Analele Universităţii din Craiova, seria Agricultură – Montanologie – Cadastru (Annals of the University of Craiova - Agriculture, Montanology, Cadastre Series) Vol. 51/2/2021

RESEARCH REGARDING LABORATORY TESTING OF SOIL PROCESSING EQUIPMENT USING THE EFFECT OF ELECTRO-OSMOSIS

BRĂCĂCESCU C.[1], VLĂDUŢ V.[1*], BIRIŞ S.ŞT.[2], UNGUREANU N.[2], POPA D.*[3], MATEI GH.[4], BORUZ S.[4], VOICEA I.[1]

[1] INMA Bucharest/ Romania; [2] University POLITEHNICA of Bucharest; [3]ARDS Secuieni; [4]University of Craiova

Keywords: soil, tilling, electro-osmosis, disc-knife.

ABSTRACT

Electro-osmosis principle consists of the application of a direct current voltage for an anode-cathode system introduced into soil. The soil water transported from the anode to cathode, on the tool-soil contact surface will produce a lubrification of an active surface and through this a great decreasing of the friction forces and implicit of the energy needed for displacing the tool through the soil. The active surface of the tilling tool is chosen in order to minimize the frictions, respective the mechanic energies needed for tilling. This paper aims to increase the popularization of the electro-osmosis technique, highlighting the advantages of using such a method for soil improvements, as well as in view of optimizing the functional parameters of the soil tillage equipment.

INTRODUCTION

Electro-osmosis principle [7] consists of the application of a direct current voltage for an anode-cathode system introduced into soil. The effect of this system consists in the mobilization of water particles from the soil and their transport in a very short time from the anode to the cathode. For tillage machines, the anode can be a disk knife and the cathode the working part.

It is known that a basic component of the force resistant to the movement of the working part through the ground is the frictional force that arises on the tool-ground contact surface. Attempts to reduce this force by other means such as: vibration of the tool, covering its active surface with enamel, lubrication of the active surface of the tool, are limited by the shortcomings of these procedures and their ineffectiveness. The ground water transported from the anode to the cathode, therefore, on the tool-ground contact surface, will produce a lubrication of the active surface and thereby a considerable reduction of the friction forces and implicit of the energy necessary to move the tool through the ground [2, 4].

The energy required for tillage is a considerable part of the total energy consumed for plant cultivation. When the soil is processed by pulling or pushing processing tools, a significant part of the processing energy is consumed to overcome the frictional forces on the contact surfaces between the tool and the ground.

The active surface of the machining tool can be chosen appropriately in order to minimize friction or mechanical energy required for machining.

Also, electro-osmosis has been implemented to improve the strength of soil [1, 3, 5, 6].

This paper aims to increase the popularization of the electro-osmosis technique, highlighting the advantages of using such a method for soil improvements, as well as in view of optimizing the functional parameters of the soil tillage equipment.

MATERIAL AND METHOD

The tillage tests for quantifying the forces necessary to move and reduce the energy obtained with electro-osmosis were performed in a soil channel with a width of 1.2 m and a depth of 0.5 m, the test section having approximately 13m long, with walls provided with rails that serve as a support for the trolley on which the processing tools are placed.

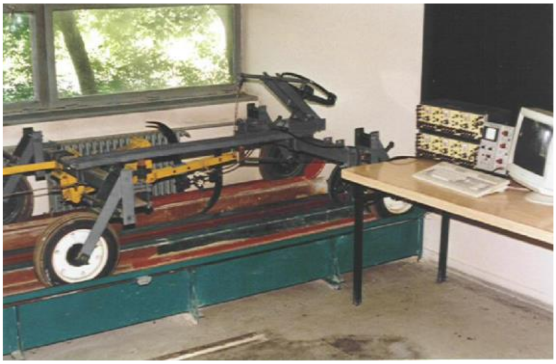

Figure 1 - Test stand for highlighting the effect of electro-osmosis on the reduction of traction force in soil tillage tests

The trolley is controlled by a drive system consisting of an electric motor and a gearbox that allows to ensure three working modes (fig. 1). The main elements that make up the equipment for producing the electro-osmosis effect are: metal frame, processing tool, disc knife (straight), processing knives, disc holder, knife holder, insulation, power supply, voltage inverter (switching source: 0÷80 V/1A), electrical circuit for electrical measurement.

The reduction of the resistance force varied, the processing tests being performed in two different soils: one sandy and another clay-loam (medium soil), with a clay content of over 16%.

Figure 2 - Equipment used in soil tillage tests with electro-osmosis (disk knife used as anode)

Figure 3 - Equipment used in electro-osmosis soil tillage tests (straight knife used as anode)

For the sandy soil, the experiments were performed at a moisture of 4.76% (21% real) and in the clay-loam soil at three moistures: 12.04%, 13.66% and 19.81%, respectively at two different working speed: 2.16 km / h and 8.55 km / h, the applied voltages being between: 0 and 40V. The experiments were performed using both a disk knife as an anode and a straight knife. For each type of soil, the tests for determining the variation of resistance were performed at the beginning without applying an electric voltage (0V), and then depending on the type of soil, the voltage varies upwards, by 20V (sandy soil) and 10V (clay-loam soil).

In the case of sandy soil, the experiments were performed as follows: for the speed of 2.16 km/h the applied voltage was varied from 0 to 40V (the variation stage being 20V) and a straight knife used as an anode. The humidity at which these experiments were performed was only 4.76% (due to the silica in the sand that hardly accumulates water), but the actual humidity of the sand layer was about 21% (the sand layer is homogeneous due to its microstructure). This variation of the tensile strength was compared with a force resulting from tillage without applying the phenomenon of electro-osmosis, resulting in the reduction of the obtained force and implicitly the energy saving obtained. Before each test, the soil surface was leveled and compacted to obtain a soil density as close as possible to that of the field. Likewise, in order to obtain a uniform humidity along the entire length of the canal, the soil was watered after which it was left for a while to reach the desired humidity.

The tillage tests were performed at a depth of 15 mm, the voltage applied from a direct current source varying between 0 and 40V. Each of the machining tools was isolated from the frame so as not to destroy the tensometric device.

RESULTS AND DISCUSSIONS

To determine the potential of water through the soil, soil moisture, penetration resistance, density and electrical resistivity were taken into account. Following these tests in the sandy soil, applying the electro-osmosis effect, a maximum reduction of 20.96% of the traction force was obtained at 40V applied voltage, using a straight knife as an anode, travel speed of 2.16 km/h, humidity of 4.76% (21% real). At a speed of 8.55 km/h, using also a straight knife as anode and the soil having a humidity of 4.76% (21% real) a maximum reduction of the traction force of 35.25% was obtained (at 40V voltage power supply).

Table 1

Test results for sandy soil processing by the effect of electro-osmosis

No.	Speed V [km/h]	Voltage T [V]	Moisture W [%]	Knife type	Force F_t [daN]	Force reduction [%]
1	2.16	0	4.76 (21)	N (straight)	23.37	-
2		20			21.45	8.21
3		40			18.47	20.96
1	8.55	0	4.76 (21)	N (straight)	35.77	-
2		20			34.00	4.95
3		40			23.16	35.25

For the clay-clay soil, the tillage tests using the electro-osmosis effect were performed at three moistures: 12.04%, 13.66% and 19.81%, using as an anode a straight knife and a disc knife.

In the case of a humidity of 19.81%, applying the electro-osmosis effect, a maximum reduction of the traction force of 21.36% was obtained (at 40V applied voltage), using a straight knife as an anode and a travel speed of 2.16 km/h. For the same soil moisture (19.81%)

but moving at a speed of 8.55 km/h, using a straight knife as an anode and using the electro-osmosis effect, was obtained a maximum reduction of the traction force of 21.19% (at 40V supply voltage).

Using a disk knife as an anode, a maximum reduction of the traction force (using the electro-osmosis effect) of 16.43% (at 40V applied voltage) was obtained, the speed of movement of the tool through the ground being 2.16 km/h, at the same soil moisture - 19.81%. If the speed of movement of the tool was 8.55 km/h, for the same soil moisture (19.81%), using another knife as an anode and using the electro-osmosis effect, was obtained a maximum reduction of the force of 30.25% traction (at 40V supply voltage).

Table 2

Test results for clay-loam soil processing by the effect of electro-osmosis (W=19.81%)

No.	Speed V [km/h]	Voltage T [V]	Moisture W [%]	Knife type	Force F_t [daN]	Force reduction [%]
1	2.16	0	19.81	N (straight)	36.86	-
2		10			35.60	3.42
3		20			32.78	8.59
4		30			29.97	16.42
5		40			28.20	21.36
1	8.55	0	19.81	N (straight)	45,19	-
2		10			43.75	3.18
3		20			41.27	8.67
4		30			38.39	15.04
5		40			35.16	21.19
1	2.16	0	19.81	D (disk)	27.07	-
2		20			25.03	7.53
3		40			22.62	16.43
1	8.55	0	19.81	D (disk)	40.14	-
2		20			35.34	11.96
3		40			30.25	24.63

In the case of a humidity of 13.66%, applying the electro-osmosis effect, a maximum reduction of the traction force of 22.33% was obtained (at 40V applied voltage), using a straight knife as an anode and a travel speed of 2.16 km/h. For the same soil moisture (13.66%) but moving at a speed of 8.55 km/h, using a straight knife as an anode and using the electro-osmosis effect, was obtained a maximum reduction in traction force of 26.12% (at 40V supply voltage).

Table 3

Test results for clay-loam soil processing by the effect of electro-osmosis (W=13.66%)

No.	Speed V [km/h]	Voltage T [V]	Moisture W [%]	Knife type	Force F_t [daN]	Force reduction [%]
1	2.16	0	13.66	N (straight)	27.91	-
2		10			26.95	3.44
3		20			25.49	8.67
4		30			23.56	15.58
5		40			22.33	19.99
1	8.55	0	13.66	N (straight)	33.42	-
2		10			31.00	7.24
3		20			30,16	9.75
4		30			28.54	14.60
5		40			26.12	21.84
1	2.16	0	13.66	D (straight)	29,11	-
2		10			28.90	0.72
3		20			26,57	8.72
4		30			23.07	20.74
5		40			22,39	23.08
1	8.55	0	13.66	D (disk)	40.70	-
2		10			38.08	6.43
3		20			36.44	10.46
4		30			33.10	18.67
5		40			30.41	25.28

Using a disk knife as an anode, a maximum reduction of the traction force (using the electro-osmosis effect) of 22.39% (at 40V applied voltage) was obtained, the speed of movement of the tool through the ground being 2.16 km/h, at the same soil moisture of 13.66%. If the speed of the tool was 8.55 km/h, for the same soil moisture (13.66%), using another disk knife as an anode and using the electro-osmosis effect, was obtained a maximum reduction of the force of 30.41% traction (at 40V supply voltage).

According to the representations in the figures 4, 5 and 6 following the application of the electro-osmosis effect in the two different soils it was obtained:

- a maximum reduction of 35.25% at 40V applied voltage between anode and cathode, travel speed of 8.55 km / h and a straight knife used as anode, humidity of 21% (for sandy soil) and
- a maximum reduction of 25.28% (using a disk knife as an anode), respectively 21.84% (using a straight knife as an anode), at an applied voltage of 40V, a travel speed of 8.55 km / h and a humidity of 13.66% (for clay-loam soil).

For sandy soil, the maximum reduction of the traction force is achieved at a humidity of 21%, at a speed of movement of the tillage tool of 8.55 km / h, using a straight knife as an anode.

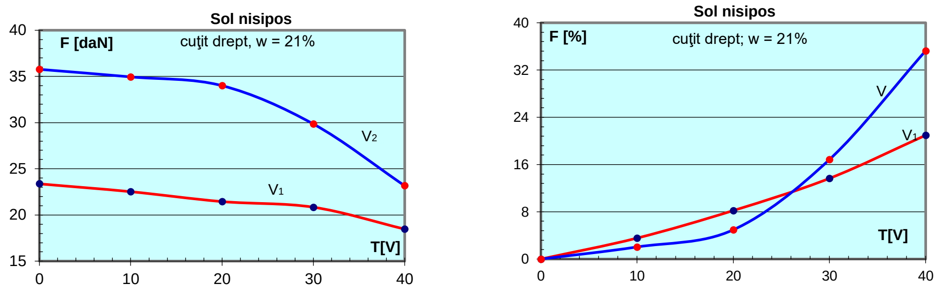

Figure 4 - Variation of the traction force with voltage when processing with a straight knife a sandy soil for:
W = 21%, V_1 = 2.16 km / h; V_2 = 8.55 km / h

For clay-loam soil, the maximum reduction of the traction force is achieved at moisture of 13.66%, at a speed of movement of the processing tool through the soil of 8.55 km / h, the effect being more pronounced when using a disc knife as anode.

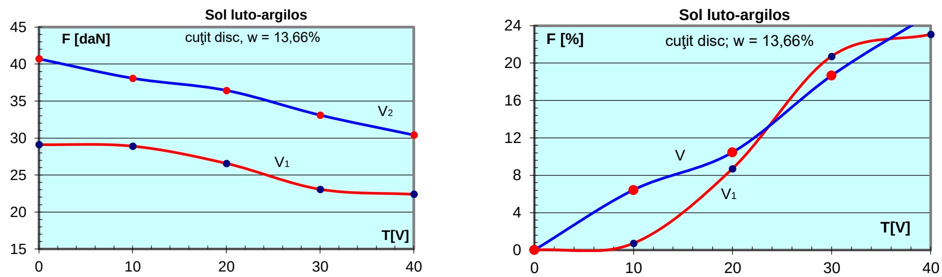

Figure 5 - Variation of the traction force with voltage when processing with a disk knife a clay-loam soil for:
W = 13.66%, V_1 = 2.16 km / h; V_2 = 8.55 km / h

Also in the case of clay-loam soil, a maximum reduction of the traction force of 21.84% was obtained, but using a straight knife as an anode, at the same humidity and speed of movement of the processing tool through the soil as in the case of the disc knife,13.66% and 8.55 km/ h, respectively.

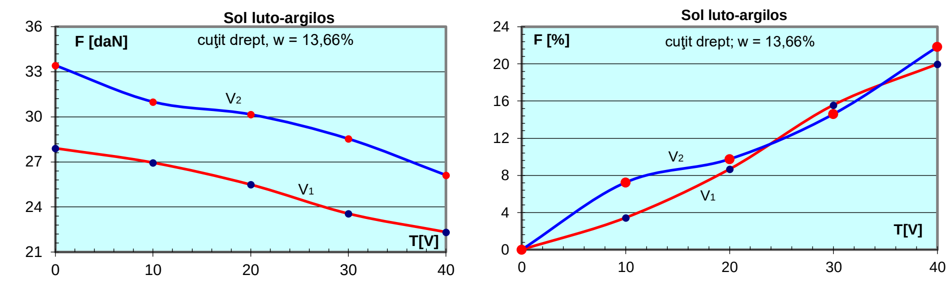

Figure 6 - Variation of the traction force with voltage when processing with a straight knife a clay-loam soil for:
W = 13.66%, V_1 = 2.16 km / h; V_2 = 8.55 km / h

CONCLUSIONS

Analyzing the obtained results, we can conclude:
- the greatest reduction of the traction force was obtained at higher soil processing speeds; this speed being limited;
- the reduction of the traction force is directly proportional to the increase of the supply voltage reaching a maximum at 40V;
- the reduction of the traction force was greater when a disc knife was used as an anode than if a straight knife was used (due to the larger active surface);
- the resistance to advancement decreases proportionally with the soil moisture, this being limited but because at very high humidity the soil adheres to the processing tool and therefore the increase of frictions.

In conclusion, the effectiveness of electro-osmosis is directly proportional to the increase in humidity, the speed of movement of the tool through the soil and the increase in supply voltage and is inversely proportional to the density of the soil and the degree of uniformity of the soil.

BIBLIOGRAPHY

1. Andronic A., Şerbulea M-S., Roşu C., Manoli D-M., 2013, *Soil improvement using the electro-osmosis,* 13th International Multidisciplinary Scientific Geoconference SGEM 2013, Albena, Bulgaria, DOI: 10.5593/SGEM2013/BA1.V2/S02.047;
2. Dano P.L., 1961, *Electro-osmosis effectiveness in reducing energy and power requirements*, M.S. thesis, Auburn, Alabama;
3. Huweg A. F. S. , Fouad K., Raine S., 2010, *Investigating the effect of electro-osmosis on sandy soil near saturated conditions,* Southern

Region Engineering Conference Tooowoomba Australia, SREC2010-T1-2;
4. Larson D.L., Clyma H.E., 1995, *Electro-osmosis effectiveness in reducing tilage draft force and energy requirements*, Transactions of the ASAE, vol. 38(5)/1995, pp. 1281÷1288;
5. Mir Mahalleh H.A., Siavoshnia M. Yazdi M., 2021, *Effects of electro-osmosis on the properties of high plasticity clay soil: Chemical and geotechnical investigations*, Journal of Electroanalytical Chemistry 880(2): 114890 Journal of Electroanalytical Chemistry 880(2):114890, DOI: 10.1016/j.jelechem.2020.114890;
6. Wang M., 2012, *Structure Effects on Electro-Osmosis in Microporous Media, Journal of Heat Tansfer In Press (5)*, DOI:10.1115/1.4005711;
7. Sahib A., I. Bushra I., Rejimon G., 2020, *Electro-osmosis: A Review from the Past*, Problematic Soils and Geoenvironmental Concerns, Proceedings of IGC, DOI: 10.1007/978-981-15-6237-2_36.