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Effect of Copper on the Tempering Behavior of S.G.Iron

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Abstract. Two different grades of Spheroidal Graphite (SG) Iron, one containing copper and another without copper was tempered at different temperatures for same duration (1 hour). The change in different mechanical properties due to tempering was ascertained for both the grades and the effect of copper (Cu) on the properties of the tempered material was studied.

Keywords: S.G.Iron, Tempering, Mechanical Properties.

1. Introduction

Ever since its discovery in 1948, the use of SG iron or ductile iron is increasing day by day. The material has an excellent combination of strength, ductility, castability and wear resistance. The properties of SG iron can be further improved by means of alloying and heat treatment. The SG iron developed in this way provides unusual properties for special applications [1].

The mostly used heat treatment technique for ductile or SG Iron is austempering. Austempered Ductile Iron (ADI) is now replacing steel in various applications [2]. It is often stated that ADI offers the best combination of good machinability, high strength to weight ratio, wear resistance, toughness and fatigue strength [3, 4]. But since the process of austempering happens to be bit tricky, conventional heat treatment procedures like annealing, normalizing, tempering is also being practiced for SG iron. Among these the study of the effect of tempering is being practiced to a considerable extent. Alloying can also improve the properties of this material to a great extent. Among the most commonly used alloying elements, copper acts as a strong pearlite promoter and increase strength and hardness without causing embrittlement of matrix [5].

2. Experimental Procedure

Two 'Y' blocks (ASTM A536) of SG iron (Grade A & B) were prepared in a coreless medium frequency induction furnace of 1500 kg capacity. The charges consists of 100 kg pig iron, 400 kg foundry returns, 500 kg steel scraps, 34 kg coconut charcoal and 2 kg of copper for preparing SG iron of grade A, No copper addition was done for SG iron of grade B. The two melts were properly treated with Fe-Si-Mg-RE (rare earth) and proper inoculation was carried out. The final chemistry of the two grades was analyzed by Spectro-Lab (M 9 model) and listed in table 1.

Table 1. Final chemistry of the two grades of SG Iron (wt %)

S.G.I. Grade	C	Si	Mn	S	P	Cr	Ni	Mg	Cu	Fe	Rest Elements
A	3.55	2.10	0.18	0.009	0.024	0.03	0.12	0.038	0.41	93.52	Balance
B	3.57	2.22	0.23	0.011	0.026	0.03	0.12	0.045	0.03	93.70	Balance

The melts were poured in a dry furan resin sand mold as per standard procedure and foundry practices. The section size of the test blocks (solid blocks) was made as per ASTM A536 specification. The samples for tensile test was cut, machined and polished from the solid blocks as per EN1563 specification. The specimens were then tempered in a heat treatment furnace at 200, 400 and 600^{0}C. The duration of tempering was 1 (one) hour in all the cases. Different mechanical properties like ultimate tensile strength (U.T.S), 0.2% offset Yield Strength (Y.S) and % of elongation (which gives a measure of ductility) were measured for all the tempered specimens. Samples were also taken from centre of the casting for characterization of graphite morphology and matrix by Digital Image Analyzer.

3. Result and discussion

The results of the experiments are shown in table 2 & 3. Table 2 lists the mechanical properties of the tempered SG Iron specimens containing copper while table 3 gives the same properties for SG iron specimens without copper. Figures 1 (a), (b) & (c) give the graphical representation of the results.

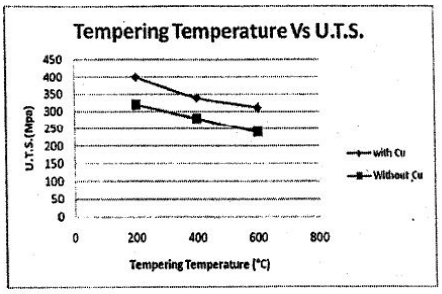
Table 2. Mechanical properties of the tempered SG iron (Grade A)

Tempering Temperature (^{0}C)	U.T.S (MPa)	0.2% offset Y.S (MPa)	Elongation (%)
200	399	217.10	8.10
400	340	205	12.02
600	310.50	194	14.70

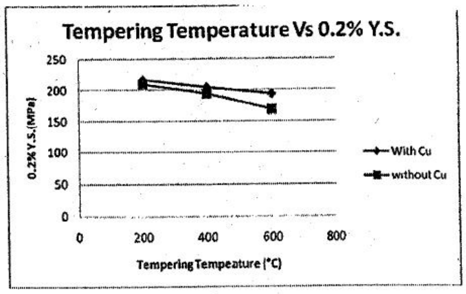
Table 3. Mechanical Properties of tempered SG iron (Grade B)

Tempering Temp (^{0}C)	U.T.S (MPa)	0.2% offset Y.S (MPa)	Elongation (%)
200	320	210	9.17
400	280	194	13.34
600	240	169	16.8

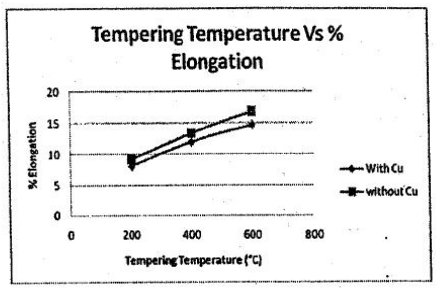
The results show that the strength of Cu bearing specimens (Grade A) is greater than those without Cu while ductility (% of elongation) is greater for the specimens without Cu (Grade B). As far as effect of the alloying element (i.e. Cu) on tempering behavior is concerned we can see that U.T.S. was decreased by 25% as the tempering temperature was increased from 200 to 600^{0}C for specimens without Cu. The reduction of U.T.S under same condition was found to be about 22% for the Cu bearing specimens. In case of Yield Strength the reductions were 19.5% & 10.6% respectively. The ductility as expected increase with tempering temperature in both the case. As obtained from the experimental results it increased by 83.2% as the temperature of tempering was increased from 200^{0}C to 600^{0}C in case of specimens without Cu. For the Cu bearing specimens the increase in % of elongation under similar conditions was found to be about 81.5%. The decomposition of austenite to ferrite plus graphite or to pearlite in SG iron casting (Eutectoid transformation during solidification) is dependent on a number of factors among which are the nodule count, the cooling rate, and the alloying additions[6]. The effect of various additions of copper and the cooling rate on the temperature of the onset of the stable and metastable eutectoid reactions describes the conditions for the growth of ferrite and pearlite. Copper is a strong pearlitic promoter [5] and in the present investigation, both the grades of SG iron specimens were analyzed by Digital Imaze Analyzer in which the results shown that grade B specimen had a matrix of 95 percent ferrite and 5 percent pearlite. Grade A specimen with 0.41percent (wt %) copper had about 60 percent pearlite and 40 percent ferrite. As pearlitic matrix is strenghter than ferritic matrix, Presence of alloy (Cu) increases the proof stress with also the tensile strength and hardness with no embrittlement in matrix.



(a)



(b)



(c)

Fig. 1: Effect of Tempering Temperature on Mechanical Properties

(a) Effect on U.T.S.,
(b) Effect on Y.S.,
(c) Effect on Ductility (Elongation)

4. Conclusions

So from the results it was concluded that:

(i) Copper bearing SG iron (Grade A) has got higher strength but less ductility than SG iron without Cu (Grade B)

(ii) Copper has got a significant effect on the tempering behavior of SG iron. It retards the effect of tempering to a significant extent. This effect is particularly significant in case of strength properties. Quite naturally strength (both U.T.S. & Y.S) decreases with the increase in tempering temperature but the rate of decreases is much lower for SG iron specimens containing Cu than the ones without Cu. However this retarding effect is not so pronounced in case of ductility (% of elongation) since it has been seen that rate of increase in ductility is almost same for both types of SG iron (Grade A & B).

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