Use of Metallurgical Residues as potential Raw materials for High Performance Refractory Castables

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Context:

The steelmaking industry generates several by-products during the different stages of steel production. As a by-product, vanadium slag account for more than 60% of the world's overall production [1]. However, it is tough to find vanadium in its pure state as it occurs in combination with various minerals [2]. Using secondary resources for refractory castables solves the issue of natural raw materials, reduces costs related to their extraction and processing, and is friendly to the environment.

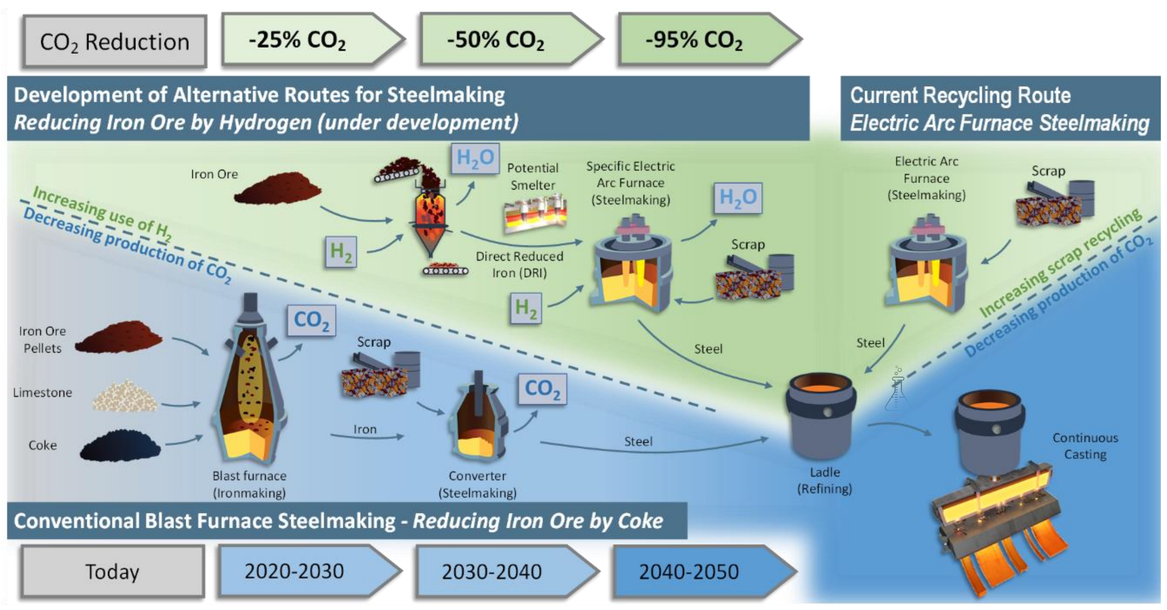


Figure 1. Towards a new steel production route.

Goals:

In order to produce nearly zero-waste results, and with the high production of vanadium slag and a high demand for vanadium, this project aims to transfer vanadium slag into high-alumina refractory castables formulations to obtain high-performance refractory castables.

Objectives of this topic:

- Reducing waste by recycling vanadium slag into refractory castables formulations
- Reducing emissions and costs related to raw material extraction and processing
- Keeping the right properties to withstand harsh conditions while the composition of slag is chemically and mineralogically variable
- Advanced metal-extraction from metallurgical residues

The methods employed:

- Using vanadium slag in high-alumina castables composition as:
  - ✓ **The bonding phase**: Investigate the distribution of the slag in the matrix, its mechanism, and comparison with the behavior of calcium aluminate binders in castables.
  - ✓ **Grog aggregates**: Mineral processing route of grog aggregates and transfer into the formulation of castables for metallurgical application.

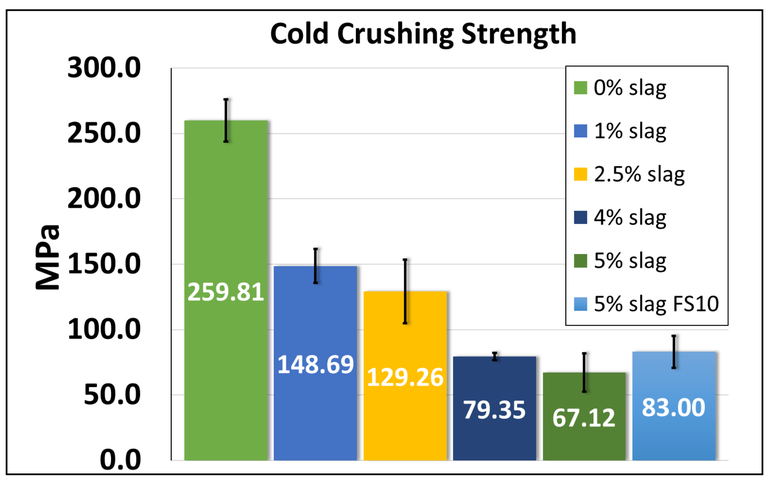
Assessment of thermomechanical behavior of castables produced in both cases is in regard.

- Extraction of Vanadium: sustainable way in respect of vanadium recovery, quality of product, and its influence imposed on the environment [3].

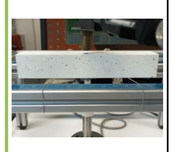
Results and Discussion:

❑ Mechanical properties

- Cold Crushing Strength determination (CCS):



- Resonant Frequency Damping Analysis (RFDA):



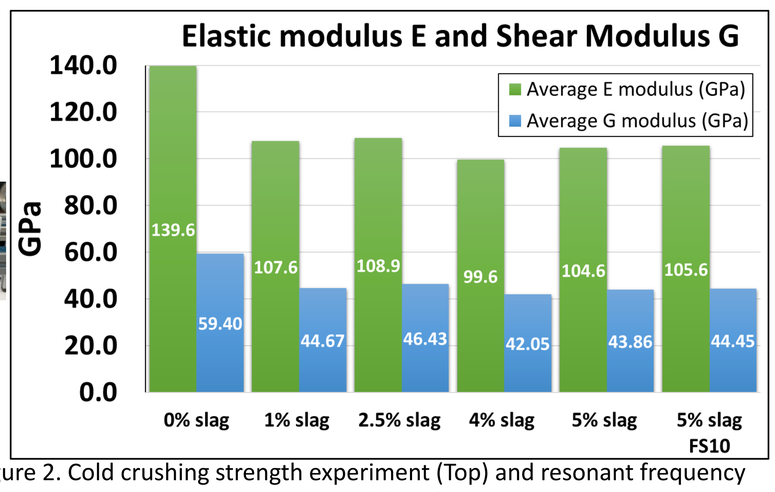
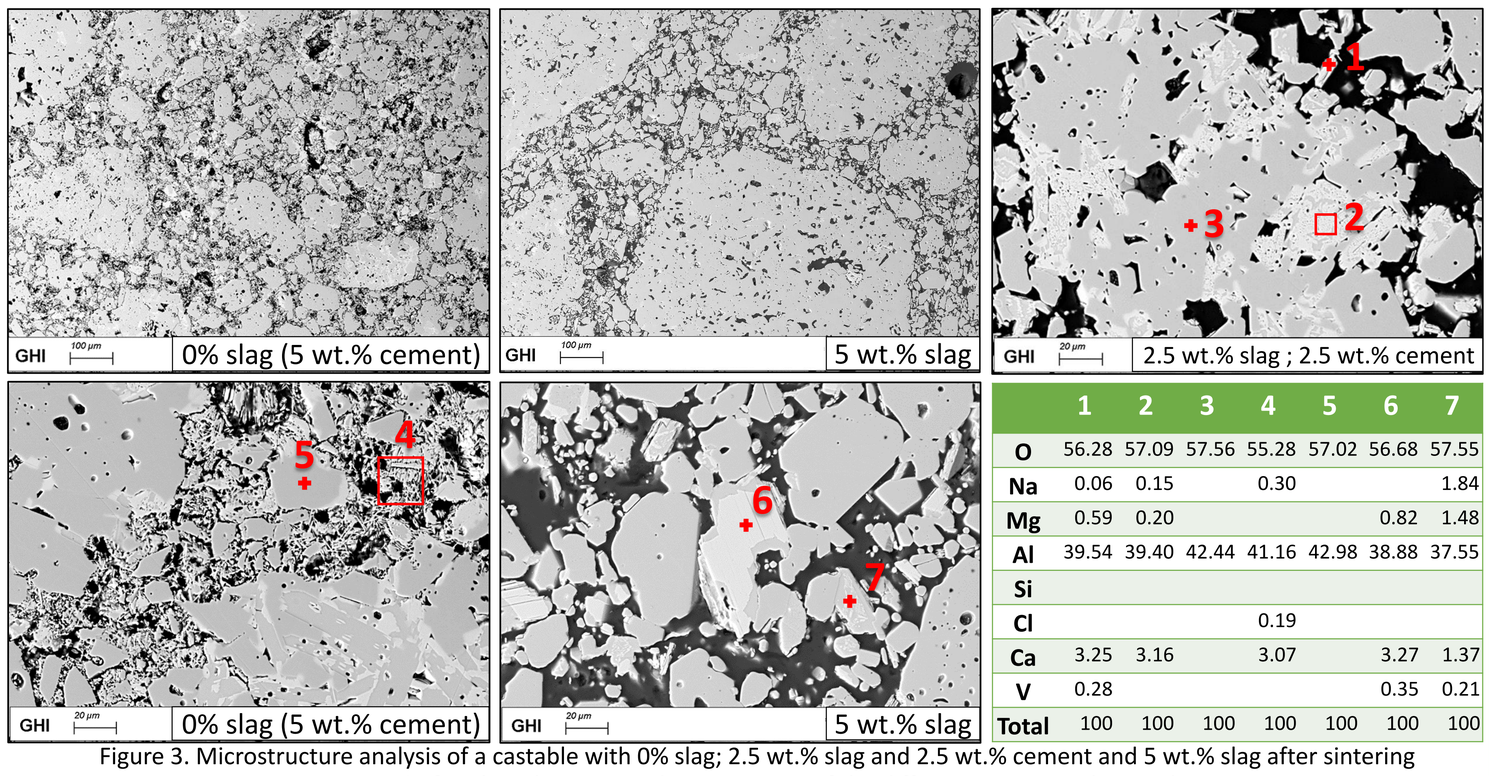


Figure 2. Cold crushing strength experiment (Top) and resonant frequency damping analysis (Bottom) on castables after sintering at 1500°C/6h.

The ability to resist failure under compressive load decreases significantly when adding slag to the formulation. However, the reference is based on high alumina castables, rarely employed in industries. E and G modulus data do not display considerable deviation with the different amounts of slag. The distribution of the slag in the matrix is a key microstructural analysis to observe the vanadium in the castable. The phases containing vanadium are always allocated with Mg, Al and Ca. The vanadium reacts preferably with these components towards a stable phase after sintering. The vanadium is not observed in the Al_2O_3 grains compared to cement which attacked the grain to form calcium aluminate phases.

❑ Microstructural analysis after sintering at 1500°C



	1	2	3	4	5	6	7
O	56.28	57.09	57.56	55.28	57.02	56.68	57.55
Na	0.06	0.15		0.30			1.84
Mg	0.59	0.20				0.82	1.48
Al	39.54	39.40	42.44	41.16	42.98	38.88	37.55
Si							
Cl				0.19			
Ca	3.25	3.16		3.07		3.27	1.37
V	0.28					0.35	0.21
Total	100	100	100	100	100	100	100

Figure 3. Microstructure analysis of a castable with 0% slag; 2.5 wt.% slag and 2.5 wt.% cement and 5 wt.% slag after sintering at 1500°C for 6h and corresponding EDS scans of the different points on the graph.

Ongoing work:

- ✓ Development of mineral processing route of aggregates and study of the behavior in refractory castables.
- ✓ Further thermo-mechanical tests with castables containing vanadium slag as the bonding phase.
- ✓ Different trials to extract the vanadium in a sustainable way
- ✓ Contact different slag suppliers for further comparison with current slag composition

References:

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Beneficiaries