CHARGING PRACTICE OF BLAST FURNACE OPERATED WITH 100% ACID PELLETS

Igor Shepetovsky, Andrew Shalygin, Konstantin Myasnikov, Rustam Nuriev (JSC Kosaya Gora Iron Works)
Philipp Bermes, Lionel Hausemer (Paul Wurth S.A.)
Chemical composition of produced pig iron

• Nodular pig iron ([Si]=0,2-0,5%, grade Si1; [Si]=0,5-1,2%, grade Si2):

<table>
<thead>
<tr>
<th></th>
<th>S, %</th>
<th>P, %</th>
<th>Mn, %</th>
<th>Ti, %</th>
<th>Cr, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum content</td>
<td>0,010</td>
<td>0,040</td>
<td>0,040</td>
<td>0,020</td>
<td>0,007</td>
</tr>
<tr>
<td>Typical range</td>
<td>0,007÷0,013</td>
<td>0,028÷0,040</td>
<td>0,025÷0,040</td>
<td>0,007÷0,020</td>
<td>0,005÷0,007</td>
</tr>
</tbody>
</table>

• Semi-nodular pig iron ([Si]=0,2-1,2%):

<table>
<thead>
<tr>
<th></th>
<th>S, %</th>
<th>P, %</th>
<th>Mn, %</th>
<th>Ti, %</th>
<th>Cr, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum content</td>
<td>0,015</td>
<td>0,050</td>
<td>0,050</td>
<td>0,025</td>
<td>0,010</td>
</tr>
<tr>
<td>Typical range</td>
<td>0,009÷0,015</td>
<td>0,035÷0,055</td>
<td>0,030÷0,085</td>
<td>0,015÷0,025</td>
<td>0,005÷0,009</td>
</tr>
</tbody>
</table>

• Foundry pig iron*: [Si]=1,2-3,6%, [S] up to 0,05%, [Mn] up to 1,5%

* A range of 0,4 % for delta Si is used in the determination of foundry pig iron sub-grades.
  Typical content of sulfur in foundry grades does not exceed 0,020%
TYPICALLY USED BURDEN MATERIALS FOR SMELTING OF BASIC (NODULAR) PIG IRON

- Acid pellets (63%Fe).......................... 98% in ore burden
- Iron ore (41÷43%Fe, 38÷40% SiO$_2$)....... 2% in ore burden
- Raw fluxes (limestone + dolomite*)..... approx. 400 kg/t pig iron
  * dolomitized limestone
- Coke: Ash – 12%, CSR – 50÷55%
Main characteristics of new BF No.1 at Kosaya Gora Iron Works

- Blow-in date: February 6, 2010
- Previous campaign: 26 years
- Working volume: 944 cu. m
- Useful volume: 1066 cu. m
- Hearth diameter: 7.2 m
- Number of tuyeres: 16
- Number of tapholes: 2 (45° in between)
- Throat diameter: 5.8 m
- Structure design: Free standing furnace
- Type of stockhouse: Conveyor, two-sided
- Feeding of burden to BF top: Skip hoist, volume of skip: 6.5 cu. m
- Charging device: PW, Mini-bell less top
- Cooling system: Double-loop cast iron staves
The MINI Central Feed BLT®

MINI CENTRAL FEED BLT
250 - 1100 m³
Peculiarities of MINI BLT installed at BF No.1 of Kosaya Gora Iron Works

- Trapezoidal cross section of the chute
- Stone-boxes along 2/3 of the chute length
- Rotation speed can be varied between 8 and 13 rpm
- 120 specially designed steel boxes with copper gaskets for mounting of wear plates
- Closed burden material rings are achieved by means of the adjustable material gate
- Two vibrating sensors and one radar probe are used to control emptying of the material hopper
- Additional use of BLT centralized lubrication system for greasing of skip hoist sheaves, bleeder valves and stockline winch
DAMAGE OF THE STAVE LOOPS IN BELLY, BOSH AND LOWER STACK

• Average rate of loops failure.................. 2 loops/month
• Total number of damaged loops after 5 ½ years operation ..........128
• Total number of damaged staves after 5 ½ years operation .............86
• Number of damaged staves in belly.....................................28 of 30
FAILURE CAUSE ANALYSIS OF STAVE LEAKAGE

• Switching twice per month from smelting of foundry grades to basic pig iron grades and vice-versa with formation of unstable accretion layers

• Aggressive thermo-chemical attack by high-ferrous primary slag formed when operating with 100% acid pellets

• High temperature fluctuations in the middle zone of BF height when operating with 100% acid pellets
MATERIAL CLUSTER EXTRACTED FROM A SHELL CUT IN THE BELLY AREA

Analysis of material (wt%) extracted from the peripheral belly zone of BF No.1

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</tr>
</thead>
<tbody>
<tr>
<td>$\text{Al}_2\text{O}_3$</td>
<td>$\text{SiO}_2$</td>
<td>$\text{Fe}_{\text{total}}$</td>
<td>$\alpha$-$\text{Fe}$</td>
<td>$\text{Fe}_{0.945}\text{O}$</td>
<td>$\text{MnO}$</td>
<td>C</td>
<td>$\text{CaO}$</td>
</tr>
<tr>
<td>1.75</td>
<td>25.06</td>
<td>42.82</td>
<td>21.24</td>
<td>28.09</td>
<td>0.07</td>
<td>7.23</td>
<td>7.84</td>
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</table>
TEMPERATURE FLUCTUATIONS IN THE MIDDLE ZONE OF BF

dt\(^0/d\tau\) = 63 °C/min recorded during damage of stave No.4 in the belly area (Jan’12)

dt\(^0/d\tau\) = 353 °C/min recorded during damage of stave No.10 in the bosh area (Dec’11)
PROTECTIVE MEASURES

• Installation of copper mini-coolers within the boss arrangement of damaged staves in the belly and bosh areas (before interim repair)

• Discharge of some burden materials into peripheral ring to protect walls and cooling elements from aggressive action of high-ferrous primary slag

• Replacement of 5 rows of staves in bosh, belly and lower stack during interim repair in Q3 2015
Target function is to find an optimum accretion thickness made of fluxes, to protect the cooling staves:

- too thin layer → ineffective protection
- too thick layer → abrupt tearing from the staves

Raw fluxes composition:
- ratio of limestone / dolomite approx. equal to 75%:25%
- total rate of raw fluxes (limestone + dolomite) …. approx. 400 kg/t pig iron
CHARGING PRACTICE TO CREATE STABLE SKULL

- Charging of 20-40% of the total limestone portion and 100% of the total dolomite portion on top of the first skip. This portion of raw fluxes is first discharged into the material hopper and results in a higher amount of raw fluxes in the periphery when discharging from wall to centre.
CHARGING PRACTICE TO CREATE STABLE SKULL (SLIDE 2)

- High distribution chute rotation speed of 13 rpm allows for a relatively even distribution of the discharged fluxes around a sufficiently long arc distance at the BF periphery.

- Charging a portion of fluxes into each ore batch with a stochastic shift of the rotational start position seems to be sufficient to ensure circumferential distribution of fluxes with protection of the whole periphery.
The main pellets portion is put at the bottom of the skip, followed by the raw fluxes, which are then covered by a small portion of pellets (approx. 25% of total weight of pellets in the first skip)
Symmetric distribution of coke along the BF radius
CONCENTRATED CHARGING OF ORE BATCH

Concentrated charging of ore batch at mid-radius
# Operation results obtained (December 2015)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
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<tbody>
<tr>
<td>Skip coke rate (65% nodular*/35% semi-nodular grades)</td>
<td>535 kg/t pig iron</td>
</tr>
<tr>
<td>Natural gas rate</td>
<td>63 m³/t pig iron (45kg/t pig iron)</td>
</tr>
<tr>
<td>Raw flux rate**</td>
<td>382 kg/t pig iron</td>
</tr>
<tr>
<td></td>
<td>(304 kg limestone/t, 78 kg dolomite/t)</td>
</tr>
<tr>
<td>Fe input with ferrous burden</td>
<td>972 kg/t pig iron</td>
</tr>
</tbody>
</table>

* including 9% of pig iron with [S] ≤ 0.007 %

** high flux rate leads to a high energy consumption for the calcination reactions in the shaft (average 25 kg of coke /t pig iron per every 100kg of raw fluxes /t pig iron)