check the different structure such as retained austenite,

Heat Treatment Effect on the Microstructural and Property Changes of Bearing Steels

L. H. Chiu[1], Y.S. Chen[1], X. Lin[1], C. J. Hu[1], Chung-Chun Wu[2]

1Department of Mechanical and Materials Engineering, Tatung university, Taipei 100-8862, Taiwan
2Mechanical and Materials Engineering, Southern Taiwan university of Science and Technology, Tainan 700-8866, Taiwan

Microstructural and property changes of bearing steels, SUJ 2 and SUJ 3 have been investigated by using different heat treatments. Specimens were austenitized at 840℃, 940℃ and 980℃ in a salt bath for 30 minutes and followed by oil quench at 90℃, Ms quench at 210℃ and marqenching at 240℃ and then tempered. The hardness of the specimens was controlled to a hardness value of 60 ± 0.5 HRC. Carbide dispersed in the tempered martensite was obtained by austenitized at 840 ℃, oil quenched and tempered. A combination microstructure of martensite and retained austenite was obtained by austenitized at 940 and 980 ℃, oil quenched and tempered at 200℃. The fully martensitic microstructure without carbide can be acquired by a sub-zero treatment. The retained austenite amount can be identified by a μ-X360 diffractometer. Volume fraction of the retained austenite of the SUJ 2 specimen quenched from 840, 940 and 980 ℃, and tempered at 200℃ was 0.9, 9.5 and 12.6%, respectively. After the subzero treatment, the retained austenite amount were decreased to 2.4% for specimen quenched from 940 and 980 ℃. Specimens were subjected to a block-on-roller type wear testing with a load of 92N at a speed of 200 rpm. The result after the wear test of 10000-cycle loading indicates that the full martensitic microstructure after the sub-zero treatment has better wear resistance than that of the quenched and tempered martensitic structure with retained austenite.

Keywords: *Bearing steel, Heat treatment, Microstructure, Retained austenite, Wear*

1. Introduction

With the rapid development of mechanical technology, the complexity and performance of steel types have also increased. Corrosion resistance, wear resistance, and fatigue resistance of the steels are also getting more and more attention.

JIS SUJ2 steel belongs to the high-quality high carbon alloy bearing steel. Highlight the advantage is good hardenability, excellent fatigue and wear resistance, another hot working performance, comprehensive mechanical properties [1-2]. It is suitable for mechanical parts such as ball bearings, steel balls, bushings, shafts, guide columns, guides and rollers.

The retained austenite is an unstable phase, which tends to cause uneven deformation of the bearing steel. Therefore, a cryogenic treatment is currently used to eliminate the retained austenite to improve the mechanical properties of SUJ2 after heat treatment [3-5].

Furthermore, the wear resistance is affected not only by the characteristics of the surface, hardness, friction coefficient, and adhesion, but also by the influence of the applied pressure and friction conditions [6-10]. The purpose of this study is to evaluate the characteristics of the SUJ2 bearing steels with different structures of the same 60 HRC hardness after different heat treatments.

2. Experimental procedures

Commercially available JIS SUJ2 (AISI 52100) steel bars were cut into several specimens measuring 12.7 mm^3. The SUJ2 specimens were austenitized at 840, 940, and 980 ℃, followed by oil quenching and then tempered.

The specimens were austenitized in a salt bath for 1 hour and then oil quenching, which followed by cryogenic treatment or not. Resulting in the different microstructures and the fraction of retained austenite and tempered martensite in specimens.

The microstructures of the different SUJ2 specimens of the same 60 HRC were evaluated by optical microscopy and X-ray diffraction. The eddy current facility was used to spheroid cementite and martensite.. The retained austenite amount can be identified by a μ-X360n diffractometer. The specimens were subjected to a block-on-roller type wear testing with a load of 42N or 92N at a speed of 200 rpm. The morphology after the wear test was observed by SEM.

3. Results and discussion

3.1 Microstructure analysis

The optical microstructures of the SUJ2 specimens after different heat treatments are shown in Fig. 1 and Fig. 2. Fig. 1(a) shows the microstructure of the as-received SUJ2 steel, in which the spheroidal cementite is uniformly dispersed in the ferrite matrix. Fig. 1(b) shows that of the SUJ2 steel via 840°C and followed by oil quench and then tempered at 200°C, in which the cementite is not completely solid-solved and dispersed in the tempered martensite matrix. Fig. 2(a) and (c) shows the structure of the SUJ2 steel via 940 and 980°C, followed by oil quench and tempered at 180°C, in which the structure of retained austenite and slim tempered martensite is observed. Fig. 2(b) and (d) shows the microstructure of the SUJ2 steel via 940 and 980°C, oil quench at 90°C, followed by cryogenic treatment for 15 minutes and tempered at 200°C, in which the retained austenite was less and tempered martensite was slimmer than that without cryogenic treatment. The volume fraction of the retained austenite after different heat treatments was as shown in Table 1. It increased with increasing austenitizing temperature and decreased with cryogenic treatment as respective.

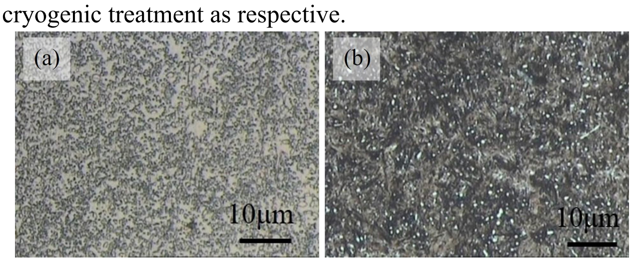

Fig. 1 Optical microstructures of the SUJ2 specimens after different heat treatments: (a) as-received, (b) austenitizing at 840°C in a salt bath for 1 hour and followed by oil quench at 90°C and then tempered at 200°C for 1 hour.

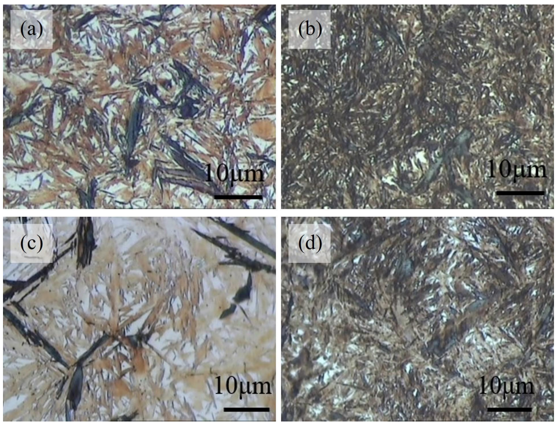

Fig. 2 Optical microstructures of the SUJ2 specimens after different heat treatments: (a) 940°C in a salt bath for 1 hour, followed by oil quench at 90°C and tempered at 180°C for 1 hour, (b) 940°C in a salt bath for 1 hour, oil quench at 90°C, followed by cryogenic treatment for 15 minutes and tempered at 200°C for 1 hour, (c) 980°C in a salt bath for 1 hour and oil quench at 90°C and tempered at 180°C for 1 hour and (d) 980°C in a salt bath for 1 hour and oil quench at 90°C, followed by cryogenic treatment for 15 minutes and tempered at 200°C for 1 hour.

Table 1 Volume fraction of the retained austenite measured in each test pieces

SUJ2	840℃ QT	940℃ QT	940℃ QT+C	980℃ QT	980℃ QT+C
RA (%)	0.9	9.5	2.4	12.6	2.4

3.2 Mechanical property analysis

3.2.1 Rockwell hardness measurement

Table 2 shows the hardness of the SUJ2 steels with different microstructures through different heat treatments. The hardness is adjusted to 60 ± 0.5 HRC by different tempering temperature.

Table 2 Rockwell hardness (HRC) of the SUJ2 steels after different heat treatment procedures

	Point 1	Point 2	Point 3	average
840℃QT	60.1	60.5	60.2	60.5
940℃QT	60.8	60.3	60.2	60.5
940℃QT+C	60.4	60.5	60.3	60.5
980℃QT	60	60.4	60.4	60.5
980℃QT+C	60.5	60.7	60.1	60.5

3.2.2 X-ray residual stress analysis

The residual stress analysis of the SUJ2 specimens is shown in Fig. 3. The data detected by μ-X360n diffractometer is shown in Table 3, indicating that compressive stress was observed in the SUJ2 specimen austenitized at 840°C or 940°C. However, tensile stress was observed in the specimen austenitized at 980°C with or without cryogenic treatment.

Table 3 also shows FWHM of the SUJ2 specimen austenitized at 840°C is 4.30, the least compared that via the other heat treatments. In comparison, FWHMs are wider for the specimens via 940 or 980°C of austenitizing temperature because the high carbon content of the martensite.

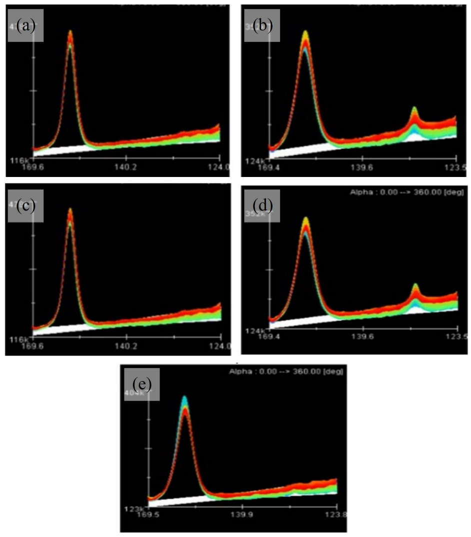

Fig. 3 μ-X360n analysis of the SUJ2 specimen by different treatments: (a) 840℃ in a salt bath, (b) 940℃ in a salt bath, (c) 940℃ in a salt bath with cryogenic treatment (d) 980℃ in a salt bath and (e) 980℃ in a salt bath with cryogenic treatment.

Table 3 The data detected by μ-X360 diffractometer

3.2.3 Eddy current analysis

Owing to the difference of magnetic property between retained austenite and martensite, the amount of retained austenite can be evaluated by eddy current signal. Eddy current detection diagram is shown in Fig. 4. It is demonstrated that the retained austenite phase in the specimen resulting different eddy current response.

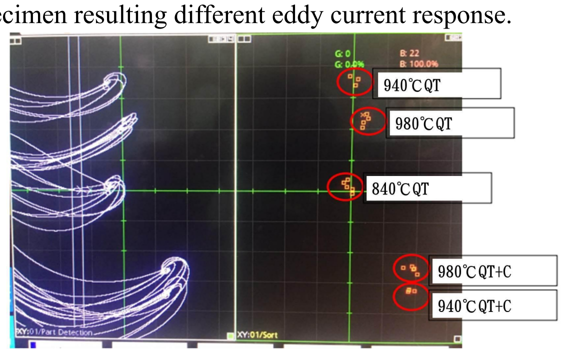

Fig. 4 Eddy current detection diagram

3.2.4 Wear property analysis

Fig. 5 depicts the weight loss of the specimens after wear test under a load 42 N. The highest weight loss exhibited by the SUJ2 steel specimen austenitized at 840°C is due to its unsolid-solved cementite dispersed in its tempered martensite matrix. Fig. 6 depicts the weight loss of the specimens after wear test under a load 92 N. Comparing Fig. 5 with Fig. 6, the wear mechanisms of the specimens between a load of 42 N and 92N are very different. In general, the full martensitic microstructure after the sub-zero treatment has better wear resistance than the quenched and tempered martensitic structure with retained austenite.

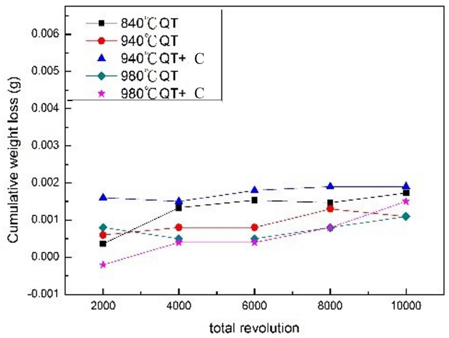

Fig. 5 Weight loss of the specimens after wear test under a load 42 N

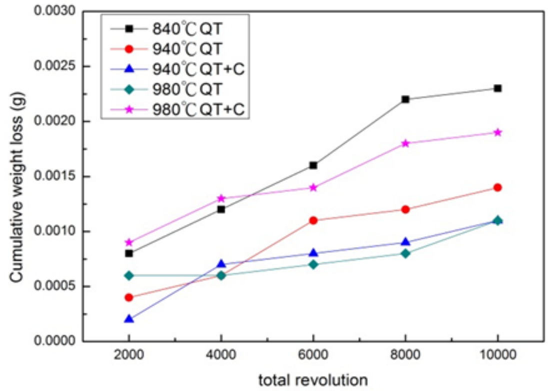

Fig. 6 Weight loss of th e specimens after wear test under a load 92 N

3.2.5 SEM observation of the surface morphology after wear test

SEM morphology of the SUJ2 specimens via different treatments is shown in Fig. 7. A large scale flake on the surface after wear test for the austenitized at 840°C, which is typical adhesion wear as shown in Fig. 7(a). The type of wear of the specimen austenitized at 940 and 980°C is scale peeling, which is adhesive wear as shown in Fig. 7(b) and (d). Fig. 7(c) and (e) shows that the type of wear of the specimen austenitized at 940 and 980°C and sequent cryogenic treatment is distributed by a deeper groove and scraped abrasive particles and partial peeling, which is a complex pattern of abrasive wear and adhesive wear.

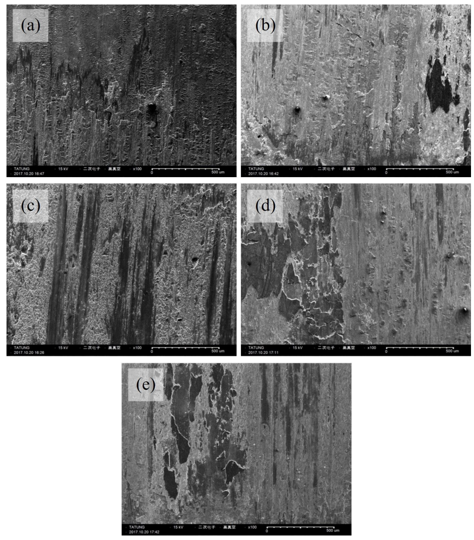

Fig. 7 SEM morphology after wear test under a load of 42N for the SUJ2 specimen at different state: (a) 840℃ in a salt bath, (b) 940℃ in a salt bath, (c) 940℃ in a salt bath with cryogenic treatment (d) 980℃n a salt bath and (e) 980℃ in a salt bath with cryogenic treatment

4. Conclusion

1. For the JIS SUJ2 (SAE 52100) bearing steels with the same hardness of 60 HRC, QT(840) specimen has the microstructure of spheroid cementite dispersed in the tempered martensite (TM), QT(940) and QT(980) specimens have the mixture microstructure of retained austenite and TM. However, the TM is the only microstructure observed in cryogenically treated specimens.
2. The peak of retained austenite can be easily identified from the pattern obtained by μ-X360n diffractometer. The retained austenite amount can be identified by a μ-X360 diffractometer. Volume fraction of the retained austenite of the SUJ 2 specimen quenched from 840, 940 and 980 ℃, and tempered at 200℃ was 0.9, 9.5 and 12.6%, respectively. The FWHM value can also be used to distinguish the carbon content of TM.
3. The response of eddy current signal can distinguish the microstructures with the same hardness of 60HRC.
4. The weight loss of the QT(840) specimen is largest among all specimens. Due to the existence of retained austenite obtained from the higher austenitizing temperature, the phenomenon of adhesive wear was observed on the worn surface.

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