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SIMULATION RESEARCH ON THE KINEMATIC BEHAVIOR OF VIRTUAL MODEL OF AGRICULTURAL MACHINERY

Summary

This paper describes the use of simulation in the design of agricultural machinery. It allows to define the kinematic behavior of the designed machine. 3D models of tractor and cooperating universal tool for strip tillage and model of cultivation aggregate with hitch to the drill were developed to conduct the kinematic analyzes. Simulation results are presented graphically on the graphs, which show the values of the measured parameters. The executed research defined reaction forces between machine and three-point hitch linkage of the tractor, the tractor stability and impact of changes in position of drawbar coupling parts on the selection of hydraulic cylinder. It was demonstrated the stability of the tractor when driving through the obstacle and the correct selection of the hydraulic cylinder, which ensures the correctness of the process of folding and unfolding.
***Key words**: tractor, tillage machine, virtual model, kinematics, simulation research*

BADANIA SYMULACYJNE ZACHOWAŃ KINEMATYCZNYCH NA WIRTUALNYM MODELU MASZYNY ROLNICZEJ

Streszczenie

W pracy przedstawiono zastosowanie badań symulacyjnych w projektowaniu maszyn rolniczych. Pozwalają one określić zachowania kinematyczne projektowanej maszyny. Do przeprowadzenia analiz kinematycznych opracowano modele 3D ciągnika rolniczego oraz współpracującego z nim uniwersalnego narzędzia do uprawy pasowej oraz model agregatu uprawowego ze sprzęgiem do siewnika. Wyniki symulacji przedstawiono graficznie na wykresach, na których przedstawiono wartości mierzonych parametrów. W przeprowadzonych badaniach określono reakcje maszyny na TUZ ciągnika, jego stateczność oraz wpływ zmian położenia elementów sprzęgu na dobór siłownika hydraulicznego. Wykazano stabilność ciągnika podczas przejazdu przez przeszkodę i prawidłowy dobór siłownika, który zapewnia prawidłowość procesu składania i rozkładania.
***Słowa kluczowe**: ciągnik, maszyna uprawowa, model wirtualny, kinematyka, badania symulacyjne*

1. Introduction

The dynamic development of computer systems has made that at the design stage can be performed kinematic simulations of individual structural elements of agricultural machinery in order to obtain the best possible solution in connection of the behavior of kinematic and endurance [6]. To comply simulations of kinematic behavior are used computer programs like NX 7.5, MDI ADAMS, Solid Works Motion 2010, CATIA. The result of the simulation is moved operation animation of individual elements of the structure of a simultaneous demonstration of the results in tabular and graphics form. In this way it is possible to define the speed, acceleration, forces the individual nodes, range of motion of moving parts and stability of machines and value of reaction forces between tractor wheels and ground [1, 2, 3]. Koike [4] described the use of kinematic analysis to determine the behavior of a specialized vehicle - garbage dump track during the transport ride through different kinds of obstacles. Kinematic models are built based on geometrical 3D models developed researching objects. They contain some simplifications in order to imitate the physical and mechanical sense and shorten the time of calculations. However, simplification may not be excessive, since they can lead to inadequate results with respect to the real object. Therefore, it is important to keep the characteristic dimensions of the structure, the mass and the location of the gravity point [5].

This article presents and discusses the main features of the two models without precision information about carried out simulations.

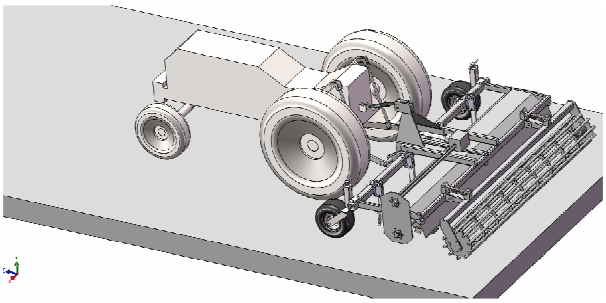
2. Goal and scope and object of the study

The purpose of the behavior simulation was to imitate real conditions of cooperating between tractor and machine to strip tillage and behavior of hitch during the raising and lowering a drill. For the first kinematic simulation prepared a mutual calculation model of the tractor and the strip tillage machine which has been modified for the specified cases. The calculation model consisted of a solid model of universal tool and a solid model of tractor * (Fig. 1).

In the construction of a toll for strip tillage was added a number of simplifications which allow for a significant reduction of simulation time. Existing in real machine pivots are not included, modeled in a simplified way a angular gear which transmitted an torque from PTO to milling drum. These simplifications have not had a significant effect on the results, which confirmed the previously conducted analysis models. An important issue in the kinematic simulation was tuned calculation to pick out relevant parameters that describe the impact of tractor wheel contact with the ground. Tuning was performed on the basis of the known time response of tractor wheels to dynamic forcing during drive through road obstacle (the experimental data). For the second kinematic simulation developed a 3D model of the

hitch (Fig. 2), which consists of the upper arm (1), a inclined frame (2) and the lower frame (3). The proposed folding system allows to lift the connected drill (5), filled with grain, above the frame of aggregate. Folding of the frame is realized by a double-acting hydraulic cylinder (4).

a)



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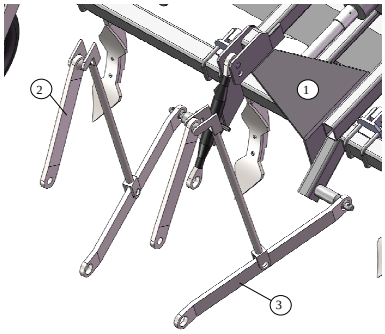


Figure 1. Kinematic calculation model of tractor with cultivation tool (a), View of the tractor three-point hitch linkage (b)

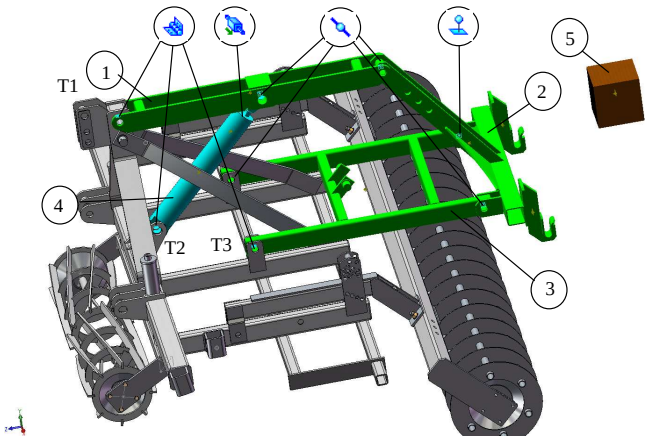


Figure 2. Points of measurement of forces during lifting and lowering the hitch for drill with marked types of nodes (described in the text. T1, T2, T3 structure of hitch nodes). On top of figure the symbols of using kinemtic constraints are presented

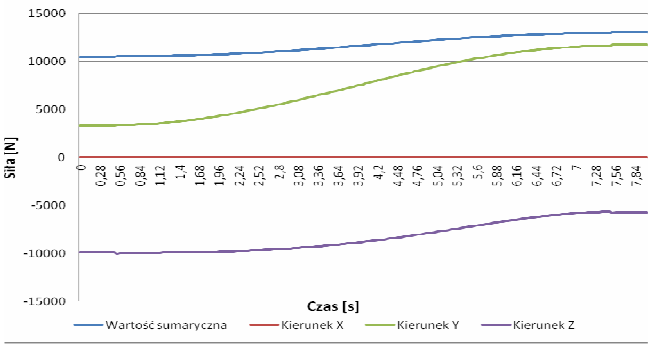
During the calculations simulated the process of raising and lowering the hitch of the drill from the operating position to the transport position (for rides on the headland) and working. Due to the work character the structure of hitch was taken multi-option loads system which taking into account the forces from the weight of the modeling carrying structure and the mass of the drill with grain. Made an analysis of the impact of changing the position of the hitch with the to reaction forces placed in pivots of hydraulic cylinder and the points of connection the hitch arms to the main frame of aggregate. Simulations were performed for working tool width 3.0 m and assumed a constant rate of extension of the hydraulic cylinder. Kinematic analyzes were carried out in the Solid Works Motion 2010.

3. Results of analysis

In the simulation of determine the reaction forces between working to strip tillage and tractor three point hitch the body of tractor was fixed to the ground. Then the machine can be raised on the back three point hitch by defining the STEP function of angular rotation of the upper arms of hitch at an angle of 23 °, which was adopted during the simulation. Determined, the individual components of the forces occurring in the connector and the lower arm of hitch and presented in a graphical form (Fig. 3). On the graphs the negative forces in the Z direction corresponds to the sense of a vector of force along the axis of the machine.

Were also performed an analysis of stability for tractor aggregate during the ride on ground on the basis of a two-speed, 5 and 10 km/h. Ground on which moved a tractor with strip tillage tool was modeled with obstacles. On the road where moving the tractor with the machine was modeled three obstacles: cross ditch depth 300 mm, cross threshold height 300 mm and cavity depth 300 mm. The simulation made a possible determine the strength of the contact tractor wheels with ground (Fig. 4). There was no observing, turning over, tilting the working tractor, however followed the loss of contact due to run into terrain obstacles. During the riding with the lower speed (5 km/h) the duration of loss of contact was not longer than 0.2 s.

a)



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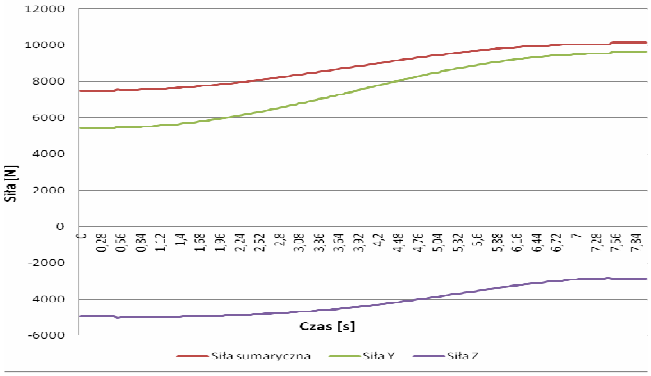
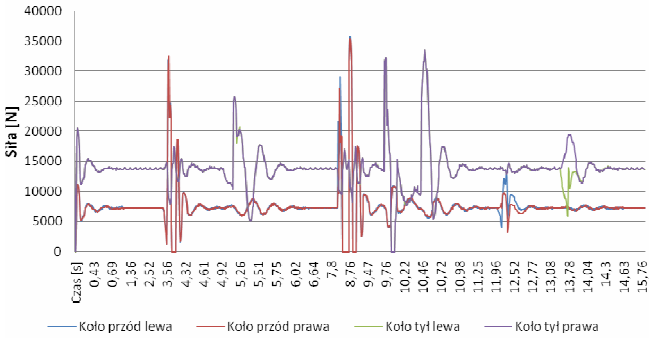


Figure 3. The time course of forces occurring in the connector and the ends of hitch arms during a lifting of tool for strip tillage (X direction - in the cross-machine direction Y - vertical direction Z - axis machine direction)

Kinematic behavior simulation of the three point hitch for drill in cultivation aggregate was performed in order to identify the impact of changing the position of structure elements together with the drill with grain to reaction forces in point of connection for one hydraulic cylinder and its correctness.

a)



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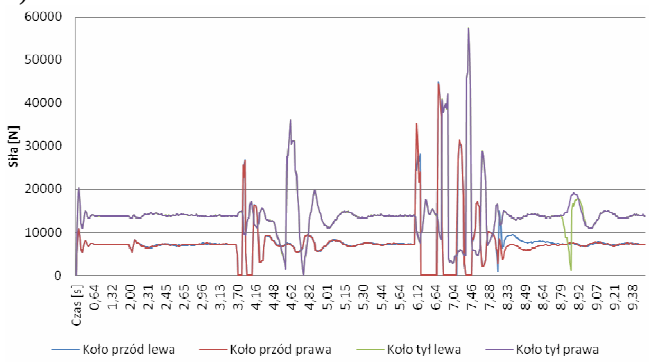

Figure 4. Graph of reaction forces between wheels and ground during the ride over the obstacles at a speed of 5 km/h (a) and 10 km/h (b)

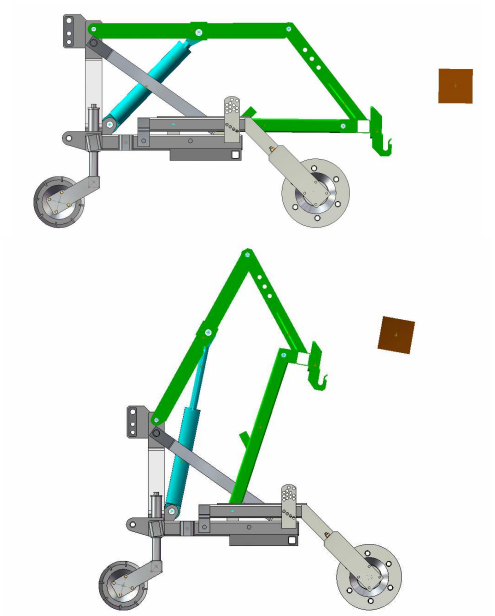

Figure 5. 3D model of the designed machine with hydraulic cylinder in working position (a) and transport position (b)

Hitch to the drill consisted of the upper arm and lower hanger, which are connected to each other and with frame holders by pivots. In model was used double-acting hydraulic cylinder. Simulations were performed on the 3D model of the cultivation aggregate frame with mounted hitch (Fig. 5) for a constant speed of hydraulic cylinder for the case of folding the drill to the transport position and unfolding to working position. At individual stages of the simulation was appointed forces and pressures occur at particular points during the folding of aggregate with drill (Fig. 6).

It has been shown that the highest value of the reaction occurs in the middle of the movement objective at the start of the folding process, when the hitch is lifted above aggregate. In the next phase of the hitch folding to the transport position, the hydraulic cylinder is partially unloaded. The maximum values of forces and pressures was recorded in the support point of hydraulic cylinder between hinge plates showed that cylinder ensures the correctness of the folding and unfolding process.

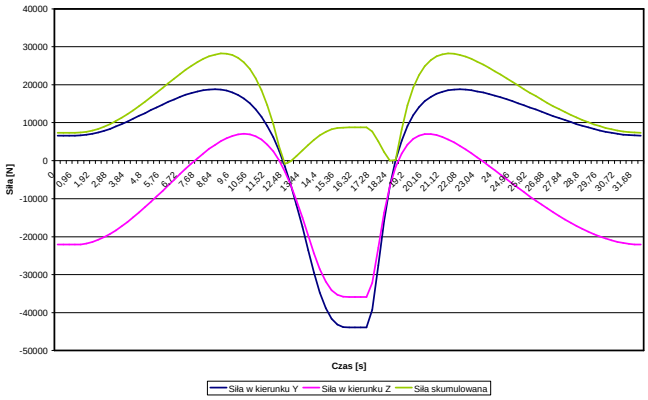

Figure 6. The time course of forces on the node T1 during raising and lowering the hitch with the drill

4. Conclusion

The analyzes of kinematic behavior of the tractor with a tool for strip tillage and mounted on the cultivation aggregate frame a hitch for the drill allowed predicted the behavior during operation and transport of machine already at the design process. The use of computer method allowed reflect a real behavior of agricultural machinery. Obtained a rich collection of results, both in the form of tabular or graphic. This has led to take action to achieve the best solutions for each nodes of agricultural machine construction and eliminate any collision. The next stage of works will be field tests of prototypes of machines which will verify the correctness of developed kinematic analysis.

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