THE STUDY WIDE SPAN TRACTOR (VEHICLES) FOR CONTROLLED TRAFFIC FARMING

ИССЛЕДОВАНИЯ СПЕЦИАЛИЗИРОВАННОГО ШИРОКОКОЛЕЙНОГО АГРОСРЕДСТВА ДЛЯ КОЛЕЙНОЙ СИСТЕМЫ ЗЕМЛЕДЕЛИЯ

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Abstract: *Promising energy technology means for controlled traffic farming are wide span tractor (vehicles). The effectiveness of the practical use of wide span tractor (vehicles) depends on a sound scientific base or theoretical frameworks, concerning the study of their technological properties. The article presents the theoretical basis of the dynamics of plane-parallel movement wide span tractor (vehicles) in the horizontal and vertical plane as well as its cornering. Developed the theory of plane-parallel movement wide span tractor (vehicle) allows for the justification of new schemes, design parameters and operating modes with acceptable controllability and stability of motion in the horizontal plane. Ride wide span tractor (vehicles), as a dynamical system, moving through the traces of permanent tramlines significantly depends on the characteristics of the irregularities of the longitudinal profile. The desired character of the internal structure of the longitudinal profile laid tramlines is almost possible to obtain the appropriate technology for its formation. Quality testing of dynamic system input perturbations, which are irregularities of the longitudinal profile permanent tramlines and the unevenness of the traction resistance of the soil, depends on the scheme and the constructive and other settings wide span tractor (vehicles). A significant impact on the smoothness of the latter renders the rigidity of the tire support wheels, the magnitude of which can be influenced, within certain limits, by changing the air pressure in them. Improve driving dynamics the technological part of the wide span tractor (vehicles) is observed by increasing the rigidity of the tire its supporting wheels and operating mass. The offered new scheme of the turn of a wide span tractor (vehicle) for controlled traffic farming on the turning strip by turning the undercarriage, using the steerable wheels from its one board around the turning centre arranged in the centre of the space between the wheels from the other board, allows shifting of the tractor, simultaneously with the turn, to the next operating position with better kinematic parameters. In addition to it, the improvement of the turnability characteristics is achieved at such a design embodiment of the wide span tractor (vehicle) when the relation of its wheelbase to the width of the wheeltrack is as small as possible.*

KEYWORDS: CONTROLLED TRAFFIC FARMING, WIDE SPAN TRACTOR (VEHICLES), AGRICULTURE, MOVEMENT IN THE HORIZONTAL AND VERTICAL PLANE, TURN.

1. Introduction

A promising direction for further stable development of the world agriculture is the introduction of innovative technologies, which should include controlled traffic farming [1-8]. Its application provides the basis for automation of most technological processes in crop production, ensures the effective implementation of "precision" agriculture and provides other significant advantages.

Promising in this respect is the use of wide span wide span tractor ore vehicles [3-11]. The use of a wide span tractor (vehicles) allows to obtain the maximum efficiency (technological, social, environmental, economic) in the processes of tillage and maintenance of crop plants [3-12].

The effectiveness of the practical use of wide span tractor (vehicles) depends on a sound scientific base and theoretical framework for the study of their technological properties. Constructive-technological features of these wide span tractor (vehicles) require the development of a fundamentally new system for their operation and use. The question in this respect, scientists have studied not enough, and the effective practical realisation of the potential of technological properties of wide span tractor (vehicles) are currently missing. Therefore, from the perspective of the solution of the food problem in the world, as well as the development of resource-saving technologies, which are based on the principles of a track system of agriculture, in accordance with the trends of scientific and technological progress in the mechanization − improving the functioning of the technical means at the expense of complex mechanization, electrification, automation and robotics − this area of research is very important.

2. Preconditions and means for resolving the problem

2.1. Analysis of recent research and publications
All known studies on this issue aimed at the study of the dynamics of tractor units based on traditional tractors, and do not relate to the solution of the specified problem. The accumulated scientific and practical experience in the use of traditional machine-tractor units in controlled traffic farming is allowed to justify certain requirements on the parameters of permanent tramlines and energy resources. However, these requirements do not take into account the atypical layout scheme wide span tractor (vehicles), specific mounting and operating conditions [13,14], therefore, needs to be clarified. At the same time, the now famous methodology of choice of constructive schemes, parameters and modes of operation of machine and tractor aggregates cannot be used to study the dynamics of movement wide span tractor (vehicles). Therefore, from the perspective of effective use of wide span tractor (vehicles), there are unresolved issues relating to the study of conditions that are imposed on their design and other parameters.

2.2. Purpose of the study
The purpose of researches is the increase of efficiency of functioning and the use of wide span tractor (vehicles) by study schemes, technological, etc. parameters.

3. Results and discussion

Wide span tractor (vehicles) is a rather complex dynamic system. This complexity is determined by its multi-dimensionality, high order differential equations of motion and especially the presence of nonlinear relationships between its individual coordinates. Therefore, at this stage of the study of the dynamics of wide span tractor (vehicles) it is advisable to consider it a simplified diagram in the form of stationary linear model. This idealization of the system in many cases is quite effective for complex agricultural units and their control systems, the dynamics of which is still insufficiently studied.

In the study of movement wide span tractor (vehicles) in the longitudinal-horizontal plane of the dynamic system has two

degrees of freedom (fig. 1), which correspond to two generalized coordinates: the heading angle φ and the displacement of the abscissa X_S of the center of mass it S_t.
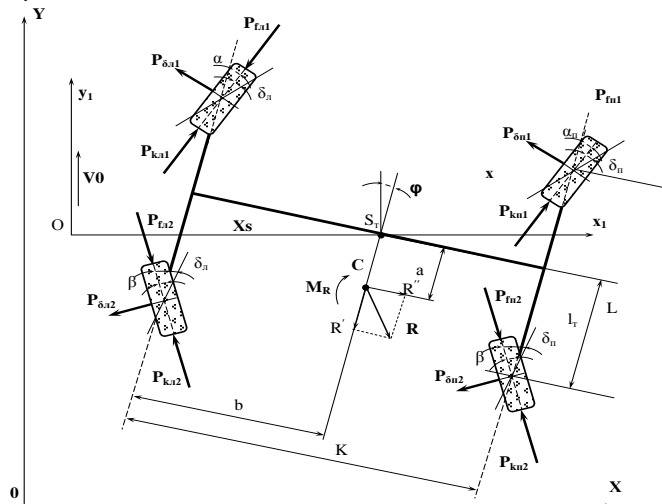

Fig. 1. *Scheme of the forces acting on wide span tractor (vehicles) in a horizontal plane when the kinematics method of its control (wheel rotation)*

Analysis of amplitude and phase frequency characteristics of the influence of circuit and parameters of a wide span tractor (vehicles) on its handling and stability of motion [15-17] have shown a significant dependence on speed. At low speeds (1m/s) have a significant nedouregulirovannymi in a dynamic system the control action (rotation angle α of the front wheels). In this case, the desired frequency of oscillation of the angle of the front wheels is at the level of 0.5 s^{-1}, where the gain value of the input control action is close to 1. However, the increasing speed, wide span tractor (vehicles) to 2 and 3 m/s at low frequencies ($\omega < 1{,}3$ s^{-1}) contributes to the overshoot of the dynamic system, at frequencies $\omega > 1{,}3$ s^{-1} on the contrary - brings characteristics to the ideal. As for the phase shift of mining, dynamic system control, when the increase of working speeds wide span tractor (vehicles) up to 3 m/s the phase-frequency characteristic closest to the ideal.

The main perturbations that cause vertical movement of the wide span tractor (vehicles) in a longitudinal vertical plane, there are irregularities of the longitudinal profile of the traces of permanent tramlines, the fluctuations of the traction resistance of agricultural implements (R_x and R_z) and the main moment of resistance (M_R) (fig. 2).
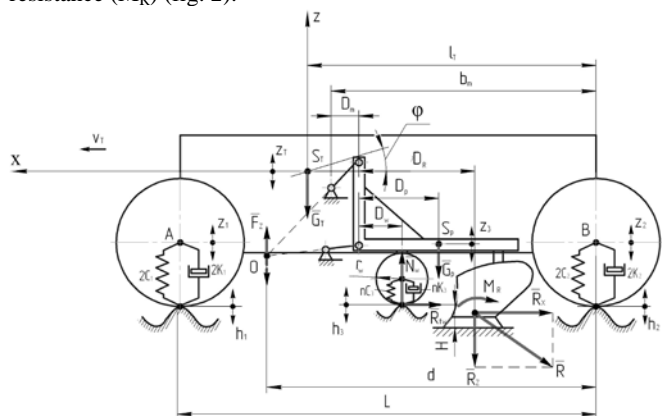

Fig. 2. *The scheme is equivalent to a dynamic system of movement wide span tractor (vehicles) in a longitudinal vertical plane*

As a result of mathematical modeling of the dynamics of plane-parallel movement wide span tractor (vehicles) in a longitudinal vertical plane established [18] that, from the point of view of the desired testing dynamic system perturbations, a significant increase in the stiffness coefficient of the tire to its supporting wheels is effective only in the case when the variances of the fluctuations of the roughness profile permanent tramlines are concentrated in the frequency range 0...8 s^{-1} and 16…20 s^{-1}. Consider a dynamic system almost does not respond to the outrage, if the main range of the variances of roughness permanent tramlines is concentrated in the frequency range of 13-15 s^{-1}. Practically this can be achieved by the appropriate technology of formation of traces of permanent tramlines or change in the stiffness of the pneumatic tire by adjusting this air pressure in it, which would ensure minimum response of a dynamic system to an input disturbance. If the variance of roughness profile permanent tramlines are concentrated in the range of lower frequencies, reducing the rigidity of the tire wheel wide span tractor (vehicles) is effective.

Theoretically established, if the main range of the dispersions of the irregularities of the permanent tramlines will be concentrated in the high frequency range of 13-15 s^{-1}, the coefficient of stiffness of the tires of the supporting wheels of the technological part of the wide span tractor (vehicles) must not be more than 25 kN/m, or at least 200 kN/m. Also found that the operational weight of the technological part worsens the dynamics of its motion in the vertical plane. Informed that the character of mining oscillations of the traction resistance of wide span tractor (vehicles) essentially depends on the position of the hinged mechanism. It is established that the displacement of the hinged mechanism of the position of rear mounting in the central – worsens the dynamics of its motion in the vertical plane. From a practical point of view the unsatisfactory result of the latter can compensate for the change in the stiffness of the pneumatic tire by adjusting this air pressure, which would ensure minimal dynamic response of the system to irregularities of the profile of permanent tramlines.

The offered new scheme of the turn of a wide span tractor (vehicle) for controlled traffic farming on the turning strip by turning the undercarriage, using the steerable wheels from its one board around the turning centre arranged in the centre of the space between the wheels from the other board, allows shifting of the tractor, simultaneously with the turn, to the next operating position with better kinematic parameters. In addition to it, the improvement of the turnability characteristics is achieved at such a design embodiment of the wide span tractor (vehicle) when the relation of its wheelbase to the width of the wheeltrack is as small as possible (fig. 3) and (fig. 4) [19].
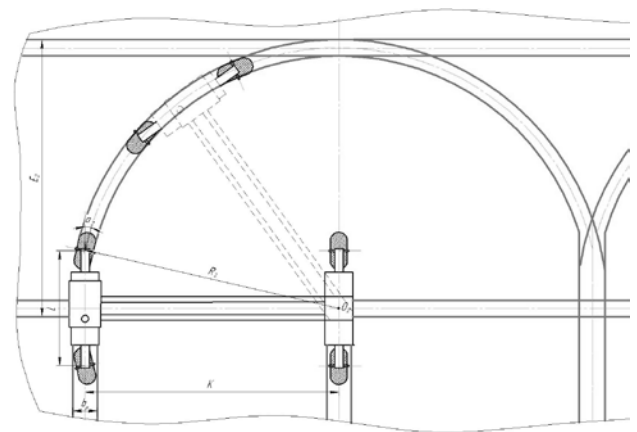

Fig. 3. *Schemes of the turn of a wide span tractor (vehicle) around the turning in the centre of the space between the wheels of one of the boards*
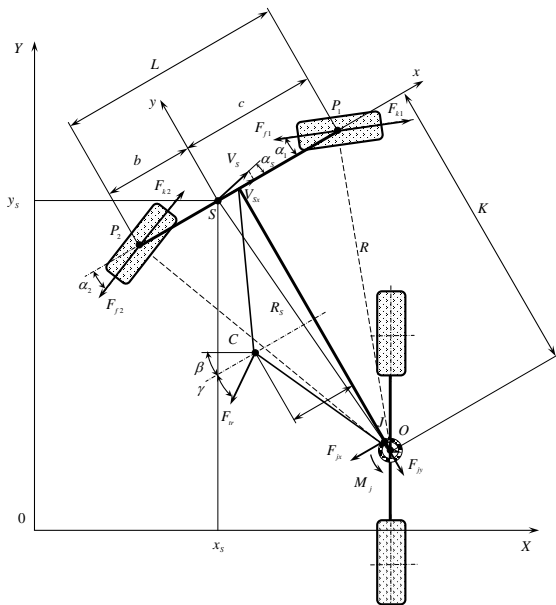
Fig. 4. *An equivalent scheme of the turn of a wide span tractor (vehicle) with steerable wheels of the left board*

4. Conclusion

1. Developed the theory of plane-parallel movement wide span tractor (vehicle) allows for the justification of new schemes, design parameters and operating modes with acceptable controllability and stability of motion in the horizontal plane.

2. Ride wide span tractor (vehicles), as a dynamical system, moving through the traces of permanent tramlines significantly depends on the characteristics of the irregularities of the longitudinal profile. The desired character of the internal structure of the longitudinal profile laid tramlines is almost possible to obtain the appropriate technology for its formation. Quality testing of dynamic system input perturbations, which are irregularities of the longitudinal profile permanent tramlines and the unevenness of the traction resistance of the soil depends on the scheme and the constructive and other settings wide span tractor (vehicles). A significant impact on the smoothness of the latter renders the rigidity of the tire support wheels, the magnitude of which can be influenced, within certain limits, by changing the air pressure in them. Improve driving dynamics the technological part of the wide span tractor (vehicles) is observed by increasing the rigidity of the tire its supporting wheels and operating mass.

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5. Literature

1. Chamen T. Controlled traffic farming – from world wide research to adoption in europe and its future prospects // Acta Technologica Agriculturae Nitra. – 2015. –№3. – P. 64–73.

2. Kingwell R., Fuchsbichler A. The whole-farm benefits of controlled traffic farming: An Australian appraisal // In Agricultural Systems. – 2011. – vol. 104, № 7. – P. 513–521.

3. Chamen W.C.T. Assessment of a Wide Span Vehicle (Gantry), and Soil and Cereal Crop Responses to Its Use in a Zero Traffic Regime // Soil & Tillage Research. – 1992. – №24(4). – P. 359-380.

4. Chamen W.C.T. Design, Operation and Performance of a Gantry System: Experience in Arable Cropping // Journal of Agricultural Engineering Research. – 1994.– №59(1). – P. 45-60.

5. Onal I. Controlled Traffic farming and Wide span tractors // Journal of Agricultural Machinery Science. – 2012. – №8(4). – P. 353-364.

6. Pedersen, H.H. Harvest Capacity Model for a Wide Span Onion Bunker Harvester // In Automation and System Technology in Plant Production / CIGR section V & NJF section VII conference, 30 June - 2 July 2011.

7. Chamen W.C.T. A New Methodology For Weed Control And Cereal Crop Production Based On Wide Span Vehicles And Precision Guidance: Biotrac // 4th EWRS Workshop on Physical Weed Control, Elspeet, The Netherlands, 20-22 March 2000. - P.51-55.

8. Pedersen H.H., Sørensen C. G., Oudshoorn F.W., McPhee J.E. User requirements for a Wide Span Tractor for Controlled Traffic Farming. International Commission of Agricultural and Biological Engineers, Section V. CIOSTA XXXV Conference "From Effective to Intelligent Agriculture and Forestry", Billund, Denmark, 3-5 July 2013.

9. Kuvachov V.P. Specialized vehicle for the trip of agriculture (In Ukrainian language) // Bulletin of HNTUA. – 2014. – № 148. – P. 63–69.

10. Kuvachov V.P., Kutsenko S.M., Kovalev V.V. Electric agricultural vehicle is an efficient solution to the problems of mechanization of agricultural production (In Ukrainian language) // Papers TSAU. – 2012. – Is. 12, v. 2. – P. 86-92.

11. Kuvachov V.P. Bridge agriculture on the basis of sprinkling machines (In Ukrainian language) // Scientific Bulletin TSAU. – 2012. – Is. 2, v. 5. – P. 15-23.

12. Kuvachov V.P. Land use in the regeneration field for working energy tools bridge type (In Ukrainian language) // Scientific Bulletin TSAU.– 2013. – Is.1, v.3. – P.116-126.

13. Kuvachov V.P. Justification of energy saturation specialized self-propelled energy means of the bridge type (In Ukrainian language) // Scientific Bulletin TSAU.– 2014. – Is.4, v.2. – C. 124-131.

14. Kuvachov V.P. Justification of energy saturation of the self-propelled energy means of the bridge type (In Russian language) // Actual problems of scientific-technical progress in the agro-industrial complex: collection of scientific articles on materials of VIII International scientific-practical conference "Resource - and energy saving in the agricultural sector. Alternative fuels". – Stavropol: AGRUS of Stavropol state agrarian University, 2013.-P.101-110.

15. Kuvachov V.P. Evaluation of stability of motion the broad-gauge of the power and process of mechanization of agricultural production (In Ukrainian language) // Papers TSAU. – 2015. – Is. 15, v.3.- C. 204-210.

16. Nadykta, V.T., Kuvachov V.P. Assessment of the manageability of the traffic the broad gauge of the power and process of mechanization of agricultural production (In Ukrainian language) // Scientific Bulletin TSAU. – 2016. – Is. 6., v.1. – P. 99-110.

17. Kuvachov V. Modeling of plane-parallel movement in the horizontal plane broad-gauge means in the kinematic method of its control (In Russian language) // Motrol. – 2015. – Vol. 17, № 9. – P. 49–54.

18. Kuvachov V., Mitkov V., Shulga O. Modelling of plane-parallel movement in a vertical plane of means for broad-gauge track system of agriculture (In Russian language) // Motrol. – 2016. – Vol.18, №1. – P. 3-12.

19. Kuvachov V.P. The kinematics of the rotation the broad-gauge mechanization of agricultural production for the track system of agriculture (In Ukrainian language) // Bulletin Sumy state University. – 2016. – Is. 10/2 (30). – P. 46-49.