Dry Sliding Wear Behavior of EN25 Steel Treated by Different Quenching Media

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ABSTRACT

The present investigation aims to study the effect of heat treatment by quenching in different quenching media (salt water, water and oil) following by tempering on wear resistance of EN25 steel. EN25 steel is an alloy of medium carbon low alloy steel which is used for many applications requiring high tensile strength and wear resistance such as connecting rods, adapters and in power sectors extensively. The specimens are machined to 20 mm in length and 10 mm in diameter. This study is done by two stages: The first stage is done by austenitizing EN25 steel to 850℃ for 1 hr by quenching the specimens in three different quenching media and then tempered at 300℃ in air. While the second stage is performed by wear test. Dry sliding wear test is done by using pin –on-disc technique by varying the loads as 5, 10, 15, 20 and 25 N, also varying the time as 5, 10, 15, 20, 25 and 30 min respectively. The microstructure examination, hardness and followed roughness tests are also done for the specimens before and after wear test. The results of this work showed that an improving in wear resistance and hardness for the specimen quenched by salt water more than for water and oil. At the same time the roughness decreasing for the specimen quenched by salt water more than for water and oil.

Key Word: EN25 steel, quenching heat treatment, quenching media, wear.

سلوك البلى الانزلاقي الجاف للفولاذ En 25 المعالج بأوساط تقسية مختلفة

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الخلاصة

يهدف البحث الحالي لدراسة تأثير المعاملة الحرارية بالتقسية في اوساط مختلفة (ماء مالح، ماء، زيت) على مقاومة البلى للفولاذ En 25 . الفولاذ En 25 هو سبيكة من فولاذ متوسط الكاربون منخفض السبائكية يستخدم في عدة تطبيقات التي تتطلب مقاومة شد ومقاومة بلى عاليتين مثل اذرع التوصيل ،المحولات وقاطعات القدرة. تم تشغيل العينات بطول 20 ملم وقطر 10 ملم . اجريت هذه الدراسة بمرحلتين: الاولى تم فيها تقسية العينات بثلاث اوساط تقسية مختلفة عند درجة حرارية 850 م^o ولمدة 1 ساعة، بعد ذلك تتم عملية المراجعة عند 300 م^o ولمدة 1 ساعة ومن ثم التبريد في في الهواء. بينما في المرحلة الثانية اجري اختبار البلى. تم اختبار البلى الانزلاقي الجاف باستخدام تقنية المسمار- على- القرص

وذلك بتغير الاحمال 5،10،15،20،25 نيوتن، كذلك تم تغير الزمن بمقدار 5،10،15،20،25،30 دقيقة على التوالي. وكذلك تم فحص البنية المجهرية واجريت اختبارات الصلادة والخشونة قبل وبعد اختبار البلى.
اظهرت نتائج البحث تحسن في مقاومة البلى والصلادة للعينة المقساة بالماء المالح اكثر مما هو عليه للعينات المقساة بالماء والزيت. وبنفس الوقت نقصان الخشونة للعينة المقساة بالماء المالح اكثر مما هو عليه للعينات المقساة بالماء والزيت.

الكلمات الرئيسية: فولاذ EN25 , معاملة حرارية بالتقسية , أوساط التقسية , البلى.

1. INTRODUCTION

Today steel is an important alloy for the rapid development of technologies to obtain the best performance of service; this can be achieved by different heat treatments processes, **Murugan, and Mathews, 2013**. Heat treatment is defined as the heating of such carbon or alloying steel depending on the percentage of carbon and then cooling to change particulate characteristics of an alloy to achieve a suitable for a certain kind of application, **Fadara, et al., 2011**. Heat treatment affected on mechanical properties such as strength, hardness and ductility and also improving wear resistance. The purpose of heat treatment for the carbon steel is to alter the microstructure by using a certain heating and then cooling in a suitable quenching media to obtain the preferred characteristics, **Ismail, et al., 2016**. Wear is defined as surface phenomena including an important three mechanisms acting simultaneously, such as adhesive wear, abrasive wear, and erosive wear. Thus the heat treatment is important to reduce the wear of machinery components at minimum level, **Naveena, et al., 2015**. Many researchers were worked about heat treatment of steel such as **Jasiwal, et al. 2015**, they studied the effect of different quenching media such as cold water, hot water and vegetable oil on the microstructure and hardness of AISI 1050 carbon steel. While **Motagi**, **and Bhosle**, **2012**, studied the effect of heat treatment by quenching and tempering on mechanical properties and microstructure of two different steel alloys with and without copper. Whilst **Alabi, et al., 2012**, studied the effect of the temperature of the water as a quenchant on mechanical properties of two different medium carbon steel containing 0.33 wt.%C and 0.4 wt. %C. Whilst **Tukur**, **et al., 2014,** were studied the effect of quenching heat treatment at 900C^{o}for 45min and then tempering at aurous tempering temperature 250C^o, 350C^o, 450C^o and 550C^o on mechanical properties (tensile strength, hardness) of medium carbon steel. The results of this work showed that increasing the hardness, yield strength, ductility and the optimum values of the mechanical properties attained at temperature of 250C^o, while **Karthikeyan, et al., 2014**, studied the effect of subzero treatment on hardness, toughness and the amount of retained austenite present in the structure of EN24 steel alloy. They are using two different heat treatments in this work, the conventional heat treatment (CHT) and shallow cryogenic treatment (SCT). The results of this investigation reveals that the amount of the retained austenite for heat treatment (SCT) less than 2%, but for heat treatment (CHT) about 15%, at the sometime increasing in toughness and ductility.

2. EXPERIMENTAL PROCEDURE

2.1. Material Used

The selected material for this work is EN25. Table 1 and Table 2 show the chemical composition and mechanical properties of EN25 steel respectively, **Funda**, **2012**.

2.2. Preparation of The Specimens

The EN25 steel specimens have been prepared by machining them to suitable dimensions, 20 mm in length and 10 mm in diameter. Then all the specimens are grinded with emery paper (320, 500 and 1000 μm) by using Al_2O_3 with 1 μm in size and polished with suitable polishing cloth by using diamond paste.

2.3. Heat Treatment

The prepared test specimens were adapted to treat by quenching. The specimens were heated at 850c^o for 1hr. in an electrical furnace. After heating, the specimens were cooled rapidly in three different quenching media (salt water, water and oil). After quenching, the specimens were tempered at 300℃ for 1 hr. and then cooling in air **Senthilkumar**, **and Ajiboye**, **2012**. The electrical furnace used in this work as shown in **Fig.1**.

2.4. Hardness Test

The hardness values of all the specimens before and after hardening by quenching were measured by Vickers method using 20 Kg for 15 Sec. Vickers hardness number can be calculated by using the following formula, **Bolton, 1988**. For each specimen three readings were taken to define the average value of the hardness.

$$V.H.N = 1.8544 \times F/d_{ave.}^2 \qquad (1)$$

3. WEAR TEST

Wear test is carried out by using pin-on-disc technique to define the wear rate for all the specimens before and after heat treatment by quenching in the different quenchants (salt water, water and oil). **Fig.2** shows the setup of wear test.

The specimens of this project are machined to suitable dimensions 20mm in height and 10mm in diameter. Specimens for wear test are grinded and polished before and after treatment by quenching, wear test is done by fixing the specimen against the hardened disc (45 HRC) rotating at 750 r.p.m.

Wear test was done by changing the vertical applied loads as 5, 10, 15, 20 and 25 N and changing the time as 5, 10, 15, 20, 25 and 30 min respectively. For each specimen before and after heat treatment the loss in weight is computed by sensitive electronic balance with accuracy about 0.1 mg (Type Mettler AE-60- made in China).

Wear rate of all the specimens was computed by using the following formula:

$$Wear\ rate = \Delta w/ 2\pi .\ r.n.t \qquad (2)$$

$$\Delta w = w1 - w2 \qquad (3)$$

4. SURFACE ROUGHNESS TEST

Table 3 shows the average values of roughness before and after wear test. Surface roughness of the specimens before and after wear test was carried out by using apparatus type Talysurf_4 products by English Taylor_Hobson company to measure roughness average (Ra), as shown in **Fig.3**.

5. RESULTS AND DISCUSION

5.1 Microstructure Evaluation

The microstructures of the specimens before heat treatment by quenching consist of ferrite and pearlite. Heat treatment by quenching is carried out at austenization temperature, and then the specimens rapidly cooling in quenching media. In this work the quenching media are salt water, water, oil respectively. Since the cooling is rapidly by the quenching, martensite phase forming immediately with some amount of the retained austenite which affected with temperature of quenching and the percentage of carbon for the steel. Since the martensite is brittle and hard, it leads to form internal stresses, **Joshua, et al., 2014**. However heat treatment by tempering must be carried out to minimize the internal stresses. Quenching by salt water leads to obtain more martensite with little retained austenite due to the cooling for salt water more rapidly than for another quechants as shown in **Fig.4**.

5.2. Effect of Different Quenchants on Hardness

The effect of different quenchants on the hardness of the specimens is shown in Table 4. From this table it is showed that the highest value of hardness obtained by cooling in salt water more than for water and oil, it is attributed to that the cooling rate for salt water more than for another quenchants, which in turn leads to form a large amount of martensite comparing with another quenchants with little amount of retained austenite as shown in **Fig.5**. The results of the hardness of the specimens treated by different quenchants are agreed with **Singh, and Mondal, 2014**.

5.3. Effect of Diffrent Quenchants on Wear Rate

Increasing the loads and the time for wear test leads to increase the wear rate for all the specimens as shown in **Fig.6** and **Fig.7.**

Since the cooling rates are different for the quenchants, therefore the wear rates are different also. It can be noted clearly from these figures that the higher wear rate is for quenching by oil and then for water and salt water respectively. It exhibits that wear rate can be minimized significantly by hardening in suitable quenchant, it is due to generation the martensite phase which leads to increasing the hardness and then decreasing wear rate, this agrees with **Hasson**, **2013**. It can be noted clearly that for salt water the wear rate less than for water and oil because of the rapidly cooling for salt water producing the hardened martensite which in turn gave highest wear resistance. Here the results agreed with **Sultana, and Islam, 2014**.

5.4. Effect of Different Quenchants on Surface Topography

Fig.8 shows the micrographs of surface topography of the specimens quenching by different quenchants. Through the wear test, there are three mechanisms observed for the treated specimens, there are adhesive, material transfer and oxidation with plowing. By changing the loads and the time many grooves were formed as a result of micro cutting of the worn surfaces without plastic deformation, which in turn lead to make the surface more roughness. Increasing the loads of wear test leads to increase the roughness, because of the formation of the grooves as a result of wear mechanism. The roughness for salt water less than for water and oil, it is attributed to that the hardness for the quenching by oil more than for water and oil and it than decreases the roughness, **Boded, et al., 2011**. The visible plowing grooves are smoother for the specimen surface quenched by salt water because of highest hardness, while the worn surfaces for the specimens quenched by water and oil have deeper grooves and parallel respectively. At the same time fine wear debris were formed as a result of the rotating between the specimens and the hardened disc, as well as forming layers of oxides. The oxidation layers obtained because of the heating occurred as a result of friction between the specimens and the rotating disc.

6. CONCLUSIONS

1- Wear rate increases with increasing the loads and time for all the specimens before and after quenching heat treatment for all the quechants.

2- Wear resistance and hardness for the specimen quenched by salt water more than for water and oil.

3- Roughness for the specimen quenched by Salt water lower than for Water and Oil.

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NOMENCLUTURE

$d_{ave.}$: average indenter diameter, mm.

F: applied load, Kgf.

n: number of rotating's of the hardened disc.

r: the radius of the distance from the center of the center of the disc to the center of the specimen, mm.

t: time of the test, second.

V.H.N: vickers hardness number, Kgf/mm^2.

Δw: the changing in weight, (gm).

w1, w2: the weight of the specimen before and after wear test, (gm).

Table 1. Chemical composition of EN25 steel in (wt. %).

Steel	%C	%Si	%Mn	%Ni	%Cr	%Mo	%S	%P
Standard value	0.4	o.3	0.6	1.5	1.2	0.25	0.005	0.01
Actual value	o.42	0.79	0.58	1.35	1.0	-	0.003	0.008

Table2. Mechanical properties of EN25 steel.

Yield Strength (MPa)	Tensile Strength (MPa)	Modulus of elasticity (GPa)	Elongation %	Hardness HV
850	635	190	13	265

Table 3. Show the readings of roughness average for the tested specimens.

The specimen	Load (N)	Values of (Ra) before wear(μm)	Values of (Ra) after wear (μm)
	5	0.015	0.090
	10	0.107	0.198
	15	0.110	0.205
	20	0.203	0.278
	25	0.235	0.309
	5	0.028	0.016
	10	0.113	0.149
	15	0.130	0.274
	20	0.210	0.276
	2 5	0.257	0.301
	5	0.109	0.167
	10	0.183	0.201
	15	0.243	0.299
	20	0.268	0.307
	25	0.279	0.321

Table 4. Show the values of hardness for the specimens with different quenchants.

Specimen	Hardness (HV)
As- received	265
Quenching in salt water & T300C^o	487
Quenching in water & T300C^o	394
Quenching in oil & T300C^o	301

Figure 1. Show the electrical furnaces for heat treatment.

Figure 2. Show the setup of wear.

Figure 3. Show the setup apparatus of roughness.

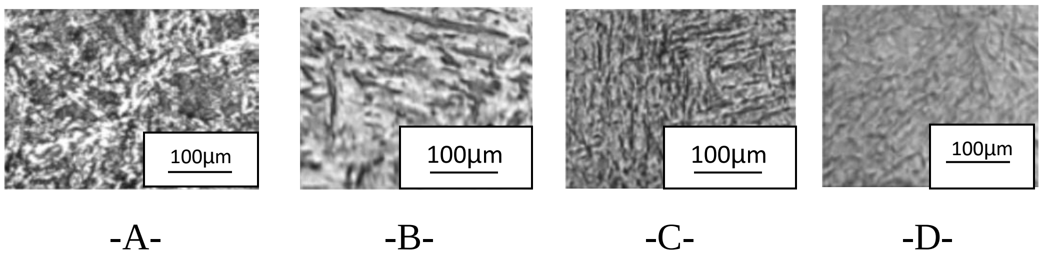


Figure 4. Photomicrographs of the specimens before and after treatment by quenching with magnification 250 X.
A-As –received.
B- Quenching by salt water.
C- Quenching by water.
D- Quenching by oil.

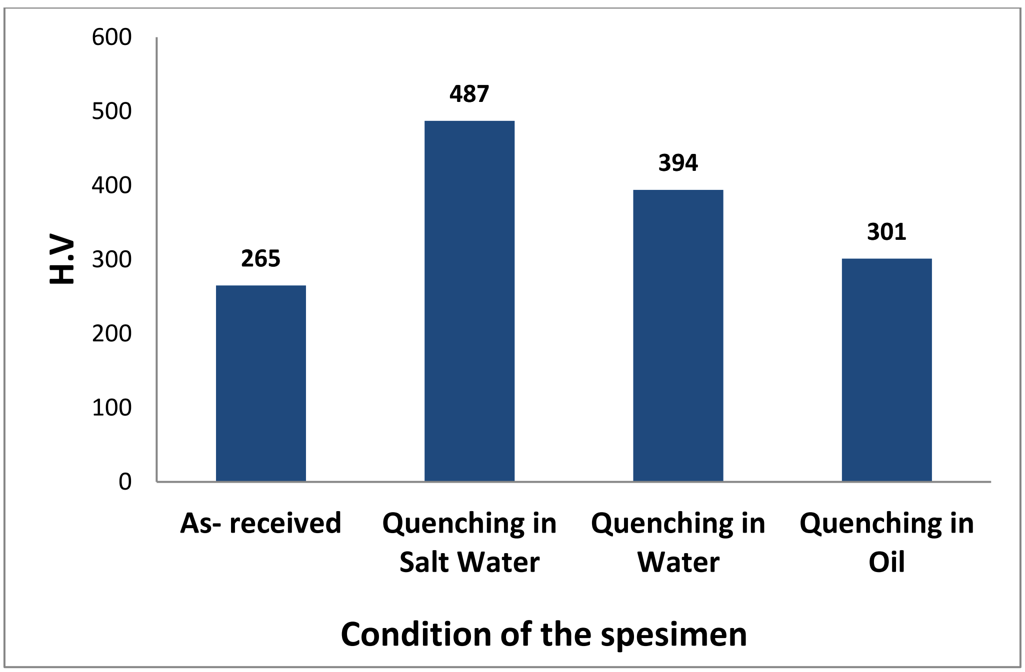


Figure 5. Show the values of hardness for the specimens with different quenchants.

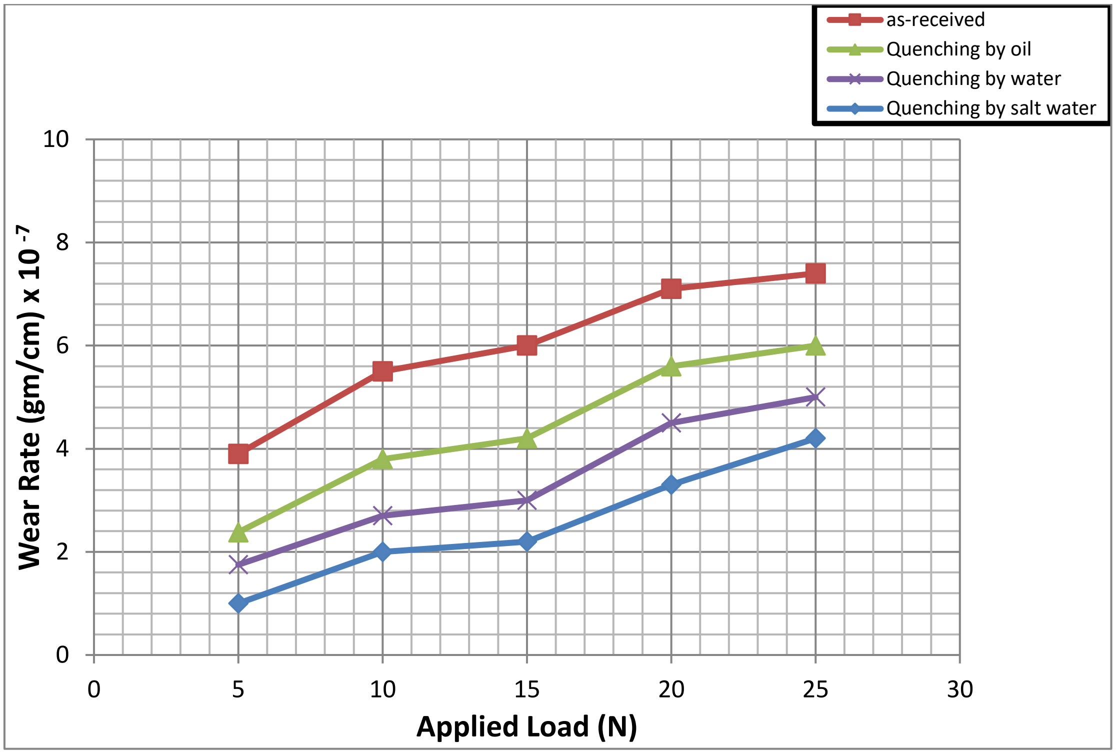


Figure 6. Relationships between wear rate and applied loads.

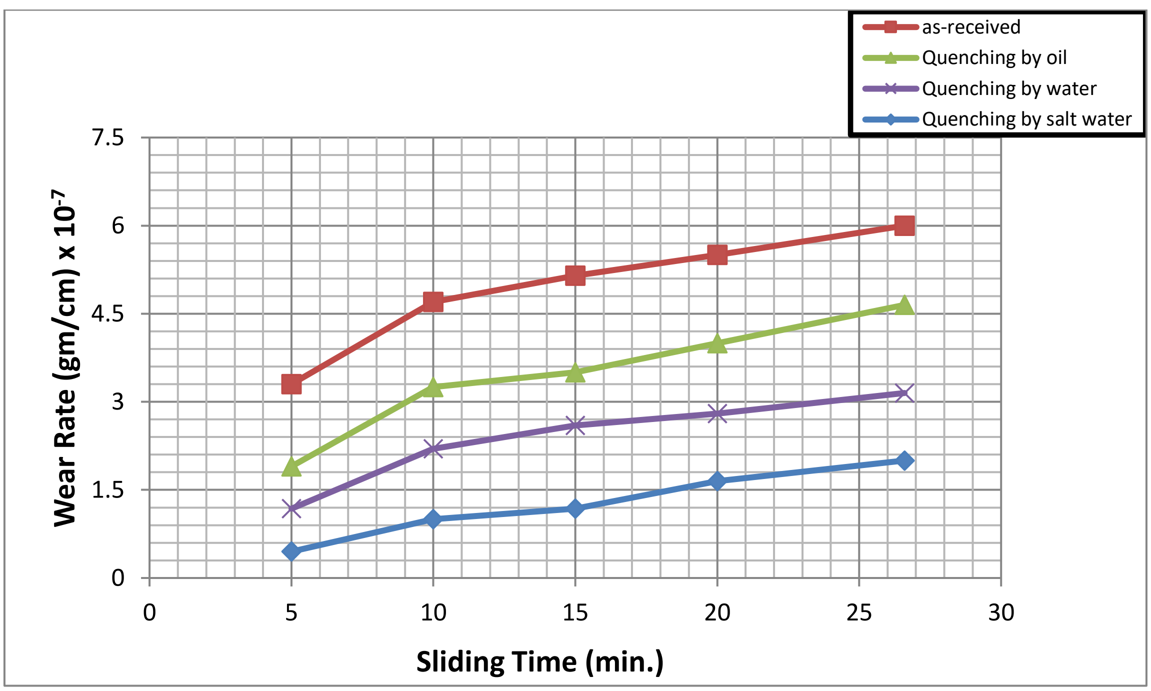
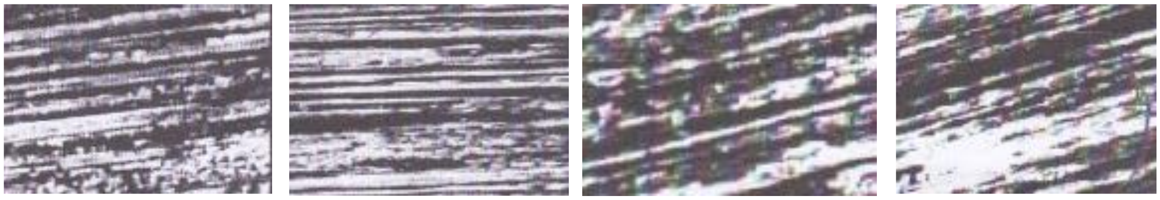


Figure 7. Relationships between wear rate and sliding time.



-A- -B- -C- -D-

Figure 8. Show the worn surfaces for the specimens treated by different quenchants before and after wear test at load 15N.

A. As –received.

B. Quenching by salt water.

C. Quenching by water.

D. Quenching by oil.