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Araştırma Makalesi Research Article

HEAT TREATMENT EFFECT ON SPHEROIDAL GRAPHITE, MICROSTRUCTURE AND MECHANICAL PROPERTIES OF NI-RESIST DUCTILE CAST IRON

Selçuk Yeşiltepe[1*], M. Kelami Şeşen[1]

[1]Metallurgical and Materials Engineering Department, Chemical Metallurgical Faculty, Istanbul Technical University

Keywords

Spheroidal Cast Iron,
Heat Treatment,
High Temperature Behaviour

Abstract

In this study high temperature behaviour of graphite nodules are investigated. Spheroidal Ni-Resist cast iron is used for specimen preparation. Prepared specimens are placed in furnace at set temperature, 900 and 1000 ^{o}C respectively. Time parameters were 1, 2 and 4 hours. In order to investigate cooling rate, specimens treated with same temperature and annealing time cooled with different cooling speeds; air cool and water quench. Metallographic and hardness tests are conducted to measure the effect of heat treatment. Results showed that carbon from graphite nodules are diffused in to ferritic matrix and formed pearlitic microstructure. At 900 ^{o}C, air cooled specimens have less pearlite than water quenched specimens in microstructure. Reverse diffusion declined pearlite rate in microstructure. On the other hand 1000 ^{o}C specimens completely transformed pearlite for air cooled specimens, martensite for water quenched specimens. As conclusion, diffusion rate and austenite carbon solution at 900 and 1000 ^{o}C effects graphite nodule behaviour.

KOROZYANA DAYANIKLI NI ALAŞIMLI SÜNEK DÖKME DEMIRLERDE ISIL İŞLEMIN KÜRESEL GRAFIT, MIKROYAPI VE MEKANIK ÖZELLIKLERE ETKISI

Anahtar Kelimeler

Küresel Grafitli Dökme Demir,
Isıl İşlem,
Yüksek Sıcaklık Davranışı

Özet

Bu araştırmada grafit kürelerin yüksek sıcaklık davranışı araştırılmıştır. Çalışmada nikel alaşımlı korozyona dayanıklı küresel grafitli dökme demir kullanılmıştır. Hazırlanan numuneler 900 ve 1000 ^{o}C sıcaklığındaki fırına yerleştirilmiştir. Zaman değişkeni 1,2 ve 4 saat olarak belirlenmiştir. Soğuma hızının etkisinin ölçülebilmesi için aynı sıcaklık ve sürede işlem gören numuneler farklı soğuma hızlarında, havada ve su verilerek soğutulmuşlardır. Isıl işlemin etkilerinin ölçülmesi amacıyla metalografik ve sertlik ölçümleri gerçekleştirilmiştir. Sonuçlar karbonun grafit kürelerden ferritik matrise difüze olarak perlitik mikro yapı oluşturduğunu göstermiştir. 900 ^{o}C'de havada soğutulmuş numuneler su verilmiş numunelerden daha az perlit içermektedir. Ters difüzyon mekanizması mikro yapıda perlit oranını düşürmüştür. Diğer yandan 1000 ^{o}C sıcaklığında ısıl işlem gören numunelerde mikro yapı havada soğumuş numuneler için tamamen perlite dönüşmüş, su verilmiş numuneler ise martenzitik yapıdadır. Sonuç olarak difüzyon hızı ve östenitin 900 ve 1000 ^{o}C sıcaklıkları için karbon çözünürlüğünün grafit kürelerin davranışına etki ettiği ortaya çıkmıştır.

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Yazar Kimliği / Author ID (ORCID Number)

Selçuk Yeşiltepe, 0000-0002-0982-3439
M. Kelami Şeşen, 0000-0002-8113-6289

[*] İlgili yazar / Corresponding author: yesiltepes@itu.edu.tr, +90-212-285-7061

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1. Introduction

Spheroidal cast iron is a popular engineering material since high ductility, good mechanical properties with economic advantages. Spheroidal cast iron also known as ductile cast iron hence the formation of brittle phase of cementite is prevented. Cementite is prevented via graphitization of carbon with magnesium or cerium graphite inoculants that trigger the formation of graphite nodules (Monchoux vd., 2000).

The most applied heat treatment of spheroidal cast iron is known as austempering process. Austempering process consists of austenizing of material followed by quenching in salt bath. Aim of the austempering process to obtain bainite microstructure. Quenching in salt bath prevents martensite formation (Hafız 2003; Novikov,2012).

Graphite behaviour at elevated temperatures is crucial for planning heat treatment conditions. Diffusion and globalization are effective mechanisms to determine graphite nodule behaviour. Graphite nodules are completely carbon except inoculant material. Surface of nodules are in contact with low carbon iron matrix. Diffusion is expected for both phase; carbon in nodules and iron in matrix would be activated with increasing temperature. On the other hand globalization mechanism that triggers spheroid shaped nodule formation prevents nodules from fall apart (Monchoux vd., 2001).

Spheroidal cast irons have different chemical compositions. Main concept of the material is spheroid shaped graphite nodules distributed among the matrix. Chemical composition of spheroidal cast iron has many different variations. One of the variations of spheroidal cast iron is Ni-Resist spheroidal cast iron which is typical ductile cast iron with nickel alloy. Ni-Resist spheroidal cast iron is used in applications where corrosion resistance is important. Ni percentage of used cast irons is up to 37% weight (URL 1, 2016).

Ni-Resist ductile cast iron is used for this study. Chemical composition and metallographic properties of starting material is determined. Experimental procedures, tests and results are given in this paper.

2. Material and Method

Chemical composition of spheroidal cast iron is determined by optical spectroscopy. Chemical composition of material is given in Table 1. Hardness test is done with manual Brinell Hardness equipment.

Metallographic sample is grinded with automatic grinding/polishing equipment. Sample is polished with 3 micron alumina paste then etching done with 2% Nital solution. Metallographic image of material is given in Figure 1.

Table 1. Chemical Composition of Specimen

Element	% weight
C	3.65
Si	2.62
Mn	0.52
P	0.062
S	0.051
Mg	0.046
Cr	0.008
Ni	2.12
Cu	0.047

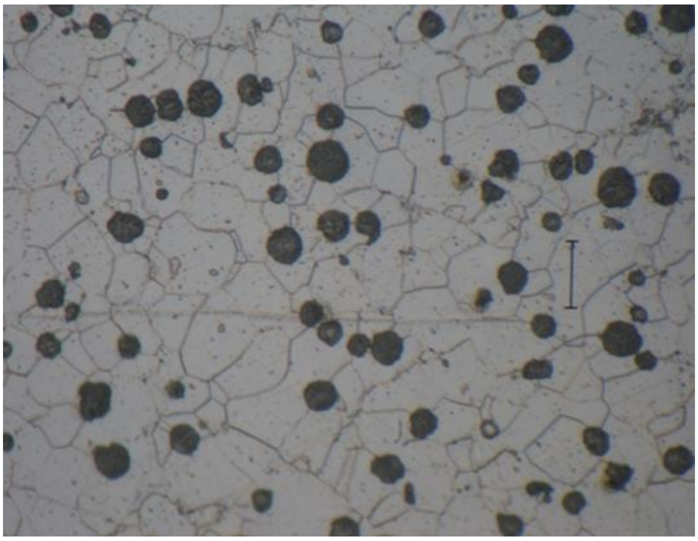

Figure 1. Original microstructure (Scale 20 micron)

Experiments are done with electric resistance laboratory scale furnace. Temperature for study is decided as 900 and 1000 oC which are above the austenizing temperature. Samples are placed in the furnace at the set temperature for 1, 2 and 4 hours. One set of samples are air cooled, other set is quenched in water in order to investigate effect of cooling rate.

3. Results

Metallographic imaging is done with Olympus polarized light microscope. All samples are imaged at 2000x magnification with 10 micron scale length. Hardness tests are performed with manual Brinell Hardness Test Machine. Hardness tests are performed with 3000 kg load for 10 seconds using a 10 mm steel ball as penetrator.

Metallographic images for 900 ^{o}C are given at Figure 2. Pearlite phase is dominant for quenched 900 ^{o}C samples. Air cooled samples of 900 ^{o}C annealing temperature are ferritic with pearlite regions. Pearlitic regions are increased from 1 to 2 hour annealing time. Decrease in pearlite phase can be seen on 4 hours sample. Quenched samples are more pearlitic than air cooled samples which have ferritic dominant microstructure. Thus with slower cooling rate carbon is tend to diffuse back to nodule.

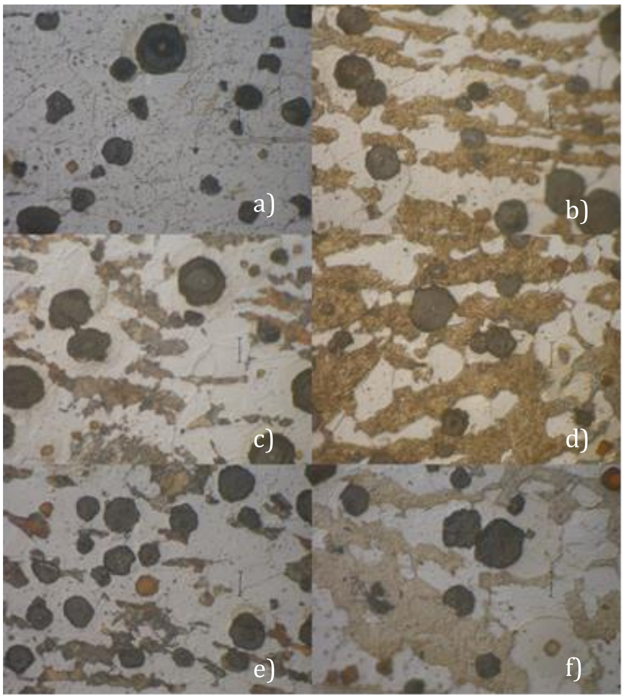

Figure 2. Metallographic photographs of 900 °C annealed samples. (a and c and e air cooled samples, annealing time 1, 2 and 4 hours respectively; b and d and f quenched samples annealing time 1, 2 and 4 hours respectively)

Hardness test results are supporting metallographic observations. Pearlitic microstructure has more hard nature than ferritic structures. Hardness results for air cooled and quenched samples for 900 °C are given in Table 2.

Table 2. Brinell hardness test results for 900 °C annealed samples.

Annealing Time	Hardness, HB	
	Air Cooled	Quenched
1 hour	172 (±1 HB)	322 (±3 HB)
2 hours	208 (±2 HB)	383 (±3 HB)
4 hours	197 (±2 HB)	317 (±3 HB)
Original	152 (±1 HB)	

Metallographic results for 1000 °C annealed samples are given in Figure 3. Quenched samples have martensitic microstructure which shows that diffusion rate at 1000 °C sufficient enough to form martensite with water quenching. Air cooled samples have pearlitic microstructure. 1 hour annealed sample has ferrite envelope around the graphite nodules while 2 and 4 hours samples are completely pearlitic.

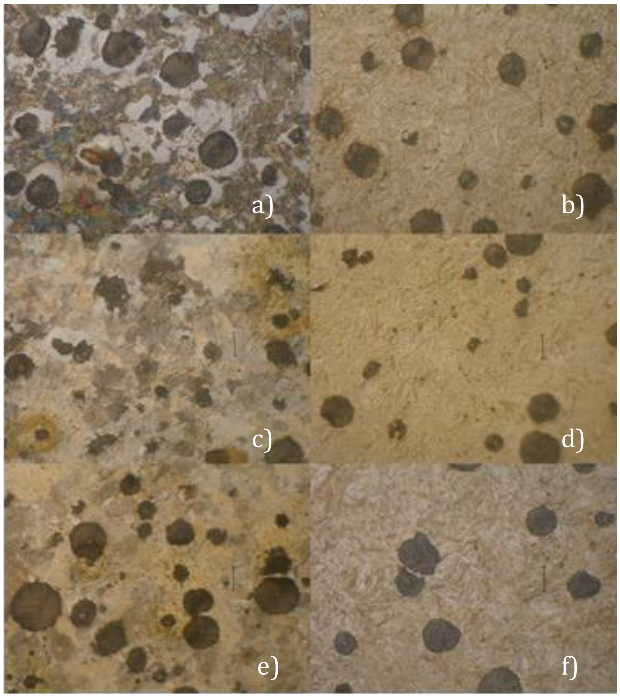

Figure 3. Metallographic photographs of 1000 °C annealed samples. (a and c and e air cooled samples, annealing time 1,2 and 4 hours respectively; b and d and f quenched samples annealing time 1,2 and 4 hours respectively)

Hardness test results of 1000 °C samples are given in Table 3. Air cooled samples have higher hardness than 900 °C samples since microstructure is pearlitic. Quenched samples have completely martensite microstructure since diffusion rate is high enough at 1000 °C to saturate matrix to carbon.

Table 3. Brinell hardness results for 1000 °C annealed samples.

Annealing Time	Hardness, HB	
	Air Cooled	Quenched
1 hour	236 (±2 HB)	649 (±3 HB)
2 hours	268 (±2 HB)	680 (±4 HB)
4 hours	262 (±2 HB)	602 (±3 HB)
Original	152 (±1 HB)	

Samples annealed at 900 °C showed ferritic – pearlitic microstructure for both air cooled and quenched samples, while at 1000 °C air cooled samples have ferritic- pearlitic microstructure though quenched samples have martensitic microstructure. Both annealing temperature and cooling rate did not result in bainite formation. Spheroidal graphite cast iron which is used in this study contains 2.12 % Nickel. Presence of nickel increases the transformation time of phases. That is also can be explain with shift of pearlite nose to the right in TTT diagrams. Thus martensite formation is easier for nickel alloyed spheroidal graphite cast irons than unalloyed. Therefore bainite formation for nickel alloyed cast irons is not expected with quenching or air cooling.

4. Results and Discussion

Results showed that annealing time, temperature and cooling rate are important parameters for ductile cast iron heat treatment. Annealing time and temperature directly linked to carbon diffusion amount. Samples have ferritic microstructure, which is the phase for low carbon containing iron – carbon alloys. Microstructure change is related to carbon diffusion amount. Carbon diffusion increases up to 2 hours annealing time. Pearlite amount increases parallel to carbon amount. Matrix saturates to carbon after 2 hour annealing time for both 900 and 1000 ^{o}C annealing temperatures. Decrease in pearlite phase and hardness values confirms that result. After saturation of matrix carbon diffuse reverse to nodules via globalization effect as a result of equilibrium between these reactions.

Annealing temperature plays crucial role for graphite nodule behavior. Carbon diffusion amount is directly depends on temperature. At 1000 ^{o}C all quenched samples transformed to martensite while 900 ^{o}C samples have pearlitic – ferritic microstructure. Formation of martensite depends on carbon amount and cooling rate. Since the cooling rate and quenching media is same for both annealing temperature it can be said increasing temperature increases diffusion rate. Carbon diffuses from graphite nodule and changes ferritic microstructure of matrix to pearlite or martensite in case of quenching.

Cooling rate is important to understand high temperature reactions. Quenching preserves high temperature microstructure. Quenched and air cooled samples indicated that at high temperature carbon diffuse into matrix and at low cooling speeds carbon tends to accumulate in graphite nodule which confirmed by pearlite phase declined in air cooled samples. Nickel alloying increases transformation time and favor martensite formation. Bainitic microstructure did not occur with quenching in presence of nickel alloying. Quenched samples of 900 ^{o}C have more pearlitic area than air cooled samples. This is a result of equilibrium between carbon diffusion from graphite to matrix and globalization effect of graphite accumulation in the nodule.

Conflict of Interest / Çıkar Çatışması

Yazarlar tarafından herhangi bir çıkar çatışması beyan edilmemiştir.
No conflict of interest was declared by the authors.

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