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# INFLUENCE OF HEATING RATE ON STABILITY OF AUSFERRITE MICROSTRUCTURE

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## ABSTRACT
*Austempered Ductile Iron (ADI) is obtained by exactly controlled heat treatment process of nodular cast iron. Ductile iron samples are first austenitised to dissolve carbon, then quenched rapidly to the austempering temperature to avoid the formation of deleterious pearlite or martensite. Resulting ausferrite microstructure consists of acicular ferrite embedded in stabile retained austenite. A new microstructure results with capability superior to many traditional, high performance, ferrous and aluminum alloys. Influence of heating rate on stability during working life of ADI casting, using thermal analysis (DTA), is presented in this paper.*

## 1. INTRODUCTION

Austempering is a heat treatment process that is applied to ferrous metals (especially for steel and different types of iron castings). In case of steel it results in a bainite microstructure whereas in cast irons it produces an ausferrite microstructure (acicular ferrite and high carbon, stabilized austenite). This type of heat treatment is primarily used to improve mechanical properties or reduce/eliminate distortion. It is developed in 1930`s by Edgar C. Bain and Edmund S. Davenport. At the beginning it was usually applied to steel products [1, 2]. Ductile iron or spheroid graphite iron was developed during 1940s. Ductile iron with its unique graphite morphology is a material that has hardness, tensile and impact properties sufficient for many different application (vehicle and agriculture industry, mining, pipes, etc.). In the second half of the twentieth century the austempering process began to be applied commercially to cast irons. Austempered Ductile Iron (ADI) was first commercialized in the early 1970s but serious research in field of ADI application was carried out at the end of 20th and beginning of the 21st century [3].
The most notable difference between austempering and conventional quench and tempering is that it involves holding the workpiece at the quenching temperature for an extended period

of time. The basic steps are the same whether applied to cast iron or steel and are as follows, [4]:

- Heating to an austenitizing temperature,
- Quenching rapidly to a temperature above martensite start (austempering temperature),
- Holding at a selected austempering temperature for a time sufficient to transform the austenite to ausferrite,
- Cooling at the air to the room temperature.

## 2. EXPERIMENTAL PART

The study objective was to determine the microstructure stability under elevated temperature conditions of Austempered Ductile Irons. Questions have been raised as to how ADI will change its microstructure after being exposed to elevated temperatures and on which temperature range the microstructure change is going to happen. For elevated temperature investigation thermal analysis method is used (DTA).

### 2.1. Material selection

Chemical composition of the initial Ductile iron is given in the table 1. Microstructure of the initial Ductile iron used for ADI production is presented in Figures 1 and 2.

*Table 1. Chemical composition of the base material*

| Composition | C | Si | Mn | S | P | Mg | Ni | Cu |
|---|---|---|---|---|---|---|---|---|
| % | 3.29 | 2.53 | 0.31 | 0.013 | 0.015 | 0.031 | 0.81 | 0.51 |

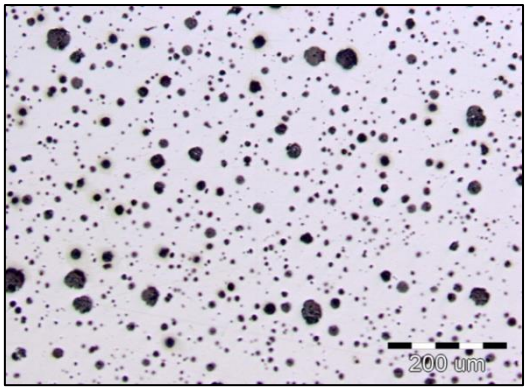


*Figure 1. Microstructure of the Ductile Iron (after polishing), 100X*

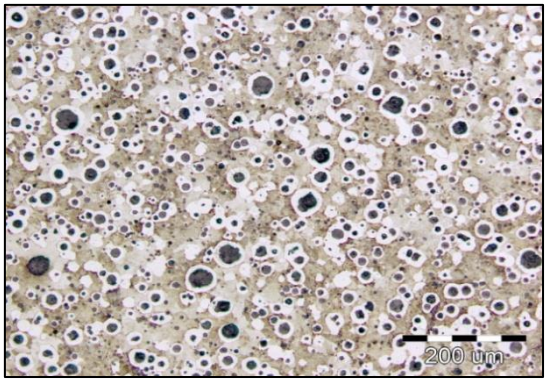


*Figure 2. Microstructure of the Ductile Iron (3% Nital etched), 100X*

Initial material was heat treated in a commercial heat treat furnaces. Austenitizing was completed at an 870 °C in the air atmosphere for the ADI samples. Austempering was done in a potassium nitrate salt bath. The temperature of the salt bath was 300 °C. Austenitization time was 80 minutes and austempering time was 90 minutes. The heat treat cycle for production of ADI samples is presented on Diagram 1.

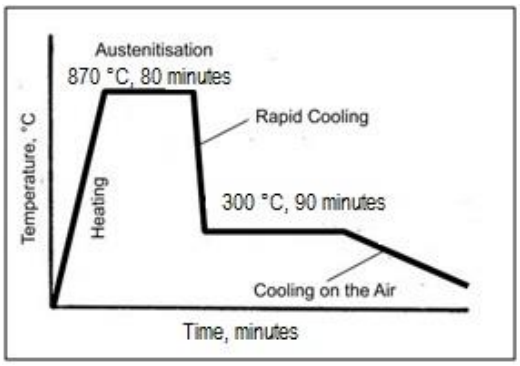


*Diagram 1. Heat treatment cycle for production of ADI samples*

The microstructure ADI sample is shown in Figure 3. Microstructure consists of well-formed graphite nodules in ausferrite matrix.

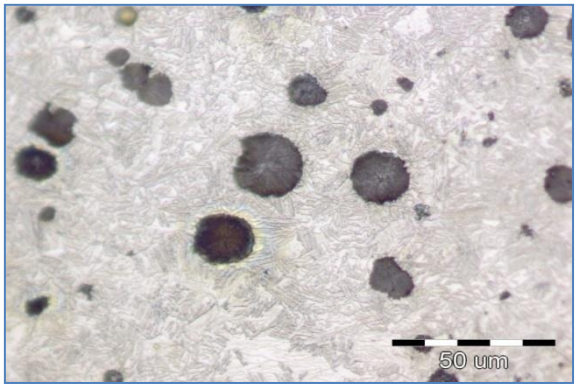


*Figure 3. Microstructure of ADI sample, (3% Nital etched), 200x*

## 2.2. Differential thermal analysis

Differential thermal analysis (or DTA) is a thermoanalytical technique that is similar to differential scanning calorimetry. In DTA, the material under study and an inert reference are made to undergo identical thermal cycles, (i.e., same cooling or heating programme) while recording any temperature difference between sample and reference. This differential temperature is then plotted against time, or against temperature (DTA curve, or thermogram). Changes in the sample, either exothermic or endothermic, can be detected relative to the inert reference. Thus, a DTA curve provides data on the transformations that have occurred. DTA may be defined formally as a technique for recording the difference in temperature between a substance and a reference material against either time or temperature as the two specimens are subjected to identical temperature regimes in an environment heated or cooled at a controlled rate, [5]. For the purpose of the investigation for this paper preparation three different heating rate during DTA testing were applied, 2K/min, 5K/min and 10K/min, respectively.

## 3. RESULTS

DTA diagrams of the ADI samples investigation are presented in Figures 4, 5, 6 and 7. DTA analysis was carried out using STA 409DC equipment.

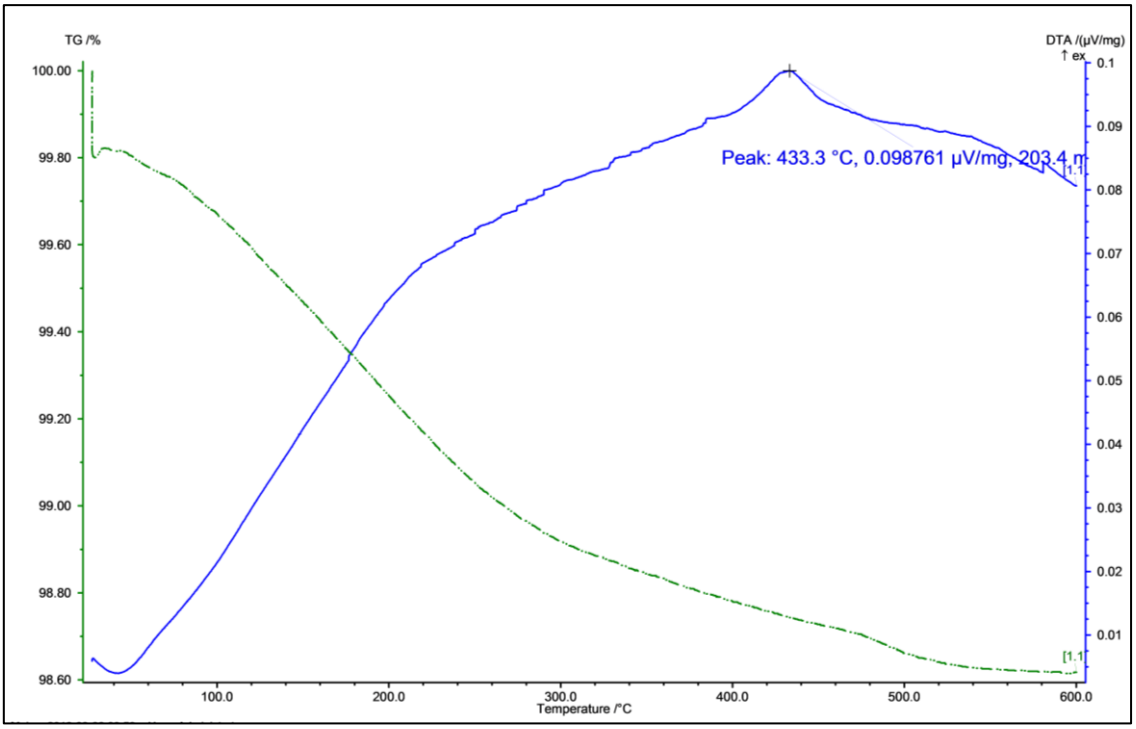


*Figure 4. DTA analysis curve, (Heating rate 2K/min)*

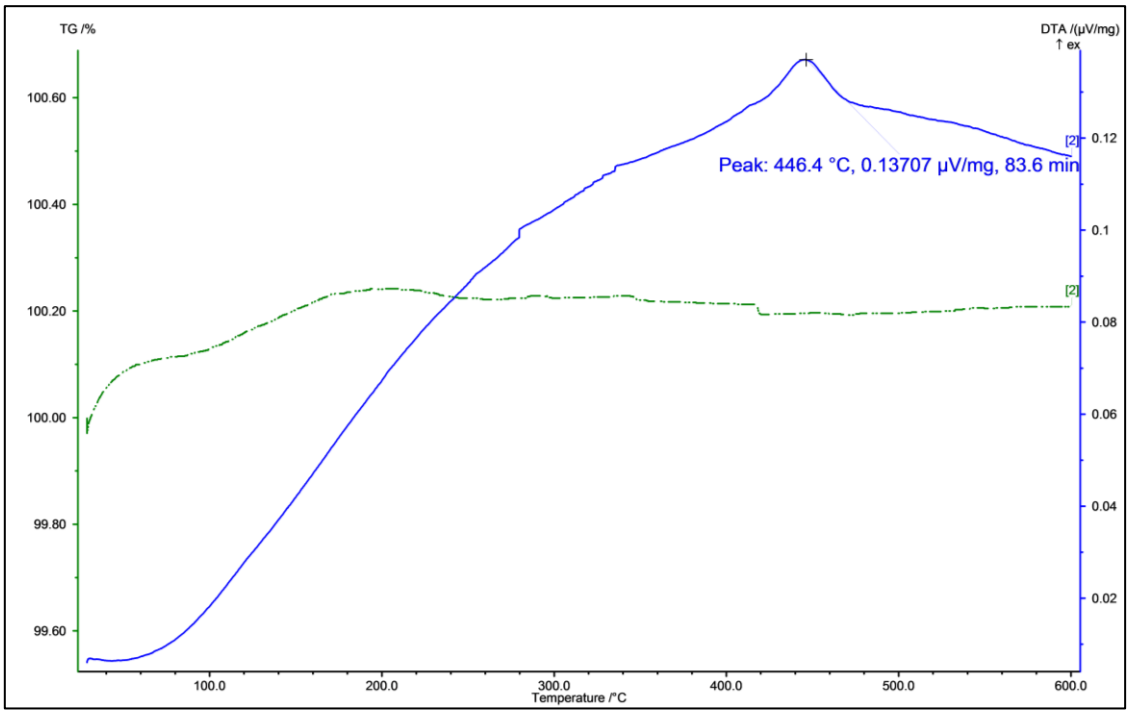


*Figure 5. DTA analysis curve, (Heating rate 5K/min)*

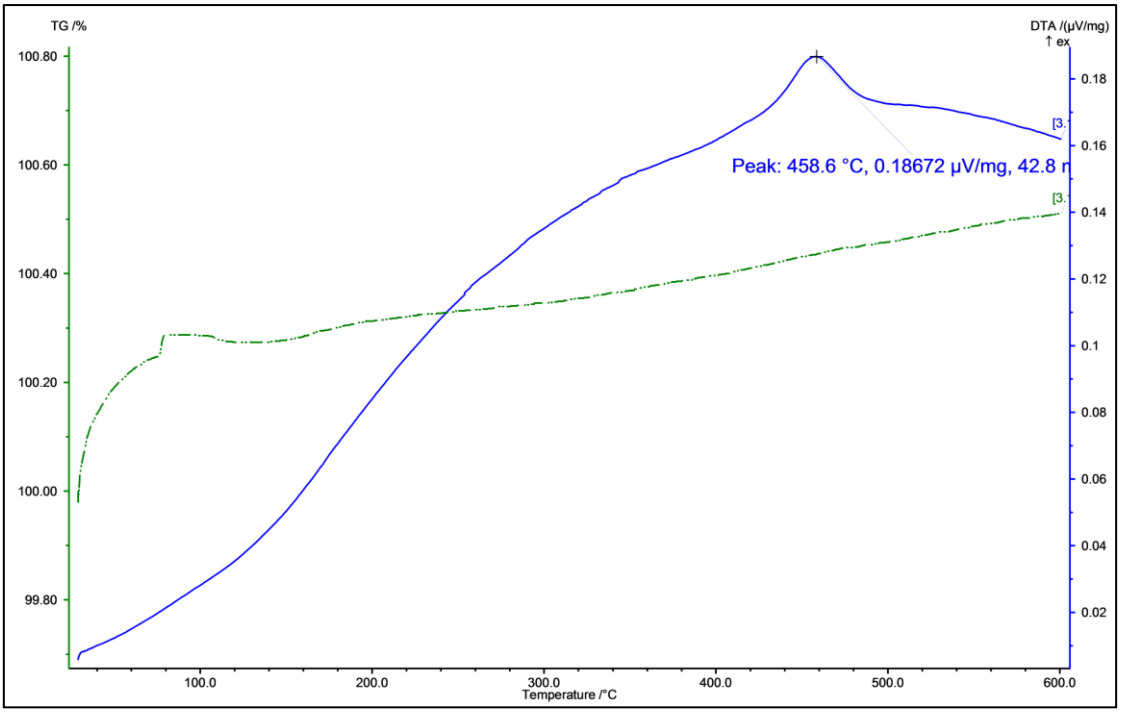


*Figure 6. DTA analysis curve, (Heating rate 10K/min)*

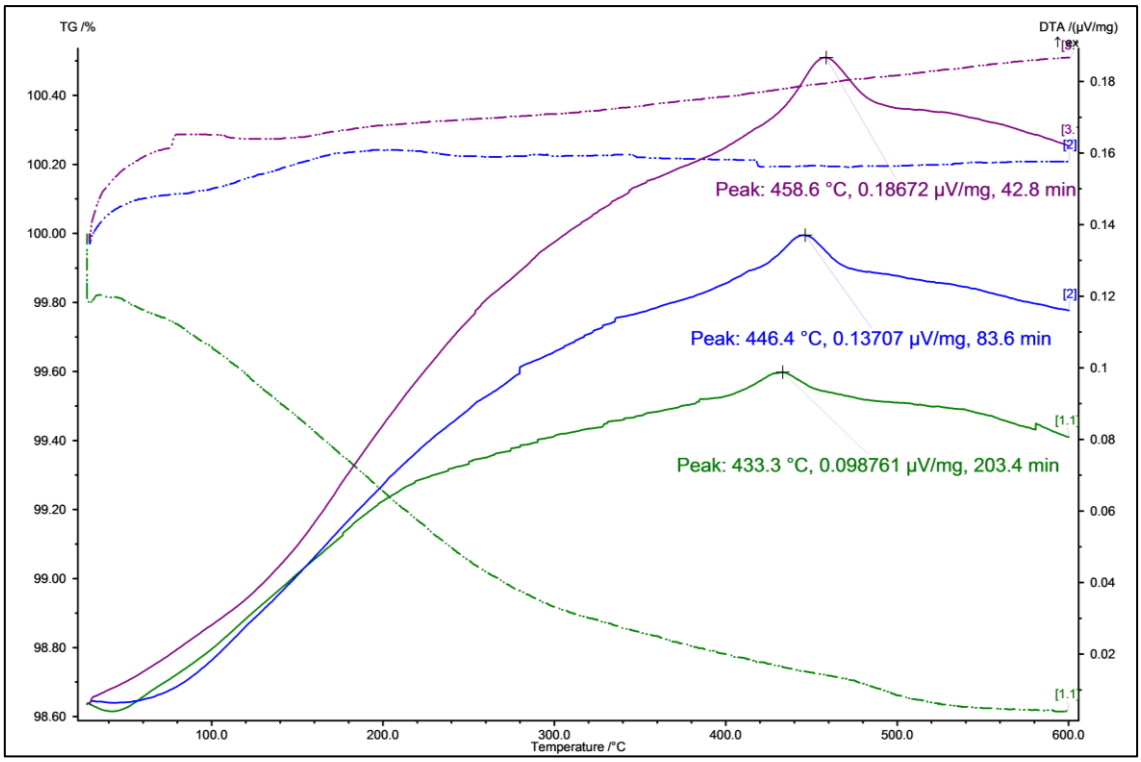


*Figure 7. DTA Analysis curves (Heating rate: 2K/min, 5K/min and 10K/min)*

## 4. CONCLUSIONS

- During the heating of the ADI samples ausferrite is stable in temperature region between room temperature and 400 °C.
- Analyzing diagrams at the Figures 4-7 is easy to see that transformation (decomposition) of the initial ausferrite microstructure happed in the temperature region above 400 °C.
- Comparing temperature values of the existing peaks on the diagrams from Figure 7 can be seen that increasing the heating rate increases temperature interval of the ausferrite decomposition.

## 5. LITERATURE


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