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Advanced Properties of Ausferritic Ductile Iron Obtained in As-cast Conditions

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Abstract

In previous studies the process parameters to obtain ausferritic ductile iron in as-cast conditions by means of engineered cooling were defined, that is without an austempering heat treatment. It was demonstrated that obtaining fully ausferritic microstructures by means of engineered cooling was feasible and that the properties met the requirements of the conventionally produced austempered ductile iron (ADI).

Keywords: *As-cast ausferrite, Fatigue, Corrosion, Mechanical properties, Impact resistance, Three-point bending test.*

1. Introduction

Austempered ductile iron (ADI) has an excellent combination of high resistance, good ductility and high fatigue strength [1, 2]. With the aim of improving production sustainability, a new process based on “engineered cooling” was developed to reduce the energy consumption during the production cycle [3, 4].

The aim of this work is to carry out an advanced characterization of the materials produced according to this alternative methodology and compare them with the properties cited in the literature or standards for conventional ADI processes in terms of low temperature, dynamic mechanical properties and corrosion behavior.

2. Experimental Details

2.1 Material

Three ductile iron melts were prepared in a medium frequency induction furnace to obtain standard keel blocks Y2 as per EN1563. The preparation method is described in details elsewhere [5].

The shake out temperature was 800ºC and three different isothermal transformation temperatures, 400, 350 and 300ºC (AUS-40, AUS-35, AUS-30) were chosen to compare the properties achieved with upper and lower ausferritic microstructures.

2.2 Tests

The static mechanical parameters measured were the ultimate tensile strength (U.T.S.), yield strength (Y.S.), elongation (E.), Brinell hardness (HB) and impact energy at 20ºC and -20ºC. Three-point bending experiments were conducted at the same temperature conditions, and fatigue tests were performed to build a Wohler diagram with a ratio $S_{min}/S_{max}=0.1$ and 20Hz in frequency. Corrosion behavior of the specimens was evaluated using electrochemical and weight loss methods in 0.03M NaCl solution.

3. Results and Discussion

The chemical composition of the three batches is shown in Table 1. Mo and Ni contents were added to avoid the pearlitic nose.

Table 1 Chemical composition (wt.-%)

Test	C	Si	Mn	Mg	Mo	Ni	Cu
AUS-40	3.61	2.10	0.15	0.044	0.21	2.80	0.04
AUS-35	3.61	2.02	0.16	0.054	0.33	2.84	0.03
AUS-30	3.52	2.10	0.17	0.045	0.22	2.87	0.06

The microstructures consist of ferrite needles (α) in a stabilised high carbon austenite (γ_{HC}) matrix (ausferritic microstructure) with nodular graphite: broad ferrite needles of upper ausferritic microstructure for isothermal transformation temperature of 400 ºC and very fine needles of ferrite for isothermal transformation temperature of 300 ºC Samples treated at 350 ºC present a mixture of both structures.

The values of the static mechanical properties are shown in Table 2 and fulfill the standards of the conventional ADI materials (UNE EN 1564).

Table 2 Static mechanical properties of the engineered cooled samples.

Property	Average values		
	AUS-40	AUS-35	AUS-30
Y.S.(MPa)	573	666	676
U.T.S.(MPa)	830	869	974
E.(%)	10.6	6.2	6.4
HB	273	289	312
Charpy at 20 ºC	12/10/11	12/13/13	9/9/12
Charpy at -20 ºC	7/8/8	8/8/8	9/9/8

Regarding the fatigue tests results, Fig. 1 shows a Wohler diagram that was plotted comparing the results from the AUS-40 and AUS-30 materials.

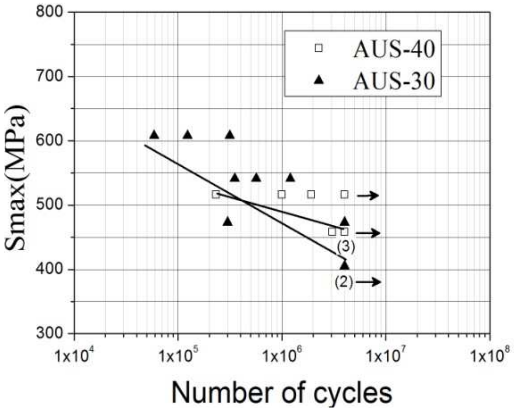

Fig. 1. Fatigue response of AUS-40 and AUS-30.

The results of the bending tests are shown in Fig. 2. All specimens present the same behavior: the load reaches a maximum and then the sample breaks suddenly which indicates that the fracture initiation is of brittle nature.

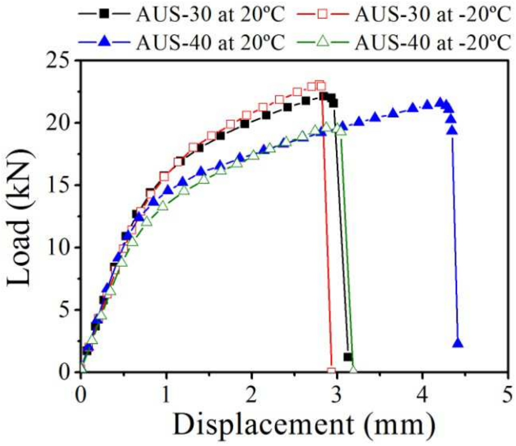

Fig. 2. Load-displacement curves of the bending tests.

The corrosion behavior of samples tested for the 300 and 400 ºC isothermal transformation temperatures is similar in terms of E-t answer but it can be seen that higher isothermal transformation temperatures shift the corrosion potential to the anodic direction. Besides, AUS-30 corrodes quicker than AUS-40 due to its higher I_{corr} value.

The behavior of the weight loss test agrees with the results of the electrochemical results tendency.

Conclusions

Based on the results obtained in this work, the following conclusions have been drawn:

- The material obtained by means of engineered cooling met the requirements of conventional ADI.
- The material AUS-40 presents a higher fatigue limit than the AUS-30 material.
- The bending tests show that the AUS-40 presents a higher displacement for the same applied load, but the maximum load is lower than in the case of the material tempered at 300 ºC.
- The effect of lowering the temperature in terms of impact and bending resistance is significant for the samples tempered at 400 ºC, while the ones tempered at 300 ºC are slightly affected.
- Upper ausferrite microstructure is shown less active than lower ausferrite in terms of corrosion behavior in NaCl.

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