ARTICLE IN PRESS

Engineering Fracture Mechanics xxx (2016) xxx–xxx

Contents lists available at ScienceDirect

Engineering Fracture Mechanics

journal homepage: www.elsevier.com/locate/engfracmech

Influence of the graphite elements morphology on the fatigue crack propagation mechanisms in a ferritic ductile cast iron

Francesco Iacoviello *, Vittorio Di Cocco

Università di Cassino e del Lazio Meridionale, DiCeM, via G. Di Biasio 43, 03043 Cassino, FR, Italy

ARTICLE INFO

Article history:
Received 7 January 2016
Received in revised form 15 February 2016
Accepted 14 March 2016
Available online xxxx

Keywords:
Ferritic ductile cast irons
Fatigue crack propagation
Degenerated graphite elements

ABSTRACT

Ductile cast irons (DCIs) are commonly considered as really interesting materials, due to their interesting combination of mechanical properties and technological peculiarities. Characterized by the high castability that is a cast irons technological peculiarity, DCIs are characterized by a very interesting combination of good mechanical properties (e.g., tensile strength and fatigue resistance). These properties are strongly influenced by the DCIs microstructure, that is defined both by the matrix (considering the morphological peculiarities like phases distribution, grain dimension, etc.) and by the graphite nodules elements, that are characterized by shape, dimension and distribution. In addition, the presence of defects (like pores, both micro and macro) can strongly affect the DCIs mechanical behaviour (e.g., considering large castings).

In this work, a ferritic DCI with degenerated nodules was obtained and the fatigue crack propagation resistance was investigated by means of fatigue crack propagation tests and compared with the behaviour of a commercial ferritic DCIs.

1. Introduction

Due to the interesting combination of mechanical and technological properties, ductile cast irons (DCIs) are widely used for different applications. Heavy section wind turbine components, railway brake discs, crankshaft, wheels, gears, pumps, valves, pipes are only a few examples of DCIs industrial applications [1–3]. Although the DCIs were discovered in 1948 with the aim to obtain a sort of "malleable iron" avoiding the necessary long (and expensive) heat treatments that characterize the malleable grades, in the last decades different chemical compositions and heat treatments have been optimized in order to obtain different matrix microstructures and to control the graphite nodules morphological peculiarities. The highest performances are obtained by means of a "austempering" heat treatment which involves the nucleation and growth of acicular ferrite within austenite, where carbon is rejected into the austenite. The resulting microstructure of acicular ferrite in carbon-enriched austenite is called "ausferrite" and it allows to obtain yield strength, toughness and impact resistance values that are comparable to many cast/forged steels, vibration dampening and heat transfer superior to other ferrous/non-ferrous alloys and an increased fracture and fatigue strength. On the other hand, the risk to obtain a degeneration of the graphite nodules shape during the heat treatment, with the consequent influence on the mechanical properties, is not negligible. In addition, many other defects can be observed in DCIs. Here follows a non standardized list [4] and some examples focused on graphite elements are shown in Figs. 1–5:

* Corresponding author.
E-mail addresses: iacoviello@unicas.it (F. Iacoviello), v.dicocco@unicas.it (V.D. Cocco).

http://dx.doi.org/10.1016/j.engfracmech.2016.03.041
0013-7944/© 2016 Elsevier Ltd. All rights reserved.

Please cite this article in press as: Iacoviello F, Cocco VD. Influence of the graphite elements morphology on the fatigue crack propagation mechanisms in a ferritic ductile cast iron. Engng Fract Mech (2016), http://dx.doi.org/10.1016/j.engfracmech.2016.03.041

Nomenclature

DCI	ductile cast irons
COD	crack opening displacement
ΔK	stress intensity factor variation
P_{max}	maximum load
P_{min}	minimum load
R	load ratio

- Carbides, due to different causes, with a key role played by the presence of carbide promoting elements such as Mn, Cr, V, Mo, and by a rapid cooling rate, Fig. 1.
- Chunky graphite, due to an excess of rare earth additions, Fig. 2.
- Compacted graphite, mainly due to low residual magnesium and/or rare earth (high temperatures or long holding time), Fig. 3.
- Exploded graphite, mainly due to an excess of rare earth additions, Figs. 2 and 4.
- Gas holes, that can be due to many causes (e.g., melting procedures).
- Graphite flotation, which potential causes can be high carbon equivalent, excess of pouring temperature, slow cooling rate in thicker sections or an insufficient inoculation.
- Irregular graphite, due to high holding and/or long holding temperature or to a poor inoculation.

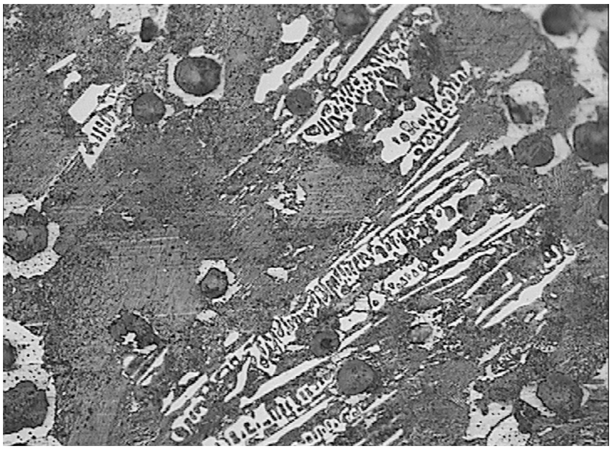

Fig. 1. Carbides in DCIs (500×).

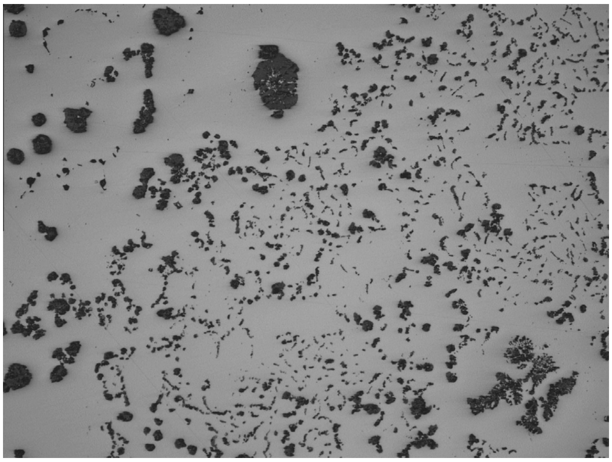

Fig. 2. Chunky and exploded graphite (100×).

Please cite this article in press as: Iacoviello F, Cocco VD. Influence of the graphite elements morphology on the fatigue crack propagation mechanisms in a ferritic ductile cast iron. Engng Fract Mech (2016), http://dx.doi.org/10.1016/j.engfracmech.2016.03.041