Tarım Makinaları Bilimi Dergisi (Journal of Agricultural Machinery Science)
2014, 10 (4), 323-327

Characterization of Agricultural Machinery Blades

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Received (Geliş Tarihi): 02.08.2014 Accepted (Kabul Tarihi): 06.08.2014

Abstract: Life of the industrial materials decrease by the tribological mechanisms like corrosion, abrasion and wear and it is possible to increase the life of these materials by the surface treatments. Wear is the most seen problem within these factors. The agricultural blades are forced to continuous and progressive forces. The reason of these forces are the clay content in the soil, the pebble in the soil and residues of the plants. The wear type seen in agricultural blades is abrasive wear. In order to increase the wear resistance of these materials, it is advised to use harder materials, apply heat treatment to materials and coat the material surface with hard coatings. The main objective of this study is to overcome the breakage problem of the blades by conducting the different characterization studies. In this study domestic and foreign blade materials were compared. X-Ray fluorescence analysis (XRF), spectroscopy analysis, energy dispersive X-Ray spectroscopy (EDX) analysis were conducted during the study. Microstructural characterization was done by scanning electron microscopy (SEM) analysis. In order to obtain the mechanical properties of the materials hardness and wear tests were used in the study.
Key words: Agricultural machinery blades, wear, characterization, hardness test, SEM, XRF

INTRODUCTION

Turkey is located in fertile soils. To cultivate this soil, machinery is widely used beside human power. These machines exposed to a lot of factors as corrosion, hard and heavy soil, wear, etc. Wear and hard soil are the main factors that damage these machines. The most important part are blades of these machines because they are directly in contact with the soil. The phenomenon of wear was given a formal definition in 1968 by the OECD as 'the progressive loss of material from the operating surface of a body occurring as a result of relative motion at its surface(Lansdown ,1986) Different wear mechanisms can be seen in the Figure 1.

The wear type seen in agricultural blades is abrasive wear. Abrasive wear is the most important among all the forms of wear because it contributes almost 63% of the total cost of wear (Neale and Gee, 2001). Abrasive wear is caused due to hard particles or hard protuberances that are forced against and move along a solid surface. Abrasive wear is divided to two main types as two-body abrasion and three-body abrasion. A distinction is made between two-body abrasion, in which wear is caused by hard protuberances on one surface which can only slideover the other and three-body abrasion, in which particles are trapped between two solid surfaces but are free to roll as well as slide (ASTM,1987) Pipe and chute liners used to transport abrasive materials, rotors of powder mixers, pivot pins in construction machinery, blades and components in agricultural and earth moving machinery, impellers in pumps handling sewage and abrasive fluid wastes, wear strips and guides are some examples of two body abrasion (Harsha and Tewari, 2002). Sleeve bearing and bushes operating in abrasive environment, lower sleeve bearing in vertical sewage pumps, vehicle spring bushes, marine stern tube bearings, chain wear strips, rope sleeve bearings are some examples of three-body abrasion (Harsha and Tewari, 2002). Type of abrasive, temperature, contact rate, load and corrosive effect of environment are the factors affecting the abrasive wear (Akbulut).

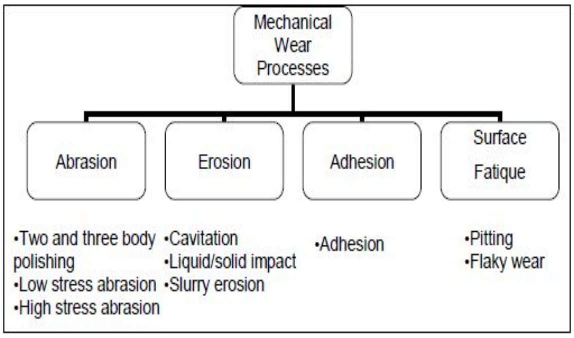


Figure 1. Mechanical wear processes

Erosive wear is caused by impingement of particles (solid, liquid or gaseous), which remove fragments of materials from the surface due to momentum effect (Kopeliovich).

Adhesion wear is a result of micro-junctions caused by welding between the opposing asperities on the rubbing surfaces of the counterbodies. The load applied to the contacting asperities is so high that they deform and adhere to each other forming micro-joints (Kopeliovich).

Fatigue wear of a material is caused by a cycling loading during friction. Fatigue occurs if the applied load is higher than the fatigue strength of the material. Fatigue cracks start at the material surface and spread to the subsurface regions. The cracks may connect to each other resulting in separation and

delamination of the material pieces (Kopeliovich).

In order to increase the wear resistance of these materials, it is advised to use harder materials, apply heat treatment to materials and coat the material surface with hard coatings.

MATERIALS and METHODS

In this study two different blades were characterized. One of them is domestic blade the other is foreign blade. Firstly in order to know the compositions of these blades chemical analysis were done. After chemical analysis, the microstructures of these blades were examined with scanning electron microscopy (SEM).

After the consideration of diffrences between two blades according to SEM images, hardness values of these blades are examined as the result of this micostructural property.

Wear is another property that is related to the microstructure, hardness and chemical composition of the blades. To consider the wear behaviour of the blades, abrasive wear test was applied to the blades.

In order to obtain elemental analysis of the samples X-Ray fluorescence analysis (XRF) was performed. For XRF study 40mm x 40mm samples were prepared for both domestic and foreign blades. But the mass percentages for carbon and boron can not be calculated in the XRF study because of the detector ranges of the machine .

In the spectroscopy analysis, the mass percentage of carbon was calculated. Spectroscopy machine works with same principle as XRF machine and carbon concentration of steel was obtained.

Also EDX analysis was performed to obtain the chemical compositions of two blades and inclusions in them.

In order to measure hardness values of the samples Rockwell hardness test was applied to both of these blades at HR-30N, 15 seconds.

For the wear behaviour of the blades wear tests were applied to the blades by the designed wear test machine.

RESULTS and DISCUSSION

XRF analysis was conducted in the study. Table 1. shows the XRF results of the samples. The the mass percentages for carbon and boron couldn't calculated in the XRF analysis.

Table 1. XRF analysis of the blades

No	Element	Unit	Celi Result	Coşkunsan Result
1	Mg	mass %	0.0559	0.0249
2	Al	mass %	0.1939	0.1509
3	Si	mass %	0.5057	0.4436
4	P	mass %	0.0113	0.0116
5	S	mass %	0.0219	0.0062
6	Cl	mass %	0.0527	0.0125
7	K	mass %	0.0319	0.0140
8	Ca	mass %	0.0526	0.0307
9	Ti	mass %	0.0444	0.0344
10	Cr	mass %	0.3755	0.1421
11	Mn	mass %	1.3818	1.5234
12	Ni	mass %	0.2017	0.0536
13	Cu	mass %	0.2222	0.0650
14	As	mass %	0.0105	0.0103
15	Mo	mass %	0.0612	0.0050
16	Na	mass %	0.2948	-
17	V	mass %	0.0090	-

**Celli is the brand name of the foreign blade, Coşkunsan is the brand name of the domestic blade.*

In the spectroscopy analysis, carbon concentration of steel was obtained. Table 2. shows the mass percentages of the components in the samples.

Table 2. Spectroscopy analysis of blades

No	Element	Unit	Celi Result	Coşkunsan Result
1	C	mass %	0.262	0.054
2	Sİ	mass %	0.230	0.288
3	Mn	mass %	1.2390	1.3198
4	P	mass %	0.0107	0.0065
5	S	mass %	0.003	0.002
6	Mg	mass %	0.0005	0.0007
7	Cr	mass %	0.362	0.130
8	Ni	mass %	0.213	0.050
9	Mo	mass %	0.059	0.005
10	Cu	mass %	0.243	0.061
11	Al	mass %	0.0222	0.0621
12	Ti	mass %	0.0385	0.0279
13	V	mass %	0.0051	0.0024
14	Nb	mass %	<0.001	<0.001
15	W	mass %	0.018	0.007
16	Co	mass %	0.0099	0.0080
17	B	mass %	0.0018	0.0008
18	Pb	mass %	<0.001	<0.001
19	Zn	mass %	<0.001	<0.001

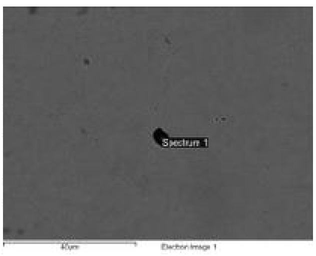
EDX analysis was applied to obtain the chemical compositions of domestic and foreign blades and inclusions in them.

Table 3. EDX analysis of blades

Producer / Elements	Coşkunsan		Celli	
	Average Weight %	Weight Std. Dev.	Average Weight %	Weight Std. Dev.
Si	0.29	0.0332	0.244	0.0586
P			0.08	0.0745
S			0.048	0.0672
Cr			0.376	0.0503
Mn			1.436	0.0607
Fe			97.85	0.0951
Total	100		100	

Table 4. Inclusion analysis of foreign blade

Element	Weight %
O	18.63
Na	1.68
Si	7.78
P	0.00
S	0.18
K	0.76
Cr	1.41
Mn	0.76
Fe	68.79
Total	**100.00**



Chemical differences between domestic and foreign blades were defined after chemical analysis.

Amount of significant alloying elements like carbon, chromium, manganese and boron were strikingly different between two blades. These differences can be seen on the working performances of these blades. As known, carbon content in steel controls the hardness by occurance of martensitic structure. Martensitic formation is controlled by quenching rate of steel. That means lower carbon content in steel causes lower hardness values generally, but on the other hand, martensitic formation is controlled by quenching. So, carbon content and quenching rate should be considered together. When added to low alloy steels, chromium can increase the response to heat treatment, thus improving hardenability and strength. Domestic blades used in this study broke easily compared to foreign blades. The reason of this breakage is related to the strength of the steel. The chromium content in domestic blade was obtained 3 times lower than foreign blades. The reason of the breakage can be related to the chromium content.

SEM study was conducted in order to obtain microstructural properties of the samples.(Figure 10 and Figure 11)

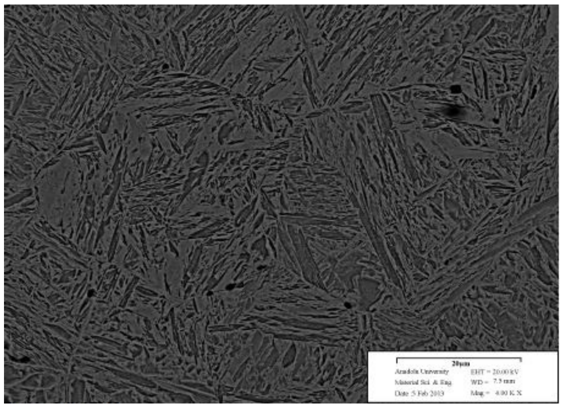


Figure 1. SEM image of foreign sample

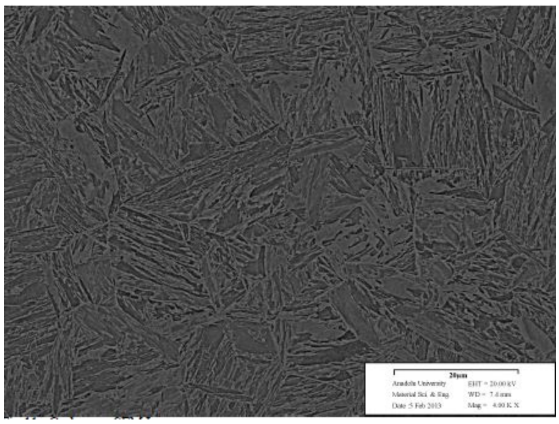


Figure 2. SEM image of domestic sample

According to these images the martensitic structure was seen on both domestic and foreign blades.

Rockwell hardness test was applied to both of these blades at HR-30N, 15 seconds. Fig. 3 and 4 show the cross sectional mesurement region and the surface measurment region of the blade respectively. Table 5. shows the measurement results of these two blades.

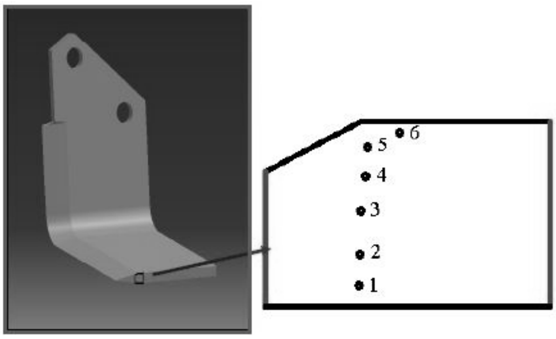


Figure 3. Cross sectional hardness measurement of the blade

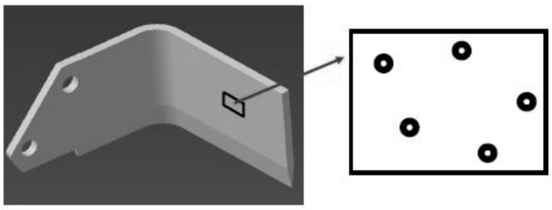


Figure 4. Surface hardness measurement of the blade

Table 5. Rockwell hardness test values of the blades

Hardness/Producer	Celli		Coşkunsan	
Rockwell Hardness (HRC-30N)	Surface	Cross-section	Surface	Cross-section
	64.8= 1.1	61.1= 5.6	57.7= 2.2	64.2= 4.6

According to these values the surface hardness of foreign blade was higher than domestic blade. It can be considered the heat treatment was applided to the foreign blade. As known, by heat treatment performance of the steel can be improved.

In order to observe the wear behaviour of the foreign and domestic blades, the wear test was applied to the blades. For this study wear test machine was designed including below parts ;

1. Weight 1 and Weight 2: Apply the pressure needed to wear the samples.
2. Plastic stabilizer: Tighten the weight up in the bolt.
3. Bolt nut 1: Holds the weights up in the bolt.
4. Bolt: Tranfers the pressure to lower levels of machine.
5. Bolt nut 2: Helps to apply the pressure directly to the sample.
6. Plastic stabilizer 2: Helps to apply the pressure homogeneously to the sample.
7. Bakalite sample: To control the behaviour of the metal during wear. Wear test machine views can be seen in the Figure 5. and Figure 6.

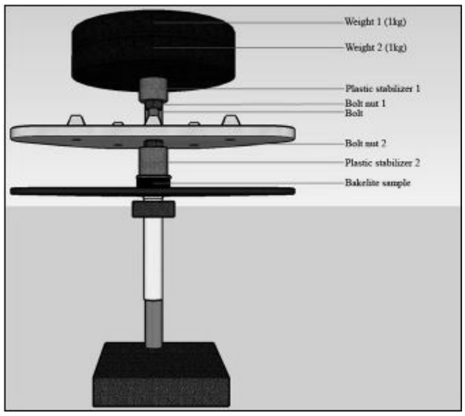


Figure 5. Wear test machine view 1

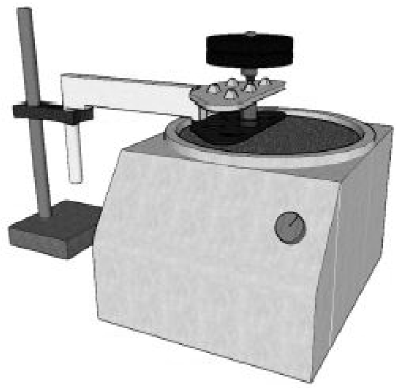


Figure 6. Wear test machine view 2

Principle of wear test machine is similar to grinding. The system seen on the images was mounted to grinding machine. Weights helps to apply the pressure needed for wear. The sample was put in the holder part of the machine and plastic stabilizer was put over the sample with the bolt nut. Weight over the sample was about 2272.8 g with all components that apply pressure to the sample. The parameters of the test were 2272.8 g weight, 300 rpm spin speed of grinding machine, 60 grinding paper, same amount of water for all samples, 15 minutes experiment time.

The metallic sample was 15x15 mm square. The amount of bakelite was weighted for two samples and same amounts were used. Before and after the experiment the height of bakalite sample was measured to determine the loss of materials because of wear.

Same parameters were applied to both of blades and compared to loss of steels. The material loss of foreign blade was 3 times higher than domestic blade, because cross-section hardness of domestic blade was higher. Table 6 shows the wear results of these samples.

Table 6. Wear test values of the samples

Producer	Celli	Coşkunsan
Wear test Results	0.107 mm	0.038 mm

CONCLUSIONS

According to all researches and experiments carried out during this study, foreign and domestic blades were compared in chemical behaviour and mechanical behaviour. According to chemical analysis main alloying element carbon content was higher in foreign blade. Chromium, molibdenum, nickel, copper and boron contents were also lower in domestic blade. Mass percentages of these alloying elements in steel as alloying element is important even in ppm levels so, the effect in mechanical properties may be catastrophic while working with these steels.

After chemical analysis, mechanical test were carried out. In mechanical tests, rockwell hardness test and wear test were applied. In hardness tests, surface and crosssectional hardness were measured. Foreign blade's surface hardness was higher compared to domestic blade. On the other hand cross-sectional hardness of domestic blade was higher compared to foreign blade. The reason of this situation can be related to the possible heat treatment. Hardness of domestic blade have desired values but this property causes breakage on working.

Advantage of this property can be seen on wear test. Domestic blade has higher wear resistance than foreign blades. If domestic blade does not break on working, it will provide higher performance.

As a result of this study it can be concluded that if domestic blade have suitable chemical composition and suitable heat treatment it will provide better results in the wear point of view. Also in the economical point of view domestic blade has an advantage over the foreign blade.

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Lecture notes of Prof. Dr. Hatem Akbulut.

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