LIBS combined with a decision tree-based algorithm: an analytical tandem for sorting of waste refractories used in steelmaking industries

Javier Moros[a], Luisa M. Cabalín[a], David Maza[b], Aintaze Soto[b], Javier Laserna[a]

[a]*Universidad de Málaga, Facultad de Ciencias, UMALASERLAB, Jiménez Fraud 4, ES 29010, Málaga, Spain*

[b]*Sidenor Aceros Especiales SL, Barrio Ugarte s/n, 48970, Basauri, Spain*

email presenting author: j.moros@uma.es

Keywords: LIBS, decision tree algorithm, classification algorithm, recycling, refractory material.

Refractories are materials that can withstand high temperatures and maintain their mechanical functions and properties during long time, even in contact with corrosive liquids or gases. These materials are indispensable for all high-temperature processes, such as the production of metals, steel, cement, glass and ceramics [1, 2]. Over a decade ago the refractory scrap recycling and the circular economy have started to gain increasing interest because of the potential benefits both from an economic (cheaper raw materials, lower treatment costs, reducing costs for landfilling) and environmental (saving virgin resources, reducing wastes and lower energy demand and CO_2 emissions compared to virgin materials) points-of-view. In this context, the present investigation focused on the design of a classification strategy based on a novel machine learning algorithm combined with optical emissions from LIBS spectral responses to the systematic categorization of refractory residues in 10 different classes. The crucial factor that judges the realistic operation of LIBS to proper sorting of spent refractories is the complex spectral similarity revealed by these materials, usually containing Al_2O_3, MgO and SiO_2 in varying proportions and ZrO in the case of isostatic. By choosing original LIBS emission intensities and intensity ratios pertinent to and involving the most relevant constituent elements (Al, Mg, C –through its related-species CN–, Si and Zr) of various refractory wastes, a decision tree with multiple nodes that decided how to classify inputs was designed and trained. The figure 1 shows the LIBS sensor operating at the UMALASERLAB facilities to the analysis of a refractory sample.

The developed strategy has been also validated in the UMALASERLAB using two sets of "blind" samples of refractory residues provided by Sidenor S.L. First, using a set of 42 “blind” samples, the 72% of the refractories were correctly classified. Then, the original decision tree was conveniently refined with another series of 30 refractory samples. Finally, the updated decission tree has been validated from a second set of 12 “blind” samples. Reported results have demonstrated that LIBS data combined with this supervised machine learning algorithm provided good classification performance with a sorting accuracy of up to 75%. Errors of classification has been mainly atributted to the inherent chemical heterogeneity of the refractory material and any potential physico-chemical alteration on the used material. These facts put even more value on the challenge of correctly classifying refractory residues.

Figure1. LIBS sensor operating at the UMALASERLAB facilities on the analysis of a refractory material.

[1] L. Horckmans, P. Nielsen, O. Dierckx, A. Ducastel, Recycling of refractory bricks used in basic steelmaking: A review. Resources, *Conservation & Recycling* (2019) 140: 297–304. DOI: 10.1016/j.resconrec.2018.09.025

[2] I. Muñoz, A. Soto, D. Maza, F. Bayón, Life cycle assessment of refractory waste management in a Spanish steel works, *Waste Managemen* (2020) 111: 1-9. DOI: 10.1016/j.wasman.2020.05.023