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The Effects of Different Types of Coating on the Wear of Ploughshare

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Abstract: This paper discusses the effects of the different types of coating on the wear of ploughshares produced from DIN EN 10 083 (30 MnB5) steel which is widely used steel for ploughs. The ploughshares were coated by electrolysis with 20 µm hard chromium, by chemical treatments with 20 µm electroless nickel and by PVD with 4 µm TiN to increase their wearing resistance. In order to observe the mechanical features of the ploughshares, specimens were pulled at a 5.8 km/h pulling speed from the sandy-clayey-loamy soil wearing channel. The wearing of the coating thickness of ploughshare was observed during the tillage experiment and also at the end of the experiment. Specimens were analyzed metallographically by scanning with a Scanning Electron Microscope (SEM) and were analyzed for their Energy Dispersive Spectrum (EDS). It was found that the average ploughing lengths for wearing of 1 µm coated layer were 736 m. for TiN, 217 m. for electroless nickel and 319 m. for hard chromium.

Keywords: Metal coating, hard chromium, TiN, electroless nickel, wear, ploughshares

INTRODUCTION and LITERATURE REVIEW

The abrasive wear of ploughshares is major problem because of huge loss of material and the resultant cost increase due to need to replace worn parts and the time involved in replacing them.

Abrasive wear resistance depends not only on the intrinsic conditions of the material, but also on the soil conditions. The influential factors are: the chemical composition, production history,mechanical properties and microstructure of material; the particle shape, size, the soil strength, density and moisture, and rock and gravel content; the relative velocity and impact angle between soil and the tool (Yu, H.J., Bhole, S.D., 1990)

All the influential factors associated with the field working conditions seem to suggest that wearing must be more than a simple process that can be explained by mechanical properties of the material such as hardness. (Foley, Lawton, Barker and Mclees, 1984). Materials to be used in soil-engaging components should be hard enough to resist wear but also tough and strong enough to resist impact and distortion (Er and Par, 2006)

Because there is no systematic statistical information about the economic loss due to the wearing of tillage equipments, this subject has not been a high priority topic in Turkey

According the Karamış (1984) friction occurs between the tillage equipment and the soil grains when the soil is tilled by cultivation equipment. The friction coefficient between the soil cultivation equipment and the soil is influenced by the inside friction of grains, by the shape of the equipment and by the pressure applied to the soil. The wearing is defined with various mechanisms. The equipment working on the soil is worn by the "abrasive working mechanism". It is sometimes possible to find both adhesive and cohesive wearing types on the working equipment in the soil.

Besides volumetric hardness processing, surface hardness processing is also often used as a means to increase the wearing resistance of the equipment. In order to increase the surface strength of equipment, it is possible to use both heat treatment and to cover the surface of the tilling equipment with a harder material (Jahanmir and Abrahamson, 1976).

Processes that increase wearing resistance are listed below;

1. Improving the basic material features by heat treatment,
2. Changing the surface features by cold deformation,
3. Choosing the right friction pair,
4. Improving the strong materials against wearing,
5. Coating the materials which are exposed to wearing

As a result of their study, Abrahamson and Jahanmir (1976) said that it would be possible to increase the wearing resistance of tilling equipment by coating the equipment and thus increase its surface strength.

Scientists such as Holmberg, Matthews (1994) and Bhushan, Gupta (1991) said that TiN was a suitable coating material because of its stable and that fact that it stuck well to the stell surface of the equipment (Holmberg and Matthews, 1994).

Dubpermell (1974) asserted that chrome coating was an important coating type for industrial applications because of its high toughness, corrosion resistance and the low friction coefficient.

According to Kahriman (2001) electroless nickel was even more important since nickel coating does not have a crystal structure and thus does not allow the development over time of galvanic cells caused by the crystal structured spaces.

Coatings have been a considerably important surface hardening process for increasing the wear resistance of steels during recent years, especially industrial cutting tools. But there are no studies found in the literature about coatings in tillage tools.

In this study, the abrasive wear behaviors of ploughshare material with different coatings were investigated by means of experiments carried out in the field on real-size components. The wear behaviors of ploughshares were evaluated by mass loss measurements after-tillage.

MATERIAL and METHOD

Experimental material was DIN EN 10083 P3 96 (30Mnb5) steel. DIN EN 10083 P3 96 (30Mnb5) steel is mainly used in manufacturing plough shares.

Eight specimens were used in the experiment. Two specimens were coated with hard chrome using the electro-chemical method called the electrolysis coating technique. Two other specimens coated with electroless nickel coating using the decreasing chemical application method. Two other specimens coated with TIN by the physical collecting technique of the physical steam coating method. Sample specimens were left uncoated.

The tillage was carried out in Central Anatolia in an experimental field in the region of Ankara / Turkey. A one-furrow plough was used for the infield experiments. Coated specimens were worn down in a 7.5 m diameter, 70 cm deep and 120 cm wide sand pool circle with a sandy-clayey-loamy type soil containing 7.65 % lime and 0.23 mmhos/cm salt. Single mineral quartz pieces played an important role in wear in the wearing channel except in the thin sand and for the pieces with diameters between 2 mm and 0.2 mm and where the mineralogical strengths were 7 mohs. Humidity was measured just before the experiment at 5.48 and was kept at the same level during the experiment. The total mass loss and wearing of coating thickness from the ploughshares were measured at the end of tillage of each 25 cycles (1178.6 m tillage length). This was considered the baselines for ploughshare were and comparisons were made with respect to these results.

The speed of the tractor and the working depth of the ploughshare were chosen 1.61 ms^{-1} (5.8 km h^{-1}) and 200 mm, respectively since these are the preferred speed and depth for traditional plows.

The wearing of coating thickness and mass loss to the ploughshares were measured before and after the experiments with an electronic scale with a sensitivity of 10^{-1} g. Coating thicknesses were measured by the Mini Test 600B-Elektro-Psysk ultrasonic tester with a sensitivity of 1 μm. Surface roughness values were determined by MAHR-Perthometer M1 and measurements were repeated three times. In order to measure the roughness of the surface formed while processing the work piece, a cut-off length of 0.8 mm was taken with a sampling length of 5.6 mm. The temperature of the environment was 22 ± 1 °C.

Microhardness values for the phases in the microstructure were determined by Vickers tester (Instron Wolpert) using a 100g load. All hardness measurements were taken from at least 3 different areas of each specimen and average value was taken. Scanning electron microscopy (JEOL 6060) was used to characterize the microstructure of the specimens. Surface morphology was observed by AFM using an Omicron VT (variable temperature) AFM instrument at room temperature with the given atmospheric pressure at Gazi University. All measurements were repeated three times and the average results were used for comparisons.

RESULTS and DISCUSSION

The mechanical properties of the coated experimental specimens are showed in Table 1. It was observed that the measured values were different for coating material in Table 1.

The highest value of the surface hardness measured for the specimen was 827 HV for TiN coating specimen. The highest coated layer thickness for the hard chromium specimen is 25 μm. The lowest average surface roughness of coated layer was 0.97 μm for the hard chromium coating specimen.

Typical 3D AFM images consisting of well-defined scan area (1000x1000nm) morphology were selected. Three dimensional topography images were obtained using a commercial 1000 MHz needle sensor as can be seen in Fig.1, Fig.2 and Fig.3.

The grains were formed in peaks and valleys-island shaped particles and were identified. Peaks and valleys-island shaped particles were clearly identified in TiN and electroless nickel coatings. It was also seen that the surface of the hard chromium and TiN coated specimens had intensive crags. 3D AFM images of coated specimens correspond with the surface roughness calculated from both surface roughness testers in Table 1.

Coated specimens were worn by the tillage in the soil channel. SEM micrographs taken by the electron scanning microscope which belongs to the worn and unworn specimens after coating have been shown in the Fig. 4, Fig. 5, Fig. 6, and Fig. 7.

The surfaces of the specimens were characterized by scratching, deep grooving and gouging caused by abrasive wear and impact with the soil and its hard particles during the soil tillage. A deep grooving and also an impact trace of hard particle soil were observed on the coated surface in Fig. 4b and in Fig. 5b respectively. Despite the high surface hardnesses of coated plowshares, they also were impacted by the soil particles and coated layers were worn at different tillage lengths.

The elemental composition at a point, along a line, or in a defined area can be easily determined to a high degree of precision (~0.1 wt%) using EDS. The objective of applying EDS analysis to this study is to identify the material transfer between ploughshare and the soil or the wearing of coated layers during experiment. The EDS analysis was conducted for ploughshares to evaluate the species present on the surface.

Micro-analysis spectrum of ploughshare surface (Figs. 8, 9 and 10) showed a typical EDS spectrum of an outer surface of coated ploughshares.

In the figure 9.a., it is seen 91,1 % TiN amount on the equipment in the EDS analysis which was made on the TiN covered experiment sample. In the figure 9.b., it is seen that there are almost ant TiN element in the EDS analysis which was made on the worn surface of the TiN covered experiment sample.

The major elements are coated materials (TiN, chromium and nickel) and iron. After the tillage experiment, weight percentage of elements sharply decreases due to the wearing of the ploughshare coated surface. Initially, there is coating material of chromium, nickel and TiN on the outer surface of ploughshare; hence EDS analyses show only peaks of iron, chromium, nickel and TiN. After the tillage experiment, the coating layer on the ploughshare has been worn out during the tillage experiments.

SEM and EDS analyses showed that abrasive quartz particles commonly seen in soil embedded in the surface of the ploughshare. Different types of coated layers of the ploughshare were worn in soil tillage.

When it is looked at the "tillage length for 1 micron wearing" graphic which shows the wearing resistance of coating given on the Figure 11; average tillage length for the wearing of 1 micron coating is 319 m. for coated hard chrome, 217 m. for coated electroless nickel, and 736 m for coated TiN. TiN coating is having to higher wearing resistance than the others in soil tillage. It can be say that the effective factors of wearing of coated layer can be thickness of coated layer, coefficient of friction, surface roughness of coated layer and adhesion of coated layer besides of other soil, draft and materials factors. At the end of soil tillage experiments, It can be say there was remarkable differences between specimens and the coated plowshares were less worn than the commercially available plowshares.

The wear mechanism of the all specimens was dominantly abrasive wear mechanisms. The factors of hardness of abrasive grain, dimension and shape of abrasive grain, shape of specimen (ploughshare) and draft force have effect on the wearing.

In general, wear resistance increases as the hardness of the material increases. However, this fact is not a definite rule due to the effect of different factors. Such factors as soil the particle shape, size, strength, density, moisture, type, size and population of the stones present in the soil and also the relative velocity and impact angle between soil and the implement all effect the wearing of tilling tools used in the soil, as well as factors induced by the materials used. It can be said that the effective factors for wearing of coated layer are the coating layer thickness,the coefficient of friction, the surface roughness of the coating layer and the adhesion of coating layer.

Table 1. Mechanical features of the experiment samples

Coating Material	Coating Method	Coating Thickness (μm)	Coating Friction Coefficient	Coating Surface Roughness (μm)	Coating Strength (HV)
TiN	PVD / Streaming Method	4	0.65-0.70	1.12	827
Electroless Nickel	Chemical Process/Chemical Decreasing Method	20	0.40-0.45	1.39	559
Hard Chromium	Electro-Chemical Methods/ Electrolyse Method	25	<0.20	0.97	698

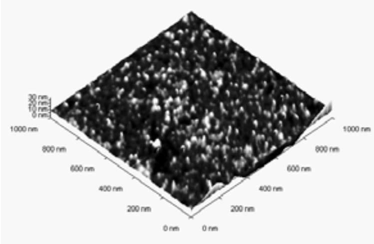


Figure 1

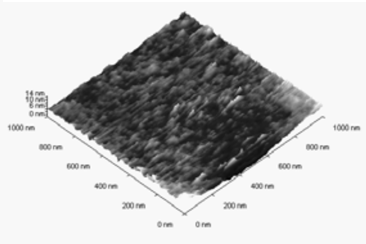


Figure 2

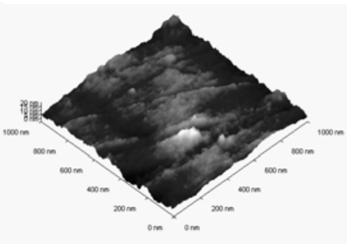
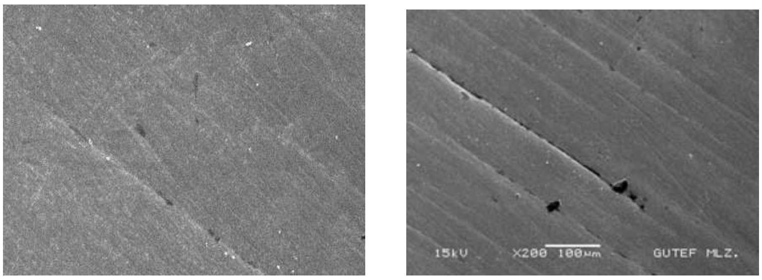
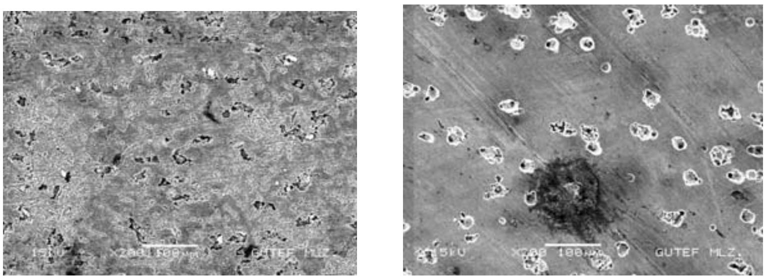


Figure 3



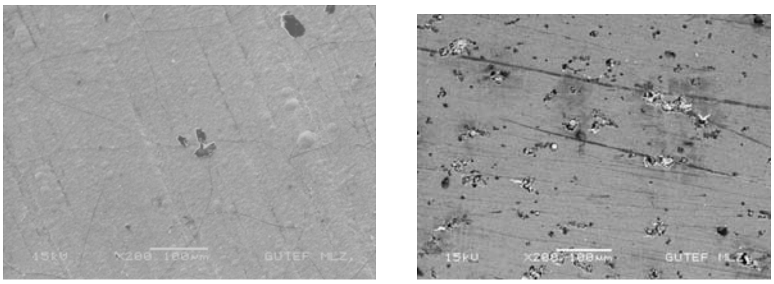
a b

Figure 4. SEM image taken from the surface of the hard chrome covered experiment sample a) unworn b) worn



a b

Figure 5. SEM image taken from the surface of the TiN covered experiment sample a) unworn b) worn



a b

Fifure 6. SEM image taken from the surface of electroless nickel covered experiment sample a) unworn b) worn

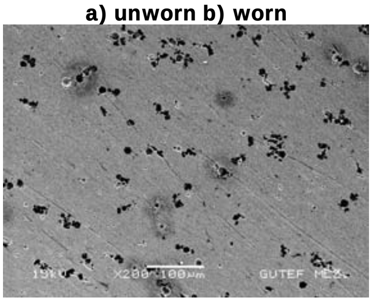
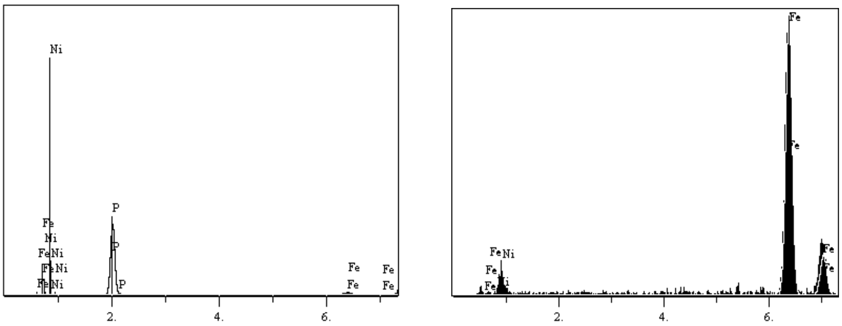
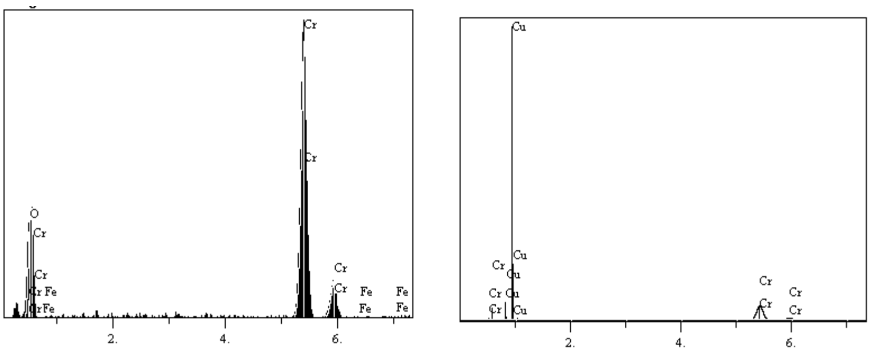


Figure 7. SEM image taken from the surface of the witness sample ERD 5630 steel experiment sample which was worn during the dragging.



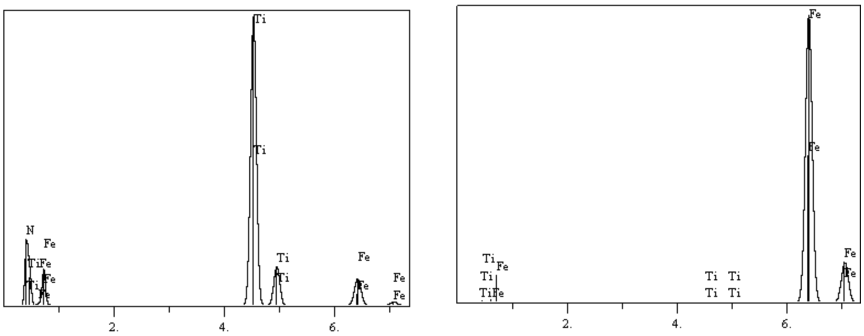
a **b**

Fig 8. Energy dispersion spectrum (EDS) analysis of the electroless nickel coated experimental specimens. a) before the tillage (unworn) b) worn after the tillage



a **b**

Fig. 9. Energy dispersion spectrum (EDS) analysis of the hard chrome coated experimental specimens. a) before the tillage (unworn) b) worn after the tillage



a **b**

Fig 10. Energy dispersion spectrum (EDS) analysis of the TiN coated experimental specimens. a) before the tillage (unworn) b) worn after the tillage

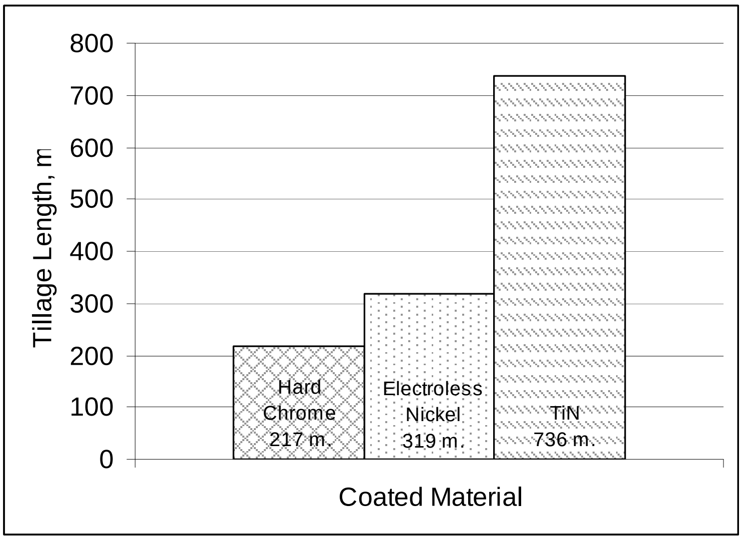


Fig. 11. The tillage length for 1 micron meter wearing of coated material

CONCLUSIONS

The wear behavior of coated layers of different material on ploughshare was investigated in this study. The results of this experimental study can be summarized as follow:

1. The wear mechanism of the all specimens was dominantly abrasive wear mechanisms.
2. Surface roughness calculated by both a surface roughness tester and AFM show similar trends in their respective data.
3. The surfaces of the specimens were characterized by scratching, deep grooving and gouging caused by abrasive wear and impact with the soil and its hard particles during the soil tillage. SEM and EDS analyses showed that abrasive quartz particles are the most commonly seen in the soil embedded in the surface of ploughshare.
4. The average tillage lengths for the wearing of 1 micron meter coating are 736 m for Tin coating, 217 m. for electroless nickel coating and 319 m. for hard chrome coating. All coated layers of ploughshares were worn, but TIN coating has a higher wearing resistance than the others in soil tillage.
5. The surface coating of ploughshare offers the potential to increase the wear strength and wear life of the ploughshare and to reduce the severity of abrasive wear in the soil tillage.

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