Application of ported kiln technology to the Grate-Kiln Process at Minntac

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Abstract

In 2001, the Minntac Division of US-Steel retrofitted one of their grate-kiln iron ore pelletizing lines with a ported-kiln air-injection system (PKAIS), the first of its kind in the world for oxide pellets. The ported kiln system injects air under the bed of pellets in the rotary kiln, causing rapid oxidation of the magnetite pellets. This rapid oxidation allows for lower kiln temperatures, which reduces fuel demand; allows for less heat load on the annular cooler; and produces higher pellet quality. Both the process and the equipment are patented developments by Metso Minerals. This paper discusses the process, the key equipment and the benefits to both the pellet plant and the downstream blast furnace operations.

Key words: Iron ore, Taconite, Pelletizing, Ported kiln, Grate-Kiln Process

History

The grate-kiln system for iron ore pelletizing was developed by Allis-Chalmers (now Metso Minerals) and was first installed at the Humbolt Mine in Michigan in 1960. In the basic flowsheet (Fig. 1), green pellets are first dried and preheated on a traveling grate. They are then indurated in a rotary kiln before being cooled in an annular cooler. Between 1960 and 2000, improvements in heat recovery, materials of construction and process control had significantly improved fuel and power consumption, product quality and capacity. However, the search for production improvements continued to be the goal of Metso.

Testing by Metso Minerals and others in the early 1990s all agreed that the complete oxidation of magnetite pellets in the rotary kiln, rather than in the annular cooler, would result in benefits to the process. Heat- and mass-balance models, along with field tests and sampling indicated that there would be a reduction in fuel use and increases in capacity. Laboratory tests using the pot-grate and batch kiln indicated improved pellet quality.

Why the benefits? In the pelletizing operation with magnetite, Fe_3O_4 is oxidized to Fe_2O_3 in an exothermic reaction. Typically, the oxidation ratios are 70% completed on the traveling grate, 5% completed in the rotary kiln and the final 25% completed in the annular cooler. By completing as high as 98% oxidation at the discharge of the rotary kiln, the following benefits were expected:

- The heat load on the annular cooler would be reduced because pellets are no longer oxidized in the cooler. Therefore, the annular cooler can cool a higher tonnage of pellets while producing a cool product.
- The temperature in the kiln would be reduced. Because oxidation, an exothermic reaction, occurs in the pellet bed of the kiln, there would be a more uniform and efficient heating of the bed to induration temperature. The lower kiln temperature would make it possible to have pellets with high reducibility and good compression strength without compromising one or the other.
- The bed in the annular cooler is normally 760-mm (30-in.) deep. As air is introduced, the bottom layer of unoxidized pellets is cooled too rapidly for oxidation to occur. For this reason a percentage of pellets on the bottom layer do not reach final strength. The PKAIS would uniformly complete the oxidation in the kiln, so the cooler would only be for cooling. In addition to other physical attributes, the distribution of pellet compression strength would be tighter.

The design of the system proved to be an engineering challenge, particularly because of concerns about how to actually install a system on a commercial scale plant, one that required over 95% availability.

Design

In 1998, Minntac and Metso Minerals entered into an engineering contract to take the PKAIS from concept to practical design. The initial concept was to utilize the standard gridded port (Fig. 2) and air-distribution system used by Metso Minerals in direct reduction plants. This was a well-proven design, having been in use at the Tinfoss facility in Norway for more than ten years. Unfortunately, during preliminary engineering, serious problems were discovered that made the direct use of this design questionable.

The maximum operating temperature of a direct reduction kiln is approximately 1,100°C (2,000°F). For an acid pellet

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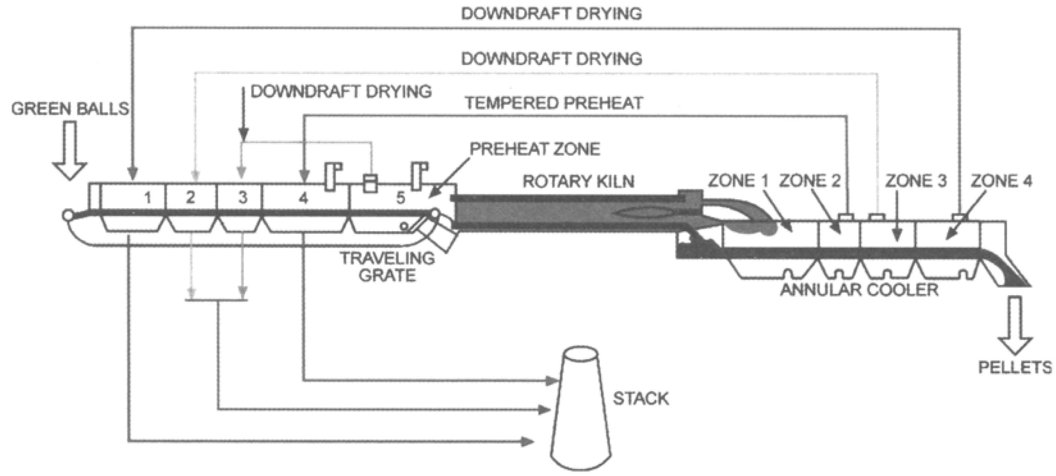

Figure 1 — Grate-kiln flowsheet.

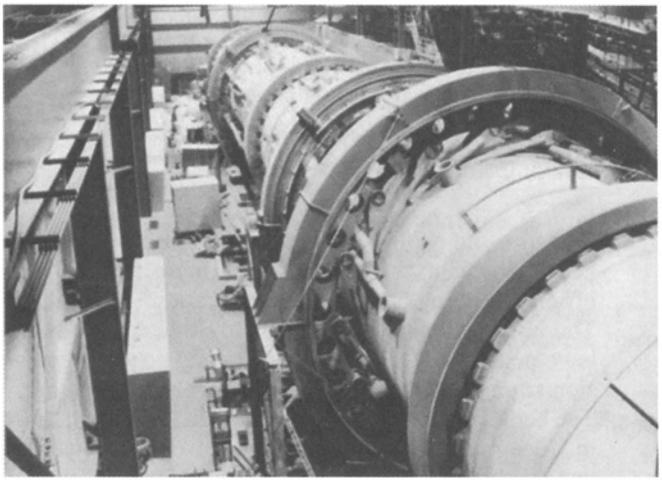

Figure 2 — Tinfoss ilmenite reduction kiln.

pelletizing operation, the operating temperature is above 1,300°C (2,370°F). After investigation, no metal could be found that would survive a temperature this high. Additional investigations into ceramics were not successful because of the impact duty requirements for the grid. Therefore, a different method of introducing air into the kiln had to be considered.

Another problem that was identified was pressure. In direct reduction, the air is supplied over the bed of material to assist in combustion, so only low-pressure air supplied by a fan is required. For pellet oxidation, the air needs to be injected under the bed of pellets, resulting in a significant pressure requirement for the air to move through the bed of pellets. As the air enters the bed of pellets, it rapidly increases in temperature and therefore volume. Laboratory testing and CFD modeling quickly confirmed that a blower, not a fan, would be required to achieve the necessary pressure for a commercial plant. The number and size of openings in the kiln to meet the pressure requirements, limited by the pressure capabilities of the rotating manifold, continued to increase.

Because of the problems with temperature and pressure (not to mention concerns with fines and slagging) a number of different designs were tried. Even so, by early 2000, no design had met Minntac's requirements, and cancellation of the project was being considered.

The refractory channel port

Metso at this point developed what has since been termed the refractory channel port design. The concept was to use the refractory in the kiln as the carrying mechanism for the air, venting into the bed through a series of slots between bricks. This solved two problems. First, the refractory already was designed for the high temperatures and abrasive environment in the kiln. Second, the design allowed for a large number of slots, increasing the cross-sectional area into the kiln and reducing the pressure requirements. Figures 3 and 4 show the actual bricks used, and Fig. 5 illustrates the concept.

Metso did further CFD modeling on the refractory channel port design to complete the estimation of performance (Fig. 6).

After discussions with Minntac, the following ideas were added to the design:

- The slots between the bricks were to be wider at the bottom than at the top, with a small angle to reduce fines entering the channel.
- A fines-return port, which fills with pellets when under the bed and then empties at the top of the arc, was added at the suggestion of Minntac's operation personnel.
- The total ported area in the kiln was increased to approximately 30% more than was deemed necessary by the model. This served several purposes. It allowed the first port to be as far uphill on the kiln as possible, starting the oxidation early, and it further reduced the pressure requirements. Also, the additional slot area provided extra capacity in case the slots plugged more than expected. Hand valves make it possible to shut off air to different parts of the ported kiln for experimentation with optimum air injection locations.
- In the ported section, each ring of refractory would be "locked" in position circumferentially by adding precast refractory anchors welded to the kiln shell.
- All the components had to be designed for continued operation. If the air to the ports was shut off, the kiln had to continue to operate. Therefore, if the design did not work, there could be no interruption to Minntac's operation — a "failsafe" design.

With the above design considerations, in the summer of 2000 Minntac placed an order with Metso for a refractory channel ported kiln supply to be installed on the plants Line 7.

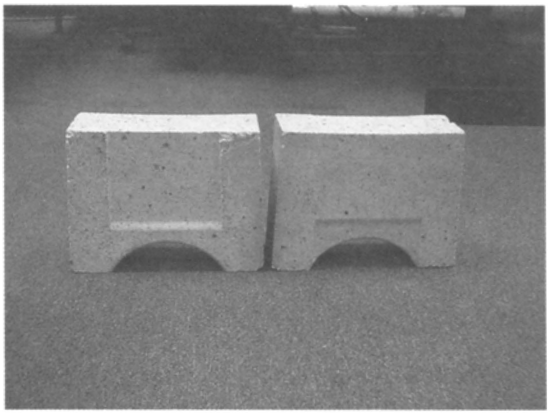

Figure 3 — Refractory channel brick.

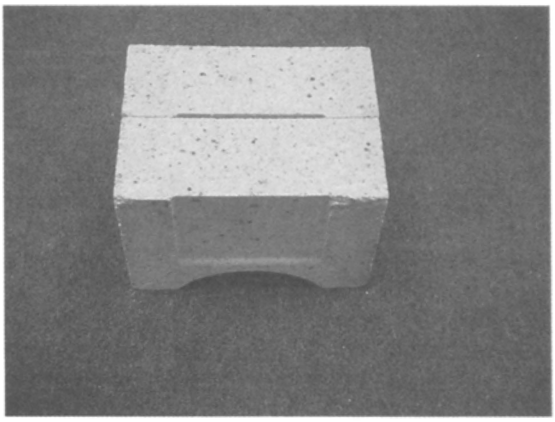

Figure 4 — Refractory channel brick.

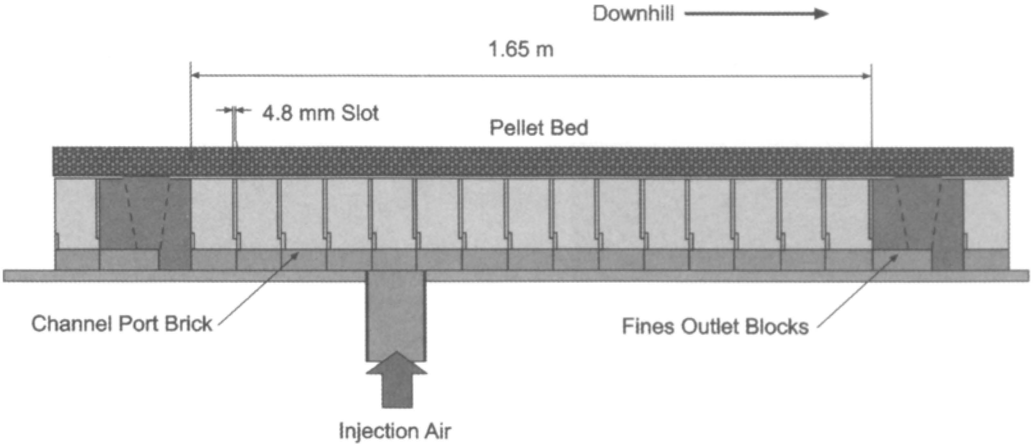

Figure 5 — Port section.

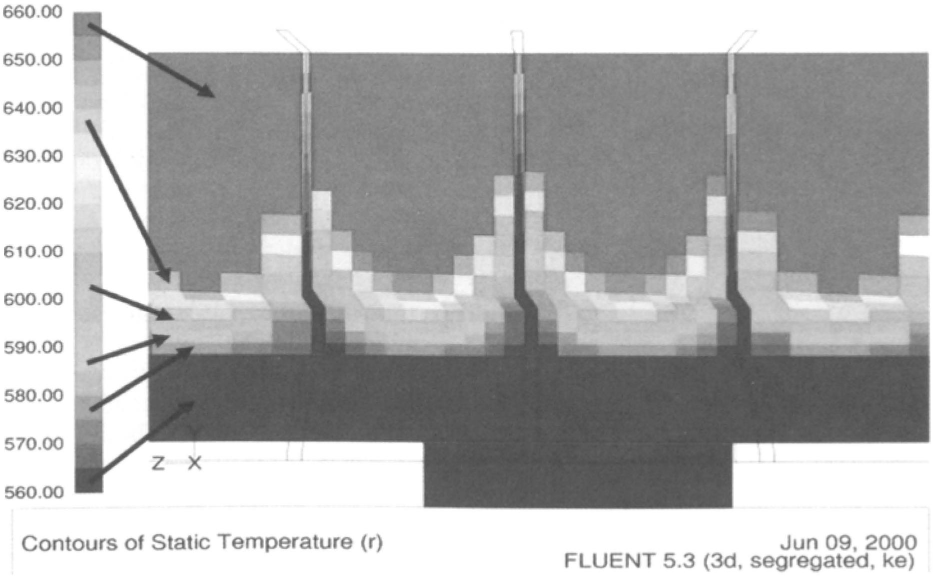

Figure 6 — Temperature gradient in refractory channel brick.

Installation and start-up

The rotary kiln on Line 7 is 6.4 m (21-ft) in diameter and 39.6 m (130 ft) long. Twelve rows, with eight ports per row, were installed in a 14.6-m (48-ft) section of the rotary kiln. Each row has a tripper valve to allow or shut off the airflow to that row. Air is supplied by a rotary lobe blower, one operating and one standby. The rotary lobe blower is installed in a separate blower building.

Installation of the ported kiln took place during an extended 21-day annual maintenance shutdown. Actual work required 19 days plus one day for cool down and one day for heat up.

Figures 7, 8, 9 and 10 show the various phases of installation. Figure 11 illustrates the air injection sequence, Fig. 12 shows the completed installation and Fig. 13 shows the inside of the kiln during operation.

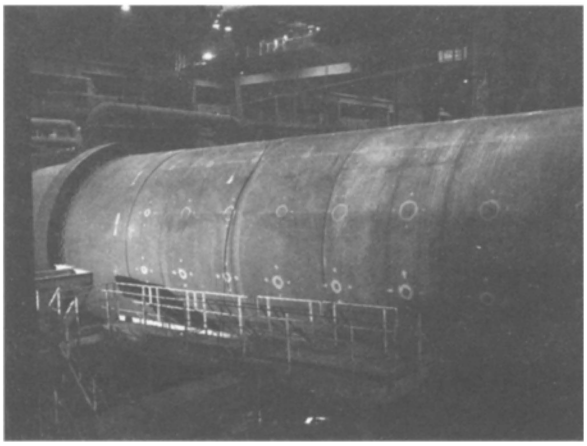

Figure 7 — Preparation.

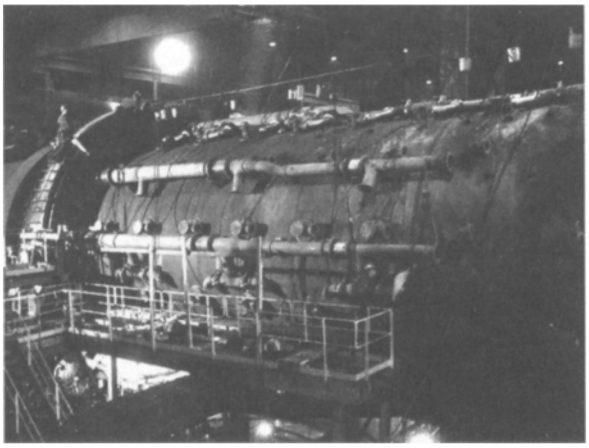

Figure 8 — Installing ducting and port castings.

Figure 9 — Installing refractory.

Results

The installation of the ported kiln system was predicated on improvement to the operation. Baseline testing of Line 7 to determine the target for the ported kiln improvement was done in the Fall of 2000. A wide variety of measurements were done around the entire induration system, including green ball analysis, temperatures and gas flows, equipment speed, utility consumption and product quality.

This information was modeled in Metso Minerals proprietary A heat- and mass-balance program for simulation of operation with the ported kiln to set expected performance. These measurements were also used to set the same operating conditions for ported operation.

Figure 10 — Slots and fines return brick.

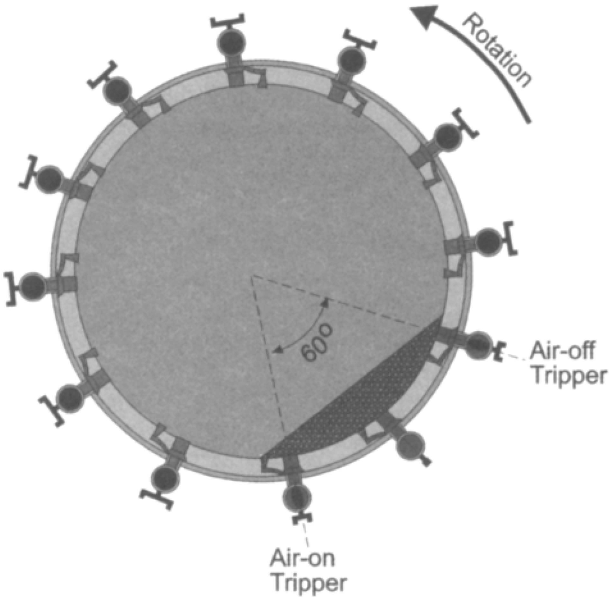

Figure 11 — Air injection sequence.

Table 1 compares the baseline operation with the actual performance of the ported kiln system under similar operating conditions.

In all areas, there was improvement. The reduction in fuel use and the increase in reducibility are related to the lower burning zone temperature. The improved LTD and compression strength relates to the complete oxidation occurring in the kiln, not in the cooler. Figure 14 shows the oxidation level and air requirements for each rate of production.

One key target was not reached and that was an increase in average compression strength shown in Fig. 15. The improvement was not as great as expected from the original testing. The problem became clear when a comparison was made between acid pellets and the fluxed pellets currently produced at Minntac.

Since start-up, Minntac has done testing that varied the amount of air injected under the bed and the location of the air injection along the length of the ported kiln to determine the effect on pellet oxidation.

During the past 18 months of operation, Minntac has seen other, less quantifiable benefits to ported kiln operation. These include:

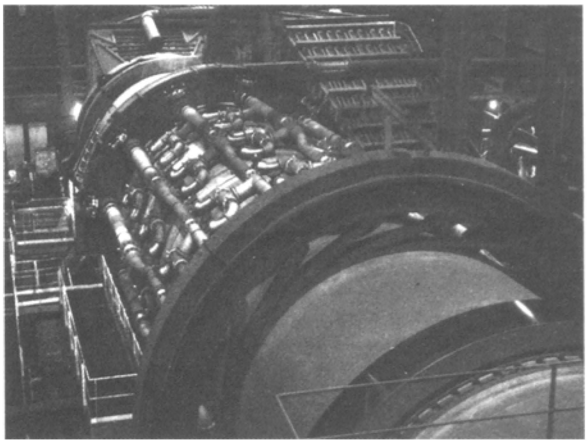

Figure 12 — Installed ported kiln assembly.

Table 1 — Operational comparison.

Parameter	Baseline, Year 2000	With ports, Year 2001
Production rate, t/h	392	400
Fuel consumption GJ/t	0.659	0.615
Compression strength, % < 136 kg	20.3	14.9
BT% +6.3 mm	97.89	98.02
AT% +6.3 mm	95.75	95.85
LTD	82.9	87.7
Reducibility	1.07	1.18

- more stable operation;
- greater operator control of product quality;
- cool pellets from the annular cooler and less maintenance on the annular cooler and discharge belts; and
- reduction or elimination of kiln ring formation.

The ports create areas that are free from slag build-up, thereby not allowing a complete ring to form, which makes a slag that does form structurally unstable.

There are also expected benefits downstream from the pellet plant because of the higher-quality pellets being produced. Higher R40 reducibility means that less coke is required per ton of hot metal. Higher LTD means fewer fines in the blast furnace.

Conclusion

The Line 7 ported kiln operation proved to be beneficial to Minntac's goals of reducing operating costs and improving pellet quality. This successful application of the PKAIS to Minntac's Line 7 has resulted in an order being placed with Metso Minerals for a second ported kiln system that was installed on Line 6 in the spring of 2003. Further investigations are also underway on future installing the ported kiln system on Lines 4 and 5.

The concept of injecting air under the bed of magnetite pellets in a grate-kiln pelletizing system to improve performance and product quality has been verified. A unique system for getting the air into the bed with high reliability has also been proven. A proposed next step in the technology is to evaluate the admixture of carbon in the pellets. This could improve performance in a magnetite operation and also make it possible to apply the ported kiln to hematite pelletizing operations.

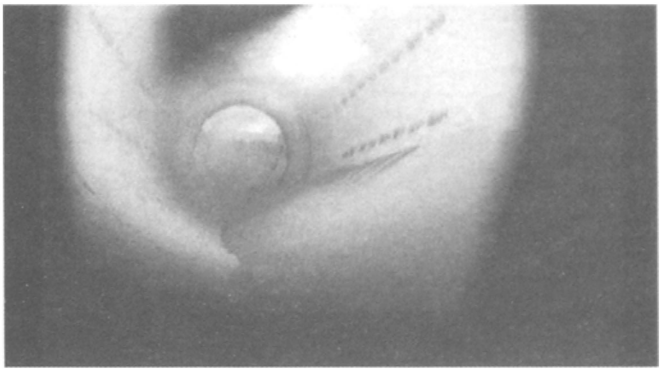

Figure 13 — In operation.

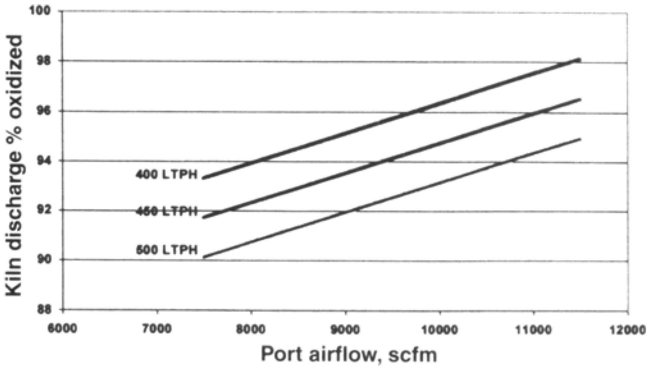

Figure 14 — Oxidation vs. airflow.

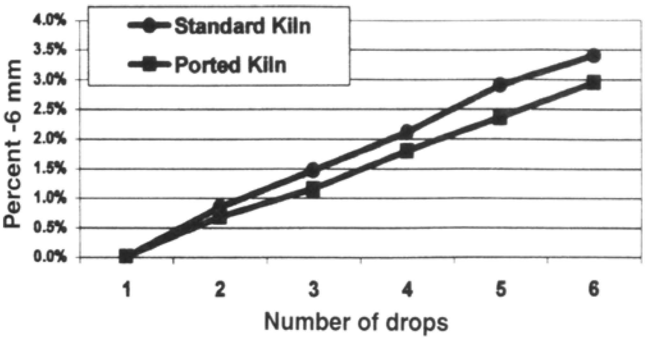

Figure 15 — Ten-meter drop test comparison.

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