Toughness Properties of Intercritically Normalized 0.14Wt%C Structural Steel.

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ABSTRACT

Steel containing 0.14wt%C was intercritically normalized at 810, 820, 830, …, 900°C for 1, 2, 3, and 4 hours at each temperature. The effect of intercritical normalizing heat treatment and the holding time on the notch impact toughness was examined. The notch impact toughness properties of the intercritically normalized and the non-heat treated as hot-rolled steel samples were determined and compared. It was found that notch impact toughness properties decreased with increase in intercritical normalizing temperature and holding time. Additionally, intercritical normalizing temperature and holding time gave rise to improvement of the notch impact toughness properties over that of the as hot-rolled steel samples.

(Keywords: intercritical normalizing, notch impact toughness, temperature, holding time).

INTRODUCTION

The mechanical properties of any structural metallic material, with certain chemical compositions, are functions of its microstructure. So the aim of any heat treatment technology is the improvement, or control, of the mechanical properties by controlling the microstructure to suit the requirements restricted on a certain piece, even for use, or for subjecting to a forming or machining technology [1].

Metals and alloys often serve under nucleation and propagation of cracks and finally cause failure of the part. The impact toughness, which reflects the work spent for failure of the specimen, is a very important quantity for predicting the behavior of the material and preventing failure under dynamic loads. The value of the impact toughness is especially important for high-strength alloys [2, 3]. It is important to know the temperature dependence of metallic materials. This dependence makes it possible to determine the temperature of the ductile-brittle transformation and the temperature range of safe operation of the material. For coarse-grained metallic materials the impact toughness tends to decrease with growth in temperature [3, 4].

Expanded application of high strength steel sheets is extremely important for reducing auto body weight and securing crash worthiness. The suspension and the chassis are positioned as critical safety parts, and therefore high reliability is required in addition to their basic functions as parts. Application of high strength steel sheets to these parts not only has a simple body weight reduction, but also has the effect of improving riding comfort and driving stability. In actual applications, high strength steel sheets must provided a diverse range of functions, including not only high press-formability, which is necessary for manufacturing complex part shapes, but also weldability during assembly, corrosion resistance and fatigue resistance properties in the finished automobile, and impact resistance in collisions [5]. The aim of the present work consisted in studying the impact toughness and its temperature dependence on the 0.14wt%C structural steel.

MATERIALS AND METHODS

Materials

The samples for the experiments comprised of notch impact toughness samples obtained from hot-rolled 16mm steel rods with chemical composition and critical temperature, given in Table 1.

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

C	Mn	Si	Cr	Mo	Al	P	AC_1 °C	AC_3 °C
0.14	0.34	0.04	0.43	0.28	0.04	0.004	730	938

The test samples used for the present work were machined from the 16mm rods to specification and tested after treatment.

Methods

The test samples were heat treated (after determining the critical temperatures AC_1 and AC_3 theoretically using empirical equations developed by Andrews [6, 7]) according to the following heat treatment schedule:

1. Samples were heat treated to 810, 830... 900°C and held for 1 hour (sries1), 2 hours (series 2), 3 hours (series 3), and 4 hours (series 4) at each temperature and then air cooled to room temperature.

2. Test samples taken from the as hot-rolled steel rods were not subjected to any heat treatment operation.

RESULTS AND DISCUSSIONS

The results of the different measurements are tabulated in Tables 2-4.

Table 2: Notch Impact Toughness Properties of the As Hot- Rolled Steel.

a_n (J/cm²)	81.43

Table 3: Effect of Temperature and Time on Notch Impact Toughness.

T/t	1 h (series1)	2 h (series 2)	3 h (series 3)	4 h (series 4)
°C	a_n (J/cm²)	a_n (J/cm²)	a_n (J/cm²)	a_n (J/cm²)
810	106.72	104.03	98.48	94.77
820	103.19	99.91	96.33	91.90
830	99.89	95.81	92.37	86.67
840	94.48	91.60	89.08	84.27
850	90.53	86.78	84.39	77.04
860	87.49	81.92	79.08	73.85
870	83.91	75.68	72.28	68.52
880	78.82	71.62	66.39	62.66
890	74.62	67.27	63.27	58.96
900	69.06	65.37	60.84	54.29

Table 4: Changes in the Notch Impact Toughness by the Different Intercritical Normalizing Temperature and Holding Time.

Temp /Time	**1 h (series1)**	**2 h (series 2)**	**3 h (series 3)**	**4 h (series 4)**
^{0}C	**Δa_n (J/cm^2)**	**Δa_n (J/cm^2)**	**Δa_n (J/cm^2)**	**Δa_n (J/cm^2)**
810	25.29	22.8	17.05	13.34
820	21.76	18.48	14.9	10.05
830	18.46	14.38	10.94	5.24
840	13.05	10.17	7.65	2.84
850	9.10	5.35	2.96	-4.39
860	6.06	0.49	-2.35	-7.58
870	2.48	-5.75	-9.15	-12.91
880	-2.61	-9.81	-15.14	-18.77
890	-6.81	-14.16	-18.16	-22.47
900	-12.37	-16.06	-20.59	-27.14

The variation of notch impact toughness (an) with intercritical normalizing temperature and holding time is shown in Figure1.

The result indicates that notch impact toughness decreased with increase in intercritical normalizing temperatures and holding times. It can be seen that all the samples exhibit similar variation trend, curves being slightly offset from each other. Notch impact toughness variation against intercritical normalizing temperature (Figure1) shows a linear pattern.

The variation of the change in notch impact toughness (Δan) with intercritical normalizing temperatures and holding times is shown in Figure 2.

Figure 2 shows a comparison of the notch impact toughness of the as hot-rolled samples with the notch impact toughness of intercritically normalized samples. The result showed that intercritical normalizing gave rise to improvement of notch impact toughness. The improvement of notch impact toughness decreased with intercritical normalizing temperatures and holding times. As noted above, all the samples exhibit similar variation trend, curves being slightly offset from each other. Variation of the change in notch impact toughness against intercritical temperature (Figure 2) is linear.

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 depends 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, amount of austenite phase is determined mainly by the intercritical heat treatment conditions. Increasing the temperature and holding time in the intercritical heat treatment, the amount of austenite increases.

When the intercritical annealing temperature is too high, the profitable effects from intecritical heat treatment may disappear. This is because the amount of austenite phase exceeds an optimum volume fraction so that the carbon concentration and harden ability of austenite phase decrease [8-10]

CONCLUSIONS

The following conclusions can be drawn:

1. The notch impact toughness decreased with increase in intercritical normalizing temperature and holding time.

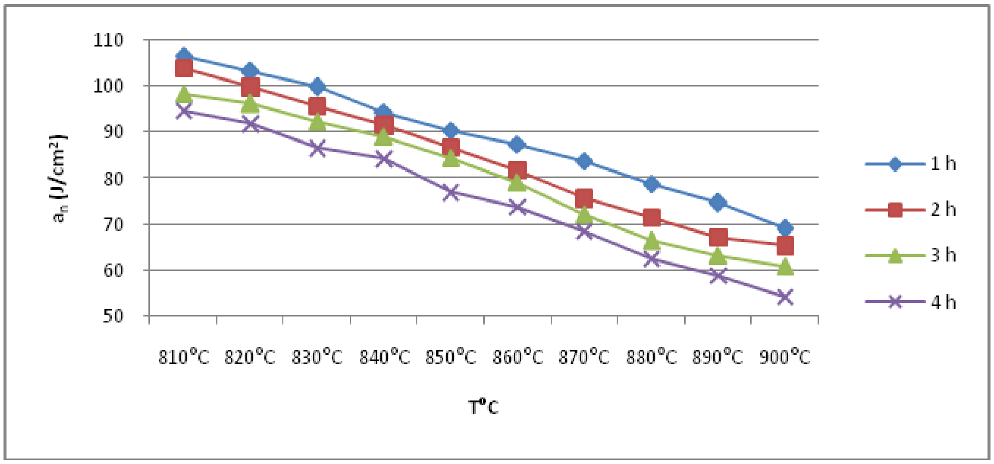

Figure 1: Variation of Notch Impact Toughness with Intercritical Normalizing Temperatures and Holding Times.

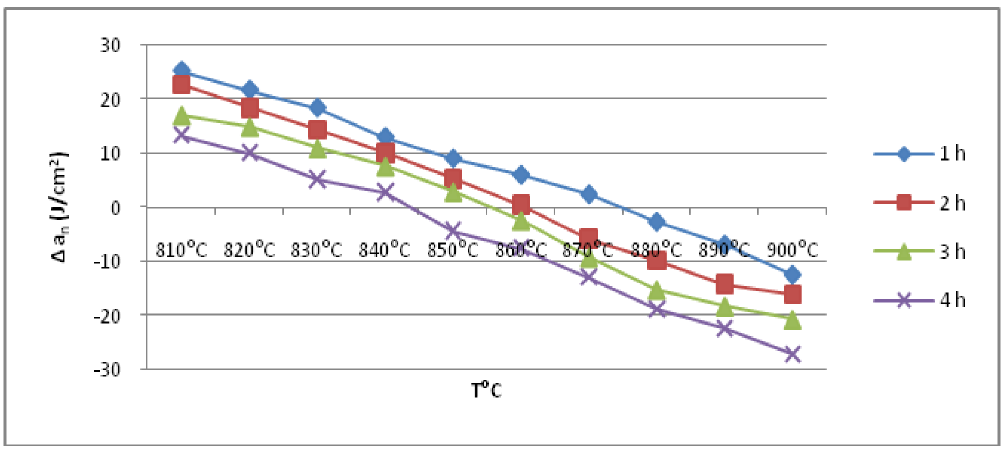

Figure 2: Variation of the Change in Notch Impact Toughness with Intercritical Normalizing Temperatures and Holding Times.

2. Intercritical normalizing gave rise to improvement of notch impact toughness over the original hot-rolled sample

3. The improvement of notch impact toughness decreased with intercritical normalizing temperatures and holding time.

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