Lab Report XRF 165

S2 PUMA Series 2

EAF Slag Analysis – Made fast and reliable with HighSense™ Technology

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 S2 PUMA when analyzing Electric Arc Furnace (EAF) slags (Figure 1). The S2 PUMA is a powerful, state-of-the-art energy-dispersive X-ray fluorescence (EDXRF) spectrometer, which uses Bruker's HighSense LE detector for optimal elemental analysis of EAF slags, including the relevant light element Mg.

The S2 PUMA 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.

S2 PUMA: Made for industrial Applications

The S2 PUMA is ready for challenging industrial environments. High system uptime is ensured by SampleCare™ technology, 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 ergonomic TouchControl™ interface and the intuitive SPECTRA.ELEMENTS software make process control a simple task.

Figure 1: Sampling from an electric arc furnace.

S2 PUMA Series 2 with HighSense™ Technology

The HighSense package of the S2 PUMA combines state-of-the-art Silicon Drift Detector (SDD) and X-ray tube technology with a closely coupled beam path. The modern, long-life time X-ray tube enables ideal sample excitation. The fast electronics and the high counts rates of the HighSense detector series unleash the true 50 W power of the S2 PUMA. The light element version of the detector – the HighSense LE – uses an ultra-thin high-transmission window for optimal detection of light elements. An easy to replace detector cap adds an extra level of safety for high uptime and low maintenance.

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. 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, in particular for minor and trace element analysis.

Calibration and Analysis

The analytical conditions were optimized for high sample throughput; i.e., we used a single analytical range to avoid time-consuming changes of beam filter, voltage, and/or current (Table 1). The analyses were conducted in vacuum mode for best analytical performance and lowest cost of operation (no helium required!).

For the calibration, we used a set of 30 certified and secondary reference materials. The elements and the compositional range covered by the calibration are listed in Table 2. A typical calibration curve is displayed in Figure 2. Calibration peaks for Mg and Al are shown in Figure 3.

Repeatability, Precision, and Accuracy

A repetition test demonstrates the excellent precision and accuracy of the S2 PUMA for EAF slag analysis (Table 3). The samples were unloaded and reloaded between the measurements.

Equipped with the HighSense LE detector, the S2 PUMA achieves this outstanding performance – even for light elements and with a single analytical range (Table 1) – in just **2 minutes** counting time!

Table 1: Analytical conditions

Elements	Voltage [kV]	Current [mA]	Measurement time [s]	Beam Filter	Mode
F, Mg, Al, Si, P, S, Ca, Ti, Mn, Fe	20	automatic*	120	none	Vacuum

*Current is maximized automatically for best count statistics.

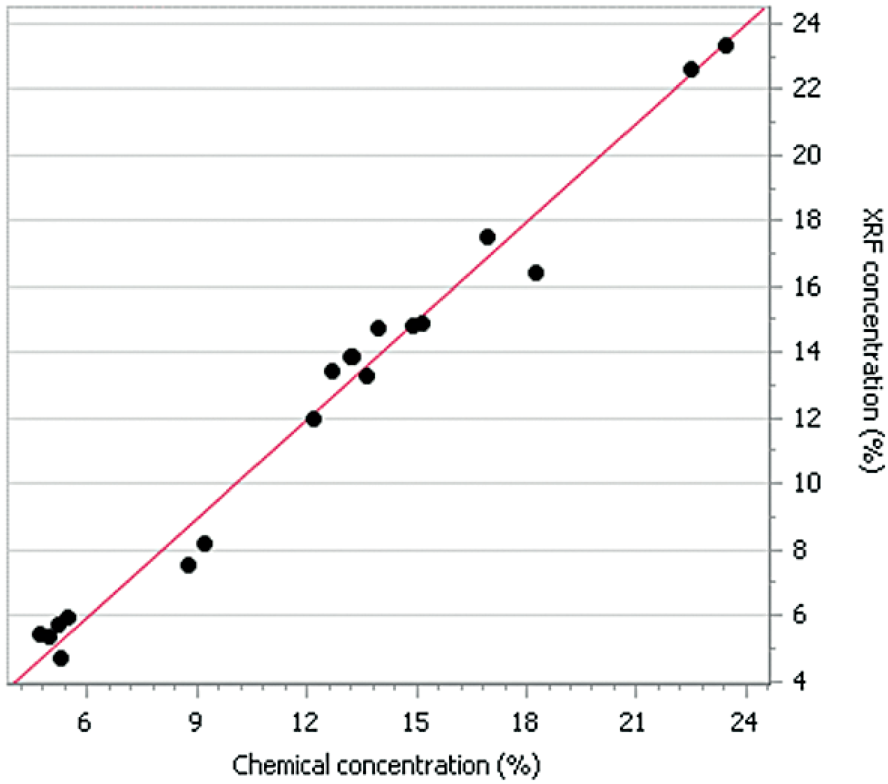

Figure 2: Calibration curve for MgO. The plotw as produced by Bruker's SPECTRA.ELEMENTS software.

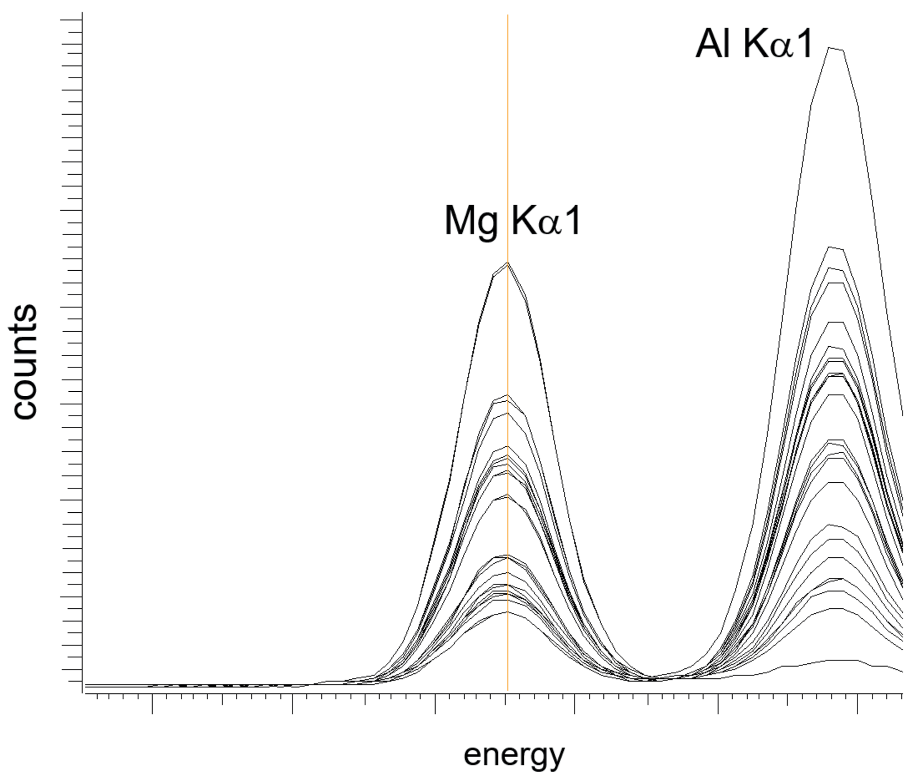

Figure 3: Calibration peaks for Mg Kα1 and Al Kα1. The plot was produced by Bruker's SPECTRA.ELEMENTS software.

Table 2: Compositional range covered by the certified and secondary calibration standards.

Compound	EAF Slags [wt%]
MgO	2.4 – 23.5
Al_2O_3	0.5 – 10.2
SiO_2	4.7 – 48.7
P_2O_5	0.01 – 16.7
S	0.03 – 0.2
CaO	1.2 – 42.9
TiO_2	0.15 – 2.3
Cr_2O_3	0.5 – 53.8
MnO	2.0 – 28
FeO	9.1 – 48.1

Conclusion

The S2 PUMA with HighSense technology, 50 W power, intuitive software, and robust design is ready for the challenging environments and applications at steel plants.

This report demonstrates the excellent capabilities of the S2 PUMA for EAF slag analysis, even for light elements such as Mg. The S2 PUMA makes process control quick and easy. The combination of the high power X-ray tube with the HighSense detector enables the S2 PUMA to accurately monitor your slag composition in just 2 minutes counting time!

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

[wt.%]	MgO	Al_2O_3	SiO_2	P_2O_5	S	CaO	TiO_2	Cr_2O_3	MnO	FeO	V-Ratio	B3-Ratio
Rep-1	13.53	6.36	14.20	0.240	0.130	26.97	0.36	2.16	5.59	29.84	1.90	1.29
Rep-2	13.61	6.38	14.20	0.240	0.130	26.97	0.37	2.16	5.59	29.84	1.90	1.29
Rep-3	13.63	6.37	14.27	0.240	0.130	27.01	0.37	2.16	5.59	29.78	1.89	1.29
Rep-4	13.56	6.36	14.21	0.240	0.120	27.00	0.37	2.17	5.58	29.85	1.90	1.29
Rep-5	13.61	6.36	14.26	0.240	0.120	27.01	0.37	2.16	5.56	29.79	1.89	1.29
Rep-6	13.55	6.38	14.18	0.240	0.130	27.00	0.37	2.17	5.58	29.85	1.90	1.29
Rep-7	13.56	6.38	14.27	0.230	0.130	27.01	0.37	2.16	5.58	29.79	1.89	1.28
Rep-8	13.55	6.37	14.24	0.240	0.130	27.01	0.37	2.17	5.60	29.81	1.90	1.29
Rep-9	13.69	6.39	14.24	0.240	0.120	27.04	0.37	2.16	5.56	29.76	1.90	1.29
Rep-10-101	...	...	...	...	...	...	...	...	...	...	...	...
Rep-102	13.75	6.54	14.41	0.240	0.130	27.03	0.37	2.17	5.56	29.62	1.88	1.26
Average [wt.%]	13.69	6.44	14.34	0.244	0.126	27.02	0.37	2.17	5.57	29.70	1.89	1.28
Abs. Std. Dev. [wt.%]	0.10	0.05	0.07	0.005	0.005	0.03	<0.01	0.01	0.01	0.07	0.01	0.01
Rel. Std. Dev. [%]	0.7	0.7	0.5	2.3	3.8	0.1	0.9	0.3	0.2	0.2	0.5	0.5
Certified	13.40	6.58	14.24	0.250	0.13	26.66	0.35	2.17	5.63	29.49	1.87	1.26
Difference	0.29	0.14	0.10	0.006	0.004	0.36	0.02	<0.01	0.06	0.21	0.02	0.02

Viscosity (V) Ratio: CaO / SiO_2; Basicity (B3) Ratio = CaO / (SiO_2 + Al_2O_3 + TiO_2)

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