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THERMAL STABILITY OF AUSTEMPERED DUCTILE IRON

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ABSTRACT
Analysis of thermal decomposition processes of the austempered ductile iron (ADI) microstructure after austempering heat treatment was performed. The material with specified phase composition and well-defined thermo physical properties, both resulting from the conducted heat treatment cycle, under controlled conditions was investigated. The differential thermal analysis of the decomposition of the ausferrite using DTA analysis was performed and temperature changes as a result of exothermal reaction of the ausferrite decomposition were recorded. The process of ausferrite decomposition in the range of 100–800°C was discussed.
Keywords: Austempered Ductile Iron, DTA, Ausferrite decomposition

1. INTRODUCTION
Austempered ductile cast iron (ADI) has been developed as a substitute for expensive steel components (mainly forged steel components) in many sectors of engineering, and especially for automotive and agricultural machinery. The properties of ADI are result of melt treatment, which controls the spheroidisation and distribution of graphite (melt treatment with magnesium bearing Ferro-alloys), and thermal processing in the solid state. These result in a complex microstructure consisting of spherical graphite embedded in an ausferritic metallic matrix. Austempering basically consists of several steps. Austenitising the matrix, quenching to the austempering temperature, holding for a controlled time (usually in the salt bath), and then cooling to room temperature. The concentration and distribution of carbon and alloying elements in the austenite control the transformation of austenite to ausferrite during austempering, [1,2].

The austempered microstructure that optimises ductility is a mixture of low carbon, needle-shaped ferrite (in the literature sometimes referred as bainitic ferrite) and high carbon, retained austenite. This microstructure, combined with spheroidisation of the graphite, results in good combinations of strength and ductility on the product. Other constituents which may result from austempering are martensite and carbides, both of which are unwanted and reduce the ductility, [2].
An interesant aspect according ADI investigation is the thermal conditions for the stability of the microstructure and the mechanical properties during service. The microstructure and mechanical

properties depend on the behaviour of constituents at elevated temperatures. From that reason stability of the high carbon austenite that can decompose into ferrite and carbides under given service conditions is of the crucial importance. During the investigation of ADI alloyed with Mn, Chobaut et al. using a dilatometric analysis observed some changes at 400 °C that was associated with the high carbon austenite decomposition into ferrite and silico-carbides [3].

In a study performed with a differential scanning calorimeter, Korichi and Priestner reported that the high carbon austenite decomposed in the vicinity of 460-470 °C. Using dilatometric analysis to study the aging reactions in ADI, Nadkarni and Gokhale observed volumetric changes of the retained austenite transformation occurring in the range of 450-550 °C. M.J, [4]. Perez et al. reported that some alloying elements (Ni, Cu, Mo) and high austempering temperature increased the ausferrite microstructure stability. According the results published by the *M*.J. Perez et al. (using similar chemical composition of the initial material and heat treatment parameters for the experiment) decomposition of the austempered microstructure starts at the austempering stage, continued during the annealing treatment, increasing the amount of carbides but no changes in the DTA curve, caused by these phenomena, can be observed. At the specific temperature (459°C), the transformation of the high carbon austenite to ferrite and cementite, via the precipitation of silico-carbides, produced an exothermic peak at the DTA curve which indicates the high carbon austenite decomposition, [5].

In the present paper experiments designed to investigate the high temperature decomposition of austempered microstructures are described.

2. EXPERIMENTAL TECHNIQUES

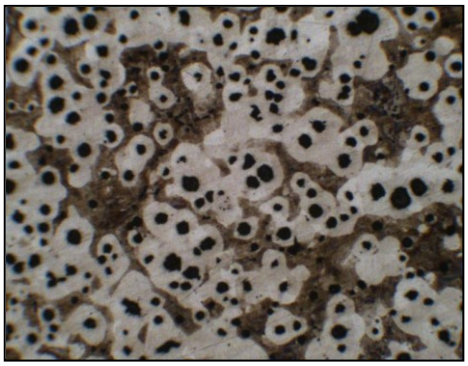
An unalloyed ductile iron was produced by induction melting using the following raw materials: steel scrap, ductile iron returns, ferroalloys. The spheroidizing process using Fe-Si-5%Mg was performed in a spheroidizing station. In-mould method of inoculation was carried out by adding Fe-75%Si. The metal was poured in silica sand moulds to produce cast smaples. The chemical composition of the cast sample is indicated in Table 1. Microstructure and mechanical properties of the cast sample are presented in the Figure 1 and Table 2.

Table 1. Chemical composition of the cast sample

Chemical composition (mass%)							
C	Si	Mn	P	S	Cr	Cu	Mg
3,56	2,09	0,482	0,011	0,003	0,111	0,340	0,040

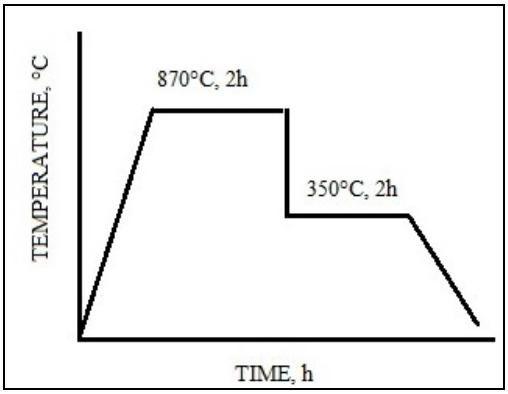
Table 2. Mechanical properties of the cast sample

Tensile strength (MPa)	Hardness HB	Pearlite content (%)	Ferrite content (%)
560	2005	20	80



The samples prepared from the cast iron were austenitized at 870 °C for 2 h and then austempered in a salt bath at 350°C for 2 h followed by cooling at the air to room temperature. Heat treatment diagram is presented in Figure 2. Microstructure of the sample after austempering process is presented in Figure 3.

Figure 1: Microstructure of the sample (Etched with Nital, mag.100)



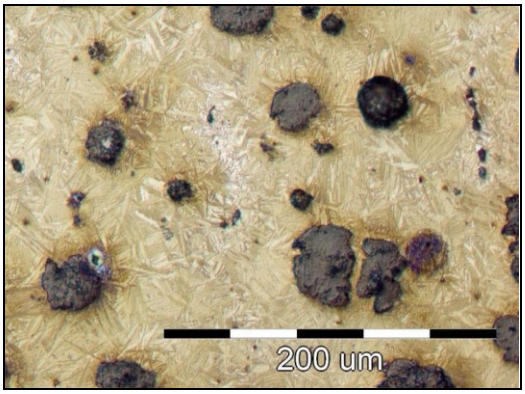


Figure 2. Heat treatment diagram *Figure 3. Ausferrite microsture after heat treatment*

Figure 3 shows that 2 h of isothermal austempering at 350 °C allowed in iron sample a martensite-free ausferritic microstructure, with unify distribution of the plate thickness within treated sample.

The thermal stabilities of the austempered microstructures were investigated using DTA analysis. Figure 4 shows the DTA curve recorded for specimen that had undergone above described heat treatment.

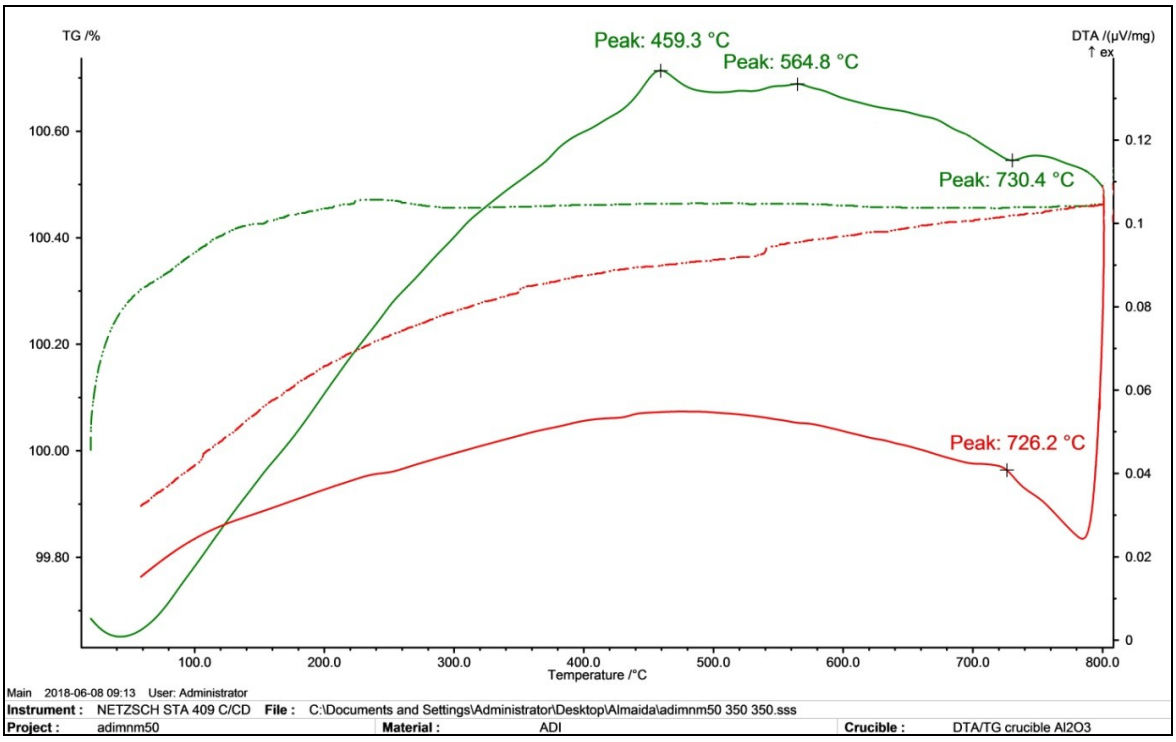


Figure 4. DTA curve of investigated sample

At the heating curve several peaks are recorded. The exothermic events that started at approximately 450°C and peaked near 460°C in the austempered specimens is characteristic of the decomposition of the retained austenite into ferrite and carbide (silico-carbides). The exotermic peak near 565°C is result of the Iron-carbide precipitation and transformation near 730°C is eutectoid transformation. Peak at the cooling curve around 725°C is, again, eutectoid transformation.

3. CONCLUSIONS

From above described experimental work, which focused to study the thermal stability of the ADI microstructure during a non-isothermal heating, the following conclusions can be drawn:

- The method of analysis consisting in investigation of the phase transformations by means of non-isothermal heating of the structurally well-defined material with simultaneous recording of temperature difference by means of differential thermal analysis (DTA) was successfully applied.
- The paths of decomposition of austempered ductile iron while heated up to ca 800°C were recognized and discussed, and the process of ausferrite decomposition was recorded
- The exothermic events that started at approximately 450°C and peaked near 460°C in the austempered specimens is characteristic of the decomposition of the retained austenite and is in good correlation with existing theoretical data.
- For optimum (processing window) ADI heat treatment, the stability of ausferrite during non-isothermal tempering up to 400°C was proved.

4. REFERENCES

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