Experimental Research on pre-reduction of Nickel silicate ore in New Ferronickel Factory in Drenas

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Abstract: - During experimental, industrial and laboratory researches of Nickel silicate ore in New Ferronickel Factory in Drenas which were done in 2007, 2008, 2009 and 2010 we have concluded that among the factors that influence the decrease of pre-reduction of Nickel ore, are: homogenization of the ore, comminuting in grains of the ore, humidity of the ore, failure to reach necessary temperatures in the rotary kiln, short period of material stay inside the kiln, big adhesions of the material inside the kiln, frontal openings. These are some of the factors that influence directly in the decrease of Nickel silicate ore pre-reduction.

With experimental, industrial and laboratory researches it has been determined the level of pre-reduction of the ore at the New Ferronickel Factory in Drenas.

During the researches that have been done in 2010, in comparison to years 2007, 2008 and 2009, we conclude that technological process at the Factory has reached significant improvements.

Key-Words: - Pre-reduction, humidity, ore, rotary–kiln, calcine, temperature, laterite area, silicate ore.

1 Introduction

In this project we have presented the experimental, industrial and laboratory researches on pre-reduction of the ore at New Ferronickel Factory in Drenas.

Starting from 2009, at the New Ferronickel Factory in Drenas except for the ores from Kosovo Mines, there are also being processed the ores from different Mines in Albania, Indonesia and Philippines [5].

1.1 Mineral composition of the ores of Kosovo

Based on the microscopic, rontgenoscopic, and termomdiffrential analysis it has been found that two Mines in Kosovo, one in Gllavica and the other in Çikatovo, mainly have Fe-Ni-Co silicate in their ore composition. Both Mines have some specific areas with mineral and chemical features.

Gllavica Mine has these areas:
- getite-yellow red clay area
- quartz-opal area
- nontronite area
- serpentin and partly nontronite hartzburgites area
- fresh peridotites area

In Çikatovo, these areas can be separated in litologic and mineral areas:
- Hydroxide with iron oolite area (secondary layer)
- nontronite area
- partly nontronite serpentines area.

From the above mentioned areas in Gllavica and Çikatovo, it is the nontronite area that is especially characterized with higher percentage
of Ni content. Other characteristics of Kosovo mines is their great Humidity of the ore, especially in Gllavica where humidity reaches up to 40% and it is internal humidity (crystal) [4].

1.2 Mineral composition of the ores of Indonesia
Ores of Indonesia are characterized by these areas:
• laterite area
• saprolite area
• serpentinite / garnierite area
Main characteristic of the Indonesia ore in the area of garnierite is very high percentage of Ni content (3.0%-5.0 %) and lower humidity. While in other areas, Ni percentage in the ore is lower and humidity is higher [3].

1.3 Mineral composition of the ores of Philippines
Based on the mineral composition, Philippine ore is laterite ore. It has high humidity (up to 40%) and approximately 2% of Ni content [3].

1.4 Mineral composition of the ores of Albania
Albania has considerable reserves of oxide ores of Ni, where we can differentiate two areas:
• Oxide-laterite area and
• Silicate area
Main characteristic of the first area is high percentage of iron content (42-46% Fe) and low content of Ni, while silicate areas is characterized with high content of SiO₂ (more than 24%) and Ni content more than 1%[1].

2 Discussions and results
With industrial, experimental, and laboratory researches during 2007, 2008, 2009 and 2010 we have determined the average values:
• The amount of calcine from rotary kiln in tones
• The amount of calcine from rotary kiln in t/h
• The amount of heavy oil consumption from rotary kiln in kg/t of calcine

• Temperature of the calcine
• The level of the ore pre-reduction
• The amount of the final product of the ore
During the period of the researches in 2007, the technological process has faced some big difficulties in its whole technological line. After a long period of time New Ferronickel Factory has started its work, while during 2007 it worked only with one technological line (only with one rotary kiln). Starting from 2008 two rotary kilns begin working, and in 2010 we have a significant improvement in technological process in New Ferronickel Factory in Drenas, because in 2010 a new metallurgical aggregate (Bernardy Dryer) was added to the process, a device that decreases the humidity of the silicate ore of Nickel, in addition during 2010 New Ferronickel Factory works without limestone. Although we have this improvement in technological process during 2010, pre-reduction of the ore can not be reached because the humidity of the ore remains still a problem in itself, because the Bernardy Dryer has not enough capacity to decrease the ore humidity, only to an limited amount of the ore the humidity could be decreased.
During industrial researches we have observed that during 2009 the rotary kilns began to suffer damages in their flame-resistant material, which damages affect the loss in temperatures and it has negative consequences in pre-reduction of the ore.
We have shown in the graphical presentations the industrial, experimental and laboratory researches. The industrial, experimental and laboratory researches of the pirometalurgical treatment of ore, in order to do ore pre-reduction and its preparations, for the process of mineral fusion, have been done in the New Ferronickel Factory in Drenas.
With laboratory researches we have determined the composition of the Nickel silicate ore during 2007, 2008, 2009 and 2010. In following table presentations we have shown the chemical analysis of the Nickel ore composition in Drenas during 2007, 2008, 2009 and 2010.
Table 1 Table presentation of average value of laboratory analysis of Nickel silicate ore during 2007-2010-Çikatovë

<table>
<thead>
<tr>
<th>Year</th>
<th>Fe</th>
<th>SiO₂</th>
<th>Mg</th>
<th>Al₂O₃</th>
<th>Ni</th>
<th>CaO</th>
<th>Cr₂O₃</th>
<th>Co</th>
<th>w</th>
</tr>
</thead>
<tbody>
<tr>
<td>2007</td>
<td>20.</td>
<td>42.</td>
<td>8.6</td>
<td>3.2</td>
<td>1.</td>
<td>2.2</td>
<td>1.1</td>
<td>0.</td>
<td>35.</td>
</tr>
<tr>
<td>2008</td>
<td>19.</td>
<td>47.</td>
<td>3.9</td>
<td>3.8</td>
<td>1.</td>
<td>1.8</td>
<td>1.3</td>
<td>0.</td>
<td>36.</td>
</tr>
<tr>
<td>2009</td>
<td>19.</td>
<td>47.</td>
<td>4.8</td>
<td>3.8</td>
<td>1.</td>
<td>1.6</td>
<td>1.2</td>
<td>0.</td>
<td>37.</td>
</tr>
<tr>
<td>2010</td>
<td>14.</td>
<td>38.</td>
<td>16.</td>
<td>4.3</td>
<td>1.</td>
<td>3.6</td>
<td>0.9</td>
<td>0.</td>
<td>33.</td>
</tr>
</tbody>
</table>

Table 2 Table presentation of average value of laboratory analysis of Nickel silicate ore during years 2008, 2009 and 2010-Gilavicë

<table>
<thead>
<tr>
<th>Year</th>
<th>Fe</th>
<th>SiO₂</th>
<th>Mg</th>
<th>Al₂O₃</th>
<th>Ni</th>
<th>CaO</th>
<th>Cr₂O₃</th>
<th>Co</th>
<th>w</th>
</tr>
</thead>
<tbody>
<tr>
<td>2008</td>
<td>17.</td>
<td>51.</td>
<td>7.5</td>
<td>1.7</td>
<td>1.</td>
<td>0.7</td>
<td>1.0</td>
<td>0.</td>
<td>29.</td>
</tr>
<tr>
<td>2009</td>
<td>18.</td>
<td>45.</td>
<td>10.</td>
<td>4.0</td>
<td>1.</td>
<td>0.6</td>
<td>1.3</td>
<td>0.</td>
<td>29.</td>
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<tr>
<td>2010</td>
<td>18.</td>
<td>50.</td>
<td>7.8</td>
<td>1.7</td>
<td>1.</td>
<td>0.7</td>
<td>1.4</td>
<td>0.</td>
<td>30.</td>
</tr>
</tbody>
</table>

Table 3 Table presentation of average value of laboratory analysis of Nickel laterite ore during years 2008, 2009 and 2010-Philippines

<table>
<thead>
<tr>
<th>Year</th>
<th>Fe</th>
<th>SiO₂</th>
<th>Mg</th>
<th>Al₂O₃</th>
<th>Ni</th>
<th>CaO</th>
<th>Cr₂O₃</th>
<th>Co</th>
<th>w</th>
</tr>
</thead>
<tbody>
<tr>
<td>2008</td>
<td>16.</td>
<td>40.</td>
<td>17.</td>
<td>3.6</td>
<td>1.</td>
<td>1.2</td>
<td>1.3</td>
<td>0.</td>
<td>35.</td>
</tr>
<tr>
<td>2009</td>
<td>15.</td>
<td>41.</td>
<td>17.</td>
<td>5.7</td>
<td>1.</td>
<td>1.2</td>
<td>1.4</td>
<td>0.</td>
<td>36.</td>
</tr>
<tr>
<td>2010</td>
<td>19.</td>
<td>31.</td>
<td>17.</td>
<td>2.9</td>
<td>1.</td>
<td>2.2</td>
<td>1.6</td>
<td>0.</td>
<td>30.</td>
</tr>
</tbody>
</table>

Table 4 Table presentation of average value of laboratory analysis of Nickel laterite ore during year’s 2008, 2009 and 2010–Indonesia

<table>
<thead>
<tr>
<th>Year</th>
<th>Fe</th>
<th>SiO₂</th>
<th>Mg</th>
<th>Al₂O₃</th>
<th>Ni</th>
<th>CaO</th>
<th>Cr₂O₃</th>
<th>Co</th>
<th>w</th>
</tr>
</thead>
<tbody>
<tr>
<td>2008</td>
<td>28.</td>
<td>36.</td>
<td>13.</td>
<td>2.5</td>
<td>2.</td>
<td>0.3</td>
<td>2.5</td>
<td>0.</td>
<td>34.</td>
</tr>
<tr>
<td>2009</td>
<td>19.</td>
<td>37.</td>
<td>3.0</td>
<td>1.2</td>
<td>1.6</td>
<td>0.</td>
<td>36.</td>
<td>0.</td>
<td></td>
</tr>
</tbody>
</table>

Table 5 Table presentation of average value of laboratory analysis of Nickel oxide ore during year’s 2008, 2009 and 2010 - Albania

<table>
<thead>
<tr>
<th>Year</th>
<th>Fe</th>
<th>SiO₂</th>
<th>Mg</th>
<th>Al₂O₃</th>
<th>Ni</th>
<th>CaO</th>
<th>Cr₂O₃</th>
<th>Co</th>
<th>w</th>
</tr>
</thead>
<tbody>
<tr>
<td>2008</td>
<td>36.7</td>
<td>17.8</td>
<td>4.2</td>
<td>6.54</td>
<td>0.8</td>
<td>3.55</td>
<td>0.0</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>2009</td>
<td>36.9</td>
<td>17.5</td>
<td>4.1</td>
<td>5.14</td>
<td>1</td>
<td>4.8</td>
<td>3.56</td>
<td>0.0</td>
<td></td>
</tr>
<tr>
<td>2010</td>
<td>43.2</td>
<td>24.1</td>
<td>6.9</td>
<td>49.1</td>
<td>0.0</td>
<td>4.56</td>
<td>0.0</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

With industrial and laboratory researches it has been determined the average value of the calcine, for both rotary kilns in tones (Fig.1) and in t/h (Fig.2). With laboratory method we have determined the composition of the calcine with the computeric apparatus called “Spektrometer”. With industrial method we have determined the amount of the calcine, with scales of containers of calcine, which were put on the calcine containers cart. From the graphical presentation (Fig.1) we can see that the average amount of the calcine in two rotary kilns is greater during 2010.
From the Fig. 2 we see that we have an increase in the average value of calcine from year to year. In this increase of the amount of calcine in 2010 contributed the rarer interruptions in rotary kilns, adhesions inside the kilns, especially at the rotary kiln number two the consumption of heavy oil has decreased, putting five tertiary air ventilators inside the kiln which have significant role in efficiency of lignite burning in the rotary kiln number 2.

As a factor of increasing the amount of calcine in tone per hour during 2010 is as well the use of dried lignite of Kosovo up to 70%, while 30% was the stone coal from Indonesia.

As another factor we have the treatment of Nickel silicate ore without limestone during 2010.

With industrial methods we have also determined the temperature of calcine.

From the Fig. 3 we see that the temperature of calcine has a noticeable increase during 2010, however this increase of temperature is not necessary for the Nickel silicate ore pre-reduction.

In Fig. 4 we see that consumption of heavy oil during 2007 is much lower compared to other years of researches, and this comes as a result of only one rotary kiln working in 2007 and with frequent interruptions. We see increase in heavy oil consumption in 2008, and this comes as a result of frequent interruptions and adhesions in the rotary kilns etc.

The consumption of heavy oil begins to drop in 2010 as a result of decreased humidity and decreased limestone amount.

With experimental researches we determined the level of pre pre-reduction in New Ferronickel factory in Drenas during years: 2007, 2008, 2009 and 2010.

As you can see from the graphical presentation Fig. 6 we have an increase in pre-reduction of ore in 2010, however this achieved value is not necessary for ore pre-reduction, because the rotary kiln in New Ferronickel Factory in Drenas is not long enough to do ore drying, warming and pre-reduction, it means the staying time is not enough for pre-reduction.
All the problems come as a result of high humidity which decreases the pre-reduction, although since 2010 New Ferronickel Factory in Drenas uses the Bernardy Dryer, a device that decreases the humidity, but its capacity is not sufficient to decrease the humidity for both rotary kilns. The rotary dryer (photo.1 Bernardy Dryer) is a device that is installed in New Ferronickel Factory in Drenas in March 2010, when the technical pass was made and it started working in July 2010. Picture of Bernardy Dryer: Technical specification of the dryer:
- Size of dryer: \( \varnothing = 3000\text{mm}, L = 10500\text{mm} \),
- Power, of motor 90kW,
- Dryer belt 700mm, motor 7.5kW,
- Installed kW power 188.5kW.

With experimental researches we have determined the final product amount of Nickel during the years 2007, 2008, 2009 and 2010. This determination of final product of Nickel we do in mechanical way, measuring the amount of Nickel gained for each refined load separately.

Fig.8 As we see from the graphical presentation we have increasing percentage of final product of Nickel from year to year.
3 Conclusion

From the abovementioned experimental results, we may conclude that the pre-reduction of calcine in rotary kilns (average values from two rotary kilns) has increased from year to year; in 2007 it was 42.7%, in 2008 - 79.8.6%, in 2009 - 86.44 and in 2010 it reaches the value of 96.6%.

This increase in pre-reduction level of calcine has positively influenced in increasing the capacities of rotary kilns consequently increasing the final amount of production from year to year.

Increase of pre-reduction in rotary kilns has also positively influenced in improving the technological process of electroreduction melting of calcine in rotary kilns, which decreases the specific consumption of electric power per tone melted calcine and per tone produced Nickel, in corporate level, that is from 111.6MWh/t Ni how it was in 2007 to 69.4MWh/t Ni in 2008, 72.2MWh/t Ni in 2009 and 69.2MWh/t in 2010.

From the experimental researches during 2007, 2008, 2009 and 2010 from the average values presentations for both rotary kilns we may conclude as follows:

The interventions that were made during 2010 (installation of Bernardy Dryer in New Ferronickel Factory in Drenas and remove of CaCO₃ smelter from the technological process) has brought improvements in technological process:

- Increase in pre-reduction level of the ore in 2010
- Increase in amount of calcine per tone/h in rotary kilns
- Increase in rotary kiln temperature
- Decrease in heavy oil consumption
- Decrease in electric power consumption
- Decrease in humidity

However, although during 2010 we have had significant increase in pre-reduction in rotary kilns, in low index of pre-reduction level has contributed the humidity of the ore, impossibility to create the reduction atmosphere inside the kiln, uncontrolled entering of the air in frontal part of the kiln (during industrial researches, adhesions in rotary kiln, collapse of flame - resistant material during kiln work), what has decreased the temperature inside the rotary kiln.

During industrial, experimental and laboratory researches of abovementioned years, we may say that although we have increase in pre-reduction level, the results of researches are not satisfactory, because starting from the preparation of raw - comminuting in grains and with homogenization of the ore, from year to year nothing has been done in improving these parts of the process, what means that mineral value depends on the ore composition from area to area.

The level of decrease in ore humidity realized in Bernardy Dryer is not sufficient because the capacity of Bernardy Dryer does not cover the capacities of both rotary kilns which work 24 hours non stop. So an small amount of the ore passes from the Bernardy Dryer in one tape and joins another tape with ore that enters the rotary kilns directly from the slag.

The size of grains (ore and reducing agent) is very important for the level of ore pre-reduction.

So, from the laboratory researches and reviews, from industrial experiences we have reached to the conclusion that with size reduction of the ore and the reducing agent, the level of ore pre-reduction in rotary kilns increases.

The time of material stay in the kiln has a significant role in pre-reduction level [2].

4 Recommendations

To install additional facilities for preparing the ore to decrease humidity e.g. installing a new drying device with higher capacity that covers the capacity of two rotary kilns, installing a device for comminuting in grains of the ore.

Possibility of avoiding the dust in the Factory.

Real quick steps to be taken in the New Ferronickel Factory for comminuting the ore in grains,

-Real quick steps to be taken for homogenization of the ore because nothing has been done on it for years,

In addition a very important issue that is worth mentioning is also that the flame-resistant material of the kilns is very much damaged and the kilns work in a bad condition.

References: