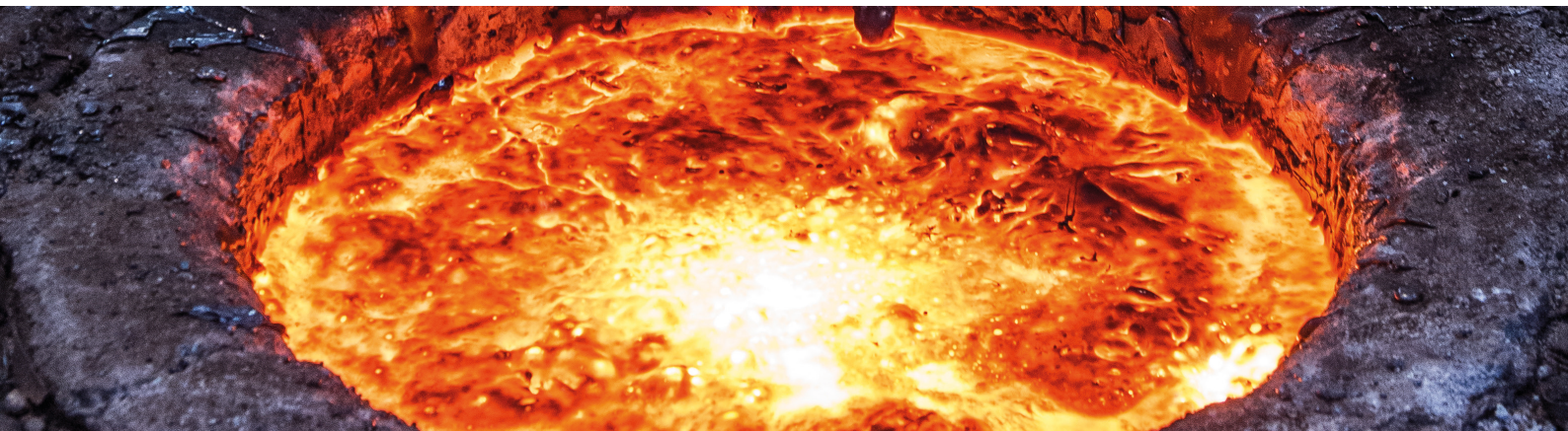


AN APPLICATION REPORT FROM
SPECTRO ANALYTICAL INSTRUMENTS

MMA 16/0



SPECTROPORT, SPECTROTEST,
SPECTROMAXx, SPECTROLAB

Cast Iron Analysis Using Spark OES

Introduction

Alloy cast irons must be accurately identified and verified to meet the chemical composition specified by a customer or an industry. The production or use of unsuitable alloy cast iron carry the risk that for example the subsequent production process does not run correctly or that the components produced do not meet the customer's requirements. Expensive rework, recalls or total loss of orders could be the result.



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Some basics about cast iron

Cast iron is a group of iron-carbon alloys with a carbon content greater than 2%. It has a relatively low melting temperature. The alloy constituents affect its color when fractured:

- **white cast iron** has carbide impurities which allow cracks to pass straight through,
- **grey cast iron** has graphite flakes which deflect a passing crack and initiate countless new cracks as the material breaks, and
- **ductile cast iron** has spherical graphite “nodules” which stop the crack from further progressing.

Depending on the solidification, the iron will evolve a white – or a grey cast structure.

On a fast-cooling process, the white structure will be evolved in the iron, whereas the grey structure will be evolved by a slow cooling process.

The main alloying elements of cast iron are carbon (C) and silicon (Si). The C concentration ranges from 1.8% - 4%, and Si from 1% – 3%. Iron alloys with lower carbon content are known as steel.

Grey cast iron has a graphitic microstructure, which causes fractures of the material to have a grey appearance. It is the most used cast iron.

Most cast irons are composed of 2.5% – 4% C, 1% – 3% Si, and the remainder iron (Fe).

White cast iron has white fractured surfaces due to the presence of an iron carbide precipitate called cementite. Because of the lower silicon content and faster cooling rate, the carbon in white cast iron precipitates out of the melt as the metastable phase cementite, Fe_3C , rather than graphite. It can efficiently be analyzed by our stationary instruments for all available elements, including carbon. This kind of iron can also be analyzed by our mobile instruments, with the exception that the carbon content will not be precise enough, e.g., to monitor a melting process.

In grey precipitated cast iron, the carbon distribution is not homogeneous. This is caused by the slow cooling process. Therefore, it is nearly impossible to achieve correct results for carbon, even with our stationary metal analyzer (see the “Carbon in Cast Iron” white paper for more details).

But a chromium level of around 1% has an influence on the metal structure. Therefore, such a cast iron can be analyzed like white cast iron. Remark: Using a mobile metal analyzer, you can get also an approximate analysis on grey cast iron material by performing 2-3 measurements in the same spot. This way it is at least possible to control the alloying elements on the spot, although the results for the carbon content are not sufficient and reliable.

Which analyzer suits best? When to use a mobile metal analyzer, when a stationary metal analyzer?

Mobile and stationary instruments can be used to analyze cast iron. To monitor a melting process, a stationary instrument must be used as the precision for carbon is higher than with a mobile instrument.

For analyses in the field or a huge and heavy sample geometry, a mobile instrument can be extremely handy. The sample preparation in such a case can be done with a hand disc grinder. The results are precise enough to determine the main elements carbon and silicon.

For analyzing cast iron samples, whether it is a mobile or a stationary metal analyzer, an optimized method is used: Cast iron requires a much longer pre-spark time. The method is named Fe-20 or Fe-20MO on a mobile metal analyzer.

The following example measurements have been performed using either of these methods.



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Examples SPECTROTEST (comparable results are achieved with the SPECTROPORT) instrument

Two samples – white cast iron – each measurement in a different spot

Table 1: Sample CKD247; Method Fe-20M0

	C [%]	Si [%]	Mn [%]	P [%]	S [%]	Cr [%]	Mo [%]	Ni [%]	Al [%]	Co [%]	Cu [%]
1	3.20	1.09	1.02	0.0851	0.0055	0.0530	0.0090	0.41	0.0204	0.0915	0.79
2	3.18	1.08	1.03	0.0825	0.0048	0.0527	0.0085	0.41	0.0204	0.0960	0.79
3	3.19	1.09	1.02	0.0869	0.0055	0.0531	0.0091	0.41	0.0205	0.0943	0.79
<X>	3.19	1.09	1.02	0.0849	0.0053	0.0530	0.0089	0.41	0.0204	0.0940	0.79
Cert.	3.12	1.01	1.16	0.095	0.005	0.054	0.015	0.42	0.013	0.092	0.81

	Nb [%]	Ti [%]	V [%]	W [%]	Pb [%]	Sn [%]	Mg [%]	As [%]	Zr [%]	B [%]	Fe [%]
1	0.0625	0.0595	0.0088	<0.0400	<0.011	0.0337	0.0413	0.0061	<0.007	<0.005	93.0
2	0.0621	0.0582	0.0088	<0.0400	<0.011	0.0326	0.0400	0.0053	<0.007	<0.005	93.0
3	0.0630	0.0601	0.0083	<0.0400	<0.011	0.0347	0.0451	0.0061	<0.007	<0.005	93.0
<X>	0.0625	0.0593	0.0087	<0.0400	<0.011	0.0337	0.0423	0.0058	<0.007	<0.005	93.0
Cert.	0.057	0.058	0.008	0.005	0.002	0.038	0.037	0.009	0.007		

Table 2: Sample CKD248; Method Fe-20M0

	C [%]	Si [%]	Mn [%]	P [%]	S [%]	Cr [%]	Mo [%]	Ni [%]	Al [%]	Co [%]	Cu [%]
1	3.45	1.73	0.26	0.0423	0.0051	0.0126	<0.0070	0.71	0.0590	0.0304	0.11
2	3.45	1.75	0.25	0.0442	0.0053	0.0120	<0.0070	0.71	0.0559	0.0357	0.11
3	3.48	1.74	0.26	0.0431	0.0049	0.0123	<0.0070	0.70	0.0560	0.0329	0.12
<X>	3.46	1.74	0.26	0.0432	0.0051	0.0123	<0.0070	0.71	0.0570	0.0330	0.11
Cert.	3.41	1.81	0.25	0.05	0.006	0.022	0.0003	0.70	0.045	0.016	0.12

	Nb [%]	Ti [%]	V [%]	W [%]	Pb [%]	Sn [%]	Mg [%]	As [%]	Zr [%]	B [%]	Fe [%]
1	<0.0110	0.16	0.16	<0.0400	0.0168	0.0127	0.0541	0.0098	0.0138	0.0240	93.1
2	<0.0110	0.16	0.15	<0.0400	0.0187	0.0129	0.0582	0.0090	0.0140	0.0240	93.1
3	<0.0110	0.16	0.16	<0.0400	0.0137	0.0130	0.0428	0.0078	0.0135	0.0242	93.1
<X>	<0.0110	0.16	0.16	<0.0400	0.0164	0.0128	0.0517	0.0088	0.0138	0.0241	93.1
Cert.	0.005	0.17	0.17	0.003	0.012	0.015	0.064	0.019	0.015	0.036	

Two samples (same chemical composition) – one white cast iron – each measurement in a different spot and one grey cast iron – all three measurements in the same spot

Table 3: Sample W (white); Method Fe-20M0

	C [%]	Si [%]	Mn [%]	P [%]	S [%]	Cr [%]	Mo [%]	Ni [%]	Al [%]	Co [%]	Cu [%]
1	2.66	2.44	0.65	0.0801	0.0278	1.69	0.0747	0.29	0.0276	0.0218	0.11
2	2.57	2.44	0.64	0.0792	0.0294	1.66	0.0726	0.29	0.0145	0.0203	0.11
3	2.63	2.43	0.65	0.0836	0.0313	1.68	0.0733	0.29	0.0148	0.0256	0.11
<X>	2.62	2.43	0.64	0.0810	0.0295	1.68	0.0735	0.29	0.0190	0.0226	0.11

	Nb [%]	Ti [%]	V [%]	W [%]	Pb [%]	Sn [%]	Mg [%]	As [%]	Zr [%]	B [%]	Fe [%]
1	<0.0110	0.0733	0.0930	<0.0400	<0.0110	0.0281	<0.0040	0.0167	<0.0070	0.0083	91.7
2	<0.0110	0.0730	0.0893	<0.0400	0.0149	0.0273	<0.0040	0.0174	<0.0070	0.0092	91.8
3	<0.0110	0.0719	0.0913	<0.0400	<0.0110	0.0279	<0.0040	0.0179	<0.0070	0.0093	91.7
<X>	<0.0110	0.0727	0.0912	<0.0400	0.0123	0.0278	<0.0040	0.0173	<0.0070	0.0089	91.7

Table 4: Sample G (grey); Method Fe-20M0

	C [%]	Si [%]	Mn [%]	P [%]	S [%]	Cr [%]	Mo [%]	Ni [%]	Al [%]	Co [%]	Cu [%]
1	2.86	2.48	0.63	0.0737	0.0367	1.66	0.0721	0.29	0.0150	0.0168	0.10
2	2.87	2.49	0.62	0.0724	0.0329	1.65	0.0725	0.29	0.0153	0.0213	0.10
3	2.92	2.47	0.64	0.0824	0.0355	1.67	0.0725	0.29	0.0254	0.0213	0.11
<X>	2.88	2.48	0.63	0.0762	0.0351	1.66	0.0724	0.29	0.0186	0.0198	0.10

	Nb [%]	Ti [%]	V [%]	W [%]	Pb [%]	Sn [%]	Mg [%]	As [%]	Zr [%]	B [%]	Fe [%]
1	<0.0110	0.0754	0.0904	<0.0400	0.0137	0.0276	<0.0040	0.0182	<0.0070	0.0092	91.5
2	<0.0110	0.0776	0.0893	<0.0400	0.0188	0.0273	<0.0040	0.0168	<0.0070	0.0087	91.5
3	<0.0110	0.0748	0.0924	<0.0400	0.0129	0.0272	<0.0040	0.0174	<0.0070	0.0012	91.4
<X>	<0.0110	0.0760	0.0907	<0.0400	0.0151	0.0274	<0.0040	0.0175	<0.0070	0.0010	91.4

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Examples SPECTROMAXx instrument

Two samples – white cast iron

Table 5: Sample CKD247; Method Fe-20

	C [%]	Si [%]	Mn [%]	P [%]	S [%]	Cr [%]	Mo [%]	Ni [%]	Al [%]	Co [%]	Cu [%]
Rep	3.12	1.01	1.14	0.0939	0.0048	0.055	0.0139	0.424	0.0134	0.0907	0.81
SD	0.0166	0.0035	0.0015	0.0022	0.0002	0.0002	0.0001	0.0002	0.00004	0.0001	0.0015
RSD	0.53	0.35	0.13	2.31	4.46	0.33	0.76	0.05	0.28	0.09	0.19
Cert.	3.12	1.01	1.16	0.095	0.005	0.054	0.015	0.42	0.013	0.092	0.81

	Nb [%]	Ti [%]	V [%]	W [%]	Pb [%]	Sn [%]	Mg [%]	As [%]	Zr [%]	Bi [%]	Ce [%]
Rep	0.0546	0.0592	0.007	<0.0070	<0.0020	0.0394	0.0374	0.0105	0.005	0.0072	0.0519
SD	0.0002	0.0004	0.0001			0.0011	0.0036	0.0006	0.0001	0.0001	0.0014
RSD	0.41	0.75	1.37			2.89	9.57	5.71	2.74	0.84	2.79
Cert.	0.057	0.058	0.008	0.005	0.002	0.038	0.037	0.009	0.007		0.048

	Sb [%]	Se [%]	Te [%]	B [%]	Zn [%]	La [%]	N [%]	Fe [%]
Rep	0.0025	0.0032	0.0121	0.0013	0.0106	0.0219	0.0192	92.86
SD	0.0002	0.0002	0.0006	0.00003	0.0003	0.0008	0.0007	0.0289
RSD	8.1	6.91	4.97	2.41	2.76	3.77	3.47	0.03
Cert.	0.002				0.013	0.022		

Table 6: Sample CKD248; Method Fe-20

	C [%]	Si [%]	Mn [%]	P [%]	S [%]	Cr [%]	Mo [%]	Ni [%]	Al [%]	Co [%]	Cu [%]
Rep	3.43	1.82	0.255	0.0463	0.0082	0.0227	<0.0010	0.71	0.0506	0.0169	0.113
SD	0.0086	0.0063	0.0004	0.0007	0.0003	0.0001		0.021	0.0004	0.0001	0.0001
RSD	0.25	0.35	0.16	1.48	3.31	0.5		0.3	0.83	0.67	0.13
Cert.	3.41	1.81	0.245	0.05	0.006	0.022	0.003	0.70	0.045	0.016	0.117

	Nb [%]	Ti [%]	V [%]	W [%]	Pb [%]	Sn [%]	Mg [%]	As [%]	Zr [%]	Bi [%]	Ce [%]
Rep	0.0031	0.171	0.17	<0.0070	0.0115	0.0165	0.0556	0.016	0.0147	0.004	0.0258
SD	0.0002	0.0015	0.0004		0.0001	0.0003	0.003	0.0015	0.0001	0.0002	0.002
RSD	5.01	0.85	0.23		0.62	1.86	5.46	9.41	0.68	6.09	7.7
Cert.	0.005	0.17	0.171	0.003	0.012	0.015	0.064	0.019	0.015	0.004	0.023

	Sb [%]	Te [%]	B [%]	Zn [%]	La [%]	N [%]	Fe [%]
Rep	0.0174	0.0057	0.0366	0.0135	0.0157	0.0085	92.93
SD	0.0008	0.0006	0.0003	0.0001	0.0027	0.0009	0.0167
RSD	4.39	10.13	0.77	1.09	17.35	10.83	0.02
Cert.	0.012	0.004	0.036	0.015	0.014		

Examples SPECTROLAB instrument

Two samples – white cast iron

Table 7: Sample CKD247; Method Fe-20

	C [%]	Si [%]	Mn [%]	P [%]	S [%]	Cr [%]	Mo [%]	Ni [%]	Al [%]	Co [%]	Cu [%]
Rep	3.12	1.01	1.18	0.0988	0.0036	0.0287	0.0136	0.422	0.0122	0.0985	0.811
SD	0.0028	0.0038	0.001	0.001	0.0002	0.0003	0.0001	0.0002	0.25	0.0002	0.0016
RSD	0.09	0.29	0.1	1	4.57	0.94	0.74	0.05	1.02	0.23	0.2
Cert.	3.12	1.01	1.16	0.095	0.005	0.054	0.015	0.42	0.013	0.092	0.81

	Nb [%]	Ti [%]	V [%]	W [%]	Pb [%]	Sn [%]	Mg [%]	As [%]	Zr [%]	Bi [%]	Ce [%]
Rep	0.0569	0.0583	0.0095	0.0051	0.002	0.041	0.0332	0.0113	0.009	0.0075	0.0516
SD	0.0003	0.0004	0.0001	0.0003	0.0001	0.0004	0.0015	0.0002	0.0001	0.0001	0.0011
RSD	0.69	0.58	0.91	4.94	5	0.97	4.51	1.66	1.05	1.42	2.13
Cert.	0.057	0.058	0.008	0.005	0.002	0.038	0.037	0.009	0.007		0.048

	Sb [%]	Se [%]	Te [%]	B [%]	Zn [%]	La [%]	N [%]	Fe [%]
Rep	0.0026	0.0009	0.0047	<0.00005	0.0172	0.023	0.0088	92.5
SD	0.0001	0.0002	0.0002		0.0003	0.0002	0.0004	0.011
RSD	3.84		4.87		1.64	0.93	4.23	0.01
Cert.	0.002				0.013	0.022		

Table 8: Sample CKD248; Method Fe-20

	C [%]	Si [%]	Mn [%]	P [%]	S [%]	Cr [%]	Mo [%]	Ni [%]	Al [%]	Co [%]	Cu [%]
Rep	3.4	1.8	0.249	0.0557	0.0059	0.0215	0.0019	0.716	0.0457	0.0161	0.124
SD	0.0074	0.0049	0.0009	0.0001	0.0002	0.0001	0.00004	0.0035	0.0001	0.0001	0.0009
RSD	0.21	0.27	0.36	0.15	3.4	0.47	2.09	0.49	0.22	0.62	0.69
Cert.	3.41	1.81	0.245	0.05	0.006	0.022	0.003	0.70	0.045	0.016	0.117

	Nb [%]	Ti [%]	V [%]	W [%]	Pb [%]	Sn [%]	Mg [%]	As [%]	Zr [%]	Bi [%]	Ce [%]
Rep	0.0041	0.17	0.17	0.0022	0.0103	0.0176	0.0609	0.0204	0.0132	0.0041	0.0266
SD	0.0001	0.0011	0.0003	0.0001	0.0001	0.0002	0.0003	0.001	0.00004	0.0001	0.0009
RSD	1.56	0.64	0.18	3	0.68	1.12	0.49	4.99	0.29	2.4	3.26
Cert.	0.005	0.17	0.171	0.003	0.012	0.015	0.064	0.019	0.015	0.004	0.023

	Sb [%]	Se [%]	Te [%]	B [%]	Zn [%]	La [%]	N [%]	Fe [%]
Rep	0.0153	0.0048	0.0042	0.0386	0.0096	0.0139	0.0052	92.9
SD	0.0004	0.0005	0.0004	0.0001	0.0001	0.0003	0.0006	0.0074
RSD	2.68		9.73	0.19	1.5	2.15		0.01
Cert.	0.012		0.004	0.036	0.015	0.014		

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Two samples (same chemical composition) – one white cast iron and one grey cast iron

Table 9: Sample White; Method Fe-20

	C [%]	Si [%]	Mn [%]	P [%]	S [%]	Cr [%]	Mo [%]	Ni [%]	Al [%]	Co [%]	Cu [%]
Rep	2.66	2.52	0.634	0.0782	0.0488	1.67	0.0823	0.297	0.0113	0.0107	0.118
SD	0.0078	0.0156	0.0032	0.0016	0.0033	0.0053	0.0005	0.0036	0.0001	0.0003	0.0006
RSD	0.29	0.62	0.5	1.98	6.74	0.32	0.56	1.21	1.2	2.63	0.52

	Nb [%]	Ti [%]	V [%]	W [%]	Pb [%]	Sn [%]	Mg [%]	As [%]	Zr [%]	Bi [%]	Ca [%]
Rep	<0.0005	0.0718	0.097	0.0058	0.003	0.028	0.0002	0.0401	0.0013	0.0023	<0.0001
SD		0.0005	0.0007	0.0003	0.0004	0.0002	0.00002	0.0014	0.0001	0.0001	
RSD		0.75	0.68	5.23	11.86	0.76	8.86	3.41	3.66	2.97	

	Ce [%]	Sb [%]	Se [%]	Te [%]	B [%]	Zn [%]	La [%]	N [%]	Nd [%]	Fe [%]
Rep	0.0008	0.0234	<0.00005	<0.00005	0.0007	0.0003	<0.0002	0.0189	<0.00005	91.6
SD	0.00004	0.0005			0.00004	0.00002		0.0009		0.02
RSD	5.16	2.32			6.46	5.55		4.76		0.02

Table 10: Sample Grey; Method Fe-20

	C [%]	Si [%]	Mn [%]	P [%]	S [%]	Cr [%]	Mo [%]	Ni [%]	Al [%]	Co [%]	Cu [%]
Rep	2.77	2.52	0.628	0.0803	0.0598	1.68	0.0822	0.294	0.011	0.0105	0.116
SD	0.0299	0.0081	0.0021	0.0011	0.0023	0.0041	0.0003	0.001	0.0001	0.0001	0.0006
RSD	1.08	0.32	0.33	1.31	3.85	0.24	0.42	0.34	0.59	0.91	0.51

	Nb [%]	Ti [%]	V [%]	W [%]	Pb [%]	Sn [%]	Mg [%]	As [%]	Zr [%]	Bi [%]	Ca [%]
Rep	<0.0005	0.0733	0.101	0.0065	0.0032	0.0291	0.0002	0.0451	0.0015	0.0027	<0.0001
SD		0.0002	0.0003	0.0002	0.0001	0.0003	0.00003	0.0003	0.00004	0.0003	
RSD		0.32	0.29	3.13	1.81	1.17	15.29	0.55	2.64	9.87	

	Ce [%]	Sb [%]	Se [%]	Te [%]	B [%]	Zn [%]	La [%]	N [%]	Nd [%]	Fe [%]
Rep	0.0011	0.0253	<0.00005	<0.00005	0.0007	0.0003	<0.0002	>0.0200	<0.00005	91.4
SD	0.0002	0.0006			0.00001	0.00002				0.0364
RSD		2.22			1.24					0.04

Summary

This report shows how mobile and stationary Spark OES instruments can be used to analyze cast iron. Differences in the performance of the two instrument categories are also shown, so that the appropriate instrument can be selected depending on the requirements.



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