SOIL AND WATER RESOURCES AS IMPORTANT OBJECTS AND PREREQUISITES FOR THE DESIGN OF AGRICULTURAL MACHINES AND THE FORMATION OF PROFESSIONAL COMPETENCIES OF AN AGRICULTURAL ENGINEER

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Summary. *The scientific, technical and pedagogical bases of studying issues of soil and water protection by future specialists in agro-engineering in of higher education institutions are presented. Some concepts and categories that are used in the educational process for students to study agricultural land reclamation machinery and equipment are analyzed. Depending on the purpose, tasks, techniques of technological processes, the types of land reclamation measures are distinguished. The example of calculation of working bodies of earth-moving reclamation machines is given. According to the developed innovative studying technologies, students first study and analyze the state of agricultural production, identify the disadvantages of technological processes, the level of technical support, and then, using mathematical apparatus, methods of engineering calculations design and construct a reclamation machine. The methodological features of calculating the power balance of the earth-moving reclamation machine, which includes the power required to: isolate the material to be processed, taking into account its deformation, are theoretically described; the movement of the material being treated, that is, providing it with kinetic energy; lifting of the processed material; overcoming the friction resistance of the treated material against the surface of the working body and guide surfaces; overcoming the full resistance of the movement of the machine, taking into account the slope of the surface of the movement to the horizon; overcoming the propulsion of the propulsion; acceleration of the machine to the calculated speed of movement (overcoming the forces of inertia); drive conveyors and accessories. The developed procedure of laboratory and practical work includes the study of the methods and features of the calculation of balance capacity components of reclamation machines, taking into account such indicators as the type of soil, its density, thickness of layer, productivity, kinematics of the working body, the required lifting height, etc. The lecturer must draw up a general report on the theoretical and practical part of the laboratory and practical work in accordance with his task and protect it from the faculty of the department. The developed pedagogical technology of cross training emphasizes that soil and water resources are important objects and prerequisites for the development of agricultural machines and the formation of design competencies of agricultural engineers.*

KEYWORDS: *AGROENGINEERING, TECHNOLOGICAL PROCESS, TECHNOLOGY TRAINING, METHODOLOGY, SOIL, WATER RESOURCES, DESIGN, AGRICULTURAL MACHINERY, POWER, SOIL PROTECTION.*

1. Introduction

Ukraine's land and water resources are diverse. Features of their effective use in agro-industrial production, conservation and multiplication are studied by future specialists in agro-engineering during the whole period of studding: lectures, laboratory-practical classes, educational and industrial practices, course and diploma design. Land reclamation is the science of ways and methods of improving land in order to increase their fertility and create the optimal regime for the growth and development of agricultural plants [1]. One of the main reasons for the lack of development of the reclamation complex in Ukraine is the lack of highly qualified agricultural engineers. In this regard, it is necessary to carry out special pedagogical and technical research aimed at developing methodological support of the educational process, improving its quality, development of professional competencies [2] of agricultural engineers. Developed pedagogical technology should provide for the throughput of the educational process in the study of soil and water resources, their protection and conservation [3, 4].

2. Prerequisites and means for solving the problem

Modern pedagogical technologies for the preparation of future agro-engineers involve studying the problematic issues of soil and water protection. As stated in [4], students study these topical issues systematically and consistently throughout the study period. At lectures, students receive information about the general theoretical features of the use of soil and water resources in agro-industrial production, and in practical and laboratory classes they investigate the mechanical and technological properties of soils, the interaction with them of working bodies of agricultural machines.

In the project activity of students, during the implementation of course and diploma projects for the initial parameters during the design of soil-cultivation equipment take agrochemical, mechanical-technological and other characteristics of soil. Agrochemical properties of soils that students study are the content of humus, nitrogen, phosphorus, potassium, soil acidity. Physico-mechanical properties of soils, which are determined during laboratory work or used in the design activity, are the soil mass, angles of internal and external friction, particle size, maximum bearing capacity, modulus of elasticity, humidity, etc. [5]. The purpose of laboratory and practical work is to broaden and deepen the students' knowledge of the basics of theory, calculation and design of agricultural machines, development of visual ideas on the basic theoretical provisions of the course on the interaction of working bodies of machines with soil, irrigation systems of land irrigation and more. The purpose of course work on agricultural machines is the technological development of the design of the machine or its components or the improvement of existing means of mechanization [6].

Future agricultural engineers should have a general understanding of erosion processes and prevent them from occurring. For example, soil erosion is the separation and movement of the upper most fertile soil layers from one place to another under the influence of water or wind. The process of water erosion consists of three steps: 1) separation of soil particles; 2) soil transfer – movement of soil particles from the site of erosion; 3) deposition of soil particles in a new place. Water erosion is appearing mostly when the effect of rain is exacerbated by the action of water flows: rain drops are separated by soil particles, and their flows are swept away [6].

Many scientific conferences have addressed the issue of soil and water protection. For example, at the II International Scientific Conference "Protection of Soils and Water Resources", the report was presented − «The main components of studies and research of conserving soils and water in technologies of agroengineers training" [8]. This report partially discloses the scientific and methodological bases for soil and water exploration by future specialists in agroengineering in higher education institutions. Innovative pedagogical technology of development of project activity is developed in the form of a method of a consistent cross study of the material based on the objective relationship of disciplines and provides a qualitatively higher level of formation of professional competencies of agroengineers on the basis of preservation and even multiplication of natural resources. The report of [8] states that the current issues of soil science are devoted to many works by well-known scholars, for example, P. Zaicka [9], M. Manojlovič [10], R. Meissner [11] and others. A particularly important scientific and production problem is the optimization of the nutrient and water regimes of the soil on the slopes. A number of scientific works are devoted to the features of soil preparation for sowing crops on sloping lands, optimization and management of technological processes in these conditions [1, 7, 9, 12, 13].

The role of science in the educational process is growing significantly. Classical, practically oriented, as well as the most modern developments of scientists in the form of didactic materials are covered in textbooks, manuals, methodological developments and are used in the educational process of agricultural engineering. It is worth to mention that due to the considerable scientific contribution of scientists, agroengineering pedagogical science and educational practice have great achievements. Significant contribution to the development of the theory and methods of vocational education were done by I. Bendera [14], V. Duganets [15], V. Man`ko [16] and other.

These accents of scientific problems are prerequisites for solving urgent problems of soil and water conservation in pedagogical technologies for the formation of professional competencies of future agricultural engineers in higher educational institutions.

3. Results and discussion

Soil is the basic means of agricultural production. Samples are taken for soil analysis. From the conducted analyzes it is possible to obtain information on: the structure of the soil and the shape of its solids; soil type, density, humidity, crushing coefficient, etc. To a certain extent, this helps to find the optimal technology of tillage and restoration of soil and the necessary equipment for carrying out technological operations. Type, soil structure, its porosity play a decisive role in plant development and crop productivity. With the optimal soil condition, fertilizer efficiency is high. For experienced farmers, along with laboratory chemical analyzes, visual assessment of soil condition is of great importance. In the study of the soil, it is necessary to pay attention to many indicators, including even the plow sole, the depth of its occurrence, how the residual residues in the soil were placed evenly, whether a layer of residues was created at the bottom of the plow layer.

Students know that plowing is done with the purpose of deep loosening of the soil, earning organic and mineral fertilizers, crop residues and weeds, creating conditions for improvement of the water-air and nutritional regimes of the soil and qualitative carrying out of the following field works. Thus, deep plowing is carried out 21-25 days after the last harrowing or application of herbicides. To ensure good plowing and reduce energy costs, for example, it is advisable to use reversible plows under sugar beets. In the presence of a large number of plant residues, it is better to plow the PIA-3-35 tiered plows. This layer-by-fall cultivation ensures maximum weeding and plowing of crop residues. In the unit with the plow in dry weather, especially in the formation of boulders, annular-spur rollers are used, and on wet soils and for qualitative development of the topsoil-harrows. As it rains and weeds sprout, the field is cultivated. Plowing is carried out at the speed of the unit up to 7 km/h.

High quality of educational process is achieved when students carry out research, engineering and technological calculations. Here is an example of a laboratory work to determine the hardness and coefficient of volumetric soil [17].

The purpose of this laboratory work is to consolidate and expand the knowledge of the technological properties of the soil by analyzing theory, conducting experimental studies in laboratory or field conditions, processing the data obtained and analyzing the results [18].

Devices and equipment: spring hardness tester (Fig. 1), 2 paper strips of millimeter or blank paper of size 70 x 500 mm (you can use 2 sheets of notebook paper, joined together), impact hardness tester, various soil samples to study their properties in laboratory conditions (2 variants), the device for experimental determination of angles and calculation of coefficients of external friction of the soil.

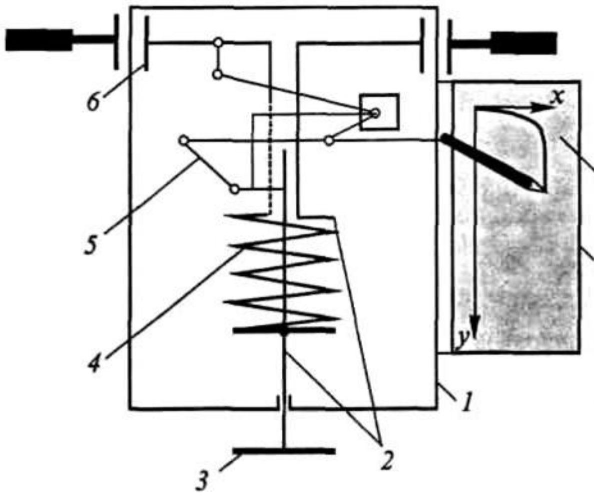

Fig. 1. *− Scheme of the tip [17]*

The students are then introduced to the theoretical part of the work. Here are some steps for example.

An indicator of soil resistance to bending is the average soil hardness. Soil hardness is measured with hardness gauge. When inserting a hard tip into the soil, a diagram is drawn (Fig. 2).

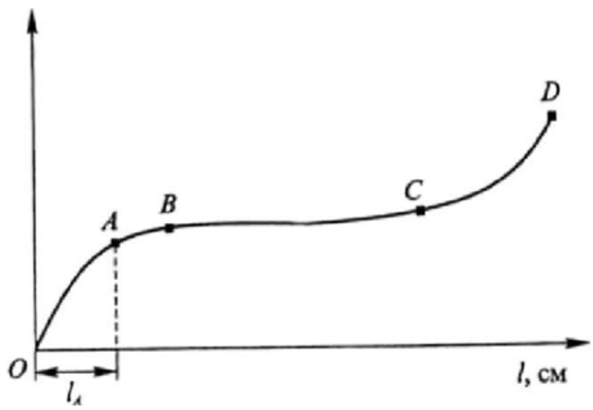

Fig. 2. *– Diagram of soil determination by the tip[17]*

There are several phases in the diagram. During the first phase (section OA), the deformation resistance increases in proportion to the depth of the tip into the ground. The second phase of AB is transitional. During this period, the cone-shaped growth from a strongly compacted soil (compacted core) is formed in front of the base of the tip. In the third phase (section of the BC), the soil is deformed by a conical outgrowth that spreads it, shifting to the sides and encountering constant resistance (ground "flowing"). The first phase is several times shorter than the third, but it is of great practical importance, since the deformation of the soil by agricultural machinery does not usually extend beyond the first section of the diagram. Only after passing the tip of the plow layer, the CD curve rises upward as a denser "plow sole" is encountered along its path.

After getting acquainted with the order of work, students perform it, draw up a report and protect [17, 18].

After studying the mechanical and technological properties of the soil, students make engineering, technological and energy calculations. As an example, we will partly consider the laboratory-practical work "Calculation of the working parameters of earth-moving reclamation machines", performed by students of specialty 208 "Agroengineering", during the study of machinery and equipment in agricultural land reclamation [1]. Purpose is to study the general methods of calculating the basic parameters of the working bodies of reclamation machines, the calculation of the balance of power; traction calculation; basics of dynamic calculation; determination of external forces and reactions acting on the machine in working order; static calculation; determination of productivity of reclamation machines with working bodies of different types.

Consider the features of calculating the power balance of reclamation machines.

Power balance is calculated at maximum workload.

The drive power of any reclamation machine with single-engine drive N' is determined by the formula, kW[1]:

$$N' = \frac{(N_d + N_{accl} + N_l + N_{fr})}{\eta_{wb}\eta_p} + \frac{(N_m + N_{pr} + N_{acc})}{\eta_m} + \frac{N_t}{\eta_t} + \frac{N_{ad}}{\eta_{ad}} = \frac{N_{wb}}{\eta_{wb}\eta_p} + \frac{N_m}{\eta_m} + \frac{N_t}{\eta_t} + \frac{N_{ad}}{\eta_{ad}}, \quad (1)$$

where N_d – the power required to separate the workpiece, taking into account its deformation; N_{accl} – the power required to accelerate the material to be treated, that is, to provide it with kinetic energy; N_l – the power required to lift the workpiece; N_{fr} – the power required to overcome the friction resistance of the workpiece material against the surface of the working body and guide surfaces; N_m – traction power; N_{pr} – the power required to overcome the propulsion; N_{acc} – power required to accelerate the machine to the estimated speed; N_t – the power required to drive the transporting organs that move the processed material beyond the transport of it directly by the main working body; N_{ad} – total power to drive additional devices that ensure the functioning of the working body; η_{wb} – the efficiency of the working body; η_{wb} – efficiency mechanisms of drive of the working body; η_m – efficiency movement; η_t – efficiency transport body; η_{ad} – efficiency additional devices; N_{wb} – total power to drive the active working body; N_m – total power to move the machine.

Taking into account the oscillatory nature of the torque and the active forces of the engine N_e for preliminary calculation take with the factor of reserve of power k_{res} = 1,2…1,4 by the formula, kW [1]:

$$N_e = k_{res} N'. \quad (2)$$

According to formulas (1) and (2) the engine power of any reclamation machine with a single-motor drive can be calculated taking into account the peculiarities of its operations, the material being processed, the number and type of working and transporting bodies.

Formula (1) in its entirety is used to calculate the balance of power of machines with one-motor drive and active working bodies having the above transporting and auxiliary devices.

For machines with passive working bodies in which the bulk of the power is used to overcome traction resistance, N_{wb} = 0 and for machines with passive working bodies in which the bulk of the power is used to overcome traction resistance, N_m.

If the working body is combined, that is, consists of several simultaneously working active or active and passive working bodies, then the corresponding capacity is calculated for each of the working bodies and summed up.

For machines with multi-motor electric or diesel-electric drives, the required power of the individual engines is also determined by formulas (1) and (2), and after selecting the engines, the total installed power of the machine N_{in} are summed up:

$$N_{in} = k_{res} \sum N_i, \quad (3)$$

where N_i − engine power required to drive individual mechanisms, kW.

Consider common ways to determine the components of the balance of power on the example of the most common excavation machines.

The approximate capacity for digging the soil N_d (kW) (see formula (1)) determine, based on the known formula V.P. Goryachkin and the works of N.G. Dombrovsky for the total tangent component of the soil response to the working body, kN:

$$\sum R'_d = 10^3 k \sum b_i\,\delta_i = 10^3 k \sum S_i, \quad (4)$$

where k − specific digging resistance, MPa; b_i − layer width (m); δ_i – thickness (m) of layer; S_i − the area of the sliced layer (m^2).

Refined calculation $\Sigma R'_d$ can be carried out by methods known from the theory of soil cutting according to the formulas A.N. Zelenina, D.I. Fedorova, Yu.A. Vetrova and others.

By multiplying both parts of formula (4) by the length of the path of the digging organ, $l = \Sigma l_i$, where l − the length of individual sections of the path, and dividing by the time of digging t, we get:

$$\sum R'_d \frac{l}{t} = k \sum \frac{b_i\,\delta_i\,l_i}{10^3 t}. \quad (5)$$

The left side of the formula is a unit of time, that is, power N_d (kW), and the right − the product of specific resistance to digging k for volumetric performance $\Pi_т$ (m^3/h):

$$N_к \cong \frac{k\Pi_т}{3{,}6}; \text{ and } N_d = \sum R'_d\,v, \quad (6)$$

where v – speed of the working body, m/s.

Formulas (6) give sufficient accuracy for technical calculations (10 ... 15%).

Specific resistance to digging k depends on many factors and is not a soil constant. If k is not defined for the respective working bodies, it is possible to temporarily use the values obtained for the excavators (Table 1). When working with soil collapse, the average values k reduced by 25 ... 40%.

Much of the reclamation machines with active working bodies are digging the soil with shavings of smaller thickness, which increase the crushing of the soil, the relative area of propagation of deformation and the volume of deformed soil in relation to the volume of shavings. Therefore, resistance to digging k (MPa) increases sharply under the hyperbolic law:

Table 1: *Average values of specific resistance to digging*

Group of soils	1	2	3	4
Number of strokes, C_{str}	1…4	5…8	9…15	16…34
Specific resistance to digging k, MPa	0,012…0,065	0,058…0,13	0,12…0,2	0,18…0,3

$$k = (0{,}11\ldots0{,}12)\frac{C_{уд}}{\delta^{\varepsilon}}, \quad (7)$$

where C_{str} − the index (number of strokes) of the densimeter characterizing the properties and condition of the soil; δ − the thickness of the sliced layer (cm); ε − an indicator of the degree depending on the type of soil for minerals ε = 0,4, for marsh peatlands ε = 0,33.

According to the experimental data, the specific soil resistance to digging [1]:

$$k = k_1\left(\frac{\delta_1}{\delta}\right)^{\varepsilon} k_{\psi}\,k_в\,k_{\alpha}\,k_г, \quad (8)$$

where k_1 − the overall coefficient of resistance to the shavings thickness δ_1 equal to 1 cm; δ − the actual thickness of the layer (cm), k_{ψ} − coefficient depending on cutting angle ψ; k_w − a factor that depends on the width of the grip b; k_{α} − coefficient depending on the angle of capture α; k_{str} − coefficient that depends on the number of strokes of the solid meter C_{str}.

Power required to accelerate the soil N_{accl} (kW), is defined as the increase in kinetic energy that characterizes the second-hand operation of soil acceleration by the formula [1]:

$$N_{accl} = \frac{mv^2}{2} - \frac{mv_{int}^2}{2} = \frac{\Pi_t \rho v_s^2}{2\cdot 3{,}6\cdot 10^6}, \quad (9)$$

where m − mass of the accelerated soil per hour, kg/h; v_s − soil speed, depending on the type and kinematics of the working body; v − finite velocity of soil particles, $v = v_s$; v_{int} − the initial velocity of the soil particles $v_{int} = 0$, m/s; Π_t − technical productivity, m³/h .; ρ − density of soil, kg/m³.

The power required to lift the soil N_l (kW), determined on the basis of lifting the volume of soil moved in one second, according to the formula [1]:

$$N_l = \frac{\Pi_t \gamma_g h_l}{3{,}6 \cdot 10^6}, \tag{10}$$

where h_l − required lifting height, m. Determined for each type of working body based on the construction profile.

Power required to overcome soil friction resistance against the surface of the working body, or the guide housing N_{fr}:(kW), found as a second operation on the friction surface length by the formula [1]:

$$N_{fr} = \frac{\Pi_t \gamma_s l_{fr} f_i}{3{,}6 \cdot 10^6}, \tag{11}$$

where l_{fr} − the length of the projection of the friction surface onto the displacement plane, m (determined based on kinematics and type of working body); f_i − coefficient of soil friction against the corresponding friction surface.

The power required to overcome the full resistance of the machine $N_м$, kW:

$$N_м = \frac{F' v_w}{3{,}6 \cdot 10^6}, \tag{12}$$

where F' – total traction resistance, kN; v_p – operating speed of the machine, m/h.

Power consumed by the propulsion N_p (kW), calculated by the formula [1]:

$$N_p = F'(v_p - v_{acct}) 3{,}6^{-1} \cdot 10^{-3} = F' v_p k_p 3{,}6^{-1} \cdot 10^{-3}, \tag{13}$$

where v_p − estimated working speed of the machine, m/h; v_{act} − actual operating speed of the machine, m/h; k_p – slip factor,%,

$$k_p = 100 \frac{(v_p - v_{acct})}{v_p}. \tag{14}$$

On mineral moist soils in normal operation of the caterpillar propulsion acceptable value k_p = 8...10%, on a crawler bog $k_p \le 15\%$, wheel drive k_p = 20...25%.

Power required to accelerate the machine (overcoming inertia forces) N_i (kW), are given by the formula [1]:

$$N_{acc} = F'_{res} v_w 3{,}6^{-1} \cdot 10^{-3} \cong x' G v_w^2 (g t_m 12{,}76)^{-1} \cdot 10^{-9}, \tag{15}$$

where F'_{res} − resistance from overcoming inertia forces during acceleration, N; v_p – operating speed, m/h.; x' − coefficient taking into account the inertia of the rotating masses of the transmission and the engine, x' = 1,1…1,3; G − machine weight, H; g − acceleration of free fall, m/s²; t_{accel} – acceleration time, t_{accel} = 3…4 c.

Power N_{tr} and N_{ed}, required for the drive of the transporting organs and additional devices are determined by known formulas depending on the type of these organs.

For indicative calculations [1]:

$$N_{tr} = x_0 10^{-2} (N_{wb} + N_m + N_t), \tag{16}$$

where x_0 = 5...7.

Specific power N_{spec}, per unit of output (kW/unit) is calculated by the formulas [1]:

$$N_{spec} = N_{eng} \Pi^{-1} \text{ or } N_{spec} = N_{in} \Pi^{-1}, \tag{17}$$

where Π − hourly performance in units of measurement of hourly performance.

The procedure for performing this laboratory-practical work is given in [1]. To do this, it is first necessary to read and summarize the basic theoretical provisions and definitions. To get acquainted in detail and to study the methodology and features of calculating the power balance of reclamation machines.

Students also do laboratory work to determine the moisture content of soils and other agricultural materials [19]. Here they learn that the humidity of various agricultural materials is determined in order to: characterize the working conditions of agricultural machines (humidity of air, soil, fertilizers, seeds, etc.); control the technological process performed by the machine (humidity of the coolant in the dryer, soil moisture in layers before and after the passage of the working body of the machine, the dynamics of humidity of agricultural material, etc.); to characterize the conditions of agricultural plant development. Humidity can be determined directly or indirectly. Direct measurements of soil moisture, seeds and some agricultural materials are carried out using special electrical appliances. This method is convenient because it does not take much time. However, often depending on the internal structure of the material and its condition, errors can occur, so such measurements should be resorted to only when high accuracy is not required.

Future agricultural engineers are also exploring agricultural irrigation machines. For example, they study the sprinklers, the algorithm for their calculation. Thus, the flow rate of the working fluid with one nozzle centrifugal type (Fig. 3) is determined by the formula:

$$Q = \frac{\alpha}{\sqrt{1 + A^2 \frac{\alpha^2}{1-\alpha^2}}} f_c \sqrt{2gH}\ ; \tag{18}$$

where $A = \dfrac{Rri}{r_0^2}$ − design characteristics of the nozzle.

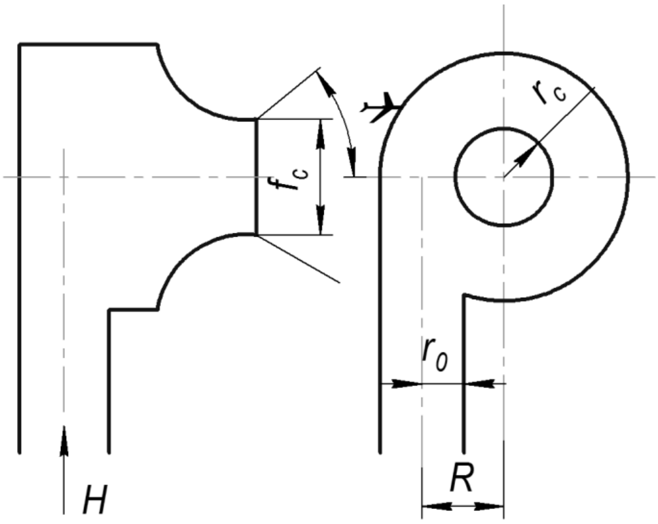

Fig. 3. *– The scheme of the centrifugal nozzle. [1]*

The dependence of the coefficient α from A determined according to the schedule (Fig. 4). Spray torch angle [1]:

$$tg\theta = \frac{2A\alpha}{1 + \sqrt{1-\alpha}}. \tag{19}$$

The flow rate of the spray nozzle with conical deflector is determined by the formula [1]:

$$Q = \mu f_0 \sqrt{2gH}.$$

Cost ratio μ depends on the contour of the inlet edges. For sharp edges μ = 0,7 ÷0,8, for the rounded ones μ = 0,9 The angle of the torch is equal to the angle of the cone 2θ.

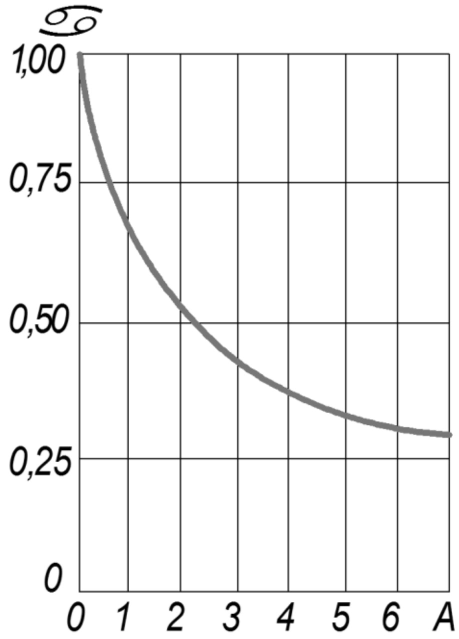

Fig. 4. − Dependency curve α from A for centrifugal nozzle

Knowledge gained by students in lectures and laboratory-practical classes is used during course and diploma design, research work. Here are urgent issues of soil protection and water resources.

4. *Conclusion*

In pedagogical technologies of formation of professional competencies of future agro-engineers in higher education agrarian institutions considerable attention is paid to the problematic issues of soil and water protection. During the educational process, students systematically and consistently study the mechanical and technological properties of soils as the main means of agro-industrial production. For the initial parameters in the project activity, soil characteristics are first and foremost taken into account, and their use presupposes fertility conservation. Some concepts and categories that are used in the educational process for students to study agricultural land reclamation machinery and equipment are analyzed. Depending on the purpose, tasks, techniques of technological processes, the types of land reclamation measures are distinguished. The example of calculation of working bodies of earth-moving reclamation machines is given. The methodological features of calculating the power balance of the earth-moving reclamation machine, which includes the power required to: isolate the material to be processed, taking into account its deformation, are theoretically described; the movement of the material being treated, that is, providing it with kinetic energy; lifting of the processed material; overcoming the friction resistance of the workpiece material on the surface of the working bodies and guide surfaces; overcoming the full resistance of the movement of the machine, taking into account the slope of the surface of the movement to the horizon; overcoming the propulsion; acceleration of the machine to the calculated speed of movement, such as overcoming the forces of inertia; drive conveyors and accessories. The developed procedure of laboratory and practical work includes the study of the methods and features of the calculation of components of the balance of the capacity of reclamation machines, taking into account such indicators as the type of soil, its density, thickness of layer, productivity, kinematics of the working body, the required lifting height, etc. In general, innovative pedagogical technology of cross training was developed, aimed at the formation of professional competencies of future agricultural engineers. Their activities will be successful if the soil and water resources are used effectively as important objects and prerequisites for agricultural machinery development.

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