

Title: Development and Production of Certified Reference Materials of Steel and Nickel Alloy Powders for Quality Control in Additive Manufacturing Processes

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Abstract:

The development of metal-based additive manufacturing technologies has created new challenges for chemical metrology, particularly in ensuring the quality and reliability of production processes. Reference materials play an essential role in this area by enabling method calibration, procedure validation, and monitoring of results. However, certified reference materials in the form of metallic powders remain scarce, while available solid or chip forms do not reflect the specific nature of 3D printing feedstocks.

The aim of this work was to develop and certify two reference materials in powder form: stainless steel 316L and the nickel-based alloy Inconel 718. These materials are widely used in additive manufacturing technologies such as Powder Bed Fusion, Directed Energy Deposition, and Metal Binder Jetting, particularly in high-reliability industries such as aerospace and energy.

To ensure metrological consistency of the assigned values, an interlaboratory study was conducted involving eight independent laboratories using various analytical techniques. The results were evaluated using robust statistical methods. Certified values were assigned only to those elements for which both the number and quality of data met the required criteria. These included key alloying elements and selected impurities, e.g., Cr, Ni, Mo, Mn, Co, Cu, C, S, Si, and N in 316L steel, as well as Ni, Cr, Mo, Nb, Al, Ti, Fe, C, S, Si, and N in Inconel 718. The uncertainty budget was calculated as the sum of contributions from characterisation, homogeneity, and stability, applying a coverage factor of $k = 2$.

Stability of the powders was assessed through transport simulation tests and long-term storage monitoring. In both cases, no significant changes in chemical composition were observed. Based on these results, the shelf life was established at 70 months for 316L steel and 75 months for Inconel 718.

This study confirmed the feasibility of developing stable, homogeneous, and metrologically reliable certified reference materials in powder form, tailored to the requirements of additive manufacturing technologies. The results fill an important gap in the availability of such reference materials, enable consistent chemical analysis of powders used in 3D printing, and demonstrate that the applied certification strategy can be extended to other powder materials. The developed reference materials have been implemented in the sales offer of the Łukasiewicz Research Network – Upper Silesian Institute of Technology.