Model of soil environment as object of mechanical tillage

S.N. Kapov[1], M.A. Aduov[2], S.A. Nukusheva[2]

[1]Stavropol State Agrarian University, Zootechnicheskiy str., 12, Stavropol city, Russia
[2]S. Seifullin Kazakh Agro Technical University, Zhenis avenue, 62, Astana city, Kazakhstan

Abstract. Today the foundation of soil treatment is to change its state by means of transferring of physical and mechanical properties of the initial state to the required one. Moreover, the transition process is carried out by simple mechanical impact of a deformer (working body), which is a solid body moving in the soil and disturbing its initial structure due to the interaction with it. As the result of processing is a non-equilibrium state of the soil, in any case, soil tillage is a process to feed it a certain amount of energy to change its properties and achievements in terms of agronomic science optimal addition, at which the maximum effect (e.g., crop yields) is obtained. Thus one of the objectives is to provide tillage supplying energy to the soil in a form and amount sequences that allow it to obtain the required condition, expending less energy as possible. It is desirable to form the energy input as low as possible "cheap", in terms of its availability.

[Kapov S.N., Aduov M.A., Nukusheva S.A. **Model of soil environment as object of mechanical tillage.** *Life Sci J* 2014;11(12s):156-161] (ISSN:1097-8135). http://www.lifesciencesite.com. 30

Keywords: soil environment, the theory of the soil, the strength characteristics of the soil environment, the stress-strain state, rheological model

Introduction

Charles Darwin wrote that land long had been preparing for the adoption of a person and in this respect it is strictly true, because man owes its existence to a long line of ancestors, and if there were any of the missing links in the chain, people would not have been those who it is. In other words, according to Darwin's theory of evolution, tools were perfected in accordance with the evolution of man [1, 2].

The history of human development, the formation of his mental and physical abilities are greatly indebted agricultural implements. Since the dawn of civilization, mankind is faced with the problem of soil treatment. From the time of "cane" agriculture, heavy physical labor forced a person to constantly monitor the process impact of the tool on the ground, to analyze it, look for ways to facilitate their work. Tillage at that time was to devote some physical work, i.e. to supply the processed layer a certain amount of energy to its disintegration. Further, the need for efficient use of energy supplied soil has forced people to look for new forms of tools: choppers (choppings), cutters, different hoes, plows, harrow - knotty (multistage log), wooden plows, further metal plows, etc., capable of more intensively act on the soil.

Evolution of agricultural tools was aimed at finding ways to reduce energy costs, which were estimated by quantitative physical energy costs and the volume of work performed. The whole history of tillage shows that man has always sought to bring a certain amount of energy (in the form of physical, thermal, mechanical work) to the treated layer in order to loosen it, i.e. to change its state. This is explained by the fact that the resulting processing becomes a non- equilibrium state of the soil, although after cessation of exposure to the soil (after a certain period of time) occurring in the treated layer of physical, chemical, biological and other processes to restore the original balance. Therefore, the need to maintain a non-equilibrium state of the soil (optimal addition of topsoil) is explained by the need to create conditions for the development of non-existent in the state of such forms of plants that we consider cultural.

And today the basis of tillage is to change its state by transferring the physical and mechanical properties of the initial state to the desired result. Moreover, the transition process is carried out by simple mechanical impact of a deformer (working body), which is a solid body moving in the soil and disturbing its initial structure due to the interaction with it. As the result of processing is a non-equilibrium state of the soil, in any case, the processing of soil is a process to feed it a certain amount of energy to change its properties and achievements in terms of agronomic science optimal addition at which the maximum effect (e.g., crop yields) is obtained [3, 4].

Research methods

An important condition for the development of tillage equipment model is the soil environment as the object of mechanical tillage. The process of interaction of working bodies and tools with soil medium is the basis of the theory of tillage. And the establishment of working bodies and instruments should be based on theoretical mappings processes occurring in the soil, based on the properties of its models rationally chosen and described by mathematical relations [5].

Applied to the theory of tillage it should be identified a number of important issues without which the further development of agricultural science is inconceivable. Theory should first answer the question of what it represents and what its soil physical foundations of destruction; secondly, to give advice on how to describe the phenomena occurring in the process of destruction, including engineering calculation methods; thirdly, to offer methods and techniques for different models of soil with a given level of physical and mechanical properties.

To solve the first problem is to define the notion “soil”. On the one hand, the soil is a discrete, multi-phase medium characterized by composition, multilevel structure and physical- mechanical properties [6, 7, 8]; on the other hand, it is a medium capable of sensing and transmitting the mechanical impact of the deformer. [9] Soil scientists still defend the idea that the soil is the "special body of the nature," which is impossible to apply the theoretical methods for the study of deformation and fracture, not to mention the mathematical methods of describing the structure of the soil. For this reason the soil as an object of machining is some medium with a wide range of physical - mechanical properties. The diversity and volatility properties of the soil are the reason that there are so many different models.

In our opinion, soil science and tillage, studying the same physical object from different points of view, should receive the results that complement each other, revealing new patterns, deepening our knowledge of the soil. Obviously, major role here are to play physics of the soil, mechanics of soil disaggregation materials, mathematical methods for describing processes, etc. Learning the basics of the deformation and fracture of the soil, it must be based on the physical structure and the actual processes occurring in the soil under the influence of deformers, and on their basis to set schemes, the criteria and the basic principles on which the model and theory of tillage should be built.

The most difficult situation is with the second problem. Here we distinguish two aspects: the physical and mechanical. The physical aspect of the phenomena occurring in the soil, in its analytic representation aims to analyze various "elementary" acts of deformation and fracture without serious claim to enter the engineering level calculation. On the other hand, in the mechanics of deformable media the engineering aspect of the problem without significant claims to take into account all the phenomena of the physical plane are considered to be the primary purpose. Moreover, methodological principles underlying the construction of the equations of mechanics, in some cases impede consistent integration of the physical processes of deformation and fracture. Similarly, physical methods of forecasting are difficult to distribute in the sphere of computing engineering.

Combining the ideas of soil physics and mechanics media is hindered by a number of fundamental circumstances. It is known that the theoretical model building requires the use of soils of different hypotheses and assumptions. Usually laws deformation environments based on the level of describing the properties of the methods of continuum mechanics, i.e. at the macro level. At the same time, the soil itself, as a discrete environment, is characterized by a multi-level structure (molecular ion level, the level of elementary particles, aggregate (micro and macro) level, etc.). The task of soil physics in this case consists in the construction, more in the description of its physical structure. This takes into account only the specific physical mechanisms of the phenomena occurring in the soil, and their influence on the properties of the structural organization. It is natural, in such a situation to develop the theory of tillage should be based on real physical processes and at the same time be suitable for solving practical engineering problems. It is known that attempts to construct such a theory have taken a long time, especially in the related fields of science. Experts also know that to create it is not yet possible. Success in creating such a theory should be sought in the study and the mathematical description of the physical structure of the soil. Here to the fore comes multilevel (discrete) soil structure and nature of the interaction between the structures of the same or different levels. We realize that to solve this problem completely impossible at this time, but to outline the main ways of creating such a theory is our mission.

Another task of the second problem is that the very development of the processes of deformation and destruction of the soil is a multi-scaled and realized simultaneously or sequentially at different interacting structural levels. When deformation takes place along with and destruction it is necessary to describe the correct state of the soil as in the deformation process and after its destruction. If we can solve this problem and thus to estimate the energy expended on the deformation and energy have gone into the destruction of soil layer, it opens the prospect of the development of engineering methods of calculation and assessment of technological processes of soils.

Solution of the third problem is connected with the need to generalize the material accumulated on soil models. Variety of existing models is explained mainly by a wide range of changes in the properties and character to solve practical problems. This leads to the need to model the soil differently. The results are valid for specific conditions adopted (hypotheses and assumptions) and cannot be extended to the whole range of possible properties of the soil. Of course, to create a model of soil that would describe any of its state is the problem of the future. But at this stage, we believe that to solve this problem a generalized model of the soil environment as the object of machining should be developed, which in future will allow choosing one or another model of the soil environment, apply relevant theory of tillage, applied engineering and calculation methods to solve practical problems.

Research results

In order to study the mechanism of energy conversion by the tools of working bodies represent the process of their interaction with the soil in the form of models and subsystem status change of soil formation (Figure 1). Determinants of subsystems are: soil as object machining properties of the soil, the method of processing and energy supplied to the soil environment by working bodies. These factors determine the state of the addition of soil formation and energy process. Energy supplied to the working body in its classical form (kinetic and potential energy of the working body), they spent on the transformation properties of the soil by its destruction, for certain messages to its elements a certain amount of energy in one form or another (mechanical or thermal), as well as changes in the structure is not just a layer, and some of its elements. The main point here is understanding the destructure of the integrity of the soil environment, as a result of soil degradation, as it is, it is the basis for such changes of physical and mechanical properties of soil, density, porosity, aggregate composition, etc.

Within the limits of the existing mechanical action of the state of the soil temperatures are achieved through the transfer of effort from the working body to the treated reservoir. Therefore, the energy conversion process by the working body is this energy flow on the deformation of the soil. Usually in these cases the total amount of energy consumed in the deformation of the soil is characterized by a specific index, such as soil resistivity. This figure depends on the state and properties of the soil, a method of processing (technological and structural parameters of the working body modes), and the physical nature of the failure mechanism of soil. That is a correct understanding of the totality of mechanical processes and physical phenomena occurring in the soil environment under the influence of the working bodies of tools is an important scientific basis for defining our attitude to the process of soil degradation, and as a result, the problem of quality control of the processing of the soil [10, 11].

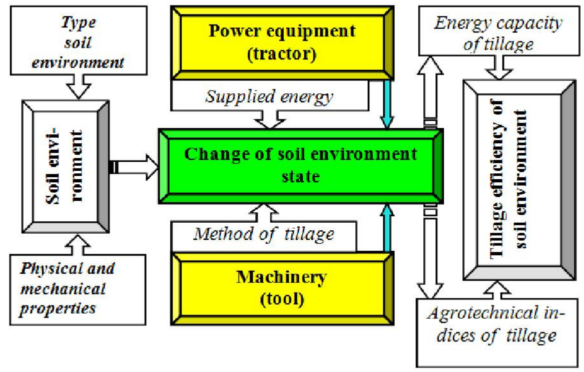

Figure 1. Subsystem status of the soil environment change

A multilevel structure of the soil environment, different scales of acts of the deformation and fracture predetermine new approach to constructing models of interaction with the working body of the soil environment. And naturally developed model should include and take into account the ideas of soil physics and fracture mechanics of modern media.

Additionally we require that the model and later theory, first take into account the dispersion of the soil and its physical foundations of destruction, and secondly, give advice on how to describe the phenomena occurring in the process of destruction, including engineering calculation methods, thirdly, could suggest methods and techniques for different models of soil with a given level of physical and mechanical properties of the soil environment [12, 13]. Then to compile structural model of destruction of soil environment as the object of machining will proceed from the following provisions (see Figure 2):

1. We proceed from the fact that the soil environment is characterized by dispersion, which has a layered structural organization: elementary, aggregate and horizon. Moreover, the size, characteristics, form of the structural units is due to the ratio, composition and location of the soil particles and aggregates, i.e. by internal structure. That is, the internal structure of the soil and its quantitative assessment of individual constituent particles and aggregates, as well as the nature of their relationship with each other structures are characterized by features of the soil environment. To

understand the relationship between structure and function of the soil is its strength (resistance to external mechanical impacts). Strength characteristics of the soil environment, ultimately dependent on its phase composition: Solid (S), liquid (L), gas (G), and their ratio (K). Represented by four components (S, L, G and K), soil environment is ambiguous. Different ratios of the components allow us to consider the soil medium, as an object with the properties of the granular medium to a solid body [6, 7].

These arguments show that the problems of describing the specific features of soils differ from the usual problems of mechanics media and regardless of their success can- not be achieved in quantitative forecasting methods of physical processes.

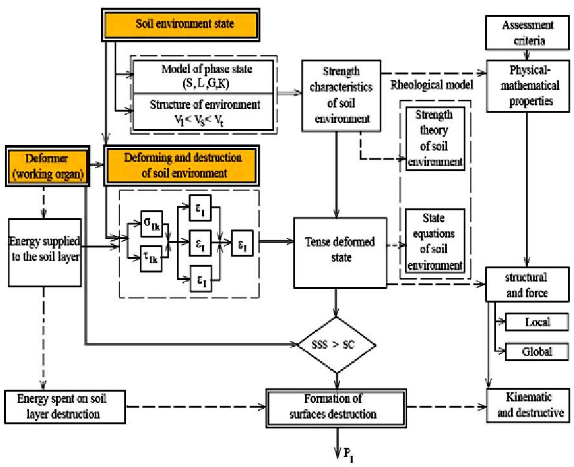

Figure 2. Structural model of the destruction of the soil environment as an object of machining

2. Suppose that there is a small region with a volume V_s, which can be regarded as an element of the solid soil environment. We'll choose the volume V_s of conditions $V_l < V_s < V_t$. Lower limit V_l depends on what is happening in it a particular process, and the upper V_t determines the nature of heterogeneity structure. Volume V_s must be so large as compared with the V_l that it, as an element of the solid soil environment was sufficient to carry out an act of mass transfer. Soil having a multilevel structure, values V_l and V_t will be different. So, if we consider the level of elementary particles, the V_l will be determined by the amount of the individual soil and V_t is volume of micro aggregates consisting of a plurality of individual. At the macro level V_l is the volume of micro aggregates and V_t is volume of macro-aggregates, consisting of a set of micro aggregates. On horizon level V_l is macro aggregates volume V_t is volume of the soil environment. From these considerations several important conclusions follow:

a) Multilevel determination of the amount of layered soil environment includes a system packages and volume V_s choice depends on the nature of the problem being solved. So a model of the soil environment can be considered the structure of the physical structure of the soil particles in the form of balls, multiple packed hexagonal or cubic systems [8]. Such multilevel packing of soil particles generates physical and energetic heterogeneity of soil pore space. Hence the problem is to find for each type of soil and the appropriate type of packaging laws of physics to explain the difference in the physical properties;

b) to describe the structure and properties of soils it is required to consider V_s at all levels on the basis of quantitative characteristics of the phase composition of the soil environment, namely, the possible combinations of elements that define a variety of soil environment found by the intersection of all possible states of the particles (W), pores (P) and contacts (K): soil environment =W l P l K, where l is logical conjunction;

c) if we consider that the mechanical destruction of the soil is the result of overcoming inter-aggregate bonds, then V_s is defined by macro level. And at the macro level the volume V_s is able to deform under the influence of various forces.

3. We shall proceed from the assumption that the soil environment is possible to isolate a relatively uniform (solid) region V_s, which under the influence of the deformer (working body) may flow processes causing deformation of the element. Denote the strain tensor through the solid soil environment ε_i. As ε_i can act elastic, inelastic and plastic deformation. Element V_s able to experience and any amount listed strains. Said deformations arise under the action of a different nature, for example, stresses normal σ_{ik} and tangential τ_{ik}.

Deformation laws in this volume may not depend on the processes occurring at other levels of the soil environment. This position allows us to consider the development of deformation in V_s as a property of a fundamental nature. At the same analytical expressions for the strain must comply with the principle of locality, i.e. make sense of the fundamental constants. In this volume it may be the energy inter-aggregate bonds.

Selecting the volume V_s, deformation act in it and studying the laws of the deformation behavior of the soil environment are key issues in this problem. Success depends on the theoretical analysis of rational choice act scale deformation.

4. Let's assume that any satisfactory approximation model is obtained if the properties of the volume V_s are expressed through the mean values of variables, and values such as, ε_i, σ_{ik}, τ_{ik} will be permanent. Statistical averaging is required to determine the parameters of the whole ensemble volume V_t of the soil environment. It is essentially a means to access the description of the physical and mechanical properties of the soil in terms of engineering mechanics. Another important point is the assumption that the volume V_s is possible to consider as a mathematical point of continuous medium. Average values of its strains ε_i and stresses σ_{ik}, τ_{ik} are now related to the measured values having macroscopic contents. This allows use of the device of continuous and differentiable functions in the continuum. For such a space the basic laws of the behavior of continuous media, for example, the equilibrium equations σ_{ik} and the equations for continuity for ε_i are formulated.

Thus, in this model the physical and mechanical aspects of deformation are assigned to different macro levels: physical - to the lower V_l, mechanical - to upper V_t.

5. Obviously, between different objects of macro levels there exists V_s interaction. So, in a volume V_s plastic deformation is developed, and in another volume - elastic. It leads to a redistribution of stresses between the first and second volumes. The nature of such redistribution depends on many factors: the mutual disposition of all volumes V_s in averaging V_t relative to each other, their mutual orientation in space, etc. For a precise calculation of the soil environment such interactions is practically impossible. However, if each volume V_s is experiencing the same effects from the other and has the same orientation in space, it becomes possible consideration of an ideal model, such as the continuous medium model.

6. Such an approach is important not only to describe the interaction between the volumes V_s, but also to use a phased model of deformation ε_i and fracture P_i. In this model, the process of forming properties of the soil medium is as follows. Tensions σ_{ik} generate micro tensions τ_{ik} able to develop and accumulate micro cracks in the soil environment. The latter causes physical aspects of micro cracks. As a result of it macroscopic deformation ε_i occurs and it is determined by averaging and spatial orientation. For the destruction of the soil environment it is necessary to achieve a certain limit of that environment. Moreover, this limiting condition is characterized by indicators such as stress and strain (under certain conditions) at various points in the environment, both individually and collectively. In the critical state value ε_i is determined by the stress-strain state (SSS). If you exceed the strength characteristics (SC) of soil (SSS) then macroscopic rupture bonds appear, i.e. failure occurs (crumbling) to form soil surfaces P_i^{Π}.

7. Ultimately, the study of description questions of the state of the soil environment, as well as acts of its deformation and fracture determines the construction of the rheological model. In the classical approach the first step is the equations of the stress - strain state (SSS) of the soil prior to its destruction, and the second stage - in establishing an acceptable theory of soil strength. For example, the state of stress in the kind of deformable soil is well described by the Maxwell or Voigt body, and the destruction of the soil - by the theory of strength of the Coulomb-Mohr.

8. Multi scale acts of deformation ε_i and fracture P_i^{Π} requires consideration of their connectivity. The problem of connectivity is of fundamental importance and affects the physical aspects of the destruction of the soil environment. Magnitude ε_i and P_i^{Π} are input and output indicators of process failure and are determined by the properties of the soil environment, and not a separate element. This means the impossibility of reducing the macroscopic properties of deformable soil properties of decayed element or group of newly formed surfaces. Therefore it is impossible to identify the mechanical micro - and macro deformation with macro destruction. Applied to the soil the connectivity factor is better to simplify the feasibility, bringing to the nature of logical and passing to generalizing indicators [14]. So, you can use efficiency (efficiency) soil degradation, if we refer the energy spent on surfaces formation to the energy spent on the soil deformation.

9. Such approach to the study of the deformation and destruction of the soil is necessary to perform two failure criteria: structural power (at the level of micro-cracks) and kinematic-burst (at the level of the macroscopic fracture). For example, in the first case, the soil may behave as a deformable medium and is characterized by the level of stress - strain state. To describe it methods of continuum mechanics may be used. In the second case, to describe destroyed soil methods of mechanics of discrete environment are applicable. Moreover, to address the question of whether the item is collapsed

soil, it is necessary to know the terms of its transition to the ruined state, i.e. failure criteria. A multilevel structure of the soil environment involves consideration of local and global failure criteria. Local criterion refers to an element of the soil, the global - to the system.

Conclusion

In conclusion, we note that the material should be taken as illustrative of the general principle of constructing a model of deformation and destruction of the soil. The reason for that are the physical processes occurring in the soil, which do not always fit into a single scheme and application to specific problems can be modified in the direction of simplification and complexity. Therefore, working formulas should reflect the nature of the implementation of acts of deformation and fracture for each task at hand. The main advantage of the proposed approach to the construction of the model soil degradation is possible physical interpretation of the phenomenological parameters of the model.

Corresponding Author:
Dr.Kapov S.N.
Stavropol State Agrarian University
Zootechnicheskiy str., 12, Stavropol city, Russia

References

1. Griffith, A.A., 1921. The phenomena of rupture and flow in solids. Phil. Trans. Roy. Soc. London A 221, pp.163-197.
2. Irwin, G.R., 1958. Fracture. Handbuch der Physik V1, pp.551-590.
3. O'Callaghan, J.R. 1964. Glavage of soil by Tined implement journal of agricultural Engineering Research. V.9, N.3.
4. Kapov, S.N., 1999. Energy aspects of interphase interactions of soil environment M., pp:101.
5. Kachinsky, N.A., 1975. Soil, its properties and life. M.: Nauka. pp: 296.
6. Bitterlich, S., P. Knabner, 2004. Numerical Methods for the Determination of Material Properties in Soil Science. Inverse Problems in Science and Engineering, 12(4): 361-378.
7. Voronin, A.D., 1984. Structural and functional hydrophysics of soil. M.: Nauka, pp. 204.
8. Voronin, A.D., 1986. Soil physics fundamentals. M.: MSU, pp.214.
9. Philin, A.P., 1975. Applied mechanics of solid deformed body. M.: Nauka, pp.832.
10. Spoor, G. and R. Godwin, 1978. An experimental investigation into the deep loosening of soil by rigid tines "J. Agric. Engineering. Res", pp. 234-258.
11. Stafford, J.V. and A. Geiki. 1987. An implement configuration to loosen soil by inducting tensile failure. Soil & Tillage Research. V.9, N4, p. 363-376.
12. Kapov, S.N. 1999. Mechanical and technological basis of energy saving developments of soil tillage machines: thesis for doctor of techn.sci.- Chelyabinsk, pp. 355.
13. Aduov, M.A. 2008. Scientific and technological basis of technical aids creation for crop seeds sowing and introduction of mineral fertilizers (on the sample of Northern Kazakhstan zone): thesis for doctor of techn., sci., Almaty, pp. 224.
14. Aduov, M.A., S.N. Kapov, S.A. Nukusheva and M.R. Rakhimzhanov. 2014. Components of coulter tractive resistance for subsoil throwing about seeds planting. Life Science Journal, 11(5s):67-71.

7/20/2014