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Austempered Ductile Iron (ADI)
Alternative material for high performance applications

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ADI grades are standardized and the requirements of current international standards (EN 1564-12 / ASTM A897-15) are given in terms of conventional mechanical properties.
Nevertheless, these properties don't show the real potential of the ADI grades. In order to promote the use of ADI parts in place of other materials, this work proposes a comparison between ADI 900 and ADI 1200 grades, both in terms of conventional and advanced mechanical properties, employing stress intensity factors and critical CTODs (Crack Tip Opening Displacement).
This study is completed with mechanical fatigue testing, so that it can be shown that the service life of ADI parts is comparable to that given by other heavier and more expensive options.

Keywords: *Austempered Ductile Iron, ADI, fracture mechanics, fatigue, alternative materials.*

1. Introduction

Conventional mechanical testing is adequate for structural integrity calculations with ductile materials under plane stress conditions. When designs involve high strength materials, plane strains are more likely to occur and both fracture mechanics and fatigue become more relevant. This is the case for ADI and in this paper the characterization of two representative grades has been investigated.

2. Experimental method

All the materials in the tests planned have been processed in industrial facilities and under production conditions. It has been checked if the "as cast" materials are capable of reaching GJS-900-8 and GJS-1200-3 grades and, after austempering, a broad mechanical characterization has been performed.

All tests have followed European EN standards, except for fracture testing (BS) and uniaxial fatigue (ASTM).

3. Results and discussion

3.1 "As cast" condition

The study materials have been obtained from 22 one-inch thickness type Y2 keel-blocks from the same heat. The "as cast" condition fulfils the requirements for a proper austempering treatment.

Table 1 Chemical composition (%)

C	Si	Mn	Mg	Ni	Mo	Cu
3.69	2.28	0.19	0.037	2.45	0.20	0.79

Table 2. Mechanical properties "as cast".

Hardness (HB10/3000W)	273					
Tensile testing	$R_{p0.2}$ (MPa)		R_m (MPa)			A (%)
	625		852			4.7
Impact testing	KV (J)			Unnotched (J)		
	5	5	5	39	34	37

Table 3 Microstructure.

Nodularity (%)	Graphite density (nod./mm^2)	Ferrite/pearlite ratio
>90	200	20/80

3.2 Austempering

The samples are machined to obtain two sets of specimen pre-shapes, with a minimum machining clearance of 2 mm. Austempering is performed under controlled atmosphere with a carbon potential of 0.8 during austenitization and inert gas protection during the transfer to the isothermal bath. After heat treatment, pre-shapes are machined to standard testing specimens and it is verified that one set of specimens has been obtained for each grade GJS-900-8 and GJS-1200-3.

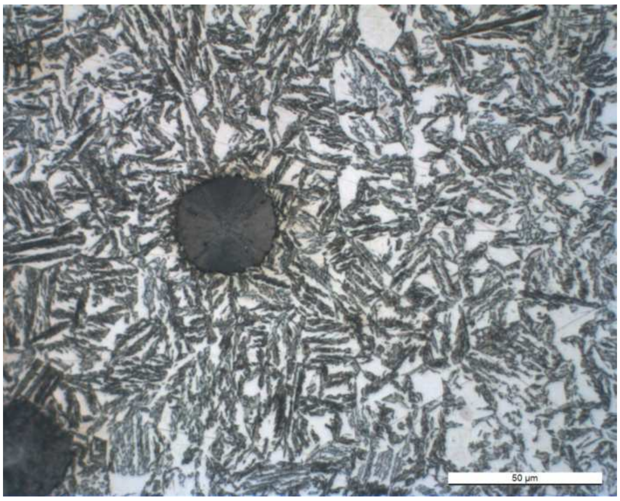

Fig. 1 GJS-900-8 microstructure.

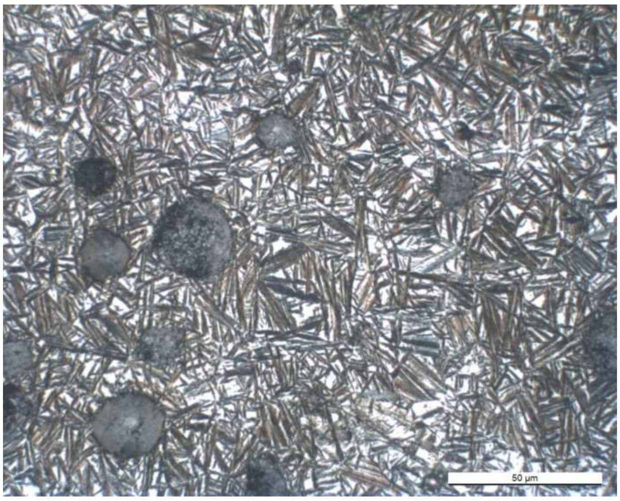

Fig. 2 GJS-1200-3 microstructure.

Table 5 GJS-900-8 mechanical properties.

Hardness (HB10/3000W)	314					
Tensile testing	$R_{p0.2}$ (MPa)		R_m (MPa)		A (%)	
	622		963		10.4	
Impact testing	KV (J)			Unnotched (J)		
	8	9	9	105	99	106

Table 6 GJS-1200-3 mechanical properties.

Hardness (HB10/3000W)	397					
Tensile testing	$R_{p0.2}$ (MPa)		R_m (MPa)		A (%)	
	1035		1260		9.8	
Impact testing	KV (J)			Unnotched (J)		
	7	7	8	104	102	94

BS7448-1 B(E) specimens with a 12.5x25 mm section have been employed for toughness testing. All fractures have shown an elastic-plastic behavior, despite the plasticity being small.

Table 7 Toughness testing.

Grade	K_Q (MPa·m$^{1/2}$)	δ_c (mm)
GJS-900-8	50.3	0.05
GJS-1200-3	63.7	0.05

Fatigue curves have been built for an average stress σ_m equal to half $R_{p0.2}$ of the grade tested. Loading amplitude $\Delta\sigma$ ranged from 50% to 100%·$R_{p0.2}$.

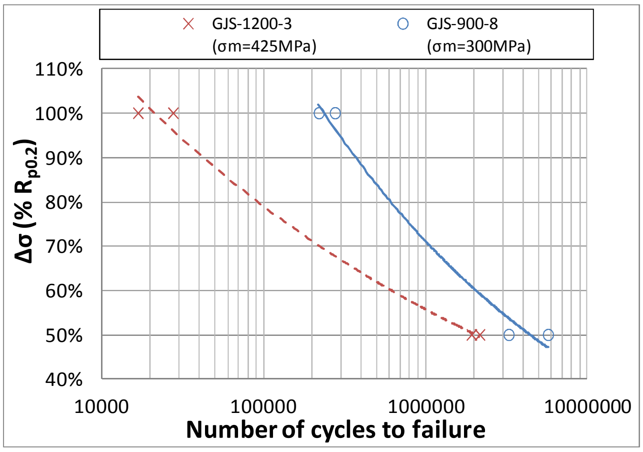

Fig. 3 S-N fatigue curves.

4. Conclusions

GJS-900-8 and GJS-1200-3 grades develop plastic crack tip blunting for the studied thickness.

The obtained fatigue curves point to service lives that are higher than the reference values given in the European Standard.

The range of applications where ADI grades become an alternative material to current solutions is extended when design calculations take into account fracture and fatigue criteria.

Acknowledgements

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