FOAMING SLAG USING DUST WASTES ON ELECTRIC ARC FURNACE

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Abstract
Foaming slag is a complex phenomenon used for producing electric arc steel because it has the many advantages.
The usual foaming agents have been replaced with a product obtained from different dust wastes generated by an integrated iron and steel works.
The used dust wastes were: coal dust, coke dust, blast furnace dust, lime dust and millscale.
The experiments on laboratory and pilot scale have demonstrated that the product obtained from dust wastes can successfully replace the usual foaming agents.

Introduction
Dust wastes from siderurgical sector have unsatisfactory grain sizes and contain heavy metals, therefore recycling is difficult.
Worldwide, the specific quantities of dust wastes from integrated steel plants are between 36 and 96 kg wastes / steel tone.
In Romania the specific quantities of dust wastes is 89 kg wastes / steel tone. These wastes are partially recycled at agglomeration and the rest are stored.

Aim of Study
Processing dust wastes (coal dust, coke dust, blast furnace dust, lime dust and millscale) trough micropelletising in order to obtain by-products.
Superior recycling of dust wastes from siderurgical sector, having ecological and economical advantages.

Experiments
The authors experimented the obtaining by-products using dust wastes from SIDEX S.A. Galai Romania. The wastes were: coal dust, coke dust, blast furnace dust, lime dust and millscale. The wastes were analysed from a physical – chemical point of view and homogenized. The wastes processing was made through micropelletising. Micropelletising is a flexible process as it offers the possibility of using one or more dust wastes. The authors were made 10 charges, they are presented in the table 1.
The grain sizes must be between 1 and 3 mm for using the micropellets for slag foaming agents in the electrical arc furnace. For his, the content of Fe, Ca and C must be between:
- Fe $\rightarrow$ 45 – 65 % of blast furnace dust and millscale;
- Ca $\rightarrow$ 5 – 15 % of lime dust and blast furnace dust;
- C $\rightarrow$ 10 – 30 % of coal dust, coke dust and blast furnace dust.
The obtaining of micropellets, their distribution into grain sizes and the resistance to manipulation are influenced by:
quantity of water used in the process;
- the Ca content in the dust lime which is the binder and the element offering resistance to the micropelets;
- the C content, given by dust coal and coke dust.

Charges 5 – 8 are optimal, the characteristics of these charges are shown in Table 2.

The optimal charges cover almost the entire range of Fe, Ca, C, proving the flexibility of micropeletising process. The optimal micropelets were used at agglomeration and as slag foaming agent for steel production in EAF.

Using micropelets as slag foaming agent

Materials

The following materials are used:
- steel bath with carbon content of 0.2%;
- synthetic slag with $i_b = 2$;
- micropelets as technological addition for slag foaming (charges 5 and 8).

Picture 1 shows slag aspect before adding the micropelets before adding the micropelets into the slag (base slag) and pictures 2 – 4 show slag aspect afteradding micropellets (3 experiments). 2/2

Conclusions

The 3 experiments showed that micropelets added to a slag with good foaming capacity conduct to a foaming process:
- the bubbles are small and uniform in experiment 2 for the same quantity of micropelets as in experiment 1;
- when the process was forced (by adding four times the quantity of micropelets used in experiment 1), the size of the bubbles was much bigger than in experiment 1 and the slag had an unhomogenous aspect.

Micropellets obtained from dust wastes from siderurgical sector – coal dust, coke dust, blast furnace dust, lime dust and millscale – can successfully replace normal foaming agents.

REFERENCE

Steel: C = 0.2%; quantity = 2 kg;

Slag: CaO = 50%; SiO$_2$ = 25%; FeO = 25%; I$_B$ = 2; quantity = 0.2 kg;

**REFERENCE SLAG**

**RESULTS**

- m = 1,4613g
- $V_a$ = 0,6 cm$^3$; $\rho_a$ = 2,4385 g/cm$^3$;
- $V_s$ = 0,45 cm$^3$; $\rho_s$ = 3,2513 g/cm$^3$;
- holes percentage = 25%;

Compact, homogenous material with small bubbles ($\Phi_{bubbles} < 2mm$)

**Figure 1** Reference slag.
Steel:  
C = 0.2%; 
quantity = 2 kg;

Slag:  
CaO = 50%;  
SiO$_2$ = 25%;  
FeO = 25%;  
I$_B$ = 2;  
quantity = 0.2 kg; 
C = 10%  
Fe = 65%  
Ca = 10%  
quantity = 12.5g

Micropellets: 

**RESULTS**
m = 2.4599g  
$V_a = 2 \text{ cm}^3$;  
$\rho_a = 1.22995 \text{ g/cm}^3$;  
$V_s = 1.2 \text{ cm}^3$;  
$\rho_s = 2.0499 \text{ g/cm}^3$;  
holes percentage = 40%;

Porous material with ununiform porosity ($\phi_{\text{bubbles}} = 1 \div 5\text{mm}$), bubbles with $\phi = 5 \text{ mm}$ represent approx. 50% of the bubbles.

**Figure 2** Slag with micropellets - charge 5.
Steel:  
- C = 0,2%;  
- quantity = 2 kg;

Slag:  
- CaO = 50%;  
- SiO$_2$ = 25%;  
- FeO = 25%;  
- I$_B$ = 2;  
- quantity = 0,2 kg;  
- C = 25%  
- Fe = 45%  
- Ca = 15%  
- quantity = 12,5g

Macroscopic slag aspect

Microscopic slag aspect

RESULTS  
- m = 1,6626g  
- $V_a = 1,5 \text{ cm}^3$; $\rho_a = 1,1084 \text{ g/cm}^3$;  
- $V_s = 0,8 \text{ cm}^3$; $\rho_s = 2,0782 \text{ g/cm}^3$;  
- holes percentage = 46,66%;

Porous material with uniform porosity ($\phi_{bubbles} = 0,5 \div 2\text{mm}$),

Figure 3 Slag with micropellets - charge 8.
Steel:  
- C = 0.2%;  
- quantity = 2 kg;  

Slag:  
- CaO = 50%;  
- SiO$_2$ = 25%;  
- FeO = 25%;  
- $I_B = 2$;  
- quantity = 0.2 kg;  

Micropellets:  
- C = 25%  
- Fe = 45%  
- Ca = 15%  
- quantity = 50g (forced process)

<table>
<thead>
<tr>
<th>Slag aspect</th>
<th>RESULTS</th>
<th>Microscopic slag aspect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Macroscopic slag aspect</td>
<td>Natural size</td>
<td>X 10</td>
</tr>
<tr>
<td>h$_{zg}$ = 83 mm</td>
<td>m = 1.0053g</td>
<td>Porous material with ununiform porosity ($\phi_{bubbles} = 1 \div 10$ mm), bubbles with $\phi = 5 \div 10$ mm are more than 70% of all bubbles.</td>
</tr>
<tr>
<td>h$_{b.m.}$ = 80 mm</td>
<td>$V_a = 0.8$ cm$^3$; $\rho_a = 1.2566$ g/cm$^3$; $V_s = 0.2$ cm$^3$; $\rho_s = 5.0265$ g/cm$^3$; holes percentage = 75%</td>
<td></td>
</tr>
</tbody>
</table>

*Figure 4* Slag with micropellets - charge 8 forced process.
### Table 1 Dust materials used in charges.

<table>
<thead>
<tr>
<th>Charges</th>
<th>Element</th>
<th>Millscale, %</th>
<th>Blast furnace dust, %</th>
<th>Coke dust, %</th>
<th>Coal dust, %</th>
<th>Lime dust, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Fe = 60% Ca = 15% C = 10%</td>
<td>64,00</td>
<td>3,31</td>
<td>5,52</td>
<td>2,21</td>
<td>24,96</td>
</tr>
<tr>
<td>II</td>
<td>Fe = 55% Ca = 15% C = 10%</td>
<td>61,92</td>
<td>3,50</td>
<td>5,84</td>
<td>2,34</td>
<td>26,39</td>
</tr>
<tr>
<td>III</td>
<td>Fe = 50% Ca = 15% C = 20%</td>
<td>52,42</td>
<td>6,70</td>
<td>11,18</td>
<td>4,46</td>
<td>25,23</td>
</tr>
<tr>
<td>IV</td>
<td>Fe = 40% Ca = 15% C = 30%</td>
<td>40,59</td>
<td>10,17</td>
<td>16,94</td>
<td>6,78</td>
<td>25,52</td>
</tr>
<tr>
<td>V</td>
<td>Fe = 65% Ca = 10% C = 10%</td>
<td>71,49</td>
<td>3,41</td>
<td>5,70</td>
<td>2,27</td>
<td>17,13</td>
</tr>
<tr>
<td>VI</td>
<td>Fe = 60% Ca = 10% C = 15%</td>
<td>65,61</td>
<td>5,15</td>
<td>8,58</td>
<td>3,43</td>
<td>17,23</td>
</tr>
<tr>
<td>VII</td>
<td>Fe = 60% Ca = 5% C = 20%</td>
<td>67,33</td>
<td>7,11</td>
<td>11,88</td>
<td>4,74</td>
<td>8,94</td>
</tr>
<tr>
<td>VIII</td>
<td>Fe = 45% Ca = 15% C = 25%</td>
<td>47,66</td>
<td>7,95</td>
<td>18,55</td>
<td>-</td>
<td>25,84</td>
</tr>
<tr>
<td>IX</td>
<td>Fe = 50% Ca = 10% C = 25%</td>
<td>54,92</td>
<td>8,20</td>
<td>19,12</td>
<td>-</td>
<td>17,75</td>
</tr>
<tr>
<td>X</td>
<td>Fe = 50% Ca = 5% C = 30%</td>
<td>56,58</td>
<td>10,24</td>
<td>23,92</td>
<td>-</td>
<td>9,26</td>
</tr>
</tbody>
</table>

### Table 2 Optimal charges.

<table>
<thead>
<tr>
<th>Charges</th>
<th>Charge composition [%]</th>
<th>Micro-peletising duration [min]</th>
<th>Humidity [%]</th>
<th>Density [g/cm³]</th>
<th>Granulometric range, [mm]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>wet</td>
<td>dry</td>
</tr>
<tr>
<td>5</td>
<td>65 10 10</td>
<td>10</td>
<td>2,5</td>
<td>1,30</td>
<td>1,27</td>
</tr>
<tr>
<td>6</td>
<td>60 10 15</td>
<td>11</td>
<td>2,9</td>
<td>1,26</td>
<td>1,22</td>
</tr>
<tr>
<td>7</td>
<td>60 5 20</td>
<td>8</td>
<td>1,6</td>
<td>1,26</td>
<td>1,24</td>
</tr>
<tr>
<td>8</td>
<td>45 15 25</td>
<td>14</td>
<td>3,1</td>
<td>1,10</td>
<td>1,07</td>
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