Effect of Quenching Media on Wear Resistance of AISI 52100 Bearing Steel Alloy

Dr. Enaam obeid hassoun
Electromechanical Engineering Department, University of Technology/Baghdad
Email:enaamobaid@yahoo.com.

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ABSTRACT

A study has been made to evaluate wear behavior of AISI 52100 steel under different quenching media. This investigation was accomplished by two stages. In the first stage of the study , quenching treatment was applied to the steel alloy and then cooling was carried out in various media (Oil , Polyvinyl Alcohol , Glycerol), and finally low temperature tempering (200C°) was applied to the quenched samples to eliminate internal stresses after transformation from austenization temperature to the temperature which the samples were cooled. Microstructural examination was achieve using light microscopic for all heat treated specimens after metallographic preparations . In the second stage , pin - on - disk technique was used to determine the wear rate of the treated specimens depending on weight loss method . Worn surfaces of the steels were examined using light microscopic to characterize the topography of the surfaces.

The results exhibited that (i) Martensitic matrices with retained austenite can be obtained depending on the quenching medium . (ii) Chromium carbides have been precipitated as a result of quenching heat treatment in different quenchants . (iii) Quenching in oil and then tempering revealed wear resistance more than other quenchants . (iv) wear cracks were presented on the worn surfaces of the steels which was used in this work .

Keywords : Quenching Media / Wear resistance /AISI 52100 Steel

تأثيرأوساط التقسية على مقاومة البليان لسبيكة فولاذ المسند AISI 52100 steel

الخلاصة

أجريت هذه الدراسة لتحديد سلوك البليان لفولاذ المسند (AISI 52100 steel في) أوساط تقسية مختلفة . تم البحث على مرحلتين : في المرحلة الاولى تمت تقسية سبيكة الفولاذ وبأوساط تقسية مختلفة (الزيت ,بولي فنيل كلورايد , الكليسرول) , بعد ذلك أجريت المعاملة ولجميع العينات التي تمت تقسيتها 200الحرارية بالمراجعة عند درجة حراية منخفضة (C)º وذلك لازالة الاجهادات الداخلية الناتجة عن التحولات من درجة حرارة الاستنة والى الدرجة التي يتم فيها تبريد العينة . تم فحص البنية المجهرية للعينات التي تمت معاملتها حراريا وذلك بأستخدام المجهر الضوئي بعد أجراء عمليات تحضيرية لذلك .

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2412-0758/University of Technology-Iraq, Baghdad, Iraq

في المرحلة الثانية أستخدمت تقنية المسمار - على – القرص لحساب معدل البلى للعينات المعاملة حراريا وذلك بالاعتماد على طريقة الفقدان بالوزن . تم فحص السطوح المعرضة للبليان بأستخدام المجهر الضوئي وذلك لتحيد طوبوغرافية الاسطح . أظهرت النتائج ما يلي : (i) تم الحصول على أرضية مارتنسايتية مع اوستنايت متبقي أعتمادا على وسط التقسية . (ii) ترسيب كاربيدات الكروم نتيجة المعاملة الحرارية في أوساط تقسية مختلفة . (iii) التقسية في الزيت ثم المراجعة تعطي مقاومة بلى أعلى من اوساط التقسية الاخرى . (Vi) ظهور بعض الشقوق على ألاسطح المعرضة للبليان لسبيكة الفولاذ المستخدمة في البحث .

INTRODUCTION

Bearing AISI 52100 steel are used in many applications where high wear resistance is needed . After conventional heat treatment (austenitization at temp. 860, quenched in oil, tempering within 2 h at 190^{o}) steel structure will consist primary and secondary carbides in martensitic matrix .Between the plates a martensite is retained an austenite [1].

While the contact surfaces of a bearings raceways and rolling elements are subjected to repeated heavy stress .It still must maintain high precision and rotational accuracy .Thus the raceways and rolling elements must be made of a material that has high hardness and good dimensional stability. Also, it has a good resistance to rolling fatigue and wear [2].Quenching hardening is a commonly used as heat treatment in manufacturing industry to increase the service reliability of components [3].The success of quenching process mainly depends on the heat transfer of the quenching medium[4].

The selection of optimum quenchant and quenching conditions both from the technological and economical point of view is an important consideration [8]. Water, brine solution ,polymer etc are used as conventional quenching media .Water and brine solution are restricted to quenching simple shapes and steels of comparatively low hard enability .This is because the occurrence of intolerable distortion ,warpage and quench cracks [5].On the other hand , convective cooling in Oil is less intensive due to relatively high viscosity and low heat capacity [2]. Polymer quenchants show low cooling rate and is required for optimal performance. Besides it is not suitable for steel and thus requiring high temperature quenching [6].

There are many investigations in this field, in previous study [7]. Reported that high carbon through hardening steels such as AISI 52100 steel and a variety of case – carburized low carbon steels are used for anti-friction bearings .High carbon steels such as AISI 52100 steel are generally cleaner than low carbon steels such as 8620 ,4118 ,4620.Also in previous study [8]. reported that the source of most fatigue problems in bearings steel are hard and brittle oxides especially large alumina particles over 30μ_m .while in another previous investigation [9], studied the tempering of a martensitic 100Cr6 (AISI 52100 steel) bearing steel during isothermal treatments. The result of the study reveal that precipitation of carbides, recovers of the dislocation structure and coarsening of mortensite lathes .

The aim of this work is to study the effect of different quenching media on wear behavior of AISI 52100 bearing steel.

EXPERIMENTAL PROCEDURES

With regards to Materials, three specimens were taken from AISI 52100 bearing steel subjected to quenching heat treatment. The changes in the microstructure and wear performance were studied as a function of the cooling media and tempering conditions. Both the chemical composition and the mechanical properties of the related bearing steel were given in Table (1) and Table (2) respectively. An appropriate heat treatment (autenizing , quenching and tempering) was applied and its values are listed in Table (3) .

Table (1) The chemical composition of the bearing AISI 52100 steel (wt -%) [10].

%Element	C	Cr	Mn	Si	p	S
Actual value	1.05	1.7	0.4	0.23	0.016	0.009
Standard value	0.95-1.05	1.3-1.65	0.25-0.45	0.15-0.35	<0.027	<0.025

*Actual value was done by using THERMO ARL 3460 – OE SPECTROMETER.

Table (2) The Mechanical properties of the bearing AISI 52100steel [10].

property	Yield stress σ_y (Mpa)	Ultimate tensile strength σ_u(Mpa.)	Young Modulus E(Gpa)	Hardness HRC (kg/mm^2)	Poisson's Ratio
Standard value	427.868	471.38	190-210	60 - 67	0.27-0.3

Table (3) Heat treatments conditions and Hardness values of the steel matrices.

Specimens	Austenizing	Cooling medium	Tempering	Hardness HB
A	850 C/15min	Oil	200 C^O/1 hr	228
B	850 C^o /15 min	Polyvinyl Alcohol	200 C^O/1 hr	210
C	850 C^o /15 min	Glycerol	200 C^O/1 hr	190

With regard to materials, in this study four specimens were taken in the annealed conditions and selected for experimental purposes. Three of the specimens were treated thermally in three different quenchants (Oil, Polyvinyl Alcohol, Glycerol), while the fourth specimen remain as – received .These specimens are exposed to several wear mechanisms under service condition .AISI 52100 is a high carbon chromium alloy steel ,which is used in a variety of mechanical applications With regards to wear test ,this was performed on polished surfaces .

Wear test was performed using pin - on - disc machine by changing loads and sliding velocity in strength of material laboratory in Electromechanical Engineering Dept. The test parameters are listed in Table (4).

Table (4) Parameters used in the wear tests.

Counterpart material	52100 (hardened)
Counterpart hardness	68HRC
Rotational speed	640 r.p.m
Normal load	(5,10,15,20,25) N
Sliding Speed	1.319,2.199 ,3.078 , 3.95 m/s

Micrographs were taken for the specimens before and after heat treatment and wear test by using computerized light microscope with magnification 270x.(MEIJI – TECHNO made in Japan) in physics thesis laboratory in Laser Engineering Dep. Wear rate evaluated by using the following equation [11] :

$$\text{Wear Rate} = \Delta W / 2\pi . r . n . t \qquad \ldots(1)$$

$$\Delta W = W_1 - W_2$$

Where:

W.R: wear rate (gm/cm)

W_1: weight of the specimen before the test (gm).

W_2: weight of the specimen after the test (gm) .

r : Distance from the centre of the specimen to the centre of the disc(cm).

n: Number of rotating disc 720 (r.p.m).

t: sliding time (min).

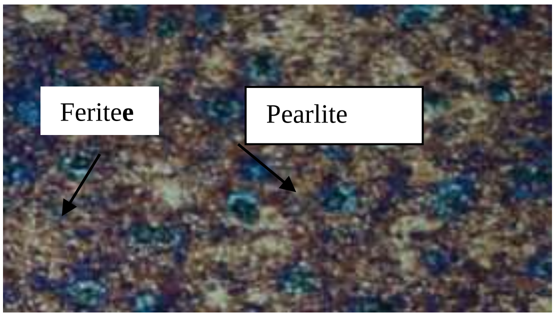
It should be mentioned that weighing of the specimens were achieved using digital sensitive digital balance (0.0001 gm.) type (Denver Instrument TD Series)

Finally for Macrohardness test , a digital portable hardness type EQ Tip apparatus is used in this study with LD type probe .The indenter of this device is small ball of hardened steel . Then the measurements for the specimens ,before and after heat treatment ,are read directly from the apparatus and then converted to HRC measurement by using special tables.

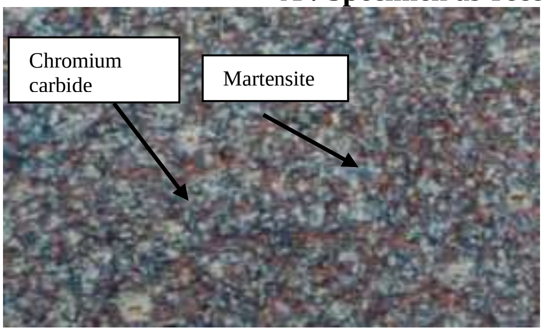
3- Results and discussion

With regards microstructural characterization. As known for steels, alloying element type and amount , quenching medium and other treatments applied determine the microstructure ,directly .The AISI 52100 steel subjected to an appropriate heat treatment (austenizing , quenching in different quenchants and then tempering). In terms of the physical metallurgy of steel, after austenizing process , it is possible to obtain a homogeneous single phase structure , namely austenite . Dissolving the most alloying elements in composition by this sort of high temperature treatment enables rearrangement of the structure. Thus a high enough hardness can be gained to the steel ,in turn lead to increase wear resistance. Physical and chemical of the final product are usually related to characteristics of microstructure .

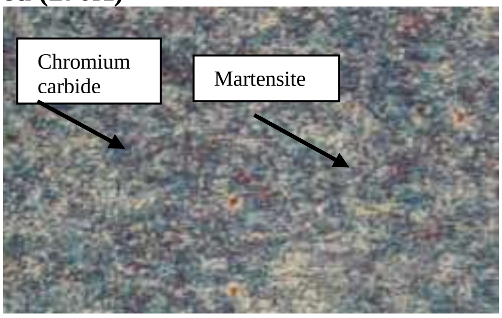
Quenching in different quenchants was made to get optimal hardness through changes of microstructure by heat treatment .The hardness of AISI 52100 steel decreases with increase of tempering temperature , the effect of tempering on hardness is very small at low temperature but as the tempering temperature increase hardness becomes prominent .It is observed that different quenchants significantly improves the wear rate and microstruchure .The quenching medium must cool the work piece rapidly to get full hardness .There were changes in hardness and wear rate which were measured for different quenchants .The microstructure of AISI 52100 steel specimens after hardening in martensite with retained austenite and carbides .



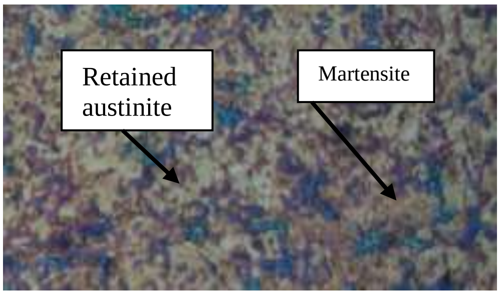
A : Specimen as-received (270X)



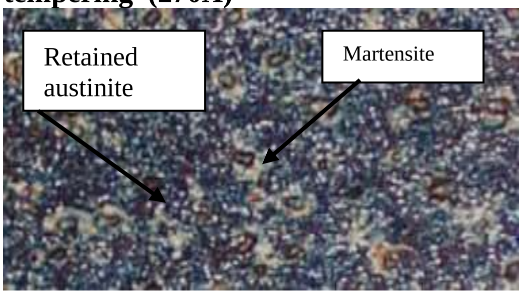
A1: Specimen quenching in oil (270X)



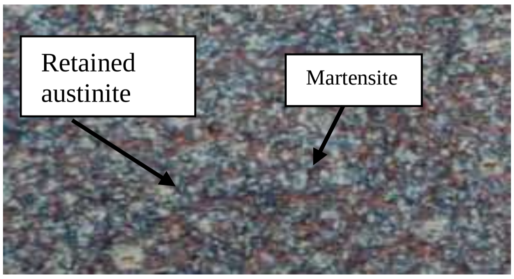
: Specimen quenching in oil and then tempering (270X)



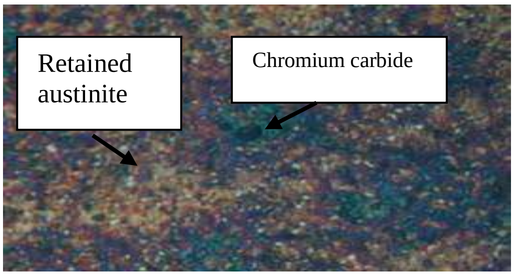
: Specimen quenching in Polyvinyl Alcohol (270X)



: Specimen quenching in Polyvinyl Alcohol and then tempering (270X)



: Specimen quenching in Glycerol (270X)



: Specimen quenching in Glycerol and then tempering (270X)

Figure (1) Photomicrographes of the heat treated specimens as follow:
A : Photomicrograph of the specimen as-received
A1,B1,C1 : Photomicrographs of the specimens quenched in different quenchants.
A2,B2,C2 : Photomicrographs of the specimens quenched in different quenchants and then tempered at 200C° ,cooled in air .

With regards to wear test. There are many typical areas in machining and tooling where adhesive wear could lead to seizures or rapid deterioration and where particular attention is required to the selection of materials which are capable of withstanding this kind of wear. Among the many applications where adhesive wear encountered, pump components, valves, and seals are most prominent.

Equally important are bearing and machinery guides .There are typical of components which have in common the essential requirement of maintaining their initial design geometry and surface integrity, often within very narrow limits to assure proper functioning of the apparatus , machine or device. Under these conditions only the smallest amount of material wear loss may be tolerable.

Figure (2) shows that increasing load lead to increase the wear rate for all the specimens .It should pointed out that oil quenchant showed the best wear resistance among the three tested quenchants .This might be attributed to the higher hardness and give more desirable microstructure of AISI 52100 steel specimen . It is inferred that the hard modified layer on the steel surface prevents the extreme pressure function to some extent. However, the quenched specimen in oil register lower wear rates than another quenchants . Also the same effect of increasing sliding speed lead to decrease in wear rate as shown in Figure (3) .The specimen quenched in oil give smaller wear rate than the another quenchants .

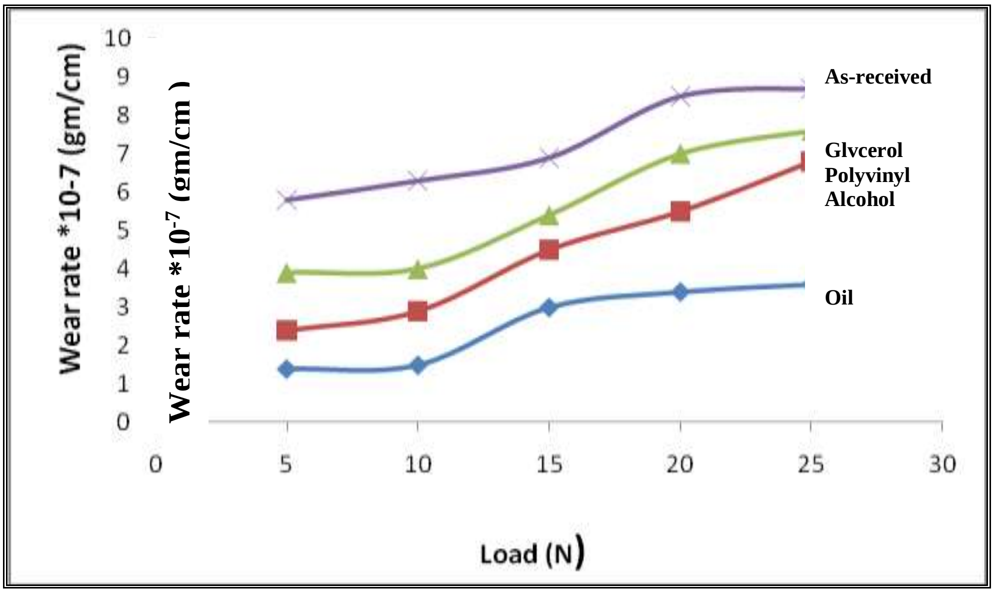


Figure (2) Relationship between wear rate and load for different quenchants and then tempering at 200°C.

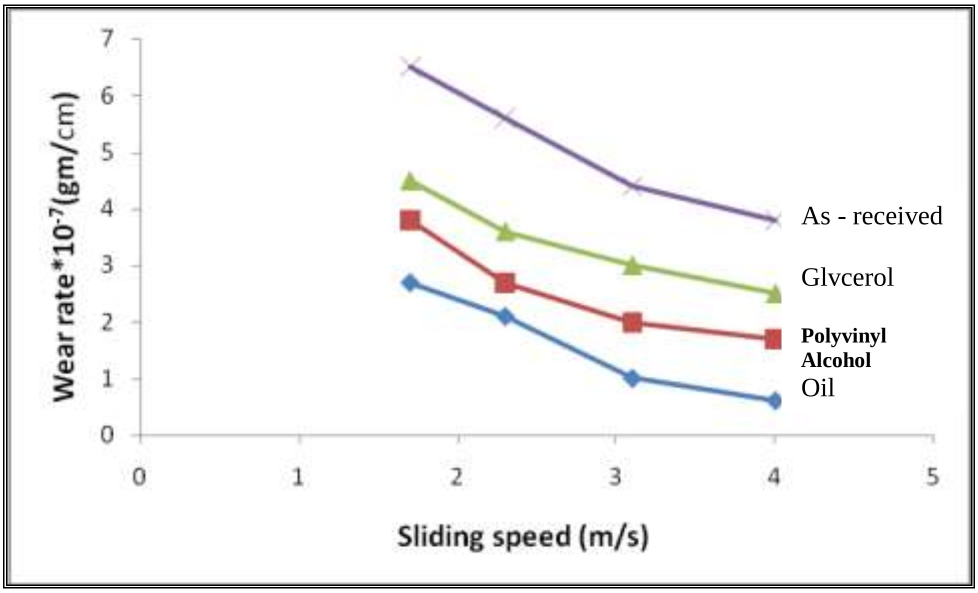


Figure (3) Relationship between wear rate and sliding speed for different quenchants and then tempering at 200°C.

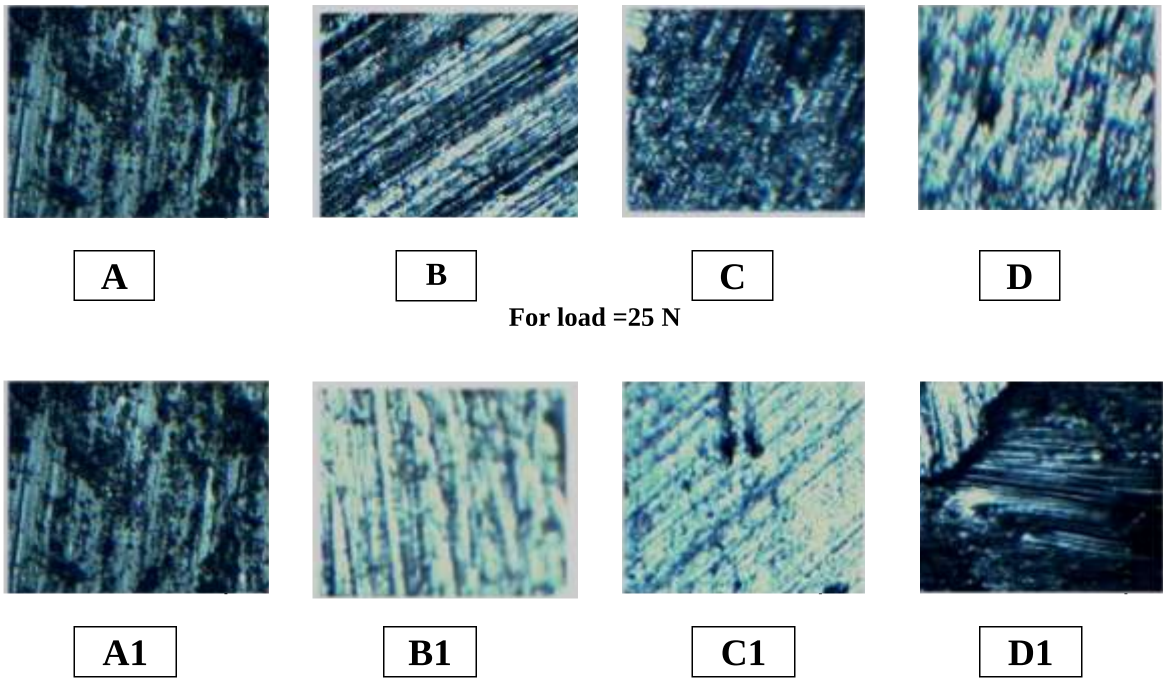
The damaged surface due to the adhesion wear for the various loads and sliding speeds has been studied for 52100 steel specimens . Photos taken by light microscope which show the lines in the direction of weariness is in the same direction with the fragment left from weariness. Also it was found that the cracks forming by that damage of weariness as shown in Figure (4) which shows the distortion took place in the surface of the specimen.

CONCLUSIONS

1- Quenching treatment in different quenchants (Oil , Polyvinyl Alcohol ,Glycerol) lead to precipitation of chromium carbides which in turn lead to an increase machrohardness.

2- Martensitic matrices and retained austenite were formed in steel as a function of quenching medium.

3- Quenching in Oil and then tempering leads to a decrease wear rate more than Polyvinyl Alcohol and Glycerol.



For sliding speed = 3.95 m /s

Figure (4) Topography of the 52100 steel specimen surface treated by different Quench ants:
A, A1: As- received (270 x)
B, B1: Quenching in Oil and tempered at 200 ^{0}C (270 x).
C, C1: Quenching in Polyvinyl Alcohol and tempered at 200 ^{0}C (270 x).
D, D1: Quenching in Glycerol and tempered at 200 ^{0}C (270 x).

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