Hardness Properties of Intercritically Normalized 0.14wt%C Structural Steel.

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ABSTRACT

Hardness properties of 0.14wt%C structural steel were examined after intercritical normalizing at various intercritical temperatures and holding times. The intercritical normalizing treatments were performed at 810, 820, 830, …, 900^{0}C for 1, 2, 3, and 4 hours. The hardness properties of the intercritically normalized and the non-heat treated steel samples were determined and compared. The results showed that hardness properties increased with intercritical normalizing temperature and holding time. Also, intercritical normalizing and holding time gave rise to loss of hardness; properties gave rise to loss of hardness properties of the as hot-rolled steel samples.

(Keywords: intercritical temperature, intercritical normalizing, hardness properties)

INTRODUCTION

Steel is a family of materials that is derived from ores that are rich in iron, abundant in the earth's crust, and which are easily reduced by hot carbon to yield iron. Steels are very versatile; they can be formed into desired shapes by plastic deformation produced by processes such as rolling and forging; they can be treated to give them a wide range of mechanical properties which enable them to be used for an enormous number of applications. Indeed, steel is ubiquitous in applications that directly affect the quality of our lives. Steel and cement constitute about 90% of the structural materials that are manufactured [1-2]

The actual factors which control the properties of steels are structural, and in carbon steels these consist of ferrite grain size, the proportion of pearlite in the structure, the pearlite spacing, solid solution hardening and precipitation effects (3-8). Of all the metallic materials of engineering importance, none exhibit a wider variety of microstructure, and hence of available or potential mechanical properties, than do steel [3, 9-12]. In general, the major futures controlling mechanical properties of ferrite-pearlite, pearlite, and austenitic structures are reasonably well understood and with defining predictive capabilities of fairly well established relationships [3, 13-16].

The objective of this work is to investigate the effects of various intercritical temperatures and holding times on hardness properties of 0.14wt% C steel. The samples used for this work comprised of hardness specimens which were obtained from hot-rolled 16 mm diameter rods with chemical composition given in Table 1.

Table 1: Chemical Composition (wt %) of the Steel Used, with its Critical Temperatures (calculated).

C	Mn	Sc	Cr	Mo	Al	P	AC_1 ^0C	AC_3 ^0C
0.14	0.30	0.34	0.04	0.43	0.28	0.004	730	938

MATERIALS AND METHODS

Materials

The test samples used for the present work were machined from the steel rods to specifications. The samples were subjected to tests after treatments in order to determine their hardness properties.

Methods

Test specimens were heated in order according to the following heat treatment schedule: 1) Samples were heated to 810, 820, 830 … 900^{0}C, held for 1 hour (series 1), 2 hours (series 2), 3 hours (series 3) and 4 hours (series 4) at each temperature. Intercritical normalizing was done in the $\alpha + \gamma$ region of the Fe-C system. The critical temperatures (AC_1 and AC_3) were calculated by Andrew's empirical equations to be 730^{0}C and 938^{0}C respectively [8, 9]; 2) Test samples taken from the as-hot rolled steel rods were not subjected to any heat treatment operation.

RESULTS AND DISCUSSION

The results of the various measurements are tabulated in Tables 2 and 3.

Table 2: Hardness of the as Hot-Rolled Steel Rod.

H (BHN)	157

Table 2: Hardness of the as Hot-Rolled Steel Rod.

T/t	1 h (series 1)	2 h (series 2)	3 h (series 3)	4 h (series 4)
^{0}C	H (BHN)	H (BHN)	H (BHN)	H(BHN)
810	81	93	98	105
820	87	96	101	111
830	95	100	108	115
840	105	107	110	120
850	110	117	120	127
860	119	124	127	132
870	124	130	134	137
880	127	134	140	145
890	134	140	145	150
900	138	143	148	154

The variation of hardness (ΔH) with intercritical normalizing temperature and holding time is shown in Figure 1. The result indicates that hardness properties increased with increase in intercritical normalizing temperatures. It also indicates that hardness properties decreased with increase in holding times.

Table 4: Changes in Hardness of the Steel by the Different Intercritical Temperatures and Holding Times.

T/t	1 h (series 1)	2 h (series 2)	3 h (series 3)	4 h (series 4)
^{0}C	ΔH (BHN)	ΔH (BHN)	ΔH (BHN)	ΔH (BHN)
810	-49	-37	-32	-25
820	-43	-34	-29	-19
830	-35	-30	-22	-15
840	-25	-23	-20	-10
850	-20	-13	-10	-3
860	-11	-6	-3	2
870	-6	0	4	7
880	-3	4	10	15
890	4	10	15	20
900	8	13	18	24

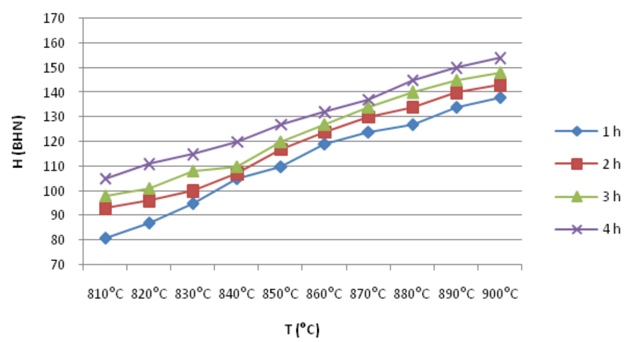

Figure 1: Variation of Hardness with Intercritical Normalizing Temperature and Holding Time.

The variation of the change in hardness (ΔH) with intercritical normalizing temperature and holding time is shown in Figure 2. Figure 2 shows a comparison of the hardness of the as hot-rolled samples with the hardness of the intercritically normalized samples. The result showed that intercritical normalizing and holding time gave rise to loss of hardness.

The loss of hardness increased with intercritical normalizing temperature and holding time. The structure of the steel obtained by intercritical heat treatment and the mechanical properties of the structure are dependent upon the amount of austenite which depend on the heating rate on heating to the two phase temperature region and on the intercritical annealing conditions, temperature and holding time. Lowering the heating rate on heating to intercritical temperature; the transformation starting temperature decreases and the ferrite starts to transform to austenite at a lower temperature. However, the amount of austenite phase is determined mainly by the intercritical heat treatment conditions. Increasing the temperature and holding tune in the intercritical heat treatment, the amount of austenite increases.

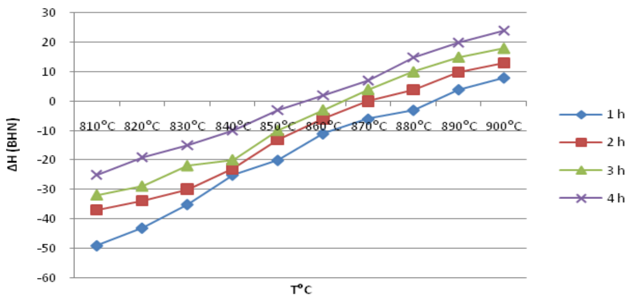

Figure 2: Variation of Change in Hardness with Intercritical Normalizing Temperatures and Holding Time.

When the intercritical annealing temperature is too high and the holding time is too long the profitable effect from the intercritical heat treatment may disappear. This is because the amount of austenite phase exceeds an optimum volume fraction so the carbon concentration and hardenability of austenite phase decreases [4, 8, 9].

The grain size of the austenite obtained depends on the dispersion of primary structure. It should be noted that in accordance with the Hall-Petch equation, smaller grain size leads to increased strength and impaired technological ductility of steel [9, 8, 16]. Besides the heating rate, the chemical composition of the steel, the amount of retained austenite and the primary microstructure before heating also influence the transformation during heating and the structure obtained from the transformation. Partial austenitization in the intercritical temperature region offers a means of optimizing the mechanical properties of dual-phase steels [3, 8, 9].

CONCLUSIONS

Hardness properties of 0.14wt%C structural steel were successful examined after intercritical normalizing at various intercritical temperatures and holding times. It was observed that hardness properties increased with increase in intercritical normalizing temperature and hardness properties increased with increase in holding time. The intercritical normalizing and holding time gave rise to loss of the hardness properties of the as-hot-rolled steel samples.

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