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INFLUENCE OF ELEVATED TEMPERATURE ON MICROSTRUCTURE TRANSFORMATION OF AUSTEMPERED DUCTILE IRON

Hasan Avdusinovic, Almaida Gigovic-Gekic
University of Zenica, Faculty of Metallurgy and Technology
Zenica
Bosnia and Herzegovina

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ABSTRACT
Austempered Ductile Iron (ADI) is a class of Ductile Iron family, obtained by heat treatment process. Ductile Iron samples are first austenitised to dissolve carbon, then quenched rapidly to the austempering temperature to avoid formation of deleterious pearlite. Resulting ausferrite microstructure consists of acicular ferrite embedded in stabile retained austenite. In case of application of the ADI casting on elevated temperatures transformation of the initial ausferrite microstructure is taking place. Influence of elevated temperature on ausferrite microstructure transformation is presented in this paper.

1. INTRODUCTION

If ductile iron is austenitized and quenched into a salt bath or any other type of hot bath at a constant temperature at the temperature interval from 260°C to 420°C and held at this temperature long enough, transformation of the initial austenite to ausferrite takes place. Cast irons that are transformed in this manner are referred to as austempered ductile irons (ADI). Transfering time from austenite temperature to salt bath must be fast enough to avoid pearlitic transformation in order to obtain desired ausferrite microstructure and, also, has to be performed above martensite start (M_s) temperature, [1, 2, 3].

Austempering results in a wide range of microstructures, depending on temperature of transformation bath and holding time at the transformation temperature. The properties are characterized by a very high strength, good ductility and toughness, and appreciably higher wear resistance than that of base material (ductile iron). This good/unusual combination of properties comes as a result of their unique microstructure (ausferrite microstructure). Ausferrite microstructure consists of ferrite and austenite (Figure 1). The exact shape of the ferrite phase and the relevant amounts of ferrite and austenite determine mechanical properties that can be controlled by the heat treatment parameters (temperature and time). Ferrite phase within ausferrite microstructure was usually named as acicular ferrite due to its needle-shaped form, [1, 2, 4]. Generally speaking, application of the ADI components is in the range from room temperature up to temperature of the second phase of the austempering heat treatment process (up to 200°C)

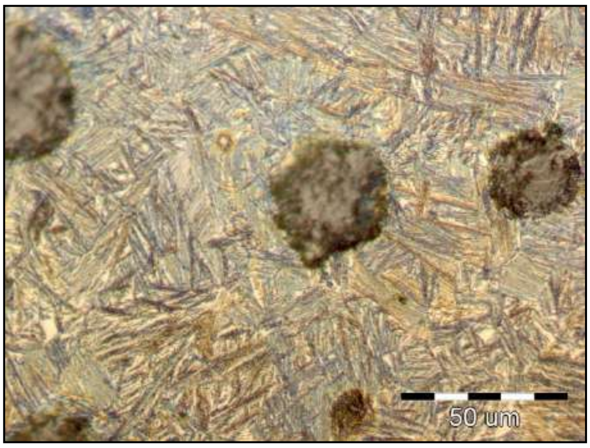


Figure 1. Ausferrite microstructure, Nital etched, 500X

It is already known that the austenite in the microstructure of ADI is stable to very low temperatures. However, if the ausferrite microstructure is exposed to elevated temperatures austenite can be transformed into ferrite and carbides, resulting in a gradual degradation of mechanical and ductile properties. The transformation of the initial ausferrite microstructure due to elevated temperature can be described with equation (1).

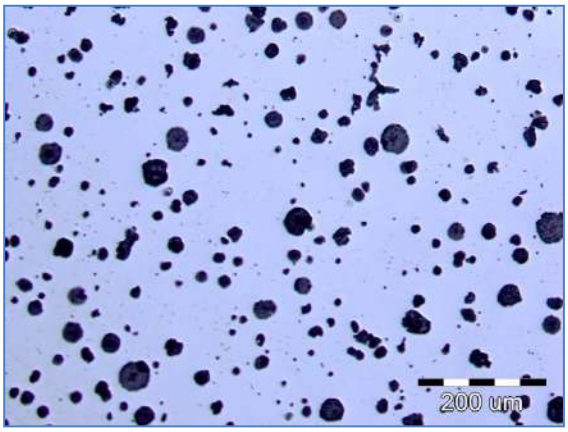
$$\gamma_{CS} = \alpha + Fe_3C \qquad (1)$$

In a study performed with dilatometer, Nadkarni and Gokhale observed volumetric changes associated to decomposition of the ausferritic microstructure, [5]. They reported the stable austenite transformation occurring in the range of 450-550°C. The aim of the investigation presented in this paper was to check microstructure changing due to decomposition of initial ausferrite microstructure.

2. EXPERIMENTAL PART

2.1. Material for investigation

Idea for the experimental part of this paper, as it has been stated in previous chapter, was to explain the influence of elevated working temperature on final microsture of austempered ductile iron. Initial material was non-alloyed ductile iron with perlitic-ferritic microstructure. Chemical composition of the ductile iron used in this experiment was C: 3.29 wt.%, Mn: 0.31%, Si: 2.53%, P: 0.015%, S: 0.013%, Cr: 0.053%, Ni: 0.81%, Cu: 0.51%, Mg: 0.031%, Mo: 0.002%, Ti: 0.004%, Sn: 0.006%, V: 0.003%, W: 0.004%. Starting material was cast in the U shape blocks and samples used in this investigation were prepared in shape of tensile test samples. Metallographic samples were cut from the samples after applied heat treatment process. All samples used in this work were initially austenitized using electric resistance furnace at 870°C for one hour followed by tempering in salt bath (KNO_3) at 350°C for one hour. For the initial ADI material preparation samples were heat treated as mentioned above. Microstructure of the base material after heat treatment is presented at the Figures 2 and 3.



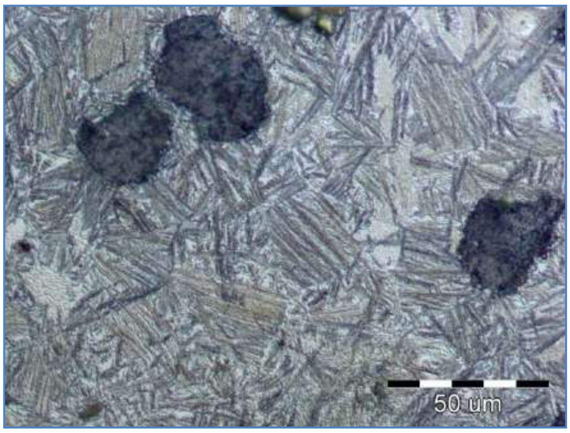


Figure 2. Austempered ductile iron microstructure Polisched condition, 100X

Figure 3. Austempered Ductile ironmicrostructure Nital Etched, 500X

2.2. Additional heat treatment of the ADI samples

In case of additional heat treatment of the ADI samples on the elevated temperature, according to the literature, decomposition of the ausferrite microstructure occurs. To identify ausferrite microstructure decomposition during reheating, six ADI samples were reheated up to the transformation temperature (Tt) and hold for 120 min then the samples were rapidly removed from the furnace and air cooled to room temperature. For the experiment six different reheating temperatures were preset, Figure 4. The suggested six elevated temperatures were result of the DTA testing of the investigated material which was part of one other research project.

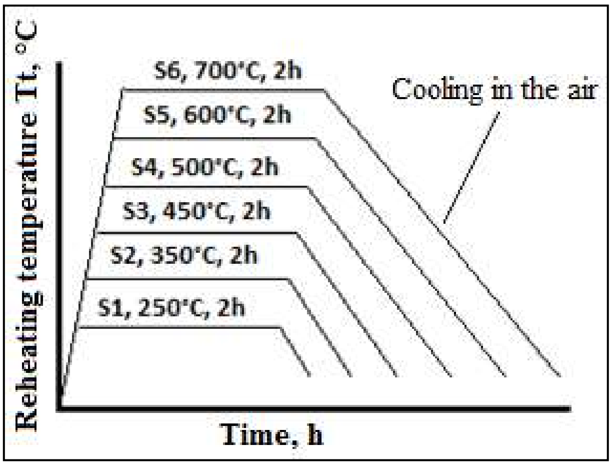


Figure 4. ADI samples reheating diagram

3. RESULTS AND DISCUSSION

3.1. Microstructure characterization of the ADI samples

After additional heat treatment of the ADI samples metallographic investigation were carried out. In the Figure 5 optical microscopy images of the microstructure of the used samples were presented.

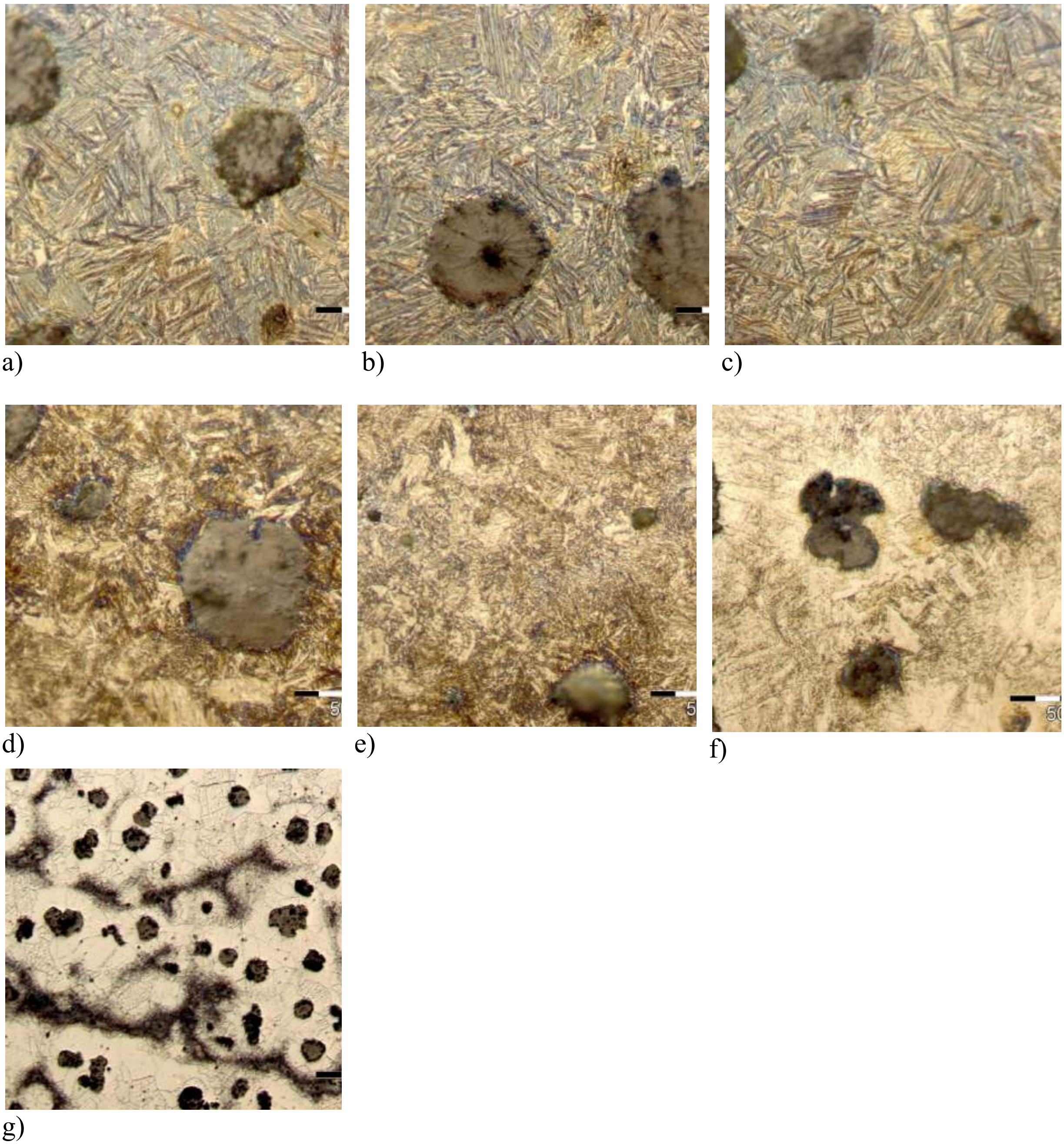


Figure 5. Microstructure of the ADI samples (Nital etched, 500X)
a) basic ADI sample, b) ADI sample reheated on 250°C, c) ADI sample reheated on 350°C, d) ADI sample reheated on 450°C, e) ADI sample reheated on 500°C, f) ADI sample reheated on 600°C, g) ADI sample reheated on 700°C.

4. DISCUSSIONS

After heat treatment of ductile iron, ADI samples with ausferrite microstructure were produced. Resulting ausferrite microstructure was characterized with uniform distribution of the needle shape ferrite phase within carbon saturated austenite phase. Additional reheating of the ADI samples at different temperature leads to ausferrite decomposition at the temperature region above 450°C, which is visible on Figure 5. With increasing reheating temperature transformation rate of carbon saturated austenite increases. Carbon saturated austenite (γCS) transforms to ferrite and iron carbide according to equation (1). At the temperature region near to eutectoid temperature graphitization (decomposition of the iron carbides) process occurs that can be observed on the Figure 5g.

5. CONCLUSIONS

The carried out investigation and analysis of the result of experiments on reheated ADI samples allow the following conclusions to be stated:

- The paths of decomposition of austempered ductile iron while reheating up to 700°C was recognized and summarized (Figure 5).
- The most intensive decomposition of the ausferrite microstructure was observed in the temperature region above 450°C.
- Near to eutectoid temperature (700°C) graphitization (decomposition of the iron carbides) process occurs and globular pearlite can be observed (Figure 5g).

6. LITERATURE

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