Air Granulation

Copper Smelting Processes

August 2018

HATCH

Introduction

Typical slag management practices in the copper industry include dumping, slow air cooling, and water granulation, as shown in Figure 1.

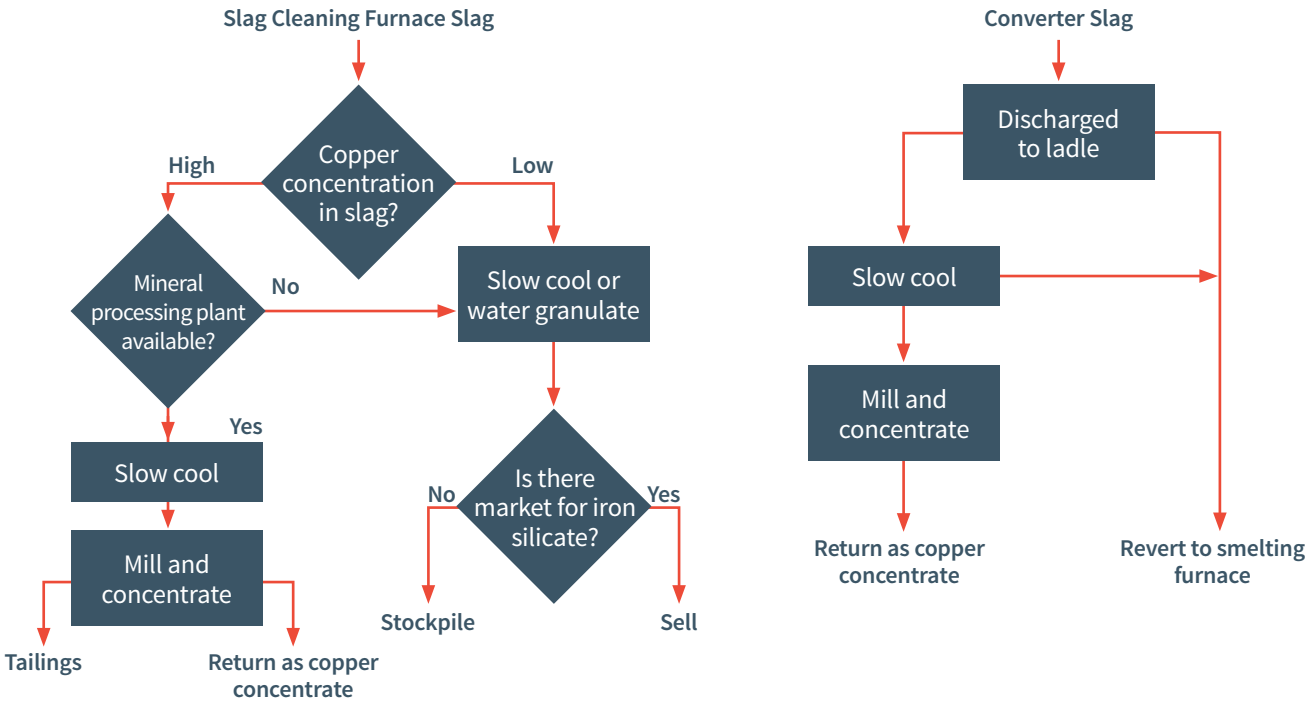


Figure 1: Copper Slag Processing Routes

Dumping is the most commonly used slag handling method for most metal production plants, but presents various challenges such as:

- Need for a large slag pit
- Need for expensive/high-maintenance “hot” mobile equipment
- Risks associated with transportation of molten slag
- No value recovery from the slag as a sellable by-product, or from slag as a source of heat

Slow cooling in pots is often a preferred approach for copper recovery at sites equipped with mills and flotation plants. It is practiced where residual copper in slag warrants such reprocessing. While this process permits copper recovery, it requires:

- Real estate for “pot fields”
- Handling/transportation of hot loads in a safe manner
- Handling of comminution dust
- Long term management of tailings

If copper concentration in the slag is low enough to be discarded, smelters have historically preferred using water granulation for easier handling of their slag.

Water granulation is comprised of two steps: i) dispersion and quenching of the molten stream with pressurized water jets; and ii) dewatering using additional equipment such as bucket excavators, screw classifiers, etc.

Water granulation addresses some of the challenging and costly steps required by slow cooling, such as molten material hauling, crushing, milling, dusting, and tailings processing. However, water granulation introduces its own set of challenges, the most significant being:

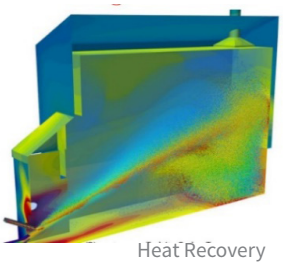
- Excessive use of water
- Risks of steam explosion
- High equipment maintenance due to wear by abrasive fines in the water
- Requirements for cooling towers and water tanks, no re-use of slag heat

Industry has sought to develop the most suitable method for dry granulation to eliminate the challenges associated with water granulation and dumping – air granulation is the simplest and most viable method in comparison to others.

Typical Slag Dumping Operation

Air Granulation

Air granulation is the simplest technology for handling slags, metals, and mattes. It has been proven at 20+ metallurgical sites around the world and has safety, environmental and economic benefits. A schematic of the technology is provided in Figure 2. Molten material discharged from the furnace is transferred via launders or pots to a feeding chute located in front of a granulation chamber. A jet of granulation air breaks apart and quenches the molten material which is collected as cold granules inside the chamber. Heat of molten material is recovered by the granulation air which may be used directly as hot air, for generation of steam, or cleaned and vented. The cooled and solidified granules can be continuously conveyed out of the chamber or periodically collected, packaged and sold.


Heat Recovery

Historically, this technology has been implemented at steelmaking sites having electric arc furnace (EAF), basic oxygen furnace (BOF), and ladle metallurgy furnace (LMF), as well as non-ferrous metal production sites producing zinc and silicomanganese – some with slag heat recovery. More recently, however, Hatch has commercialized air granulation for processing of Platinum Group Metals (PGM) converter slag, and we are doing the same for ironmaking blast furnace and other non-ferrous streams.


Valuable Slag By-Product

The major advantages of this technology include:

- A safer work environment – no risk of explosions
- Water-free processing – no acid mist or dewatering
- A cleaner work environment – quick cooling results in stable, low-dust products
- Higher up-time and lower maintenance than water granulation
- Potential for heat recovery
- Increased productivity of mattes and metals – decoupling of primary and secondary processes
- Reduced leaching of elements from slag
- Reduced OPEX and CAPEX costs as compared to standard water granulation technologies
- Revenues from sale of high-quality, value-added products

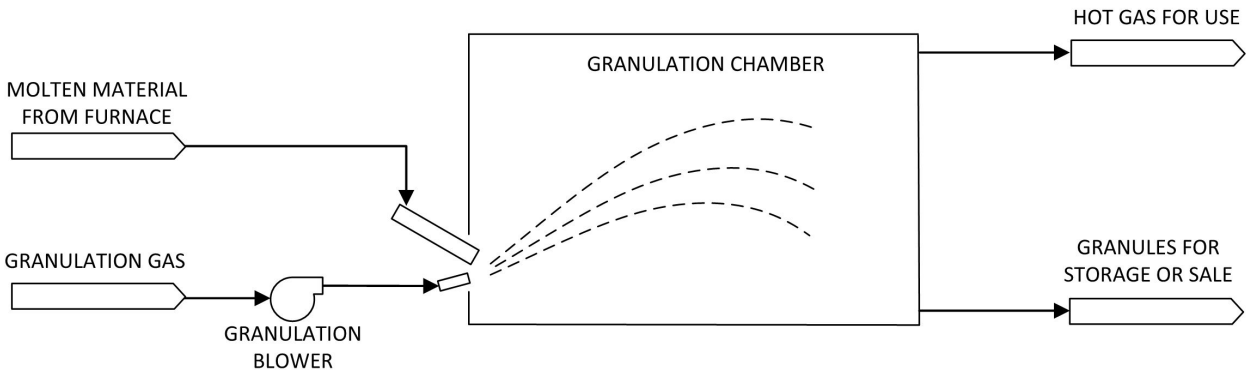


Figure 2: Schematic Process Flow Diagram of the Air Granulation with Heat Recovery

Hatch's Experience

Copper Slag

PGM Convertor Slag

Ni Furnace Slag

Figure 3: Air Granulated Slags

Air Granulation of Slags

Hatch has recently implemented air granulation for processing of PGM convertor slag, and has also successfully granulated steelmaking slag; ironmaking blast furnace slag; lead-zinc slag; PGM furnace and converter slags; nickel furnace and converter slags; copper furnace slags; and ferrochrome slag. Some examples are shown in Figure 3.

Hatch's air granulation of copper settling furnace slag produced a granular product with particle size ranging between 1 mm to 5 mm, with particle size distributions being largely independent of scale of the process setup. Typical particle size distributions are shown in Figure 4.

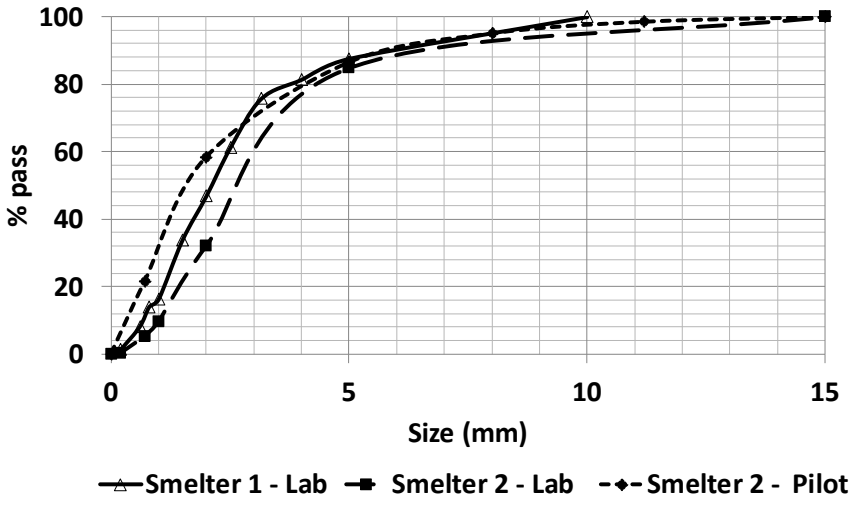


Figure 4: Particle Size Distribution of Air Granulated Copper Settling Furnace Slags

Leaching behaviour of the air granulated product was also investigated and compared to that of water granulated samples. Due to presence of steam in the water granulation process, particles are rather porous (in some instances hollow) and therefore have a large specific surface area. Whereas air granulation produces solid and denser particles with lower specific surface area. Leaching is a surface phenomenon and is directly controlled by the total contact area of the particles and the aqueous solution. Hence, theoretically, it is expected that air granulated samples show a lower leachability than water granulated samples.

Comparison of leaching behaviour of air granulated slag and a water granulated product is shown in Table 1. The leachates obtained from the air granulated product show metal leachabilities within the same range or slightly lower than those obtained from water granulated product. As such, the air granulation process demonstrates the ability to produce a product that has comparable or improved chemical stability to the water granulated samples. The same trend was also demonstrated in the pilot-scale air granulated slag product from a lead-zinc smelter, and also from commercially produced air granulated steelmaking slags.

Table 1. Leaching Behaviour of Air Granulated Copper Settling Furnace Slags

Leachate	As	Pb	Cd	Ca	Cr (tot.)	Cu	Mo	Na	Ni	Zn
Units	µg/l	µg/l	µg/l	mg/l	µg/l	µg/l	µg/l	mg/l	µg/l	µg/l
Smelter 1										
Air Gran. Sample 1	3.01	<0.5	1.04	<0.5	<0.5	45.2	49.7	0.65	1.83	26.1
Air Gran. Sample 2	1.23	<0.5	0.95	<0.5	<0.5	62.9	30.8	0.48	1.74	26.2
Water Gran. Sample 1	2.05	0.135	0.12	<0.5	<0.1	3.11	0.57	0.16	0.63	4.3
Water Gran. Sample 2	13.1	1.19	1.09	<0.5	<0.5	28.7	18.8	1.29	2.79	38.1
Smelter 2										
Air Gran. Sample	<10	<10	<10	-	-	23.2	-	-	<15	61.4
Water Gran. Sample	14.7	12.7	2.0	-	-	25.7	-	-	15.3	78.3

Note that leaching tests were performed in accordance to EN 12457 Compliance Test for Leaching of Granular Waste Materials and Sludges.

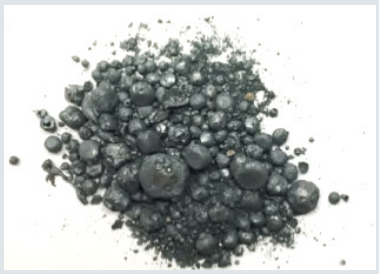
Air Granulation of Mattes and Metals

In addition to slag, Hatch has tested the capabilities of the air granulation to treat other molten materials, including copper matte, blister copper, nickel matte, PGM matte, steel, and pig iron; some examples shown in Figure 5.

Preliminary characterization of lab-scale and pilot-scale granulated samples showed limited oxidation and compositional change to the product as a result of the granulation process.

Granulated Copper

Granulated Steel



Granulated Pig Iron

Figure 5: Air Granulated Metals

Hatch Approach

Hatch offers a staged approach for adoption of air granulation technology through on-site laboratory-scale and pilot-scale testing, prior to full-scale implementation.

On-Site Laboratory-Scale Testing

On-site laboratory-scale testing is a low cost and low risk first step to evaluating the technical and economic feasibility of air granulation. This will involve the use of hand-held ladles for melt sampling and subsequent pouring onto an air granulation jet blowing into a small chamber. Several kilograms of air granulated sample will be produced at the rate of ~1 kg/min over a one-week test campaign. These samples may then be used for material characterization and initial market testing. An example of the lab-scale test work is shown in Figure 6.

Hatch will provide:

- Laboratory-scale air granulation blower and nozzles
- Hand-held ladles
- Hatch personnel for on-site support and consulting

Client will provide:

- Small granulation chamber fabricated of light gauge steel – see Figure 7
- Operators for melt sampling

Figure 6: Laboratory-Scale Testing

Figure 7: Laboratory-Scale Granulation Chamber

On-Site Pilot-Scale Testing

On-site pilot-scale testing is a larger-scale system for producing several tonnes of sample for additional material testing/characterization, market evaluation, and optimization of process parameters scalable to full-scale implementation. This will involve use of a crane-carried ladle to first collect and then transport molten material to the air granulation system. The ladle will subsequently pour molten material onto a trough located above an air granulation nozzle which blows into a granulation chamber – see Figure 8. The granulation chamber will consist of a standard 40-foot shipping container with simple modifications, and if necessary, an additional fan system for off-gas capturing. The molten material will flow down the trough and into the granulation jet, dispersing into the granulation chamber. Sample material will be produced at the rate of 30 - 50 kg/min over the course of a two-week test campaign. An example of the pilot-scale test apparatus is shown in Figure 9.

Hatch will provide:

- Pilot-scale air granulation equipment, consisting of:
  - Blower (i.e. fan, motor, inlet filter, silencer)
  - Variable speed drive
  - Ducting
  - Nozzle and nozzle support
- Off-gas equipment, if required, consisting of:
  - Fan
  - Variable speed drive
  - High temperature ducting
  - Filter housing and filters
- Hatch personnel for on-site support and consulting

Figure 8: Pilot-Scale Testing

Client will provide:

- Granulation chamber
- Feeding trough
- Tilting ladle
- Operators for molten material handling

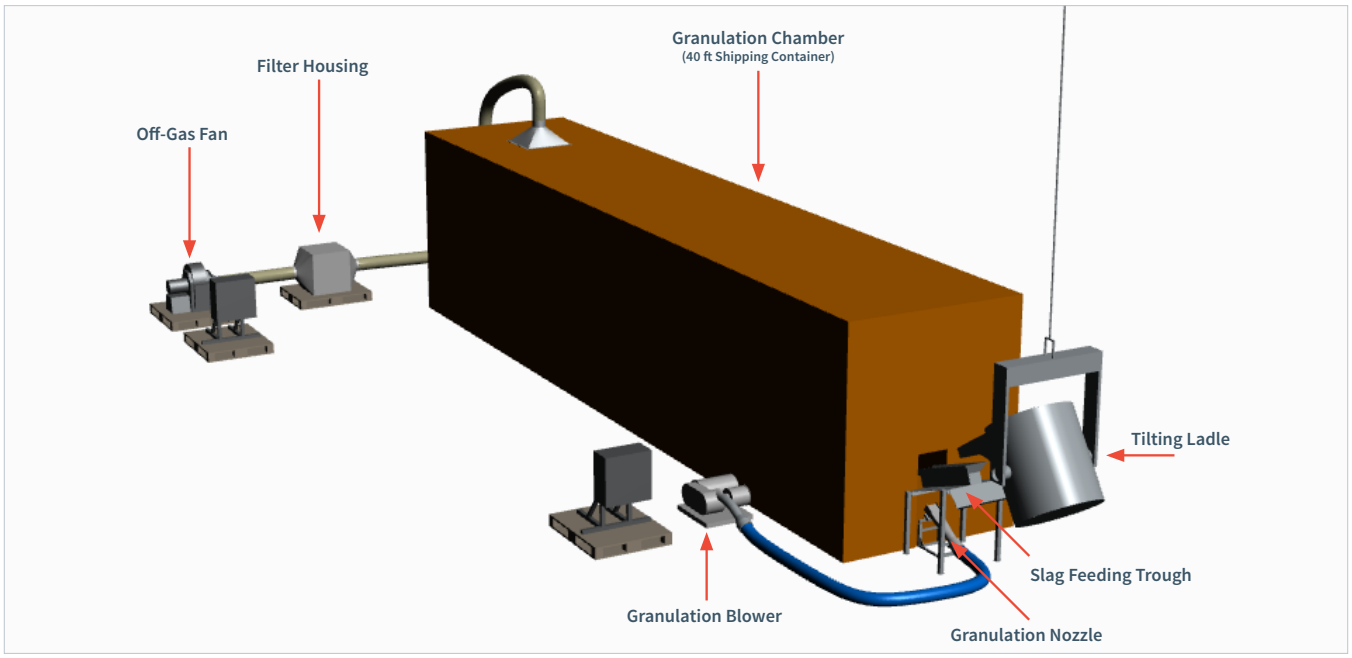


Figure 9: Pilot-Scale Test Apparatus

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About Hatch

Whatever our clients envision, our engineers can design and build. With over six decades of business and technical experience in the mining, energy, and infrastructure sectors, we know your business and understand that your challenges are changing rapidly.

We respond quickly with solutions that are smarter, more efficient, and innovative. We draw upon our 9,000 staff with experience in over 150 countries to challenge the status quo and create positive change for our clients, our employees, and the communities we serve.

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