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A System for Elemental Analysis of Aluminum Chips, based on Neutron Activation Analysis

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Abstract

The performance of the demonstrator of the system for elemental analysis of aluminum chips is presented. The system is based on neutron activation analysis and isotopic neutron source of PuBe emitting $2x10^6$ n/s. The detection system comprises of large 3.5x8 inch $LaBr_3$ scintillators with an option of easy change to 5x5x10 inch NaI(Tl) or 5x5 inch BGO. The industrial samples under study are constantly moving through a vertical pipe in a closed loop system which mimics the industrial conditions at aluminum refinery. The system performance is presented in relation to the recorded gamma spectra and gamma lines characteristic for the following chemical elements: Al, Si, Cu, Fe, Mg, (Mn, Ni, Pb, Cr, Ti, Zn). The results are compared to the standard industrial analysis based on spark optical emission spectroscopy and multiple sample collection.

1. Introduction

One of the major aims of the H2020-SPIRE project entitled Retrofitting Equipment for Efficient Use of Variable Feedstock in Metal Making Processes (REVaMP) is to develop neutron systems for elemental analysis of raw materials (scrap) used in electric and oxygen steelmaking, aluminum refining and lead recycling.

In a frame of the Aluminum Use Case the so-called Large Sample Senor (LSS) had been proposed for stationary analysis of samples in volumes of up to 1m³. In the course of the Project and after detailed discussions between the scientific and industrials partners, the LSS design evaluated towards the continuous measurements of material moving inside a vertical pipe.

2. The Demonstrator Setup

This updated approach fits well into industrial conditions at Grupal-Art aluminum plant in Barcelona, Spain. Moreover, instead of samples, the LSS system can analyze a whole batch of aluminum chips before they fill the container and will be introduced into the furnace.

Fig. 1: The real industrial conditions at Grupal-Art plant - the cleaned aluminum chips are elevated and dropped into a container. The red area shows the place for the LSS introduction.

The key elements of the LSS demonstrator are:

- the **Main Module** (containning the scintillation detectors and isotopic neutron source) - a black box with vertical pipe above
- the **Vibrating Elevator** and **Vibrating Linear Conveyor** assuring constant moving of the tested material in a closed loop system
- the **Control Cabinet** with power supplies, data acqusition electronics and control computer

Fig. 2: Photo of the LSS demonstrator placed in the experimental setup that mimics the industrial conditions at Grupal-Art aluminum refinery.

3. The Main Module

The core of the LSS module:

- an isotopic neutron source of PuBe (or AmBe) emitting $\sim 2x10^6$ n/s
- data acqusition based on commercial digitizer CAEN DT5730 (8 Channels, 14 bit, 500 MS/s)
- a set of large scintillation detectors - possible application of 3 detector types:
  - ▶ NaI 5x5x10 inch (cuboid)
  - ▶ BGO 5x5 inch (cylinder)
  - ▶ **LaBr3 3.5x8 inch (cylinder)**

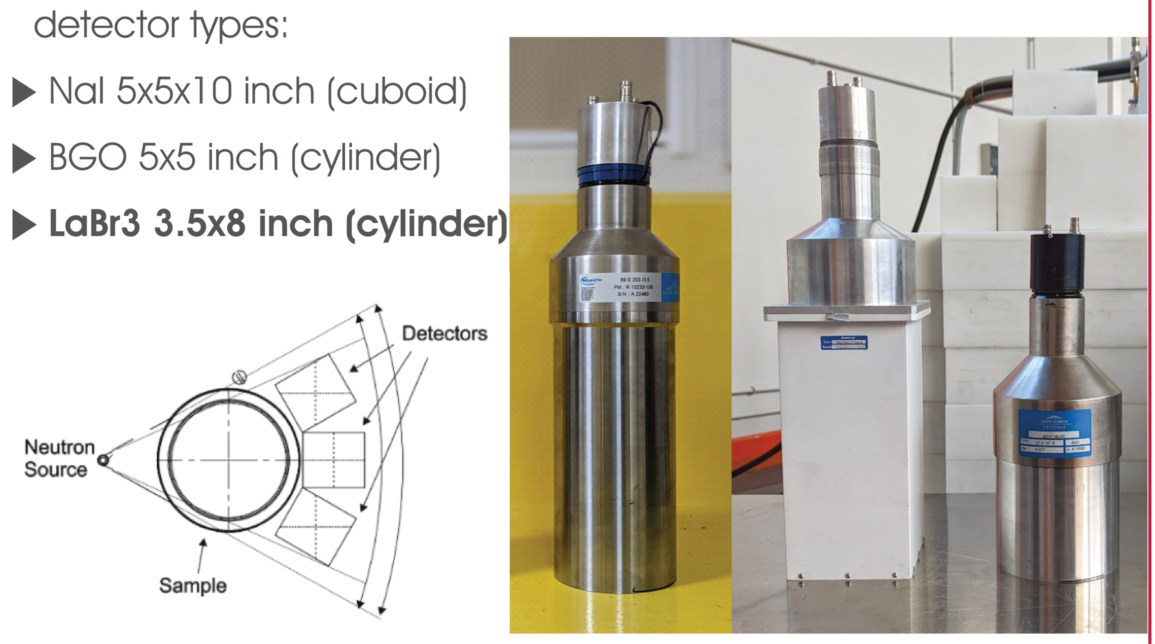

Fig. 3: One of the possible layouts of scintillation detectors inside the LSS Main Module (left) and photos of the detectors possible for application inside the LSS: LaBr, NaI, BGO (starting from right).

4. The Industrial Samples

Grupal-Art provided to NCBJ 9 types of industrial samples (labelled as: A, B, C, D, E, F, G, H, J) of aluminum chips for initial measurements and calibration.

Additional industrial samples, agreed for the final tests of the LSS sensor in a closed-loop system, were delivered later from Grupal-Art (5 types, labelled as: VA, VB, VC, VD, VE).

The chemical composition of these samples had been verified at the plant by means of arc/spark optical emission spectrometry (OES) analyser.

Table 1: Chemical composition (% of content) of 5 industrial samples provided by GRU for final tests of the LSS demonstrator.

	Al	Si	Cu	Fe	Mg	Mn	Ni	Pb	Ti	Zn	Cr
VA	96,22	0,82	0,39	0,55	0,74	0,16	0,02	0,27	0,02	0,14	0,14
VB	98,69	0,65	0,06	0,27	0,07	0,09	0,01	0,01	0,02	0,08	0,01
VC	88,37	6,97	2,92	0,66	0,10	0,32	0,04	0,03	0,10	0,37	0,04
VD	91,69	7,32	0,13	0,16	0,39	0,06	0,01	0,00	0,11	0,04	0,01
VE	91,94	6,36	0,23	0,38	0,46	0,23	0,01	0,02	0,08	0,15	0,06

Fig. 4: Photos of industrial samples of aluminum chips provided by Grupal-Art for industrial tests of the LSS demonstrator.

5. The Artificial Samples

The industrial samples do not provide the full range of concentrations required for the LSS system calibration. Moreover, the content of some elements is close to, or below 1%, which is the measurement limit. Therefore, artificial samples were introduced.

Fig. 5: The pure element samples prepared for calibration of the LSS prototype: a) plastic packets 200-250mm long and 4-5mm in diameter, b) plastic pipes 250mm long and 12mm in diameter, c) plastic rods 250mm long and 45mm in diameter, d) metal (Fe, Cu, Al) rods 250mm long and 12mm in diameter.

6. Spectra and Results

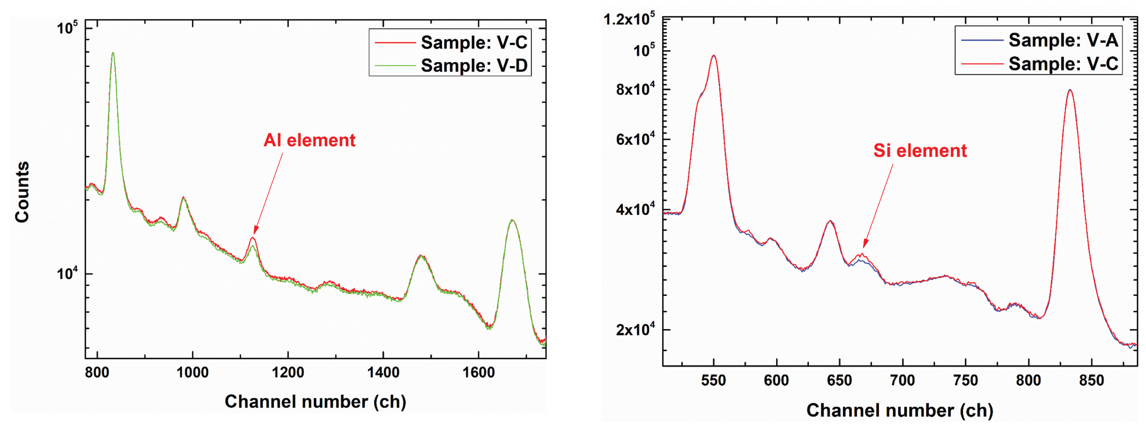

Fig. 6: Zoomed energy spectra recorded in LaBr scintillation detector, during the measurements of industrial samples V-A and V-C (left) and V-C and V-D (right).

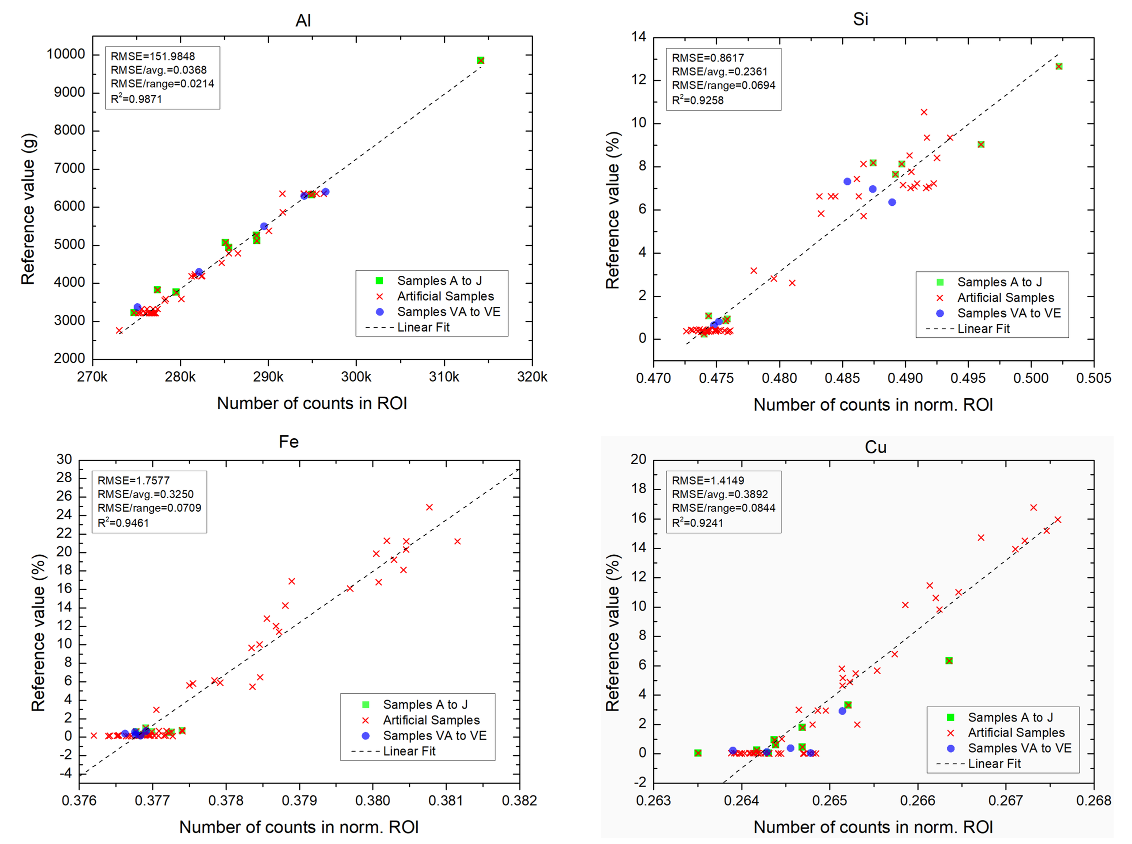

Fig. 7: The calibration lines (dashed) obtained for Al, Si, Fe and Cu from artificial, static samples (in a rotating container) in a form of chips (red crosses) and from the first batch of industrial samples A to J (red crosses on green background). The blue circles are the verification data recorded with the second batch of industrial samples VA to VE (not taken into account during the fitting).

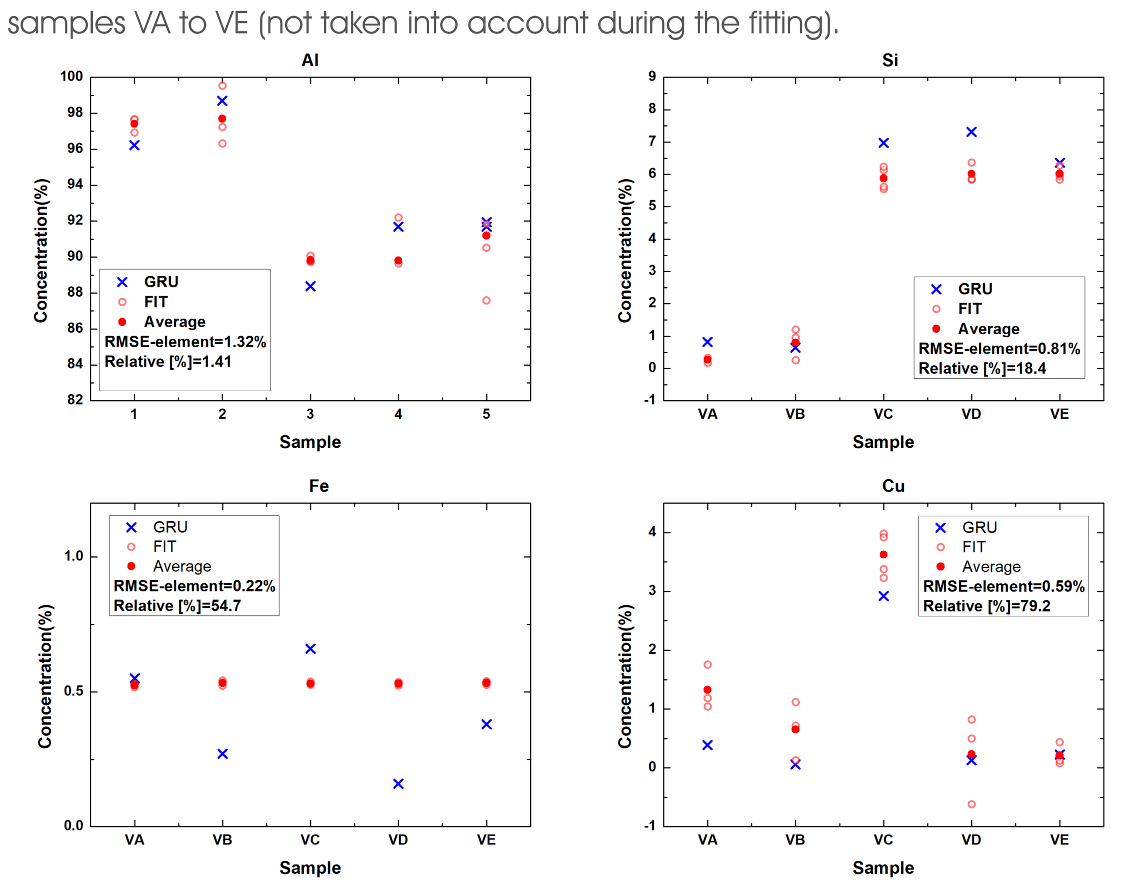

Fig. 8: The distribution around the real values (blue crosses) of the validation data obtained for Al, Si, Fe and Cu from constant flow measurements of industrial samples VA to VE (red circles). The red circles represent the individual measurements, the filled circle is the mean value.

7. Conclusions

- The LSS demontrator has been successfully tested in industrial conditions with real industrial material (aluminum chips) from Grupal-Art aluminum refinery.
- The measurements with artificial samples, assuring well-defined data for a wide range of elemental content, suggest that the system accuracy could be improved for industrial materials.
- The results suggets that the best calibration can be achieved by means of well characterized industrial samples.
- LaBr scintillation detectors are preferred in such systems.

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