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THE EFFECT OF AUSTENITIZING CONDITIONS IN THE DUCTILE IRON HARDENING PROCESS ON LONGITUDINAL ULTRASONIC WAVE VELOCITY

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Preliminary Note – Prethodno priopćenje

The paper presents results of a research on the effect of austenitizing temperature and time adopted in the hardening operation on the ultrasonic wave velocity in ductile iron. It has been found that with increasing austenitizing temperature and with the passage of the austenitizing time, a monotonic decrease of the ultrasonic longitudinal wave velocity value occurred. Implementation of ultrasonic testing of results obtained in the course of the cast iron hardening process both in production and as-cast conditions, requires development of a test methodology that must take into account the influence of base material structure (degree of nodularization, graphite precipitation count) on the ultrasound wave velocity.

Key words: ductile cast iron, austenitizing temperature, austenitizing time, hardening, ultrasonic testing

INTRODUCTION

Thermal treatment of ductile iron that includes the operation of austenitizing was proven to be always beneficial, one way or another. For instance, the two-stage annealing of ductile cast iron carried out in order to obtain the ferritic structure allows to obtain better ductile properties that the single-stage process. The two-stage normalizing annealing of unalloyed ductile iron increases both tensile strength and yield strength compared to the single-stage annealing. In the course of the heat treatment applied to ductile iron, the most commonly used austenitizing temperatures are 900 °C, 950 °C, and 1 000 °C [1-3].

Austenitizing of cast irons is aimed at obtaining, to the maximum possible extent, the austenite homogenous as far as its chemistry is concerned. However , reduction of both chemical and structural microsegre-gation (decomposition of cementite and other phases) requires that very high temperatures must be sometimes applied. Austenitizing at high temperatures brings about also some undesirable results related to decarburization and oxidation of the casting skin. Austenitizing temperatures exceeding 950 °C [4] lead to excessive development of austenite grains which results in degradation of the cast iron resistance to dynamic loads and increases of the nil ductility transition temperature. Too high austenitizing temperatures promote graphite denodularization [5] which results in degradation of ductility and impact strength. It is a well-known fact that the effect of the austenitizing time on formation of ductile iron structure and mechanical properties is less prominent than the role of temperature. In general, extension of the austenitizing time increases the tensile strength [3]. It is commonly accepted that obtaining a required increase of the tensile strength in ductile irons by means of the increased austenitizing temperature is more beneficial than obtaining the same result by extending the austenitizing time, also for economical reasons. It follows from the available literature that the commonly applied minimum ductile iron austenitizing time ranges from 0,5 to 3 hours. An important issue in any foundry consist in prompt determining whether the material of a freshly obtained casting is the ductile iron or the gray cast iron, as well as quick evaluation of mechanical properties of the material in casting walls. To this end, an effective methodology has been developed for ultrasonic testing of structure and mechanical properties of ductile irons [6-9].

Experience of the present authors indicate that cast irons with seemingly similar microstructure and similar mechanical properties in as-cast conditions and after the heat treatment are not equivalent to each other ultrasonically. For this reason, relationships determined in a specific foundry for the purpose of ultrasonic testing of microstructure and mechanical properties of castings in as-cast conditions cannot be applied to castings after heat treatment.

In view of the above, the study described in this paper was undertaken aimed at determining the relationship between the longitudinal ultrasonic wave velocity on one hand and the austenitizing temperature and time on the other that would be useful for diagnosing the effects of ductile iron hardening process.

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EXPERIMENTAL CONDITION

Cast iron for the research with the following chemical composition: 3,6 % C, 2,05 % Si, 0,81 % Mn, 0,05 % P, 0,01 % S, 0,03 % Cr, 0,13 % Cu, 0,07 % Mg was obtained in a cupola, of which test plates with dimensions 430 × 300 × 20 mm were cast. After cutting off 40 mm wide side strips along the casting edges, 60 plates with dimensions 50× 50× 20 mm were sectioned. The plates were subject to heat treatment followed by measurements of the longitudinal ultrasonic wave velocity. Austenitizing temperatures of 900 °C, 950 °C, and 1 000 °C were applied and austenitizing times of 0, 1, and 3 hours. Specimens were hardened in oil at 20 °C. For each measurement point, thermal processing was carried out on a set of 5 plates.

On the specimens, after removing a layer about 0,2 mm thick, measurements of the longitudinal ultrasonic wave velocity were performed in four different regions by means of Echometer 1073VS velocity meter equipped with 10,4/6 PB 4 ultrasonic head. The wave velocity value for each data point of the graph was adopted as the arithmetic average of individual measurements.

EXPERIMENTAL RESULTS

Results of examination of the effect of austenitizing temperature and time adopted in

the hardening process on c_L value are given in Table 1 and plotted in Figure 1.

Example microstructures of samples after hardening are presented in Figure 2. An example view of the gap between graphite nodule and matrix and the model of carbon transfer from graphite to austenite via the matrix is presented in Figure 3.

Table 1 **Longitudinal ultrasonic wave velocity c_L as a function of ductile iron austenitizing temperature T_A and austenitizing time τ_A**

Austenitizing temperature T_A / °C	Austenitizing time τ_A / h	c_L / m/s
900	0	5 500
	1	5 50
	3	5 65
950	0	5 259
	1	5 00
	3	5 23
1 000	0	5 117
	1	5 38
	3	5 000

CONCLUSIONS

Strong influence of the austenitizing temperature on the ultrasonic wave velocity revealed in the present study should be considered consistent with expectations as it is a well-known fact that with the increase of the temperature, development of austenite grains is observed [4] and as a result, long spines of hardening products are obtained (Figure 2). It is also known that with the increase of the austenitizing temperature and time, graphite precipita-tions are subject to dissolving. This in turn contributes to formation of gas gaps surrounding graphite precipitations (Figure 3).Another explanation could include the possibility of partial loss of contact between the matrix and graphite precipitations resulting from a difference between the diffusion coef-

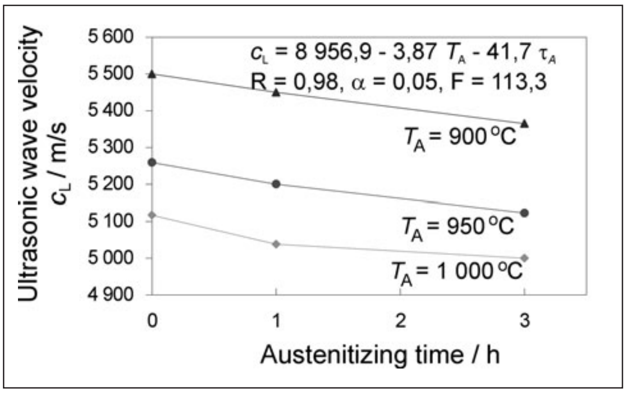

Figure 1 The effect of ductile iron austenitizing temperature and time on the ultrasonic wave velocity c_L

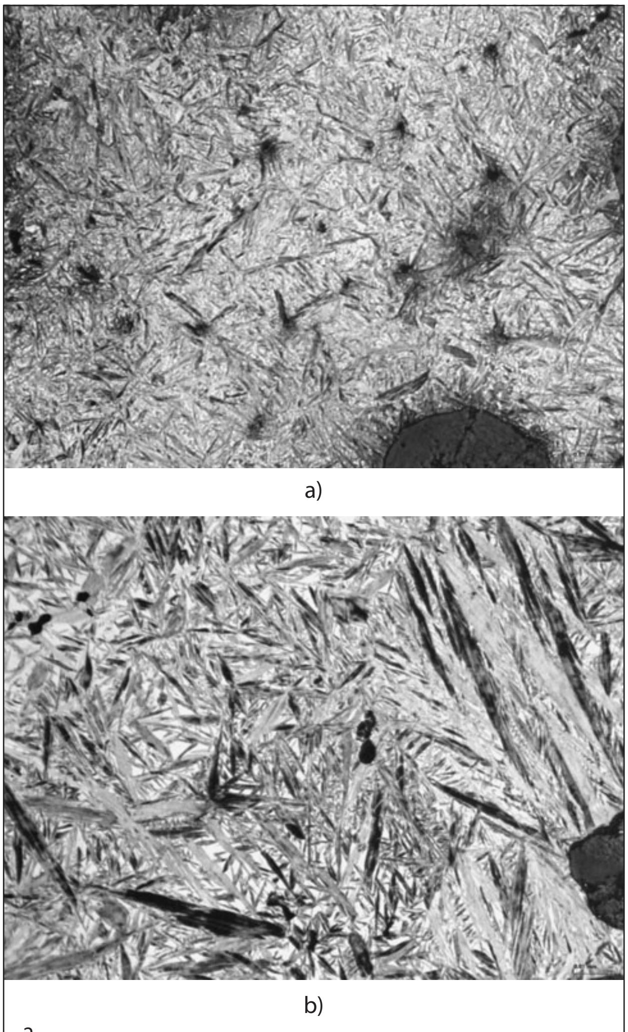

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Figure 2 An example microstructure of ductile iron samples after hardening: a) 900 °C/1 h/oil, b) 1 000 °C/3 h/oil

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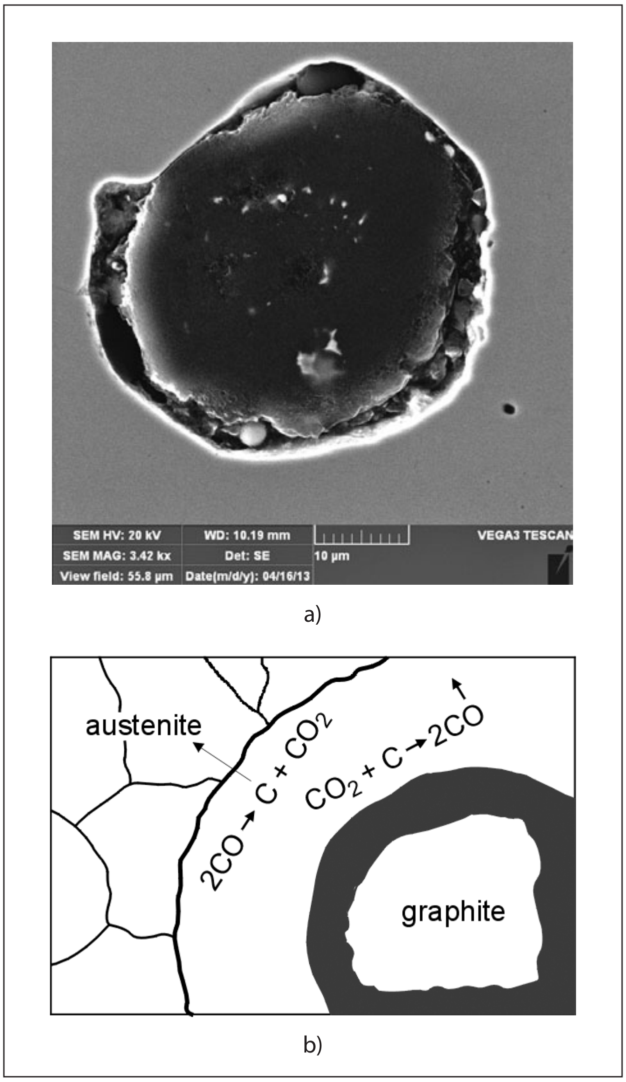

a)

b)

Figure 3 A view of a gap between graphite precipitation and matrix (T_A = 1 000 °C/3 h) - a), transfer of carbon from graphite to matrix in the course of austenitizing - b)

ficient of carbon and self-diffusion coefficient of iron values of which, for instance, at 950 °C are 1,8 $\times 10^{-7}$ cm^2/s and 7,3 $\times$ 10^{-13} cm^2/s, respectively. As the result, microporosity of the cast iron increases. Appearance of micro-discontinuities in the material results in turn in extension of the path that must be covered by ultrasonic wave in view of the increased number of reflections occurring at boundaries of the discontinuities when the wave travels along the casting material.

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Note: J. Snakowski is responsible for English language, Rzeszów, Poland