ZESZYTY PROBLEMOWE POSTĘPÓW NAUK ROLNICZYCH 1976, z. 168

RELATIONSHIP BETWEEN THE COEFFICIENT OF FRICTION SOIL-METAL DEPENDING ON THE CHARACTERISTICS OF THE SOIL AND ON THE KIND OF METAL

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The development of agriculture is followed by mechanization of the soil cultivation processes. It brings about a necessity of finding new solutions in order to elaborate new agricultural instruments so that they could as well as possible be adapted to the working conditions. That is why it should be a good knowlegde of physico-mechanical soil properties which would resolve upon construction of a given agricultural instrument, and upon the kind of material to use to perform it [6]. The resistance an agricultural instrument meets when working against the soil is the sum of soil consistence forces, adhesion, internal friction and external one. In order to suromount the resistence connected with the external friction forces about 30-40% of the whole energetic expenditure is spent [6]. In this connection a great interest can be observed in relation to the problems of the influence of the soil factors and of the metal properties on the value of the external friction coefficient.

Because of variety of methods applied in investigation some difficulties are encountered when trying to compare the results of investigations carried out by different authors. In consequence, it is often enough that a considerable difference of the value of friction coefficient can be met with, when consulting the literature.

Generally speaking, the value of the coefficient of friction of metal against the soil depends on the soil humidity [1, 2, 3, 5, 7], mechanical composition of the soil [5, 7], soil structure [6], metal surface [5, 6, 7], slipping rate [8] and normal pressure [5, 7].

No comprehensive investigations concerning the above problems have been carried out in Poland. The purpose of the present paper is to offer the results of investigation on the value of the coefficient of external friction for some typical soils of Lublin district and for the kinds of steel used to make agricultural instruments.

METHOD OF INVESTIGATION

A ring apparatus of Kloth [7] made in the Experimental Establishment of Jagiellonic University was applied to measure the value of friction coefficient. A propulsive element was built onto the apparatus in order to achieve a constant rate of slipping of the ring against the soil.

The investigation was carried out (see Table) on the following kinds of soil representing different characteristics:

1. Podsolic soil formed from loose sand — horizon A_1, and C,
2. Brown soil formed from sandy loam — horizon A_1,
3. Brown soil formed from loess — horizon A_1,
4. Chernozem formed from loess — horizon A_1,
5. Humic rendzina formed from cretaceous marl — horizon A_1.

The investigation was carried out in laboratory conditions in order to get a full control of the oscillation of the soil humidity. The soil was collected from the fields into the containers (120×60×40 cm) and made humid until achieving the full value of water capacity. In order to determine the influence of humidity on the value of the coefficient of friction soil-metal a series of measurements was carried out as the soil dried up. Measuring rings were made of three kinds of steel which are usually used in production of agricultural instruments: M65, St5, St3.

Steel surface state as determined with application of WG-4 standards corresponds $\nabla 9$ (smooth steel). The investigation was carried out at a normal pressure of 0.15 kG/cm^2. Slipping rate of the ring was 0.1 m/ /sec.

Physical and chemical properties of the soil were determined with the help of methods which are usually applied in podological investigation.

DISCUSSION

Fig. 1 shows the relationship between the value of the coefficient of external friction on humidity in the original moment of the dynamic friction. The curves representing the above relationship were plotted for the systems M65 steel/a given kind of soil. The curves differ distinctly in shape what is the direct result of the different mechanical composition of the examined soils. The curve plotted for the system steel/ /loose sand from horizon C shows that there is only ansignificant change

Table

Mechanical composition and some properties of the soils investigated

Kind of soil	Content of mechanical fractions %				Humus content %	$CaCO_3$ content %	Hygroscopic capacity %	Upper plastic limit %	Lower plastic limit %	Plasticity index
	1-0,1 mm	0,1-0,02 mm	<0.02 mm	<0.002 mm						
Podzolic soil formed from loose sand horizon *C*	88.0	10,0	2	2	—	—	0.62	—	—	—
Podzolic soil formed from loose sand horizon A_1	85.0	11,0	4	2	1.64	—	0.70	—	—	—
Brown soil formed from sandy loam horizon A_1	62.0	17.0	21	9	1.60	—	2.48	16.7	12.8	3.9
Brown soil formed from loess horizon A_1	1.0	60.0	39	14	1.16	—	3.30	27.3	22.7	4.6
Chernozem formed from loess horizon A_1	0.5	64.5	35	8	2.40	—	3.28	27.3	22.8	4.5
Humic rendzina formed from cretaceous marl horizon A_1	36.0	20.0	44	24	2.80	9.1	7.33	36.6	22.9	13.7

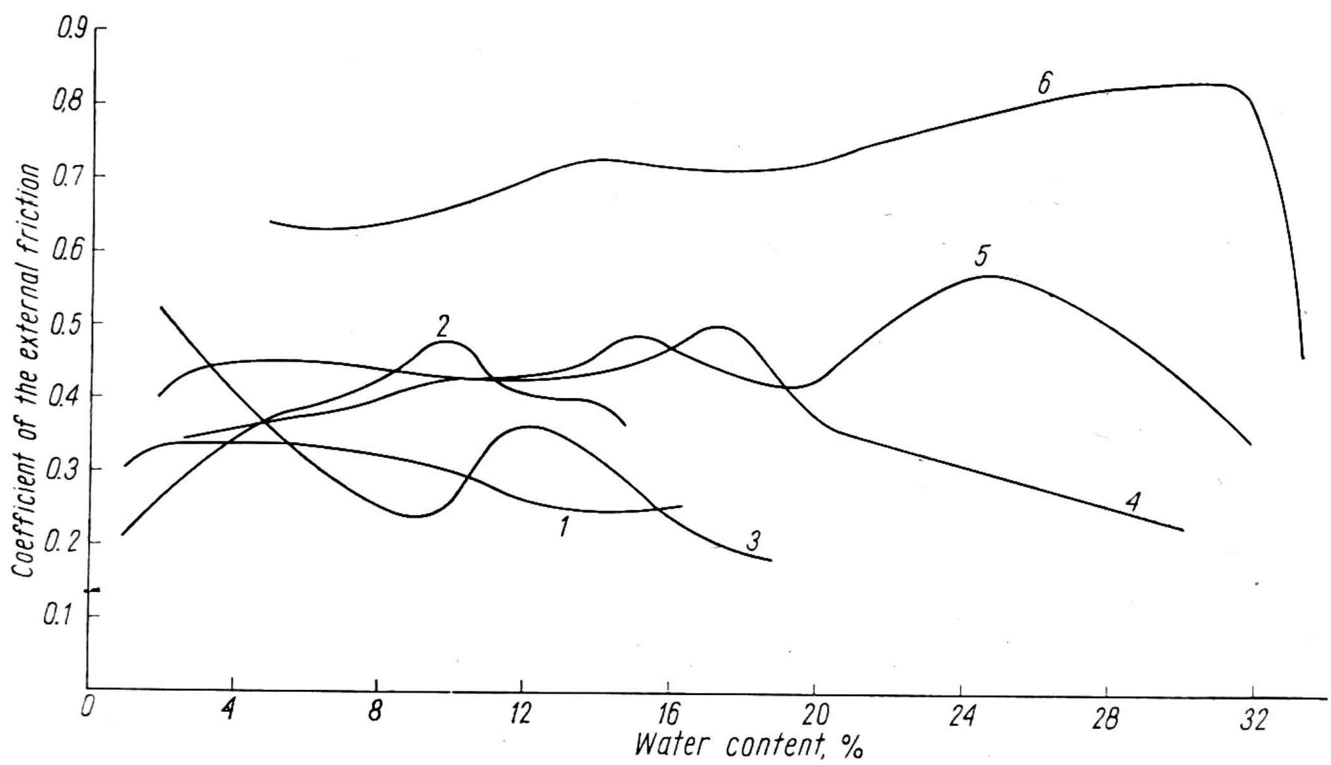

Fig. 1. The influence of water content on the coefficient of friction soil — steel M 65. *1* — podsolic soil formed from loose sand (horizon C), *2* — podsolic soil formed from loose sand (horizon A_1), *3* — brown soil formed from sandy loam (horizon A_1), *4* — brown soil formed from loess (horizon A_1), *5* — chernozem formed from loess (horizon A_1), *6* — humic rendzina formed from cretaceous marl (horizon A_1)

of the value of the external friction coefficient when the water contents changes inside of the range 1-10% in the sand free of moulder and colloids. As soon as the amount of water is above 12% the friction coefficient becomes a constant value of 0,25. On the accumulation horizon of the same kind of soil there is quite another kind of relationship. On the A_1 horizon there can be observed a much more clear reaction of the friction coefficient of the soil humidity changes — notwithstanding that A_1 horizon, characterized by nearly the same mechanical composition as the soil parent rock, contains 1.64% of humus. The increase of water contents from 1% to 10% results a gradual increase in the value of the friction coefficient from 0.20 to 0.49. As the humidity reaches over 10% there can be observed a delicate decrease in the value of the coefficient. Even a stronger influence of the water contents on the friction coefficient value can be observed for the brown soil formed from sandy loam. Within the range of humidity 1-9% the friction coefficinet decreases from 0,53 till 0.28. Then its value increases and reaches 0,36 at he humidity of 12%. A further increase of humidity results again in the decrease in the value of the coefficient of friction. This kind of relationship resembles parabolic curve of the third degree.

In the A_1 horizon of the brown soil formed from loess there can be observed only quite an insignificant reaction of the external friction coefficient on the increase in the soil humidity. It is only within the range of humidity of 15-17,5⁰/₀ that an increase in the coefficient value can be observed. Aa 17.5⁰/₀ of humidity there is a maximum of the coefficient value (0.51) and then its value reduces till 0.30. In order to determine the influence of humus contents on the friction coefficient' value (for loess soils) some measurements were carried out in the system M65 steel-chernozem. The curve of the relationship between the coefficient value and the humidity of such a system shows two maximum points — first maximum at 15⁰/₀ of humidity, the second one at 25⁰/₀ of humidity. The second maximum is high and reaches till 0.58. Especially in the state of considerable humidity contents clear differences can be observed between the chernozem soil and the brown soil, both of a very close mechanical composition but of a different humus contents (brown soil — 1.16⁰/₀, chernozem — 2.40⁰/₀). The highest value of the friction coefficient shows within the whole range of humidity the heavy humic rendzina. In the state of maximum hygroscopicity the friction coefficient of this soil is 0.64. Within a very long range of humidity 5-31⁰/₀ the coefficient increases steadily. Its maximum point is at 0.79. Above the humidity 31⁰/₀ the value of the coefficient sinks rapidly and reaches 0.35 at the water contents of 34⁰/₀.

A similar kind of relationship between the value of the friction coefficient and the soil humidity present also the systems with St5 and St3 steel. The most significant quantitative differences between particular kinds of steel can be observed when the measurements are carried out in the horizon A_1 of the sand soil and of the chernozem soil.

In the Figs. 2—7 the influence of steel quality on the value of the external friction coefficient is represented. The highest values of the coefficient within the whole range of humidity shows usually St3 steel, the lowest ones — M65 steel (Figs. 2, 4, 5).

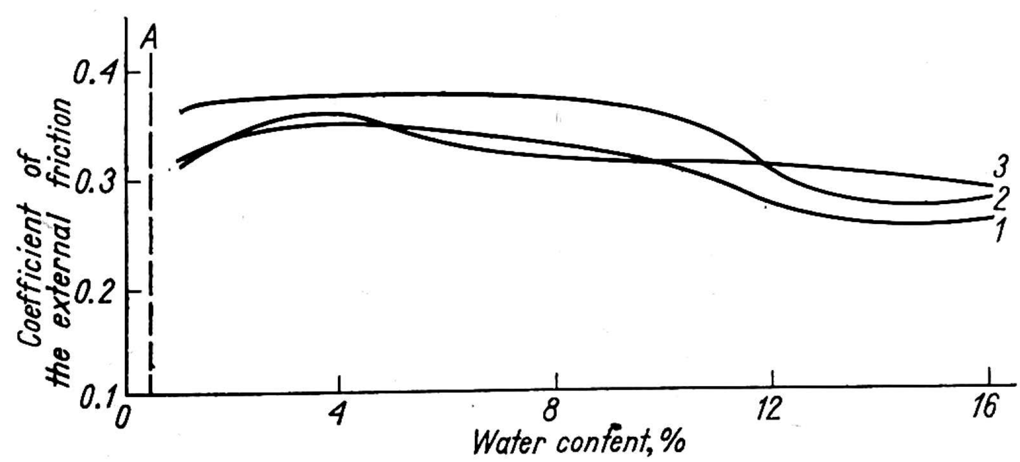

Fig. 2. The influence of water content on the coefficient of friction podsolic soil formed from loose sand (horizon C) — steel. *1* — steel M 65, *2* — steel St 3, *3* — steel St 5, *A* — hygroscopic capacity

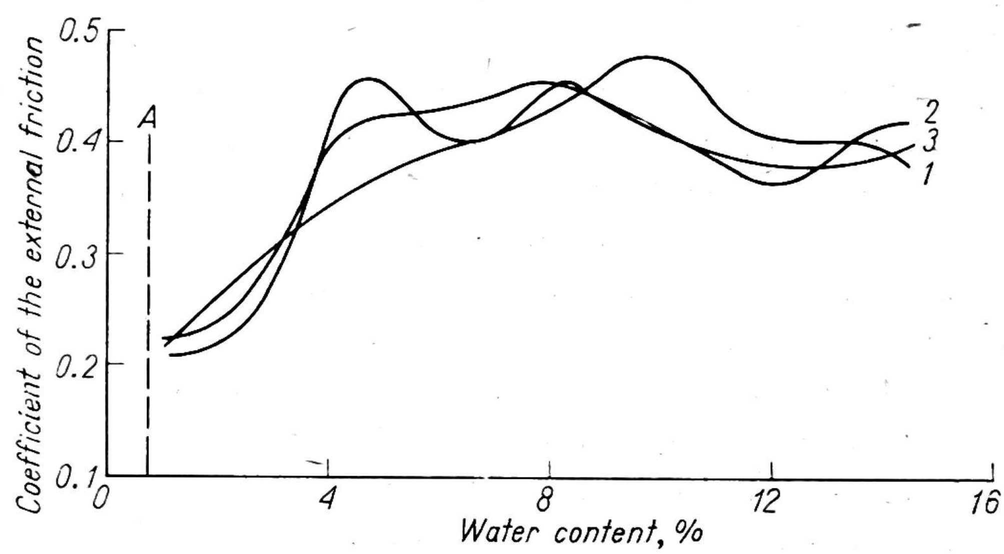

Fig. 3. The influence of water content on the coefficient of friction podsolic soil formed from loose sand (horizon A_1) — steel. *1* — steel M 65, *2* — steel St 3, *3* — steel St 5, *A* — hygroscopic capacity

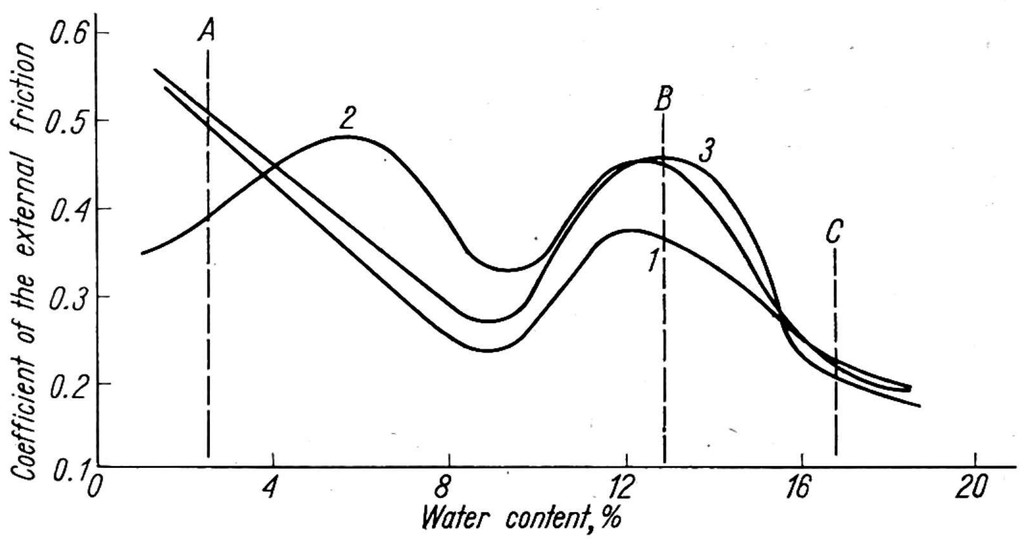

Fig. 4. The influence of water content on the coefficient of friction brown soil formed from sandy loam (horizon A_1) — steel. *1* — steel M 65, *2* — steel St 3, *3* — steel St 5, *A* — hygroscopic capacity, *B* — lower plastic limit, *C* — upper plastic limit

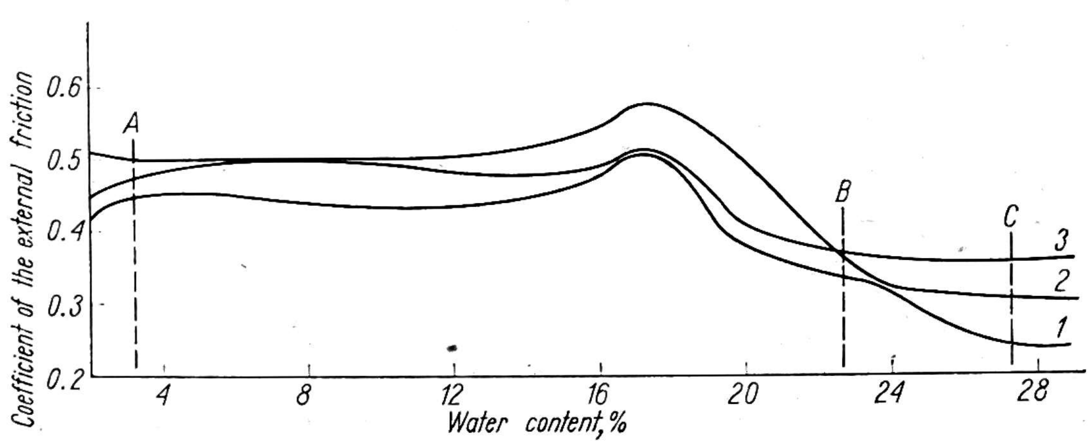

Fig. 5. The influence of water content on the coefficient of friction brown soil formed from loess (horizon A_1) — steel. Designations as in Fig. 4

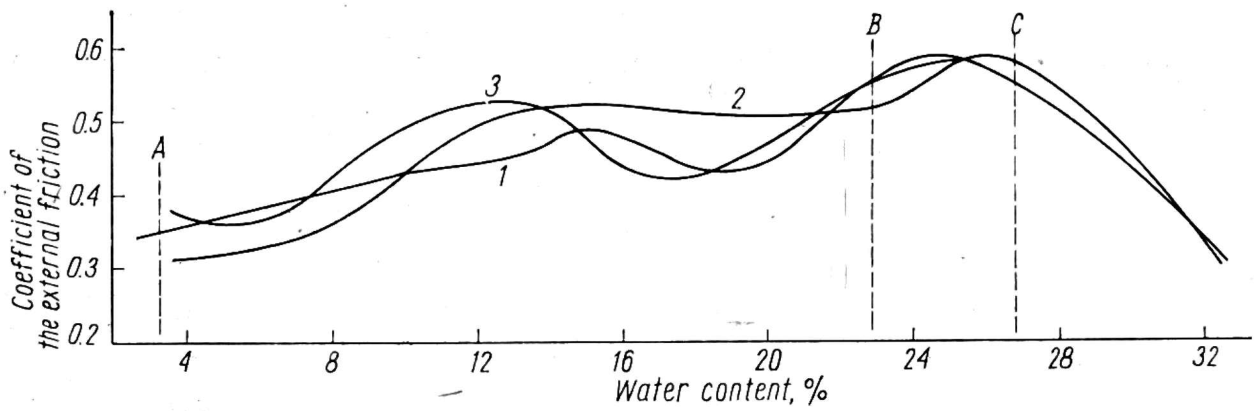

Fig. 6. The influence of water content on the coefficient of friction chernozem formed from loess (horizon A_1) — steel. Designations as in Fig. 4

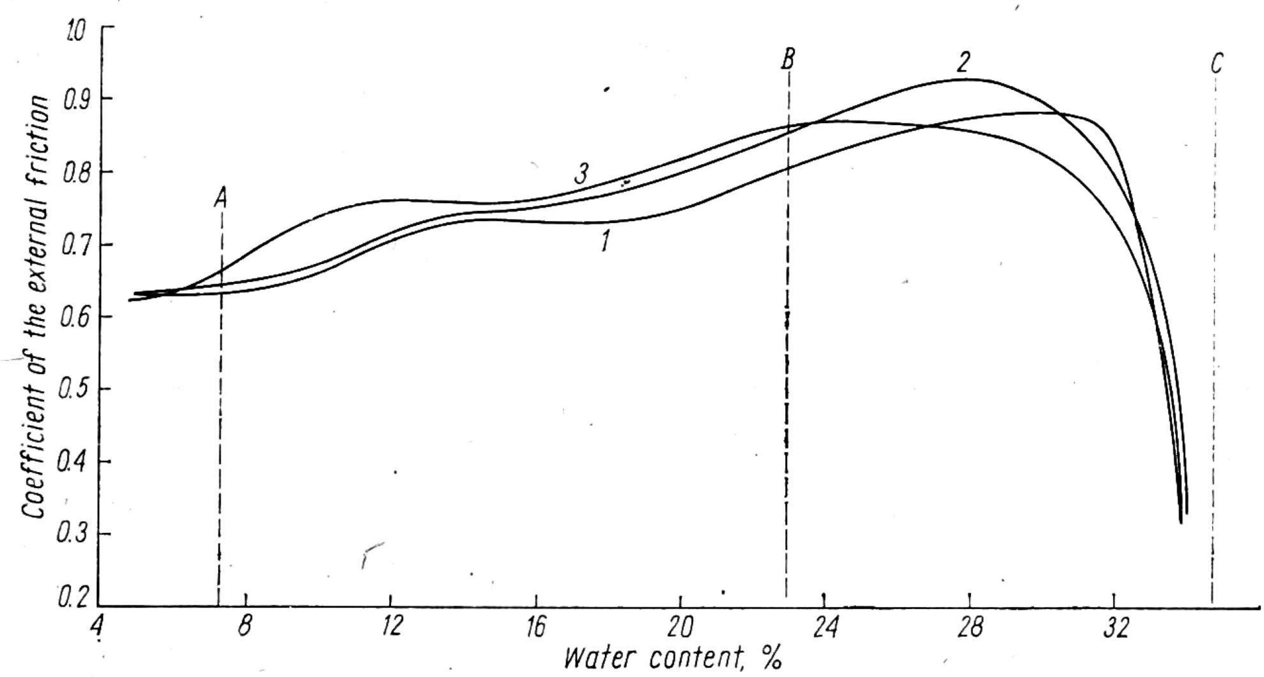

Fig. 7. The influence of water content on the coefficient of friction humic rendzina formed from cretaceous marl (horizon A_1) — steel. Designations as in Fig. 4

CONCLUSIONS

The results obtained confirm the conclusions drawn by Nichols [5] who states that the value of the coefficient of friction soil-metal is determined by the amounts of the absorbed water and by the portative force of the soil being a function of the contents of colloids in soil. Soils formed of sand and light clay are characterized by low friction coefficients richer in colloids loess soils are characterized by higher values of the friction coefficient, and the heavy rendzina has the highest values of the coefficient. Humus contained in the soils plays an important modificating part as it causes an increase in the value of the external friction coefficient of the humid soil.

The properties of the soil do also decide the shape of the curve representing the relationship between the coefficient and humidity. As it was mentioned above, every soil is characterized by a proper shape of the curve. The influence of the steel quality is not, of course, without any importance, though it is usually the quantitative and not the qualitative one.

The differences of the friction coefficient values for the particular, macroscopically similar, smooth kinds of steels in the system of the same soil should be most probably explained by a different hydrofilic properties of the steel. Moreover, the curves of the relationship between the friction coefficient and the humidity have usually a more complicated shape than it is described in the literature.

A fact should be streessed here that two maximum points are characteristic for some curves (Figs. 3, 4, 6). It is most probably the result of a different reaction of the particular kinds of steel on different states of saturation the soil with water. Preliminary investigation which are discussed in this paper are still going on in order to give a full explanation of the mentioned problems.

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KSZTAŁTOWANIE SIĘ WSPÓŁCZYNNIKA TARCIA GLEBA-METAL W ZALEŻNOŚCI OD WŁAŚCIWOŚCI GLEBY I RODZAJU STALI

Streszczenie

Przeprowadzono pomiary współczynnika tarcia zewnętrznego w typowych glebach Wyżyny Lubelskiej. Do badań wybrano następujące gleby o zróżnicowanych właściwościach:

1. Gleba bielicowa wytworzona z piasku luźnego.

2. Gleba brunatna wytworzona z gliny lekkiej.
3. Gleba brunatna wytworzona z lessu.
4. Czarnoziem wytworzony z lessu.
5. Rędzina czarnoziemna wytworzona z kredy piszącej.

Pomiary wykonano przy pomocy aparatu Klotha. Pierścienie pomiarowe zostały sporządzone z trzech gatunków stali używanych do produkcji elementów roboczych narzędzi uprawowych: M65, St5, St3. Stan powierzchni pierścieni, określony przy pomocy wzorca typu WG-4, odpowiada △ 9 (stal gładka). Badania wykonano przy obciążeniu normalnym 0,15 kG/cm². Szybkość poślizgu pierścienia wynosiła 0,07 m/sek.

W celu określenia wpływu wilgotności gleby na kształtowanie się współczynnika tarcia gleba-metal kolejne serie pomiarów prowadzono w miarę wysychania gleby, rozpoczynając od stanu gleby zbliżonego do granicy płynności w glebach spoistych oraz od stanu całkowitego nasycenia wodą w piasku.

Otrzymane wyniki wskazują, że o wartościach przyjmowanych przez współczynnik tarcia zewnętrznego decydują właściwości gleby, a szczególnie skład mechaniczny. Gleby wytworzone z piasku i gliny lekkiej posiadają niskie współczynniki tarcia, bogatsze w koloidy gleby lessowe — wyższe, ciężka rędzina — najwyższe. Dużą modyfikującą rolę odgrywa próchnica, podwyższając znacznie współczynnik tarcia zewnętrznego gleby wilgotnej.

Właściwości gleby decydują również o kształcie krzywej zależności współczynnika tarcia od wilgotności.

Wpływ stali na współczynnik tarcia gleba-metal ma raczej charakter ilościowy niż jakościowy. Gatunek stali w większym stopniu decyduje o wartościach współczynnika niż o kształcie krzywej jego zależności od wilgotności.

А. Словиньска-Юркевич

ОБРАЗОВАНИЕ КОЭФФИЦИЕНТА ТРЕНИЯ ПОЧВА-МЕТАЛЛ В ЗАВИСИМОСТИ ОТ СВОЙСТВ ПОЧВЫ И ВИДА СТАЛИ

Резюме

В типичных почвах Люблинской возвышенности проводились измерения коэффициента внешнего трения. Для исследования были выбраны следующие почвы с дифференцированными свойствами:

1. Подзолистая почва образованная из рыхлого песка.
2. Бурозем образованный из легкой глины.
3. Бурозем образованный из лёсса.
4. Чернозем образованный из лёсса.
5. Черноземная рендзина образованная из мягкого мела.

Измерения проводились аппаратом Клота. Изумерительные кольца были выполнены из трех видов стали употребляемых для производства рабочих элементов орудий по обработке: M65, St5, St3. Состояние поверхности колец, определенное с помощью эталона типа WG-4 отвечает ▽ 9 (гладкая сталь). Испытания проводились при нормальной нагрузке 0,15 кг/см². Скорость скольжения кольца составляла 0,07 м/сек.

С целью определения влияния влажности почвы на образование коэффициента трения почва-металл, очередные серии измерений проводились по мере

обсыхания почвы, начиная с состояния почвы приближенного к границе текучести в связных почвах и с состаяния полного насыщения водой в песке.

Полученные результаты показывают, что принимаемые коэффициентом внешнего трения величины обусловлены свойствами почвы, а особенно ее механическим составом. Для почв образованных из песка и легкой глины коэффициенты трения низкие, тогда как для более богатых коллоидами лёссовых почв они выше, а для тяжелой рендзины — самые высокие. Роль сильно модифицирующего фактора играет гумус, способствуя значительному повышению коэффициента внешнего трения влажной почвы.

Свойства почвы определяют также форму кривой зависимости коэффициента трения от увлажнения.

Влияние стали на коэффициент трения почва-металл носит скорее количественный чем качественный характер. Вид стали обуславливает в более сильной степени величину коэффициента, чем форму кривой иллюстрирующей его зависимость от увлажнения.