DRY COPPER SLAG ATOMISATION: ON SITE LABORATORY-PILOT SCALE TRIALS AT COPPER SMELTER FACILITY

Irene RUIZ-ORIA, Jesús OVALLE, Leandro GONZÁLEZ, Alberto MEJÍA, Guillermo RÍOS

Atlantic Copper S.L.U. Avda. Francisco Montenegro s/n, 21001 Huelva, Spain

iruizori@fmi.com, jovalleg@fmi.com, lgonzale1@fmi.com, amejiape@fmi.com, griosran@fmi.com

Introduction

Atlantic Copper S.L.U. is a company dedicated to the treatment of copper ore concentrates and their transformation into anodes and cathodes in order to obtain high quality copper. The capacity of copper anodes production is about 330 000 tpy and 285 000 tpy of copper cathodes. Atlantic Copper also produces sulphuric acid (around 1 million tpy) and anode slimes rich in precious metals as gold and silver.

During the smelting process, the Flash Furnace produces molten matte and slag, and a process gas with high SO_2 content. The molten material flows into the settler, where the denser components (slag) settle out, leaving the lighter components (matte) on top. The matte is transferred to the next stage of the process, the Converters, while the molten slag flows directly to the Electric Furnace through launders. Likewise, a similar separation of the matte occurs in the Converters, sending the molten slag produced to the Electric Furnace and the blister copper to the Refining Furnaces.

The mission of the Electric Furnace (fed by the molten slag of the Flash Furnace and Converters) is to recover part of the copper and other valuable metals contained in the slag, thus minimising the copper losses in the process, reducing the copper concentration in the molten slag (from 2 to 6%) to less than 1%. This molten slag from the electric furnace is quenched and granulated with water to obtain iron silicate, a chemically stable by-product with industrial applications, such as construction filler, sandblasting or concrete production.

Among other properties, granulated slag must be an inert, non-water absorbing and non-leaching material.

Dry granulation

Atlantic Copper, which remains at the forefront of technology in the metallurgical sector with the application of the Best Available Techniques (BAT), contacted the

technology-based company, HATCH, which had developed a dry atomisation technology for iron silicate, Ecomaister-HATCH Eco2STAR. This technology is being currently implemented on a large scale in Asia in plants for the treatment of steel, zinc and SiMn slag. However, it has not been adapted yet to treat copper slag in any copper smelter worldwide.[1,2]

Despite the fact that the current process to produce granulated slag at Atlantic Copper is a usual and successful process, several drawbacks related to the use of water could be solved or minimised with the use of a new technology of dry granulation; for instance:

- Economic and environmental costs due to the huge use of water.
- Risks of steam explosions due to the water-molten slag combination.
- H_2S gas formation.
- Leaching of acids and metals in the water stream (which must be treated for reuse or discharge)
- Formation of porous particles, not valid for certain applications of the final product.
- No recovery of the heat energy of the iron silicate.

Target

Due to the interest that this technology can have for the Atlantic Copper smelter, it was proposed to carry out some tests of the Ecomaister-Hatch air atomisation at laboratory-pilot scale in the facilities of Atlantic Copper. The main objective was to study and determine the effects of air atomisation on the composition, leaching and granulometry of the slag when molten slag is quenched and granulated by means of air atomisation.

Method and Description

The laboratory-pilot was installed by HATCH at the Atlantic Copper facilities. A scheme and a picture are shown in Figure 1.

Figure 1: Scheme of the laboratory-pilot Ecomaister-Hatch design by HATCH (left) and the one installed in Atlantic Copper during a test (right)

Operation

Molten slag is discharged from the electric furnace and conveyed to a slag-feeding chute located in front of the atomisation chamber. The operator preheats a ladle spoon in slag stream before taking the sample and quickly moves over to blower/enclosure. Then, the operator discharges slag such that the ladle spoon is facing away from the nozzle and is in close proximity to the nozzle. An air jet from an atomiser granulates and quenches the molten slag into the granulation chamber, as shown in Figure 1. Inside the chamber, the granulation blast air passes co-currently to the hot granules to cool the particles and to obtain a hot gas stream. The cooled and solidified granules, shown in Figure 2, are collected, labeled and analysed.

Figure 2: Samples collected after dry granulation of the slag

Slag Temperature Measurement

Using a pyrometer, the temperature of the surface of the slag was measured before atomisation begins (when the operator is preheating the ladle spoon), once the slag sample is taken by the operator and immediately after atomisation is completed.

Slag Flow Rate Measurement

The slag flow rate was calculated measuring the duration of the discharge carried out by the operator and weighting the slag mass at the end of the atomisation when the operator is discharging the slag for atomisation.

During the process, in addition to temperature and slag flow rate, other data are collected, such as the air flow rate and the angle of incidence of the air with respect to slag flow.

Test phases

Tests were divided into three phases:

1. The first one consists in the preparation of isolated samples, in different conditions of the process (slag temperature, bath level) and different pouring conditions (blower speed, spoon emptying rhythm). This experiment was repeated to have a wide range of samples to analyse.
2. The second phase is based on continuous granulated slag production, having slag spoons emptying rhythm repeatedly until a considerable amount is reached to collect. At this stage, the flow of the blower is not set to a fixed setpoint, but oscillating to help cool the floor of the chamber and dissipate the heat of the slag, so that the slag does not melt over the previous slag by its own remaining heat.
3. During the third phase, a portable thermocouple is used, focusing the slag flow to that point in order to measure the temperature during the process. The measurement probe was located in such way that it was possible to measure the temperature of the slag during all the process. In addition, a thermal imager was used outside the chamber to check the temperature.

Results

Figure 3 provides a visual summary of the completed test runs.

The samples collected were pre-sieved, rejecting particles > 1 cm, and calculating the yield as the percentage of particles < 1 cm. The vast majority of the pre-sieved material (bulk) presented a yield of 100%. Then, the bulk was analysed by XRF, ICP and XRD to determine composition and crystalline *vs.* amorphous content. The composition barely differs between all the samples prepared. In order to simplify, in Table 1 the mean composition of the iron silicate is shown.

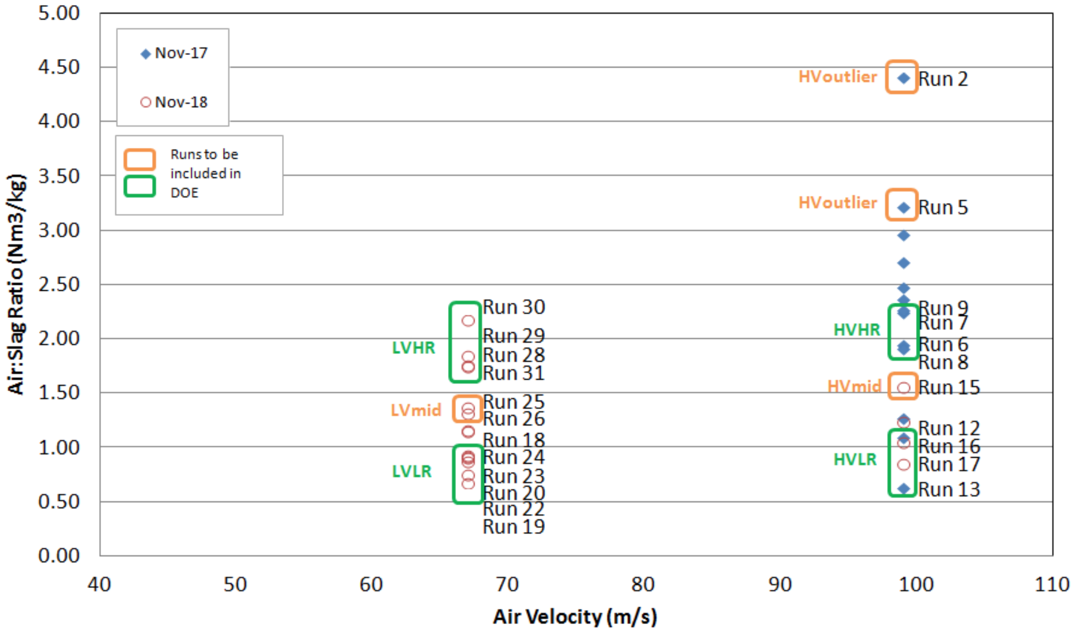

Figure 3: *Summary of* test *runs completed;* The acronyms noted in the runs represent: HVLR = High Velocity, Low air-to-slag Ratio, HVHR = High Velocity, High air-to-slag Ratio, LVLR = Low Velocity, Low air-to-slag Ratio LVHR = Low Velocity, High air-to-slag Ratio, HVoutlier = High Velocity data points that are well above the targeted air-to-slag ratio, HVmid = High Velocity data points midway between air-to-slag ratio targets; LVmid = Low Velocity data points midway between air-to-slag ratio targets

Table 1: Mean composition of the iron silicate produced by air atomisation; Obtained by XRF

Composition	%Fe	%Al	%Ca	%Cu	%K	%Mg	%Na	%Si
Mean sample	43.52	1.65	1.46	0.65	0.56	0.37	0.05	28.96

The bulk was sieved in many different sizes, from 0.2 mm to 10 mm in order to obtain particle size distribution curve (following the UNE EN 933-1 standard), apparent density (UNE 103301) and Mohs hardness. Similar results were found in all samples, showing apparent density around 2.2 g/cm^3, Mohs hardness < 7 and a grading curve typically like the one showed in Figure 4. Typical samples from wet granulation presented apparent density around 3.7 g/cm^3, Mohs hardness > 6 and over 80% of particles smaller than 4 mm.

To determine leaching behaviour, samples were analysed according to UNE-EN 12457/4 standard. Except few of the samples, almost all of them showed acceptable leaching behaviour to be considered as non-hazardous waste, which gives a vision of how inert is the product. In Table 2, a representative result obtained in the leaching analysis is shown.

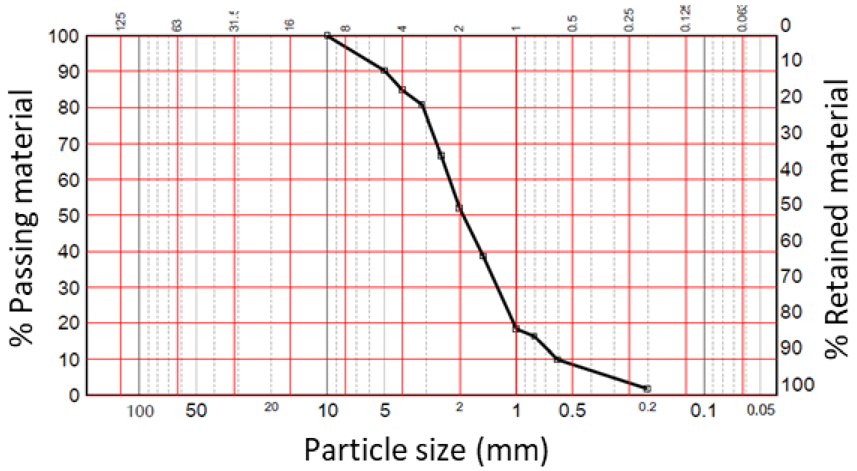

Figure 4: Example of particle size distribution curve, obtained with the bulk of slag samples

Table 2: Representative results obtained in the leachate analysis from samples from dry and wet granulation; and specifications to be acceptable for non-hazardous waste

	pH (20°C)	Conductivity (µs/cm)	Cu (mg/l)	As (mg/l)	Pb (mg/l)	Zn (mg/l)	Cd (mg/l)	Ni (mg/l)
Dry granulation	6.50	7.58	< 0.20	< 0.1	< 0.1	< 0.2	< 0.1	< 0.15
Water granulation	6.50	11	0.83	0.08	< 1	< 0.2	< 0.2	< 0.3
Non-Hazardous Waste			5	0.2	1	5	0.1	1

Conclusions

Tests carried out over real molten slag with laboratory-pilot Ecomaister-Hatch air atomisation showed that it is possible to obtain good quality granulated iron silicate. Compared to water granulation, the composition, granulometry and Mohs hardness were in the same range, while, the apparent density decreased, which can be due to a more porous material (further analysis must be carried out). Regarding the analysis of the leachate, samples obtained by dry granulation showed better features as compared to the current slag, presenting values good enough to be considered as Non-hazardous waste. Dry granulation is, this way, a granulation process that could avoid the formation of H_2S gas produced by the use of water, take advantage of the air heated by the slag in order to recover energy, and able to produce iron silicate with at least the same quality than that obtained by traditional water granulation.

References

1. S. Faucher, L.C. So, S. Mostaghel, S.K. Lee, S.-Y. Oh, "Recent developments in commercial scale dry slag granulation and energy recovery", AISTECH, 2016.
2. S. Faucher, S. Mostaghel, L. C. So, S. Y. Oh, "Recent developments in dry slag granulation: a path to improving safety and sustainbility of the metallurgical sector", 71th ABM Annual Congress, (2016).