

On the structure of ausferrite in ductile iron

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Matrix of the heat treated ductile iron can be distinguished into several different types of ausferrite - mixture of austenite and bainitic ferrite. It may contain fine or feathery ferrite plates, mechanically unstable austenite grains, martensite, nanoausferrite, etc. Each of these structures will affect the properties of ductile iron. The article described these structures and their impact on selected properties.

Keywords: Ductile Iron, Ausferrite, Microstructure, Nanostructure, Austempering.

1. Ausferrite matrix of ductile iron

Detailed examinations of the microstructure morphology of an ausferritic matrix in ductile iron show several characteristic features, which can be discussed as dependent on the time of isothermal transformation. With short time of this transformation (A point on Fig. 1), the ductile iron tends to form an almost fully martensitic matrix, containing only a very small amount of the precipitates of lamellar ferrite. This is due to complete transformation at ambient temperature of the thermally unstable austenite.

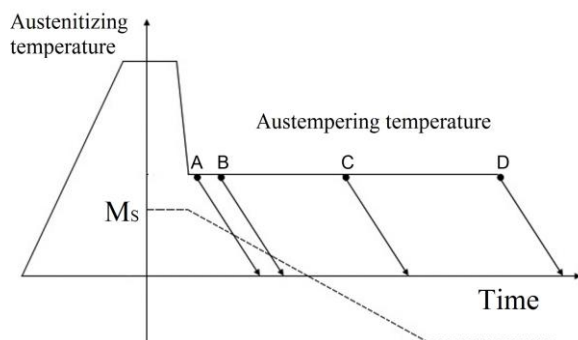


Fig. 1 Schematic representation of time-related changes in temperature during heat treatment shaping the ductile iron matrix (changes in the M_s temperature during isothermal transformation).

Slightly longer time of the transformation increases ferrite content in the form of packets of plates separated by carbon-rich austenite. The continuation of transformation leads to austenite

stabilization. This makes the matrix of ductile iron fully ausferritic with austenite present in two forms, i.e. in the form of layers separating the plates of ferrite and in the form of blocks located between the ferritic-austenitic packets. Very long time of the isothermal transformation usually leads to the formation of typically bainitic microstructure or, in term of very low temperature of austempering, could leads to the nanoausferritic structure (D point on Fig. 2) [1,2].

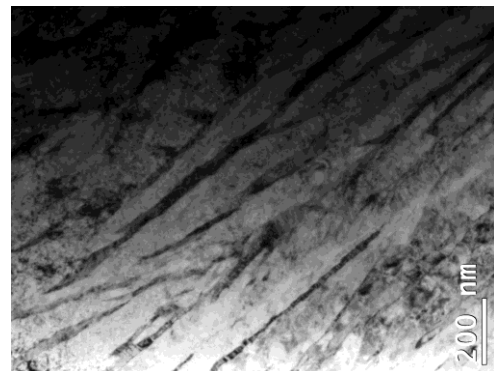


Fig. 2 Nanoausferritic matrix of ductile iron. phot. Emilia Skołek, PhD, DSc.

Studies show that with the progressing time of isothermal transformation, austenite acquires its thermal stability and the M_s temperature is decreasing [3]. The schema neglects the time and temperature of the isothermal transformation, but the results of experiments clearly indicate that changes in the M_s temperature will follow a general course similar for all types of the ausferritic ductile iron.

2. Ausferrite transformation during subzero treatment

In classic austempered ductile iron [4], the time of isothermal transformation usually ends in the region between points B-C (Fig. 1). From Figure 1 it can be concluded that in this range the M_s temperature will drop below room temperature. This indicates the condition in which austenite can be stable at ambient temperature, because its M_s temperature will be slightly lower than room temperature. However, even

a small change in the temperature, e.g. during subzero treatment, can trigger the martensitic transformation. This theory has been verified experimentally [5] by treatment of ausferritic ductile iron samples at the temperature of liquid nitrogen (-196°C). Microscopic examinations of areas containing austenite showed the presence of a phase with quasi-martensitic morphology appearing in those places after the process of freezing. In the same microstructure, areas of stable austenite located between the ferrite plates were traced, which means that these are the areas heavily oversaturated with carbon migrating from the regions of growing ferrite plates.

3. Mechanical instability of austenite

Analysis of the freezing process indicates that austenite transformation into martensite at temperatures below M_s occurs only in some specific areas of the microstructure, i.e. in the blocky austenite. These places are also privileged for the deformation-induced transformation [6-8]. As a result of such transformation, hard, carbon-rich, martensite is formed. This effect can be easily observed during microscopic examination of samples after hardness measurements, when the indenter permanently deforms the tested material, leaving a ring of plastic deformation around the indentation. Martensite formed under a pressure of the penetrating indenter of the hardness tester also creates problems in finding a clear relationship between hardness and austenite content in ausferrite [9]. The same problem appears in numerous other tests, e.g. in the static tensile test, when martensite is traced on fractures of the specimens after failure [7]. Martensite of this type is also present in samples subjected to machining or abrasion wear. Therefore, using TEM images of the microstructure and diffraction patterns, it is difficult to tell if the examined martensite is a result of the transformation caused by technological process or transformation due to wrong sample preparation. The phenomenon of martensitic transformation is related with proper level of stress or strain which, arising in the examined material, can trigger TRIP effect [6,8].

4. Effect of high temperature on ausferrite transformation

Ausferritic ductile iron is known to suffer a drastic drop of mechanical properties when subjected to the impact of high temperature. This is extremely important for the technological process and possible

high temperature applications. The cause of such changes are transformations occurring in the ausferrite. Deeper analysis of this problem indicates that high temperature provides energy necessary to activate and complete the bainitic transformation. At a temperature above 400°C , different for the different types of ausferrite, intense exothermic reaction begins. It is related with the formation of a mixture of ferrite and carbides originating from the austenite.

The decomposition of ausferrite to form a bainitic structure under the effect of high temperature carries a specific activation energy associated with this transformation. From calculations made in [10] it follows that to activate the transformation in ductile iron treated in a high range of the isothermal transformation temperatures (370°C and 400°C) it is necessary to supply the energy of 200kJ/mole . For a lower range of the transformation temperatures, i.e. 300°C and 320°C , this energy increases to about 280kJ/mole . From the studies it also follows that with the higher heating rate more of the activation energy is needed to trigger the bainitic transformation and the temperature at which this transformation starts must be higher, too.

Acknowledgements

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