Journal of Materials Processing Technology 220 (2015) 251–256

Contents lists available at ScienceDirect

Journal of Materials Processing Technology

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

Surface layer inoculation of a sand cast hypoeutectic gray iron melt

Sebastian F. Fischer[a,*], Hergen Groß[a], Andreas Bührig-Polaczek[a], Matthias Bünck[b]

[a] Foundry-Institute, RWTH Aachen University, Intzestrasse 5, 52072 Aachen, Germany
[b] Access e.V., Intzestrasse 5, 52072 Aachen, Germany

ARTICLE INFO

Article history:
Received 13 October 2014
Received in revised form 13 January 2015
Accepted 29 January 2015
Available online 7 February 2015

Keywords:
Cast iron
Gray iron
Surface layer metallurgy
Inoculation

ABSTRACT

A suspension containing a powdered inoculating agent was developed and sprayed onto the surface of the sand mold's cavity prior to casting. Metallographic examinations and Brinell hardness measurements show that by this method an inoculated microstructure containing mainly type A graphite can be reproducibly achieved from an untreated hypoeutectic gray iron melt. This effect can be shown in the whole specimen and is statistical significant in the focused specimens regions next to the surface and center. An inoculating agent's powder size of 100–200 μm is most suitable to achieve a large amount of type A graphite and homogeneous low Brinell hardness.

1. Introduction

Gray iron is inoculated to nucleate flake graphite and to obtain a stable eutectic structure which is free from carbides or ledeburite. Riposan et al. (2013) showed that by employing inoculation, the eutectic undercooling and recalescence are reduced leading to a decreased chill tendency and thus to a decreased presence of free carbides. These free carbides have to be avoided because they severely deteriorate the machinability of cast iron.

Chisamera et al. (2009) showed that inoculation affects the morphology of the eutectic graphite and, hence, the heat conductivity and the mechanical properties, as well. Loper (1999) gives an overview in his paper of the relation between the undercooling and the graphite structure: The preferred A-type graphite (DIN EN ISO 945-1): characterized by short, stubby, randomly orientated, and uniformly distributed graphite flakes, results from a lower degree of undercooling due to a sufficient inoculation treatment. With moderate undercooling, the graphite appears as a rosette with fine graphite in the center of the eutectic cell surrounded by coarser graphite flakes (B-type). With considerably more undercooling, D-type graphite is randomly precipitated in interdendritic regions.

According to Riposan et al. (2010), for flake graphite, inoculation mainly improves those micro-inclusions already existing in mean to high sulfur containing iron melts rather than creating new compounds, which act in combination with manganese and sulfur as nuclei. It has been demonstrated by Riposan et al. (2003), that the graphite flake nucleus consists of a (Mn,X)S-type particle surrounding a complex oxide.

The success of the melt treatment depends on the inoculation agent's chemical composition, the amount of the added agent and the time at which the agent is added relative to the melt processing time. Chisamera et al. (2011) showed that the treatment using FeSi-agents containing Ca and Ba decreases the eutectic undercooling and thus the amount of primary austenite dendrites and also the dendrite lengths in gray cast iron. According to Ruff and Wallace (1976), the use of Al and Ti leads to an increased number of nuclei for austenite which results thus in an increased amount of primary austenite. Regarding the influence of the agent's quantity added to the melt, Huerta and Popovski (2005) state that an inoculation over-treatment leads to irregular graphite shapes, slag defects and micro-shrinkage. In addition to this, over-inoculation excessively increases the production costs.

Due to fading of the inoculation effect, Riposan et al. (2013) suggest that the inoculation of the iron base melt should be conducted as short as possible before the casting process. The experiments of Huerta and Popovski (2005) demonstrated that the effect of inoculant fade is rapid and can occur within the first 2–6 min after inoculation. The so called late in-mold inoculation is an appropriate method to counteract the effect of inoculation fading. For this, sintered or cast blocks made from an inoculation agent are put in the drag prior to casting. By using late in-mold inoculation, Chisamera et al. (2008) were able to obtain complete inoculation of a synthetic cast iron melt possessing a low sulfur level of 0.02 wt.% and a carbon-equivalent of 3.9%. However, the costs of these inoculation blocks are two to three times higher

* Corresponding author. Tel.: +49 241 80 96790; fax: +49 241 80 92276.
E-mail address: s.fischer@gi.rwth-aachen.de (S.F. Fischer).

http://dx.doi.org/10.1016/j.jmatprotec.2015.01.029

Table 1
Chemical and physical properties of the used inoculation agent.

Si (wt.%)	Ba (wt.%)	Ca (wt.%)	Al (wt.%)	Fe	Density (g/cm^3)	Melting temperature (°C)
72–78	2–3	1–2	Max 1.5	Rest	3.1	1325

Table 2
Characteristics of the used inoculation suspensions.

Suspension no.	Grain size (μm)	Amount (g)	Agent's amount on mold surface (g)	Agent's amount per step wedge (wt.%)
1	≤50	60	2.64 ± 0.68	0.14 ± 0.04
2	≤50	80	4.04 ± 0.76	0.21 ± 0.04
3	100–200	60	3.68 ± 1.00	0.19 ± 0.05

than the costs of conventional granular inoculation agents which are used for the so-called pouring stream inoculation method.

In the present work the so-called surface layer metallurgy was applied to realize a cost effective and flexible inoculation of a hypoeutectic gray iron melt. In his Ph.D. thesis Helling (1995) showed that the application of the surface layer metallurgy is a promising method to realize die casting of ductile iron. For this, a water-based suspension containing a powdered inoculation agent was developed and sprayed onto the mold cavity's surface prior to casting. The powder is a residue from the production of conventional agents. Until now, these powders find no direct or profitable application thus making them highly available and very cheap. In the present paper, the impact of this method on the microstructural and mechanical properties of a sand cast hypoeutectic gray iron containing very low silicon (1.29 wt.%) and sulfur (0.007 wt.%) contents and a carbon equivalent (CE) value of 3.7% was investigated by means of metallography and hardness measurements.

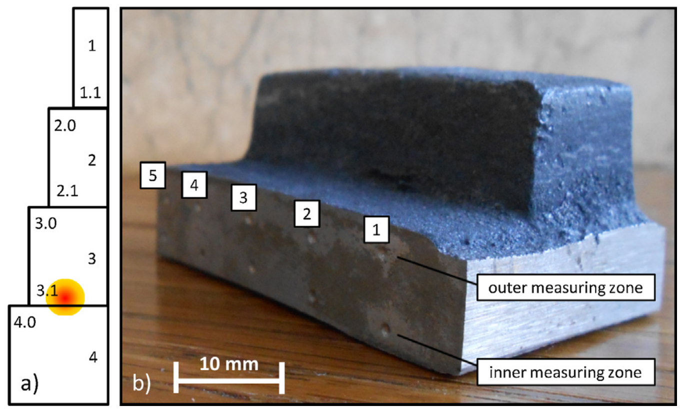

Fig. 1. (a) Step wedge (200 mm × 50 mm; step height: 10–40 mm) and sampling positions (steps 1–4, metallographical sections 1.1–4.0) and the last point of solidification. (b) Position and description of the hardness measurements at a separated sample.

2. Experimental procedure

The inoculation suspensions used consisted of 37 g water: as a carrier material, 3 g polymeric suspension agent and a grain-classified agent (≤50 μm or 100–200 μm, Table 1). To investigate the effect of the agent's grain size and amount on the inoculation of a cast iron melt, different suspensions were prepared (Table 2) and tested. During all sand mold preparations, the suspensions were manually sprayed at same pressure, spraying angle and distance to the surfaces for always 2 s to ensure comparability. To determine the sprayed inoculation agent's quantity, paper sheets were sprayed equally and weighed before spraying and after drying. As pattern a 4-stepped wedge (200 mm × 50 mm) was chosen to reveal the influence of the cooling rate on the suspensions' inoculation effect. The steps vary in height between 10 and 40 mm (Fig. 1a). Each sand mold (recirculated green sand, 8 wt.% bentonite, 1.5 wt.% lustrous carbon producer, 50% compressibility) contained two step wedges. Per suspension setting (Table 2), two step wedges were produced and an additional one without agent as reference specimen from the same melt.

After coating the sand molds with the suspensions, pig iron, steel scrap, and FeSi75HP were melted in a graphite crucible using a 50 kg induction furnace, and cast, following a 5 min holding time at 1500 °C and deslagging, in the prepared molds at a temperature of approx. 1350 °C. The spectrometrically measured chemical composition of the melt is given in Table 3. The silicon and sulfur content was set at a low level to obtain adverse inoculation conditions.

Table 3
Chemical composition of the untreated cast iron melt in wt.%.

C	Si	P	S	Mn	Al	Ti	Cu	CE (%)
3.24	1.29	0.008	0.007	0.16	0.006	0.012	0.06	3.7

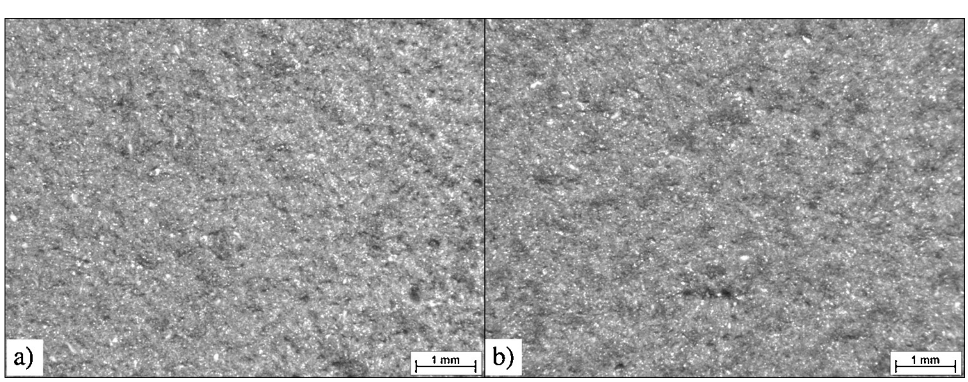

Fig. 2. Stereo microscope images of the sand blasted surfaces of the (a) suspension 3 treated and (b) untreated specimen.