Effect of New Hard Facing Materials of Tillage Tools on Draft and Roughness

Zein El - Din. A.M, Saad. F.Ahmed and R. G. Abdel Hamied
Department of Agriculture and Bio Systems Engineering, Alexandria University, Faculty of Agriculture, Egypt.

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ABSTRACT

Tillage consumes a large amount of energy because of the high draft requirements. Thus, the importance of soil-metal sliding action is an important factor, which consumes energy. The control of soil movement on the tillage tool is a major desired action. Also, the kind of surface governs the bath of movement of the soil. The adhesion between the tool surface and the soil is greater than that of the cohesion. Thus, the main objectives of this investigation are to determine the draft required for a simple tillage tool produced from different types of steel API 52, K110 and M238 which were treated with different treatments. The effect of these different treatments on the share hardness was tested and evaluated. Results showed that the draft requirements of coated shares by carbon nanotube-hard chromium composite were less than that of untreated shares by about 43.92%, 44.14 %, and 38.02 % respectively. Also, it was found that hardness was improved by coating with carbon nanotube-hard chromium composite CNT+HCR which gave the highest value for hardness compared to other treatments. On the another hand, the lowest value of surface roughness was obtained in carbon nanotube-chromium composite treatment after tillage of 200 hours followed by hard chromium treatment in all type of steel.

Key words: draft, coating, roughness.

INTRODUCTION

Tillage is a practice of modifying the state of soil provides conditions favorable to promote plant growth. It represents the most energy consumption item in the farmer budget. High draft requirements of tillage tools are due to friction of large amount of soil sliding over the surface of the metal tillage tool. The frictional forces are high and the abrasion effect makes the plow ineffective. The abrasion properties of soil are similar to the dynamic frictional properties.

When the soil grains are rolling over the tool surface, it scratching, breaking or grinding it. The properties of the sliding material such as sharpness, size, and moisture content are affect by the abrasion of tillage tool. The dynamic action of soil sliding over the tool surface involves more than the mechanical loss of metal due to friction.

The objective of the tillage tool is to manipulate a soil as required to achieve a desired soil condition. There are three abstract design factors namely, 1. Initial soil condition, 2. Tool shape and, 3. Manner of tool movement. These three design factors control or define the soil manipulation. The results of these three input factors are evidenced by two output factors, namely, 1. The final soil condition and, 2. The forces required to manipulate the soil. All five factors are of direct concern to a tillage implement designer. Ananthachar (2016)

Tillage is associated with soil displacement and sliding on tillage tool. Soil friction parameter against the tillage tools that have wide contact surface with soil, increases the required draft and consequently energy consumption would be increased. According to its definition, friction is the resistance against relative motion of two tangential objects to each other when sliding, resulted by an external force or pressure Kepner et al (1978)

Wear can be problematic whenever moving machine parts come in contact with each other. Wear is the major reason that limits the durability of many agricultural tools. Agricultural soil-cutting tools have their own characteristics of wear, which are different from other types, since they interact with soils of various textures, moistures and other unpredictable conditions in the field increasing wear. The basic surface modification techniques are used by many research scholars to improve the surface characteristics.

Abrasive wear is a major cause for the premature failure of many agricultural ground tools especially engaged in some dry land agricultural areas. Heavy agricultural equipment operators and farmers always faced with the frequent labor, equipment downtime and reinstating costs of worn out earth engaging components. The tillage capacity of the worn out tools decreases whereas the fuel penalty increases Fernandez et al (2001)

Most agricultural operations are carried out on the field and are subjected to friction and wear of material that have accompanied man since his very beginning. Wear is defined as damage to a solid surface, generally involving progressive loss of material, because of relative motion between that surface and a contacting substance(s) Gurrumoorthy et al (2007).

Wear is influenced by the hardness, dimension, and shape of the abrasive particles; the shape of the plowshare and the draft. Er and Par (2006)

Wear of soil engaging components occurs because the materials used are normally softer than the natural abrasives in the soil. Most of the agricultural tools are manufactured by the small scale industries. Due to improper material and surface hardening treatments, the quality of tools does not conform to the Bureau of Indian Standards resulting in high wear rates and reduced life, which are hardly as per with the standards which affects operational life of tillage tool. So, there was a need to study wear characteristics of agricultural tools, as to provide the suitable tools. Punamchand et al (2016)

Materials used in soil-engaging tools should be hard enough to resist wear but also tough enough to resist impact and distortion Foley et al (1984). The toughness and hardness of plowshare material, which is subject to high wear, should be optimized to satisfy the working conditions. A suitable solution requires a tradeoff between the surface properties and the strength of the material. Several methods have been investigated to increase the wear resistance of soil tillage tools. Teflon coating, liquid emulsion, electro-osmosis, hard chrome and other surface hardening techniques have been tried. However these techniques are difficult to apply in the agricultural industry because of their cost and inconvenience.Nitriding, carburizing, heat treatment Instead, conventional heat treatment techniques (e.g., quenching and tempering) are widely used to improve the mechanical characteristics of tillage tools.

Er (2004) studied that the abrasive wear behavior of two boron steels. AISI 15B35H and AISI 15B41H boron steel are compared by considering hardness and abrasive wear rate. The test carried out heat treated and untreated cubic steel specimens. He observed that the hardness of untreated boron steel specimens are increased with increasing carbon content of the test material and this positively effect the abrasive wear resistance

Mamman and Oni (2005) studied the draft performance of a chisel plow model using a soil bin. The design parameters considered were: nose angle, slide angle, depth and speed. The draft increased with increases in tillage depth and the levels of nose and slide angles and the cutting edge height

Experiments were carried out in the soil-bin with sandy loam soil. The objectives of this study are:

- To determine the effect of different treated tillage tools on draft requirements.
- To determine the effect of different treated materials on hardness, roughness and consequently the abrasion tillage tools.

MATERIALS AND METHODS

In order to increase the hardness of the tool surface with a good adhesive property, we suggested alternative techniques based on four steps using only standard industrial methods. The first step is a thermal treatment which commonly used to improve the surface properties of ferrous materials for increasing wear and abrasion performance of the materials. The second step is increasing the carbon content at the surface of the substrate using a standard nitro carburizing process. The third step is coating the specimen with a layer of hard chromium. The last step is coating the specimens with a layer of carbon nanotube-hard chromium composite. The plowshares produced from different steel). An equal sized dimensioned metal (25*5*1 cm) were cut and produced from steel API 52, K110 and M238 similar to a simple plowshare. The bottom edge of each specimen was beveled at an angle of 30° to provide a sharp cutting edge. The chemical composition of plowshares used in this study was measured by spectrometer to determine the spark analysis as shown in Table (1).

Treatments of plowshares (tools):

Fifteen equal sized specimens' plowshares were produced from different carbon steel API 52, K110, and M238 and classified into five groups (each group three specimens) as follows:

Group 1, was treated by conventional heat treatment HT

Group 2, was treated by nitrocarburizing treatment NC

Group 3, was coated with hard chromium HCR

Group 4, was coated by hard chrome-carbon nanotube composite CNT+HCR.

The heat and nitrocarburizing treatments are conducted in BÖHLER EDELSTAHL GMBH & CO.

Table 1: The Chemical Composition of steel (Average %):

Type of steel	C	Si	Mn	P	S	Cr	Mo	Ni	V
API 52	0.063	0.13	1.12	0.002	0.008	0.010	0. 03	0.011	0.002
K110	1.55	0.30	0.31	0.018	0.019	11.30	0.75	0.15	0.75
M238	0.42	0.26	1.47	0.006	0.001	1.930	0.21	0.99	0.007

Where:

C: carbon element, Si: Silicon, Mn: Manganese, P: Phosphorus, S: Sulfur, Cr: Chromium, Mo: Molybdenum, Ni : Nickel and V: Vanadium

Heat treatment

Annealing: 800 to 850°C- slow controlled cooling in the furnace at a rate of 10 to 20°C/h down to approx.600°C further cooling in air. Stress reliving : 650-700 °c slow cooling in furnace intended to relive stresses set up by extensive machining, or in complex shapes, after through heating hold in neutral atmosphere for 1 to 3 hours. Hardening: 1020 to 1040°C, complex shapes air simple shapes/air blast oil, salt from (220-250°c or 500-550°c).Holding time after temperature equalization: 15 to 30 minutes. Tempering: slow heating to tempering temperature immediately after time in furnace 1 hours for each 20 mm of work piece thickness but at least 2 hours / cooling in air.

Nitrocarburizing treatment

This treatment is a surface treatment applied to finished steel surface to increase both adhesive wear resistance and fatigue limit of steel material. After nitriding, stress reliving at about 300°c is recommended. If salt bath nitriding is to be effected, we recommended elevated hardening temperature (1060-1080°c) with subsequent tempering in two cycles 1^{st} at 520°C.2^{nd} at 30-50°C below 1^{st} tempering temperature. Then bath nitirding. Tuffride process is carried out at 570°c; holding time 30 minutes for a depth of nitration of about 0.03 mm.

Coating with hard chromium

In order to ensure the satisfactory adhesion of chromium deposits, the parts must be almost perfectly clean and free of any grease. In this treatment the operation conditions were: - Bath solution was containing 250 g L^{-1} chromic acid+ 2.5 g / l catalyst.

- Complete current density 50 A dm^2 at 55°.
- Thickness of coating: 30 micron.

Soil bin facility

The experiments were conducted in an indoor soil bin of dimensions length, width and depth of 11*1.24*1 m, respectively, located in the Department of Agricultural and Bio systems Engineering, Faculty of Agriculture, Alexandria University. This facility features the state of the art technology with respect to the instrumentation, control and automation Fig (1).

Test Procedure

Generally, the system is conceived to operate in two phases processing, and tillage experiments. Prior to each tillage experiment, the soil was prepared to 1) completely destroy the effects of prior soil manipulation, 2) produce the desired state of the soil, and 3) ensure that the soil in the bin is uniformly prepared throughout the test zone. For the soil processing, the carriage is positioned at the bench mark (initial starting) position. Then one of the cylinders is used to lower the tiller to the required depth. The tiller hydraulic motor is started and the speed of rotation is adjusted using the flow control valve. The carriage is moved at a very slow speed as the pulverization process continues. This is continued until just before the end of bin and the motion of the carriage is stopped (through the proportional valve).The tiller motor is turned off and the tiller raised to its uppermost position. The carriage is returned to its starting points.

When the moisture addition is required, the carriage is moved as before while the nozzles for moisture addition are turned on. After that, the carriage is returned to its benchmark and the rotary tiller operation is repeated once more. For soil leveling, the leveling blade is lowered to the required depth by threaded rods. The carriage is again moved to the end of the bin as before and returned to its benchmark.

Figure 1: Soil bin facility

To adjust the soil density, the roller is lowered to the required depth using the cylinder and the motor is started. The speed of rotation is adjusted as in the case of the tiller after which the carriage is moved at a slow speed again **so** that the soil gets compacted to the desired density. At the end of the bin, the carriage is stopped, the roller rotation stopped, and the roller raised. The carriage is moved out of the bin for the next phase. This operation can be repeated depending on the required final state of the soil.

The tool in each case was attached to the tool bar on the tool carriage and adjustment made to give the required rake angle and depth of operation. The carriage was then winched from the starting point at constant speed 0.67 m sec^{-1} by operating the starting switch from the power unit. Draft data were collected with a load meter (dynamometer) and mean values of three replicates were used for computation and analysis.

Experimental design for soil bin test

Tool forces experiments were conducted to determine the effect of different tool dependent variables on some independent variables for sandy clay loam soil. The types of tools as shown in Fig (2) were used in the conducted experiments. The prepared soil in the soil bin was maintained constant throughout all the test runs. The moisture content was kept in the range 9-10 % during the tests. The compaction roller of the soil processing carriage and a penetrometer for random testing were used to ensure uniform soil condition throughout the test runs. In between runs, the soil bin was leveled and compacted using the soil processing carriage. The dependent variables to be measured were soil failure resistances draft and vertical force**.**

Soil characteristics and measurements

Physical and mechanical soil characteristics were measured and analyzed in the Agricultural and Biosystems Engineering Department, Faculty of Agriculture, Alexandria University. The mechanical analysis of the soil was classified as a sandy caly loam soil having 7.70% clay, 13.40%silt and 78.90% sand

Soil Physical Properties Measurements

The physical properties of soil used in this study are given in Table (2).

Figure 2: A simple tillage tool used in the soil bin experiments

Table 2: Physical properties and particle size distribution of soil used in experiment

Soil site	**Particle size distribution, %**			**Soil Texture**	**BD g/cm^{-3}**	P.W.P% **m^{3}m^{-3}**	F.C % **m^{3}m^{-3}**	k_s **mmh^{-1}**
	Sand %	**Silt %**	**Clay %**					
EL Hammam	78.90	13.4	7.7	Sandy Clay Loam	1.32	13.78	21.55	22.57

Where:
F.C.: field capacity, m^3/m^3
BD: bulk density, g/cm^3
Ks: saturated hydraulic conductivity, mm/h
PWP: Permanent Welting Point, m^3/m^3

Soil Moisture Content Determination

The soil moisture content was determined directly using gravimetric sampling technique, in which the weights of wet samples were measured, and then soil samples were dried in an oven at a temperature of 105-110°c for 24 hours. Soil moisture content percentage on wet basis was calculated as Gardner, (1986).

Soil bulk density

Soil bulk density was determined using the core method, Blake(1965). A steel cylinder (5cm internal diameter and 4cm height) was used to take soil sample. Sample weight was measured and from the known volume of cylinder, the apparent soil density was determined.

RESULTS AND DISCUSSION

Effect of different treatments of plowshares on draft

In order to study the effect of the different treatments of plowshares on the draft. Table (3) and Fig (3) show the variation of draft under different treatments. It is clear that the draft of both HT and NC are higher than that of coating methods. For all treatments, the draft of the coating by carbon nanotube–hard chrome composite CNT+HCR was consistently lower than the all other treatments it means that this treatment reduce the draft requirements by about 43.92%, 44.14 % and 38.02 % for API52, K110, and M238 respectively.

Effect of different treatments on hardness

Hardness of tillage tools was measured by using Vickers hardness tester (Zwick/ZHU187.5). Hardness was measured with 100 g loads, dwell time of 10 seconds and diamond indenter. Average surface hardness distribution of all treated specimens were measured and listed in Table (4) and Fig (2). It can be concluded that there is a clustering in the range of 181-307 HV. The highest hardness was 307.32 HV obtained from steel K110 the treatment coated with carbon nanotube composite (CNT+HCR).In steel API 52 and M238 hardness was 248.62 HV and 293.24 HV respectively.

Effect of different treatments on roughness

The average surface roughness of the experimental specimen for different treatments were measured before and after tillage as presented in Table (4) by MAHR Prethometer M1 measuring instrument using 3 replicates. In order to measure the roughness of the surface, a cut – off length of 0.75 mm was taken from sample. As is clearly seen from Table (4), Fig (3, 4, 5) there is difference in surface roughness of the material was observed for all the measurement performed before and after tillage. It can be seen that the lowest value of surface roughness was obtained in carbon nanotube-chromium composite treatment after tillage of 200 hours followed by hard chromium treatment in the all type of steel. On other hand, the highest value of surface roughness was obtained in nitrocarbourizing treatment in API 52, while in case of M238 and k110 the specimens treated by heat treatment gave the highest surface roughness.

Table 3: The required draft of plowshares for the of different treatment

Treatment of plowshares	Draft (N)		
	API 52	K110	M238
Reference	543.90	470.60	476.60
Heat treatment (HT)	429.50	420.70	438.40
Nitrocarburizing treatment (NC)	374.80	383.60	399.30
Hard chrome (HCR)	369.80	300.60	313.80
Carbon nanotube - Hard chrome (CNT+HCR)	305.00	262.90	295.40

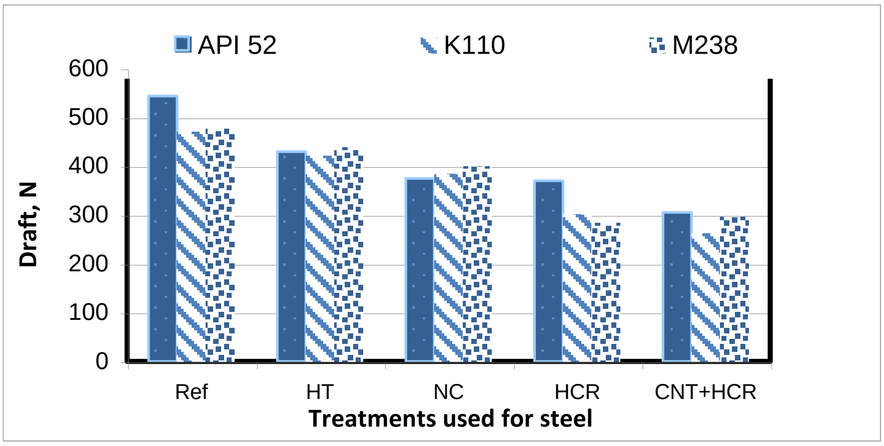

Figure 3: Effect of different treatments on draft requirements

Table 4: Effect of different treatment of plowshares on hardness

Treatments of plowshares	Hardness (HV)		
	API 52	**K110**	**M238**
Reference	181.00	193.82	186.5
Heat treatment (HT)	212.48	263.27	260.24
Nitrocarburizing treatment (NC)	229.24	279.28	270.45
Hard chrome (HCR)	238.35	282.12	235.45
Carbon nanotube - Hard chrome (CNT+HCR)	248.62	307.32	293.24

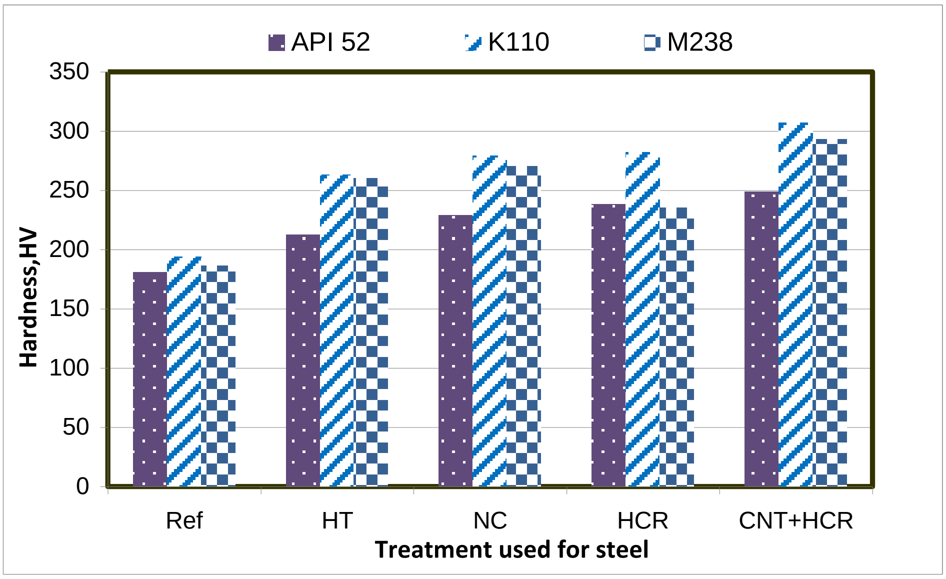

Figure 4: Effect of different treatments on hardness

Table 5: Surface roughness at different treatments before and after tillage

Sample code	Type of treatments	Average Surface Roughness (Ra), µm	
		Before tillage	**After tillage**
API 52	Ref	5.5	8.0
	HCR	1.5	2.5
	HT	1.5	5.0
	NC	2.0	5.5
	CNT+HCR	0.3	0.8
K110	Ref	0.9	3.5
	HCR	1.12	1.5
	HT	6.0	7.5
	NC	0.9	1.5
	CNT+HCR	0.12	0.9
M238	Ref	1.0	6.5
	HCR	0.4	1.0
	HT	0.6	3.5
	NC	1.0	1.5
	CNT+HCR	0.3	0.4

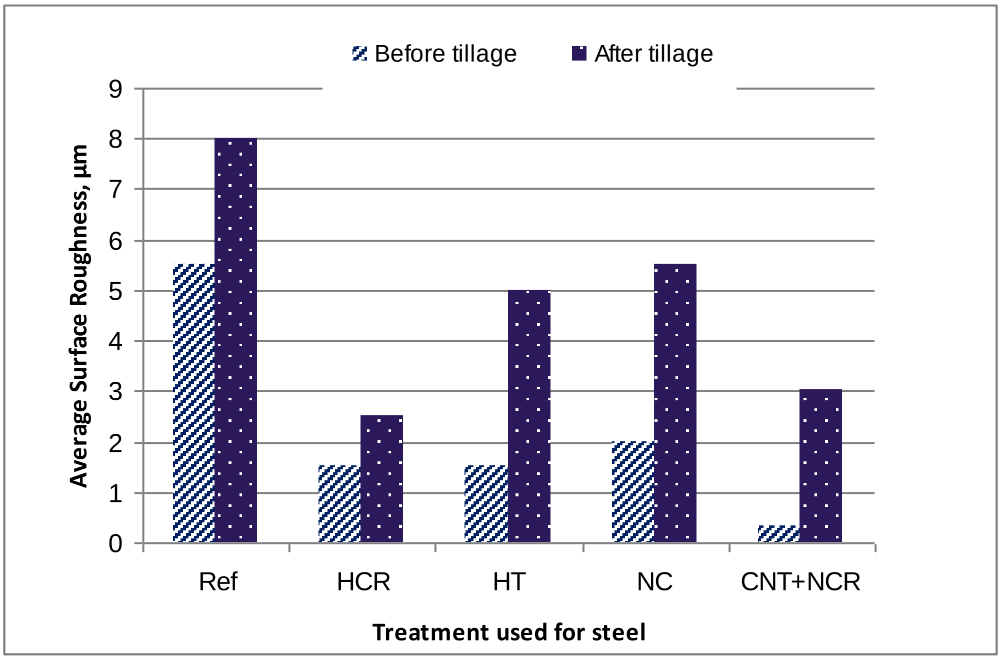

Figure 5: Average surface roughness before and after tillage, API52

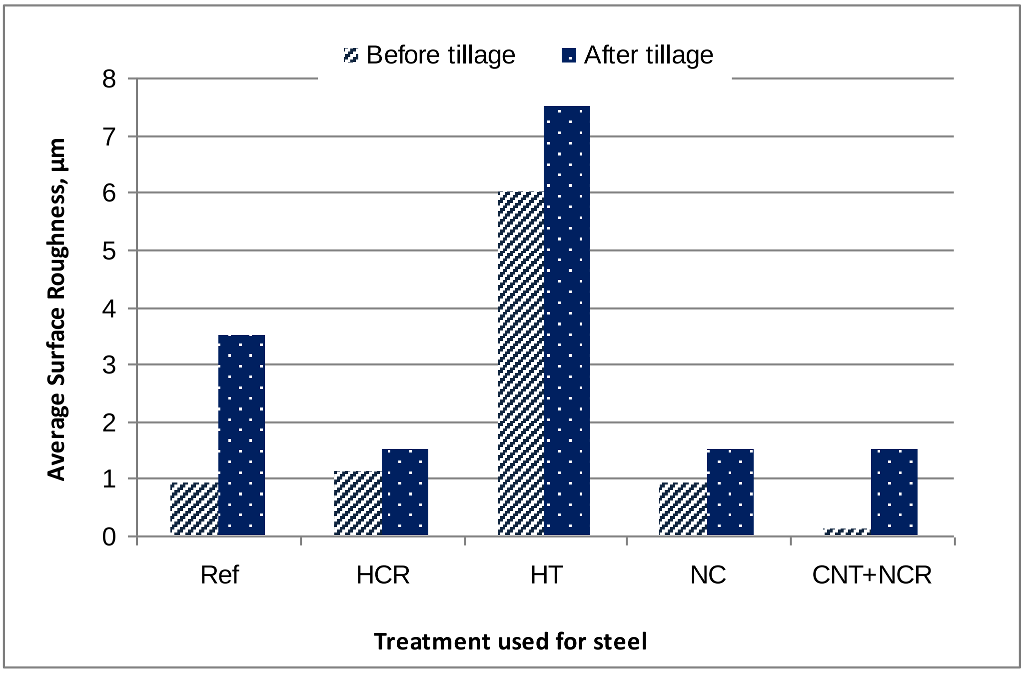

Figure 6: Average surface roughness before and after tillage, K110

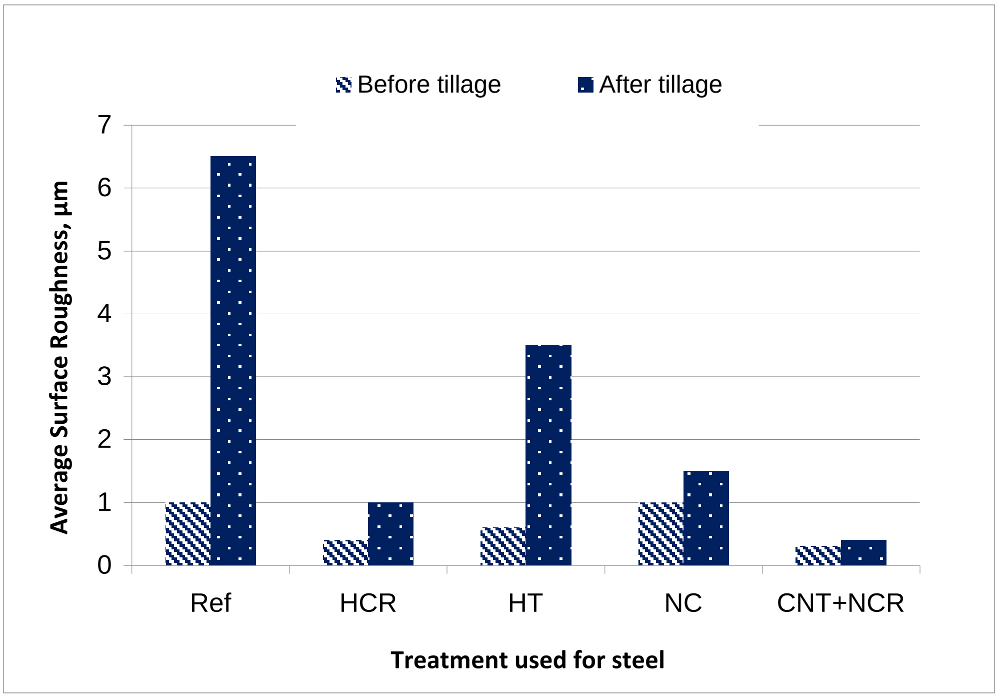

Figure 7: Average surface roughness before and after tillage, M238

CONCLUSION

In general, we can conclude that coating by carbon nanotube - hard chromium composite was the appropriate treatment for decreasing the draft requirements compared with other treatments. Also, it was found that hardness was improved by coating with carbon nanotube-hard chromium composite CNT+HCR which gave the highest value for hardness for all types of steel. It is very important to declare that the surface roughness of tools plays a very good indicator for estimating abrasive wear. Our results showed that the lowest value of surface roughness was found with carbon nanotube-chromium composite.

REFERENCES

Ananthachar. **2016**. Mechanics of Tillage and Traction. Machinery. Agricultural Engneering College and Research Institute, TNAU .

Blake, GR. **1965**. Methods of Soil Analysis, part 1, American Society of Agronomy.

Er U., **2004**. The abrasive wear behavior of boron steels. Eng.& Arch. Fac. Osmangazi University, **17 (2)**.

Er U., Par B. **2006**. Wear of plowshare components in SAE 950 steel surface hardened by power boriding. Wear **261**: 251-255

Foley, A.G., P.J. Lawton, and V.A. Barker McLess .**1984**. The use of alumina ceramic to reduce wear of soil engaging components. J. Agric. Eng. Res. **30**: 37-46.

Fernandez,J.E, R.Vijande, R.Tucho, J.Rodriguez, and A.Martin. **2001**. Materials selection to excavator teeth in mining industry, Wear 250 P: 11-18

Gurrumoorthy, K., Kamaraj, M., Prasad Rao,K. and Venugopal, S. **2007**. Development and use of combined wear testing equipment for evaluating galling and high stress sliding wear behavior, Material and Design, **28**: 98-108.

Kepner, R. A., R. Bainer and E. L Barger .**1978**. Principles of Farm Machinery. Publishing Company, INC. Westport, Connecticut.TextBook

Mamman, E., and K. C. Oni. **2005**. Draught performance of a range of model chisels furrowers. Agricultural Engineering International: CIGR Journal, **3(7)**: 1–7.

Punamchand, R., Spakale, T. Ghanashyam, and A. K. Sharma. **2016**. Influence of surface hardening process on wear characteristics of soil working tools- A review International Journal of Engineering Sciences & Emerging Technologies, **8**: 191-201.

الملخص العربى

معالجة أسطح أسلحة الحراثة بمواد جديدة وتأثيرها علي قوة الشد وخشونة السطح

عبد الله مسعد زين الدين، سعد فتح احمد، رضا جلال عبد الحميد
قسم الهندسة الزراعية والنظم الحيوية– كلية الزراعة– جامعة الأسكندرية

تستهلك عملية الحراثة كمية كبيرة من الطاقة وذلك بسبب أرتفاع قوة الشد اللازمة. ولذلك فأنه من الاهمية بمكان الأخذ في الأعتبار الأحتكاك الناجم عن أنزلاق التربة فوق سطح المعدن والتي تعتبر من العوامل الرئيسية في إستهلاك الطاقة. كما أن نوع مادة سطح السلاح تتحكم في حركة التربة فوق السلاح نتيجة إلتصاقها به. لذلك كان الهدف من هذا البحث هو إيجاد تأثير العوامل المؤثرة علي قوة الشد اللازمة للحراثة. وقد تم أستخدام أسلحة بسيطة مصنعة من مواد حديدية مختلفة وهي (API 52 , K110 and M238) كما تمت معالجة أسطح هذه الأسلحة بمعاملات مختلفة أما حراريا أو بتغطيتها بطبقة مركبة من الكربون النانومتري والكروم، وقد أظهرت المعاملة الأخيرة أنخفاضا في قوة الشد اللازمة بمقدار (38.02%, 43.92% , 44.14%) علي الترتيب عن مثيلتها الغير معاملة. كما أوضحت النتائج أرتفاع درجة صلابة السطح المعالج بمركب الكربون النانومتري والكروم عن باقي المعاملات الاخري. كما أعطت نفس المعاملة السابقة أقل قيمة لخشونة للسطح و معامل الاحتكاك أقل. وقد تم الحصول علي هذه النتائج السابقة بعد أستخدام الأسلحة المشار إليها في إجراء عملية الحراثة لمدة ٢٠٠ ساعة تشغيل.