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Study of the Effect of Copper Addition on Secondary Carbides with High Chromium Wear – Resistant White Cast Iron

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Abstract: In this article, high – chromium 280X29NL malleable white cast iron is produced by reducing the chromium content from 28.86 – 31% to 13 – 14%, adding up to 1.0% Cu, changing its chemical composition, and heat treating the alloy without reducing its mechanical properties. A new brand 280X29NL (sample 3) alloy was developed that is inexpensive and wear – resistant.

Introduction

High – chromium wear – resistant white cast irons contain 11 – 30% Cr and 1.8 – 3.6% C and are enriched with molybdenum, manganese, copper and nickel as additional alloying elements to iron alloys. Their typical microstructure consists of primary or eutectic carbides (M_7C_3) in the austenitic matrix of the alloy and is one of its transformation products [1 – 2]. The microstructure provides the hard eutectic carbides present and ductility and strength in the matrix. The property of increasing the hardness and ductility of this alloy is one of the main requirements [3 – 4]. The alloy is heat treated from 800^{0}C to 1000^{0}C to obtain high hardness, stabilize the cast austenitic structure, and remove small secondary carbides (SC) precipitates in the matrix. During heat treatment, the amount of chromium and carbon in the matrix decreases. The main reason for this is the formation of carbides in this process, and the formed carbides increase the temperature of the beginning of martensite formation, and as a result, a mixture of martensite and residual austenite appears [5 – 7]. Some elements such as Cr, Mo, Ni and Cu are added to increase the hardness of alloys [8 – 12].

Temperature, together with the composition and time of absorption of alloying elements, changes the kinetics of formation of secondary carbides. The addition of Cu helps harden the alloy, but stabilizes austenite and delays carbon diffusion [13]. Therefore, the presence of Cu has a strong effect by changing the formation time of secondary carbides. Time, temperature, and Cu content affect the distribution, velocity, and microhardness of the precipitated carbides.

Materials And Methods

In order to normalize the high – chromium wear – resistant white cast iron alloys and their chemical composition, high – quality slags have been developed based on experience. They were liquefied in an induction furnace and samples up to 10 inches long and 1 inch in diameter were poured into a sand – clay mold.

The chemical composition of the alloy was proposed below and the developed chemical composition is given in Table 1.

Table 1. Chemical composition of the proposed alloy

Brand	Elements, %								
	C	Si	Mn	Cr	Mo	Ni	Cu	P	S
Sample 3	2,7-2,9	0,9-1,2	0,6-0,8	13-14	0,7-0,9	0,7-0,9	0,8-1,0	0,060-0,070	0,020-0,040

After coordination of the slag material, it was heated to a temperature of 1480 – 1500^0 C in an IST – 0.4 induction furnace, after removing the slag, ferroalloys were introduced, and after holding for 10 minutes, it was poured into a sand – clay mold.

After cooling in cast sand-clay mould, it was subjected to mechanical processing and the chemical composition of the alloy was determined by “SPEKTROLAB – 10M” equipment.

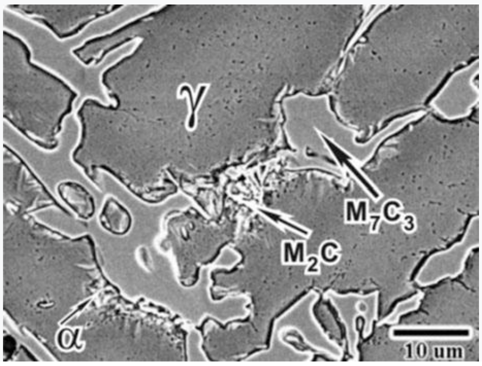
Table 2. Chemical composition of the alloy

Brand	Elements, %								
	C	Si	Mn	Cr	Mo	Ni	Cu	P	S
Sample 3	2,75	0,99	0,67	13,88	0,80	0,75	1,05	0,070	0,036

Result

Figure 1 shows the cast structure of the alloy, eutectic M_7C_3 carbides and austenitic matrix; however, small amounts of martensite and molybdenum M_2C carbides can be observed. During heat treatment, the amount of chromium and carbon in the matrix decreases. The main reason for this is the formation of carbides in this process, and when the formed carbides are cooled to room temperature, a martensite structure appears [14 – 16]. Figure 2 – Carbides such as M_7C_3 and M_2C, ferrite and martensite are not visible in the alloy due to the small size of the X – ray microscope.

Copper residues and segregation were not observed. In figure 3, copper is evenly distributed in the matrix.



1 – Picture. Microstructure of white cast iron

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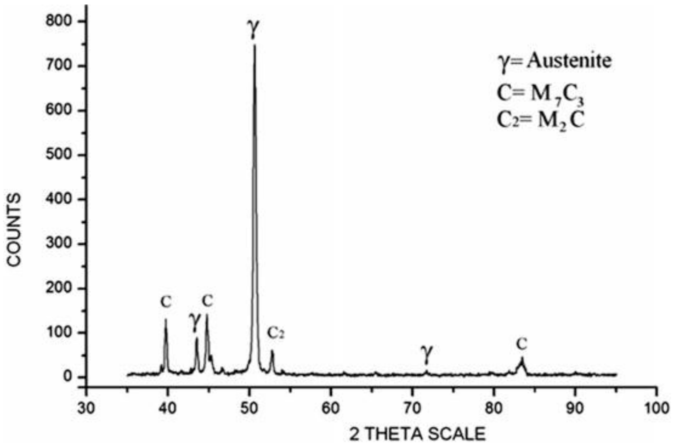
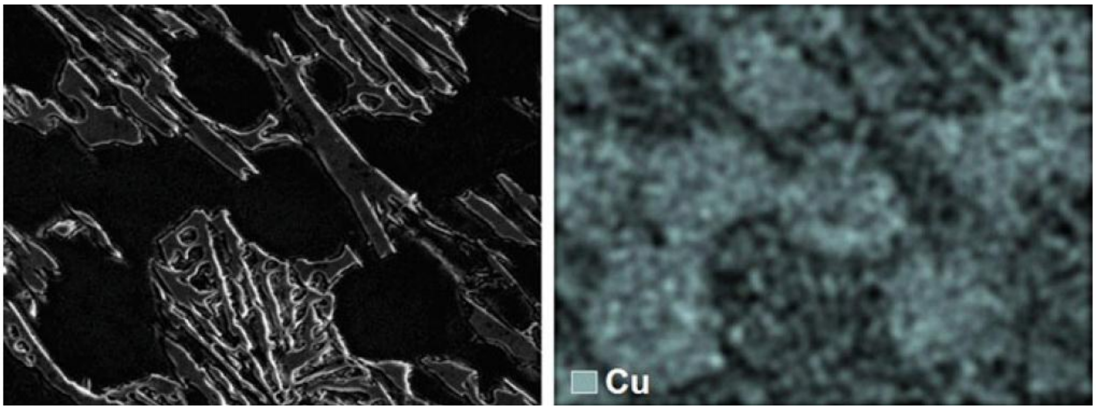


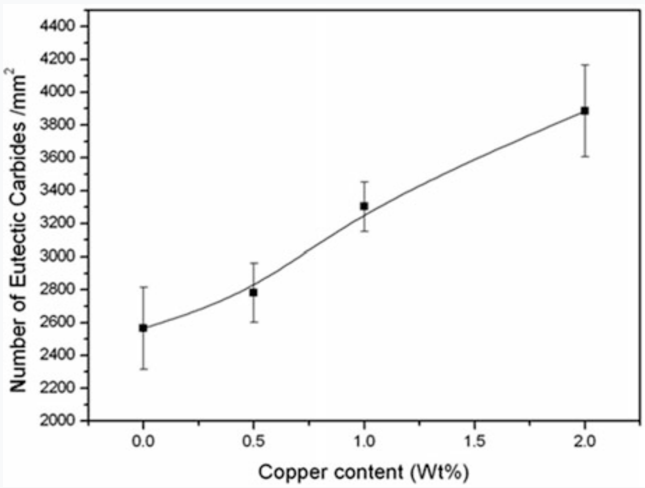
2 – picture. XRD image of D – alloy in casting conditions



3 – picture. The chemical composition of copper is shown through the SEM microscope.

Table 2. Eutectic Carbide Volume Fraction

Cu %	0	0,6	1,1	2,1
ECV frac.	26,5%	27%	27,5%	26,5%



4 – picture. Copper content as a function of eutectic carbides/mm^2

There is no significant difference in volume fraction of eutectic carbide, but there is a different distribution. Figure 4 shows eutectic carbides by number of square millimeters.

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4 – as shown in the figure, with the addition of copper, the number of carbides/mm2 increases, but the size remains almost constant; it is more likely to be considered a continuous eutectic carbide.

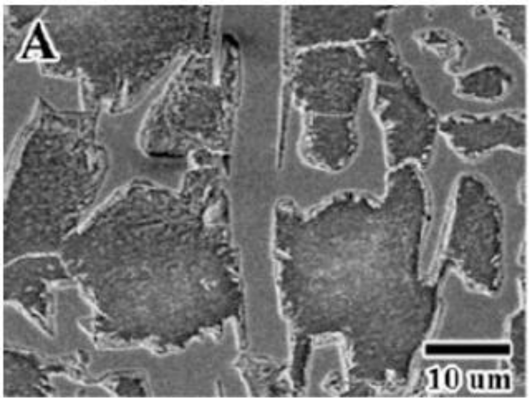
The information given above is based on the observations of many researchers and others, who have studied the effect of copper in ductile white cast iron.

Stabilized structure after heat treatment

Heat treatment changes the volume of phases, increases the volume of carbide and separates martensite from austenite during cooling, over-stabilization of the austenite phase is shown after treatment at 850^0 C. The number and size of precipitated carbides are functions of temperature, time, and chemical composition.

Number and average diameter of secondary carbides

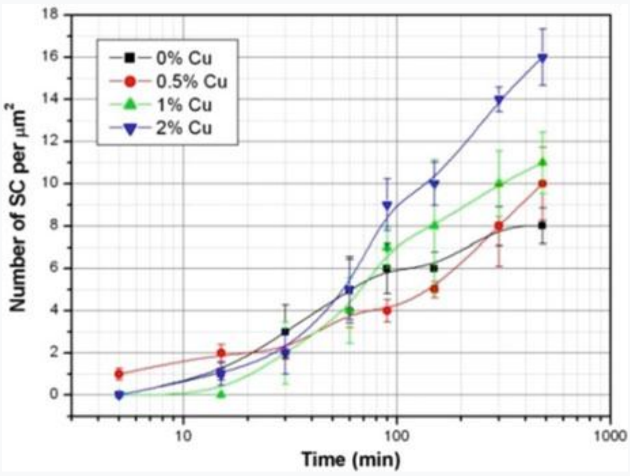
Figure 5 shows the microstructure of ductile white cast iron with 1% copper added and heat treated at 850^0 C for 15 minutes.



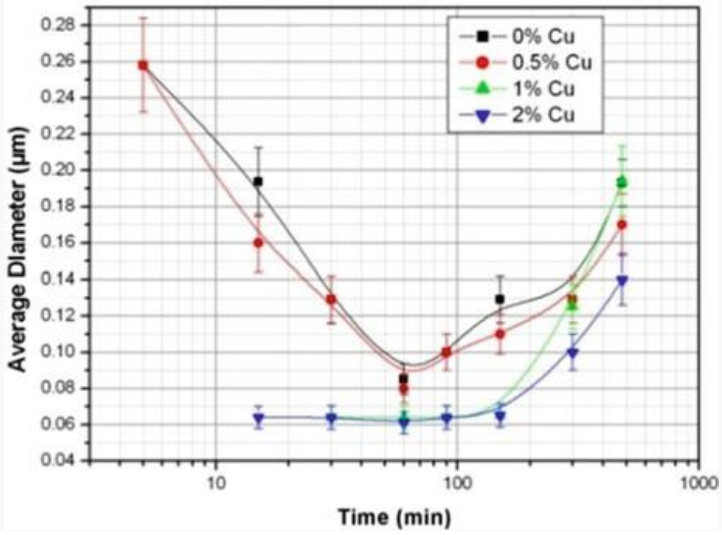
5 – picture. SEM shows the microstructure of iron with 1% copper added and heat treated at 850^0C for 15 minutes

In pictures 6 – 7, small particles can be seen when copper is added to the alloy. We can also see small diameter residual carbides with high copper content. Figure 6 shows residual carbides with low copper content after short – term processing. But most of the particles there are 0.20 – 0.25 mm in diameter.

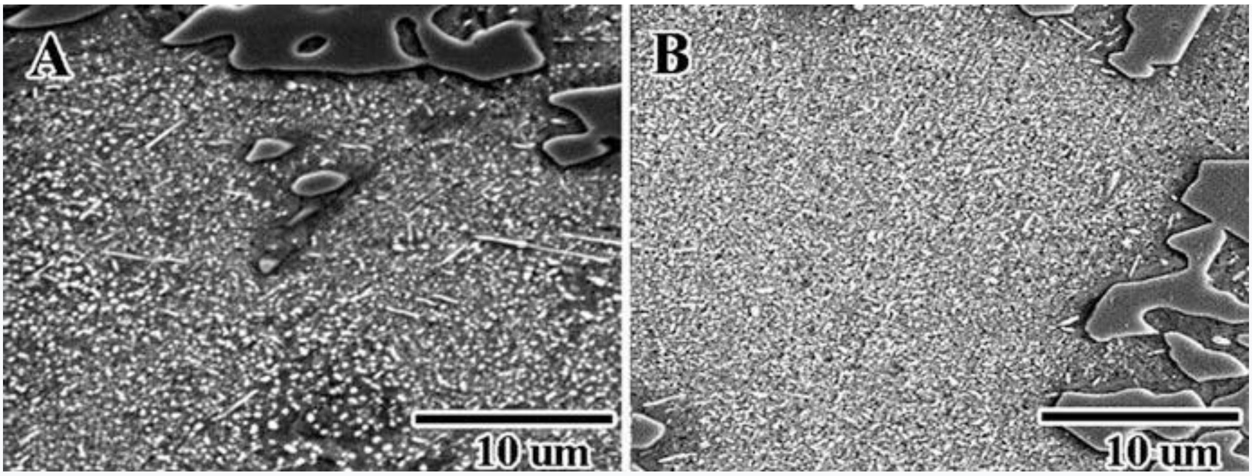
The best result is when 1 – 2 % copper is added to the alloy and held for 15 minutes, the diameter of the residual carbides is very small, about 0.06 mm.



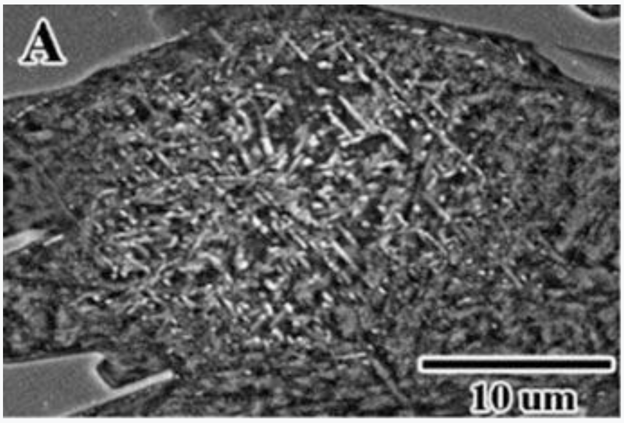
6 – picture. Number of precipitated carbides as a function of soaking time at 850^0 C



7 – picture. Average diameter of SEC. Carbides as a function of soaking time at 850^0 C



8 – picture. SEM micrographs showing secondary carbide precipitation during destabilization heat treatment at 850 ıC. (a) Base alloy, (b) 2 wt% of copper alloyed white iron



9 – picture. SEM micrographs of the alloy with 1% of copper heat treated for 15 min at 850^0

Conclusion

Copper additions caused continuous eutectic carbide transformation in the as-cast state. After heat treatment, an increase in the number of residual particles was observed during low temperature treatment. When processed at 850^0 C, the diameter of the secondary carbides and their uniform distribution were observed. A stabilization fraction of secondary carbides was observed at lower temperatures and with longer retention. As the temperature increased, the volume content of austenite also increased. During the heat treatment of ductile white cast iron, the austenite phase moderated and slowly precipitated carbides; moreover, melting of eutectic carbides was observed if it was held for a long time. The change in microhardness with the change in heat treatment resulted in the reduction of secondary carbides and the transformation of austenite to martensite.

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