EAF PROCESS OPTIMIZATION WITH AMIGE SMARTFURNACE SYSTEM

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SYNOPSIS

With the increasing number of high productive EAF, and the variability in raw materials and product demand, the need for a system capable of adapting to the operation conditions in real time is essential. With state of the art technology, the AMIGE SmartFurnace system, featuring optimization tools like the DigitARC PX3 Electrode Regulation System and the ZoloSCAN Laser Off Gas Analyzer, has helped improve highly productive AC and DC furnaces.

This paper discusses two implementations of the AMIGE SmartFurnace system. First, the installation of the SmartFurnace system in the 120t Double Shaft DC EAF in Yamato Steel Co. Ltd., in Japan, including Electrode Regulator, and Chemical and Electrical Energy Optimization Modules. Second, the implementation of the SmartFurnace Off Gas Module in the 100t AC EAF in Vallourec Star, in the United States, based on an Off Gas Laser analyzer, for a closed loop control of the Chemical Energy input. The technology in these both cases is described, and the results are shown.

KEYWORDS: EAF OPTIMIZATION – DC & AC EAF – OFF GAS ANALYSIS – CHEMICAL ENERGY CONTROL

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INTRODUCTION
The need to adapt to different operation conditions, and to respond to changing raw material quality, cost, or market demand, represents a challenge in the EAF optimization task, with different production objectives, priorities and constraints that may change over time. No matter what the main drive is, the main goal of the optimization task usually is to find the balance point of the needed trade-offs to maximize the benefits in every heat.

In this paper two particular cases with the results of a similar scope are shown. The first one a DC Double Shaft EAF in Yamato Steel, Japan, and a second one an AC EAF in Vallourec Star, in Youngstown, Ohio, USA. In both plants, different control modules of the optimization system were used. The description of these modules is shown below.

CONTROL SYSTEM DESCRIPTION
The SmartFurnace EAF Optimization system setup is basically the same for any furnace type, and consists of two entities, the DigitARC PX3 electrode regulator, and the Electrical and Chemical energy supervisory control modules. These two interacting systems provide an integral optimization solution of the furnace operation parameters, interconnected to the PLC’s through the process network using proprietary drivers, and to the electrode control valves. The architecture of the system is displayed on Figure 1.

DigitARC PX3 Electrode Regulator
The electrode regulation system installed on both the AC and DC furnaces is designed with a fast closed loop control and execution of complex algorithms supported by a dedicated CPU that allows a fast data acquisition. Several optimization tools and process monitoring features are implemented, such as:
- Monitoring of Arc Stability for AC and DC EAF’s
- Control output filtering to eliminate resonance frequencies in the arm
- Advanced hydraulic valve tests
- Preemptive Cave In and a Dynamic Non Conductive Charge detection
- High speed acquisition of Electrode Speed and Electrode Hydraulic Pressure
- Regulator and furnace performance reports

An additional processing unit is used for logging, diagnostics, and connectivity. This dual setup allows a fast execution of the control program with zero delay on the control commands sent to the proportional valves. It also provides dedicated I/O for high speed data logging used for both control and diagnostics like the electrode arm pressure and electrode position. It also includes a user friendly graphic interface.

Additionally, with the installation of precise position sensors it is possible to evaluate the behavior of the electrode movements, making Electrode Tests. Differences in the results of the tests overtime may indicate changes in the dynamics of the hydraulic system, or mechanical issues.
SMARTFURNACE MODULES
The optimization task consists on finding the balance among all the parameters considering specific production goals that might change over time. The optimization system is designed to provide a robust and flexible solution to adapt the furnace operation to the actual situation of scrap quality, mix, steel grade, practices, furnace conditions, etc. The modular design of the system gives the possibility to provide a tailored optimization solution to the specific needs of the client, allowing to add them gradually as they are needed. These subsystems are SmartARC, Oxygen, DRI, Slag and latest Off-Gas Modules. The base of these modules is the VisualKB platform, an expert system graphic programming software developed by AMIGE.

SmartARC
Using dynamic power profiles, this system adapts to the current heat conditions changing the electrical parameters that provide the flexibility to the operation in order to achieve optimal performance. These parameters include the transformer and reactor taps, regulation mode, and current/voltage setpoints. This platform allows to have EAF optimization tools like:
- Cross Arc detection
- Furnace roof and Water Cooled Panels protection
- Balance control
- Refractory protection

Oxygen Module
The C and O2 flow control is done with this module. In order to do so, the bath current oxidation is estimated using the injected oxygen value, and the estimated oxygen demand
of the furnace reactions. With these statistical calculations, the system is able to determine the precise moment to start and stop the oxygen lancing. A precise control of the oxidation and carburization minimizes the delays at the end of the heat to correct the steel carbon content, and decreases the FeO levels in slag.

Slag Module
The submodule for slag control determines the recommended fluxes that should be added to the furnace to achieve an optimal level of MgO saturation in the slag, based on the chemical analysis. This condition promotes the formation of foamy slag, arc stability, and protection of the refractory. The estimations of the system allow minimum FeO contents in the slag and lower energy losses in the slag formation process. The main screen of the modules for slag control is shown in figure 2

Off Gas Module
The latest integration to SmartFurnace is the module for off gas control, using the ZoloSCAN laser monitoring sensor. The tunable diode laser absorption spectroscopy (TDLAS) technology of this probe, has proved to accurately provide real time monitoring of the CO, CO2 and H2O concentration at a speed that allows to close the chemical energy control loop. Laser transmitter and receiver heads with automatic alignment are installed on the duct, sending a single laser ray through optic fiber up to the duct gap, and returning to the control cabinet again by optic fiber. The usual setup of the off gas probe is shown on Figure 3. With the online real time measurement of the CO and CO2, it is possible to dynamically adjust the Oxygen, Carbon and Natural Gas usage, and measuring H2O, the Abnormal Water Vapor Detection module can alert the risk of unusual water sources in the furnace.
The CO/CO2 ratio, energy consumption, arc stability and estimated steel bath oxidation are used by the Off Gas Control Module to modify carbon injection during refining. Carbon references are subjected primarily to the stability of the bath and its estimated oxidation. A subsequent compensation is carried out by the Off Gas Control Module, taking into account instant and average heat CO/CO2 ratios, a variable CO/CO2 ratio target and a previous validation of the off gas data.

The H2O monitoring can identify abnormal concentration of water in the furnace exhaust gas. In order to generate AWV alarms, this module calculates the expected amount of water vapor inside the furnace and compares it against the Zolo off gas analyzer measured H2O%. Using a custom based logic, the AWV module generates a warning or an alarm with its severity level to the furnace operators via HMI communication. The water vapor estimation is based on a multivariable nonlinear model, which takes into account several process related variables such as off gas flow, used energy, off gas temperature, furnace stability, electrode cooling flow, tilt angle, air intake, etc. Figure 4 shows the AWV model estimated water vapor percentage and the ZoloSCAN measured H2O% on a typical two charge heat with normal water vapor throughout the heat. The measured H2O% (dotted line) and the estimated H2O% (solid line) follow each other closely.
RESULTS

Vallourec Star
Vallourec Star, a joint venture between Vallourec and the Sumitomo Corporation, is a leading producer of premium seamless pipes (Oil Country Tubular Goods – OCTG) used primarily in oil and gas applications. It offers the latest technology in steel making and pipe mill production, heat treatment and threading facilities and customized specialty service products. The electric arc furnace at Vallourec Star has the following characteristics:

- 6 meter diameter Fuchs AC EAF
- 100 tap ton capacity with average 25 ton hot heel.
- 78.4 MVA Transformer with a 5.1 ohm online reactor
- Maximum 1100 V and 59.25 KA
- 4 PTI burners.

With the objective to further optimize the Electric Arc Furnace process, Vallourec Star installed the ZoloSCAN Laser Off Gas Analyzer in late 2015. With this measurement, it is possible to close the control loop of chemical energy, helping to optimize the use of carbon and oxygen.

Table 1 provides the results of the optimization process under one crew operation regime. A 100% scrap grade and a 30% pig iron grade were considered for the economic analysis. These two grades represent about 75% of current and historical Vallourec Star production. The EAF performance has been evaluated by analyzing the main operation EAF process indicators such as energy consumption, electrode consumption, productivity, additions made to the heats, etc. Only indicators that were statistically
different (better/worse) are presented. In addition, critical EAF process variables have also been analyzed, e.g. steel temperature at tap, level of steel oxidation at tap, %FeO in slag and the slag foaming quality during refining.

Table 1. Results of operation

<table>
<thead>
<tr>
<th></th>
<th>Natural Gas</th>
<th>Charge Carbon</th>
<th>Foamy Carbon</th>
<th>EAF Electrode</th>
<th>Alkalamna</th>
<th>EAF Electrocity</th>
<th>Total Oxygen</th>
<th>Dissolved Oxygen at Tap</th>
<th>Tap Temperature</th>
<th>FeO in Slag</th>
<th>Average Slag Stability</th>
<th>Power On Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>% Change</td>
<td>-3%</td>
<td>4%</td>
<td>-11%</td>
<td>-11%</td>
<td>0%</td>
<td>-3%</td>
<td>2%</td>
<td>0%</td>
<td>17°F higher</td>
<td>0%</td>
<td>-20%</td>
<td>-5%</td>
</tr>
<tr>
<td>% Change Summary</td>
<td>0%</td>
<td>N/A</td>
<td>0%</td>
<td>-11%</td>
<td>-7%</td>
<td>-5%</td>
<td>2%</td>
<td>-19%</td>
<td>12°F higher</td>
<td>-4%</td>
<td>-5%</td>
<td>-6%</td>
</tr>
</tbody>
</table>

Yamato Steel Japan
In mid 2016, the DigitARC PX3 Electrode Regulator for DC EAF was implemented in Yamato Steel, Japan, together with the SmartFurnace Oxygen Module and SmartARC for DC furnaces. Yamato Steel Co Ltd specializes in the manufacture of rolled steel products. It offers H-beams, channel steel, I-beams, steel sheet piles, unequal legs, among other shapes. The furnace has the following characteristics:

- DC Double Shaft EAF
- 120 tapped tons.
- 6700 mm shell
- 102 MVA
- Maximum 120 kA and 718 VDC on the secondary
- 6 burners, 2 postcombustion burners and 4 Carbon Injection
- Multipin bottom electrode

When the system was first installed the main goal was to evaluate the process looking for potential improvements. This is a very atypical furnace which preheats the scrap in the double shaft so normally the scrap is charged hot, and requires very little energy to complete the melting process. Due to this the energy consumption was already very low and it was not possible to compare the performance with other furnaces with similar operation, so it was difficult establish a performance benchmark. In the carbon balance analysis, it was noted that the charge carbon was low in quality and late carbon boils suggested it was melting late in the heat, suggesting it was not relevant in terms of chemical energy contribution. Hot and cold spots were identified in the furnace and some tests were run reducing the charge carbon and replacing it with other forms of chemical energy (mostly gas/oil). Soon after the start-up the benefits of this new strategy started to show. The results of the system implementation reported by Yamato Steel after approximately two months of operation are as follows:
- Kwh/Ton 5% decrease
- P-On 4% decrease
- Oxygen consumption 15% decrease
- Injected Carbon 4% decrease
- Charged Carbon 95% decrease
- Lime unchanged
- Dolo Lime unchanged
- Gas/Oil 24% increase
- Electrode consumption 6.5% decrease
- Bottom electrode life unchanged
- Yield unchanged

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REFERENCES
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