front tyre; 5 – tractor body; 6 – soil cultivator implements; 7 – hydraulic cylinder; 8 – rear tyres; 10 – rear actuator; 11 – hitch-system hydraulic parameter control units; 12 – rear tyres control units

With a constant spring stiffness coefficient, reducing the damping coefficient, the force of the hydraulic hitch-system hydro cylinder decreases. The Working Model simple tractor simulation model checking on the basis of the experimental investigations let to improve its coincidence with the real machine aggregate.

Results and discussion

Changing the tractor hydraulic hitch-system (stiffness and damping) parameters and speed during the simulation from 3-14 km·h^{-1} there are different pressure values in the hitch-system hydraulic cylinder obtained. The experimentally obtained hydraulic hitch-system pressure values and the Working Model program simulation pressure values are shown in Fig. 5.

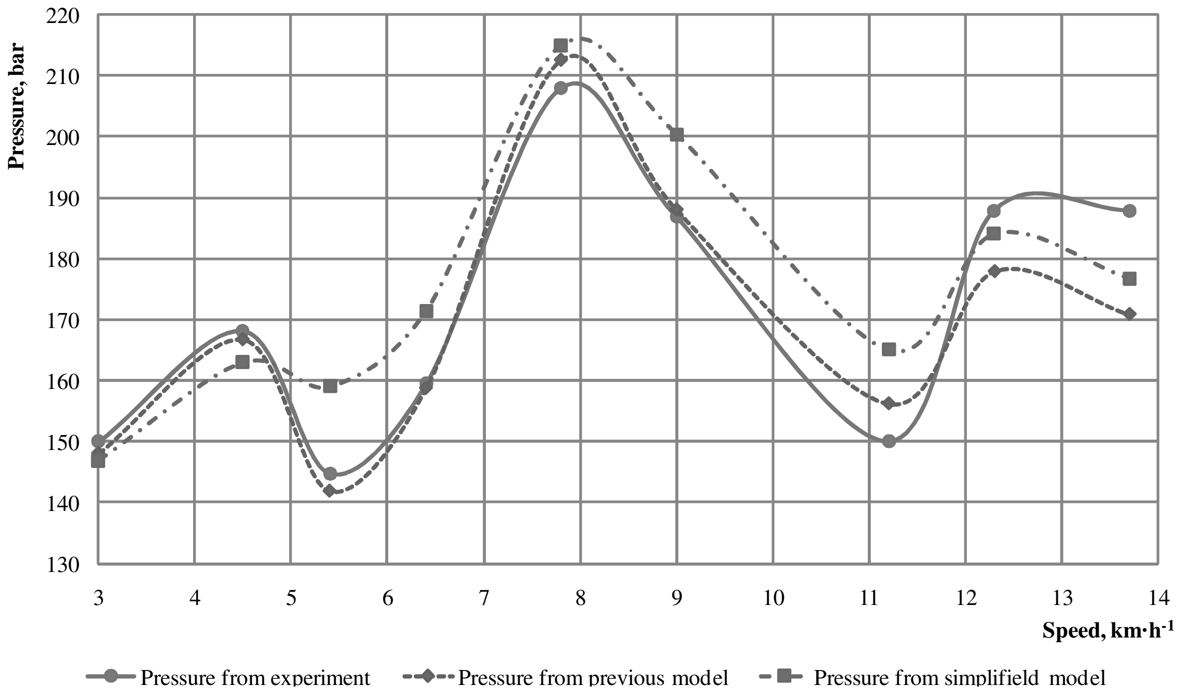

Fig. 5. **Pressure in tractor hydraulic hitch-system of hydraulic cylinder**

The maximum mean value of pressure in the hydraulic hitch-system is observed at the driving speed 7.8 km·h^{-1} and it reaches 210 bar in the experiment, but at the same speed it reaches 212 bar in the simulation results.

Simplifying the model in Working Model software it is possible to obtain a similar result as in the previous model. The maximum pressure oscillation amplitude (Fig. 5) is observed at the speed 7.8 km·h^{-1}, and it reaches 212 bar in the simulation, but at the same speed it reaches 215 bar in the simulation results with a simple model. The differences between the simulation and simplified model results are less than 10 %. The simplified model of the tractor-implement can be used for development of an analytical model.

These differences are caused by some inconsistency for stiffness of tyres in the simulation model and can be eliminated. Therefore, Working Model simulation for a simple model of the tractor hydraulic hitch-system can be recommended for investigation of the possibility to reduce the amplitude of pressure pulsations by changing the parameters of the hydraulic system.

Conclusions

1. Working Model software lets to create a simplified model for tractor vertical oscillations and simulate movement with different speed and road roughness values.
2. The maximum pressure oscillation amplitude was observed at the speed 7.8 km·h^{-1}, and it reaches 210 bar in the experiments, but at the same speed it reaches 215 bar in the simulation results.
3. Working Model simulation for the tractor hydraulic hitch-system can be recommended for investigation of the possibility to reduce the amplitude of pressure pulsations by changing the parameters of the hydraulic system.
4. The difference between the simulation and simplify model results is less than 10 %.

Acknowledgements

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