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Impact of soil moisture on wear intensity of the actuating elements of soil processing machines

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Abstract

The aim of the study consisted in the determination of the impact of soil moisture on wear intensity of bipod and tined actuating elements of soil processing machines made of different materials.

We conducted the operation study according to the current regulatory documents on three types of soil processing machines: cultivators, plows, and common disk assemblies. Movement speed varied between 10...13 km/h for plows, and between 11...15 km/h for disk assemblies. During operation, we observed the change of linear dimensions and weight of the actuating elements of soil processing machines. Determination of the change of weight and linear dimensions was done after 10 ha of running time per one arrowheaded tine, 30 ha of running time per one disk, and 5 ha of running time per one trail.

As a result of the studies, we have determined that the increase of soil moisture in sandy loam and clay loam soils leads to the increased wear intensity of the actuating elements of soil processing machines. Obtained mathematical dependencies allow determining the value of moisture where the most intensive abrasive wear of actuating elements takes place, after which the wear intensity decreases. Depending on the type of actuating elements, the moisture of sandy loam soils where the process of abrasive wear is the most intensive is 8...12 %, and for clay loam soils this figure is 9...13 %.

The study of the impact of soil moisture on wear intensity of the actuating elements in clay soils was conducted at the moisture before and after the extremum of function, therefore the value of moisture where the most intensive wear takes place was determined experimentally. Consequently, when working in clay loam soils, the wear process for the actuating elements of the soil processing machine is the most intensive at the moisture of 13...16 %.

The material of the actuating element of the soil processing machine does not influence the overall tendency of the impact of soil moisture on wear intensity

Key words: actuating element, soil, moisture, steel, wear intensity, soil processing machines

Introduction

Abrasive wear is one of the most common phenomena leading to the loss of good working order for agricultural machines. Actuating elements of soil processing machines are most prone to abrasive wear. The solution to the issue of increasing the durability and wear resistance of the actuating elements of soil processing machines shall not only be based on the improvement of structural parameters and physical and mechanical properties of the surfaces of actuating elements, but also the implementation of justified operation modes for machines. The selection of rational operation modes shall be based on the physical and mechanical properties of the soil environment considering the opportunities of self-organization processes. Moisture is one of the main factors that determine the abrasive properties of the soil environment, which is why determination of the impact of soil moisture on intensity and nature of wear of actuating elements of soil processing machines is a relevant objective.

Literature review

The issue of abrasive properties of the soil environment was studied at different times by E. Rabinovych [1], M.M. Severniov [2], V.M. Tkachov [3], S.I. Vasyliev [4], V.V. Aulin [5] and others. Their works provide quality insight into the issues of the impact of soil hardness, grain particle size, and abrasive particle size on wear intensity of the actuating elements of soil processing machines, however, pay insufficient attention to the issue of the impact of soil moisture on wear intensity in actual operating conditions.

In most works, laboratory or stand researches were used to determine the impact of soil moisture on wear intensity, which is associated with significant material costs to conduct operation studies.

M.M. Severniov determined the impact of soil moisture on wear intensity of steel samples in laboratory conditions (Fig. 1) [2].

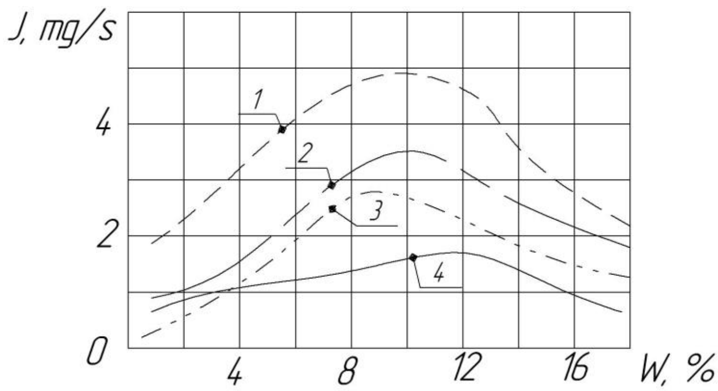


Fig. 1. Dependence of wear intensity on soil moisture:
1 – Sand; 2 – Sandy loam; 3 – Light clay loam; 4 – Clay

Soil always contains a small percentage of acids and salts (sodium salt, chlorine salts of calcium, magnesium, phosphates, etc.) which increase the activity of the adsorption environment significantly and facilitate the material dispersion process after solution in water. This explains the increase of wear intensity in sandy soils and sandy loam soils at the moisture of 10...12 % [2].

In clay soils, moisture acts as grease on the friction surface. Considering the fact that wear here is a process where destruction and wear of the material that forms a friction connection take place as a result of its multiple destructions, it becomes obvious that the increase of the moisture leads to the decrease of the force of friction connections, and, consequently, the decrease of the wear of the smallest metal volumes from the friction surface. This explains the gradually changing nature of the dependency curves of wear from moisture with a change of their mechanical composition [2].

Fundamental studies of the impact of moisture on the wearability of soils were conducted by S.P. Vasyliev and L.S. Yermolov in 1960 [4]. Graphical dependency presented in Fig. 2 was obtained as a result.

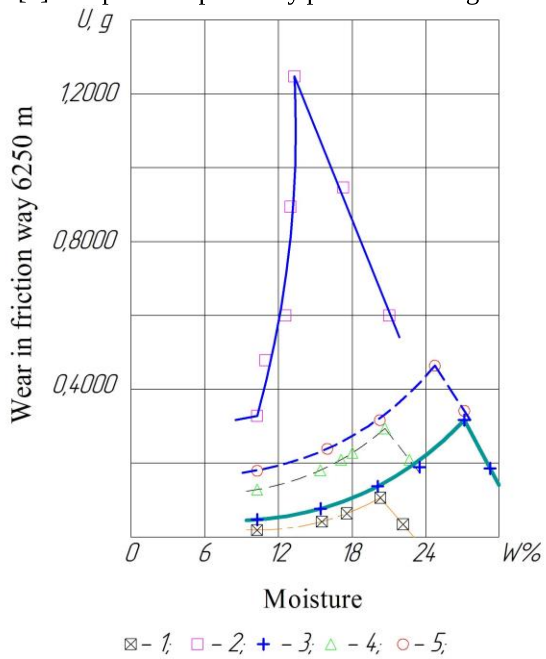


Fig. 2. Dependence of wearability of soils on moisture:
1 – Dark gray light podsolic mid clay loam on forest clay loam. 2 – Common black earth on clay sand. 3 – Light-clay black earth on carbonate forest clay loam. 4 – Dark gray on forest clay loam. 5 – Clay-loam black earth

To determine the impact of moisture of the abrasive environment on the wear rate of steel samples, KR-1 laboratory machine was used. As a result of research, it was determined that the increase of soil moisture leads to the increase of samples wear rate to the limit common for every type of soil, after which it starts decreasing rapidly with soil transfer to consistent state [4]. The results of these studies cannot be used in practice, as the study conditions do not reflect the operation conditions of the actuating elements of soil processing machines.

In the work [6], it is pointed out that lack of moisture in soil decreases its heat conductivity, which results in the formation of temperatures that accelerate the wear process in the area of interaction of the abrasive particle with metal.

E. Rabinovych states that the increase in soil moisture leads to an increase in the steel wear rate for 10...20 % [1].

In the work [7], it is noted that moisture has a significant impact on wear intensity. The lowest abrasive wear of metal is observed at optimal soil moisture when specific resistance during its processing is minimum. Moisture plays the main connecting part in the sand and sandy loam soils, where there are few clay particles. There is a threshold for these soils at which they have maximum abrasiveness. Soil abrasiveness decreases beyond the soil moisture threshold. Research data indicate that clay and clay-loam soils have the smallest abrasiveness at absolute moisture of 14...18 %. Sandy loam soils manifest maximum abrasiveness at absolute moisture of 14 %. In case of an increase or decrease of moisture, soil abrasiveness becomes weaker. The abrasiveness of soils is the lowest at absolute moisture of 9...10 %.

Authors of the work [8] determined that change of soil moisture has a different impact on wear intensity of actuating elements depending on soil type (Fig. 3).

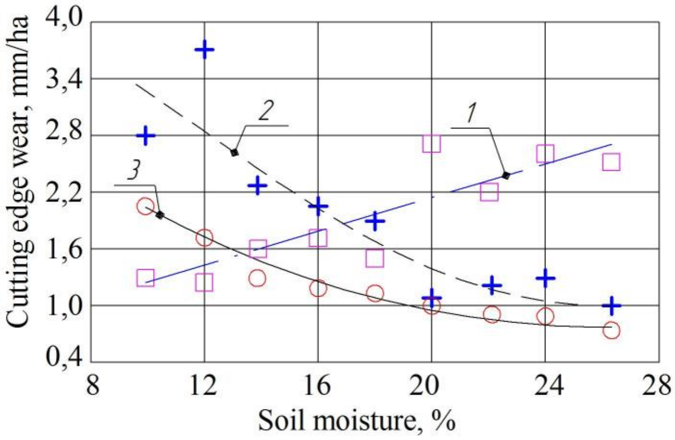


Fig. 3. Impact of soil moisture on wear intensity of the actuating elements of soil processing machines: 1 – sandy soil; 2 – load soil; 3 – clay soil

At operation of plow actuating elements on clay-loam and clay soils, a decrease of wear intensity was observed, unlike in case of operation on sand soils. This phenomenon can be explained by the ability of clay-loam soils to absorb moisture, which then acts as grease, to a larger extent [8].

Despite the great practical and theoretical significance of the studies conducted, the impact of soil moisture on the following remains undetermined:

- intensity and nature of wear of disk and bipod and tine actuating elements of soil processing machines in actual operation conditions;
- wear intensity of disk and bipod and tine actuating elements of soil processing machines at different degrees of abrasive particle attachment in soil.

Purpose

The research aims to determine the impact of soil moisture on the intensity and nature of wear of the actuating elements of soil processing machines considering the actuating element material and degree of abrasive particle attachment in soil.

Methods

Operation studies of the impact of soil moisture on wear intensity of the actuating elements of soil processing machines were conducted in agricultural enterprises of Zhytomyr and Vinnytsia regions in 2016-2018. The average speed was 12 km/h for the soil processing disk assembly, 10 km/h for the plow, 11.5 km/h for the cultivator.

The studies were conducted on agricultural machines indicated in Table 1.

Table 1.

Actuating elements used in the study process

Soil processing machine	Soil type	Actuating element	Actuating element material + applied wear-resistant material
John Deere 2210 cultivator	Sandy loam	Arrowheaded tine	28MnB5
	Middle clay loam		65H
	Light clay		
PLN-3-35	Sandy loam	Bipod	65H
	Middle clay loam		
	Light clay		Hardox 500
UDA-4,5	Sandy loam	Disk actuating element, daisywheel type	28MnB5
	Middle clay loam		65H
	Light clay		

Mass wear of actuating elements was determined on CP 34001 S laboratory scales by Sartorius (Germany).

Fields in all cases were after harvesting of grain crops (winter wheat and barley). Movement speed varied between 10...13 km/h for the plow, and between 11...15 km/h for disk assembly. To determine the nature of the change of abrasive wear, we observed the change of linear dimensions of the components of actuating elements of soil processing machines. Determination of the change of weight and linear dimensions was done after 10 ha of running time per one arrowheaded tine, 30 ha of running time per one disk, and 5 ha of running time per one trail.

Results

The results of the conducted operation studies of the impact of moisture on wear intensity of the actuating elements of soil processing machines can be found in Table 2.

Table 2

Impact of soil moisture on wear intensity of the actuating elements of soil processing machines (fields after grain crops)

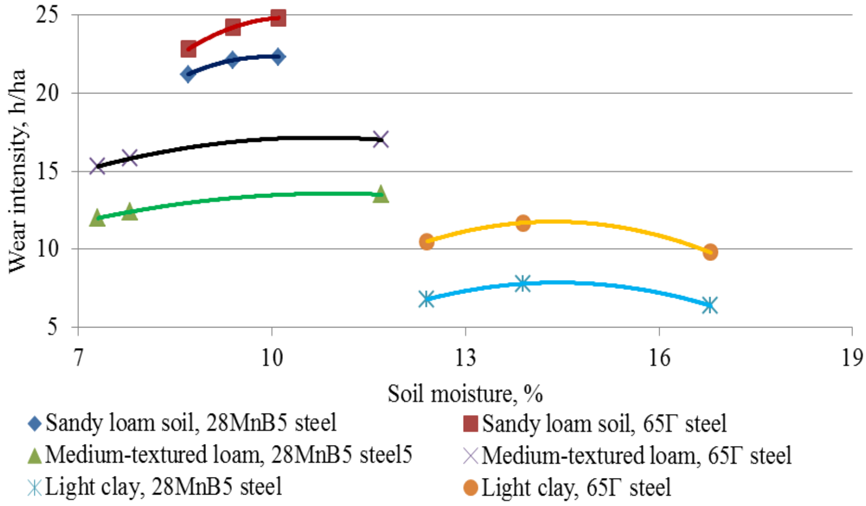
Soil	Year of research	Moisture, %	Intensity of wear, g/ha		Year of research	Moisture, %	Intensity of wear, g/ha		Year of research	Moisture, %	Intensity of wear, g/ha	
			28MnB5 or Hardox 500 steel	65H steel			28MnB5 or Hardox 500 steel	65H steel			28MnB5 or Hardox 500 steel	65H steel
Arrowheaded tine												
Sandy loam	2016	8,7	21,2	22,8	2017	10,1	22,3	24,8	2018	9,4	22,1	24,2
Middle clay loam	2016	7,8	12,4	15,8	2017	11,7	13,5	17,0	2018	7,3	12,0	15,3
Light clay	2016	12,4	6,8	10,5	2017	16,8	6,4	9,8	2018	13,9	7,8	11,7
Disk actuating element												
Sandy loam	2016	8,7	0,065	0,065	2017	10,1	0,068	0,069	2018	9,4	0,067	0,068
Middle clay loam	2016	7.8	0,037	0,039	2017	11,7	0,04	0,045	2018	7,3	0,034	0,037
Light clay	2016	12.4	0,019	0,024	2017	16,8	0,017	0,022	2018	13,9	0,02	0,027
Bipod												
Sandy loam	2016	8,7	65	79	2017	10,1	71	85	2018	9,4	69	83
Middle clay loam	2016	7,8	37	55	2017	11,7	41	59	2018	7,3	35	51
Light clay	2016	12,4	22	32	2017	16,8	20	29	2018	13,9	25	34

Data in Table 2 allow concluding that the change of soil moisture in different types of soil has a different impact on wear intensity of the actuating elements of soil processing machines (Fig. 4).

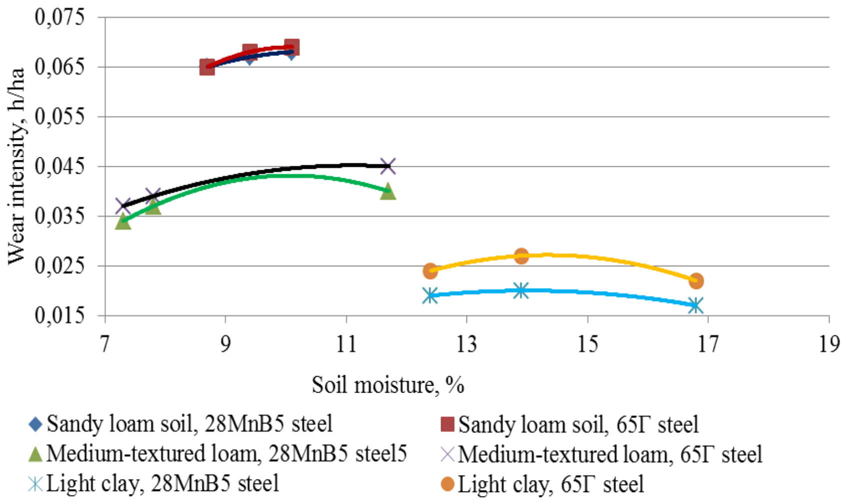
As a result of the studies, we have determined that the increase of soil moisture in sandy loam and clay loam soils leads to the increased wear intensity of the actuating elements of soil processing machines. Obtained mathematical dependencies allow determining the value of moisture where the most intensive abrasive wear of actuating elements takes place, after which the wear intensity decreases. Depending on the type of actuating elements, the moisture for sandy loam soils where the process of abrasive wear is the most intensive is 10...13 %, and for clay loam soils this figure is 9...13 %.

The study of the impact of soil moisture on wear intensity of the actuating elements in clay soils was conducted at the moisture before and after the extremum of function, therefore the value of moisture where the most intensive wear takes place was determined experimentally. Consequently, when working in clay loam soils, the wear process for the actuating elements of the soil processing machine is the most intensive at the moisture of 13...16 %.

The material of the actuating element of the soil processing machine does not influence the overall tendency of the impact of soil moisture on wear intensity.



a)



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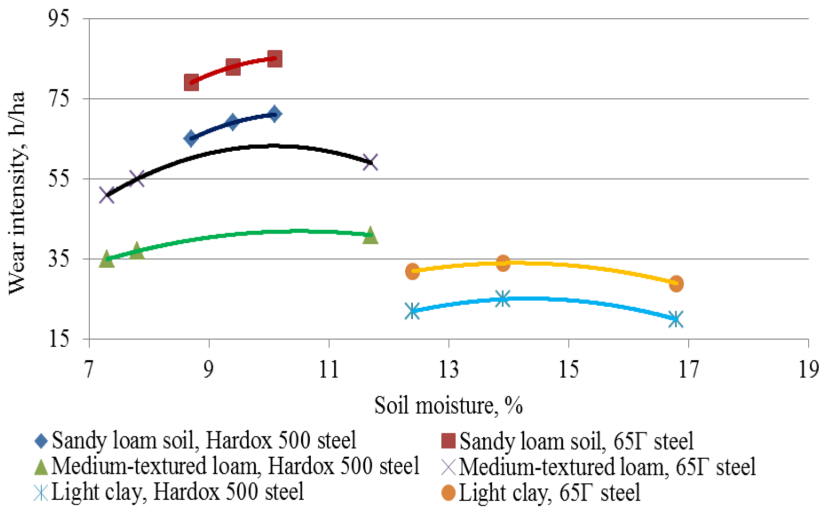

c)

Fig. 4. Impact of soil moisture on wear intensity of the actuating elements of soil processing machines (experimental data):
a) – arrowheaded tines. b) – disk actuating elements. c) – bipod

To determine the impact of soil moisture on the nature of wear, we observed the wear intensity of the components of actuating elements of soil processing machines (Table 3).

Table 3.

Correlation of wear intensity of nose and blade part for different types of soils and soil moisture (serial bipod, 65H steel, 5 ha of operation per bipod, winter wheat fields)

Correlation of bipod toe and blade wear intensity	Soil moisture, %								
	8,7	10,1	9,4	7,8	11,7	7,3	12,4	16,8	13,9
Sandy loam soil	1,48	1,59	1,51	-	-	-	-	-	-
Middle clay loam	-	-	-	2,19	2,21	2,18	-	-	-
Light clay	-	-	-	-	-	-	2,31	2,34	2,33

Intensification of the process of wear of the nose part of the bipod is observed with the increase of moisture of sandy loam soils. This trend is also observed in clay loam and clay sands, but it is not as prominent.

The results of previous theoretical studies show that the degree of abrasive particle attachment in the soil can influence the nature of the wear of actuating elements significantly. To confirm or dismiss this statement, we conducted studies on sandy loam soil at three different degrees of abrasive particle attachment:

1. Plot after winter wheat;
2. Plot after winter wheat, second plowing.

Research results can be found in Table 4.

Table 4

Correlation of wear intensity of nose and blade part in the conditions of sandy loam soil at different degrees of abrasive particle attachment (serial bipod, 65H steel, 5 ha of operation per bipod, processing depth 200 mm in all cases)

Research conditions	Soil moisture, %		
	8,7	10,1	9,4
Plot after winter wheat	1,48	1,59	1,51
Plot after winter wheat, second plowing	0,71	0,72	0,72

Change of the degree of abrasive particle attachment in soil has a significant impact on the nature of wear of the actuating elements of soil processing machines. Change of soil moisture in loose soils (with a small degree of abrasive particle attachment) does not influence the nature of wear of the actuating elements of soil processing machines (Table 4).

Conclusions

It has been determined that the nature and intensity of wear of the actuating elements of soil processing machines changes in case of an increase of soil moisture. Upon the increase of soil moisture, its wearability increases to the limit common for each type of soil, after which the wear intensity starts decreasing. The material of the actuating element of the soil processing machine has no impact on the general trend of the change of wear intensity of the actuating elements of soil processing machine upon the change of soil moisture. Soil moisture has no impact on the nature of wear of actuating elements in case of operation of soil processing machines on loose soils.

References

1. Rabinowicz, E., Dunn, L.A., Russell, P.G. (1961). A study of abrasive wear under three-body conditions. Wear, 4, 345-355: URL: https://doi.org/10.1016/0043-1648(61)90002-3.

2. Severnev, M. M., Podlekarev, N. N., Soxadze, V. S., Kitikov, V. O. (2011). Iznos i koroziya sel`s`koxozyajstvenny`x mashin [Wear and corrosion of agricultural machinery]. Minsk: Belarus. Navuka, 333 p.

3. Tkachev, V. N. (1995). Rabotosposobnost` detalej v usloviyax abrazivnogo iznashivaniya [Parts performance under abrasive conditions], Moskva: Mashinostroenie, 336 p.

4. Vasil'ev, S. P., Ermolov, L. S. (1960). Ob iznashivayushchej sposobnosti pochv [Soil wear ability]. Povyshenie dolgovechnosti rabochih detalej pochvoobrabatyvayushchih mashin. 130-141.

5. Aulin, V. V., Tykhyi A. A. Trybofizychni osnovy pidvyshchennia znosostiikosti i nadiinosti robochykh orhaniv gruntoobrobnykh mashyn z rizalnymy elementamy: monohrafiia [Tribophysical bases of increase of durability and reliability of working bodies of tillage machines with cutting elements: monograph], Kropyvnytskyi: Lysenko V.F., 2017, 278 p.

6. `Lekhman, S. D. (1969). Issledovanie processa abrazivnogo iznashivaniya rabochih organov pochvoobrabatyvayushchih mashin v svyati s mekhanicheskim i himicheskim dejstviem rabochej sredy. (Master`s thesis). Urainskaya SKHA. Kiev, 19 p.

7. Bartenev, I. M., Pozdnyakov, E. V. (2013). Iznashivayushchaya sposobnost' pochv i ee vliyanie na dolgovechnost' rabochih organov pochvoobrabatyvayushchih mashin [Soil wear ability and its effect on the durability of the working bodies of tillage machines]. Lesotekhnicheskij zhurnal, 3, 114-123.

8. Natsisa A., Papadakis G., Pitsilis J. (1999). The Influence of Soil Type, Soil Water and Share Sharpness of a Mouldboard Plough on Energy Consumption, Rate of Work and Tillage Quality. Journal of Agricultural Engineering Research, 72, 171-176: URL: https://doi.org/10.1006/jaer.1998.0360

Борак К.В. Вплив вологості ґрунту на інтенсивність зношування робочих органів ґрунтообробних машин

Завдання дослідження полягало у визначенні впливу вологості ґрунту на зміну інтенсивності зношування лемішно-лапових та дискових робочих органів ґрунтообробних машин, які виготовлені з різних матеріалів.

Експлуатаційні дослідження проводили згідно діючих нормативних документів на трьох типах ґрунтообробних машин: культиваторах, плугах та універсальних дискових агрегатах. Швидкість руху для плугів варіювалась в межах 10…13 км/год, культиваторів та дискових агрегатів – 11…15 км/год. В процесі експлуатації слідкували за зміною лінійних розмірів та ваги робочих органів ґрунтообробних машин. Визначення зміни ваги та лінійних розмірів проводили після напрацювання 10 га на одну стрілчату лапу, 30 га на один диск та 5 га на один леміш.

В результаті досліджень встановлено, що збільшення вологості ґрунту на супіщаних та суглинкових ґрунтах призводить до підвищення інтенсивності зношування робочих органів ґрунтообробних машин. Отримані математичні залежності дозволяють встановити значення вологості, при яких спостерігається найбільш інтенсивне абразивне зношування робочих органів, після чого інтенсивність зношування зменшується. В залежності від типу робочих органів вологість супіщаних ґрунтів при якій процес абразивного зношування протікає найінтенсивніше, складає 8…12 %, а для суглинкових – 9…13 %.

Дослідження впливу вологості ґрунту на інтенсивність зношування робочих органів, на глиняних ґрунтах проводилася, при вологості до і після екстремуму функції, тому значення вологості при яких відбувається найінтенсивніше зношування визначено експериментально. Відповідно при роботі на глиняних ґрунтах процес зношування робочих органів ґрунтообробних машин протікає найінтенсивніше при вологості 13…16 %.

Матеріал робочого органу ґрунтообробних машин не впливає на загальну закономірність впливу вологості ґрунту на інтенсивність зношування.

Ключові слова: робочий орган, ґрунт, вологість, сталь, інтенсивність зношування, ґрунтообробні машини.