SHAFT COOLERS FOR EFFICIENT AND ENVIRONMENTAL FRIENDLY SINTER COOLING*

Michaela Böberl[1]
Edmund Fehringer[2]
Susumu Kamikawa[3]

Abstract

State of the art sinter coolers are working based on the cross flow cooling principle. Thus, only a part of the thermal energy can be used for heat recovery application. The other part of the cooling air is brought unused to the environment. Furthermore, environmental regulation regarding dust emission and intelligent usage of exergy are getting stronger. Therefore, Primetals Technologies developed sinter coolers based on the counter flow principle. The cooling air passes the sinter bed in counter-flow direction enabling a direct heat transfer from the hot sinter to the air. The exhaust gas temperature can be maximized by using the total heat of the hot sinter. Due to the possible usage of the total exhaust gas amount, diffusive dust emission is reduced to zero. Two types of counter flow coolers are in the portfolio of Primetals Technologies. One type is based on a stationary shaft, in which the hot sinter is charged. The flow of the hot sinter is in vertical direction from top to bottom, in counter direction than the cooling air. The second type is a circular hopper cooler. The hot sinter is charged on top of a moving bed. At the bottom of the bed the sinter is discharged. The cooling air flows also from the bottom to the top, following the counter flow principle. Depending on the requirements, one of the two counter flow cooler types can be chosen for optimized and efficient cooling of hot sinter..

Keywords: Sinter Cooler, Counter Flow Principle, Shaft Cooler, Environment, Energy.

[1] *Primetals Technologies / Austria.*
[2] *Primetals Technologies / Austria.*
[3] *Primetals Technologies / Japan.*

1 INTRODUCTION

Iron ore sinter is an essential burden component for the blast furnace route of crude steel production. About 130 million tons of sinter are produced in the European Union [1]. Worldwide, the production of sinter is about 5 to 6 times higher.

A thermal energy of about 390 MJ per ton sinter is contained in the sinter considering an average sinter charging temperature of 550°C. For the successive equipment, the sinter has to be cooled down. Thus, the heat source coming from the hot sinter is one of the biggest heat sources of a steel plant. Due to the so far used cross-flow coolers this heat is not or only partly used. In contrast to that, a direct heat transfer of hot particles to the air (heat transfer medium) is enabled with this counter flow cooling of the hot sinter. The produced hot air can be directly used in downstream processes to generate steam and electricity or to preheat or dry operating mediums in the iron and steel industry.

2 MATERIAL AND METHODS

State of the art, sinter coolers are based on the cross flow cooling principle. The cooling air is pressed through the sinter bed perpendicular to the moving direction of the sinter bed. The particles at the bottom of the cooler are always exposed to the ambient cooling air, giving their heat to the cooling air. Thus, the particles in the top layers experience already warmed up air from the bottom layer. This results in an unequal effective cooling time over the height of the sinter bed, since the bottom layers are cooled faster than the top layers. Thus, the top layers of the sinter cooling bed experiences a higher air temperatures than the bottom layers. This effect is more pronounced in the first part of the cooler.

Due to the cross-flow cooling principle the off-air of the cooler decreases with the length of the cooler. Only about the first third of the off-air can be taken for waste heat recovery systems producing steam. Some amount of the off-air from the last two thirds could be used for combustion air or could be brought back to the sinter machine. However, the rest of the heat is lost to the environment.

Furthermore, circular sinter coolers are a source of diffusive dust in steel works. The charging and the discharging of the sinter coolers are dedusted. A part of the cooler is open and the cooling air goes to the ambient. Dedusting of the sinter coolers would require huge dedusting units, which are bigger than for the waste gas dedusting of the sinter machine.

3 RESULTS AND DISCUSSION

3.1 Counter flow cooling

To overcome the issues of cross flow coolers, a counter-flow cooler design is the innovative solution. This means, that the cooling air flows in opposite direction to the sinter material flow. Thus, the same effective cooling time for the whole material (irrespective of the position) and therefore an effective heat transfer from the material to the air can be reached. This leads to a maximized hot off-air temperature, which is only slightly lower than the solid charging temperature. This signifies that nearly all of the heat contained in the solid is transferred to the air. Due to the high temperature of the off-air, the whole amount of the exiting air can be used for waste heat recovery

systems. The counter flow cooler design increases the efficiency of the heat transfer and the usability of the exiting air to the maximum possible.
The main advantages of counter flow cooling compared to state-of-the-art cross flow cooling are summarized in
Table 1.

Table 1. Summarized comparison between circular cross-flow cooler and shaft cooler based on the counter-flow principle [2]

	Circular Cooler (cross-flow principle)	Shaft Cooler (counter-flow principle)
Specific air demand	100%	30% - 40%
Heat usable for WHR producing steam	~ 30%	100%
Bed height	1.5m	~6m
Required dedusting unit	100%	< 40%
Power generation	14-25kW/tSinter	20-36kW/tSinter

The specific air demand of a circular cooler is about three times higher than that of a counter-flow cooler. But only a third of the air amount for the circular cooler can be used for steam production and therefore for electric power generation. Compared to that, the complete amount of the exiting air of a shaft cooler could be used for steam production and electric power generation. These differences are reflected also in the possible specific power generation rate. The specific power generated by the heat of counter-flow cooler is at least 1.5 times higher than the one of a circular cooler.

Therefore, Primetals Technologies has developed two kind of high efficient sinter coolers based on the counter-flow principle. One is the circular hopper cooler, where the sinter is charged to a moving bed. The other is the shaft cooler, where the sinter is charged into a stationary shaft. Both types of counter-flow coolers have all the advantages as mentioned in
Table 1. Depending on the requirements of the customer one of the two counter-flow coolers can be applied.

3.2 Circular hopper cooler

Primetals Technologies has developed an innovative high efficient sinter cooler which has reduced the cooling air to less than half of conventional sinter coolers. As the result, all of cooling air sucked from the sinter bed has high temperature enough to generate superheated steam for power generation and is dedusted by the dust collector. First commercial one of this environmentally friendly cooler was installed in NSSMC Wakayama Steel Works at 2008 and has been operated satisfactory with superior cooling performances.

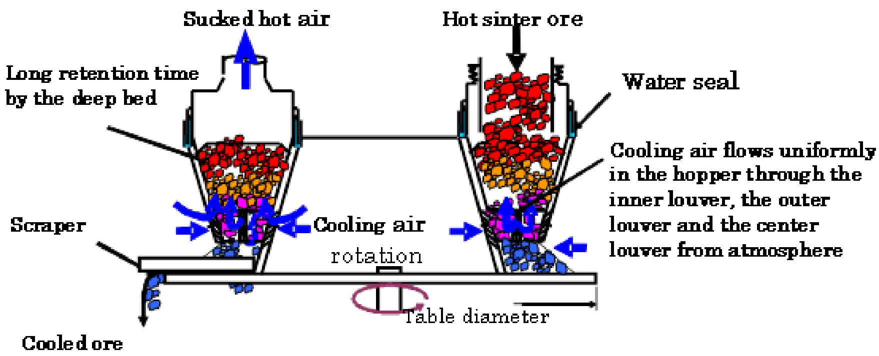

Figure 1. Concept of circular hopper cooler

Figure 1 shows the concept of this counter flow cooler. To improve the cooling performance, all of cooling air is sucked and flows as the uniform counter current flow in the deep bed. Iron ore sinter supplied to the top of the rotating bed flows down and is finally scraped out from the bottom of the bed after a long retention time such as 2 hours. In addition to the flow from outer and inner louver air is also sucked from center louvers. The air is sucked through the cooling bed by a cooling air fan. As the results, cooling efficiency was significantly improved and the cooling air volume decreased to less than half of conventional type. All of cooling air is recovered as the temperature is high enough to be utilized for electric power generation. Since all of cooling air is sent to the dust collector, there is no dust emission from cooler. Footprint required for cooler is almost half of conventional type.
The cooler hopper will be mounted on the supporting roller. Some of supporting roller will be connected directly to the driving motors with the cyclo reducers and make the cooler rotate by the friction force between cooler supporting rail and driving rollers. Hot sinter ore supplied to the inlet chute from sintering machine discharge hopper will deposit in the inlet chute and descend in the cooler hopper gradually according to the scraped volume by the plough inserted in the bottom of the cooler hopper and is finally scraped out to the discharge conveyor.

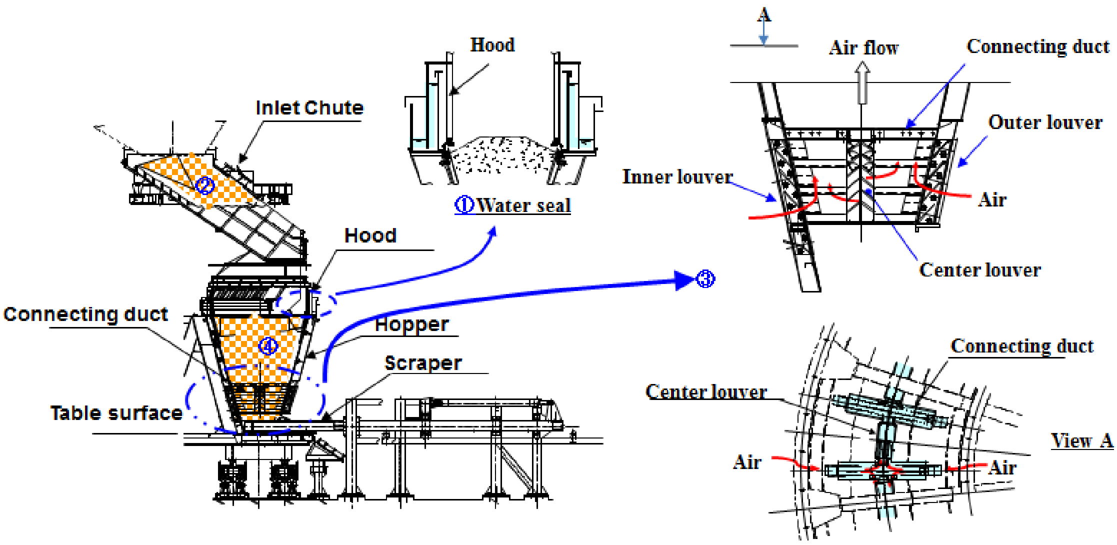

Figure 2. Special features of the circular hopper cooler

Figure 2 shows the special features of a circular hopper cooler which are:
(1) the water seal. All of sucked cooling air is sealed perfectly by water seal which was mounted between fixed hood and rotating hopper.

(2) the material seal. Sinter ore height in the inlet chute is controlled at the height required for preventing air leakage by adjusting rotating speed of hopper.
(3) the uniform counter-current flow achieved by the flow also from the center louvers not only from inner and outer louvers. The cooling air is sucked from the both ends of connecting ducts which are set between outer louvers and inner louvers. Air from the connecting duct flows to the center louvers which are fitted between connecting ducts. And finally, air is sucked in the sinter bed. This air flow from inner louvers, outer louvers and center louvers forms the uniform up flow in the sinter ore bed.
(4) the long retention time such as 2 hours by the deep bed. The pressure drop in the bed is almost the same as required for the conventional circular cooler type because of half air volume.
All of these special features help to improve the cooling efficiency significantly.

Figure 3. Circular hopper cooler installed at NSSMC Wakayama No.5 sinter plant.

Table 2. Operational results of the circular hopper cooler at Wakayama sinter plant No. 5

	Operation Results
Capacity	380t/h (Nov.2008)
Unit Cooling Air Vol.	800m3/t-sinter
Discharged Ore Temp.	63℃～68℃
Inlet Ore Temp.	500～550℃
Waste Gas Temp.	370℃
Bed Pressure	abt.3.9kPa @ 5.0mHight
Table Diameter	Φ17.86m

Figure 3 shows the new cooler which has been delivered for Wakayama #5 Sinter plant. This cooler has a capacity of 400t/h. The outer diameter of about 18m is so small that it was possible to install it in the sinter building. The operation has started in November 2008. Some operational results are shown in **Erro! Fonte de referência não encontrada.**. Unit cooling air volume is less than half of conventional type and the amount of unit heat recovery per ton sinter ore is more than double.

At the moment, Primetals Technologies is constructing the 2nd circular hopper cooler replacing the biggest existing cooler in Japan for NSSMC Ooita Steel Works.

3.3 Shaft Cooler

Primetals Technologies has developed a second type of counter flow cooler, the shaft cooler. The shaft cooler is based on a not moving shaft. A cross section of the shaft cooler is depicted in Figure 4.

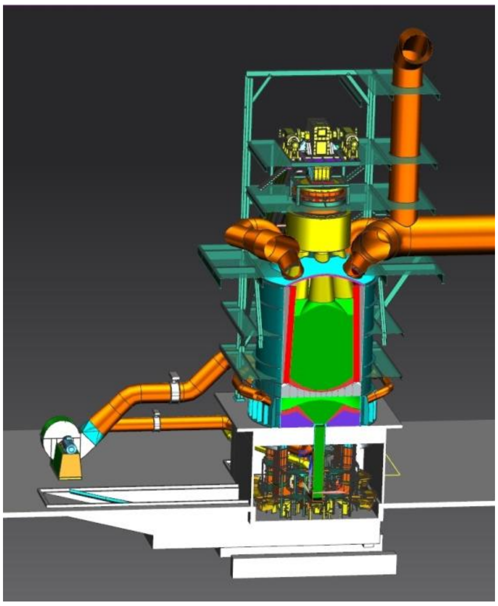

Figure 4. Cross section of a shaft cooler

For obtaining an efficient cooling, care has to be taken of the design of the main components. A homogenous flow through the cooling bed is essential for optimizing the heat transfer between the solid material and the air and thus maximizes the off-air temperature. Segregation effects or different sink velocities of the solid material prohibit a homogenous air flow through the cooling bed. This results in lower off-air temperature compared to the optimum situation due to a less effective heat transfer. Therefore, the charging to the shaft and the discharging from the shaft are of crucial importance. The hot sinter is charged by a pan conveyor to the charging system on top of the shaft cooler. The charging system is a combination of rotating and stationary parts in order to provide as less segregation of the sinter as possible. A nearly segregation free bed is essential for optimized cooling behavior and energy output. While the sinter flows from the top to the bottom of the shaft it is cooled by the provided cooling air. After the sinter is cooled it is discharged by equipment fulfilling the requirements of air sealing and homogeneous material discharge. The right design of the discharge is important for a homogenous sink velocity of the solid material. The sealing equipment not only guarantee an optimized discharge but also minimize the cooling air to leak out to the ambient to a minimum. The cooling air fan is providing the cooling air, which is pressed through the sinter bed from the bottom to the top of the sinter bed. Thus, the air flow is in opposite direction through the sinter bed compared to the flow of the sinter. Due to the counter flow principle, the maximum possible amount of heat is transferred from the sinter to the cooling air. This allows an optimized and maximized usage of the thermal energy contained in the hot sinter.

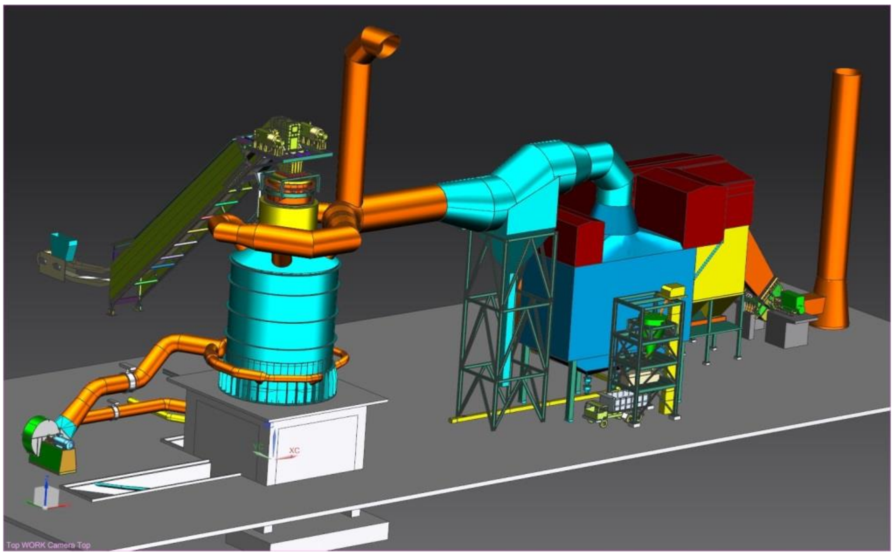

Figure 5. Energy management concept for the utilization of the thermal energy contained in the sinter by using a shaft cooler

Figure 5 shows the energy management concept for the utilization of the off air from a shaft cooler. The off-air is sucked by a second fan - the heat recovery fan - to the waste heat recovery system. In order to relief the heat recovery system from dust, a preduster is placed before. The heat recovery fan ensures a slight under pressure at the top of the shaft cooler. This prevents hot off-air leaking to the ambient. Furthermore the charging equipment is designed to reduce false air to nearly zero. If the off air is distributed to the ambient via a stack, a filter system is placed before the heat recovery system to fulfil the environmental limits. The air after the heat recovery system could also be brought back to the sinter machine. This would have the advantage that no additional filter system is required.
The waste heat of the sinter cooling can be utilized for producing steam. The steam can either be used for generating electrical power or also for driving the waste gas fan, which is one of the highest power consumers of a sinter plant.

4 CONCLUSION

With the development of the circular hopper cooler and the shaft cooler, Primetals Technologies has achieved two highly innovative developments for optimizing the usage of the thermal energy contained in the hot sinter. Both designs allow an efficient heat transfer between the hot sinter and the air. Therefore, nearly the total heat contained in the hot sinter can be transferred to the cooling air, leading to a maximization of the exhaust gas temperature and a more efficiently application for steam production and electric power generation. Since both systems are quasi closed systems, the diffusive dust emissions are reduced to almost zero. The counter-flow coolers developed by Primetals Technologies are innovative sinter cooling aggregates which increase not only the energy efficiency to a maximum but are also highly environmentally friendly compared to conventional coolers.

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