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Microstructure and mechanical properties of austempered ductile iron with different strength grades

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ABSTRACT

Austempered ductile irons (ADIs) with three strength grades were produced successfully by different two-stage heat treatments. The microstructure and mechanical properties of ADIs such as tensile strength, yield strength, elongation and impact toughness were studied. The results show that the strengths of the three grades ADIs well satisfy the requirement of ASTM standard 897M-06 grade 900/650/09, grade 1050/750/07 and grade 1200/850/04. Meanwhile, the ductile and impact toughness of the ADIs are larger than those required by the ASTM standard. The microstructure has obvious influence on mechanical properties and fracture behavior. With the decrease of austempering temperature, yield strength and tensile strength of the ADIs increase, while both the impact energy and elongation of them decrease.

1. Introduction

Austempered ductile iron (ADI) is considered as a new kind of engineering material and exhibits excellent combinations of high strength, ductility, toughness, fatigue strength and wear resistance [1–5].The attractive properties of ADI are related to the unique microstructure that consists of high carbon austenite and acicular bainitic ferrite with graphite nodules dispersed in the matrix [6]. In recent years, it has been applied to many engineering components such as gears and crankshafts [7,8]. Considerable works have also been conducted on microstructural characteristics as well as mechanical properties and the influences of factors such as austempering temperature, austempering time and alloying elements on microstructure and mechanical properties have been investigated [1–3,9–13].

With the development of ADI, standards for ADI have also been published [14]. In ASTM standard 897M-06, there are 6 grades of ADI according to the ultimate tensile strength. In later years, the research and application of ADI have developed rapidly in China and the standard GB/T 24733-2009 has been published in 2009 [15]. However, researches on ADIs are related primarily to the austempering process parameters rather than to the standard ADI strength grade, which can be confusing to the designer of ADI structures [4]. So the microstructure and properties of ADI with different strength grades should be studied in detail to supply useful information for the ADI makers and component designers. In this study, ADIs with three strength grades were produced; the microstructure, tensile tests and impact tests were conducted; the influences of microstructure on mechanical properties and fracture behavior during impact testing were discussed.

2. Experimental procedure

Experimental material and heat treatment: The composition of the ductile iron used in this study was (wt%) 3.70 C, 2.60 Si, 0.19 Mn, 0.62 Ni, 0.20 Mo, 0.61 Cu, 0.013 S, 0.025 P, 0.035 Mg, and balance Fe. The ductile iron was cast in the shape of 25 mm Y-blocks as shown in Fig. 1. In order to obtain ADIs with different strength grades, the cast irons were treated by different heat treatments. The first kind of samples, shortened as ADI1, were austenitized at 910 °C for 120 min and transferred rapidly to a salt bath held at a preselected austempering temperature of 380 °C for 60 min. The second kind of samples, shortened as ADI2, were austenitized at 900 °C for 110 min and austempered at 340 °C for 60 min. The third kind of samples, shortened as ADI3, were austenitized at 910 °C for 150 min and austempered at 300 °C for 120 min. After the heat treatments, samples for microstructure observation, hardness test, tension test and Charpy impact test were taken from the bottom of those blocks as indicated in Fig. 1.

Microstructure: The samples were etched in 4% nital solution at room temperature after being polished, then they were observed by an optical microscope. The graphite morphology was rated for

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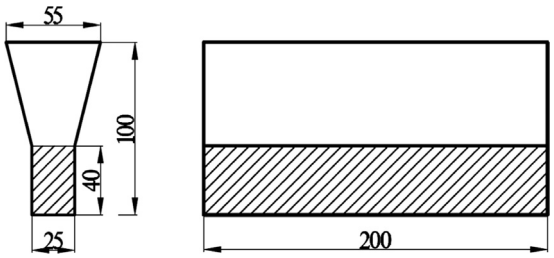

Fig. 1. Dimensions of Y-blocks (unit: mm).

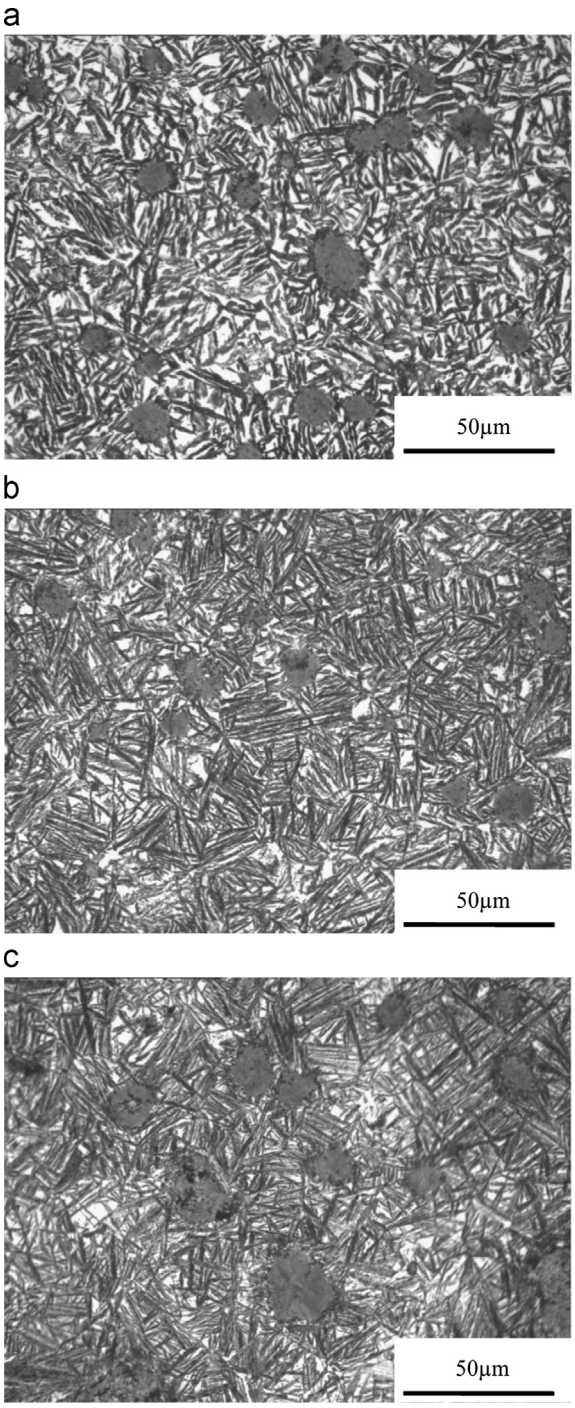

Fig. 2. Microstructures of ADIs observed by optical microscope. (a) ADI1; (b) ADI2; and (c) ADI3.