Effect of Quenching Media on the Mechanical Properties and Abrasive Wear Resistance of (34Cr4) Steel Blade with Soil Texture Used in Agricultural Equipments

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ABSTRACT

In this paper, a study the effect of quenching media on the mechanical properties and abrasive wear has been done on steel blade (34Cr4) for agriculture equipment with soil texture. It has found that heat treatment technique is promising to improve the quality of agriculture equipments and components working in soil under dry conditions. Abrasive wear resistance is very important in many applications and it is directly correlated with hardness of metal surface. The heat treatments have large role to alter the mechanical properties and wear resistance of steel type (34Cr4). It was found that the wear resistance increases with increase hardness which increases with varying quenching media as follows; 38HRC, 56.6 HRC, 58.3 HRC and 60.6 HRC for as – received sample, caustic Soda (10%), engine oil and flaxseed oil respectively. It was found also that the wear resistance increases with decreasing toughness to values 48.3 J, 45 J, 40.2 J and 27J respectively. Wear was presented on the worn surfaces of the steels which were used in this work. All mechanical properties depended on microstructure which consists of martensitic structure and some amount of carbide particles.

Keywords: Microstructures, abrasive wear, heat treatment, Tillage process.

تأثير وسط التقسية على الخواص الميكانيكية ومقاومة البلى الحكي لريش فولاذ (34Cr4) مع نسجة التربة والمستخدمة في المعدات الزراعية

الخلاصة:

في هذا البحث, تم دراسة تأثير وسط التقسية على الخواص الميكانيكية ومقاومة البلى الحكي لريش فولاذ (34Cr4) المعدات الزراعية المستخدمة مع نسجة التربة. وجد ان تقنية المعاملات الحرارية هي المسؤولة في تحسين نوعية الاجزاء والالات الزراعية في العمل بالترب في ظروف جافة. وتكون مقاومة البلى الحكي مهمة في تطبيقات كثيرة وهي ذات علاقة مباشرة مع صلادة سطح المعدن. ان المعاملات الحرارية لها دور كبير في تغيير الخواص الميكانيكية ومقاومة البلى لفولاذ نوع (34Cr4) . حيث وجد ان مقاومة البلى تزداد مع زيادة الصلادة باختلاف وسط التبريد مثل: 60.6 HRC, 58.3 , HRC, 56.6 HRC, 38HRC الاوساط تمثل بدون معاملات, لصودا 10%, زيت المحركات و زيت الكتان على التوالي. وجد كذلك ان مقاومة البلى تزداد عند نقصان قيم العساوة للمعدن عند قيم 48.3 J, 45 J, 40.2 J, 27J وهي قيم طاقة الصدمة بمقياس شاربي تمثل عينات بدون معاملات , لصودا 10%

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, زيت المحركات و زيت الكتان على التوالي. ظهور البلى على سطوح الفولاذ البالية (التالفة) المستخدم في هذا العمل. كل الخواص الميكانيكية تعتمد على البنية المجهرية والتي تتكون من البنية المارتنسايتية وقليلا من حبيبات كاربيدية.

INTRODUCTION

Abrasive wear has been emerged as a serious problem in the field of engineering particularly for the metallic surface of working components in machines. Important shortening of service life by abrasive wear appears on parts of machines working in soil. Alloy steel is mainly used to overcome abrasive wear-related problems due to their high strength and toughness. Various efforts are going on to reduce abrasive wear rate by changing the chemical composition, microstructure, and mechanical properties. Many researchers suggested heat treatment process as a suitable technique for obtaining combination of properties to resist the abrasive wear. Abrasion wear is one of the most dominant types of wear, and abrasion wear resistance is very important in many applications. It is well known that hardness of commercially pure metals influence on its abrasive wear resistance and that higher hardness imply a higher wear resistance. Raval et al [1] (1990) studied the abrasive wear mechanism could be divided in four types: ploughing, cutting, fatigue and fracture (cracking), resulting with different surface appearance. And they found martensitic phase is usually considered for improved wear resistance of agricultural components steel. Bress an et al [2] (2007) studied the abrasive wear of the soil-engineering components such as reversible shovel are usually fitted on cultivator as soil working tool for many purposes such as loosen the soil, destroy weeds and to mix soil particles. En 45 springs steel is used in the manufacturing of reversible shovel was which caused of concern as cause's damage to material. They found increases the cost and time lost in replacing worn parts of agriculture machinery. Cryogenics is neither a substitute for heat treatment not a coating but an affecting factor of the entire volume of the material.

Das et al. [3] (2008) studied the several techniques developed over the year to increase the abrasive wear resistance of soil tools in order to improve the efficiency agricultural equipments for the help of electro deposition, vapor deposition, thermal spraying surface, hard facing, cladding, ion implantation and heat treatment. They found the microstructure of high chromium after weld depositing consists of hypoeutectic, eutectic or hypereutectic microstructure.

Chahar et al. [4] (2009) studied the effect of different heat treatment process on abrasive wear behavior of medium carbon alloy steel for enhancing the service life of soil working components of agricultural machineries. They found that the increase of the wear resistance depends on the way in which the metal is being hardened (alloying, heat treatment or work-hardening) and that in some cases wear resistance decreases with increase of hardness.

The aim of the present work is to study the effect of heat treatments with quenching media as caustic Soda (10%), engine oil and flaxseed oil on the microstructure, hardness, toughness, and abrasive wear resistance of agricultural tillage equipments steel type (34Cr4) with soil texture and compared with steel which was no treated.

Experimental Procedure.

Materials:

The chemical composition of steel (34Cr4) was used in the work, is indicated in Table (1). The samples were prepared for abrasion wear by flame cutting and milling into final dimensions 225 mm length, 65mm width, and 6mm thickness.

Table (1): The actual and standard chemical composition of (34Cr4) steel.

Element wt%	C%	Si%	Mn%	P%	Cr%	Mo%	Ni%	Cu%	Al%	Fe%
Actual	0.346	0.298	0.761	0.008	0.812	0.023	0.120	0.003	0.009	Bal

Heat treatments:

Three samples of steel which applied heat treatment processing were carried out in furnace model F62730, with different quenching media and compared with fourth sample which was no treated (as-received) as shown in the Table (2).

Table (2): Samples& process and conditions of heat treatments.

Samples	Heat treatments	Conditions of heat treatments		
		Austeniting Temp. (^{O}C)	Soaking time (min)	Quenching media
A	As received	NA	NA	NA
B	Quenching &Tempering at 250 ^{o}C	910	45	Caustic Soda (10%)
C	Quenching &Tempering at 250 ^{o}C	910	45	engine oil
D	Quenching &Tempering at 250 ^{o}C	910	45	flaxseed oil

Specimen Preparation:

The metallographic examination of the specimen preparation involves the following steps:-

1- The samples are cut to dimensions 10mm ×10mm ×6 mm.

2- All samples are ground with SiC emery paper of grit 80, 120, 600, 800, and 1000. Slurry of Al_2O_3 particles of size of 5µm and 0.5 µm were used for polishing process, with a special cloth.

3- Etching process was carried out using the solution consisting of 2% nitric acid (HNO_3) and 98% alcohol and followed by dried in air.
4-The optical microscopy type RGH, with digital camera connected to the computer is used optical microscope model (C 0.46X) TVLENS. All the etched samples were studies using optical microscope at a magnification of 500X. J-Image program was used to grain size measurement.

Hardness Test:

Rockwell Hardness (HRC) was carried out by using (Indentc machine, production by England) which is depend on ISO 650-1/2 /2005. All specimens' were prepared with dimensions 10mm× 10mm × 6mm (length, width and thickness).

Impact Test:

Charpy impact test was applied to toughness test by using machine test model JBS-300 china manufacturing which depends on ASTM23. All specimens' were prepared with dimensions 10mm×10mm with V-notch 45^o, and 2mm depth.

Abrasive wear test:

Abrasion wear tests of steel blade (34Cr4) were carried to study the effect of heat treatments on wear properties of steel blade. Flat sample with dimensions 225mm length, 65mm width, and 6mm thickness was prepared for abrasion test. The experimental wear resistance was carried out with tillage process of soil, testing applies with agriculture equipment (rotivator blade) actually with 15 cm average depth in soil texture type silt clay loam as shown in Table 3; Physical and chemical properties of soil. Table 4; shows the used parameters during the testing operation. The agriculture equipment carried out with tractate machine type (New Holland TD-80). Fig 1; has shown the arrangement of steel blade with different heat treatment. Each specimen was weighted on a weighing machine (sensitive balance) with a least 0.001gm before and after the wear test that were conducted for all the samples of various types treatment. Three times tillage times as 10hr, 20hr and 30hr, applied for all specimens with different heat treated.

The weight loss calculated as eq.

$$\Delta W = W1 - W2 \quad \ldots(1)\ [5]$$

Where:

ΔW: variation in weight loss (gm).
W1: weight of the specimen before the test (gm).
W2: weight of the specimen after the test (gm).

Table (3): The physical and chemical properties [1].

Depth 15 cm	Properties	
7.70	ph	
2.74	Ec(ds/m)	
1.32	Bulk density (gm/cm^3)	
16-17 %	Moisture content (%)	
Silty clay loam	Soil texture	
37.2	Clay %	Soil analysis
35.6	Silt %	
27.2	Sand %	

Table (4): parameters used in the wear test

Tractor type	**New Holland TD-80**
Tillage equipment	Rotavator blade
Tractor speed	7.185 Km/hr
P.T.O speed	1000 r.p.m
Cover angle	45^o

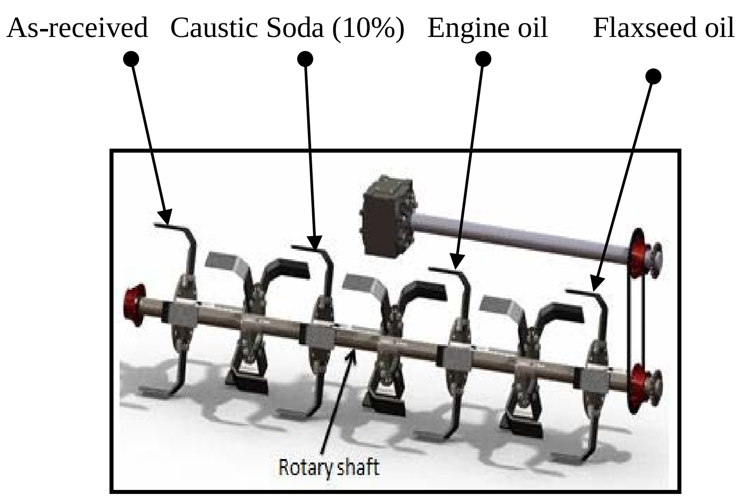
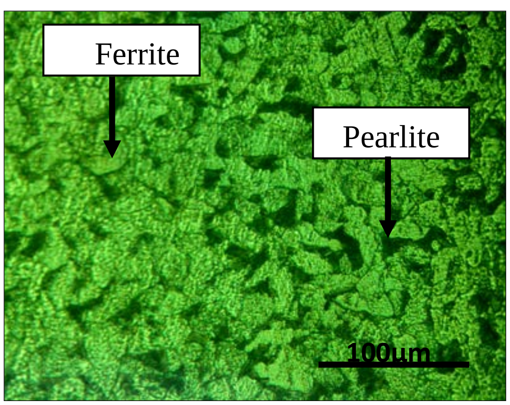


Figure (1) shows the assembly of samples blades with various heat treatments.

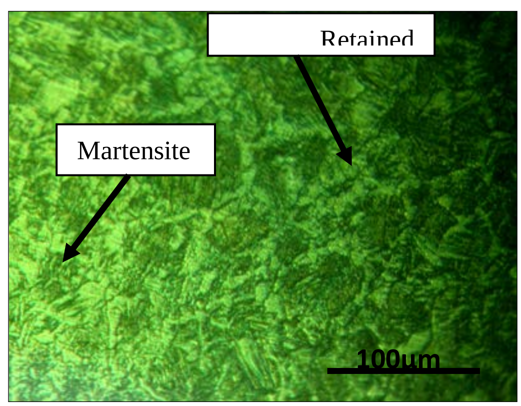
Results and Discussions:

Microstructures evaluation

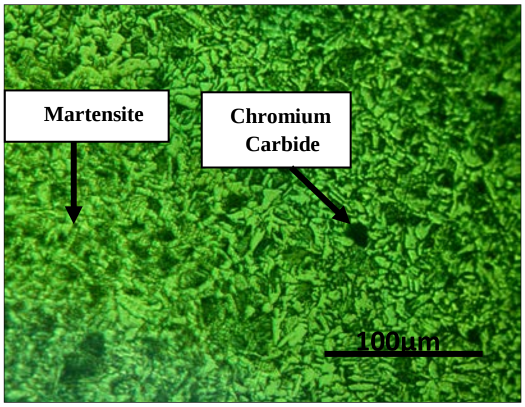
Fig(2.a); show the structure of steel (sample A), as received (no applied any heat treatment), the microstructure consist of ferrite and pearlite phases, the grain sizes (28.85) µm (measured by J- Image programmed) that's agreements with results of [6]. Fig(2.b); shows the (sample B), effect of heat treatment (quenching in caustic Soda (10%) media and followed tempering. The microstructure consists of martensitic structure, and retained austenite with large grain size (19, 11) µm. These results are good in agreements with result of [7]. They found that the microstructure of medium carbon steel specimens after hardening (martensite with retained austenite). Fig(2.c); shows the effect of heat treatment (quenching in engine oil media and followed tempering) (sample C) on microstructure which consists of martensitic structures, and some carbide particles as shown in Table 5; x-ray diffraction test type (mini flex 2) Rigaca company . The grain size (15.34) µm, is smaller in size than sample A and B. These results were good in agreement with results of [8]. They found that the quenching medium carbon steel when cool the work piece rapidly to get full hardness due to small particle size of martensitic structures, and some carbide. Fig(2.d); shows the effect of heat treatment (quenching in flaxseed oil media and followed tempering) (sample D) on microstructure which consists of martensitic structure, retained austenite and some carbide particles as shown in x-ray diffraction Table 6; with small amount of retained austenite. The grains are smallest grain size (12.31) µm than sample B and C. These results were good in agreement with results of [9]. They found that microstructure of medium carbon steel specimens after hardening is martensite with retained austenite and carbides.



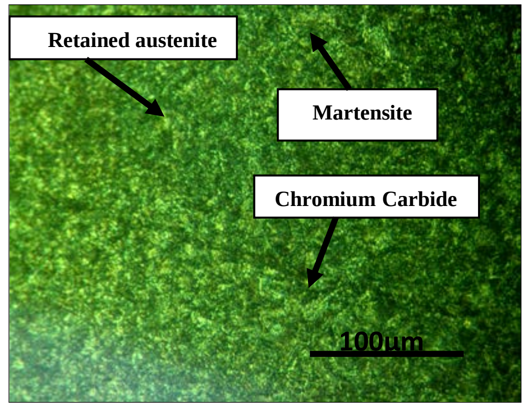
A: Specimen as-received Grain size; 28.85 µm.



B: Specimen quenching in Caustic Soda (10%) Grain size; 19, 11 µm.



C: Specimen quenching in Engine oil Grain size;15.34 µm.



D: Specimen quenching in Flaxseed oil Grain size; 12.31µm.

Figure (2) Photomicrographs of sample (A) before heat treated and samples B, C, and D after heat treatments with followed by tempered 250 ^{O}C.

Table (5): The phases by x-Ray diffraction of specimen C.

2theta	d measured (nm)	d standard (nm)	I/I_O	Phase
33.7	0.266	0.266	55	Cr_7C_3
39.5	0.228	0.228	61	Cr_7C_3
44.9	0.210	0.210	68	Fe_3C
61.8	0.152	0.152	67	x-Fe_2C
73.7	0.128	0.128	69	Cr_7C3
76.1	0.125	0.125	85	$Cr_{23}C_6$
73.7	0.128	0.128	75	Cr_7C_3
76.1	0,125	0.125	77	$Cr_{23}C_6$
81.9	0.117	0.117	87	$Cr_{23}C_6$
84.6	0.11	0.11	97	Fe_7C_3
	0.114	0.114	68	Fe_3C

Table (6): The phases by x-Ray diffraction of specimen D.

2theta	**d measured (nm)**	**d standard (nm)**	**I/I_O**	**Phase**
39.5	0.228	0.228	42	Cr_7C_3
33.7	0.266	0.266	44	Cr_7C_3
42.6	0.212	0.212	59	Cr_7C_3
79.8	0.120	0.120	66	$Cr_{23}C_6$
84.3	0.114	0.114	68	x-
50.1	0.182	0.182	74	Fe_2C
57.4	0.160	0.163	70	Cr_7C_3
65.6	0.142	0.142	71	Fe_3C
34.7	0.258	0.254	77	Fe
86.9	0.136	0.135	87	Fe_3C Cr_7C_3

Hardness test

Table (7; shows the relationship between hardness, toughness and different quenching media of the samples after each treatment. The media quenching effects to change in Rockwell hardness number after most of the austenite is transformed. It is clear from the table that the sample A, is lower hardness (38HRC) and high toughness (48.3 J) because it consists of ferrite and pearlite with large grain size. The effect of quenching media was lead to increase the hardness number of sample B to (56.6HRC) with decrease toughness to (45 J). That's effect to decreasing in losses volume, because is owing to lath martensite forming. The hardness was increased in sample C, to (58.3HRC) with decrease toughness to (40.2 J) which resulted from fine grain size of martensite structure. Increase in hardness (60.6 HRC) with decrease toughness to (27.6 J) lead to less volume loss for sample D, lath martensite and retained austenite with fine structure. These results are a good agreement with results of [10]. She found the effects of structure phases on mechanical properties.

Table (7): Hardness and toughness of samples with different quenching media.

Sample	Heat treatments	Quenching media	Hardness (HRC)	Toughness (J)
A	As-received	NA	38	48.3
B	Quenching &Tempering at250 ^{o}C	Caustic Soda (10%)	56.6	45
C	Quenching &Tempering at250 ^{o}C	Engine oil	58.3	40.2
D	Quenching &Tempering at250 ^{o}C	Flaxseed oil	60.6	27.6

Weight loss

Fig. (3); shows the typical variation of weight loss as function of the testing time for blade of steel (34Cr4) with different quenching cooling media. It's very clear when increase hardness lead to decrease weight loss or increase wear resistance. Increase weight loss (decrease wear resistance) of sample, A (without heat treatment), because of decreasing in hardness. Cooling media has effects on the hardness value and that's effects on wear resistance. The best sample which has a good wear resistance or lower weight loss of sample D, which was cooling in flaxseed oil media. This result from increase in hardness due to phase transformation and carbide precipitate according to x-ray diffraction as shown in Table 6 and this result was a good agreement with results of [11, 12]. They found the abrasive wear resistance of high chromium depends on hardness and toughness after heat treatment. Destabilization heat treatment causes secondary carbides in the dendritic austenite. Hardness and fracture toughness are influenced by destabilization heat treatment).

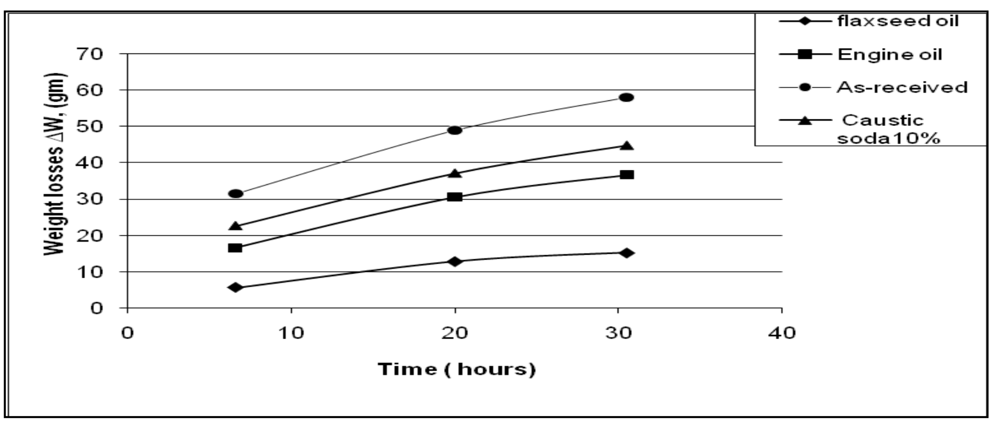


Figure (3) Variation of weight loss of specimens as function of media cooling and testing time.

Worn surfaces of the steels were examined using light microscopic to characterize the topography of the surfaces. Fig. (4.A); show the damage on the worn surface of specimen as-received (no heat treatment) and illustrates an " deep pit in surface" a change in the surface materials is plastic deformation and involves a larger deformed volume compared to flattening of the surface oxides as shown in Fig. (4.B)., which indicates a small flattening damage of the surface due to improve the surface hardness).

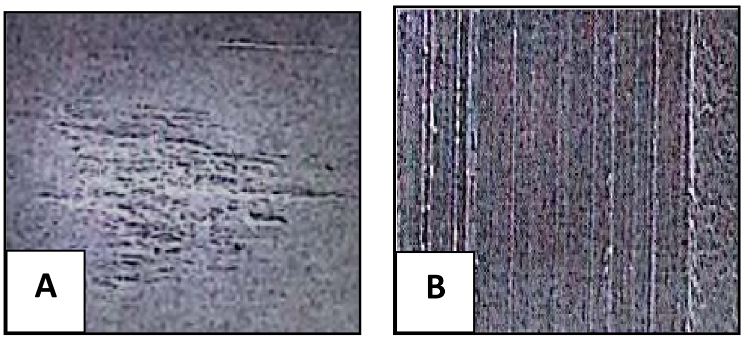


Figure (4) Topography of the 34Cr4 steel specimen surface treated by various Quenching media due to wear with the soil after 10 hour.
A: As- received (no treated) (270 X) and
B: Quenching in flaxseed oil and tempered at 250 ^{0}C (270 X).

CONCLUSIONS

1- Quenching media (Caustic Soda (10%), engine oil and flaxseed oil) effect to precipitation of chromium carbides which lead to increase the hardness and abrasive wear resistance.

2- The wear resistance increases because of martensitic and retained austenite which was formed in steel as a function of quenching media.

3- Increase in abrasive wear resistance due to formation of carbide and decrease toughness with varying quenching media.

4- The damage on the worn decreases due to effect heat treatment (high hardness) compared with the no heat treated specimen.

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