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STOCKHOUSE–BASED DRYING AND PRE–HEATING OF COKE AND PELLETS*

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Abstract

In places where Blast Furnaces are usually located, climatic factors may be unfavorable. Raw materials may be exposed to e.g. rain during transport/storage, bringing moisture into the process with consequences for stability and hot metal cost. This paper describes a technology for drying and pre-heating pellets and coke in the stockhouse. It does not require additional handling or logistical equipment and does not introduce extra transfer steps and degradation. Not only can moisture content be reduced, it can be controlled to a stable level by the operator.
Keywords: Blast furnace operation; Raw materials; Blast furnace process; Moisture.

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1 INTRODUCTION

Stable operation of a blast furnace requires careful consideration of dozens of inputs and factors. Heat and mass balance at the top of the furnace are those among the key factors to be taken into account. High temperatures at the top mean extra heat loss, process inefficiency, high dust emission, unnecessary load to the charging equipment, uptakes, downcomer and gas cleaning plant. Temperatures below a certain threshold mean moisture that enters the furnace with the raw materials will not get evaporated and the “process” water that ascends from the lower furnace will be condensed. As such the top part of the burden will start accumulating the water resulting in reduced “process height” of the blast furnace available for the physical and chemical reactions. Therefore, furnace operators balance the process conditions at the furnace top to the acceptable operating regime.
This balance is disturbed in case of high moisture input with the raw materials, or when the burden has a too low temperature. Most blast furnaces are exposed to this challenge, but to a different extent each. In tropical areas, heavy rain seasons lead to the stockyard materials reaching almost saturation moisture levels, with e.g. coke moistures up to 12–14% preventing that the desired productivity is achieved.
Wet and cold burden causes disturbance to the blast furnace operation, making the process unstable [1] and undermining the availability of equipment [2]. The heat coming from the lower furnace upwards is insufficient to maintain the required top temperatures and therefore the entire temperature profile inside the furnace changes compared to that of the summer time. This forces the operators to run furnaces less efficiently, reducing productivity and increasing consumption of the expensive coke.

2 PROBLEM DEFINITION

In general, blast furnaces operated with low productivity, somewhat higher total fuel rates and high rates of warm sinter are not likely to recognize the challenge of cold or wet burden. These furnaces have a healthy balance between the heat coming upwards, moisture input at the top and temperature of the burden charged into the furnace. Furnaces that are likely to suffer the most are those with high productivity and high injection rates of natural gas or high–volatile pulverized coal. Natural gas brings substantial amounts of hydrogen into the furnace, which is converted to water via reduction reactions in the furnace shaft. An example of a water balance at the top of a furnace is given for different injection materials in Table 1. Backgrounds of Blast Furnace moisture balance are found in literature [3].

Table 1. Moisture balance at furnace top for different operating conditions

	Units	All coke		Coal injection		Natural gas injection	
		Normal moisture	High moisture	Normal moisture	High moisture	Normal moisture	High moisture
coke consumption	kg/tHM	490	490	380	380	380	380
coke moisture content	mass %	3%	9%	3%	9%	3%	9%
moisture input with coke	kg/tHM	15	44	11	34	11	34
pellets consumption	kg/tHM	1,600	1,600	1,600	1,600	1,600	1,600
pellets moisture content	mass %	1%	4%	1%	4%	1%	4%
moisture input with pellets	kg/tHM	16	64	16	64	16	64
Steam addition to blast	g/Nm3	40	40	20	20	20	20
Hot blast consumption	Nm3/tHM	870	870	870	870	870	870
Steam addition to blast	kg/tHM	35	35	17	17	17	17
"Process" moisture from steam addition	kg/tHM	14	14	7	7	7	7
Pulverized coal injection rate	kg/tHM	-	-	120	120	-	-
Pulverized coal volatiles	mass %	-	-	17%	17%	-	-
H2 input with coal	kg/tHM	-	-	5.1	5.1	-	-
"Process" moisture from PCI	kg/tHM	-	-	18	18	-	-
Natural Gas injection rate	kg/tHM	-	-	-	-	100	100
H2 input with Natural Gas	kg/tHM	-	-	-	-	22.5	22.5
"Process" moisture from NG	kg/tHM					81	81
Total moisture at the top	**kg/tHM**	**45**	**122**	**53**	**124**	**115**	**186**
			273%		234%		161%

Blast furnace operators have a typical set of measures to respond to increased moisture input. One of the first actions is to reduce the oxygen enrichment of the hot blast. In the essence, this increases the furnace's throughput of nitrogen, which does not participate in the chemical reactions but rather acts as a heat transport media bringing energy from the lower furnace to the upper burden layers. Sometimes, the above change is sufficient, but in more challenging situations, the operators are forced to increase the coke rate. This leads to production of more gas at tuyere level and, as a consequence, a higher pressure drop over the furnace. Running the furnace with an increased pressure drop leads to unstable burden descent and forces operators to reduce productivity.

The steps described above are quantified in Table 2:

- The first column gives a case for a balanced furnace operation – in this way a furnace operation can be sustained.
- The second column ("disturbance") shows the impact of increased moisture in coke – top temperature drops to 68 °C – such operations cannot be sustained for a prolonged period.
- Column 3 – "Response step #1" – oxygen enrichment is reduced resulting in increased top temperature (88 °C), but achieved level is insufficient for a stable operation.
- "Response step #2" is an additional 25 kg of coke per tonne hot metal that takes the top temperature to the required minimum, but takes the pressure drop to unacceptable level. The absolute level of pressure drop may not be extreme, but there are always good reasons why a specific furnace operates at a specific pressure drop.
- "Response step #3" brings the furnace back to the original pressure drop. This last column represents again balanced operation that can be sustained.

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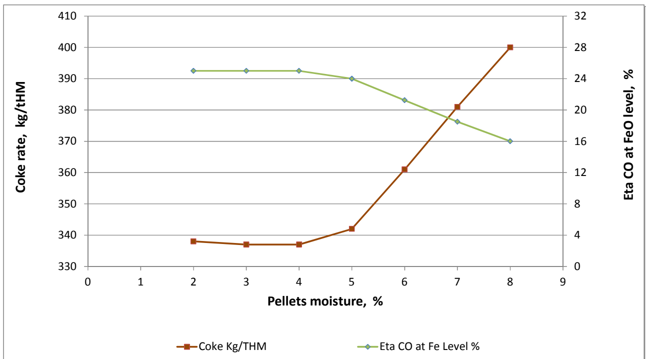
Table 2. Typical operator's response to increased moisture input

Change		Base	Coke moisture increased	O_2 down till min RAFT	CR up till T_{top} = 100	Production decreased
Issue		balanced	Low T_{top}	Low T_{top}	dP higher than Base	balanced
Coke moisture	%wt	5.0	13.0	13.0	13.0	13.0
Total iron burden moisture	%	1.5	1.5	1.5	1.5	1.5
Daily production	ton/day	3592	3592	3592	3592	3344
Productivity (WV), delay free	THM/m3/24h	2.3	2.3	2.3	2.3	2.1
Blast volume	Nm3/min	2457	2457	2564	2664	2489
O2 enrichment (additional)	%vol	7.0	7.0	5.8	5.8	5.8
Total blast moisture	g/Nm3	45	45	45	45	45
Blast temperature	°C	1000	1000	1000	1000	1000
Raceway flame temperature	°C	2157	2157	2102	2116	2113
Blast pressure	kPa(g)	205	205	210	217	205
Burden pressure drop	kPa	124	124	129	136	124
Top pressure	kPa(g)	81	81	81	81	81
Top gas temperature	°C	112	68	88	101	100
Topgas volume	Nm3/min	3891	3891	4004	4176	3900
PCI rate (dry)	kg/THM	120	120	120	120	120
Coke rate	kg/THM	442	442	442	467	468

Comparing the first and the last columns of Table 2, we can find production loss of 7% and increased coke rate by 6%.



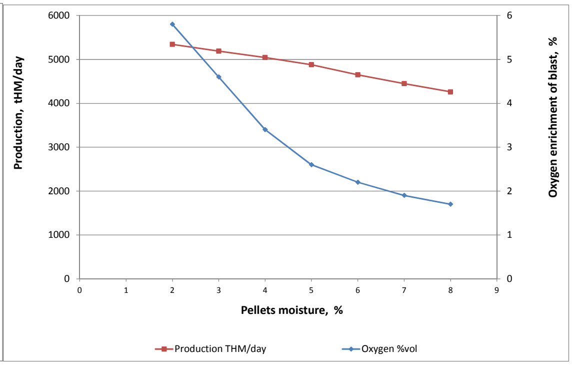


Figure 1. Impact of Pellet moisture on a blast furnace operated with a 100% pellet-burden.

Naturally, combining the effect of moisture in pellets and in coke and adding the temperature at which these materials are charged into the furnace brings even larger impact on the operational results. Heating frozen pellets (23 °F) with 6% moisture to 35 °C (95 °F) and 3% moisture, gives potential to increase furnace production by more than 20% and reduce coke rate by 12%.

3 ENGINEERING SOLUTION

The operator actions described above are not the only possible response to this challenge. Every company carefully manages logistics of the burden materials, targeting to eliminate operations from stockpiles, minimizing coke moisture with wet or dry quenching systems, considering "warm" sinter charge and so on. In addition to this, Danieli Corus has developed and patented a system to dry and preheat the burden materials within the blast furnace stockhouse. This system can be retrofitted

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in every stockhouse and offers a robust, reliable and energy efficient solution to the challenge described in this article.
The basic principle of the system is as follows. A dry hot gas is supplied to a stockhouse silo to heat up the material and remove moisture. Cooled and saturated, this gas is then taken out from the silo in a controlled way and passes through a gas cleaning installation. The stockhouse silos are not designed to withstand the pressure, therefore the entire system is carefully balanced to operate at slight over– and under–pressure in its different parts. The same pressure drop limitation determines that not all the materials can be treated this way, the system is limited to the coke, nut coke and pellets.

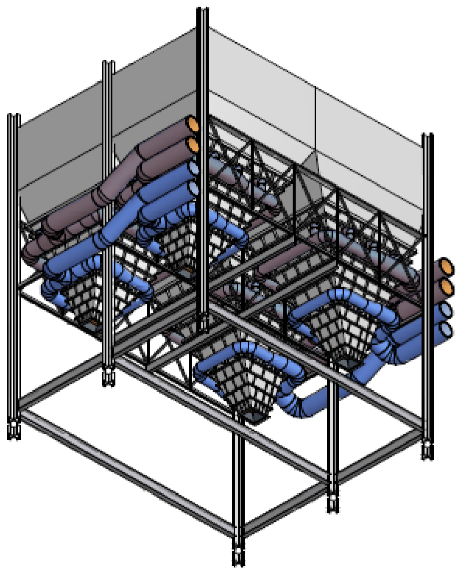

Figure 2. Impression of the stockhouse pre–heating system.

The system comprises of several fans, hot gas generator, ducting, gas collector, de–dusting system and overall process control. See Figure 2 for an impression. As an alternative to the hot gas generator, a waste heat recovery system can be used. The economic feasibility of a waste heat recovery solution is subject to specific site conditions.
The pre–heating system can be designed to make coke and pellets completely dry (0% moisture). This, however, may not be economical in all cases and an attractive solution for a specific furnace requires analysis of the historical operational data. In most cases, drying to 1–2% moisture is sufficient and enables to limit the load on the de–dusting part of the new facility.
The payback time for the new drying system for coke and pellets is estimated to be in the range of 12 months. This depends on the accessibility of the stockhouse for the modification and possibility to connect the system within minimum outage time for the blast furnace.

4 SUMMARY AND CONCLUSIONS

Managing a blast furnace through a heavy rain season is a challenge. It requires to adjust the operations to high moisture input and a sometimes cold burden. In most cases, the result is reduced production and increased coke rate that translates into a substantial increase in costs of hot metal. In some cases, optimizing logistics of material flows can lead to cost–effective solutions.

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Danieli Corus has developed a system that offers an engineering solution to the humid and cold burden. The system can be built within the blast furnace stockhouse, offering the operators a new tool to control the moisture and temperature of the materials just before they are charged into a blast furnace.
The new system is characterized by a relatively quick payback of about 12 months. The system is designed to help blast furnace operators during cold and rainy seasons but also during the rest of the year in stabilizing two of the most varying parameters in blast furnace process.

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