The Beneficial Effects of Feeding Dry Copper Concentrate to Smelting Furnaces and Development of the Dryers

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Abstract – By placing additional demands on energy and gas flow, the moisture content of a copper concentrate has an adverse effect on the smelting process. Different drying technologies, such as directly heated rotary dryers, flash dryers, and steam dryers, are available to solve this problem. The energy requirements of and off-gas generated from different dryer types are compared. The performance of the steam dryer was found to be superior to that of the others. In particular, the rotary steam dryer and its benefits are discussed. Structural properties confer an advantage on the rotary steam dryer, for wear on tube elements is eliminated, and drying efficiency is improved. If steam is available, the rotary steam dryer is an excellent choice for drying copper concentrates.

INTRODUCTION

The raw materials in copper smelting contain generally 6–14% moisture. The level of moisture classifies smelting as either a wet-feed or a dry-feed process. Requirements of the moisture content of feed vary from process to process. The most demanding processes are flash smelting and the Mitsubishi process, which require dry concentrates (<0.5% moisture).[1] Reverberatory furnaces can tolerate a maximum of 7% moisture in the feed; and ISA furnaces and Noranda reactors, up to 10% moisture. Compared with dry feed, the use of wet feed in copper smelting has disadvantages, such as increased energy consumption and off-gas flow. This paper describes the benefits of drying the copper concentrate, presents different drying technologies, and demonstrates the superiority of the rotary steam dryer.

ADVANTAGES OF USING DRY FEED

The amount of water fed to a smelting furnace can vary from 6–16 tons per hour, with feed rates of 60–160 t/h of concentrate containing 10% water. This water in the smelting furnace adds no value; on the contrary, it adds to the cost of the process. The additional energy required and increased off-gas flow are presented here; the calculations for wet and dry feed are compared. Figure 1 illustrates the effects of wet feed on the smelting furnace.

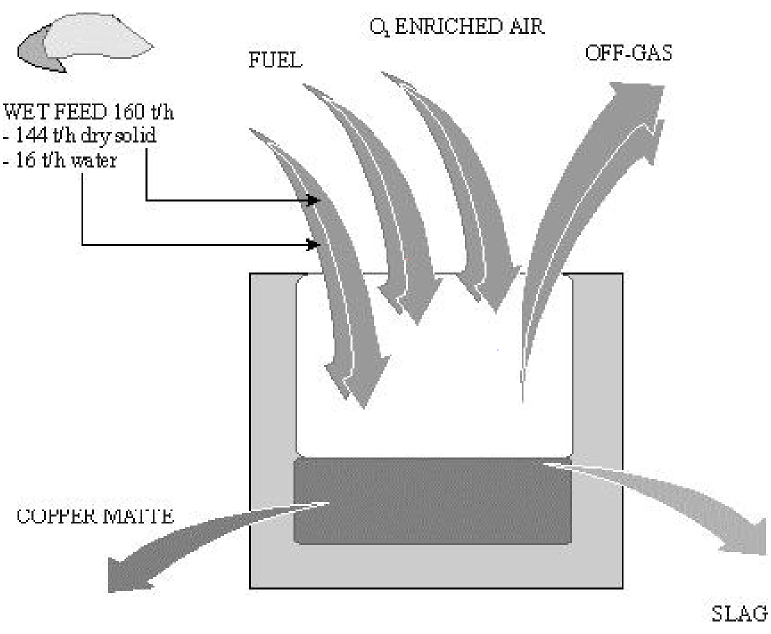

Figure 1: Schematic diagram of unnecessary water feed of 16 t/h to a smelting furnace

Reduced Energy Consumption When Using Dry Feed

The additional energy needed to smelt wet feed in the smelting furnace is twofold: one part heats and evaporates the water in the feed and increases the temperature of the vapour to 1200°C; the other part increases the temperature of the combustion gas to 1200°C. We ran a calculation for the additional energy required for wet feed to the furnace. We selected a basis of 144 t/h dry feed and oxygen enrichment of 40% in the combustion air. We explored two cases:

- Case 1: 160 t/h wet feed, moisture content 10%
- Case 2: 144.43 t/h dry feed, moisture content 0.3%

Table I shows the energy requirements for the two cases. Almost 120 GJ/h of energy is required for wet feed, compared with only 7.4 GJ/h for dry feed. For an operational year of 340 days the difference of 112.5 GJ/h results in an energy consumption equivalent to 22 960 tons of heavy oil.

Table I: Comparison of heating capacity required for removal of water from a smelting furnace and from a steam dryer, GJ/h

	Smelting furnace		Steam dryer
Item	wet feed	dried feed	wet feed
Moisture in feed, wet base	10.0	0.3	10.0
Energy to increase water temperature	5.7	0.2	5.7
Energy to evaporate water	36.2	1.0	35.2
Energy to increase water-vapour temperature	37.0	1.1	0.4
Energy to increase off-gas temperature	41.0	5.2	3.3
Total energy	119.9	7.4	44.6

Two factors are taken into consideration in a steam dryer. A steam dryer requires 44.6 GJ/h of energy to heat up and evaporate the water; a smelting furnace needs 7.4 GJ/h for the dry concentrate. The difference between drying wet feed in a smelter and a steam dryer amounts to 67.9 GJ/h of energy. This energy raises the off-gas temperature from 115°C to 1200°C, which is actually energy wasted. Drying the feed before smelting can save this energy, equivalent to 13 800 tons of heavy oil per year.

Using a dryer instead of a furnace to evaporate the water from the feed can have a beneficial effect on the energy arrangement of the whole smelter. The smelter can use energy from steam or off-gas produced on the plant, thereby avoiding the use of fuel from outside. Furthermore, drying the feed beforehand affects furnace design and performance. As metallurgical furnaces are sized according to the total energy requirement or gas-flow velocity, so extra volume is needed for wet feed to release the additional energy and/or convey off-gas. Dry feed makes smaller furnaces possible. Changing from wet to dry feed in an existing furnace increases capacity.

Reduced Off-gas Flow When Using Dry Feed

Water in the smelting furnace evaporates, which requires an amount of vapour to be handled. Using dry feed instead of wet feed reduces significantly the amount of water vapour in the smelting furnace. As less energy is demanded in the furnace, as discussed, so the demand for oxygen and associated nitrogen is reduced in combustion, which results in reduced emissions and simpler off-gas equipment. A comparison of the amount of off-gas to be handled in the two cases, wet and dry feed, are illustrated in Table II.

Table II: Additional off-gas flow in the smelting furnace due to the feed being wet

	wet feed at 10% moisture		dry feed at 0.3% moisture	
	normal flow	actual flow	normal flow	actual flow
Item	normal m^3/h	actual m^3/h	normal m^3/h	actual m^3/h
Water vapour from feed	3 200	17 266	540	2 914
Combustion gas	22 200	119 782	2 550	13 759
Total off-gas flow	25 400	137 048	3 090	16 672

For wet feed the additional gas flow is approximately 25 400 Nm^3/h. The dry feed (0.3% moisture) creates only 3090 Nm^3/h additional gas. Furthermore, for a wet-feed process the high temperature of 1200°C converts to an actual gas flow of as high as 137 000 m^3/h. Dry feed reduces the actual off-gas flow by over 120 000 m^3/h. The reduced off-gas flow can be handled by smaller equipment downstream, units such as gas ducts, gas coolers, or waste-heat boilers, ESPs, induction fans, stacks, even equipment in an acid plant. Less off-gas also means fewer emissions from the plant. The use of dry feed instead of wet feed reduces environmental concerns, such as emissions of carbon dioxide or entrapped-dust. Even water vapour has an adverse effect on the off-gas line.

Additional water vapour weakens the strength of SO_2 in the furnace gas. The dilution of SO_2 becomes more severe when straight air or air slightly enriched in oxygen is used. The smelting of wet feed needs additional oxygen-enriched air for the combustion of fuel, which dilutes the SO_2 produced.

DRYING PROCESSES AND EQUIPMENT

Development in Copper-Concentrate Drying

Processes to dry concentrate have developed in recent decades. Starting from direct-heated dryers such as rotary-drum dryers and flash dryers, drying technology has evolved into indirect-heated steam dryers.

Direct-heated dryers employ hot gas from combustion or other processes to heat up and dry the material by direct contact. The combustion gas is usually produced in a separate chamber by burning fossil fuels. A dryer of this type has certain space requirements, and it produces emissions that may harm the environment, emission gases such as CO_2 and SO_2. Flash dryers consist of a rotary drum, a cage mill, and a flash drying tube. The cage mill associated with this type of dryer may be problematic: it is subjected to wear and needs to be repaired fairly frequently.

By the 1990s indirect steam dryers came into operation. In this application, steam instead of combustion gas is used as the heating medium. Steam is generated in the waste-heat boilers of the plant; additional fossil fuel or a separate combustion chamber is no longer needed. The dryer is consequently smaller. The application also provides for energy to be used throughout the plant. The first application of a steam dryer in copper smelters was of a stationary type. In 1999 a rotary steam dryer was successfully commissioned.

Energy consumption and off-gas flow vary with dryer type. Both variables affect the energy efficiency of the drying process. A comparison of these two variables for rotary dryers, flash dryers, and steam dryers is summarized in Tables III and IV.

Table III: Comparison of energy required in different drying processes at a wet-feed rate of 160 t/h and moisture content of 10%, GJ/h

Energy needed to—	Rotary	Flash	Steam
Heat and evaporate water	51.7	48.1	51.1
Combust gas and increase air temperature	11.3	18.1	3.3
Total	63.0	66.2	54.4

The energy required to heat up the combustion gas and air favours steam dryers significantly. For heating the feed and evaporating the water all dryers require almost the same amount of energy.

Table IV: Comparison of exhaust gas flow in different drying processes at a wet-feed rate of 160 t/h and moisture content of 10%, Nm^3/h

Gas flow	Rotary	Flash	Steam
Water vapour	19 400	19 400	19 400
Dilution/purge air	41 100	22 600	25 000
Combustion gas	62 900	130 800	0
Total	123 400	172 800	44 400

The most significant energy loss in the off-gas flow is due to the combustion gas. In steam dryers such losses do not occur, as combustion gas is not needed for drying. Compared with flash dryers, steam dryers reduce the off-gas flow by 128 400 Nm^3/h; compared with rotary dryers, steam dryers reduce the off-gas flow by 79 000 Nm^3/h. This reduction in exhaust-gas flow means smaller gas handling equipment; the reduction in size can be 2.5–3.3 times smaller than direct-heated dryers. Exhaust gas from steam dryers contains only water vapour and air; there are no harmful components such as SO_2 or CO_2.

Steam dryers allow lower drying temperatures; the concentrate temperature at the outlet is 100–120°C. This reduces the risk of fire ignition, and precautionary measures such as the introduction of nitrogen are unnecessary.

Features of the Kumera Rotary Steam Dryer

The Kumera steam dryer is a rotary-type dryer.[3] It was developed for copper-concentrate drying. One of its key features and advantages is the rotation of the steam-tube package together with the rotary drum. The structural properties of the dryer improve water evaporation and eliminate tube wear. Figure 2 illustrates a unit.

Steam as an indirect heating medium offers at least two benefits: (1) it lowers temperatures in the dryer, and (2) with an outlet temperature of 100–120°C, the risk of fire ignition is very low.

Mechanical Features

The Kumera steam dryer consists of a rotary drum with a steam-tube package of individual tube elements. Two riding rings support the drum; each ring rolls on two support rollers. The drive mechanism consists of a girth gear and pinion connected to a speed reducer and electric motor with a frequency converter. The rotation of the drum improves water evaporation, as the material is properly mixed and the bed is relatively loose. Other advantages include the prevention of build-up and clogging of the concentrate. Following a cycle in the drum, the wet material is heated up, water is evaporated and the vapour released to the dryer chamber. As the steam-tube package rotates with the rotary drum, material in the drum turns with the drum shell at the same rate as the steam-tube package. This eliminates wear on the tubes by an abrasive wet feed, be it copper concentrate, sand, reverts, or slag. The wear rate of tube elements is a function of the distance of relative movement of the tube elements with respect to the bed and applied pressure on the tube surface. The turning bed hardly moves with respect to the shell and the tube elements. Therefore, the distance of relative movement is close to zero and tube wear is eliminated.

Figure 2: Kumera steam dryer

Eliminating the tube wear brings other advantages, such as low electrical energy consumption. Mechanical power used against friction force on the tube surface is small because the relative speed of the tube elements with respect to the bed is small. When rotating, the dryer shell conveys the copper concentrate through the dryer. The tube elements do not push the material. Therefore, a mechanical torque to the tube elements, one needed to balance the friction force, is not applicable to the dryer.

These structural features confer advantages on the Kumera steam dryer by—

- Eliminating wear on the tubes
- Improving the evaporation of water
- Retaining flexibility in maintenance, as a leaking tube element can be unplugged from the dryer; other elements can be left in operation
- Retaining flexibility in drying capacity—and maintaining a high capacity in a single unit (up to 250 t/h)
- Permitting a small installation area and height; and as the heaviest element only weighs less than 2 tons no overhead crane is needed for maintenance
- Lowering the consumption of electrical energy
- Freeing units from build-up and from clogging

Operational features and references

Kumera steam dryers have been installed in Germany, Bulgaria, and Japan. These industrial applications have demonstrated the high operational availability of the dryer. The smelters have benefited from, for example, low operational costs and long intervals between maintenance. Easy process control adjusts product quality (*i.e.*, moisture content of the dried concentrate) by changing only a few operating variables. The Kumera steam dryer adapts easily to fluctuations in feed rate and the moisture content of wet feed.

CONCLUSIONS

Drying a wet concentrate before smelting confers advantages such as reduced energy consumption, smaller volumes of exhaust gas, and fewer harmful emissions to the environment; it prevents SO_2 from being diluted, and the installation of smaller gas-handling equipment reduces initial investment costs.

In comparison with direct-heated dryers such as rotary-drum dryers and flash dryers, rotary steam dryers are more energy efficient and environmentally friendly. The special structural features of rotary steam dryers confer many additional benefits: they eliminate wear on the tubes and increase drying efficiency. If steam is available as a heating medium, the rotary steam dryer has been shown to be an excellent choice of dryer for copper concentrates.

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