Lab Report XRF 162

S6 JAGUAR

- EAF & LMF Slag Analysis – Efficient Process Control made Easy

Slag is an important agent in high temperature metallurgical processes. It is tuned to an equilibrium condition for maximum action on the metal purity, least attack on the refractory lining, and optimal physical properties. Dosage of slag enhancing additives – such as lime and dolomite – is performed based on the chemical composition of the slag. Thus, for steelmakers seeking to manufacture steel more profitably, it is essential to monitor the slag composition accurately and fast.

There are different types of slags, depending on the procedure used for steel/metal manufacturing. This report demonstrates the excellent performance of the S6 JAGUAR when analyzing Electric Arc Furnace (EAF) slags and Ladle Metallurgy Furnace (LMF) slags. The S6 JAGUAR is ready for difficult industrial environments, such as metallurgical plants. It combines reliable and accurate slag analyses with high system uptime and fast time-to-result.

S6 JAGUAR: A Benchtop System with Full WDXRF performance

The S6 JAGUAR wavelength-dispersive X-ray fluorescence (WDXRF) spectrometer is the most powerful benchtop WDXRF on the market. Equipped with modern software solutions and state-of-the-art hardware, the S6 JAGUAR is ideally configured to enable best-in-its-class analytical performance. With a 400 W X-ray tube and HighSense™ technology, it offers outstanding sensitivity for a wide range of elements (F to U).

High system uptime – even in dusty environments – is ensured by our SampleCare™ technology, dedicated high-duty air filters, sturdy design, and overall high quality components. The integrated vacuum mode minimizes the operational costs when compared to XRF systems with helium mode only. The TouchControl™ interface and the SPECTRA.ELEMENTS software make process control a simple task.

Sample Preparation

The slag samples were crushed and the remaining metallic iron was removed with a magnet before grinding. The slag powders were pressed to pellets by using 15 g of sample material and 1 g grinding aid (Figure 1). The key advantage of pressed pellets when compared to fused beads is the fast and simple procedure. Careful pellet preparation enables high repeatability and reliability, specifically for minor and trace element analyses.

Figure 1: Sampling of slag in a steel production plant .

System Configuration, Calibration, and Analyses

The analytical conditions and the crystal setup were optimized for the determination of major and minor elements in slag samples (Table 1). The analyses were conducted in vacuum mode for best analytical performance and lowest cost of operation (no helium required!).

Two calibrations were performed, one for EAF slags and one for LMF slags. For each calibration, we used a set of 8 certified reference materials (CRMs) and 8 validated secondary standards. The elements and the compositional range covered by the calibrations are listed in Table 2. A typical calibration curve is displayed in Figure 2.

Table 1: Analytical conditions

Elements	Voltage [kV]	Current [mA]	Analyzer crystal	Filter	Detector
Na, Mg	30	13.3	XS-55	none	FlowCounter
Al, Si	30	13.3	PET(002)	none	FlowCounter
P, S	30	13.3	Ge(111)	none	FlowCounter
K, Ca, Ti	50	8	LiF(200)	none	FlowCounter
Mn, Fe	50	8	LiF(200)	none	HighSense XE

Repeatability, Precision and Accuracy

Repetition tests for EAF slags (Table 3) and LMF slags (Table 4) demonstrate the excellent precision and stability of the S6 JAGUAR for slag analyses (Table 3 and 4). The samples were unloaded and reloaded between the measurements.

Table 2: Compositional ranges covered by the CRMs.

Compound	EAF Slags [wt.%]	LMF Slags [wt.%]
Na_2O	0 – 0.4	0 – 0.4
MgO	2 – 17	0.7 – 20
Al_2O_3	2 – 10	6 – 40
SiO_2	8 – 49	20 – 45
P_2O_5	0.01 – 8	0 – 0.2
S	0.04 – 0.2	0 – 1.2
CaO	1 – 45	20 – 65
TiO_2	0.1 – 4	0.1 – 0.9
Cr_2O_3	0.6 – 54	N.A.*
MnO	3 – 28	0.3 – 10
Fe_2O_3	9 – 50	0.2 – 10

*Cr is not relevant for LMF Slags.

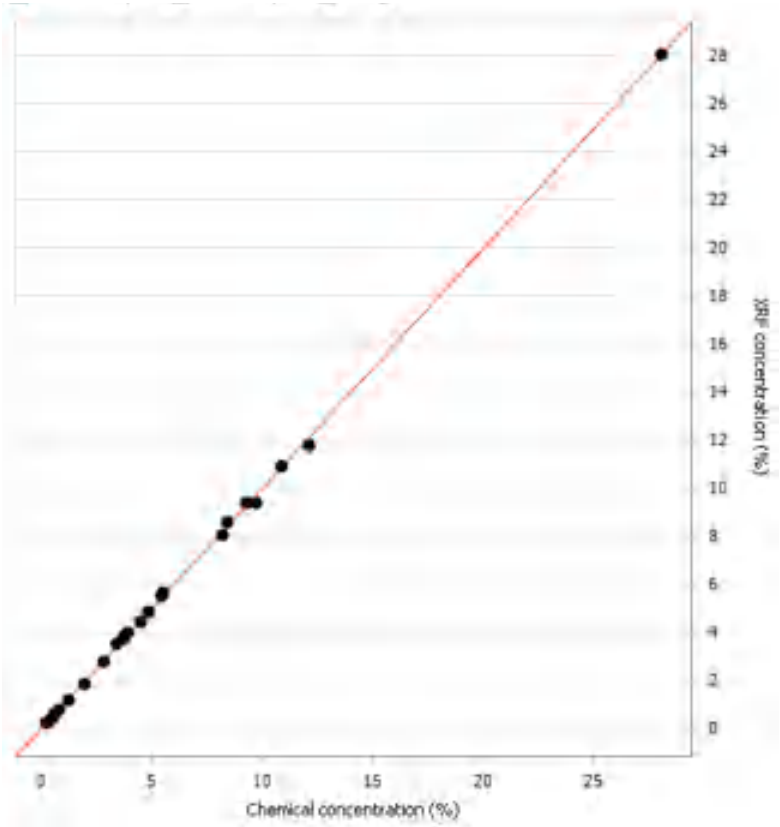

Figure 2: Calibration curve for MnO (R^2 = 0.99957). Plot produced by Bruker's SPECTRA. Elements software.

Table 3: EAF Slags – Stability, Precision, and Accuracy

[wt.%]	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	S	CaO	TiO_2	Cr_2O_3	MnO	FeO
Rep-1	0.128	14.28	3.31	15.77	0.635	0.068	22.01	0.163	1.739	8.11	31.19
Rep-2	0.131	14.23	3.31	15.79	0.626	0.066	22.00	0.162	1.736	8.12	31.14
Rep-3	0.134	14.26	3.32	15.77	0.637	0.067	22.02	0.163	1.745	8.12	31.14
Rep-4-29	…	…	…	…	…	…	…	…	…	…	…
Rep-30	0.126	14.28	3.32	15.75	0.632	0.065	21.98	0.164	1.740	8.11	31.11
Average	**0.132**	**14.28**	**3.32**	**15.79**	**0.635**	**0.066**	**21.99**	**0.164**	**1.740**	**8.11**	**31.13**
Abs. Std. Dev.	**0.007**	**0.039**	**0.011**	**0.027**	**0.004**	**0.001**	**0.021**	**0.001**	**0.003**	**0.010**	**0.031**
Rel. Std. Dev. [%]	**5.2**	**0.28**	**0.33**	**0.17**	**0.65**	**1.3**	**0.10**	**0.86**	**0.19**	**0.12**	**0.10**
Certified	–	14.46	3.23	15.69	0.62	0.04	21.99	0.150	1.74	8.16	31.17
Difference	–	0.18	0.09	0.10	0.015	0.026	<0.01	0.014	<0.01	0.05	0.04

Table 4: LMF Slags – Stability, Precision, and Accuracy

[wt.%]	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	S	CaO	TiO_2	MnO	FeO
Rep-1	0.128	14.28	3.31	15.77	0.635	0.068	22.01	0.163	8.11	31.19
Rep-2	0.131	14.23	3.31	15.79	0.626	0.066	22.00	0.162	8.12	31.14
Rep-3	0.134	14.26	3.32	15.77	0.637	0.067	22.02	0.163	8.12	31.14
Rep-4-29	…	…	…	…	…	…	…	…	…	…
Rep-30	0.126	14.28	3.32	15.75	0.632	0.065	21.98	0.164	8.11	31.11
Average	**0.132**	**14.28**	**3.32**	**15.79**	**0.635**	**0.066**	**21.99**	**0.164**	**8.11**	**31.13**
Abs. Std. Dev.	**0.007**	**0.039**	**0.011**	**0.027**	**0.004**	**0.001**	**0.021**	**0.001**	**0.010**	**0.031**
Rel. Std. Dev. [%]	**5.2**	**0.28**	**0.33**	**0.17**	**0.65**	**1.3**	**0.10**	**0.86**	**0.12**	**0.10**
Certified	–	14.46	3.23	15.69	0.62	0.04	21.99	0.150	8.16	31.17
Difference	–	0.18	0.09	0.10	0.015	0.026	<0.01	0.014	0.05	0.04

Conclusion

The S6 JAGUAR is a benchtop WDXRF system, which can compete with many full-size WDXRF systems. The high performance in a compact size stems from a smart combination of cutting-edge technical components and innovative geometric design; including the HighSense XE detector, the closely coupled beam path, and the 400 W X-ray tube.

This report highlights the outstanding capabilities of the S6 JAGUAR for slag analysis. The S6 JAGUAR enables tight process control via accurate monitoring of the slag composition. This allows to enhance the properties of slag while using additives sparingly. In combination with fast time-to-result, the S6 JAGUAR adds real values to your metallurgical plant and pays back rapidly!