Environmental Management Elements of The Electric Arc Furnace

The paper presents a theoretical and experimental analysis of the polluting generating mechanisms for steel making in the Electric Arc Furnaces (EAF). The scheme for the environment’s polluting system through the EAF is designed and presented in this paper. The ecological experimenting consisted of determining by specialised measures of the dust percentage in the evacuated gases from the EAF and of thereof gas pollutants. From the point of view of reducing the impact on the environment, the main problem of the electric arc furnace (EAF) is the optimisation of the powder collecting from the process gases, both from the furnace and from the work-area. The paper deals with the best dependence between the aggregate’s constructive, functional and technological factors, which are necessary for the furnace’s ecologisation and for its energetically-technologically performances increasing.

The electric arc furnace (EAF) is an important polluting emissions generator, having a strong impact over the environment [1, 2]. The most important polluting emissions of the EAF [3, 4, 5] are:

- The powders resulted during the technological operations of base material loading and steel melting, refining, alloying and evaporation which contain heavy metals (Cr, Ni, Zn, Pb, etc) and can reach values of 15 kg/t steel [6].
- The gases resulted from the melting and refining processes, which mainly contain CO, CO2, SO2, and NOx [7].

From the total polluting emissions, over 95% are generated during the technological operations of melting and refining, as well as heavy metals oxides (Ni, Cr, Cd, Pb, Cu). The chemical composition of these emissions is extremely variable and directly dependent on the following parameters [8]:

- the composition of the base materials that make up the loading;
- the melting managing way;
- the refining process that is used (with gaseous oxygen or air);
- the period the melting and refining last; the grade of the elaborated steel.

In table 1 there are presented the chemical composition’s variation limits for the powder generated during the steel elaboration in electric arc furnaces [9] in the USA and Germany, from loading that consists of scrap iron.

<table>
<thead>
<tr>
<th>No.</th>
<th>Component</th>
<th>USA</th>
<th>Germany</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Fe</td>
<td>16.4-38.6</td>
<td>21.6-43.6</td>
</tr>
<tr>
<td>2</td>
<td>Si</td>
<td>0.9-4.2</td>
<td>0.9-1.7</td>
</tr>
<tr>
<td>3</td>
<td>Al</td>
<td>0.5-6.9</td>
<td>0.1-1.5</td>
</tr>
<tr>
<td>4</td>
<td>Ca</td>
<td>2.6-15.7</td>
<td>6.6-14.6</td>
</tr>
<tr>
<td>5</td>
<td>Mn</td>
<td>1.2-9.0</td>
<td>1.0-14.5</td>
</tr>
<tr>
<td>6</td>
<td>Fe2O3</td>
<td></td>
<td>0.4</td>
</tr>
<tr>
<td>7</td>
<td>Mg</td>
<td>1.9-13.9</td>
<td>0.5-16.9</td>
</tr>
<tr>
<td>8</td>
<td>FeO</td>
<td>2.5-7.3</td>
<td>0.9-4.8</td>
</tr>
<tr>
<td>9</td>
<td>P</td>
<td>0.0-1.0</td>
<td>0.1-0.5</td>
</tr>
<tr>
<td>10</td>
<td>Fe3O4</td>
<td>0.0-1.0</td>
<td>N/A</td>
</tr>
<tr>
<td>11</td>
<td>Zn</td>
<td>0.0-3.3</td>
<td>0.5-6.9</td>
</tr>
<tr>
<td>12</td>
<td>Cr</td>
<td>0.0-0.8</td>
<td>0.00-1.1</td>
</tr>
<tr>
<td>13</td>
<td>Ni</td>
<td>0.2-2.4</td>
<td>N/A</td>
</tr>
<tr>
<td>14</td>
<td>Pb</td>
<td>0.03-0.3</td>
<td>1.3-5.0</td>
</tr>
</tbody>
</table>

Table 1. The chemical composition of the powder generated by the electric arc furnace (EAF)

The gaseous phase of the emissions that come out of the EAF mainly consists of the following components: CO, CO2, NOx, and SOx, but it also contains other components, very toxic ones, such as volatile organic components resulted from the organic oils burning that decreases the purity of the base material.

The EAF powder emissions classification and content are presented in table 2.

<table>
<thead>
<tr>
<th>No.</th>
<th>Emission Type</th>
<th>Technological phase of the elaboration process</th>
<th>Emission Content (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Primary</td>
<td>Melting - Refining</td>
<td>93</td>
</tr>
<tr>
<td>2</td>
<td>Secondary</td>
<td>Loading</td>
<td>2.75</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Evacuation</td>
<td>3.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Through lack of tightness (door, arched tank, the space around the electrodes)</td>
<td>0.75</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>The charge duration</td>
<td>100</td>
</tr>
</tbody>
</table>

Table 2 EAF powder emissions classification and content

Materials and Methods

From the point of view of reducing the impact over the environment, the most important step is the optimisation of the powder collecting from the process gases [10-13] both from the furnace and from the work-area. This optimisation is both for the work conditions improvement and for the following of the limits imposed by the work and environment protection legislation.

The factors determined by the previous demands, along with the EAF’s performances increasing, involve the following: the gases’ collecting extension; the increasing of the separation range or the reducing of the gases’ powder content; the reducing of the functioning costs by reducing the energy consumption; the reducing of the maintenance costs and of the investment costs; noise protection; the work conditions improvement.

For the polluting emissions not to get into the work bays’ atmosphere and into the environment, the electric arc furnaces had to be equipped with efficient captivation and purification equipment [14, 15].

The powder emissions generated during the technological steps of a charge can be divided into primary and secondary emissions depending on their content from the total powder quantity generated during the whole charge duration.

Figure 1. The scheme of the environment polluting system through the EAF.
Ecological Possibilities of the Electric Arc Furnace

For the removal of burnt gases that are evacuated from the electric arc furnace the successive realization of two categories of processes is needed [15-18]:

- the burnt gases captivation;
- the burnt gases removal.

The burnt gases captivation can be achieved with one of the following variants:

- hoods;
- exhausting pipe in the arch (through the fourth orifice in the furnace's arch);
- mixed (hood + the fourth orifice in the arch).

The burnt gases removal system can be:

- dry, without the gases' washing;
- centrifugal, with the help of the cyclones;
- filter type with filters with bags (textile materials) or electrofilter.

An example of a wet removing plant used at a 10 t EAF is presented in figure 2.

The solution of gases' exhaust through a fourth orifice in the arch was adopted and that proved to be the best way of catching the gases from an electric arc furnace.

The exhausting pipe (2) which has cooling ribs was settled to the metallic construction of the furnace's arch, so that it can follow all its dumping and oscillation movements.

The evacuated gases removal proceeding from the electric arc furnaces, expected to be used in sideway takes into consideration: the mixed solution of the gaseous phase collecting, both through the fourth orifice of the arch (provided with a cooled linkage) and through a mobile hood electrically operated and placed above the furnace (for the secondary emissions catching); the gases' cooling with air exhausted at the surrounding temperature; filtering element – filter with bags; the necessary draught providing – through a room exhaust (both for the fourth orifice from the arch and for the arch).

Results And Conclusions

In figures 3, 4 and 5 there are presented the main results of the O₂, CO₂ respectively CO percentage variation in the waste gases during the melting in the EAF.

The decision upon the type of process and plant that are used to remove the evacuated burnt gases from the electric arc furnace takes into consideration the following criteria: not to negatively influence the technological process; the possibility of trimming in the available space; the realization of the environment protection under best circumstances; safety in exploitation; minimum investment volume; minimum exploitation cost; the purified substances' best use.

The using of the removal plant influences the pressure regime in the EAF. Along with the fake exhausted air volume increasing phenomenon (and the increasing of the burnt gases' volume, gases that are evacuated from the EAF) caused by the worn furnace's arch, this aspect imposes the use of cooled arches and walls.

The EAF's thermo regime intensification and its best seal, technological priorities that lead to the EAF's productivity increasing, as well as the specific energy consumption decreasing, must be done by avoiding the uncontrolled ignition risk of the gaseous phase on the removal plant's route. For this, the introduction of the burning chamber is extremely important.

References