Araştırma Makalesi
Adıyaman Üniversitesi Mühendislik Bilimleri Dergisi
22 (2024) 165-171

EVALUATION OF AUSTEMPERING STUDY OF FERRITIC CAST IRON

Tanju TEKER[1*], S. Osman YILMAZ[2]

[1]Sivas Cumhuriyet Üniversitesi, Teknoloji Fakültesi, İmalat Mühendisliği Bölümü, Sivas, 58140, Türkiye
[2]Namık Kemal Üniversitesi, Mühendislik Fakültesi, Makine Mühendisliği Bölümü, Çorlu, Tekirdağ, 59160, Türkiye
Geliş Tarihi/Received Date: 16.02.2024 Kabul Tarihi/Accepted Date: 26.03.2024 DOI: 10.54365/adyumbd.1438508

ABSTRACT

This study analyzed the effect of austempering temperatures on the structural characterization of ferritic spheroid cast irons. Austempering is the austenitization of the materials at 900 ºC for an adequate period to obtain a complete austenitic structure and then quenching to an interval temperature for precipitation of ausferrite. Subcritical diffusion time was achieved as 1.5 h for 320, 420, and 520 ºC ausferrite temperatures. Metallurgical description of samples was defined using optical microscopy, energy dispersive spectrometry, X-ray diffraction and microhardness. The austempering temperature had a remarkable effect on the phase variations of the ferritic ductile cast irons. The higher degree of austempering produced a coarser structure called ausferrite.
Anahtar Kelimeler: *Austempering, Microstructure, Ausferrite, Hardness.*

FERRİTİK DÖKME DEMİRİN ÖSTEMPERLEME ÇALIŞMASININ DEĞERLENDİRİLMESİ

ÖZET

Bu çalışmada, ferritik sfero dökme demirlerin yapısal karakterizasyonuna östemperleme sıcaklıklarının etkisi analiz edilmiştir. Östemperleme, tam bir östenit yapı elde etmek için malzemelerin 900 ºC sıcaklıkta yeterli bir süre östenitlenmesi ve ardından bir aralık sıcaklığında su vermedir. Östemperleme 320, 420 ve 520 ºC' de 1.5 saat süreyle elde edilmiştir. Numunelerin metalurjik karakterizasyonu, optik mikroskop, enerji dağılımlı spektrometri, X-ışını kırınımı, mikrosertlik kullanılarak belirlendi. Östemperleme sıcaklığı, ferritik sfero dökme demirlerin faz değişimleri üzerinde dikkate değer bir etkiye sahipti. Daha yüksek derecede östemperleme, ausferrit adı verilen daha kaba bir yapı üretti.
Keywords: *Östemperleme, Mikroyapı, Ausferrite, Sertlik.*

1. Introduction

Ferritic ductile cast iron (FDCI) consists of a ferritic matrix and a spheroidal graphite microstructure. After heat treatment, ausferrite, acicular ferrite and bainite can be observed in the structure [1-3]. The matrix with graphite is intended to create an ausferrite structure by isothermal heat treatments. FDCI has superiority such as lower density and cost, lubrication properties, high elongation and toughness [4,5]. Austempering is a method that produces austenite base structure in DCI. The

[*1] e-posta: tanjuteker@cumhuriyet.edu.tr ORCID ID: https://orcid.org/0000-0001-7293-0723 (Sorumlu Yazar)
[2] e-posta : oyilmaz@nku.edu.tr ORCID ID: https://orcid.org/0000-0001-7593-6135

method is a two-step process. The first stage is austenitization for 1 to 4 h in the temperature level of 815–920 ˚C. It is then quickly quenched in a salt bath. The casting is held isothermally at the detected isothermal annealing temperature in the salt bath. Depending on the desired properties of the casting, the austenite annealing temperature range is 230–450 ˚C. At higher austempering values, the ferrite nucleates and transforms into austenite [6-8]. A less isothermal annealing temperature will produce a finer, larger ferrite rate and higher yield rate. Austempering time and degree are effective in the occur of ausferrite structure. A higher degree of austempering produces a smaller proportion of coarse ferrite [9-10]. Mandal et al. [11] reported the impress of austempering on the strength values of high-Si cast material. Austempering significantly improved the strength and ductility of the casting.

The aim of this research is to detect the impress of austempering temperatures on the structural characterization of Ce inoculated ferritic ductile cast irons.

2. Material ve Method

The chemical values of the samples included in the study was 3.10%C, Bal.%Fe, 4.30%Si, 0.24%Mn, 0.020%Cr, 0.12%Ce, 0.02%S, 0.025%P (wt.-%). Melting was done in a 300 kg induction furnace using steel scrap. Alloying elements were melted in an induction furnace at 1510 °C. The melt was transferred to the casting ladle at 1460 °C. The austempering parameters of test samples are presented in Table 1. In the first stage, the samples were austenitized at 900 °C for 1.5 h. Then, it was immersed in a salt bath for austempering and kept at this temperature for 1.5 h. Then the samples were cooled to room temperature. Austempering was applied at temperatures of 320, 420 and 520 °C. For metallographic studies, samples were sanded using 80-1200 mesh emery paper and polished a 2 µm diamond solution. After etching with 2% nital solution, it was examined by optical microscopy (OM), energy distribution spectrometry (EDS). Phase contents were identified by Bruker brand X-ray diffraction (XRD) in Cu-Kα radiation. Microhardness results was detected using a 100 g load at 0.5 mm intervals on the Qness Q10 microhardness machine.

Table 1. The austempering parameters of test samples.

No	Destabilization Temperature	Destabilization Time	Subcritical Diffusion Temperature	Subcritical Diffusion Time	Quenching
S-Ref.	As-Cast	-	-	-	-
S1	900 ºC	1.5h	320	1.5h	Air
S3	900 ºC	1.5h	420	1.5h	Air
S4	900 ºC	1.5h	520	1.5h	Air

3. Experimental results

3.1 Evaluation of microstructure

Fig. 1 shows OM micrographs of S-Ref, S1, S2, S3 specimens austenitized at 900 ºC and austempered at 320, 420 and 520 °C. The ADI structure consisted of pearlite, graphite and ferrite. The microstructure of the austempered sample contained acicular dark ferrite and ausferrite. When the subcritical phase transformation temperature was low as 320 °C, the ferrite layers were unevenly oriented and thin. As the subcritical temperature increased from 320 °C to 420 °C, bainitic ferrite laths grew up. Austenite was sandwiched between adjacent ferrites. A thickness rich in austenite and carbon was obtained. In the first step of the transformation, ferrite nucleated at austenite grain boundaries and separated into plates or laths before transforming into carbon austenite. Therefore, ferrite and ausferrite

emerged in the structure of the samples. The ausferrite formed in the first stage of the transformation had upper lateral growth, and the surrounding ferrite contained less carbon. The EDS values of the casting sample is displayed in Fig. 2. C, Fe, Ce, Si, Mn, S were the main elements of the casting sample. The white particles in Fig. 2 show that the primary precipitates are Ce_2O_2S with heterogeneous nuclei. Ce_2O_2S inclusions produced thinner primary ausferrites. It provided heterogeneous nucleation of ausferrrites [12].

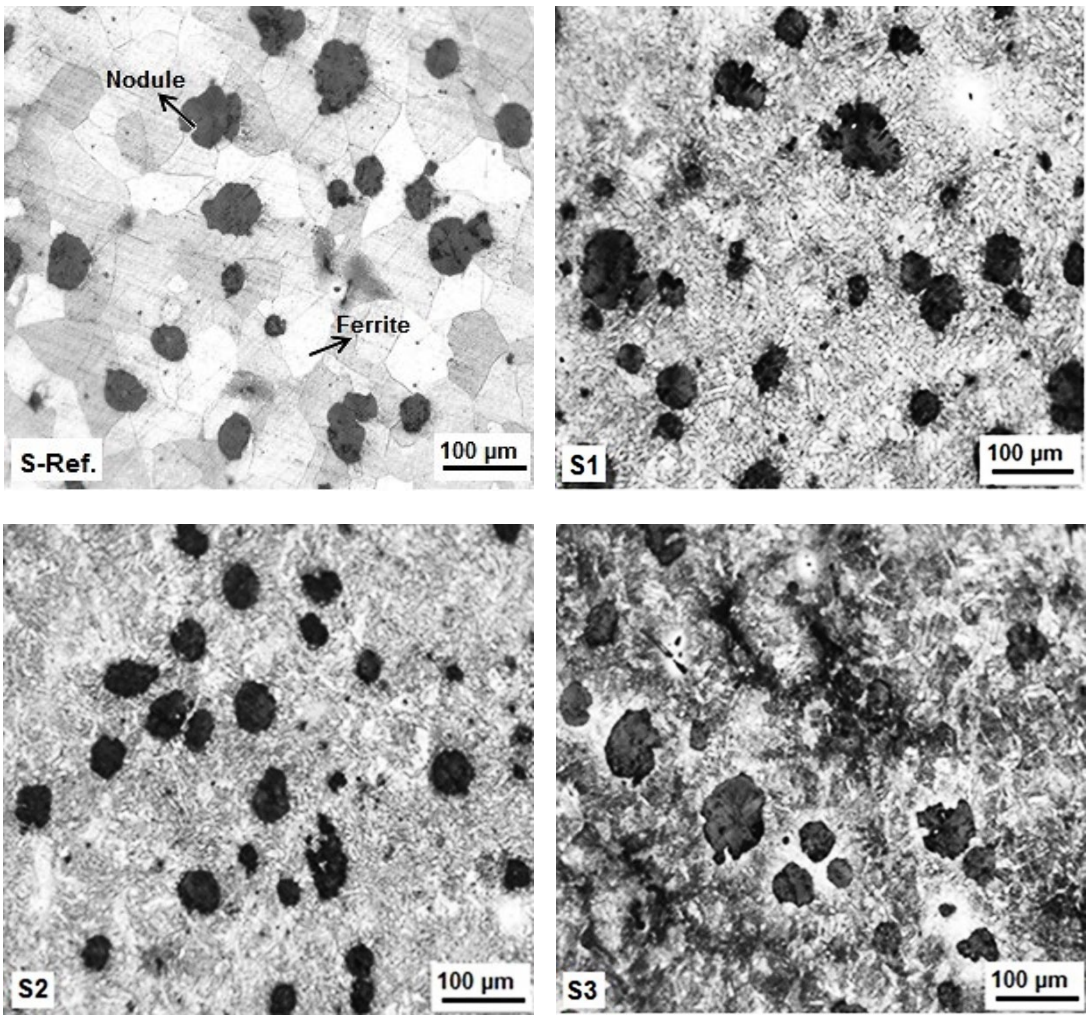

Figure 1. Optical micrographs of austempered samples at 320, 420, 520 ˚C at 1.5 h.

The silicon content in the produced ductile iron castings is desired in the range of 2.45-2.80%. It was sufficient to prevent melt cooling and at the same time facilitate the production of sufficient nodules [13]. The excessive silicon contained in the ferritic iron suppressed cementite precipitation during the austempering and retained a significant amount of stable high-carbon austenite.

Austenite and ferrite gradually coarsened as the austempering degree increased. Very slim ferrite and austenite were obtained at the lower austempering temperature. On the other hand, rough and hairy ferrite characteristics of upper bainite were obtained at higher austempering degrees. As austempering progresses, these ferrite needles increase larger and as a result the remaining austenite absorbs carbon, thereby increasing the carbon intensity of the austenite [14,15]. At higher temperatures, decomposition of austenite to ferrite occurred due to the free energy diversity. At higher temperature, austenite was precipitated by spread of carbon into existing graphite nodules along grain boundaries. At high subcritical diffusion temperatures, the ferrite structure nucleated and transformed

into ausferrite. At higher subcritical diffusion temperatures such as 420–520 °C, the rate of ausferrite incremented. At 520 °C, large areas of austenite separated from each other and coarse ferrite formed. The increasing the subcritical diffusion temperature leaded the ausferrite spicules to thicken and the ferrite velocity to increase. Average lath and ausferrite lengths were the same [16, 17]. It produced finer and larger volume ferrite fractions at lower critical diffusion temperatures. The X-ray patterns of the produced ferritic ductile iron are presented in Fig. 3. The base phases created in the samples were ferrite (α), ausferrite, graphite.

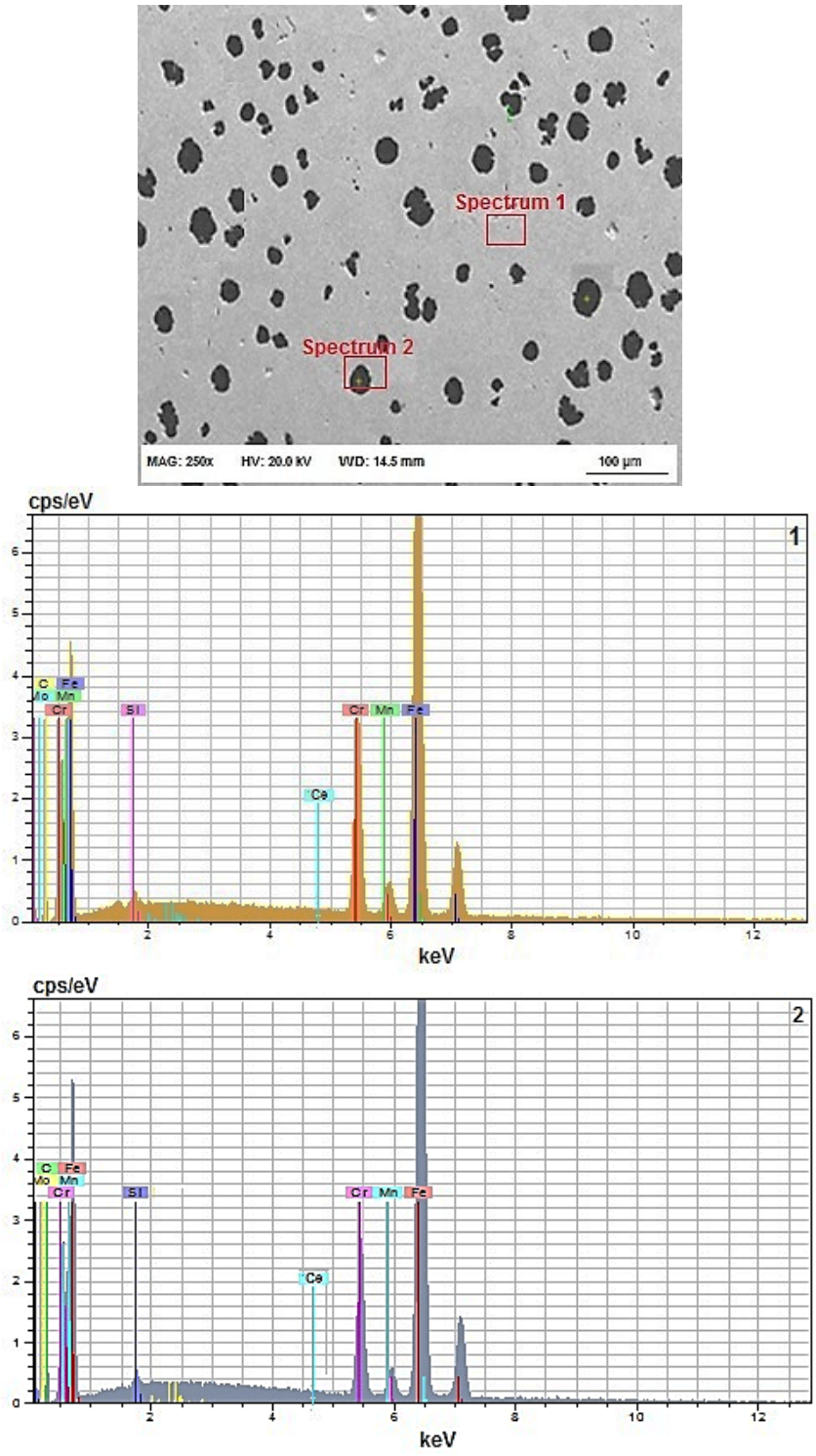

Figure 2. EDS analysis of S-Ref sample.

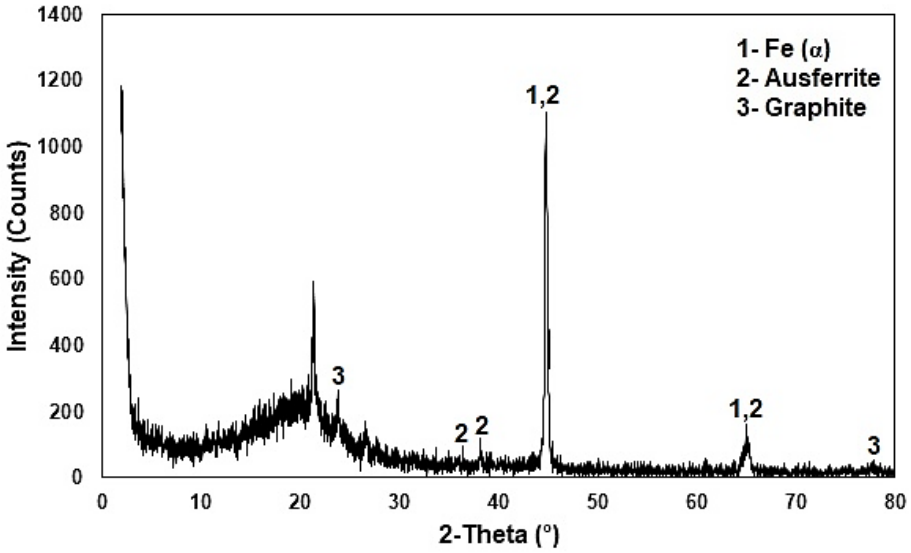

Figure 3. XRD results of S3 sample.

3.2. Hardness

The effect of austenitizing temperature on the hardnes is shown in Fig. 4. The hardness increased as the subcritical diffusion temperature decreased. Fine ausferrite created at low subcritical diffusion temperatures had higher hardness. The hardness of ausferrite appeared at higher temperatures was lower. As the isothermal annealing temperature increased, the extent and interval of austenite became more favorable for the transformation of austenite to martensite. Austenite was a softer structure and increasing austenite ratio reduced the hardness. In addition, grain coarsening caused a decrease in hardness [18-20].

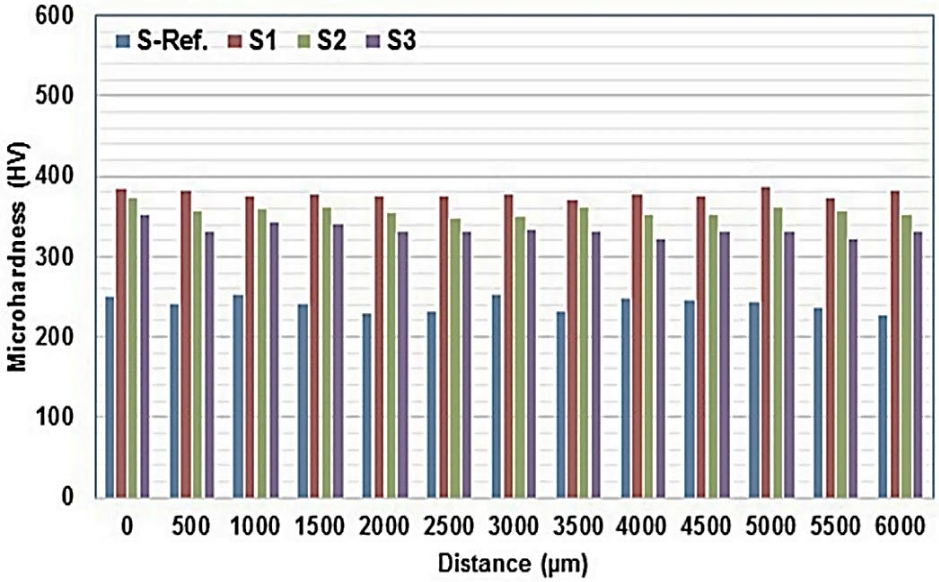

Figure 4. The hardness amounts of as-cast and austempered samples.

4. Conclusion

The results obtained are as follows:
The austempering degree had a remarkable action on the phase variations of the ferritic cast irons.
The higher degree of austempering produced a coarser structure called ausferrite.
Finer and larger bulk ferrite were obtained at the lower austempering temperature.
Hardness raised from 240 HV to 360-380 HV by austempering heat treatment. But, it declined due to the coarser ausferritic appeared with increasing austempering temperature.
The phases created in the samples were ferrite (α), ausferrite, graphite**.**

Acknowledgment

The authors were grateful to Kayalar Copper Industry and Trade Incorporated Company for their assistance in conducting the experiments.

Disclosure statement

No potential conflict of interest was reported by the authors.

References

[1] Chang LC. Carbon content of austenite in austempered ductile iron. Scripta Materialia 1998; 39: 35–38.
[2] Ławrynowicz Z, Dymski S. Mechanism of bainite transformation in ductile iron ADI. Archives of Foundry Engineering 2006; 6: 171–176.
[3] Szykowny T. Isothermal eutectoidal transformation in ductile cast iron EN-GJS-500-7. Archives of Foundry 2005; 5: 303–312.
[4] Dymski S, Giętka T. Influence of gradual austenitizing on chosen properties of ADI. Archives of Foundry Engineering 2008; 8: 185–190.
[5] Giętka T, Dymski S. Predicting ADI mechanical properties. Archives of Foundry Engineering 2009; 9: 267–274.
[6] Nofal AA. Advances in the metallurgy and applications of ADI. Journal of Metallurgical Engineering 2013; 2: 1–18.
[7] Jianghuai Y, Putatunda SK. Influence of a novel two-step austempering process on the strain-hardening behaviour of austempered ductile cast iron (ADI). Materials Science and Engineering A 2004; 382: 265–279.
[8] Kiani-Rashid AR. Influence of austenitising conditions and aluminium content on microstructure and properties of ductile irons. Journal of Alloys and Compounds 2009; 470: 323–327.
[9] Sidjanin L, Rajnovic D, Eric O, Smallma RE. Austempering study of unalloyed and alloyed ductile irons. Materials Science and Technology 2010; 26: 567–571.
[10] Ramadan M, Fathy N. Influence of semi-solid isothermal heat treatment on microstructure and mechanical properties of ductile cast iron. Journal Minerals and Materials Characterization Engineering 2014; 2: 26–31.
[11] Mandal D, Ghosh M, Pal J, De PK, Ghosh Chowdhury S, Das SK, Das G. Effect of austempering treatment on microstructure and mechanical properties of high-Si steel. Journal of Materials Science 2009; 44: 1069–1075.
[12] Ochulor EF, Adeosun SO, Amuda MOH, Balogun SA. Strength characteristics of inoculated and nodularized thin wall ductile iron castings. Journal Minerals and Materials Characterization Engineering 2015; 3: 94–105.
[13] Qu Y, Xing J, Zhi X, Peng J, Fu H. Effect of cerium on the as-cast microstructure of a hypereutectic high chromium cast iron. Materials Letters 2008; 62: 3024–3027.

[14] Aranzabal J, Serramoglia G, Rousiere D. Development of a new mixed (ferritic-ausferritic) ductile iron for automotive suspension parts. International Journal of Cast Metals Research 2003; 16: 185–190.
[15] Rao PP, Putatunda SK. Comparative study of fracture toughness of austempered ductile ırons with upper and lower ausferrite microstructures. Materials Science and Technology 1998; 14: 1257–1265.
[16] Rao PP, Putatunda SK. Dependence of fracture toughness of austempered ductile ıron on austempering temperature. Metallurgical Materials Transactions A 1998; 29: 3005–3016.
[17] Erdogan M, Kilicli V, Demir B. Transformation characteristics of ductile iron austempered from intercritical austenitizing temperature ranges. Journal of Materials Science 2009; 44: 1394–1403.
[18] Yang J, Putatunda SK. Improvement in strength and toughness of austempered ductile cast iron by a novel two-step austempering process. Materials and Design 2004; 25: 219–230
[19] Benam AS. Effect of alloying elements on austempered ductile iron (ADI) properties and its process: Review. China Foundry 2015; 12: 54–70.
[20] Erdogan M, Kilicli V, Demir B. The influence of the austenite dispersion on phase transformation during the austempering of ductile cast iron having a dual matrix structure. International Journal of Materials Research 2008; 99, 751–760.