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Solubility of Hydrogen and Nitrogen in liquid cast iron during melting and mold filling

Attila Diószegi[1], Jessica Elfsberg[2] and Zoltán Diószegi[3]
[1] Materials and Manufacturing - Foundry Technology, Jönköping University, SE-551 11, Jönköping, Sweden
[2] Scania CV AB, SE-151 87 Södertälje, Sweden
[3]Volvo Group Trucks Operation, SE-541 87 Skövde, Sweden

Defect formation like gas- and shrinkage porosity at cast iron component production is related to the content of gaseous elements in the liquid metal. The present work investigate the solubility of hydrogen and nitrogen in liquid iron aimed for production of lamellar and compacted graphite cast iron. The used methods and instruments are a combination of commercial measuring devices and novel experimental assemblies for measuring solubility of hydrogen and nitrogen during melting and mold filling of a complex shaped cast component. The obtained results reveal the role of the charge material and the mold filling on the solubility of the investigated elements.

Keywords: *gas porosity, shrinkage porosity, lamellar cast iron, compacted graphite cast iron, hydrogen, nitrogen.*

1. Introduction

Hydrogen and Nitrogen are two important elements solved in liquid cast iron influencing the formation of gas- and shrinkage porosity formation [1]. Previous investigations indicate that the solubility of hydrogen and nitrogen is temperature dependent with a remarkable lowering of solubility at solidification and transformation from liquid to solid state [2]. Investigations in different iron foundries, performed under various production conditions, indicate that the content of hydrogen and nitrogen in the liquid iron is well below the solubility limit of hydrogen respective the nitrogen in solid state [3]. Liquid iron prepared for compacted iron production have a lower level of solved H and N than liquid iron aimed for production of lamellar graphite iron. Mold filling experiments of artificial cast samples in combination with measurement of gas content were indicating increase of the hydrogen and nitrogen content during the mold filling as a function of the average velocity of the liquid metal in the gating system [4]. The research question of the present work is how the mold filling influence the hydrogen and nitrogen content of the liquid iron at casting a complex shaped automotive cast component.

2. Experimental procedure

2.1 Experimental setup of a complex shaped cast component

An experimental setup according to Fig. 1 and Fig. 2 was created to measure the hydrogen and nitrogen concentration in the liquid iron after filling a complex shaped automotive cast component. In the top of the mold cup the yellow surface indicate where the liquid metal is poured into the mold cavity while the purple colored cylindrical volume indicate where the liquid iron was collected for measurement after passing the mold cavity.

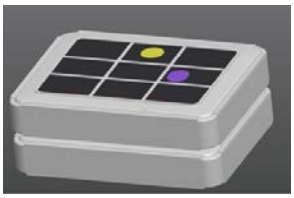

Fig.1 Molding box

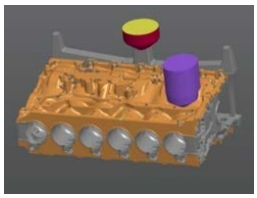

Fig.2 Mold cavity

2.2 Experimental description

The mold box presented in Fig.1 was molded on a Künkel-Wagner molding line in green sand and the quartz sand made internal cores were hardened by epoxy harts. The cylindrical cavity aimed for the direct measurement of hydrogen and the collection of samples for nitrogen measurement was drilled in the cope. Liquid metal melted in an induction furnace were transferred to a pouring ladle before casting. At casting the compacted graphite iron the induction melted base iron was transferred to a special ladle where a standard Mg treatment was performed prior casting. Melt temperature measurement, direct hydrogen measurement and collection of samples for nitrogen measurements were performed in the pouring ladle before casting and in the cylindrical cavity above

the casting after the mold filling. Experiments casting lamellar graphite iron was repeated five times while compacted graphite iron were cast four times.

2.3 Experimental instruments used for measuring the concentration of the solved gaseous elements in liquid iron.

Hydrogen concentration were measured using the measurement system HYDRIS from Heraeus Electro-Nite based on immersing a measuring unit into the liquid metal. The detailed measuring principle is described in the Multi-Lab Hydris Operational and Instruction Manual [5]. Nitrogen concentration was measured by an OE spectrometer ARL 3460 on specimens collected by SaF400P6 samplers from Heraeus Electro-Nite.

3. Experimental results

The measured hydrogen content is presented in Tab. 1 which indicate an average low level of hydrogen in the ladle, below the hydrogen solubility in austenite (4 ppm) [3] for both LGI and CGI production. The hydrogen increase after pouring varies from 22% to 116% at casting LGI and from 26% to 153% at casting CGI, approaching the solubility limit in solid state. The main source of the increased hydrogen is the humidity in the molding material and the absorption mechanisms has, in an earlier work, been demonstrated to be the extended interface between the liquid iron and the gases filling the mold cavity [4].

Table 1. Measured hydrogen levels (ppm).

Sample	LGI		CGI		Hydrogen solubility in austenite [3]
	Ladle	Mold	Ladle	Mold	
1.	1,8	3,65	1,5	1,9	
2.	2	2,45	1,3	3,1	4
3.	1,8	2,45	1,2	3,2	
4.	1,7	2,55	1,3	3,3	
5.	1,8	3,9			

The measured nitrogen content is presented in Tab. 2 indicating an average high level of nitrogen already in the ladle at LGI production. After pouring the nitrogen content exceeds the nitrogen solubility limit in austenite (90 ppm) [3]. At production of CGI the nitrogen content remains at about 65% of the solubility limit and no significant change in the nitrogen content can be observed after mold filling.

Table 2. Measured nitrogen levels (ppm).

Nitrogen measurement					
Sample	LGI		CGI		Nitrogen solubility in austenite [3]
	Ladle	Mold	Ladle	Mold	
1.	84	92	61	59	
2.	86	96	62	58	90
3.			62	66	
4.			71	67	

Comparing the results, lower level of both hydrogen and nitrogen at melting iron aimed to CGI production is attributed to the cleaner charge content including returned CGI and SGI chips and pig iron. The increase of hydrogen is significant during the mold filling independent on the type of liquid iron. Local segregation of hydrogen and nitrogen can easily exceed the solubility limit of those elements in the austenite fulfilling one of the criteria for porosity formation at solidification.

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References

[1] I. L. Svensson, H. Fredriksson: SolidificationTechnology in the Foundry and Cast House; Coventry; England; 15-17 Sept. 1980, pp 376-380.

[2] I.L. Svensson: Solidification Technology in the Foundry and Cast House, Coventry, England, 15-17 Sept. 1980, pp 253-262.

[3] J. Orlenius, L. Elmquist, A. Diószegi: Transactions of the American Foundry Society, Vol. 115, pp. 617-623. 2007.

[4] A. Diószegi, T. Björklind, Z. Diószegi: Key Engineering Materials Vol. 457. pp 422-427. Trans Tech Publications, Switzerland, 2011.

[5] Multi-Lab Hydris Operational and Instruction Manual, Heraeus Electro-Nite AB