Preconditioning of Gray Iron Melts using Ferrosilicon or Silicon Carbide

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ABSTRACT

The scope of the current work is to quantify eventual effects of preconditioner choice on microstructure, mechanical properties and casting performance in gray cast iron melts produced under carefully controlled laboratory conditions. The experimental approach involves preconditioning of gray iron melts, produced according to the same charging/time and temperature/time program, with either high purity ferrosilicon (HP-FeSi), standard ferrosilicon (Std. FeSi), abrasive grade silicon carbide (Abr. SiC) or metallurgical grade silicon carbide (Met. SiC) as the preconditioning agent.

In general there are only minor differences in microstructural features and mechanical properties in the experimental irons produced using the four different preconditioning agents. The carbon and silicon yield was found to be lowest for the irons produced with the abrasive grade SiC and highest for the irons produced using standard grade FeSi. The amount of graphite in thick section size specimens was found to be highest in the irons produced with metallurgical grade SiC and lowest in the irons produced with standard FeSi. In thin section specimens the amount of graphite was highest in the irons produced with FeSi and lowest in the irons produced with SiC. All examined thick plate specimens had type A graphite, size 3, with some minor type D graphite areas. The graphite was also mainly type A, size 4, in the thin plate specimens, small areas of type B and type D graphite were also present. The eutectic cell number is slightly higher in the irons produced with SiC than in those produced with FeSi.

INTRODUCTION

In cast iron carbon precipitates during solidification by a eutectic reaction either as the thermodynamically stable graphite phase (gray iron) and/or the metastable cementite phase (mottled or white iron). Whether the stable or the metastable phase forms depends on the nature and treatment given to the liquid, in particular, its graphitization potential, preconditioning, inoculation treatment and cooling rate. The achievement of the required properties in all cast irons, both as-cast and heat treated, depends largely upon adequate control of temperature, chemical composition and metal processing. This control, in turn, is primarily determined by the correct choice of raw materials for both the initial furnace charge mix and the subsequent preconditioning of the melt. Preconditioning is here regarded as a pretreatment of the gray iron melt in order to increase the response to the subsequent inoculation.(Hugot 1988) Silicon increases the graphitization potential strongly and is always present in higher concentrations in gray irons. Silicon is normally added to the iron during melting either as ferrosilicon or as silicon carbide.

Silicon carbide (SiC) is used as a preconditioning agent in both cupola furnaces as well as in induction furnaces for industrial production of gray cast iron. SiC is claimed to have some specific advantages as compared to other commonly used silicon and carbon sources. These advantages include higher eutectic temperature, higher liquidus temperature, higher number of eutectic grains and lower shrinkage porosity.(Scubert 1984, Venkateswaran 1989, Benecke 1994) Silicon carbide dissolves endothermly in the iron melt at a rate that is slower than that of ferrosilicon which dissolves exothermly.(Benecke 1987, Kimstach 1992, Deng 2000) Benecke and co-workers have shown that metallurgical grade SiC performs better as a preconditioner than does the more pure abrasive grade SiC. They further reported that FeSi did not perform as good as SiC as preconditioner of small (0.5 kg) cast iron melts.(Schubert 1984, Venkateswaran 1989, Benecke 1994, Benecke 1987)

The scope of the current work is to quantify eventual effects of preconditioner choice on microstructure, mechanical properties and casting performance in larger gray cast iron melts (80 kg) produced under carefully controlled laboratory conditions. The experimental approach involves preconditioning of gray iron melts, produced according to the same charging/time and temperature/time program, with either high purity ferrosilicon (HP-FeSi), standard ferrosilicon (Std. FeSi), abrasive grade silicon carbide (Abr. SiC) or metallurgical grade silicon carbide (Met. SiC) as the preconditioning agent. In addition to the eventual effects caused by selection of ferrosilicon or silicon carbide this experimental matrix will also reveal how the changes in purity of the preconditioning agents will influence the properties of the produced gray irons.

MATERIALS AND EXPERIMENTAL PROCEDURE

The experimental gray cast irons were produced in batches of 80 kg using a melt based on 70% steel and 30% recycled iron. The target analysis for the casting experiments was 3.3 %C, 2.0 %Si, 0.75 %Mn and 0.05 %S. Prior to the first experimental cast iron melt a dummy charge was melted in order to preheat the furnace and T-pot ladle. Insulating kaowool plates were kept on the top of the furnace and the ladle at all times during the experiments to limit the heat loss to the surrounding atmosphere. During charging, heating and melting the induction furnace followed the same power-time program as a means to keep the thermal history of the iron as controlled as possible in the "in-furnace" phase. The iron had a temperature of 1500°C when it was poured into the T-pot ladle. The iron was then transferred, in time intervals of 20s and in batches of 15 kg, into insulated cups made of alumino-silicate fibers for inoculation. Inoculant was placed in the cups prior to filling with molten iron. Irons that were not inoculated were also transferred in the same amount into cups in order to maintain similar thermal history in the two cases. After a holding time of two minutes the iron was poured into a sand mould for casting of specimens for metallographic examination as well as into a sand mould for casting of tensile bars. Coin shaped samples for analysis of chemical composition were quenched in a copper mould, after filling of the sand forms, using some of the remaining melt in the inoculation cups. Table 1 gives an overview of the casting experiments performed in the present work.

Table 1. Overview of casting experiments.

		Experiment no.							
		1	2	3	4	5	6	7	8
Furnace	Standard FeSi	x							x
	High Purity FeSi			x			x		
	Metallurgical SiC		x					x	
	Abrasive grade SiC				x	x			
Inoculation cup	No inoculant	1a	2a	3a	4a	5a	6a	7a	8a
	Foundry grade FeSi	1b	2b	3b	4b	5b	6b	7b	8b

RAW MATERIALS AND CHARGE ADDITIONS

Ordinary St37 steel bars with a cross section of 100mm by 100mm were cut into pieces with a weight of 26.5 kg. Two of these bars were used in each furnace charge together with 23 kg iron returns. After charging the furnace with steel and iron returns, ferrosilicon or silicon carbide was added in an amount sufficient to reach the target composition. Desulco graphite was also added to the furnace in order to reach the desired carbon level. Both the silicon source as well as the graphite was added together with the steel and iron returns prior to turning on the furnace power. When the furnace charge was molten a small amount of FeS was added to the melt in order to reach the target sulfur concentration in the iron. Table 2 summarizes the chemical composition of the raw materials used in the experiments.

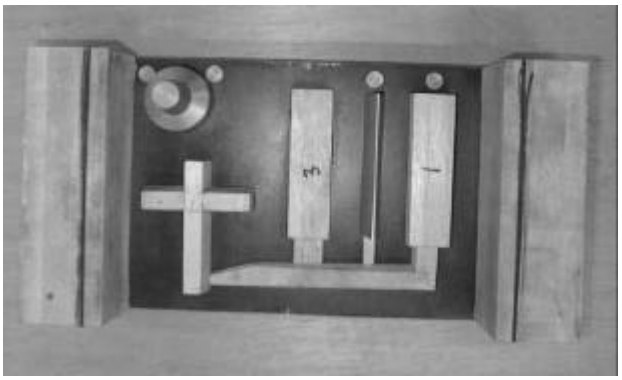
Table 2. Chemical composition of raw materials.

Material	Element (in wt%)								
	C	Si	Mn	P	S	Al	Ca	Ti	Fe
Steel	0.20	0.15	0.6	0.028	0.005	-	-	-	Bal.
Iron returns	3.07	1.18	0.81	0.016	0.016	-	-	-	Bal.
Standard FeSi	0.067	75.0	-	-	-	0.64	0.33	0.086	Bal.
High purity FeSi	-	76.6	0.097	-	-	0.055	0.023	0.016	Bal.
Foundry grade FeSi	-	76.2	0.10	0.010	-	1.14	0.82	0.074	Bal.

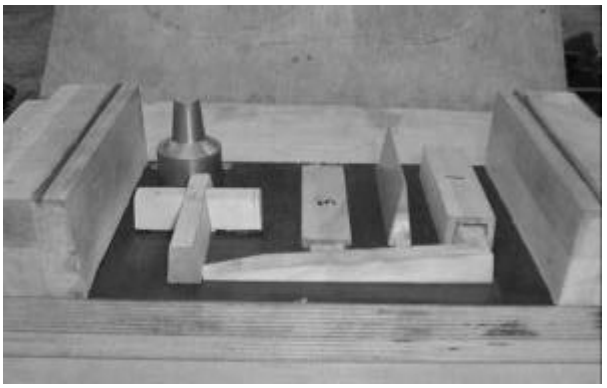
Material	Compound/Element (in wt%)							
	SiC	C	Si+SiO_2	Si	SiO2	Fe2O3	Al2O3	CaO
Metallurgical SiC	85.5	6.5	7	-	-	0.4	0.04	0.05
Abrasive grade SiC	98.5	0.20	-	0.6	0.7	0.09	0.03	0.03

CASTING CONDITIONS

The experimental gray irons were cast into a sand mould to produce one thick plate (90mm long, 25mm wide and 20mm thick), one thin plate (90mm long, 25mm wide and 5mm thick), a standard chill wedge sample, a cross shaped sample (90mm long and 64mm wide) and a cylinder used for machining of tensile test bars. Figure 1 show photos of the model used to produce the mould.



Top view



Side view

Figure 1. Model used to produce moulds for test casting of gray irons.

CHEMICAL ANALYSES

Coin shaped samples for chemical analyses using XRF were quenched in a copper mould using melt remaining in the inoculation cups after casting of the samples for evaluation of the microstructure and mechanical properties. Carbon and sulfur were analyzed using a standard Leco procedure on samples extracted from the outer end of the 20mm thick plate.

METALLOGRAPHIC EXAMINATION

Samples for metallographic examination of the gray irons were extracted from a cross section cut at the center of both the thin plate and the thick plate. The metallographic samples were prepared according to standard metallographic techniques, i.e. polished to a 1µm diamond spray finish, for characterization of the graphite flake shape and size according to ASTM A247 plate II and III, respectively. Subsequently the polished samples were etched in 2% nital for quantification of the microstructure constituents such as ferrite, pearlite, carbide and graphite by means of point counting (minimum 500 points at a magnification of 200x) in the light microscope. The microstructure were also documented by micrographs taken at the same magnification. The eutectic cell count was determined after etching of the re-polished metallographic specimens using Stead's reagent (10 g. cupric chloride, 40 g. magnesium chloride, 20 ml hydrochloric acid, 1000 ml ethanol) for approximately 3 hours. Micrographs were taken at a magnification of 12.8x and the eutectic cell count is measured from the micrographs by comparison to the BCIRA Broadsheet 94-2 *"Comparator charts for counting eutectic cells"*.

Chill formation

The cast chill wedge samples were broken at the center and the size of the white iron zone formed at the tip of the sample is used as a measure of the chill forming propensity of the produced gray irons. Macro photos were taken for documentation purposes and also in order to directly compare the chill formation in the different specimens.

Shrinkage porosity

The cross shaped specimens were cut in a cross section through the center of the cross to evaluate pore forming tendency in the irons. The cutting of the specimens is illustrated in Figure 2. The specimens were ground down to 2400 grit paper finish. A cross is scratched into the polished surface to mark the middle of the specimen. Micrographs were taken at a 4x magnification such that each micrographs represent an area of 2.3x3.1 mm. Shrinkage porosity is measured by point counting in the light microscope using small grid which represents an area of 0.81x0.81 mm. Ten fields per specimen are measured giving a total measured area of 6.56 mm^2.

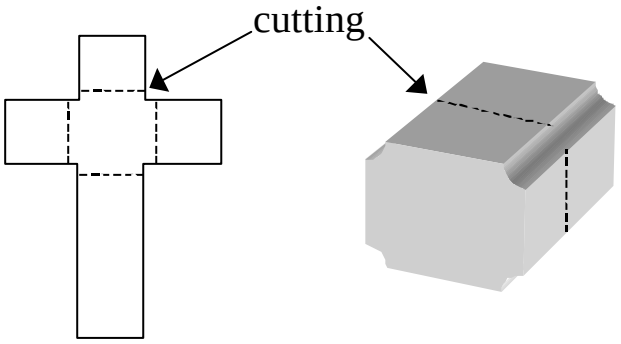


Figure 2. Cutting of cross shaped samples to evaluate porosity forming tendency.

MECHANICAL TESTING AND HARDNESS MEASUREMENTS

Tensile testing of cylindrical bars with dimensions given in Figure 3 were performed in an Instron testing machine using a cross head speed of 4.0 mm/min. Brinell hardness was measured on each metallographic sample using a hardness tester with a 2.5mm steel ball indenter and a load of 62.5kp.

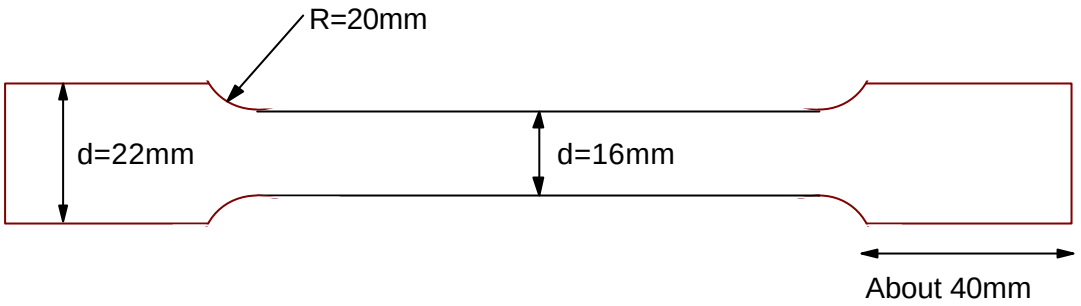


Figure 3. Dimensions of tensile test specimen.

RESULTS AND DISCUSSION

CHEMICAL COMPOSITION

With a carbon concentration in the range from 3.25% to 3.47% and a silicon concentration in the range from 1.93% to 2.19% carbon equivalents in the range from 3.9% to 4.2% were reached. This corresponds to slightly hypoeutectic to eutectic compositions, thus in some cases it can be expected to see traces of primary austenite dendrites in the microstructure. It seems from the analysis of the chemical composition that reproducible concentration of silicon is achieved when silicon is added both as ferrosilicon or as silicon carbide. There is however a weak tendency for lower silicon recovery when silicon carbide is used as the silicon source. Table 3 summarizes the composition of the produced gray irons.

Table 3. Chemical composition of produced gray irons.

Sample	Si source	Elements (in wt%)[1]						
		C	Si	Mn	S	P	Al	Cu
1	Std. FeSi	3.31	2.08	0.76	0.050	0.016	0.006	0.040
2	HP FeSi	3.39	2.09	0.76	0.053	0.016	0.010	0.038
3	Met. SiC	3.29	2.10	0.76	0.055	0.016	0.008	0.040
4	Abr. SiC	3.25	2.00	0.74	0.052	0.016	0.010	0.040
5	Abr. SiC	3.25	1.93	0.75	0.053	0.016	0.008	0.038
6	Met. SiC	3.30	2.10	0.76	0.053	0.016	0.009	0.040
7	HP FeSi	3.45	2.04	0.76	0.054	0.016	0.015	0.040
8	Std. FeSi	3.47	2.19	0.75	0.051	0.016	0.009	0.042

[1]Ce<0.005, La<0.005, Cr<0.022, V<0.005, Ni=0.05, Mo<0.004, Nb<0.005, Ti<0.010, Sn<0.004, Zr=0.008

MATRIX MICROSTRUCTURE

The microstructure found both in the thick and thin plate consists mainly of graphite flakes in a pearlittic matrix. Very little ferrite was found, i.e., less than 6 percent in the thick plates and less than 8 percent in the thin plates. The graphite content in the thick plates varies within the range 8 to 14 volume percent, while the graphite content in the thin plates is a little bit lower and varies from 5 to 11 volume percent. Only minor differencies in the microstructure is seen when comparing the irons made with ferrosilicon and silicon carbide, also the use of high purity ferrosilicon and abrasive grade silicon carbide gives no significant change in the microstructure. Table 4 gives the detailed results from the quantitative microstructure analysis and Figures 4 to 7 show typical micrographs from the produced irons.

Table 4. Microstructure in thick and thin plates of gray cast iron (in vol. pct.).

	Sample	Si-source	Thick plate			Thin plate		
			Graphite	Ferrite	Pearlite	Graphite	Ferrite	Pearlite
Un-inoculated	1a	Std. FeSi	13	1	86	8	1	91
	2a	HP FeSi	10	1	89	10	1	89
	3a	Met. SiC	8	0	92	6	0	94
	4a[1]	Abr. SiC	11	1	88	-	-	-
	5a[1]	Abr. SiC	10	4	86	-	-	-
	6a	Met. SiC	11	1	88	7	8	85
	7a	HP FeSi	10	6	84	8	8	84
	8a	Std. FeSi	8	2	90	9	2	89
Inoculated	1b	Std. FeSi	9	1	90	10	2	88
	2b	HP FeSi	11	2	87	11	1	88
	3b	Met. SiC	14	0	86	8	3	89
	4b	Abr. SiC	11	1	88	10	1	89
	5b	Abr. SiC	13	1	86	5	2	93
	6b	Met. SiC	11	1	88	8	2	90
	7b	HP FeSi	12	0	88	8	2	90
	8b	Std. FeSi	12	2	86	7	3	90

[1] No data available for thin plate due to poor filling of mould.

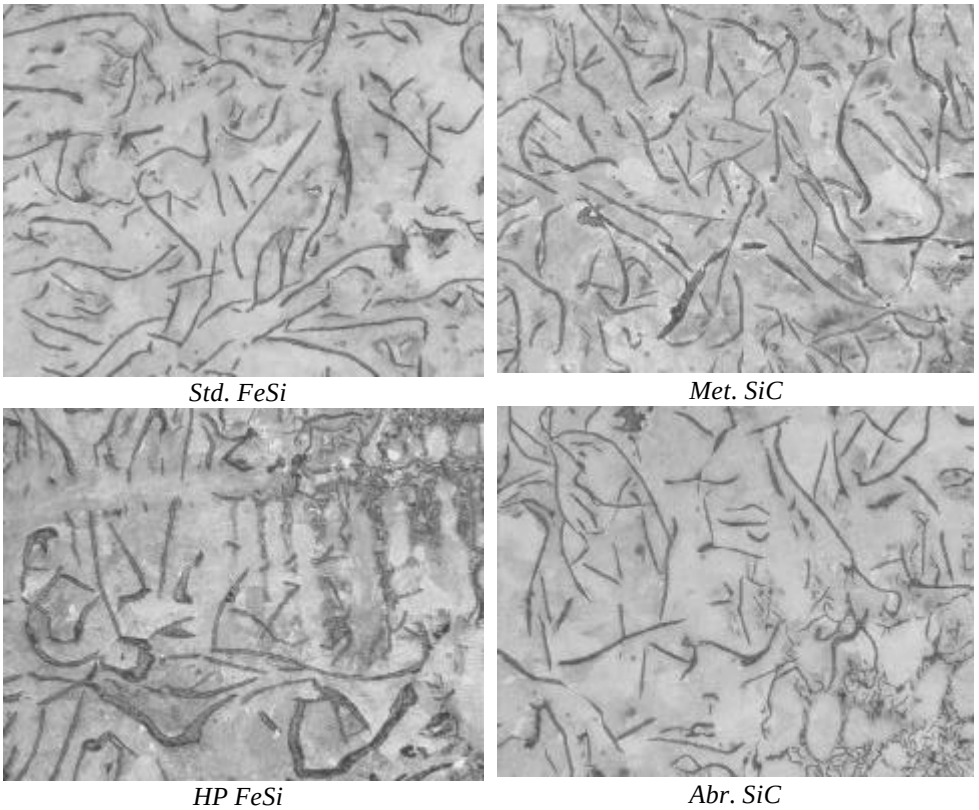
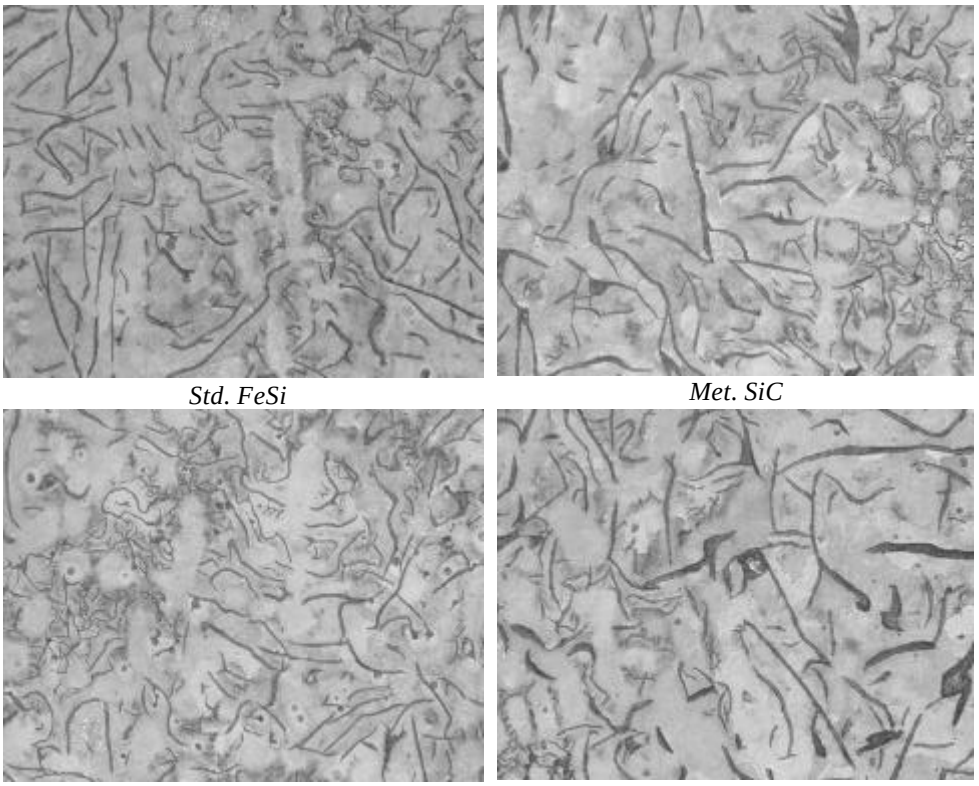


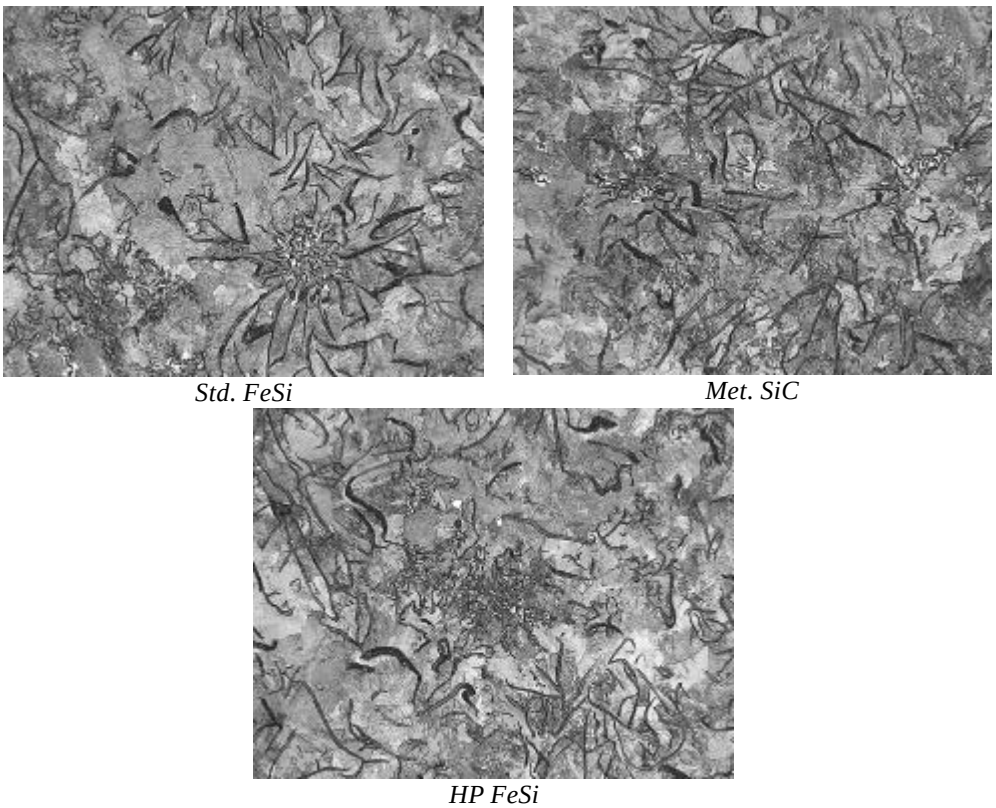
Figure 4. Micrographs showing the microstructure in un-inoculated gray iron thick plate specimens.



Std. FeSi *Met. SiC*

HP FeSi *Abr. SiC*

Figure 5. Micrographs showing the microstructure in inoculated gray iron thick plate specimens.



Std. FeSi *Met. SiC*

HP FeSi

Figure 6. Micrographs showing the microstructure in un-inoculated gray iron thin plate specimens.

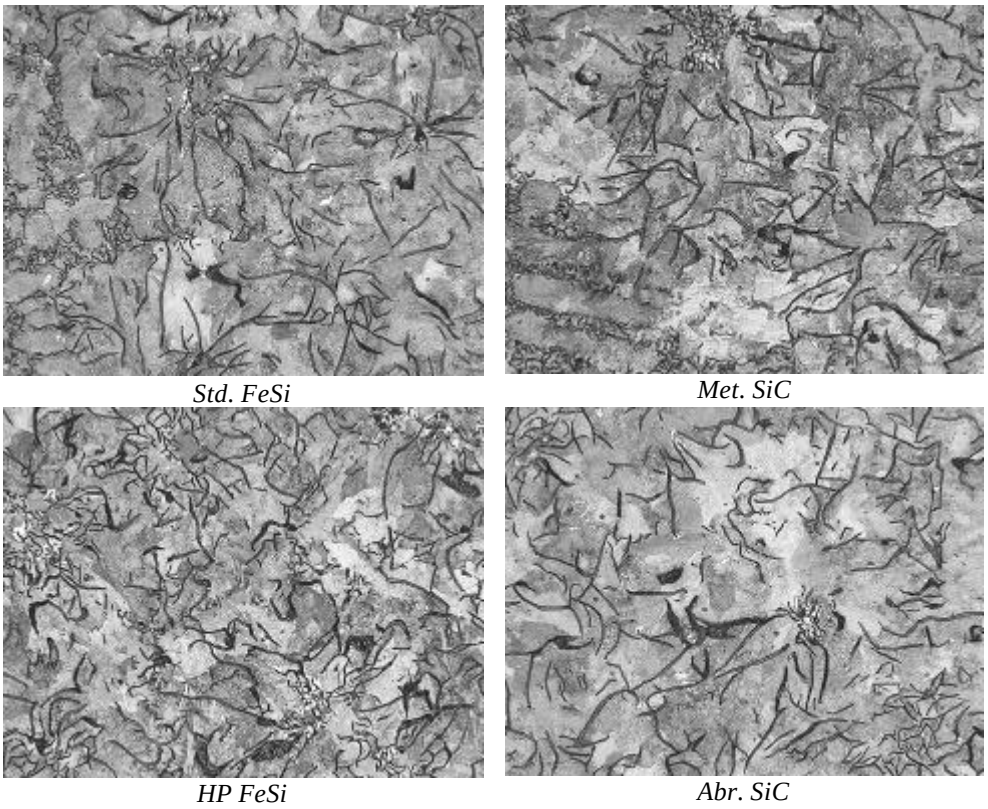


Figure 7. Micrographs showing the microstructure in inoculated gray iron thin plate specimens.

GRAPHITE CHARACTERIZATION

In the thick plate specimens the graphite is of type A, i.e., the graphite flakes are randomly distributed and oriented throughout the matrix. However, most of the specimens also have colonies of type D graphite which is undercooled graphite where small flakes are located between austenite dendrite remainings. The graphite flakes are in general of size 3 according to ASTM A247 plate III, this means that the largest flakes have a length of 0.25mm to 0.5mm. In some cases, where type D graphite exist together with the type A graphite the graphite size for the type D graphite is also classified. Mostly the size of the type D graphite is classified as size 6, i.e., the largest flakes of the type D graphite is 0.03mm to 0.06mm. Some of the type D graphite are of size 7 where the largest flakes are 0.015mm to 0.03mm.

Type A graphite is also the most predominant graphite type in most of the thin plate samples. Type B graphite is, in some cases, the major graphite type. Type B graphite is formed in irons of near-eutectic composition that solidify with greater undercooling than associated with type A graphite. Rosettes containing fine graphite, which are characteristic of type B, precipitate at the start of solidification. The heat of fusion associated with their formation increases the temperature of the surrounding liquid, thus decreasing the undercooling and resulting in the formation of type A graphite between the type B rosettes. Type B graphite is formed in one parallel of the un-inoculated iron made with standard ferrosilicon and in one parallel (both inoculated and un-inoculated) of the irons made with high purity ferrosilicon as well as in one of the un-inoculated irons made with metallurgical SiC. Table 5 gives the detailed results from the graphite characterization.

EUTECTIC CELLS

The eutectic cell count in the thick plates are in the range from 169 to 311 cells per square centimeter. The iron produced with abrasive grade silicon carbide addition gives the highest cell count. The cell count in the thin plate are about five times higher than the cell count of the thick plates and ranges from 1221 to 1807 cell per square centimeter. Highest cell count in this case is obtained for the irons produced with abrasive grade silicon carbide (one parallel) and high purity ferrosilicon (one parallel). Inoculation gives as expected a systematically increasing cell count for all examined samples. Table 6 and Figure 8 summarize the data from the measurement of eutectic cell numbers in the produced irons.

CHILL FORMATION

The formation of chill on standard chill wedge samples does not seem to be sensitive to the selection of silicon source. The data given in Table 7 and Figure 9 shows that there is some scatter between the two parallel samples produced using the four different silicon sources.

Table 5. Graphite type and size in thick and thin plates of gray cast iron.

	Sample	Si-source	Thick plate		Thin plate	
			Graphite type	Graphite size	Graphite type	Graphite size
Un-inoculated	1a	Std. FeSi	A (D)	3 (6)	B	4
	2a	HP FeSi	A (D)	2 (6)	B (D)	3
	3a	Met. SiC	A (D)	3	B (A,D)	3
	4a[1]	Abr. SiC	A (D)	3 (6)	-	-
	5a[1]	Abr. SiC	A (D)	3	-	-
	6a	Met. SiC	A (D)	3 (6)	A (D)	4 (6)
	7a	HP FeSi	A (D)	3 (6)	A (B)	3
	8a	Std. FeSi	A (D)	3 (7)	A (B,D)	3
Inoculated	1b	Std. FeSi	A	3	A (B)	3
	2b	HP FeSi	A	3	B (A)	3
	3b	Met. SiC	A (D)	3	A (B,D)	3
	4b	Abr. SiC	A (D)	3 (7)	A (B,D)	3
	5b	Abr. SiC	A	3	A (B)	3
	6b	Met. SiC	A (D)	3 (6)	A (B)	3 (6)
	7b	HP FeSi	A (D)	3	A (B)	3
	8b	Std. FeSi	A (D)	3	A (B)	4

[1] No data available for thin plate due to poor filling of mould.

Table 6. Eutectic cell count in gray iron samples.

		Un-inoculated Cell count [#/cm^2]			Inoculated Cell count [#/cm^2]	
Si-source	Sample	Thick plate	Thin plate	Sample	Thick plate	Thin plate
Std. FeSi	1a	273	1382	1b	273	1607
HP FeSi	2a	220	1607	2b	273	1807
Met. SiC	3a	273	1607	3b	273	1807
Abr. SiC	4a[1]	273	-	4b	311	1807
Abr. SiC	5a[1]	273	-	5b	311	1607
Met. SiC	6a	220	1382	6b	220	1607
HP FeSi	7a	220	1607	7b	273	1607
Std. FeSi	8a	169	1221	8b	220	1382

[1] No data available for un-inoculated thin plate sample due to poor filling of mould.

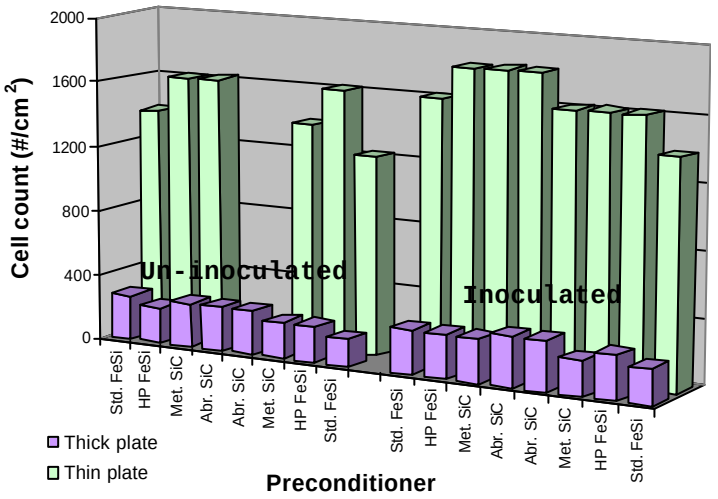


Figure 8. Eutectic cell count in samples of thick and thin plates of gray iron.

Table 7. Results from chill measurements on chill wedge samples.

Un-inoculated	Inoculated

Si-source	Sample	Chill (mm)	Sample	Chill (mm)
Std. FeSi	1a	4.5	1b	2.0
HP FeSi	2a	5.5	2b	4.0
Met. SiC	3a	4.0	3b	1.0
Abr. SiC	4a	3.5	4b	3.0
Abr. SiC[1]	5a	-	5b	1.0
Met. SiC	6a	5.5	6b	2.0
HP FeSi	7a	3.5	7b	2.0
Std. FeSi	8a	4.0	8b	3.5

[1] No data available for un-inoculated sample due to poor filling of mould.

SHRINKAGE POROSITY

The shrinkage porosity of the experimental gray irons, measured as an area fraction on a polished surface at the center of the cross shaped specimen, is very low. Some pores were, however, found in all examined specimens, the highest amount porosity was 1.4 per cent and was observed in the iron produced with high purity ferrosilicon. Table 8 summarizes the results from the porosity measurements.

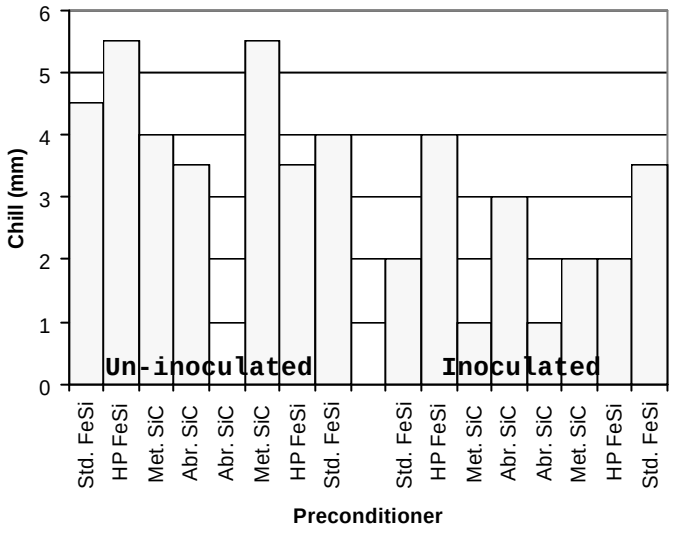


Figure 9. Amount of chill on chill wedge samples from experimental gray irons.

Table 8. Results from porosity measurements.

	Un-inoculated		Inoculated	
Si-source	Sample	Average porosity (area%)	Sample	Average porosity (area%)
Std. FeSi	1a[1]	-	1b[1]	-
HP FeSi	2a	0.85	2b	0.75
Met. SiC	3a	1.4	3b	0.7
Abr. SiC	4a	0.5	4b[1]	-
Abr. SiC	5a[1]	-	5b	0.5
Met. SiC	6a	0.9	6b	0.5
HP FeSi	7a	0.7	7b	0.95
Std. FeSi	8a	0.7	8b	1.1

[1] No results available due to poor filling of mould.

MECHANICAL PROPERTIES

The Youngs modulus of the produced experimental gray irons varies from 89 GPa to 108.8 GPa. There is no systematic variation of the modulus with varying silicon source of the iron, even inoculation of the iron seems not to give any systematic change of the Youngs modulus. The yield strength varies from 135 to 172 MPa and the tensile strength varies from 172 to

209 MPa. There is not observed any dependency of tensile properties on silicon source of the gray iron. However, there is a slight tendency for better reproducibility of the tensile test data for the irons produced with high purity ferrosilicon and abrasive grade silicon carbide as silicon source as compared to the standard ferrosilicon and metallurgical silicon carbide grade. The strength of the irons, both yield strength and tensile strength, as well as the hardness are higher for the inoculated irons than for the not inoculated irons. This behavior can probably be ascribed to the increase of the cell count due to inoculation. The data from the tensile testing and hardness measurements are summarized in Table 9 and Figure 10.

Table 9. Mechanical properties of produced gray cast iron.

	Sample	Si-source	Youngs modulus GPa	Yield strength MPa	Tensile strength MPa	Hardness (BHN) Thick plate	Thin plate
Un-inoculated	1a	Std. FeSi	95.7	160	197	180	192
	2a	HP FeSi	103.7	158	196	178	199
	3a	Met. SiC	108.8	167	201	178	203
	4a	Abr. SiC	98.7	148	177	178	-[1]
	5a	Abr. SiC	98.9	155	199	179	-[1]
	6a	Met. SiC	105.2	157	196	175	200
	7a	HP FeSi	95.4	139	175	167	191
	8a	Std. FeSi	95.9	135	172	166	187
Inoculated	1b	Std. FeSi	98.3	165	209	185	203
	2b	HP FeSi	98.8	166	205	178	203
	3b	Met. SiC	95.6	171	198	185	208
	4b	Abr. SiC	97.7	172	197	183	207
	5b	Abr. SiC	96.9	169	207	183	203
	6b	Met. SiC	92.8	163	194	177	205
	7b	HP FeSi	92.7	139	176	171	189
	8b	Std. FeSi	89	144	179	164	192

[1] No results available due to poor filling of mould.

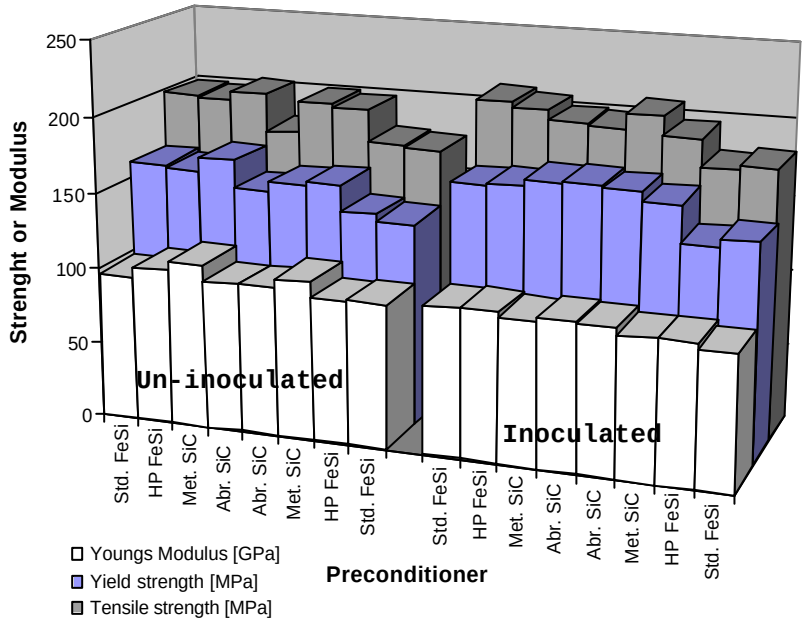


Figure 10. Mechanical properties of produced gray cast iron.

SUMMARY

The results from an analysis of the microstructure in gray irons produced with different silicon sources show that the iron matrix consists of pearlite with a small amount of ferrite (1-4 vol. pct.). In both in the inoculated and uninoculated samples of the thick plate the graphite is of type A with some type D graphite. In the inoculated thin plate the graphite is mainly of type

A with some type B and D graphite, while the graphite in the uninoculated thin iron is of type A and B with some D graphite. The eutectic cell count in the thick plates is in the range from 247 to 311 cells/cm^2 for the inoculated irons and in the range from 220 to 273 cells/cm^2 in the uninoculated irons. In the thin plates the cell count for the inoculated irons is in the range from 1495 to 1707 cells/cm^2, and in the not inoculated irons the cell count is in the range from 1302 to 1607 cells/cm^2. The yield strength is in the range from 153 to 171 MPa and the tensile strength is in the range from 191 to 202 MPa for the inoculated irons, while lower yield strength values (148 to 162 MPa) and tensile strength values (185 to 199) are obtained for the uninoculated irons. There seems to be no systematic changes in the microstructure and mechanical properties with changing silicon source. A summary of the experimental data is given in Tables 10, 11 and 12.

Table 10. Summary of data for the thick plate specimens (average numbers).

		Chemistry		Microstructure			Graphite			
	Si source	%C	%Si	G	F	P	Type	Size	Cell count	BHN
Un-inoculated	Std. FeSi	3.39	2.14	11	2	87	A (D)	3 (6)	221	173
	HP FeSi	3.42	2.07	10	4	86	A (D)	3 (6)	220	173
	Met. SiC	3.30	2.10	10	1	89	A (D)	3 (6)	247	177
	Abr. SiC	3.25	1.97	11	3	86	A (D)	3 (6)	273	179
Inoculated	Std. FeSi	3.39	2.14	9	2	89	A (D)	3	247	175
	HP FeSi	3.42	2.07	12	1	87	A (D)	3	273	175
	Met. SiC	3.30	2.10	13	1	86	A (D)	3 (6)	247	181
	Abr. SiC	3.25	1.97	12	1	87	A (D)	3 (7)	311	183

Table 11. Summary of data for the thin plate specimens (average numbers).

		Chemistry		Microstructure			Graphite			
	Si-source	%C	%Si	G	F	P	Type	Size	Cell count	BHN
Un-inoculated	Std. FeSi	3.39	2.14	9	2	89	A,B (D)	4	1302	190
	HP FeSi	3.42	2.07	9	5	86	A,B (D)	3	1607	195
	Met. SiC	3.30	2.10	7	4	89	A,B (D)	4 (6)	1495	202
	Abr. SiC[1]	3.25	1.97	-	-	-	-	-	-	-
Inoculated	Std. FeSi	3.39	2.14	9	3	88	A (B)	4	1495	198
	HP FeSi	3.42	2.07	10	2	88	A,B	3	1707	196
	Met. SiC	3.30	2.10	8	3	89	A (B,D)	3 (6)	1707	207
	Abr. SiC	3.25	1.97	8	2	90	A (B,D)	3	1707	205

[1] No results available due to poor filling of the mould.

Table 12. Summary of data for chill, porosity and strength measurements (average numbers).

	Si source	Chill mm	Porosity area%	Youngs modulus GPa	Yield strength MPa	Tensile strength MPa
Un-inoculated	Std. FeSi	4.3	0.7	96	148	185
	HP FeSi	4.5	0.8	100	149	186
	Met. SiC	4.8	1.2	107	162	199
	Abr. SiC	3.5	0.5	99	152	188
Inoculated	Std. FeSi	2.8	1.1	94	155	194
	HP FeSi	3.0	0.9	96	153	191
	Met. SiC	1.5	0.6	94	167	196
	Abr. SiC	2.0	0.5	97	171	202

CONCLUSIONS

Based on the examination of gray cast iron specimens produced using either standard ferrosilicon, high purity ferrosilicon, metallurgical silicon carbide or abrasive grade silicon carbide as preconditioning agent the following main conclusions can be drawn with respect to microstructure, mechanical properties and casting performance:

- In general there are only minor differences in microstructural features and mechanical properties in the experimental irons produced using the four different preconditioning agents.
- The carbon and silicon yield was found to be lowest for the irons produced with the abrasive grade SiC and highest for the irons produced using standard grade FeSi.
- The amount of graphite in the thick section size specimens was found to be highest in the irons produced with metallurgical grade SiC and lowest in the irons produced with standard FeSi. In the thin section specimens the amount of graphite was highest in the irons produced with FeSi and lowest in the irons produced with SiC.
- All examined thick plate specimens had type A graphite, size 3, with some minor type D graphite areas. The graphite was also mainly type A, size 4, in the thin plate specimens, here small areas of type B and type D graphite were also present.
- The eutectic cell number is slightly higher in the irons produced with SiC than in those produced with FeSi. The chill formation in a standard chill wedge sample is virtually similar for irons produced using FeSi and SiC as preconditioning agent.
- No significant amount of shrinkage porosity was found in any of the cast specimens.
- The mechanical properties (Yield and tensile strength and hardness) is slightly higher for the irons produced using SiC. This is due to the lower Carbon recovery with SiC and the fact that lower C gives improved tensile properties.

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