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Effect of silicon content and defects on the lifetime of ductile cast iron

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Abstract. In this work, the influence of microstructure on the mechanical properties has been studied for different grades of ferritic ductile cast iron. Mechanical tests were carried out and the effect of silicon on the resistance of material was well noticed. An increasing silicon content increases the strength and decreases the ductility of material. The lifetime and endurance limit of material were affected by the presence of defects in material and microstructure heterogeneity. Metallurgical characterizations showed that the silicon was highly segregated around graphite nodules which leads to the initiation of cracks. The presence of defects causes the stress concentration and leads to the initiation and propagation of cracks.

1 Introduction

The evolution of material properties is mainly associated with the changes in microstructure [1-2]. The lifetime of cast iron is often controlled by the propagation of cracks initiated from defects. The purpose of this paper is to present the effect of silicon content and defects on the material resistance to any loading type (static, dynamic or cyclic). The study was focused on a ferritic ductile cast iron which has a good ductility and a very good ability to resist the failure energy. The properties of cast iron are affected by the quantity and the nodularity of graphite nodules, chemical composition, defects, temperature, etc. [1-6]. The most commonly observed defects in the casting materials are the shrinkage, crater, micro cavity, segregations, inclusions and non-spherical graphite nodules which differ in their shape, size, chemical composition and location. The micro-cracks initiated from these defects propagate to a large size before coalescing and forming a major crack which leads to failure.

2 Mechanical characterizations

2.1 Tensile and Charpy tests [1]

Tensile and Charpy tests, carried out at room temperature showed that increasing silicon content in ductile cast iron increased the material tensile strength and decreased its ductility and the impact energy necessary to failure.

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2.2 Fatigue tests

The purpose of fatigue tests was to determine the lifetime and endurance limit of spheroidal graphite cast iron. Tension-compression fatigue tests were carried out using cylindrical specimens of 8 mm of diameter. These specimens were subjected to uniaxial cyclic loading with a load ratio of -1. These tests were carried out at room temperature with a cycle frequency of 20 Hz and applied stress amplitudes varying from 225 to 330 MPa.
Wöhler curves showed that the endurance limit of GJS 600-10 and GJS 500-14 was 302 and 297 MPa, respectively. Fig. 1 presents all results obtained from the ductile cast iron GJS 500-14.

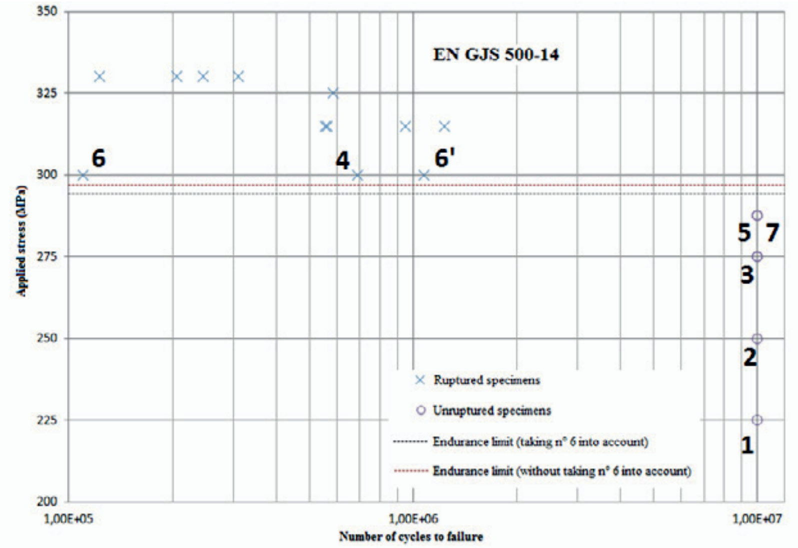

Figure 1. Wöhler curve of cast iron GJS 500-14.

3 Microstructural analysis: Defects and failure modes

We present here the failure mechanism of fatigue and Charpy specimens. The rupture of fatigue specimen n°-6 (Fig. 1) was largely premature. The analysis of its rupture surface (Fig. 2) showed an important agglomerate of graphite in the area of crack initiation. We could also determine the percentage of brittle failure (zone surrounded by the green line (Fig. 2)).

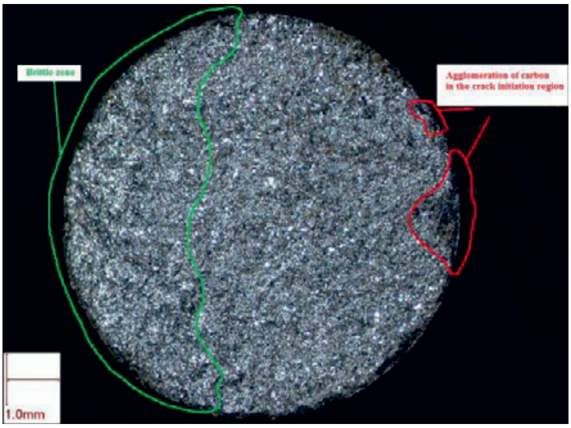

Figure 2. Rupture surfaces of fatigue specimen n° 6 (Fig. 1).

The analysis of failure surfaces of Charpy specimens showed two zones: bright (cleavage failure) and darken (ductile failure). Different types of defects (Fig. 3) were identified and many cracks observed at the interface between the ferrite and the graphite nodules were due to the segregations of silicon. In fact, the applied load causes the displacement of dislocations (microplasticity) [6] and initial deformations concentrate at the graphite nodules–matrix interface. The weakness of cohesion and the elimination of bonding forces decrease mechanical properties and cause the brittle fracture of material.

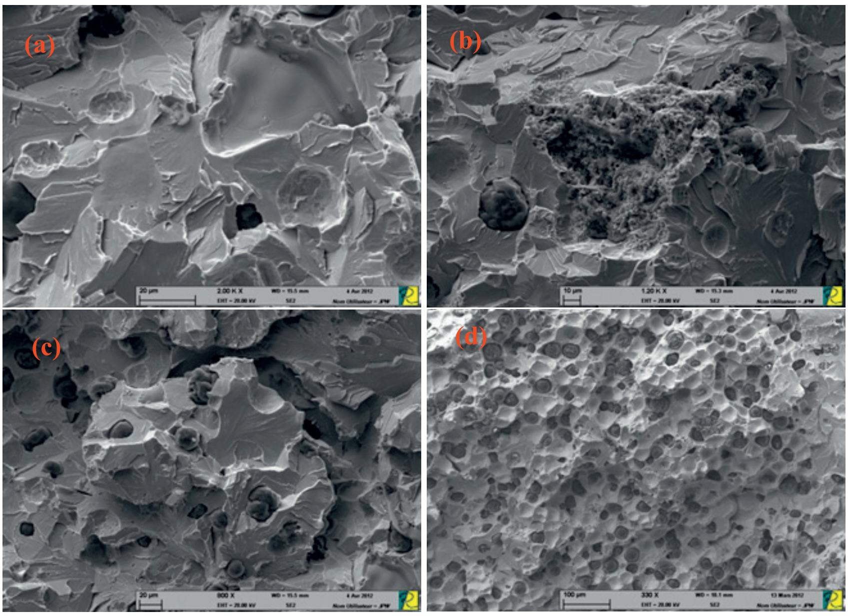

Figure 3. Different defects in ductile cast iron (Shrinkage (a) and crater (b)) and failure modes: brittle cleavage fracture (a,b,c) and ductile intergranular failure (d) (GJS 600-10, non-notched Charpy samples).

4 Conclusions

We studied the influence of silicon and defects on the mechanical properties of ferritic ductile cast iron. We found that increasing silicon content in ductile iron increased the material tensile strength, decreased its ductility and the impact energy necessary to failure and changed little the endurance limit. The worse behavior of some specimens was due to the defects presented in iron as well as the silicon highly segregated around graphite nodules which favorites the brittle cleavage fracture.

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