UDC 631.319.07-02

VYZNACHENNYA OPTYMALNYH PARAMETRIV KERUVANNYA ҐRUNTOOBROBNYMY AHREHATAMY AS DYNAMICHNYMY SYSTEMAMY

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In statti zaproponovano teoretychnyy approach doslidzhennya kerovanosti and stiykosti movement mobilnoho silskohospodarskoho ahrehatu, predstavlenoho as dynamichnoyi systemy chto modelyuye yoho movement that vykorystovuyut for optymizatsiyi protsesu keruvannya. Eksperymentalnu metodyku vykorystovuyemo for vyznachennya corners vidhylennya ahrehatu in protsesi roboty ta yoho vchasnoho zabezpechennya optymizatsiyi parametriv keruvannya.

Dynamichna systema, parametry, modelyuvannya, mobilnyy silskohospodarskyy ahrehat, keruvannya.

Formulation of the problem. Silskohospodarski ahrehaty - skladni dynamichni systemy. Vony pratsyuyut in Crises chto nA vplyvayut bahatochyselni nayriznomanitnishi zovnishni faktory that postiyno change. For mobilnyh ahrehativ takymy faktoramy is nerivnosti poverhni polya, fizyko-mehanichni vlastyvosti ground (volohist, density, mehanichnyy sklad ta al.), Which vytraty neobhidno vklasty nA its obrobku and peremischennya ahrehatu; vlastyvosti roslyn (vrozhaynist, zabrudnenist ta al.) zmina masy ahrehatu in protsesi vykonannya tehnolohichnoho protsesu ta al.

Analysis of recent research. In mobilnyh silskohospodarskyh ahrehativ (MSA) variability zovnishnih faktoriv at the working vzayemodiyi orhaniv mashyn of obroblyuvanym seredovyschem

(Ґruntom, roslynamy) and drivers of poverhneyu polya nosyt skladnyy harakter movement okremyh tochok chto harakteryzuye in znachniy degree of quality bahatoh operatsiy obrobitku ground (oranka, mizhryadna kultyvatsiya ta al.). Naukovi osnovy doslidzhen and vyprobuvan silskohospodarskoyi tehniky zakladeni akademikom VP Horyachkinym that nazvav novyy napryamok in nautsi - "zemlerobska mehanika" [1].
P. Vasylenko in podalshomu za dopomohoyu equations mehaniky opysav protses poyavy vypadkovyh zburen movement

silskohospodarskoyi mashyny [2]. In svoyih chyselnyh pratsyah of zemlerobskoyi mehaniky vony zvertaly uvahu nA imovirnyy, vypadkovyy harakter pokaznykiv roboty silskohospodarskyh ahrehativ cherez variability zovnishnih umov. For vyrishennya zadach zahalnoyi and statystychnoyi dynamiky mobilnyh silskohospodarskyh ahrehativ vynykaye neobhidnist pobudovi modeley in their movement. In zahalnomu vypadku equations of motion mobilnyh ahrehativ will neliniynymy and tse znachno uskladnyuye zadachu kontrolyu za vplyvom keruyuchyh action to zabezpechennya yakosti vykonannya ahrotehnichnyh operatsiy. Reaktsiya nA keruyuchi effect (influence) mozhe harakteryzuvaty Nor only degree doskonalosti its funktsionalnu stabilnist, a takozh and tehnichnyy stan mashyny. Povedinku ahrehatu, yoho funktsionuvannya under chas vykonannya tehnolohichnyh operatsiy in normalnyh Crises ekspluatatsiyi, opysaly za dopomohoyu rozroblenyh ranishe teoretychnyh metodiv and zasobiv eksperymentalnyh doslidzhen movement MSA. Vyvchennyu zadach dynamiky silskohospodarskyh ahrehativ paid bahato uvahy Vasylenko PM, Pohorilyy LV, Anilovych VY, Kutkov GM, Roslavtsev A. V., Nadykto VT, VN Bulhakov, Hyachev LV, SY Hukov, Podryhalo ta M. A. et al. Kozhen are vyrishuvav okremu zadachu dynamiky, a tsilomu in bulo zrobleno Mighty vklad in teoretychne obґruntuvannya komplektatsiyi ta efektyvnoyi roboty ahrehativ. Bulo rozrobleno and zaproponovano for rozhlyadu dynamichni modeli MSA chto zabezpechyly vyrishennya bahatoh zadach, pov'yazanyh of vplyvom okremyh elementiv ahrehatu nA pokaznyky yoho movement and roboty [3, 4]. MSA vidnosyatsya till the dynamichnyh system, which matematychni modeli vidobrazhayut vzayemozv'yazok between output and input vplyvamy their pohidnymy and intehralamy [5]. Dynamichni vlastyvosti traktornyh ahrehativ suttyevo zalezhat of parametriv osnovnyh elementiv (detaley, ahrehativ etc.) kontrol tehnichnoho stanu which mozhe be vykonanyy shlyahom analizu their dynamichnyh harakterystyk.

Tse may be deposited systemy zvychaynyh dyferentsialnyh equations chastynnyh pohidnyh, vidpovidni dyskretni modeli ta al. Vidminnoyu osoblyvistyu matematychnoho opysu lyuboyi dynamichnoyi systemy is te chto its povedinka rozvyvayetsya in chasi harakteryzuyetsya ta n functions x1 (t), ... xn (t), which nazyvayutsya variables stanu (fazovymy koordynatamy) systemy.

Meta doslidzhen. For vyznachennya parametriv keruvannya mobilnymy silskohospodarskymy ahrehatamy neobhidno Congress to develop matematychni modeli which would vrahovuvaly all osnovni pokaznyky ta were predstavleni as dynamichnyh system. Matematychni modeli dynamichnyh system may be deposited in different pobudovani formah.

Results. In zemlerobskiy mehanitsi rozriznyayut modeley three types - physical, rozrahunkovi and matematychni. Pershi opysuyut yavyscha and protsesy in vidpovidnosti them till the fizychnoyi pryrody. Rozrahunkova model peredbachaye vykorystannya suchasnyh metodiv matematyky and obchyslyuvalnoyi tehniky. Matematychni modeli dayut zmohu analitychno predstavyty mozhlyvosti ahrehativ that vony opysuyut. Movement mobilnoho silskohospodarskoho ahrehatu as dynamichnoyi systemy mozhe be kerovanym and protyahom pevnoho chasu nekerovanym. In this regard, during chas rozrahunku and konstruyuvannya, a takozh vyprobuvannyah and doslidzhennyah silskohospodarski ahrehaty povynni rozhlyadatys as kerovani dynamichni systemy chto skladayutsya number of tsiloho vzayemozaminnyh pidsystem. Model ahrehatu mozhna rozhlyadaty as rozrahunkovoyi shemy, yaka be naybilsh povno vidobrazhala realni umovy funktsionuvannya ahrehatu. In protsesi realizatsiyi kerovanoho movement povedinka dynamichnoyi systemy zalezhyt of kilkosti keruyuchyh functions U1 (t) ... Uk (t). Prypustymo takozh chto mobilnyy silskohospodarskyy ahrehat vyznachayetsya odnoznachno, if applicable zadana vektor function keruvannya U (t) = (U1 (t), ... Uk (t)) and pochatkovyy stan systemy x0 = x (t0) = (x1 (t0), ... xn (t0)), de t0 - pochatkovyy chas.

For opysu MSA as dynamichnoyi systemy, skorystayemos matematychnoyu modellyu which zapyshemo as systemy zvychaynyh dyferentsialnyh equations zapysanyh in normalniy formi Koshy:

$$\frac{dx}{dt} = F(x, U) \quad (1)$$

Where: x = (x1, ... xn), U = (U1, ... Uk), F (x, U) = (F1 (x, U), ... Fn (x, U)) - vidoma vektor function.

Systemy till the appearance of (1) all chastishe za pryvodyatsya matematychni modeli dynamichnyh system of bezperervnym perebihom chasu. Napryklad, if applicable povedinka dynamichnoyi systemy (MSA) opysuyetsya systemoyu dyferentsialnyh equations chastynnyh pohidnyh ta vidbuvayetsya in prostori and chasi, verily, provodyachy dyskretyzatsiyu za systemy prostorom pryhodymo till the zvychaynyh dyferentsialnyh podibnyh equation (1), which rozv'yazok provodytsya as a function chasu. Figure 1 NA zobrazheno dynamiku vektora function as kuta vidhylennya movement MSA at vykonanni ahrotehnichnyh operatsiy, the function chasu with zminoyu napryamku zhidno zapysanoho dyferentsialnoho equation (1). If applicable poyednaty kintsevi tochky vektora functions, verily we otrymayemo hrafik kuta vidhylennya napryamku movement ahrehatu, TOB, then build the travel time angle.

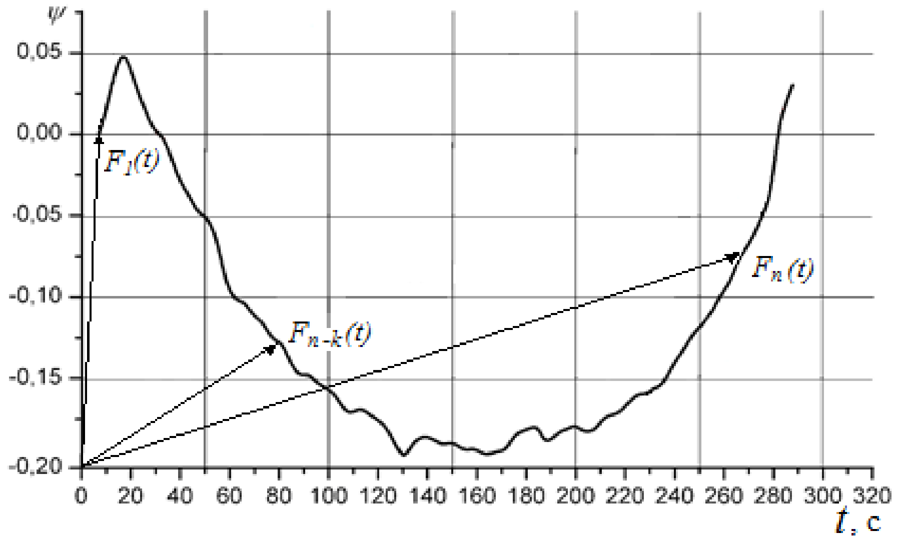

Fig. 1. Hrafik kuta vidhylennya napryamku movement MSA as a function chasu.

Navedene nA pochatku prypuschennya position concerning odnoznachnosti protsesu keruvannya zhidno equation (1) vyznachayetsya umovamy teoremy Pro isnuvannya and uniqueness rozv'yazku zvychaynyh system in formi Koshy.

For vyrishennya zadachi optymalnoho upravlinnya systemoyu (1) zrobymo prypuschennya. In pochatkovyy moment t0 dynamichna systema (1) znahodytsya in stani x0, neobhidno vyznachyty takyy keruyuchyy syhnal U (t), which zabezpechyt perehid systemy till the zadanoho kintsevoho stanu xT = x (t) (different from pochatkovoho) de T ≤ ∞ - kintsevyy chas. Zazvychay neobhidno, perehid Recipients of tochky x0 till the tochky xT (perehidnyy protses) was pevnomu sensi naykraschym sered all mozhlyvyh. In nashomu vypadku, we koly rozhlyadayemo dynamichnu systemu (MSA) perehidnyy protses povynen zadovolnyaty umovi minimum chasu perehodu of odnoho stanu till the inshoho, abo umovi minimalnoyi vytraty enerhiyi. Takyy naykraschyy perehidnyy protses pryynyato nazyvaty optymalnym protsesom. We zabezpechymo in takomu vypadku, nA keruvannya dynamichnoyu systemoyu naymenshi vytraty chasu abo enerhiyi.

MSA chto ruhayetsya is avtonomnoyu dynamichnoyu systemoyu, osnovni zovnishni influence nA which pryzvodyat till the change kilkosti enerhiyi chto nA vykorystovuyetsya peremischennya. These actions pravylo, vyklykayut change shvydkosti postupalnoho movement ahrehatu chto harakteryzuyetsya equation:

$$\frac{dv}{dt} = \frac{P_{\partial} - \sum P_c}{m_{аг}}, \quad (2)$$

Where: P_∂ - Rushiyna syla ahrehatu (dotychna syla traction traktora); $\sum P_c$ - Suma all forces oporu ahrehatu movement; $m_{аг}$ - Pryvedena till the postupalno-ruhomyh chastyn masa ahrehatu.

In equation (2) with dostatnim nablyzhennyam mozhna take postiynoyu pryvedenu ahrehatu masu ($m_{аг} - const$). Oporu forces in motion ahrehatu protsesi roboty zalezhat of faktoriv, bahato of which are variable velychynamy, napryklad stan soil and relyef mistsevosti, hlybyna obrobky, speed rezhym etc. In vidpovidnosti till the change of power changes and oporu rushiyna syla ahrehatu. Tse pryzvodyt till the toho chto dv/dt (Pryskorennya) in protsesi vykonanni ahrehatom pevnoho tehnolohichnoho protsesu postiyno changes as velychynoyu za, za didst znakom. Zaproponovanym equation opysuyetsya perehidnyy protses in yakomu we mozhemo obyraty optymalne keruvannya systemoyu. Parametr, which pevniy extent zabezpechuye efektyvne keruvannya and mozhe sluhuvaty pokaznykom efektyvnosti perehidnoho protsesu dynamichnoyi systemy is pryskorennya.

Realnyy movement MSA as dynamichnoyi systemy different from idealnoho movement za vyznachenoyu trayektoriyeyu. For kontrolyu dynamiky pryskoren was rozroblenyy vymiryuvalno-reyestratsiynyy kompleks that dozvolyaye kontrolyuvaty pryskoren change (Fig. 2) rezhymi on-line, in troh ploschynah za dopomohoyu trohkoordynatnyh datchykiv-akselerometriv. NA hrafiku zobrazheno dynamiku side pryskoren ґruntoobrobnoho ahrehatu - traktora MTZ-80 + 3-35 PLN.

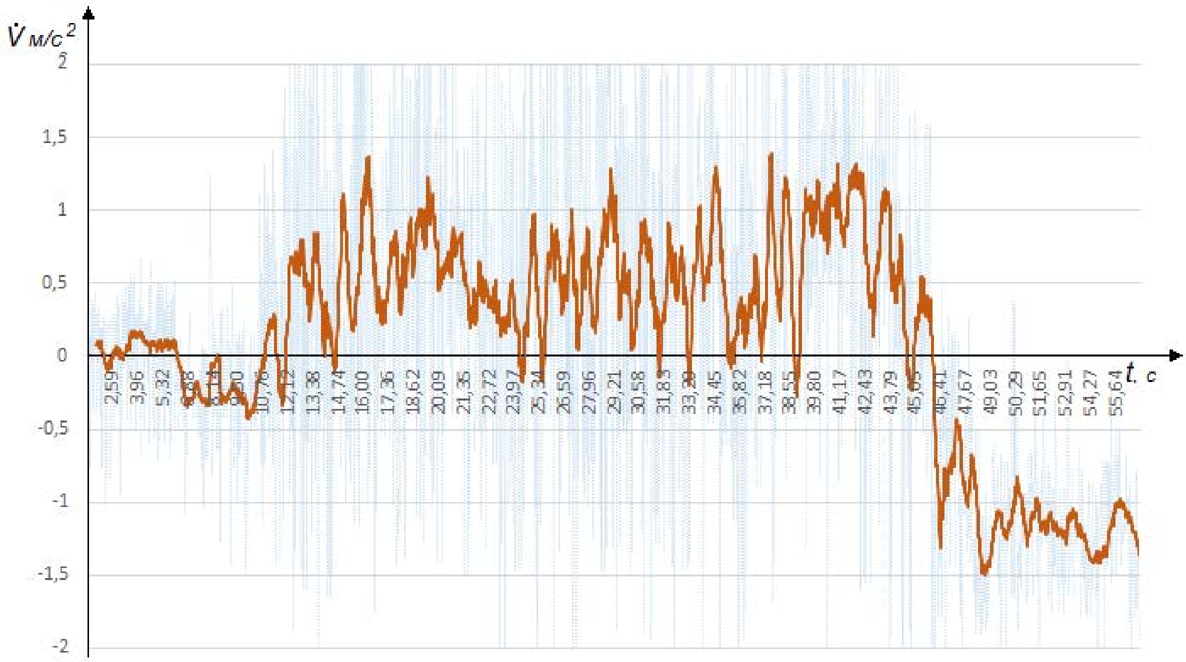

Fig. 2. Hrafik dynamiky side pryskoren measured za dopomohoyu vymiryuvalno-reyestratsiynoho kompleksu 1 - masyv measured danyh; 2 - vidfiltrovanyy syhnal.

If applicable till the uvahy take metod [6] Pro vynyknennya partsialnoho pryskorennya of action kozhnoyi okremoyi forces in tsomu vypadku movement MSA zapysuyetsya za dopomohoyu partsialnyh pryskoren as:

$$\ddot{x} = \ddot{x}_T + \ddot{x}_K + \ddot{x}_R \text{ And (3)}$$

Where: $\ddot{x}_T$ - Is partsialnym pryskorennyam chto vynykaye in protsesi rozhonu MSA at vidsutnosti any traction forces okrim R; $\ddot{x}_K$ - Partsialne pryskorennya traktora under force only oporu kochennyu nA kolesah traktora; $\ddot{x}_R$ - Partsialne pryskorennya MSA by the forces oporu silskohospodarskoho znaryaddya.

In nayavnosti vymiryuvalnoho kompleksu that zabezpechuye vymiryuvannya, reyestratsiyu and obrobku bokovyh pryskoren ahrehatu, tse dozvolyaye vykorystovuvaty metod partsialnyh pryskoren. In perehodi systemy with odnoho stanu till the inshoho vidbuvayetsya zmina pryskoren and kuta napryamku ahrehatu movement. In protsesi doslidzhennya linear motion modeley mobilnyh ahrehativ bulo vstanovleno chto of movement of deyakymy obmezhennyamy, mozhna predstavyty takym chto skladayetsya of dvoh Nor pov'yazanyh movements: pozdovzhnoho and bokovoho at tsomu pozdovzhniy movement vyznachayetsya kolyvannyamy ahrehatu in pozdovzhno-vertykalniy ploschyni, a bokovyy - in horyzontalniy ploschyni. Systema equations komponent partsialnyh pryskoren mozhe be zapysana, linearizovana and predstavlena as systema chto opysuye zburenyy movement nastupnomu follows:

$$\begin{aligned} \Delta a_x &= -\Delta_2 \ddot{\psi}_1 + \Delta_1 \dot{\psi}_1^2 \\ \Delta a_y &= -\Delta_1 \ddot{\psi}_1 - \Delta_2 \dot{\psi}_1^2 \end{aligned} \text{ And (4)}$$

systemy equations for rozv'yazku vvedeni poznachennya $\Delta a_x = a_{x1} - a_{x2}$; $\Delta a_y = a_{y1} - a_{y2}$; $\Delta_1 = \rho_2 \cos\alpha_2 - \rho_1 \cos\alpha_1$; $\Delta_2 = \rho_2 \sin\alpha_2 + \rho_1 \sin\alpha_1$. Deyaki skladovi is vidomymy, a vyznachayutsya other cherez eksperymentalno measured komponenty pryskoren a_{x1}, a_{y1}, a_{x2}, a_{y2}.

In skladanni equation (4) prypuskalos chto $\sin\psi_1 \approx \psi_1$, $\cos\psi_1 \approx 1$, Pochatkove vyrishennya zaznachenoyi problemy rozhlyanuto doslidzhenni at MSA, as dvohmasovoyi modeli (traktor and silskohospodarske ґruntoobrobne znaryaddya) dynamichnoyi systemy with chotyrma stupenyamy svobody [6]. For vyrishennya postavlenoyi zadachi skorystayemos dynamichnoyu modellyu, yaka bula rozhlyanuta in roboti [6] and vyznachymo dynamiku forces are chto nA ahrehat in horyzontalniy ploschyni and zabezpechuyut change napryamku ahrehatu movement. NA osnovi zahalnyh teorem kinematyky ploskoparalelnoho movement absolyutno tverdoho tila [7] otrymayemo nastupni zalezhnosti kursovoho kuta ψ_1 traktora of komponentamy pryskoren in tochkah M_1 and M_2 nA osnovi (4).

$$\begin{aligned}&\Delta a_X = \psi_1'' \left[\rho_2 \sin(\psi_1 - \alpha_2) - \rho_1 \sin(\psi_1 + \alpha_1)\right] + \\ &+ \dot{\psi}_1^2 \left[\rho_2 \cos(\psi_1 - \alpha_2) - \rho_1 \cos(\psi_1 + \alpha_1)\right], \\ &\Delta a_y = \psi_1'' \left[\rho_1 \cos(\psi_1 + \alpha_1) - \rho_2 \cos(\psi_1 + \alpha_2)\right] + \\ &+ \dot{\psi}_1 \left[\rho_2 \sin(\psi_1 - \alpha_2) - \rho_1 \sin(\psi_1 + \alpha_1)\right],\end{aligned} \quad (5)$$

After a series peretvoren systemy (5) otrymayemo dyferentsialne equation for kursovoho kuta traktora:

$$\psi_1'' = \sqrt{\frac{\Delta a_X^2 + \Delta a_Y^2}{\Delta}} \sin(\psi_1 - \varphi), \quad (6)$$

Where: $\Delta = \Delta_1^2 + \Delta_2^2$, $\varphi = arctg\left(\frac{\Delta_1 \Delta a_X + \Delta_2 \Delta a_y}{\Delta_1 \Delta a_y - \Delta_2 \Delta a_X}\right)$.

Vyraz (6) is neliniynym dyferentsialnym equation druhoho poryadku. In vykorystanni standartnyh chyselnyh metodiv lehko otrymaty yoho vyrishennya. Takyy approach daye mozhlyvist in protsesi movement MTA kontrolyuvaty changes $\psi(t)$ zadanoho of napryamku ta otsinyuvaty stability and kerovanist ahrehatu.

The equation of zapysani urahuvannyam vidhylen dopomahayut in rozuminni teoriyi keruvannya mobilnym silskohospodarskym ahrehatom. Posylayuchys nA zapysani equation is solved zadacha optymizatsiyi, yaka maye praktychne znachennya.

Vysnovky

WITHa rezultatamy vyprobuvan dovedeno, Zaproponovanyy approach doslidzhennya kerovanosti and stiykosti movement MSA, as predstavlenoho dynamichnoyi systemy, yaka modelyuye movement MSA, mozhlyvo vykorystovuvaty for optymizatsiyi protsesu keruvannya. Eksperymentalnu metodyku mozhlyvo vykorystovuvaty for vyznachennya corners vidhylennya ahrehatu in protsesi roboty ta yoho vchasno zabezpechuvaty optymizatsiyu parametriv keruvannya.

Otrymani rezultaty kontrolyu dynamiky pryskoren under chas perehidnoho protsesu in roboti ahrehatu, may be deposited at vykorystani modelyuvanni parametriv keruvannya in roboti ґruntoobrobnyh silskohospodarskyh ahrehativ.

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In the state predlozhen teoretycheskyy podhod for yssledovanyya upravlyaemosty and ustoychyvosty dvyzhenyya mobylnoho selskohozyaystvennoho ahrehata, predstavlennoho in vyde dynamycheskoy systemы, modelyruyuschey His dvyzhenye, kotorыy yspolzuyut for optymyzatsyy protsessa upravlenyya. Эksperymentalnuyu metodyku yspolzuem for opredelenyya uhlov otklonenyya ahrehata in protsesse His rabotы and svoevremennoho obespechenyya optymyzatsyy parametrov upravlenyya.

Dynamycheskaya systema, parametrы, modelyrovanye, mobylnыy selskohozyaystvennыy ahrehat, upravlenye.

The article suggests theoretical approach to the study of controllability and stability of the motion of mobile agricultural units, presented in the form of a dynamic system, which simulates its movement used to optimize the management process. We use experimental methods to determine the angles of deflection of the machine during operation and timely provision of optimizing the control parameters.

Dynamic system parameters modeling, mobile agricultural units, management.

UDC 631.313.02

CONDITIONS self-organization TRYBOSYSTEMY "The working body - SOIL"

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