THE RESEARCH PECULIERITIES OF PARAMETERS AND CHOICE OF AGRICULTURAL MACHINES IN PEDAGOGICAL TECHNOLOGIES FOR INNOVATIVE PROJECT ACTIVITY IN TRAINING AGROENGINEERS

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Summary. *The structural-logical model of training of future specialists in agroengineering for innovative project activity has been developed on the basis of a systematic comprehensive study of the theoretical course of agricultural machines, the deepening of the students' scientific work on the development of supporting and moving elements of machine-tractor units, including pneumatic tires. The samples of individual fragments from the algorithm and the method of calculation of wheels used in the educational process are provided and the general and professional competencies of the agroengineer are created, especially during the implementation of future specialists in agro-industrial production of higher education courses in the course of master's and master's studies. It is noted that the training of agroengineers for innovative project activities is carried out in accordance with the Law of Ukraine "On Higher Education" and the standards of higher education of Ukraine. The influence of interdisciplinarity in the system of cross-cutting project preparation on the readiness for implementation of production practical tasks is investigated. It is confirmed that the support-run elements of aggregates in the conditions of complex terrain contributes to the development of erosion processes and negatively affect the soil fertility. Any tire better satisfies the condition of permissible wheel pressure on the soil if the air pressure in the tire is low. Improving the technological process of manufacturing tires for agricultural purposes allows them to ensure their quality, reliability and operational safety.*

KEYWORDS: *WHEEL TIRES, AGRICULTURAL MACHINERY, TECHNOLOGY, PROJECT TRAINING, PROJECT ACTIVITY, STUDYING PROCESS, THEORY*

Introduction.

Science and education are closely interconnected and able to develop effectively in a single integrated system of scientific, methodological and pedagogical activities. Educational process is an intellectual, creative activity of scientific and pedagogical workers, students, practitioners and other interested subjects in the sphere of higher education and science [1].

The training of future agroengineers is based on the formation of professional competences in a harmoniously developed personality capable of solving various tasks of production activity. The object of the study and activities of the agroengineer are the phenomena and processes associated with the effective functioning of agricultural machinery and mechanized technologies in agro-industrial production [2]. The educational process of students of the specialty "Agroengineering" is aimed at training specialists capable of solving professional specialized tasks and applied problems related to the use of agricultural machinery in mechanized production technologies, primary processing, storage and transportation of agricultural products, technical service of mechanization facilities, etc.

In the structural and logical scheme of training future agroengineers, the basic discipline is "Agricultural machines", students learn about the structure and principle of operation of agricultural machines, regulation and adjustment of them for optimal modes of work, as well as the theoretical basis of technological processes of working bodies, the method of development and designing new and improving existing structures [3]. Studying discipline in addition to classroom activities involves the independent performance of course work, the purpose of which is the technological development of the design of agricultural machinery or its units, or the improvement of existing machines to ensure the implementation of mechanized production processes of growing crops and improving the operational, economic and environmental performance.

The main scientific directions of the master's work in the field of agroengineering are to increase the productivity of aggregates, expand their versatility, combine energy resources with other implements and ensure their reliable handling, minimize the negative impact on the environment and soil, improve the working conditions of machinery, as well as traffic safety. Agricultural machine-tractor aggregates are driven across the field by overwhelming majority by means of a wheeled driving system. The processes that occur when the wheels interact with the soil, affect not only the performance of the machines, but also the properties of the soil, as the object of cultivation and the environment of cultivating crops.

Practical, scientific and educational activities show that the problem issues on the peculiarities of the substantiation of parameters and the choice of tires of agricultural machinery wheels in pedagogical technologies of agroengineering training for innovative project activities are still insufficiently studied and require further fundamental theoretical and experimental studies, scientific substantiation and generalizations.

Prerequisites and means for solving the problem.

For a long time, scientists have been engaged mainly in the study of the processes of interaction of the running system with the soil and traction-coupling properties of machines. Regarding the deformation of pneumatic tires of agricultural wheels, these issues are not sufficiently studied.

The problem issues related to the design of agricultural machinery, preparation of agroengineering specialists for the project activity, including the features of substantiation of parameters and selection of tires of wheels, are not sufficiently studied.

In [4], the main components of the preparedness for the project activity of the agroengineer as a specialist are presented, which are united in physical and mathematical, general technical and special blocks and general and professional competences, which should be mastered by the bachelor of specialty 208 "Agroengineering". For example: to design equipment and equipment of production areas, agricultural machines, their knots, mechanisms, various connections; carry out standard design calculations of knots and parts of machines and non-standard equipment; rational assembly of machine aggregates in existing production lines of crop and livestock production; to determine the technical condition of tractors, cars and aggregates of complex equipment [2], to optimize transport processes, etc.

In [5] presented an innovative system of scientific and methodological developments that affect the formation of special professional competencies of agroengineering. The basis of this system is the latest textbooks, manuals, monographs, programs and other teaching materials, as well as advanced pedagogical technology of training, which is based on the progressive, phased development of the future specialist's readiness for the project activity. Such pedagogical technology of training provides a comprehensive, comprehensive formation of professional competencies of agroengineering in accordance with regulatory requirements and standards of education, including [1, 2]. Students'

scientific activity, which is based on the development and modernization of agricultural machinery, plays an important role in the design training. It was noted [5] that the first voluminous work of the student in the educational process is the course work on the discipline "Agricultural Machines". Its successful implementation is a solid ground for effective and effective graduate design, writing master's thesis.

The general issues of the theory of design training were studied deeply by: Bryukhanova N.O. [6], Kolesnikova I.A. [7], Gorchakov-Siberian M.P. [7], Nychalko N.G. [8], Zyazun I.A. [8], Goncharenko S.U. [8] et al. The theory, methodology and practice of design training for agroengineering, including in view of the design of agricultural machinery, were studied and investigated: Bendera I.M. [9, 10, 11], Duganets V.I. [12], Pryshliak V.M. [4, 5, 13] and others. Also, the questions of improving the methodology of preparing future engineers are devoted to the work of A. Asherova, O. Kovalenko, M. Lazareva, D. Chernilevsky, P. Yakovyshina, and the methodological aspects of the future of agroengineering have been reflected in the scientific researches of I. Buzik, A. Demin, S. Daukilas, A. Esaulov, P. Luzan, V. Manke, I. Palamara, S. Pastushenko, V. Yaroshenko, transformation of independent educational activity into readiness for professional self-development by means of technologies of personally oriented education − is reflected in the monograph Bondar M.M., Zhuravsky L.M., Ostapenko E.O., Pryshliak V.M., Kutsenko A.G. [14].

Actual issues of studying the design, operation of tires, reducing the harmful effects of the effect of running systems of the machine tractor unit on the soil are devoted to the work [15, 16, 17, 18], and their production − [18, 19].

Solution of the examined problem.

As noted in [5], the theory and practice of project preparation for future agroengineering involves the widespread use of a scientific component in the educational process during classroom classes, independent work of students. The scientifically substantiated cross-cutting, interdisciplinary, sequential and phased development of agricultural machinery involves achieving a high quality learning outcomes and innovative technology development. Apart from the fact that students during their studies at the institution of higher education take part in research processes, conferences, construct and model the means of mechanization, they are to complete the term paper at the 3rd year, and in the master's degree - a master's degree. Here, students mainly count, design and study the working bodies of agricultural machines. However, there are works in which auxiliary but very important nodes, mechanisms or systems of machines are presented. The same applies to the support and running elements of agricultural machines, including wheel tires.

The type of wheel tires of agricultural machines should be selected, taking into account the permissible action of the wheels on the soil. Preferably the ecological pressure limit of the wheels on the soil, depending on its type and state, is taken at a pressure of 0,1-0,15 MPa.

First, for one of the circuits [3], it is necessary to determine the radial load of the wheels on the soil (kN), which will correspond to the required lifting capacity of the wheels of the machine, using the formulas:

for front wheels

$$G_2 = 10^{-3} a Q_{_M} g / n_2 L ; \qquad (1)$$

for rear wheels

$$G_1 = \left(10^{-3} g Q_{_M} - n_2 G_2\right) / n_1 , \qquad (2)$$

where a − center of gravity of the car relative to the rear axle, m [3];

$Q_{_M}$ − operating mass of the machine, kg [3];

g − acceleration of force weight, m/s^2;

n_2 − number of front wheels [3];

L − longitudinal base of the car, m [3];

n_2 − number of rear wheels [3].

After receiving the radial load of the wheels on the ground, you can proceed with the selection of the necessary tires, following this sequence of actions. First, using the calculated payload capacity of the rear and front wheels (G_1 and G_2), for tabl. 1 choose a tire capable of providing their payload, i.e.

$$G_{_{Ш}} \geq G_1, \; G_{_{Ш}} \geq G_2 . \qquad (3)$$

Table 1
Load ratios and tire pressure to select a mode at 30 km / h.

Tire designa-tion	Air pressure in the tire chamber $P_{_{Ш}}$, MPa								
	0,1	0,11	0,12	0,13	0,14	0,15	0,16	0,17	0,18
	Permissible load on the bus $G_{_{\partial}}$, kN								
5,0-10		-	-	-	2,1	2,2	2,3	2,35	2,45
6-16		-	-	-	3,4	3,55	3,7	3,8	3,9
6,5-16		-	-	-	3,9	4,05	4,2	4,35	4,5
7,5-20		-	-	-	5,9	6,1	6,3	6,6	6,8
8,25-15			-	-	7,95	8,25	8,5	8,8	9,15
9,5-32	6,90	7,30	7,70	8,0	8,4	8,85	9,05	9,4	9,7
9-16	-	-	-	-	8,5	8,85	9,5	9,8	10,45
12-16	-	-	-	-	12,0	12,6	13,0	13,5	14,0
15,5-18	-	-	-	-	13,6	13,9	14,8	15,4	16,4

It has been established that any tire will better satisfy the achievement of permissible wheel pressure on the ground *P,* if the air pressure in the tire is low. After the previous choice of tires, under its designation in the table. 2 linear sizes are selected: outer diameter D_k and width of the tire $e_{_{Ш}}$. After that, it is checked whether the selected tires are provided to the given ecologically permissible pressure on the soil, using the formula

$$G_{_{\partial}} = 0,12 \pi P_{_{Ш}} P^2 e_{_{Ш}}^2 D_{_{к}}^2 / \left(\pi^2 P_{_{Ш}}^2 \sqrt{e_{_{Ш}} D_{_{к}}^3} + 4 p^2 \sqrt{D_{_{к}} e_{_{Ш}}^3}\right), \quad (4)$$

where $P_{_{Ш}}$ – tire pressure, MPa (Table 1);

P – permissible wheel pressure on the ground, MPa [3];

$e_{_{Ш}}$ – width of the tire (for cars working in intermediate rows, the width of the tire must be less than the width of the row), cm (Table 2);

$D_{_{к}}$ – external diameter, cm (Table 2) ;

In tabl. 1 shows only data for air pressure in the chamber up to 0,2 MPa. Tires with pressures greater than 0,2 MPa are not recommended for use on field machines

Table 2
Characteristics of tires for agricultural machines

Brief descript-tion	Brief description			
	Model	Outer diameter $D_{_{к}}$, cm	Tire width $e_{_{Ш}}$, cm	Mass, kg
5,0-10	В-107	51,0	14,0	6,5
6-16	Л-225	75,0	17,5	17,5
6,5-16	Я-275Л	77,8	18,5	25
7,5-20	В-103	91,0	20,5	33
8,25-15	И-83	83,2	22,0	30
9,5-32	В-110	124,0	24,0	50
9-16	Я-324А	89,6	25,5	41
12-16	Л-163	93,0	32,5	44
15,5-18	КФ-105А	98,0	39,5	75

If after the calculations

$$G_{_{\partial}} < G_1, \; G_{_{\partial}} < G_2 , \qquad (5)$$

then it is necessary to choose the bus with other parameters; and if the tire could provide a condition

$$G_{_{\partial}} \geq G_{1,2} , \qquad (6)$$

it is impossible to pick up, the wheel must be taken with twin tires. In this case, the number of tires for the wheel is determined from the ratio

$$Z = \frac{G_{1,2}}{G_{_{\partial}}} . \qquad (7)$$

Then repeat the same calculations for the second scheme of the wheel drive of the car. The numbers for the tire, for example, 5.0-10, reflect: the first figure is the width of the profile of the tire in inches, the second is the tire's diameter on the disc in inches.

As an example, according to such an algorithm, students of the 3rd year of specialty 208 "Agroengineering" conduct substantiation of parameters and choice of tires, performing course work on the discipline "agricultural machines".

During the study in the magistracy, future specialists in agroengineering conduct theoretical and experimental research at a higher scientific level. Let's give an example of conducting such researches for wheels of agricultural machines during their movement in the field.

The processes of interaction of running systems with the soil depend on its mechanical properties, that is, resistance, deformation and destruction. A large amount of experimental data on the patterns of deformation and destruction of soil has been accumulated. But they are of a different nature due to the diversity of soil types, conditions and methods of measurement, and the lack of standardized methods for the integrated assessment of mechanical properties. The use of this data to develop methods for forecasting mechanical properties is not possible. This is due to the large number of proposed empirical formulas and models of deformation of soil [15].

In order to evaluate the interaction of the running system with the soil, the regularity of its compression and displacement is used, which implies the processes of formation of the trace (track) and traction (traction) formation. These patterns are determined by the corresponding displacement of the deformers (dies).

The diagram of the interaction of the rigid wheel with the soil during rolling in a driven mode is shown in Figure 1.
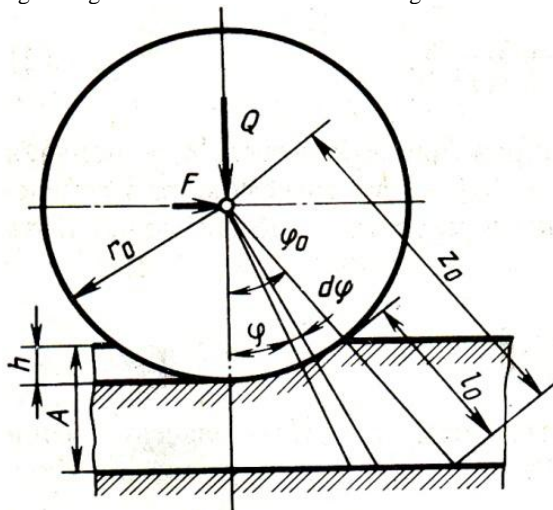

Fig. 1. The scheme of deformation of the soil [15]

Observations show that the deformation of the soil by a moving wheel at different time points extends predominantly to the normal to the rim. Accordingly, the relative deformation ϵ and the rate of deformation $\dot\epsilon$, elemental volumes in the sectors corresponding to the corners, $d\varphi$ to which all its array is divided into angles $\varphi°$ contact and thickness A of the active layer (deformed) can be represented as follows [15]:

$$\epsilon = \frac{z_0}{l_0}\left(1 - \frac{\cos\varphi 0}{\sin\varphi}\right); \qquad (8)$$

$$\dot\epsilon = -\omega\frac{z_0}{l_0}\cos\varphi°\left(\frac{\sin\varphi}{\cos^2\varphi}\right), \qquad (9)$$

where z_0 i l_0 – the dimensions are shown in the diagram; φ – the value of the contact angle; ω – angle of rotation of the wheel.

Normal wheel load Q and longitudinal strength F, necessary to overcome the rolling resistance, due to the processes of interaction of the wheel with the soil, are equal to the sum of the normal and tangential elementary soil reactions

$$Q = \int_0^{\varphi 0}\sigma\cos\varphi Br_0\,d\varphi\,; F = \int_0^{\varphi 0}\sigma\sin\varphi Br_0\,d\varphi\,,$$

where σ – contact voltage (elementary soil reaction)
B and r_0 – contact width and wheel radius.

To solve these equations, it is necessary to use the analytical relationship between voltage and deformation.

The deformation of the soil (its elementary volumes) is completely reflected in the Kelvin model, to which the rheological equation corresponds:

$$\sigma = E_2(\epsilon + \acute\tau\,\dot\epsilon), \qquad (10)$$

where E_2 − deformation module; $\acute\tau$ – time after action

(viscosity ratio μ_2 to the deformation module) $\left(\acute\tau = \dfrac{\mu_2}{E_2}\right)$

Pattern of propagation resistance σ_z in depth z in the direction of force P Bussinesca formula is displayed [15]:

$$\sigma_z = KP/z^2, \qquad (11)$$

where K − dimensionless multiplier.

To determine the effect of the solid reinforcing layer on the nature of the propagation resistance used correction coefficient.

Also (using coefficients) the Bussineska formulas are corrected with the aim of approximation of the calculated patterns of propagation of resistance in soft soils to real

Deformation of pneumatic tires and soils adequately reflects the three- and two-element rheological models, respectively. Using the scheme of interaction of the elastic wheel with the soil and the selected rheological models of contacting bodies, we find an analytical description of the processes of simultaneous deformation at wheel rolling. For this, the elementary sector of the scheme of interaction (Fig. 2) will be presented in the form of sequentially placed models of pneumatic tires and soil.
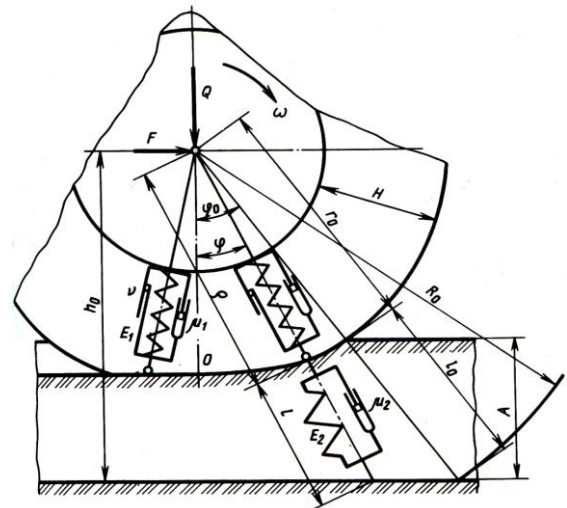

Fig 2. Interaction of rheological models of tires and soil [15].

Determine what changes occur with the models when rolling the wheel on the ground. If time t deduct from the moment when $\varphi = \varphi_0$, then on the front of the contact $\varphi = \varphi_0 - \omega t$, − and on the back − $\varphi = \omega t - \varphi_0 = -(\varphi_0 - \omega t)$. Then for any t within the angles of contact, the following relationship is valid [15]:

$$\Delta\rho + \Delta l = \Delta R; \qquad (12)$$

$$\frac{d\rho}{dt} + \frac{dl}{dt} = \frac{dl}{dt}; \qquad (13)$$

$$\epsilon_1 E_1 \pm \dot\epsilon_1\mu_1 \pm \nu E_1 sgn\epsilon_1 = \epsilon_2 E_2 \pm \dot\epsilon_2\mu_2; \qquad (14)$$

$$R_0\cos\varphi_0 = R\cos(\varphi_0 - \omega t), \qquad (15)$$

where ρ, l i R_0 − the sizes are shown in fig. 2, and $R = \rho + l$. Indices 1 with designations indicate that they belong to the tire, and 2 to the ground. The "plus" signs correspond to the front of the contact, and the "minus" is the rear.

The equation of correlation with respect to deformations and their velocities is obtained after the time division of expressions (12) and (13) into a product Hl_0R_0, where H – tire profile height l_0 and R_0 – initial values of sizes R and l.

Can be recorded [15]

$$\epsilon_2 = \frac{\Delta R - \epsilon_1 H}{l_0}; \;\; \dot\epsilon_2 = \frac{\frac{dR}{dt} - \dot\epsilon_1 H}{l_0}. \qquad (16)$$

Value ΔR and $\frac{dR}{dt}$ can be found from equation (15), ie

$$\Delta R = R_0 \left(1 - \frac{\cos \varphi_0}{\cos(\varphi_0 - \omega t)} \right);$$

$$\frac{dR}{dt} = -\omega R_0 \cos \varphi_0 \frac{\sin(\varphi_0 - \omega t)}{\cos^2(\varphi_0 - \omega t)}.$$

After substitution, expression (14) values ϵ_2 and $\dot{\epsilon}_2$, represented by the calculation of formulas for ΔR and $\frac{dR}{dt}$, we obtain the differential equation of the interaction of the elastic wheel with the ground

$$\pm \dot{\epsilon}_1 \left(\mu_1 + \frac{H}{l_0} \mu_2 \right) + \epsilon_1 \left(E_1 + \frac{H}{l_0} E_2 \right)$$

$$= \frac{R_0}{l_0} E_2 \pm v E_1 sgn\epsilon_1 - \frac{R_0}{l_0} E_2 \cos \varphi_0 \frac{1}{\cos(\varphi_0 - \omega t)}$$

$$\pm \frac{R_0}{l_0} \mu_2 \omega \cos \varphi_0 \frac{\sin(\varphi_0 - \omega t)}{\cos^2(\varphi_0 - \omega t)}. \qquad (17)$$

This equation does not have an exact solution, since integrals are not expressed through elementary functions. Numerous methods of integration and grounds for using Taylor series are used for it. These methods do not allow (the second because it is large) to add elementary soil reactions to represent the forces acting on the wheel in the analytical form.

After conducting such an example of theoretical studies, graduates begin to create a laboratory installation and conduct experimental research in laboratory or field conditions.

As a result of scientific research, a pedagogical system was developed, basing on the example of the interaction of the supporting and moving elements of machine-tractor units with soil and on the consistent study of topical production issues, contributes to the improvement of the quality of training and the development of design competencies of the agroengineer.

Results and discussion. The developed innovative system of scientific and methodological training of future specialists is based on a planned, cross-cutting, step-by-step growth of knowledge, skills and abilities of future agroengineering. Course designing and master's work provide a qualitative growth in the design competencies of the graduate.

Conclusion. The obtained results of the conducted research give grounds to conclude that an effective process of formation of readiness for the project activity of future specialists in agroengineering is possible on the basis of cross-cutting innovative teaching technologies. Coursework and master's work contribute to the development of scientific activities. It is important that they have practical orientation, since this will substantially motivate the students to complete them.

References

1. Law of Ukraine "On education" from 01.07.2014, № 1556-VII / Newspaper "Voice of Ukraine" dated 08.06.2014. − № 148.

2. The standard of higher education of Ukraine is the first (Bachelor) level of education in higher education − bachelor, field of knowledge − 20 Agrarian sciences and food specialties - 208 Agroengineering // Approved and put into effect by order of the Ministry of Education and Science of Ukraine dated 12/5/2012, No. 1340. − Access mode: https://mon.gov.ua/storage/app/media/vishcha-osvita/zatverdzeni%20standarty/12/21/208-agroinzheneriya-bakalavr.

3. Designing agricultural machines. Tutorial / I.M. Bendera, A.V. Rud, Ya.V. Koziy and others; ed. I.M. Bendery, A.V. Rudia, Ya.V. Kozia − Kamyanets-Podilsky: FOP Sysin O. V., 2010. − 640 pp

4. Pryshliak Viktor. Role of project preparation in formation professional competence of future specialists in agroengineering / Viktor Pryshliak // TRANS MOTAUTO WORLD: International scientific journal. − Sofia, Bulgaria: trans & MOTAUTO WORLD, YEAR II, ISSUE 4/2017. − 162-165, ISSN PRINT 2367-8399, ISSN WEB 2534-8493.

5. Pryshliak Viktor. Theory of project preparation of agroengineers on the basis of scientific work on the development of agricultural machinery / Viktor Pryshliak // SCIENCE. BUSINESS. SOCIETY: International scientific journal. − Sofia, Bulgaria: Scientific-technical union of mechanical engineering "Industry 4,0", National society «Industrial & national security», YEAR 3, ISSUE 4/2018. − 145-149, ISSN PRINT 2367-8380, ISSN WEB 2534-8485.

6. Brukhanova N.O. Theory and methods of system design teacher training future engineers-teachers: Dis. … Dr. ped. Sciences: 13.00.04 – Kharkiv, 2011. − 594.

7. Kolesnikova I.A., Gorchakova-Sibirskaya M.P. Pedagogical designing. − Moscow: Academy, 2007. − 288.

8. Designing the process of professional training in vocational education institutions: monograph / [N.G. Nichkalo, IA Zazyun, S.U. Goncharenko and others.]: Ed. N.G. Nobody. – K. − Khmelnytsky: KhNU, 2010. – 335 p.

9. Bendera I.N. Full-time course and diploma designing − a way to enhance the independent work of students of agrarian-engineering specialties / Ivan Bender, Wojciech Tanas / Problemy inzynierss rolnitsz w aspekcie rolnictwa zrownowazonego. – Lublin, 2005. – P. 180-192.

10. Graduate design in higher educational institutions of the Ministry of Agrarian Policy of Ukraine: teaching method. manual / [I.M. Bendera, O.V. Datsishin, O.V. Korolchuk et al.]; for ed. T.D. Ishchenko, I.M. Bendery. − K.: Agrarian Education, 2006. − 256 pp.

11. Bendera I.M. The theory and method of independent work of future specialists in agricultural mechanization in higher education: Dis. ... Dr. ped. Sciences: 13.00.04 − K., 2008. − 579.

12. Duganets V.I. Theory and practice of production training of future specialists in agrarian-engineering direction: diss. ... doc. ped Sciences: 13.00.04 / Duganets Viktor Ivanovich. - Kamenets-Podilsky, 2015 − 501.

13. Pryshliak Viktor. Method of projects in the theory learning of a future agricultural engineer / Viktor Pryshliak // TRANS MOTAUTO WORLD: International scientific journal. − Sofia, Bulgaria: trans & MOTAUTO WORLD, YEAR I, ISSUE 4/2016. – 39-41, ISSN 2367

14. Transformation independent learning activities in readiness for professional self-development by means of personal technology based learning: Monograph / M.M. Bondar, L.M. Zhuravska, E.A. Ostapenko, V.M. Pryshlyak, A.G. Kutsenko. − Nizhin: LLC "Publishing" Aspect-Polygraph", 2016. − 760.

15. Vodyanik I.I. Processes of interaction of tractor running systems with soil. − Chisinau, 1987. − 63 p.

16. Vodyanik I.I. Ways of reducing the harmful effects of ITS running systems on soil in the conditions of the Southwest of Ukraine. − Chisinau, 1987. − 63 p.

17. Vodyanik I.I. // Operational properties of tractors and cars. − Kyiv: Harvest, 1994. −220 p.

18. Alixeychuk N.A., Budko Yu.V., Terekhov B.A. // Increase of permeability of agricultural machines. − Minsk: Harvest, 1979. −135 p.

19. Bekin N.G., Petrov B.M. Equipment for manufacturing pneumatic tires. − M.: Kolos. – 1998. − 479 p.

20. Gavrilov B.G. Tire production. − M.: Kolos. − 1998 − 379 p.