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EFFECT OF HEAT TREATMENT AND PRIOR FATIGUE DEFORMATION ON CORROSION PROPERTIES OF 4340 STEEL IN SALINE WATER

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4340 steel has been subjected to a few standard heat treatment cycles and also has been subjected to a fatigue deformation in a few strain ranges. Corrosion resistance properties of these treated specimens were studied by potentiostatic method in saline water. Corrosion resistance of ferrito-bainitic structure was found to be poorer than other micro constituents. Fatigue deformation not only affect E_{corr} and I_{corr}, it also changes the polarization behavior of the steel.

Keywords: 4340 steel, low cycle fatigue, E_{corr}, I_{corr} and ferrito-banitic Structure

INTRODUCTION

Microstructure affects corrosion resistance property of alloys [1] and heat treatment changes the amount, distribution and morphology of micro constituents in steel. 4340 is low alloy steel, which is used for heavy duty, high strength parts, such as gears and aircraft tubings [2].. This steel is subjected to a variety of heat treatments [3] depending upon the application to which it is subjected. Moreover during some specific applications it is exposed to cyclic loading.

In the present work 4340 steel has been subjected to a few standard heat treatments and has also been subjected to prior fatigue deformations in different strain ranges. Changes in the micro-structure due to the different heat treatments were characterized by metallography, hardness study and XRD analysis. The differently treated samples were polarized in saline water by potentiostatic technique. Corrosion parameters were studied as a function of heat treatment and fatigue deformation. It was found that heat treatment affects I_{corr} of this steel but does not affect its E_{corr}. Corrosion resistance property of ferrito- bainitic structure was found to be poorer than other microstructure. Fatigue deformation not only affects E_{corr} and I_{corr}, it also changes the nature of the polarization curve of the alloy in saline water.

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EXPERIMENTAL

4340 steel samples, the composition of which is given in Table I were normalized, annealed, quenched and tempered at 573 K and quenched and tempered at 773 K for subsequent corrosion studies. The resultant microstructures were studied by metallographic, macrohardness and XRD techniques. Quenched samples and tempered at 573 K and 773 K temperatures respectively were subjected to low cycle fatigue deformation. Completely reversed room temperature strain cycling tests were carried out in servo hydrostatic Instron 8501 machine using +/- 20% axial strain extensometer with varying stain ranger (0.5%, 1.0% and 1.5%) on 12.5 mm gauge length circular samples of the steels []. The low cycle treatment details and their numberings are given in Table II. Corrosion studies of the samples of exposed area 1 sq.cm. were carried out using a standard polarization set up as per ST 72 and using Wenking Standard Potentiostat. One flat surface of each cylindrical specimen was ground and polished adopting the following procedure. Grinding was done manually on the silicon carbide abrasive papers sequentially on 60, 120, 240, 320, 400, 00 grit silicon carbide papers. Specimen was rotated by 90^0 between successive papers and visual inspection. It was ensured that scratches from the previous step had been removed completely. Between each grinding step each specimen surface was washed briefly under

running water and wiped dry. After grinding on 600-mesh abrasive paper, specimens were cleaned with soap solution, rinsed in running water and alcohol and then dried under the hot blower. Polishing was carried on a Sylvet cloth using coarse Geosyn-Grade I slurry of Al_2O_3 (particle size = 5 μm). Specimens were then cleaned in soap solution washed under water and die under the hot blower. They were then polished on another cloth using very fine Geosyn-Grade I slurry of Al_2O_3 (particle size = 1 μm). Specimens were cleaned, washed by water and then by alcohol and dried. Quasistationary polarization using a step voltage of 10 millivolts per 1 minute was carried out in 0.5 N (3.4% NaCl, *p*H 8) saline water as per ASTM G72 procedure. Saturated calomel electrode was used as reference electrode.

From the polarization diagrams Figs. 1 and 2, E_{corr} and I_{corr} values of the differently treated samples were evaluated by Tafel extrapolation as well as by linear polarization methods. α_a and α_b values required for linear polarization method were calculated from the Tafel slopes [5].

RESULTS AND DISCUSSION

Microstructures are given in Figs. 3 to 8 in plate. Hardness values are presented in Table I and summarized XRD data are presented in Table II. The summarized corrosion data are presented in Table III.

The microstructure of the as received sample is that of normalized structure, ferrite, bainite and austenite are the micro constituents. The hardness value confirms this and it appears that the amount of austenite is slightly on the higher side. XRD data confirms this observation as the 'd' value confirms ferritic structure but a lower peak height suggests lower amount of ferrite as compared to annealed structure. The microstructures of annealed and air-cooled samples are similar which contain coarse pearlite with upper bainite, ferrite and very small amount of austenite. Due to very slower cooling in annealing the amount of pearlite in air-cooled sample is more than that annealed sample. The hardness values of these samples are almost same. It appears that the rate of cooling obtained during the air-cooling is somewhat slower than generally obtained during normalizing. This is why the microstructure of air-cooled samples resembles that of the annealed ones. Ferrite peaks in XRD are found to be higher than austenite suggesting

TABLE I: Hardness values

Treatments	Hardness (VHN)
As received (AR)	271.5
Ai cooled (AC)	370.5
Quenched (Q)	571.5
Tempered at 773 K (T773)	405.5
Tempered at 573 K (T573)	464.5
Annealed (A)	329.0

TABLE II: X-ray date

Treat-ments	Pulse height of diffracting planes in mM (110)	(200)	(211)	Re-marks
AR	11.5	0.8	2.6	Sharp peaks
A	21.6	0.6	2.1	Sharp peaks
AC	22.1	0.6	2.2	Sharp peaks
Q	8.7	0.6	1.7	Split peaks
T773	18.4	1.0	2.4	Sharp peaks
T 573	11.5	0.6	2.3	Sharp peaks

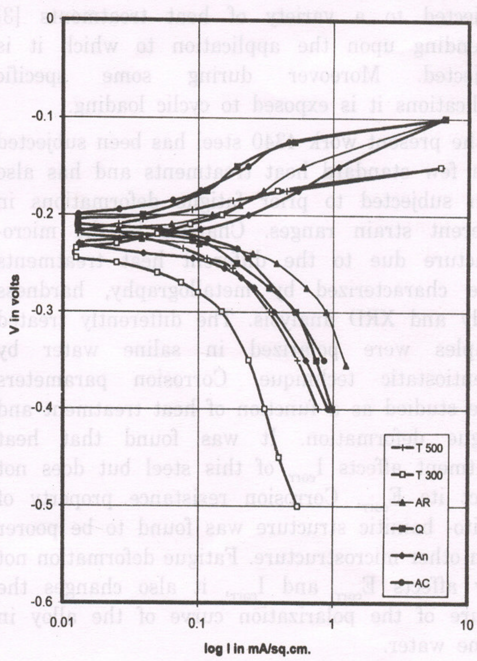

Fig. 1: Polarization diagram

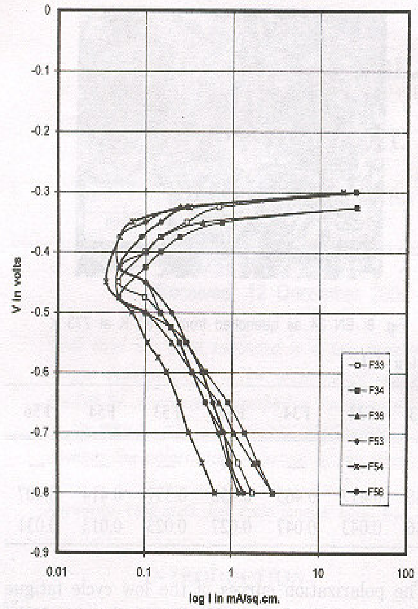

Fig. 2: Polarisation diagram

lower amount of austenite. The quenched microstructure contains martensite and retained austenite. The hardness is also high due to high amount of martensite. Ferrite peak that is now is due to martensite and is lower than the earlier ones because of the presence of appreciable amount of retained austenite. Quenched and tempered at 773 K samples show tempered martensite, ferrite, austenite and bainite whereas samples quenched and tempered at 573 K samples show tempered martensite, bainite and austenite, the last constituent being more in the low temperature tempered specimen. The hardness values are in accordance with the microstructures revealed. Because of absence of ferrite in the low

Fig. 3: EN 34 as received.

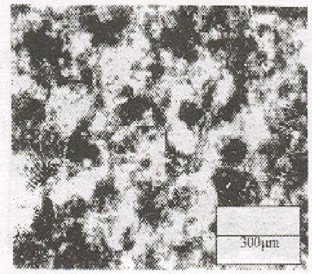

Fig. 4: EN 34 annealed at 1183 K

Fig. 5: EN 34 air cooled from 1183 K

temperature tempered specimen hardness is found to be more. XRD also confirms this by showing lower peaks for ferrite.

The results reveal that E_{corr} values are not affected by heat treatment. Corrosion rate of the quenched sample is more compared to quenched and tempered samples. This agrees well with earlier findings [6]. Corrosion rate of the as received sample was found to be highest followed by the annealed specimen. This is probably because of ferrite and bainite structure, which enhances micro galvanic corrosion. Examinations of the polarization curves of the different

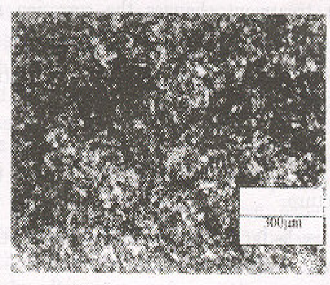

Fig. 6: EN 34 quenched from 1183 K and tempered at 573 K

Fig. 7: EN 34 quenched from 1183 K and tempered

Fig. 8: EN 34 as quenched from 1183 K at 773 K

TABLE III: Corrosion data

	AR	A	AC	Q	T773	T573	F33	F34	F36	F53	F54	F56
E_{corr} in volts vs SCE	—0.238	—0.214	—0.200	—0.210	—0.213	—0.238	—0.417	—0.465	—0.450	—0.397	—0.414	—0.407
I_{corr} in $mA.cm^{-2}$	0.100	0.090	0.048	0.056	0.022	0.036	0.043	0.047	0.027	0.023	0.013	0.031

heat-treated samples reveal a very interesting result. It is seen that the samples in which the amount of ferrite is less, exhibit a good change-over from Tafel to trans - Tafel zone.

The E_{corr} values of the low cycle fatigued samples are found to be higher than the non-fatigued samples. However I_{corr} values of the fatigued samples are found to be lower. The reason that can be attributed to this is that low cycle fatigue presumably relieves residual stresses stored in the samples during quenching. Higher tempering temperature is found to lower both E_{corr} and I_{corr} values. The polarizations of the fatigued samples are also different from the non-fatigued samples as there are no linear polarization regions in these curves.

CONCLUSION

¤ Heat treatment changes the corrosion rate of the samples but does not affect E_{corr}.

¤ Corrosion resistance of ferrito-bainitic structure found to be poorer.

¤ The nature of the polarization curve is affected by the amount of ferrite present in the structure.

¤ Low cycle fatigue deformation affect both E_{corr} as well as I_{corr}.

¤ The polarization curves of the low cycle fatigue deformed samples are unique because of the absence of the linear polarization region.

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