ZESZYTY PROBLEMOWE POSTĘPÓW NAUK ROLNICZYCH 1976, z. 168

THE INFLUENCE OF AGRICULTURAL ENGINEERING TECHNICS ON THE CONDITION OF SOILS A SURVEY OF THE POLISH STUDIES

Janusz Haman, Adam Pukos

Institute of Mechanization of Agriculture, Agricultural Academy, Lublin,
Institute of Agrophysics PAN
Lublin

The first work concerning the influence of agricultural implements on soil condition, which was published in Poland was „The Theory of the Plough, Hiller and Harrow" by Prof. Zieliński [24] from the Agricultural Institute at Marymont. It was published in 1883 in Polish and Russian. In this work the author deals with soil movement on the surface of the tool by adopting a model of elastic isotropic body i.e., practically, Hooke's model, assuming that volume determination can be excluded.

His considerations resulted in the development of a method for designing plough mouldboards which is treated as a twisted bar of rectangular cross-section.

Prof. Zieliński also gave a method for determining the depth of ploughing and stability conditions of the furrow, which resembles those given in university manuals. He also dealt with the problem of the working depth affecting on the arms spacing of the cultivator, but the deformation zone was determined experimentally.

There are only a few Polish copies of Prof. Zielińskis' book available, whereas its Russian edition is quoted fairly often.

In the latter edition the author is presented as a Russian scientist, which was probably caused by the spelling of the name in the Russian edition.

The most outstanding scientific work, however, which was published on Poland's territory before World War I, was that of Tadeusz Gołogurski [6], professor of agricultural mechanization in the Jagiellonian University. His work „The Work of Tools in the Ground" was published in Polish in 1911, and in 1913 its translation in German. The Polish edition of this work did not awake a great interest in this problem, because in those days there was lack of specialists dealing with agricultural mechanization and tillage in Galicja (Austrian occupation territory). The popularity of the edition of this work in German, however, was great in those days, although it was published in Austria and Russia. Scientists of such rank as Gariaczkin and Bernstein not anly quoted Gołogurski's work, but they communicated with him by lively exchange of letters. That was not surprising as Gołogurski's conceptions were quite a revelation. He assumed in his considerations that the Mohr's hypothesis of the highest shearing stresses can be adapted for soil. Gołogurski constructed an experimental system making the determination of plane stress condition possible. He defined the directions of cleaving the furrow under the action of a simple wedge; he determined the coefficients of internal friction and of that against steel as well as instant soil resistance to crashing and breaking. From the results of the measurements carried out the constructed a model of zone of stresses and deformations for tools of flat, cylindrical and spherical surfaces. Studying the form of „sliding surfaces", as he himself called them, he found a good coincidence of the calculations with the experimental results. He also developed a formula for the angle at which the furrow is left with a flat wedge

$$\omega = 90^\circ - \frac{\alpha + \varphi + \rho}{2},$$

where
α — scraping angle of wedge,
φ — external friction,
ϱ — internal friction.

This formula was introduced again in the USSR, in 1953 by Ajzensztok, and in Poland — by Brach [3] in 1956. Although Gołogurski did not present a proper scheme in his work, he suggested a method for studying cohesion and the angle of internal friction of soil according to the method of Mohr's circle as well as an apparatus enabling the performance of such studies. The construction of this apparatus is approximate to that of the contemporary apparati of instant shearing introduced into practice only in the thirties. The methods of studying tools in a glass soil channel making the determination of the kinematics of the furrow and cleavage angles possible, which Gołogurski applied are almost the same as those used in USA, in 1925 by Nichols when he studied the work of plough elements in N.T.L. Alabama.

It is noteworthy that Gołogurski being an excellent mathematician made his work very interesting from the mathematical point of view, and some of the solutions of partial differential equations introduced by him can be an interesting contribution to this branch of mathematics.

It is to be regretted that Gołogurski's work being the first in the field of studies on soil deformation was his only one. Although he was active till 1928, he did not work on this problem any more. He concentrated his studies on the process of cutting stalks by harvesting machines, which resulted from his close connections with the industry of agricultural machines developing in Poland after World War I. Gołogurski's studies were not unfortunately taken up by anyone of his students, therefore this direction of science disappeared in Poland for many years; only building specialists dealt with soil mechanics.

It was only in 1950 when further studies on the effect of aggricultural machines on the ground were undertaken in Poland. The first papers were written in Wrocław, where Martini undertook studies on kinematics of the furrowslice turned up by the plough. He did not quite take into consideration both the deformation processes and forces acting on the implement. His studies had only an experimental character. The studies conducted by Weres in Poznań, and the continued by Kozicz were of similar character. Their purpose was to determine the influence of soil pressing by the tractor wheels on plant yields. In this case the experiment did not involve studies on changes of any physical features of the soil; only the effects of soil pressing were measured from determinations of plant yields. Those observations were then utilized by other authors to interpret some theoretical hypotheses, but no direct practical results were obtained.

Some studies were carried out by Bernacki [1] in connection with construction of ploughs for fast plaughing, and active tools. They concerned above all the processes of cutting, not giving any information about soil conditions.

Studies leading to the first descriptions of rheological models of soil, which can be utilized in processes taking place on cutting or pressing soil by agricultural machines, were started in Warsaw and Lublin in the fifties. We would like to stress that general studies on rheological models and on state equations (constitutive) for the soil are carried out by many centres of which that in Wrocław established by Prof. Igor Kisiel has the greatest achievements. There, the universal prognostic model of Maxwell-St. Venant was designed for soils, which, in addition to parameters expressing elasticity, viscosity and plasticity limit, included that of volume viscosity. This model is that of Zener when plasticity limit is not exceeded. Kisiel's [12] considerations were utilized by Szwaj [18] on developing his rheological model adjusted to conditions of soil cutting. These studies, however, are of a speculative character, in which many assumptions are adapted which are far from the conditions typical for

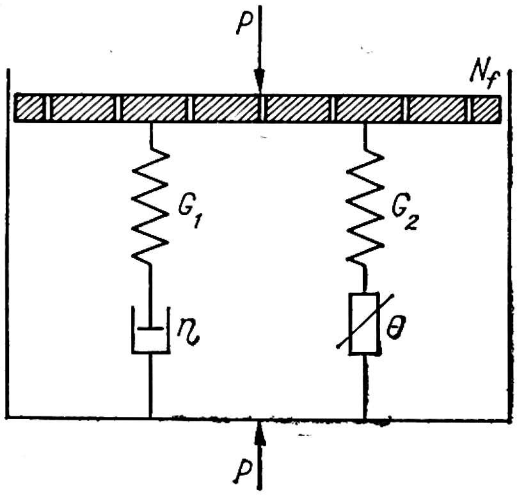

Fig. 1. Kisiel's model M/V

the function of tools and agricultural vehicles. Numerous fundamental studies on soil physics are also conducted, the purpose of which is either to justify the proposed rheological models, or to learn the phenomena connected with mass exchange in the system soil- plant- environment. As the time for delivering our paper is limited, these studies will be briefly dealt with. Some of them were discussed more extensively in the communications.

In the Warsaw centre three trends of studies can be distinguished. The staff directed by Cz. Kanafojski [11] undertook investigations on processes of soil shearing. Resistance of soil cut with a vibrating string was studied. It was shown that resistance decreased the more so the higher was the acceleration of wibrations, e.g., at a constant shearing speed of 0.146 m/s, the vibrating string at the average speed of 0,5 m/s with the amplitude of 7.5 mm decreased the shearing resistance by 28%. On increased acceleration at the same average vibration rate, i.e., by decreasing their amplitudes, the resistance is decreased by 40%. The authors attribute these results partially to tixotropy and partially to changes of the shearing force direction.

Studies of the phenomena connected with the cooperation of mechanisms of moving tractors and agricultural machines with the ground started under the direction of Kanafojski are now continued by Sołtyński and his staff. Sołtyński published a part of his studies in the book „Mechanics of the Vehicle-Ground System" [14] in Poland and USA. They concerned above all the problems of adhesion of the wheel and caterpillar to the ground. At present the purpose of these studies is to obtain the fundamentals for the theory of geometric modelling of simple processes occurring on driving in a prop in simple soil shearing, soil moving and in the work of an elementary wheel and caterpillar. The authors of these studies do not tend to interpret the phenomena by constructing rheological models or by seeking the deformation zone under the object studied. On the basis of numerous studies carried out on soil samples in the soil channel they found that in order to estimate the proper tractional parameters, i.e., traction and soil pressing forces, there should be determined only the unitary shearing stress, soil cohesion, the angle of internal friction and some modules correlating the value of deepening a measurement prop with its dimensions. Taking advantage of the demensions analysis, the authors seek proper scales for the parameters mentioned, which would enable a geometric modelling of simple working elements in the sense ground deformations, tractional and pressing forces.

Another kind of studies of the implement-soil systems was carried out by Stopyra [16]. He experimented on shearing resistances of tools as a function of ground parameters, furrow geometry and speed of the implement movement.

The results of the studies confirm the thesis that soil shearing resistance is the function of the speed of movement; however, the power exponent determining this influence is variable and it does not only depend on the kind and condition of the soil but on the geometry of the implement as well.

He obtained sufficiently exact relationships characterizing the work of ploughs for deep plougling and moving at a relatively low speed.

Similar studies were carried out by Musiał *et al.* in the Institute of Mining, Wrocław. They called their attention to the fact that the description of the forces appearing in the shearing process can change in relation to the kind of the soil shorn. The studies of the shearing forces were conducted on a wheel bucket ladder excavator.

It was found that in the case of loose soil shearing force can be expressed as a function of furrow-slice cross-section; whereas on cutting rocks of a high cohesion, the cutting force should be expressed as a function of unitary length of the tool's cutting edge. Wojtkiewicz obtained results which indicate that shearing with a tool whose cross-section is of U-shape causes resistances proportional to the unitary length of the cutting edge.

Studies on material characteristics of soils when the ground is preseed on by moving agricultural machines and tractors, are carried out by Kołodziej. In his studies ground is treated as a continuous medium assuming that the elementary volumes of the ground dealt with are very large in comparison with the size of the particles. Such an assumption virtually permits to use the condition equations for a continuous isotropic medium.

Attention is, however, drawn to the necessity to determine the parameters in concrete boundary conditions but that requires studies to be carried out in natural conditions.

To solve concrete cases Kołodziej has been seeking equations describing the problem of Boussinesq and has found a differential equation which describes the deformation of soils by a rigid prop. The form of this equation confirms the results of Sołtyński's studies as regards the possibility of geometrical modelling a deformation process of this kind.

The author campared the calculation results in soils of different types and he obtained a high coincidence.

The studies carried out in the Department of Agricultural Mechanization and then in the Institute of Agricultural Mechanization, Academy of Agriculture, Lublin, went in a different direction. In 1953, on studying the effect of ploughing speed and soil moisture on deformation processes, Haman [9] found that due to a high air content in pores of arable soil its infiltration is very rapid. As a result the time derivative of the spherical part of the deformation tensor is significant and it considerably determines both the deformation work and the final soil compaction.

It decisively affects the conditions of plant vegetation the more so, because no water filtration takes place in relation to short-lived loadings in agricultural processes. Thus soil moisture undergoes significant changes. These studies initiated a whole cycle of investigation on rapid deformations, which are still being conducted.

Szwaj [18, 19] has begun studies on rheological models of soil and experimentally showed the significant effect of the rate of tension increase and its duration on plastic volume deformation. To examine the modules characterizing the derivatives of deformation tensors, he constructed a special triaxial apparatus in which the movement speed of the piston realizing a higher main stress reached 1.5 m/s. During measurements all main tensions, volume deformation of the sample and changes in its length were recorded.

Szwaj's studies resulted in defining the tensor of stress as follows:

$$S = S_c' + S_c'' + S_p' + S_p'',$$

where

$S_c' = 2GT'$ — the part of the tensor producing constant deformation of the form,

$S_c'' = 3KT''$ — the spherical part of the tensor producing constant volume deformation,

$S_p' = 2\lambda \dot{T}'$ — additional resistance of viscous flow (viscosity),

$S_p'' = 2R\dot{T}''$ — additional resistance resulting from changes in volume (volume viscosity).

In the formula T', T'' denote corresponding parts of the strain tensor, whereas $\dot{T}'$, $\dot{T}''$ their time derivatives, G and K — corresponding modules, whereas λ and R — coefficients characteristic for resistances resulting from viscosity. The values of these coefficients change with the value of the difference between the normal stresses, deformation rate and soil moisture. It was simultaneously found that the increase in deformation speed causes an apparent increase both in cohesion and in internal friction resulting from a considerable filtration resistance.

Further studies of Szwaj conducted in the Institute of Building Mechanization resulted in developing the adapted rheological model permitting to model spatial systems realizing ortothropic properties. This is a model of an elastoplastic-viscous medium consisting of Maxwell's and St. Venant's elements. Such a system corresponds to the euggestion presented by Kisiel. Taking, however, into consideration that the process of soil cutting as well as its deformation by the mobile elements of the tractor consists in reaching periodically the limit state, Szwaj suggested to introduce into the model two leaning walls being able to move when the force acting on the piston reaches the value corresponding to the state of limit equilibrium in the soil. Such a model adjusted to the spatial system permits to take into consideration all modules and coefficients previously presented in the tensory equation.

It also enables to take into consideration a slower increase of the highest main stress, as deformation of the soil develops, which has been proved experimentally.

This can be realized by a proper formation of the element Θ of the model.

The proposed model was applied by Szwaj on taking into consideration the process of shearing the furrow and made the determination of the surface af soil cleavages occurring upon the action of the tool possible.

This is probably the most developed soil model at present, which reproduces the real shearing process, utilizing, however, the state equations for a continuous isotropic medium.

In order to study experimentally the influence of the deformation rate on its value better, i.e, to determine, the parameters λ, R more exactly, studies in the soil bin are conducted on a large scale in Lublin.

Miczyński and Worona studied the resistances of the flat element of various dimensions at various angles in relation to the direction of the movement, at considerable speeds.

The results obtained confirmed the laboratory studies of Szwaj, i.e, the decrease in the energy of volume deformation as the speed of the tool movement increases.

A secondary result of these studies was the confirmation of the presented conceptions of Sołtyński [14] of modelling working elements.

At present studies on soil compaction under a rigid wheel rolling at various speed on the soil are conduced. These studies have been undertaken by Karczewski by using the isotopic method of soil compaction measurement. The source of radiation is cesium isotop Cs^{137}, and the indicator — scintillation counter. This method is on the one hand accurate, because it makes the measurement in points distant about 1 cm from each other possible, and on the other hand it is safe, because Cs^{137} emits radiation of a relatively small energy and is a safe source. The studies have not been finished yet, but it is known from the present results that an increased speed of the wheel movement not only causes a decrease in compaction but a decrease in the deformations zone as well. At the wheel movement of 0.09 m/s the volume deformation statistically significant can still be found at the depth of 20 cm whereas at the speed of 2 m/s it is found at the depth of about 8 cm. This confirms the hypothesis of the filtrating character of volume deformation which is thought to be not of a too high rate.

It can be assumed from the results that an increased speed of the movement of vehicles and tools can significally contribute to limit the harmful process of soil pressing.

Because of the existing difficulties in carring out measurements which mainly hamper the development of studies, Gawda undertook an attempt to apply the method of ultrasonic examination of soil compaction. Her work had a methodical character and it followed from its results that temporal changes in soil compaction can be examined by using ultrasounds of 50 KHz. In contrast to the isotopic method, this one is not sensitive to moisture changes. This method is of a goot distribution enagling measurements in points. We can expect that in future studies will be carried out using simultaneously both methods.

Studies on furrow cracks conducted in 1958 called attention to the fact that they are accompanied by vibrations of the tool blade which are not generally produced by the furrow breaking itself, but the negative friction between the furrow and moudboard. In order to study this phenomenon Haman [8, 9] designed a special plough of a constant friction angle and a system for studying the influence of speed on friction coefficients of steel on soil.

These studies and the later ones of Zdanowicz [23] resulted in finding that the course of friction is not linear and results from overlapping dry and viscous processes of friction. Hence the term of mixed friction was adapted in considerations about friction of soil against the tool. In the case of low speeds only dry friction occurs, the value of which, as shown by the studies, decreased with speed increase. The reason of the phenomenon has not been adequately elucidated. At high speeds viscous friction is significant, the value of which increases proportionally to the speed. Thus the curve illustrating the changes of friction forces versus the movement speed has a distinct minimum, the position of which depends on the kind of soil and its condition. The general friction forces can be determined by the equation

$$F = F_{Rt\infty} + A_{exp}(-\lambda V) + BV^{\mu}$$

where $F_{Rt\infty}$ corresponds to friction forces at exactly given speeds, A, B, λ, μ are positive coefficients, whereas V is the speed of furrow movement on the tool.

The decreasing friction in the range of lower speeds is particulary interesting because it creates conditions for the appearance of self--excited vibrations of the tool, which can be the reason of damages or they can decrease the working resistance of the tool in definite conditions. Zdanowicz [22] studied this problem in detail, finding the conditions producing such vibrations. The results of the studies were utilized in constructing the working elements of such implements as cultivators and ploughs patented by Orzechowski.

The studies of Słowińska-Jurkiewicz on friction coefficients of steel against soil showed that they vary in a wide range in relation to moisture and humus content. These functions are on the whole non-monotonic and often have several extremes. This can lead to the appearance of quite unexpected dynamic effects in tools, the more so that the coefficients of internal friction and cohesion undergo similar changes.

The physical reasons of this changes have not been adequately defined yet, and studies to elucidate them are being intensively conducted in Poland.

In this case those of Stępkowska are the leading ones which are being conducted in the Institute of Hydroengineering PAN at Gdańsk. They concern the influence of the internactions of London-van der Waals and the repulsion pressure of diffusion layers on mechanical property of soils, i.e., on cohesion and the angle of internal friction. The authors express the opinion that cohesion is mainly produced by effects of a long distance interactions, whereas internal friction is produces by contact forces. However, this problem is very complex and the number of variables effecting the characteristics is very big. The results obtained, confirmed the thermodynamic interpretation of shearing, from which it appears that on pure extension the change of potentiol energy of repulsion forces is transformed into heat and undergoes dissipation.

The studies carried out so far did not result in obtaining a proper constitutive equation expressing the conditions of stress and strain and operators determining the bonduary conditions for a homogenous granular medium not to mention soils which are a complex medium. Hence models of continuous media are used in the conceptions of interpretative and prognostic models, which always appears in the conception presented.

Nevertheless, the physical connections obtained so far permit to determine, adequately from the practical point of view, deformations and dislocations of the medium, particulary in the case of limit state. The knowledge of this relations makes a fairly accurate prognosing of the mechanical effect of tillage.

From the point of view of agrophysics, however, the final purpose is to determine the effects in the system of the living organisms (plants or animals) and the medium. Therefore, more and more attention is paid to the effects of soil on plants. The studies are concentrated on such problems as water availability for plants (Trzecki, Kowalik, Zawadzki), gas economy in the soil (Kowalik, Cieśla), and thermodynamic processes taking place in the soil. However, only the last years have given the first results of studies on the dynamics of these phemomena, which results from deformation processes of the soil in natural conditions and those caused by agricultural machines and vehicles. This studies are concentrated now in the Institute of Agrophysics in Lublin, the activity of which we would like to present in the last part of this paper.

One of the chief problems of this Institute is realization of studies on theoretical fundaments and methods for measurements of physical phenomena in the soil. One direction of its studies is devoted to designing new apparatuses used for studies in soil mechanics and modifying known measurement methods and laboratory and field equipment. The apparatuses used for such studies are almost unavailable and are characterized by many faults, the main one of which is their adjustment for statical measurement. Also theoretical studies on the proper choice of investigation methods and combining mechanical treatment of soil with its physical and physico-chemical properties are conducted. The constructional data of the new apparatuses are the subject of seperate communications.

Two prototypes of soil penetrometers and adhesiometer were constructed in the Institute of Agrophysics and the triaxial apparatus of the Norwegian type was adjusted to pedological studies.

Penetrometers are used for practical purposes in rapid determinations of tractional properties of soils as well as ploughing resistance. It is difficult to determine theoretically what soil properties affect the value of the force needed to introduce the penetrometer cone into the soil; however, the results obtained make an approximate determination of the strength of the soil and its resistance to agricultural machines possible. Sołtyński [14] quotes the results of the studies of American authors, which confirmed the utility of the measurement method described.

In the apparatuses constructed in the Institute of Agrophysics the chief fault has been eliminated which appeares even in the latest penetrometers, i.e., the impossibility of accurate determination of penetrability in all points of the soil profile, guaranteeing an accurate registration of results. The soil penetrometer with a manual drive has been widely used in field studies and it is used in many scientific institutes in Poland.

Furthermore, there has been designed an apparatus for determining the coefficient of adhesion between soil and materials of which agricultural tools and wheels of vehicles are built. The tests carried out showed a far more higher repeatability and accuracy of results, as compared with Kaczyński's apparatus. This effect was obtained by constant increase in the force breaking the disc of the material examined off the soil and by using an electric control enabling the registration of adhesion.

The registration penetrometer with the manual drive and the universal steered meter being a part of the adhesiometer are protected by Polish patents.

As far as rheology is concered, Pukos and Walczak [13] surveyed the existing rheological models and their physical basis. The authors showed by example of the models of Hooke, Newton and Kelvin-Voigt how linear rheological models can be justified by means of linear thermodynamics of irreversible processes. It was also pointed to the possibility of eliminating the assumption of continuity and homogeneity of the soil medium by utilizing statistical methods studying stress-strain histeresis. The considerations on the applicability of the research methods used in ground science and civil engineering to the dynamic problems of soil loading resulted in adapting the triaxial apparatus to kinematic programmes of studies.

Out of the apparatuses used in Poland the Norwegian type was chosen which is an improved apparatus of Bishop and Henkel — the English classicists of triaxial studies, and it guarantees a constant deformation rate and a high precision of measurements. The use strength machines in civil engineering is adapted for quasi static programmes of studies. An exception were the papers of Szwaj [18, 19] previously presented.

In studies on mechanical properties of agricultural materials the requirements of present construction technics postulate, as it was stressed in the paper of Haman and Zdanowicz [10], the necessity of learning the rheological properties of materials, i.e., the influence of the strain rate $\dot{\varepsilon}$ and that of loading, i.e. increase rate of the stresses $\dot{\sigma}$. For this purpose a hydraulic drive for a serial triaxial apparatus was constructed by extending the existing range of strain velocity (0.3 to 12 mm/h) up to the value of 3.9 m/s with the possibility of its further increase.

Stress and deformation are registered by means of a loop oscillograph with ultraviolet or photographic recording. The kinematic programme of studies, when a definite rate of sample shortening is applied, has two advantages, as compared with the statical programme, in which stress programme is applied at a time (e.g. classical studies of triaxial compressing at $\sigma_2 = \sigma_3 =$ const. and stress σ_1 is realized by direct loading of the sample). Firstly, the kinematic programme gives a more complete information about the properties of the material, because it can cause a change of the stress — or deformation state (loading, decrease of loading) in a wide deformation range, and in the statical process, after reaching a certain point we have a damage, and disruption of deformation becomes impossible.

Moreover, there exist measurement possibilities beside stress and strain, of the derivatives of these values after the time, that is indispensible in experimental verification of rheological models with viscosity, in which the mechanical condition of the material is an evident function of time.

As in granular material such as the soil the action of the stress deviator produces formal changes, initial studies were carried out with the action of the constant spherical part of the tensor stress through a successive increase in the axial stress and decrease in the hydrostatic pressure in the chamber and also with a constant deviator of this tensor. This enables to eliminate the relation between the isotropic stress and the change in the sample volume and to separate deformations voluminous and formaloues.

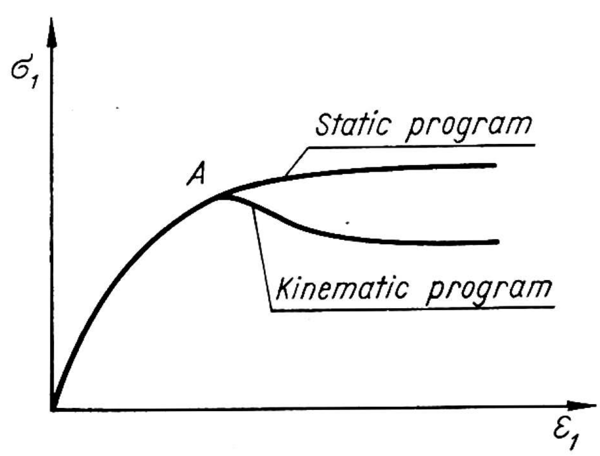

Fig. 2. Programmes of the triaxial test

Study programmes with decreasing sample load at required deformation or stress values are being prepared which will make the separation of elastic and plastic features possible.

It seems that other types of apparati realizing the complex stress conditions, i.e., when $\sigma_1 \neq \sigma_2 \neq \sigma_3$ (e.g. the apparatus of Bojanowski and Drescher in which the shape of the sample is that of a thin-walled pipe) useful for statical studies, are too complicated for realization of the programme of kinematic studies, particularly for "undisturbed" samples. The planned studies are to elucidate this problem in future.

The second direction of the work in this Institute are studies on the influence of multiple mechanical treatment and loading of the soil by vehicles and agricultural machines in a year's cycle of cultivation. These processes virtually affect physical properties of the soil, among others such as aggregation, unit weight, porosity distribution. These features affect water-air relationships, water retention and other properties. Walczak studied the influence of compaction on energetic condition of water in loess and proper chernozem formed from heavy loam. It was found that mechanical compaction affects water content per 1g of soil for pF values smaller than 3. It follows that mechanical compaction for loess up to 1.7 g/cm^3, for chernozem up to 1.655 g/cm^3 does not cause changes in the content of pores smaller than 3 μ.

The characteristics of moisture-suction was obtained in processes of wetting and drying of soil in the pF range 0—2.7. It was found that the surface of histeresis loop increased considerably with the decrease in volume weight. Hence it follows that it is necessary to take into consideration the histeresis effect in the description of water transport, particularly in soils of a small compaction degree. A theoretical interpretation of this phenomenon was prepared and universal domain theory of hysteresis was applied to the description of soil pores distribution. It enables a description of pores distribution in three-dimensional system of coordinates (the smallest pore radius, the biggest pore radius and pore volume of definite dimensions mentioned above).

It was found that in soils of low mechanical compaction a great number of pores exist with a considerable difference between r_{max} and r_{min}.

With the increase in mechanical compaction the shape of pores becomes more regular.

Konstankiewicz studied the influence of pressure on pores distribution in the soil of various moisture. Air-dry soil formed from loess was studied, for which water characteristics (suction-moisture) were determined. After the equilibrium was established on each suction applied, the soil sample was loaded in the oedometer with outflow of water. For the three pressures used (1, 2 and 3 kG/cm^2) consolidation curves were drawn (dependence of sample settling at the time t).

For each of five moisture values three straight lines were obtained, the slope of which was smaller for higher ballasts. At lower moisture values the difference in the slope is smaller. For different moisture values with the same ballast the straight lines comprise a larger range of settling as sample moisture decreases.

At each moisture and after each deformation the distribution of pores in the soil was examined using a mercury porosimeter. The total volume of pores decreased with ballast increase at each moisture. The highest differences occurred between 1 and 2 kG/cm² ballasts, and for 2 and 3 kG/cm² ballasts the differences were slight. At the same ballasts but at different moistures a decrease in the volume of pores occurs as moisture decreases with only one exception of pF = 2.0 (the upper limit of water available for plants). The percentage participation of pores of the same dimensions at different ballasts distinctly varies between the ballasts 1 and 2 and 3 kG/cm². The differences between the two last ballasts are very small.

It can be concluded from the review of the studies on the influence of machines and vehicles on soil condition that further studies will be conducted in Poland. The opinion whether it is worth-while to concentrate efforts to develope more accurate rheological models in search for state equations for complex media is very controversial. There are many scientists who maintain that experimental and mathematical difficulties connected with studies of such a complex medium as soil are enormous and they will demand large resources incommensurate to the practical value of the results for which many other valuable and technically useful data could be obtained. It seems to us that the actual progress of theoretical studies on the mechanics of continuous media and prognostic models in Poland induced to their continuation; however, it should be taken into consideration that a success in the nearest future can be expected only in cases of simpler systems.

Theories of shearing and tractional processes are also believed to develop fairly rapidly. These studies will require a considerable concentration on the methodological problems and searching new apparati useful for studies on rapid deformations and enabling evaluation of "local" phenomena. Studies on physico-chemical interpretation of mechanical characteristics are also needed.

A further development of studies on geometrical modelling of more and more complex working elements as well as processes of multiple deformation typical for agricultural conditions is also expected. This is connected with correlated utilization of research possibilities of agrophysicists and scientists dealing with the problem of building, mining machines and founding.

In the programme of future studies, however, special attention should be paid to consequences of the effect of machines significant from the point of view of agricultural processes. Whatever the development of basic studies would be, it should be remembered that the losses suffered from ignorance of the effect of soil cultivation technique on the future crops are of the highest importance and it should be expected that the knowledge of these phenomena will require enormously extensive and systematic studies on which particularly big efforts and resources should be concentrated.

REFERENCES

1. Bernacki H.: Zagadnienia prędkości orki. Rocz. Nauk rol. Ser. C. 67, 3, 1958.
2. Bierzycki S.: Ciągówka. Warszawa 1921, Księgarnia Rolnicza.
3. Brach J.: Teoretyczne podstawy skrawania gruntów w maszynach do robót ziemnych. Arkady 1960.
4. Brach J.: O dwóch modelach rozkładu naprężeń. Arch. Bud. Masz., 1961.
5. Drescher A.: Wpływ nagłej zmiany prędkości odkształcenia... Arch. Inż. Ląd. XII, 3, 1966.
6. Gołogurski T.: Die Technologischen Prozesse bei der Bodenbearbeitung. Nakładem D. E. Friedleina.
7. Haman J.: O potrzebie studiów nad mechaniką gleb. Masz. rol. 1/1959.
8. Haman J.: Studium nad dwoma przypadkami drgań samowzbudnych. Annales UMCS, XIV-E-1961.
9. Haman J.: Wpływ szybkości orki i wilgotności gleby na pracę jej odkształcenia objętościowego. Annales UMCS, X-E, Lublin 1955.
10. Haman J., Zdanowicz A.: O potrzebie rozszerzania studiów nad reologią materiałów w rolnictwie. Rocz. Nauk rol. 68-C-2, 1968.
11. Kanafojski C., Ptaszyński S.: Z teorii cięcia prostoliniowym ostrzem. Biuletyn IMER, Nr 4, 1965.
12. Kisiel I., Lysik B.: Zarys reologii gruntów. Arkady, Warszawa 1966.
13. Pukos A., Walczak R.: Podstawy teoretyczne badania właściwości mechanicznych gleb. Problemy Agrofizyki 7, 1973.
14. Sołtyński A.: Mechanika układu pojazd-teren. MON, Warszawa 1966.
15. Stopyra L.: Wpływ szybkości skrawania na wydajność i opory pracy maszyn ziemnych. Biul. WAT, Nr XLV/1951.
16. Stopyra L.: Niektóre problemy dotyczące teorii pługów okopowych. Biul. WAT, Nr 11/12, 1960.
17. Stopyra L.: Analiza metod zwiększania wydajności pługów okopowych. Referaty V Międzynarodowej Konferencji Mech. Roln. Ziemn., II-A-52, Warszawa 1965.
18. Szwaj S.: Wytrzymałość gruntów na ścinanie przy szybkich odkształceniach Arch. Bud. Masz XI, 3, 1964.
19. Szwaj S.: Podstawowe badania w zakresie mechaniki gruntów w zastosowaniu do maszyn rolniczych. Rocz. Nauk rol., 68-C-1, 1966.
20. Świeżawski T.: Kołowe pługi motorowe, Poznań, 1928.
21. Winek H.: Metody obliczania oporów skrawania gruntów. Zesz. nauk. PWarsz. Mechanika, 12/1963.
22. Zdanowicz A.: Analiza drgań samowzbudnych narzędzia w procesie skrawania gleby. Lublin 1965.
23. Zdanowicz A.: Podstawowe problemy mechaniki procesu skrawania gruntów narzędziami rolniczymi. Dysertacja, Lublin 1967.
24. Zieliński M.: Teoria pługa, obsypnika i brony. Nakład własny, Warszawa 1884.

J. Haman, A. Pukos

WPŁYW TECHNIKI ROLNICZEJ NA STAN GLEB PRZEGLĄD BADAŃ POLSKICH

S t r e s z c z e n i e

Przedstawiono historycznie rozwój badań w zakresie mechaniki gleb w Polsce. Szczegółowo omówiono wyniki badań uczonych z ośrodków warszawskiego i lubelskiego, gdzie ten rodzaj badań był zainicjowany w latach pięćdziesiątych oraz osiągnięcia Instytutu Agrofizyki PAN w Lublinie.

Autorzy zwrócili uwagę na badania wpływu maszyn i pojazdów na stan gleby oraz fizyczną interpretację tego wpływu z punktu widzenia procesów rolniczych. Na podstawie wyników dotychczasowych badań można wnioskować, że pomimo dużych trudności matematycznych i eksperymentalnych oraz kosztów badań zjawisk mechanicznych w glebach, należy je kontynuować wobec nieznajomości wpływu zmechanizowanej uprawy na plony.

Я. Хаман, А. Пукос

ВЛИЯНИЕ СЕЛЬСКОХОЗЯЙСТВЕННОЙ ТЕХНИКИ НА СОСТОЯНИЕ ПОЧВ. ОБЗОР ПОЛЬСКИХ ИССЛЕДОВАНИЙ

Р е з ю м е

Приводится исторический обзор развития исследований в области механики почв в Польше.

Подробно обсуждаются результаты исследований ученых из научно-исследовательских центров в Варшаве и Люблине, где эти исследования были начаты в пятидесятых годах, а также достижения Института агротехники ПАН в Люблине.

Особое внимание авторы уделяют исследованиям касающимся влиянию машин и средств транспорта на состояние почвы, а также физической интерпретации этого влияния с точки зрения сельскохазяйственных процессов. На основании результатов проведенных до сих пор исследований можно заключать, что несмотря на значительные математические и экспериментальные трудности, а также высокие издержки связанные с исследованиями механических явлений в почвах, эти работы должны продолжаться ввиду недостаточного изучения влияния механической обработки почвы на урожаи культурных растений.