SINTER BASICITY INCREASE THROUGH INSERTION OF MAGNESIUM SILICATE MINILUMPS

BY

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SYNOPSIS

PASEK Dunite is an ultramaphic rock with a basic chemical classification, being olivine its principal mineral. It is used as a flux in ironmaking due to its physical and chemical properties, improving permeability, productivity, alkali removal and reducing energy consumption in the blast furnace.

Regarding the global tendency of integrated plants to avoid as many raw materials as possible in the sinter, many plants are taking measures such as maximizing the Fe through the sinter, avoiding additional SiO$_2$ and increasing basicity. PASEK Dunite is mostly used as a lump flux, nevertheless, plants which face logistical constraints have looked for alternatives to profit from the benefit of using lumpy Dunite. The introduction through the sinter has been evaluated using Minilumps, obtaining a stronger sinter which allows productivity increase by reducing the return fines and improving permeability in the BF.

This method may help plants introduce MgO in the most effective way. Several tests performed showed that Dunite effectively sticks to the sinter matrix and have a significant percentage of inert material which does not influence sinter composition and quality, reaching the BF as a lump. Several grain sizes of PASEK Dunite could be used depending on the aim of each plant.

Keywords: Fluxes; Dunite; Sinter; Minilumps; Magnesium Silicate; Basicity

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1. Introduction

PASEK Dunite is an ultramaphic rock exploited in the north of Spain with a basic chemical classification, being olivine its principal mineral which has been naturally weathered over a long period of time. PASEK Dunite has been extracted and processed since 1972 from the largest magnesium silicate ore mine in Spain and one of the largest in the world, located at the Spanish region of Galicia. The mine has a capacity of over two Mton per year; up to date, more than 27 Mton have been extracted, processed and commercialized. The deposit of the mine is estimated in 600 Mton

![Spanish Dunite mine in Galicia.](image)

Magnesium silicates are commonly used as blast furnace (BF) fluxing additives, not only to adjust the slag MgO content, but also to promote potassium elimination with the slag and limit the harmful accumulation of potassium in the stack [1].

Quarried, crushed, sized and screened fluxes are added to the blast furnace in small quantities to perform the following functions:

- Magnesia addition, to fluidify the slag and adjust its MgO content to the optimum value (6 to 9%), required by its basicity index and alumina content [2].

- Adjustment of the slag volume to its optimum value, connected to the slag basicity index.
- Improvement of primary slag formation kinetics (at a Tª of 1200° to 1400°C) if the magnesia silicate used is indeed a flux, as it is for DUNITE. In this case the desulfurization of pig iron is improved.

- Absorption of potassium vapours in the lower shaft and improvement of the kinetics of their fixation as K\(_2\)O in the slag [3].

PASEK Dunite, being a magnesium silicate, is used as a flux in the ironmaking processes due to its physical (low softening and melting points, high strength to mechanical stresses and customized grain size distribution are the most important) and chemical properties, improving permeability, productivity, alkalis removal and reducing energy consumption in the blast furnace.

Due to internal logistical constraints, plants interested in the use PASEK Dunite lumps are not able to provide the appropriate conditions for its use due to the lack of the required infrastructure (additional silos, conveyor belts…) and, due to these difficulties, plants have been searching for other alternatives in order to be able to use the product.

This paper describes a very innovative way of introducing small sized lumps of Dunite through the sinter bed, avoiding the need of implementing expensive logistical solutions.

2. Discussion.

PASEK Dunite is used in the ironmaking process as a flux due to its physical, chemical properties which are shown below.

Regarding its physical properties there are two parameters that need to be highlighted because explain the high reactivity of the rock at industrial processes:

- The softening temperature: 1280°C
- Open porosity at 850°C, approximately 20%.

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crushing resistance (Baron)</td>
<td>1400 g/cm(^3)</td>
</tr>
<tr>
<td>Abrasion index</td>
<td>4.5</td>
</tr>
<tr>
<td>Impact resistance (IRSID) in fines</td>
<td>&lt; 10 mm = 6%</td>
</tr>
<tr>
<td>Abrasion resistance (MICUM) 200 T. in fines</td>
<td>&lt; 10 mm = 16%</td>
</tr>
<tr>
<td>Thermal shock resistance 200 T. in fines</td>
<td>&lt; 10 mm = 5.3%</td>
</tr>
<tr>
<td>Hardness (MOHS scale)</td>
<td>6.5-7</td>
</tr>
<tr>
<td>Softening point</td>
<td>1280 °C</td>
</tr>
<tr>
<td>Fusion point</td>
<td>1430 °C</td>
</tr>
<tr>
<td>Real density</td>
<td>2.50</td>
</tr>
<tr>
<td>Apparent density</td>
<td>1.70</td>
</tr>
<tr>
<td>Open porosity at 850°C</td>
<td>19.5%</td>
</tr>
</tbody>
</table>
With regard to its chemical description PASEK Dunite is a rock mainly formed by magnesium silicate compounds, whose principal basic components are oxides, such as MgO, SiO$_2$, Fe$_2$O$_3$, Al$_2$O$_3$…

Table II. Detailed composition break-up of Dunite.

<table>
<thead>
<tr>
<th>Dunite</th>
<th>Chemical Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>MgO</td>
</tr>
<tr>
<td>Average</td>
<td>37.19</td>
</tr>
<tr>
<td>Std. Dev</td>
<td>0.05</td>
</tr>
</tbody>
</table>

2.2. Minilumps purpose.

2.2.1. PASEK Dunite Lump.

As said above, PASEK Dunite is used as a flux in the ironmaking process. Depending on its grain size it can be used either on the blast furnace or in the sinter plant.

There are several benefits brought into the pig iron manufacturing process by using this rock as a lump, it acts as a fluxing agent and a slag conditioner. All these benefits derive from its favorable and well balanced physical and chemical properties, which do affect different parameters of such importance for hot metal as permeability in the blast furnace, effective alkali removal and lower energy consumption in comparison with other fluxing agents.

Regarding its physical characteristics (see Table I), there are three main characteristics that should be highlighted:

- Low softening and melting points (1200 °C and 1430°C, respectively) and a narrower range between these temperatures in comparison with other fluxes used
- High strength to mechanical stresses (abrasion, shatter, impact…). This characteristic means that Dunite doesn’t generate fines by itself so no sieving is needed
- Optimal grain size distribution (over 90% of the material is in the range from 10 to 40 mm, no fines produced)

With regard to the chemical composition (see Table II), its LOI content derives in an important increase on the specific surface of the rock. In fact, at the moderate temperature of 800°C, an open porosity is reached (20%), which leads to a better alkali removal.

Figure 2. Calcined Dunite open porosity
In comparison with other slag conditioners used in the industry, the fluxing activity of PASEK Dunite starts at the beginning of the operation, in the upper part of the blast furnace. An analysis carried out by the Belgian Ceramic Institute digs into this effect, and it can be seen that this happens due to its lower softening and melting points. This effect helps the formation of primary slags, and increases the productivity of the furnace.

This is one of the main reasons why Dunite has been used as a fluxing agent for the last forty years, competing in the market with other products with a higher MgO content, but whose fluxing activity is much more limited due to the higher softening and melting temperatures and much more limited specific surface.

2.2.2. PASEK Dunite Minilumps.

Since 2008 there is a global tendency in the market leading to an increase in the silica content of the commercial iron ore. Best quality iron ores with a higher content of Fe are becoming scarce and the ones coming from South America, Australia or Africa, have increasing amounts of SiO$_2$. This tendency it is not believed to be reversed and it will probably continue in the future. Due to this problem, many integrated steel plants are trying to modify some aspects of their processes, in order to minimize this new tendency. The actions these plants are taking are the following:

- Optimize sinter productivity by maximizing the total Fe input through the sinter.
- Avoid introduction of additional SiO$_2$ through the sinter.
- Increase sinter basicity as much as the operation allows it.

This leads to a tendency where integrated steel plants tend to avoid as many raw materials as possible in the sinter bed outside iron ore fines and coke. In case of Dunite, due to the benefits of PASEK Dunite in BF operation mentioned above, this does not cause a problem since most times Dunite is inserted directly as a lump in the BF, but there are plants which face internal logistical problems, due to the lack of appropriate equipment (raw material bunkers, conveyor belts, etc), and have looked for alternatives to profit from the benefit of using the lumpy form of Dunite.

Owing to this difficulties one of the largest worldwide steel producers together with the Pasek Technical Center developed a very innovative idea of introducing in the process MgO in lump form through the sinter without the need of a significant investment. The development was to assess the introduction to the BF of MgO bearing materials in lump form through the sinter bed (Figure 3). The grain size of this materials introduced in the sinter bed, needs to be compatible with the sinter raw materials, and certainly smaller than the lumps that are introduced directly in the BF. It has to be considered that the maximum particle size in the sinter mix is in the range of 10 mm.
Several tests were carried out with different types of materials, including Dunite and Olivine, with different grain size distributions.

### 2.2.3. Sintering process.

Sintering is one of the most commonly used agglomeration processes and the purpose of the sinter plant is to process fine grained raw materials into a coarse grained iron ore sinter, ready to be charged to the blast furnace. Sintering of fine particles into a porous clinker-sinter is necessary to improve the permeability of the burden, making reduction in the blast furnace easier and improving its operation.

It is necessary to produce a high quality sinter that has high reducibility, this parameter is intimately related with the porosity and structure of the mineral phases, it reduces the intensity of blast furnace operations and reduces the coke consumption. There are certain advantages of using sinter instead of other materials which include recycling the fines and other waste products, to include flue dust, mill scale, lime dust and sludge. Sinter helps eliminating raw flux in the blast furnace, as it is introduced in the burden with the sinter. This reduces coke consumption in the furnace, as well as helps generating less slag, improving blast furnace productivity.

The obtained sinter needs to have an adequate granulometry, with a size around 12-35 mm. The coarser particles are crushed to obtain smaller fractions, and those lower than 5 mm are the return fines, which are recycled to the sinter hoppers. The final product of sinter with the appropriate size will be transported to BF as the main source of iron-contained material.
2.2.4. **Interphase MgO bearing material – sinter**

Considering the sintering process operational temperature, PASEK Dunite finds itself at an intermediate stage between its softening and melting point. This imply that Dunite reacts partially during the sintering process. The reaction begins in the outside layer and it goes progressing towards the core of the rock.

Regarding the carried out tests, and related with the softening and melting properties of PASEK Dunite, at the end of the sintering process, when sinter is crushed into smaller pieces which will head the blast furnace with a conveyor belt, Dunite is already “glued” and evenly distributed into the sinter pieces, while most Olivine stones are not fused and fall apart, being re-screened together with the sinter fines.

Figure 5 shows a micrography of a sinter piece (dark grey colour) containing a Dunite minilump (light grey colour). The interphase Dunite – sinter can be observed (medium grey colour). Such interphase is in fact the mechanism through which the Dunite minilump remains stuck to the sinter matrix at the end of the sintering process.
Figure 5. Micrography of sinter. Dunite minilump and sinter interphase.

On the contrary, Olivine is in a raw state at this temperature and behaves like a fully inert rock placed on top of the matrix. As a result, the interphase olivine – sinter does almost not exist and the “gluing effect” is therefore much more limited.

2.2.5. Mini lumps optimal size.

Several tests were carried out with different grain size distributions:

1. A 5/15 mm grain size distribution was used at the first trial. The result was not satisfactory, as the standard deviation on MgO in the bedding pile was higher than admissible, due to the segregation of the larger particle size to the bottom of the pile.

2. A second test was then performed with a 3/10 mm. Better results were obtained in comparison with the previous test. In this case the segregation effect disappeared and the MgO was homogenously distributed along the pile and the sinter. Another trial was performed using 1/10 mm instead of 3/10 mm. No significant change was noticed between these two options, only a slight higher degree of reacted Dunite in the sinter bed.

3. A final test was then carried out with a 0/10 mm Dunite. The idea behind it was to analyze the effect of both products, Dunite fines (0/3 mm) and Dunite lumps (3/10 mm) in operation. The results were also satisfactory and the segregation effect was also not noticeable in this trial.

In all of the above cases, an important additional effect regarding the use of Dunite was noticed: the non-generation of any type of dust when handling the product or using it in the application, as opposed to other raw materials which were tested. This effect does bring several benefits to the operation, both from the operational point of view as well as from environmental issues.

2.2.6. Effects on the sinter basicity
Based on the different tests performed, a new concept was introduced: the so called “fake basicity”. The idea of this concept is the possibility of increasing the basicity (the fake basicity) of the sinter by bringing inert components into the blast furnace through the sinter, without affecting its productivity. We can see this effect with the following example, with real operational figures:

1. Let’s consider a sinter bed with a normal operation (a basicity of 2 is used in this example).

<table>
<thead>
<tr>
<th>Normal Operation</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>MgO</td>
<td>1%</td>
</tr>
<tr>
<td>SiO₂</td>
<td>5%</td>
</tr>
<tr>
<td>CaO</td>
<td>10%</td>
</tr>
<tr>
<td>Basicity</td>
<td>2</td>
</tr>
</tbody>
</table>

2. During the trial with mini lumps it was observed that some of the MgO and SiO₂ remains inert (corresponding to the Dunite mini lump which has not reacted):

<table>
<thead>
<tr>
<th>Mini lumps operation</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>MgO</td>
<td>0.5%</td>
</tr>
<tr>
<td>SiO₂</td>
<td>4%</td>
</tr>
<tr>
<td>CaO</td>
<td>10%</td>
</tr>
<tr>
<td>Basicity</td>
<td>2.5</td>
</tr>
</tbody>
</table>

As a result, the basicity of the sinter increases in 0.5 while the productivity and quality on the sinter bed remains.
3. Conclusions.

The use of mini lumps is a very innovative method that the most important integrated steel plants are adopting in order to introduce MgO in their process in the most effective way.

PASEK Dunite shows the best balance between mechanical and physical properties for this application, as it effectively sticks to the sinter matrix and have a significant percentage of inert material which does not affect the sinter composition and reaches the blast furnace as a lump.

Plants which desire the most effective homogenization of MgO along the sinter bed should chose the 3/10 or 1/10mm distributions, whereas plants which need to combine both fines and lumps during agglomeration should rather use the 0/10mm distribution.

In some of the cases a small increase of the slag level was observed (between 1 and 2 Kg/ton of pig iron). In any case, the benefits of the introduction of the lumpy product through the sinter overcame this

The environmental evaluation of the test with Dunite was also successful, as no dust emissions were observed, no matter which grain size distribution was used for the test.

4. References.


ANNEX I