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INFLUECE OF THE AUSTEMPERING TEMPERATURE ON THE HARDNESS OF THE AUSTEMPERED DUCTILE IRON SAMPLES

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ABSTRACT
Austempered Ductile Iron (ADI) is a ductile iron subjected to two steps heat treatment process – austenitization and austempering. The heat treatment gives to ADI high value of mechanical properties ie. tensile strength, hardness, etc. However, designers in most cases are unfamiliar with this material that can compete favorably with steel and aluminum castings, weldments and forgings. In this paper investigation of the influence of the austempering temperature on the hardness of the ADI samples is presented.
Key words: hardness, ADI, austempering,

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

A diagram that illustrates Austempering process is presented in Figure 1.

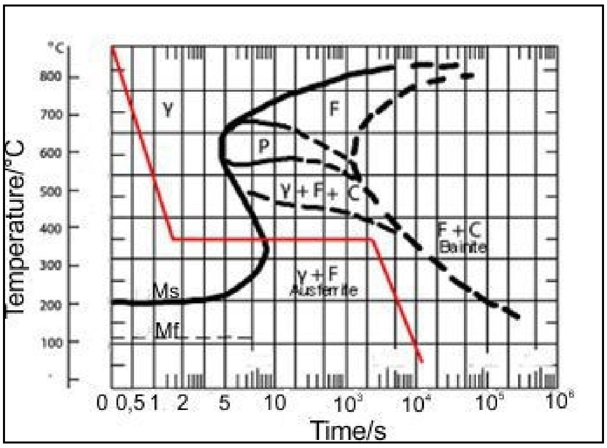

Figure 1.I-T Diagram of the Austempering process, [1]

In case of underlining some improvements, austempered materials are often compared to conventionally quench and tempered materials with a tempered martensite microstructure. In cast irons these improvements include, [1]:

- Higher ductility and impact resistance for a given hardness,
- Increased wear resistance for a given hardness.
- Increased tensile strength,
- A low distortion, repeatable dimensional response,
- Increased fatigue strength,

2. EXPERIMENTAL PROCEDURE

The main idea of the experiment was to produce unalloyed ductile iron and prepare samples for heat treatment, heat treatment of the samples for different austempering temperature, and at the end microstructure and hardness investigation and compare of the results. The ductile iron base material was prepared and chemical composition of the melt is presented in Table 1.

Tabele 1. Chemical composition of the base material

Chemical composition / mass %						
C	Si	Mn	S	P	Mg	CE
3,48	2,10	0,40	0,012	0,027	0,045	4,18

Malt was poured in to U blocks and after cooling, a certain number of samples for heat treatments were cut. The thicknesses of the samples were the same for all samples.

Main task of the investigation is to determine influence of the austempering temperature on the hardness of the treated samples. According to the pervious investigation and literature research austempering temperature for ductile iron is in the range 250-420°C. In case of this experiment nine different austempering temperatures were chosen (260°C, 280°C, 300°C, 320°C, 340°C, 360°C, 380°C, 400°C, 420°C). According to the plan of experiment nine sets of samples were cut from the U blocks. Each sample set consists of three samples. All other parameters of the heat treatment (austenitization time and temperature and austempering time) were the same for all treated samples.

Prior to heat treatment of the samples dilatometric investigation of the base material was conduct to set austenitization temperature. Dilatometer DIL 402/C/7 (Netzsch) was used (heating/cooling rate: 5K/min). Dilatometric curve is presented on the Figure 2 and the heat treatment diagram of the samples is presented on the Figure 3. Based on dilatometric curve at the Figure 2 austenitization temperature of 850°C was set. Austenitization time (60 min) and austempering time (90 min) were chosen based on the thickness of the samples

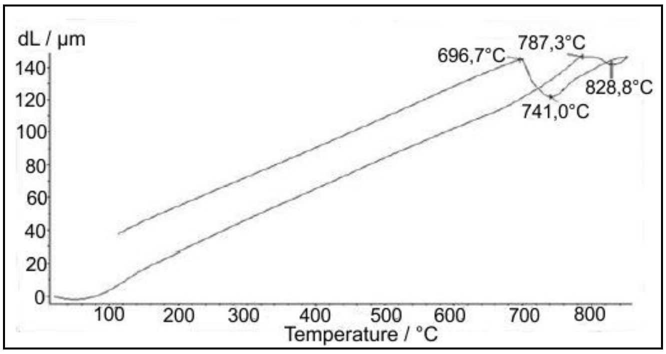

Figure 2. Dilatometric curve of the base material

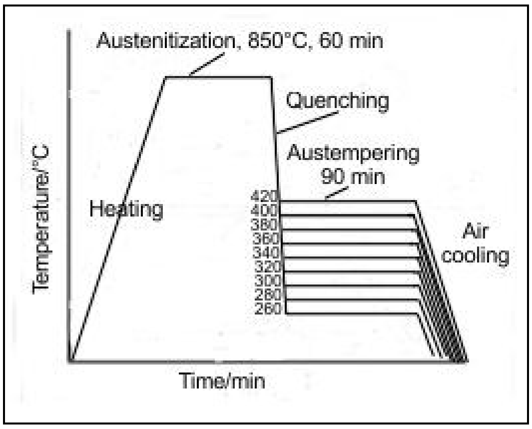

Figure 3. The heat treatment diagram

Induction furnace for austenitization and KNO_3 salt bath for austempering were used.
Microstructure of the base and heat treated samples were investigated using Olympus light microscope and for hardness investigation Brinell test method according BAS EN ISO 6506-1/01 was used, [5].

3. RESULTS AND DISCCUSSION

Microstructure of the base material was pearlitic/ferritic metallic matrix with embedded graphite nodules. Microstructure of the base material is presented on the Figures 4 and 5.

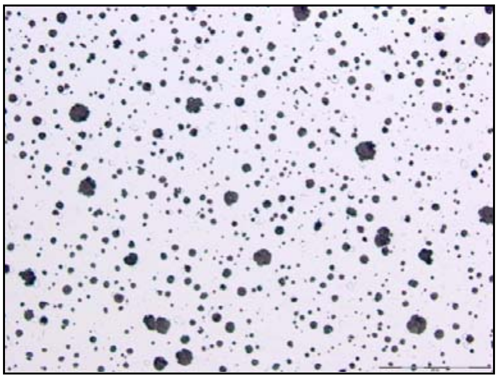

Figure 4. Microstructure of the base material unetched, 100x

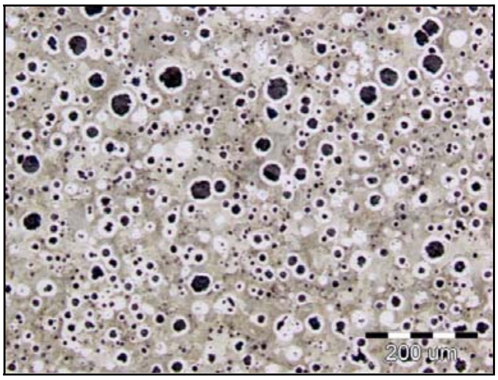

Figure 5. Microstructure of the base material Nital etched, 100x

Hardness of the base material (average value of five measurements) was 265 HBW. Tensile strength of the base material (average value of the three measurments) was 690 MPa. According to BAS EN 1563:1997 base material corresponds to EN-GJS-600 class of ductile iron, [6].
The results of the hardness investigation of the heat treated samples at the different austempering temperature are presented in Table 2 and Figure 6

Table 2. Hardness of the heat treated samples

T_a /°C	260	280	300	320	340	360	380	400	420
HBW	441	406	387	282	354	340	309	299	298

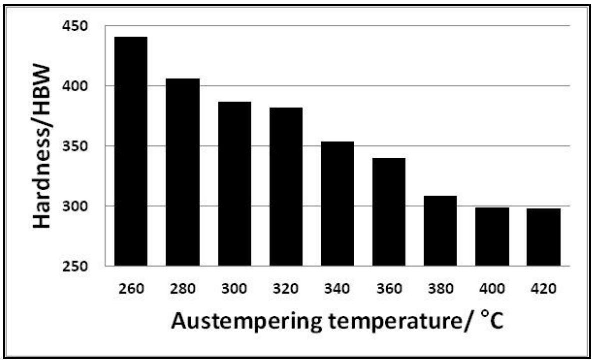

Figure 6. Hardness of the heat treated samples for different austempering temperature

Microstructure of the sample after heat treatment is presented on Figures 7 and 8. Due to space limitation of the paper microstructure of the heat treated samples for two different austempering temperature are presented

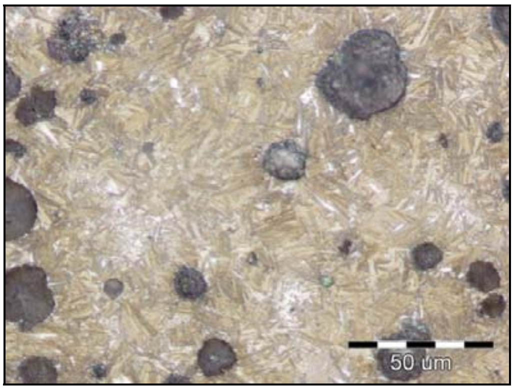

Figure 7. Microstructure of the tested sample. Austempering temperature 280°C. Nital, 500X

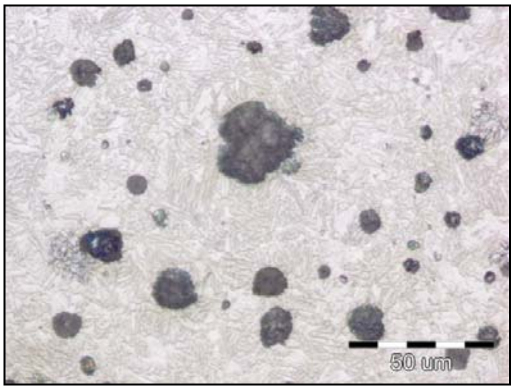

Figure 8. Microstructure of the tested sample. Austempering temperature 420°C. Nital, 500X

4. CONCLUSIONS

Summarizing the data after investigation following can be concluded:

- Plan of the experiment (parameters of the heat treatment processes) was prepared correctly and obtained results follow the research idea
- The heat treatment is a very powerful tool for designing mechanical properties of the material (ductile cast iron)
- With increasing austempering temperature hardness of the heat treated samples decreases
- Microstructure of the heat treated samples consists of needle like acicular ferrite and retained austenite and was uniform at the cross section of the tested material.

Acknowledgements

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5. LITERATURE

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