

# Effect of Temperature on Ausferritic Nodular Cast Iron Microstructure

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Received 16.06.2014; accepted in revised form 22.08.2014

## Abstract

The work presents the results of the studies of the effect of the temperature on the microstructure of ausferritic nodular cast iron. The ausferrite in the matrix was obtained by way of a specific combination of molybdenum and copper. The cast iron underwent annealing at the temperatures of 520, 550 and 580°C. The work presents the effect of the annealing temperature on the fraction of austenite in the cast iron matrix. The annealed and non-annealed cast iron hardness is given. The work also proves that an increase in the temperature up to 580°C causes a drop in the cast iron hardness.

**Keywords:** Innovative casting materials and technologies, Nodular cast iron, Ausferrite, Annealing

## 1. Introduction

Ausferrite in the nodular cast iron matrix can be obtained both by way of heat treatment, that is isothermal quenching [1 ÷ 6] or through a specific combination of the alloy additions [7 ÷ 9]. It constitutes a desired microstructure in the cast iron matrix used in the construction of elements which are required to have high abrasive and adhesive wear resistance [10 ÷ 13]. The thematic literature provides information on the nitration process of cast iron performed with the purpose to increase its abrasive wear resistance [13 ÷ 16]. So far, no attempts have been made at examining the effect of the temperature on the properties of ausferritic cast iron obtained without heat treatment. The lack of such available literature data created the aim of this work, which is examining the effect of the annealing temperature on the microstructure and hardness of ausferritic nodular cast iron in the aspect of the use of nitration.

## 2. Test methodology

The cast iron assigned for the tests was melted in an induction furnace PI30 by Elkon with the crucible capacity of 30 kg. The charge consisted of special pig iron of the composition shown in Table 1, ferrosilicon FeSi75 and technical pure molybdenum and copper. The molybdenum and copper were introduced into the cast iron in order to obtain an ausferritic matrix in the state as-cast. The nodulation and inoculation of the cast iron were performed by the Inmold method. The chemical composition range of the cast iron is presented in Table 2.

Table 1.  
Chemical composition of special pig iron

Chemical composition, %				
C	Si	Mn	P	S
4.07	0.60	0.025	0.046	0.009

Table 2.

Chemical composition range of examined cast iron

Chemical composition, %				
C	Si	Mn	Cu	Mo
3.76÷3.95	2.36÷2.53	0.03÷0.05	2.09÷2.51	1.43÷2.04

The test samples were cut out of test casts, with the wall thickness of 25 mm. The annealing process was conducted in a chamber resistance furnace produced by Neoterm. The temperatures of 520, 550 and 580°C were used. The samples were annealed for the time of 8 h. The above choice was determined by the practically applied nitration temperatures.

The metallographic measurements were performed by means of an optical microscope MA200 by Nikon, with the magnification of  $\times 1000$ .

The cast iron hardness was tested by the Brinell method with the use of a hardness tester HPO-250 for the conditions of 2.5/187.5/30.

The fraction of the austenite in the cast iron was tested by the X-ray diffraction method with the use of a diffractometer iXRD by PROTO.

### 3. Test results

Figure 1 shows a representative microstructure of the cast iron containing about 2% Mo and 2% Cu without heat treatment.

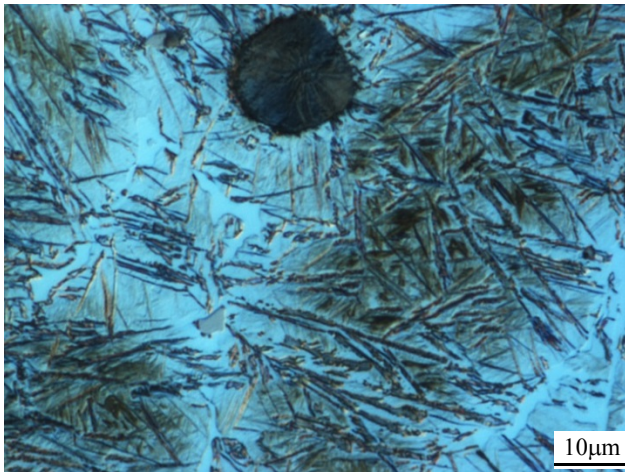


Fig. 1. Representative microstructure of ausferritic nodular cast iron without heat treatment: nodular graphite, ausferrite, carbides

Fig. 1 suggests that, in the matrix of the cast iron containing the above additions, we obtain ausferrite without isothermal quenching. The carbides in the matrix increase the wear resistance of this type of cast iron [7].

Figures 2 ÷ 4 show representative microstructures of the cast iron annealed at 520, 550 and 580°C for 8 h.

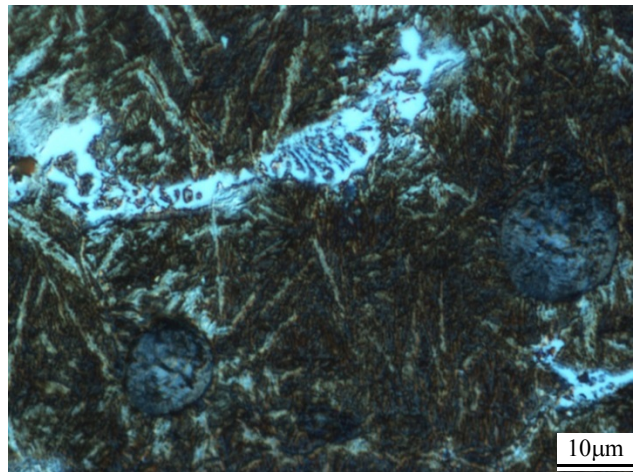


Fig. 2. Representative microstructure of nodular cast iron annealed at 520°C

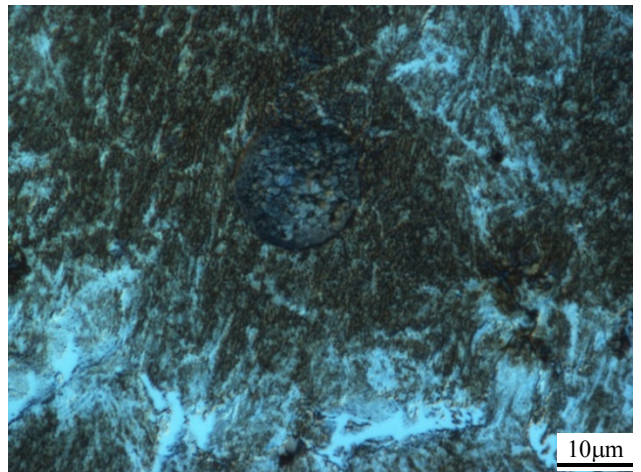


Fig. 3. Representative microstructure of nodular cast iron annealed at 550°C

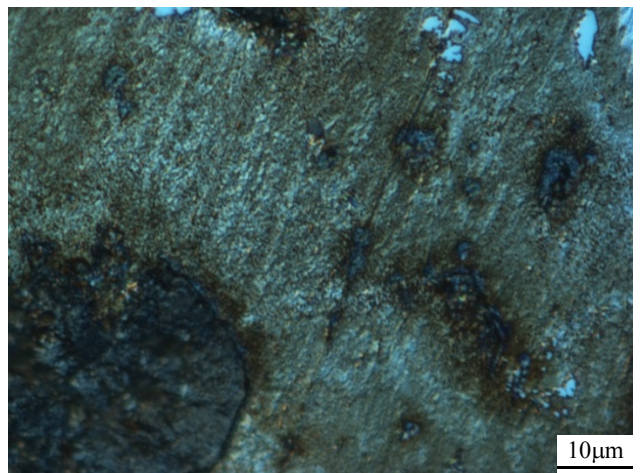


Fig. 4. Representative microstructure of nodular cast iron annealed at 580°C

By way of the X-ray method, the samples were tested in respect to the amount of the austenite in the non-annealed cast iron and the austenite remaining after the annealing process. The results of the measurements are compiled in Table 3.

Table 3.  
Austenite fraction in non-annealed and annealed cast iron

Annealing temperature, °C	Austenite volume fraction in cast iron, %
–	16
520	2.5
550	1.5
580	1.0

The data presented in Table 3 suggests that annealing the cast iron at 520°C caused a drop in the austenite fraction (from 16% to 2,5%). An increase of the annealing temperature up to 580°C caused a decrease in the austenite fraction down to 1.0%.

The cast iron hardness test results are shown in Table 4.

Table 4.  
Hardness of non-annealed and annealed cast iron

Annealing temperature, °C	Range of HB hardness	Mean HB hardness
–	349 ÷ 438	393
520	404 ÷ 418	411
550	394 ÷ 425	409
580	224 ÷ 243	233

From the data included in Table 4 we can infer that the hardness of non-annealed cast iron is within the range of 349 ÷ 438 of HB units. It is mostly dependent on the surficial fraction of the carbides. In a cast iron containing a high concentration of Mo and Cu (about 2.0 and 2.5%, respectively), we also observed the presence of a small amount of martensite (about 5%). Annealing the cast iron at 520°C caused a mean hardness increase by 18 of HB units. This increase was probably a result of the secondary carbide precipitation. An increase in the temperature up to 550°C did not cause any significant changes in the mean hardness of the samples. Increasing the annealing temperature up to 580°C caused a drop in the hardness of the examined cast iron down to 224 ÷ 243 pf HB units, which gives the mean hardness decrease equaling 176 HB.

## 4. Conclusion

From the included test results, we can draw the following conclusions:

1. Annealing within the temperature range of 520 ÷ 580°C causes a drop of the austenite fraction in the cast iron from 16 to 1.0 ÷ 2.5%.

2. An increase in the annealing temperature up to above 550°C causes a significant drop in the cast iron hardness (in average by 176 of HB units).
3. We suggest the use of nitration of ausferritic nodular cast iron with carbides obtained in the state as–cast at the temperature of up to 550°C.

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