

An Assessment of Hand-Held XRF Analyser Performance for the Characterisation of Aluminium Scrap [†]

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Abstract: The characterisation of aluminium scrap plays a crucial role in its recycling, and hand-held X-ray fluorescence (XRF) analysers offer a portable and efficient solution for on-site analysis. This study focuses on assessing the performance of a hand-held XRF analyser for the characterisation of aluminium scrap using the gage repeatability and reproducibility (Gage R&R) method.

Keywords: statistical quality control; Gage R&R; aluminium recycling

1. Introduction

In comparison to other widely used materials such as copper, lead, magnesium and steel, aluminium production has one of the largest energy differentials between primary and secondary production [1]. With the use of modern technology, the process of aluminium recycling requires much less energy consumption than its primary production. This helps conserve energy and raw materials while reducing the demands for landfill space for final waste disposal, making it an example of a circular economy.

As the aluminium recycling process now accounts for an integral part of the production of new products from scrap materials, the primary aluminium production industries have also turned their attention to the production of secondary aluminium. The presence of deleterious impurities in recycled aluminium alloys is increasing and this is the main disadvantage compared to primary alloys. The continuous increase of undesirable elements can be mitigated by different technologies, preliminary operations and treatments, and by optimising the melting process. Since the aluminium scrap that a company can receive is heterogenous, it is particularly important to carry out the correct quality characterisation (sorting) prior to any treatment or melting process [1,2].

Portable X-ray fluorescence (pXRF) is a valuable technique for real-time decision support in mining, metallurgy and environmental applications, providing cost-saving alternatives to laboratory analysis and efficient data collection in remote or harsh field conditions [3]. Over the past decade, portable X-ray fluorescence analysers have been miniaturised into handheld analysers which can be used for on-site characterisation/sorting of metal scraps, including aluminium scrap. Figure 1 shows the on-site analysis of metal scrap with a hand-held XRF analyser, as well as the aluminium scrap in the form of compressed cubes.

This study aims to evaluate the effectiveness of this portable and efficient solution for the on-site analysis of aluminium scrap, based on a hand-held X-ray fluorescence (XRF) analyser. The gage repeatability and reproducibility (Gage R&R) method is employed to assess the performance of the hand-held XRF analyser [4].



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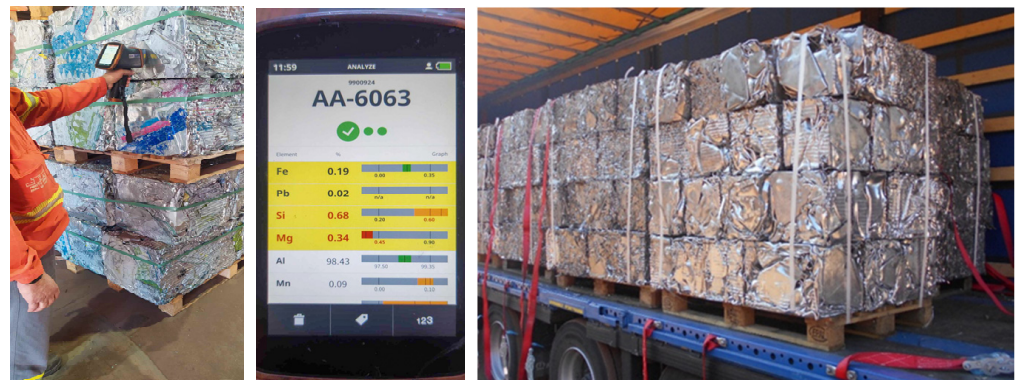


Figure 1. (Left) on-site analysis of metal scrap with hand-held XRF analyser. (Right) Compressed aluminium scrap bundled in cube size.

2. Materials and Methods

Five aluminium alloy samples of known composition (certified reference material) named standard 8079, 12207, 2008, 61308 and 68452 were used. The measurements were taken on each sample using the handheld XRF analyser (type X-MET8000 Expert). The crossed gage reliability and reproducibility method was used to assess the performance of the XRF analyser. This technique is suitable when the tests performed are non-destructive, as in the case of determining the chemical composition of the Al scrap using the XRF analyser [5,6]. To assess the repeatability and reproducibility, multiple measurements were taken on each sample using the handheld XRF analyser by 3 different operators (A, B, C). Operator A measured all standards, followed by B and then C. Each operator performed 10 repetitions of the measurement for each sample, as shown schematically in Figure 2. The chosen Gage R&R method can also be applied to real samples (aluminium scrap) to measure the repeatability and reproducibility error. However, if the systematic error needs to be calculated (as in this case), then certified reference material must be used.

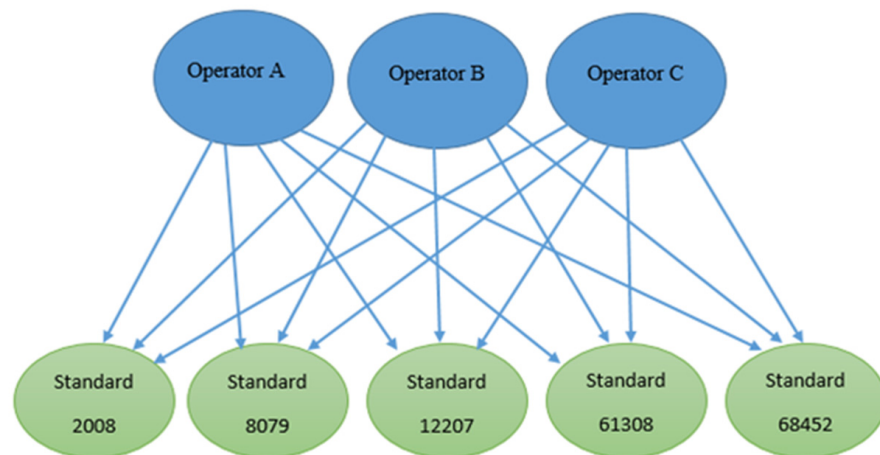


Figure 2. Methodology of taking measurements (Crossed Gage R&R).

3. Results and Conclusions

The results of the Gage R&R analysis are summarised in Figure 3. Based on the percentage contribution of each source of variability (repeatability, reproducibility, parts) to the total variation suggested by the QS 9000 standard [2], the random error of measurement (repeatability and reproducibility) is acceptable for Si, Mg, Mn, Fe, Cr and Cu (<10%), relatively high for Zn (between 10% and 30%) and unacceptable for Zr, Pb and Ni (>30%). The large measurement error for these elements (Zr, Pb, and Ni) is due to their low content in the aluminium scrap and the short measurement time used. Accuracy could be improved by increasing the measurement time, but this may be impractical in routine aluminium scrap sorting where several measurements need to be made. Furthermore, it is clear that the random errors are mainly due to the measurement repeatability of the instrument and much less to the instrument operators. Regarding the systematic error (bias), it is considered acceptable for Si, Cu, Cr, Fe and Mg, while for Mn, Ni, Pb and Zn, it is considerably high, and recalibration and adjustments of the instrument are necessary and/or a larger measuring time is required. Additionally, the correlation plots (Figure 4) between measurements and actual values showed that the systematic error varied within the measurement range for all measured elements. Based on the observed correlation, linear regression equations were calculated and proposed to correct the systematic error. For certain measured elements (e.g., for Cr), further measurements are necessary because the current measurements do not uniformly cover the measurement interval. Therefore, additional standards need to be chosen and applied in Gage R&R analysis.

Overall, the results indicated that the hand-held XRF analyser exhibited good repeatability and reproducibility, as well as a strong correlation between the measurements and the reference values, for the majority of alloying elements and impurities. These findings support the adoption of hand-held XRF analysers as efficient tools for the on-site analysis of aluminium scrap, facilitating rapid decision-making and quality control in the recycling industry.

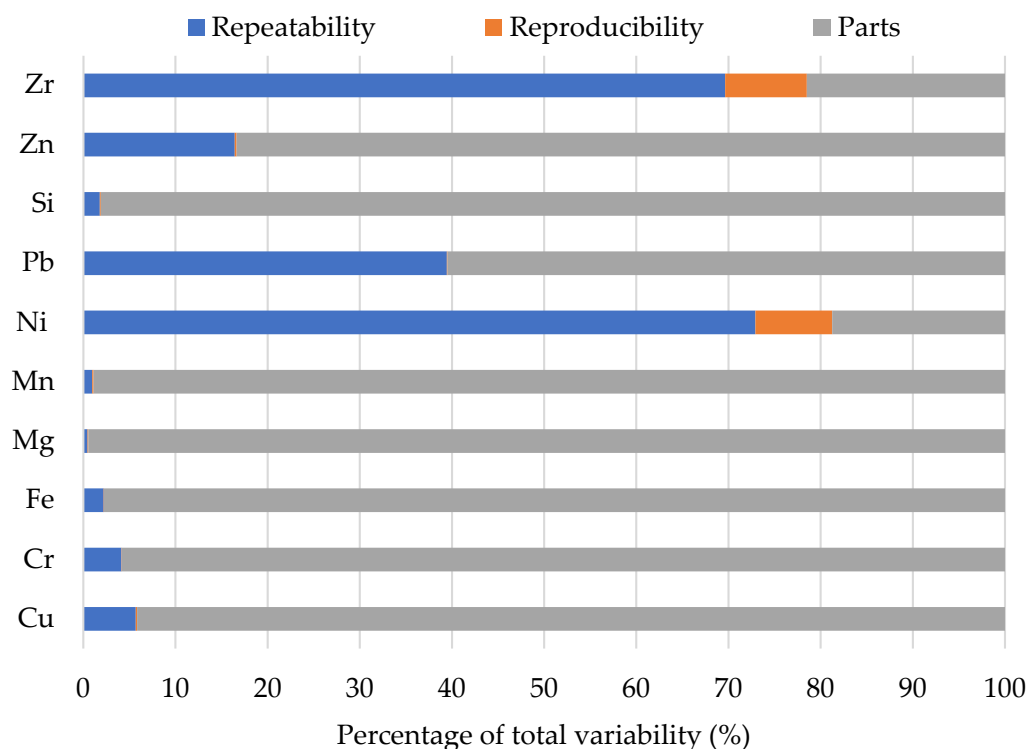


Figure 3. Random and systematic error as a percentage of the mean value of the measured elements.

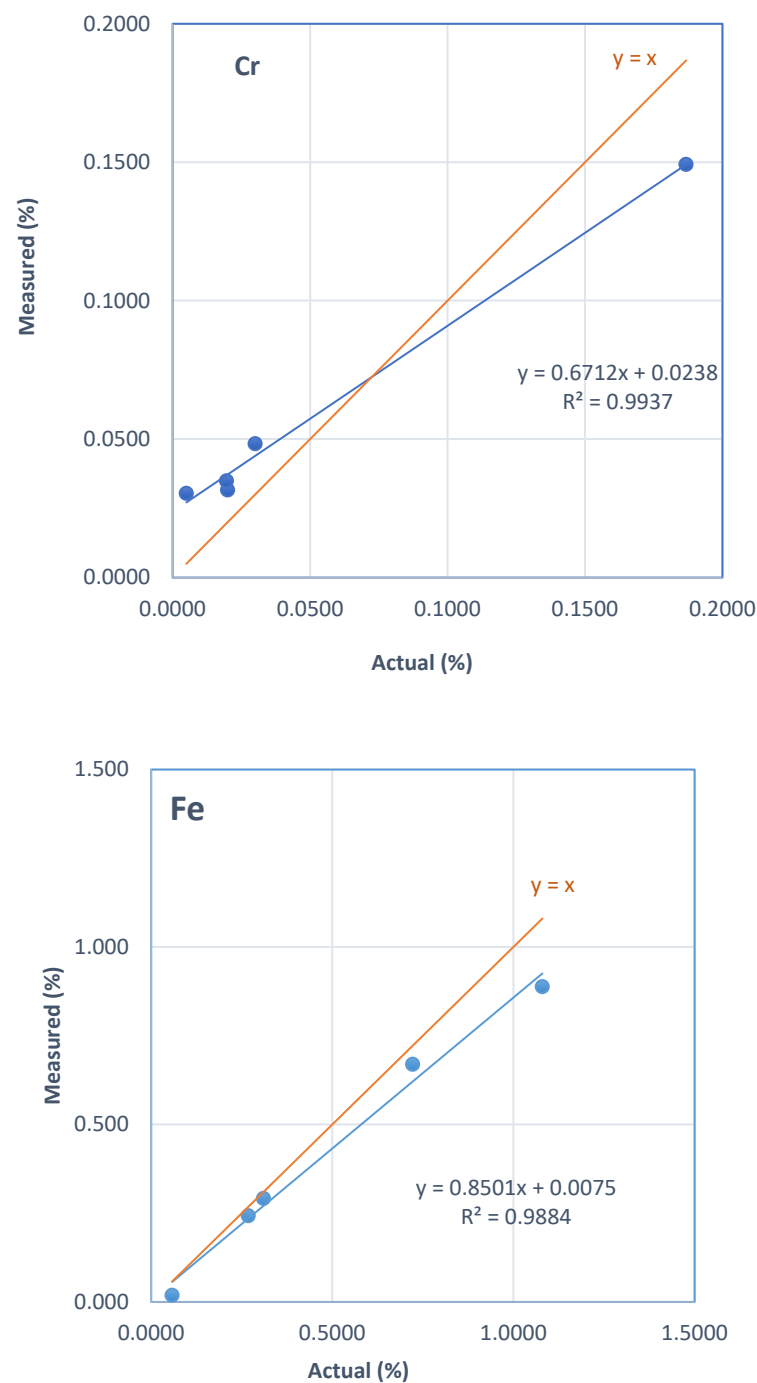


Figure 4. Correlation plots of actual and measured concentration for Cr and Fe.

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