Improving EAF performance and enhancing safety with EFSOP®

Tenova’s Goodfellow Inc EFSOP® system was commissioned at Ferriera Valsabbia SpA, Italy, on their 80t EAF to improve its performance while increasing safety using Water Detection Technology™. The improvements achieved were better post-combustion, an overall reduction in consumption costs and a more efficient furnace operation. The water detection system alerts the operator to the possibility of abnormal water events in the furnace, thus improving plant safety.

Authors: Nadia Boin, Armando Vazquez and Pierluca Levrangi
Tenova Goodfellow Inc. and Ferriera Valsabbia S.p.A.

Ferriera Valsabbia SpA, Italy, was founded in 1954 and produces rebar, wire mesh and billets via the EAF route. Equipment details are listed in Table 1.

Tenova Goodfellow’s EFSOP® system was installed in October 2007 to improve EAF performance and to increase safety by detecting the presence of water that is not considered a normal part of the furnace operation.

EFSOP® SYSTEM
The EFSOP® system measures and analyses the off-gas composition (CO, CO2, H2, and O2) at the fourth hole of the EAF in real time, and uses this information for closed loop control (CLC) process optimisation. Additionally,

<table>
<thead>
<tr>
<th>Plant item</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Furnace diameter</td>
<td>5.2m</td>
</tr>
<tr>
<td>Furnace capacity</td>
<td>80t tapped</td>
</tr>
<tr>
<td>Annual production</td>
<td>850,000t</td>
</tr>
<tr>
<td>Ave. productivity</td>
<td>112.5t/h</td>
</tr>
<tr>
<td>Transformer</td>
<td>80MVA</td>
</tr>
<tr>
<td>Burners (custom build)</td>
<td>4 pairs of burners</td>
</tr>
<tr>
<td>Post-combustors</td>
<td>2+4</td>
</tr>
<tr>
<td>Oxygen injectors</td>
<td>4 supersonic injectors</td>
</tr>
<tr>
<td>Carbon injectors</td>
<td>2 injection points</td>
</tr>
</tbody>
</table>

Table 1 Ferriera Valsabbia EAF details

Fig 1 Schematic of the EFSOP® system components
off-gas analysis provides useful information to production personnel to help better understand the EAF operation and to reduce overall conversion costs.

Figure 1 illustrates the three main components and how they are integrated into the control of the furnace. The main components are:

- Patented probe
- HMI and SCADA computer
- Gas analyser

The patented water-cooled sample probe is mounted in the water-cooled D1-duct and continuously extracts sample gases from the furnace. It is equipped with an automated purging system designed to purge both the probe and the filter with pressurised nitrogen during charging and helps to ensure the probe is cleaned and is able to sample the furnace gas. The probe is in a customised position to ensure that the sample extracted is true furnace off-gas that has not been diluted by air entering at the combustion gap.

The sample gasses are drawn under vacuum through the barrel of the probe then transported through a heated sample line to the analyser cabinet where the sample is filtered for dust and dried before reaching the multi-gas analyser. This measures $O_2$, $CO$, $CO_2$, and $H_2$ and sends the data to the plant PLC. The SCADA/HMI computer then determines the optimal set-points for the furnace equipment (burners, injectors, damper position, etc) for dynamic closed loop control.

**OPTIMISATION**

With regards to EAF optimisation, the most significant improvement to the process at Ferriera Valsabbia SpA came from the reduction in methane consumption. Burner set-points were tuned with the CLC system to help reduce methane consumption during periods where more efficient post-combustion of carbon monoxide was occurring, resulting in savings in electricity use and power-on time. The HMI was used to implement operational programs based on a melting percentage provided by the plant and provided a convenient platform to make changes to, and to track, burner profiles that were tested and used. It also allowed Ferriera Valsabbia to create customised operational programs for differing conditions. For example, programs were implemented and optimised for low production conditions and to target specific productivity for higher demand periods.

In addition to the implementation of closed-loop control of the chemical package, algorithms were implemented to control the fourth hole damper, which further helped improve the furnace efficiency and reduce operating costs. The control of the damper was based...
on the calculated percentage of nitrogen in the off-gas. Nitrogen is determined as the balance concentration in the off-gas \( (N_2 = 100\% - O_2 - CO - CO_2 - H_2) \). Nitrogen does not participle in the combustion reaction and can lead to the generation of NOx if passed under the arc of the electrode. Also, the continuous drafting of air through the furnace wastes heat, and so must be minimised.

The damper control algorithm implemented at Ferriera Valsabbia has three damper set points based on \( N_2 \)%. The three settings work as follows: Setpoint #1: if \( N_2 \% > X \); Setpoint # 2: if \( N_2 \% < Y \) and; Setpoint # 3: if \( Y > N_2 \% > X \).

Overall, this allows the damper to be open to maximum when large amounts of combustible gases are present in the furnace and to maintain as much heat in the furnace when the combustible gases are at their lowest. The third setpoint allows for a much more dynamic control and smoother transition of damper position based on what is actually in the furnace as opposed to a more traditional static control of the damper. This dynamic control helped increase post-combustion in the furnace, thereby improving the efficiency of heating and scrap melting.
decreasing overall conversion costs and reducing the heat load on the fume system.

**WATER DETECTION**

EFSOP Water Detection Technology™ uses the off-gas analysis to determine abnormal water events in the furnace. First the normal level of water in the EAF operation such as electrode water spray, moisture contained in the scrap and the by-products from combustion reactions is characterised. This ‘normal’ level of water is then compared to the level of water encountered during the active heat to trigger an alert condition. Abnormal water events can be created by water panel leaks, rain or snow contained in the charge and changes in scrap that contain higher than normal levels of oils or organic material (turnings, tyre wire, etc). The benefits of detecting abnormal water can minimise the risk of furnace and fume system explosions that can lead to equipment damage, injury and loss of life.

The technology is a statistical method and so there exists a trade-off between the confidence level of abnormal water detection and false alarms. For instance, if the confidence limits for water detection are set to 100%, the system will alert at all probable water events, but with an unacceptable number of false alarms. At a lower confidence limit, the number of false alarms decreases, but at the risk of missing probable water events. Tuning requires that the confidence limits are set such that the maximum number of water events are indicated at an acceptable level of false alarms while significantly increasing the number of false alarms.

The system uses the concentration measurement of hydrogen and the ratio of hydrogen to carbon monoxide in the off-gas as an indication of the level water in the furnace. Water participates in oxidation reactions in the EAF such as the conversion of carbon monoxide to carbon dioxide and that of iron to iron oxide and produces hydrogen as a reaction product. The ratio of hydrogen to carbon monoxide will vary throughout the melting and refining periods of any one heat and from one heat to the next. The pattern of this variability is similar over a given time period of heats utilising the same burner practice and scrap mix. Using statistical off-gas data of historic heats, a general fingerprint of the H₂ and H₂/CO ratio is made for each burner practice broken down by charge and refining periods.

The fingerprint profiles of H₂ and H₂/CO ratio determined at Valsabbia were plotted on an energy consumption basis (kWh/charge, MWh/charge tonne, melting % etc), as shown in Figure 2. The practice is characterised by segmenting the H₂ and H₂/CO ratio into defined timing bins (kwh/charge, MWh/charge tonne, etc). The size of the timing bins are defined for a period where the fingerprint trends show a level of relative constancy and the thresholds for each of the alert metrics (H₂ and
H₂/CO) are generated for each of the defined bins. Smaller bin sizes increase the sensitivity to alert for abnormal water conditions, but give more false alerts, whereas larger bin sizes will generalise the fingerprint and thereby reduce the sensitivity to give a reduced rate of false alerts.

Figure 3 provides an example of alert threshold bins for detecting abnormal levels of hydrogen.

The alert thresholds are generated based on the statistics from the fingerprint of historic heats. A dynamic model based on a moving window of historic heats continuously updates the alert thresholds on a heat by heat basis to account for changes in the process, scrap mix and seasonal variations. The size of the moving window can also be adjusted to influence the sensitivity of detecting abnormal water conditions. A smaller window of heats will improve the sensitivity of change, but will also generate more false alerts on every instance a change in the level of water is detected. A larger window will decrease the sensitivity to change over the given number of heats and reduce the occurrence of false alerts.

For operations with significant process changes, a larger moving window can be suggested and the sensitivity can be further improved for these types of operation by segregating the different operations into identifiable practices. This information can then be used to automatically call up different water detection alert thresholds for the identified practice.

Tiered alerting levels to indicate the probability of an actual abnormal water event are also provided. The tiered alerting provides three levels of alerts (low, medium, high) based on the duration of the heat or charge in an alert condition (cumulative alerting of both H₂ and H₂/CO metrics). The user has the ability to define the duration as a percentage of power-on time to trigger a medium and high level alert. The low level alert condition is triggered on the occurrence of an alert condition greater than the minimum wait time (in seconds) to alert.

The configuration of the tiered alerting allows the plant to decide on the appropriate action to be taken in response to the alert level and furnace operating conditions. Alerts triggered for known abnormal water events such as rain water or snow contained in the charge can be explained and, as such, the operator response can be more conservative. Whereas consecutive abnormal water alerts triggered for each charge or heat without explanation may prompt a more serious response to stop and investigate for possible leaks.

The system has the ability to discount heats within the moving window that will not be incorporated into the dynamic model for alert threshold generation. This feature is critical in the event of an actual water leak, in which case the user would not require the dynamic model to adjust alert thresholds to higher values. The trigger to discount heats is based on operator input on the EFSOP® HMI as shown in Figure 4 as ‘Click to Confirm’ green buttons on the bottom right of the image.

Preliminary results The technology was tested via controlled water injection trials through the slag door. Approximately 50l/min of water was injected as soon as possible after startup. Due to slag exiting, the furnace at the end of charges and refining, trials were only conducted in the first and second charges and water injection into the furnace was stopped before the end of the charge. The algorithm was able to distinguish the charges with water injection from those without by means of an increased alert on time.

Figure 5 shows the off-gas analysis trend for H₂% in two different charges, the setpoints for H₂% in both charges, and the period in which water was injected via the slag door. The dark blue line H₂ SP indicates the H₂% dynamic setpoint that was calculated by the system, whereas the light blue line indicates the actual H₂% read by the off-gas analysis system in that specific charge. It should be noted that in the later part of the first charge, where flat bath conditions exist, the current value is often over the H₂% setpoint line. In this case the alert for H₂% was triggered continuously during the flat bath conditions.

Similarly, Figure 6 shows the results of the water injection trial when analysing for H₂/CO. The H₂/CO generated setpoint is indicated by the blue line and the calculated real time H₂/CO value for the heat is indicated by the purple line. During flat bath conditions when the water was being injected through the slag door, the H₂/CO alert was being triggered continuously. These trials were repeated in multiple heats with similar results.

In related trials, additional water was also injected into the furnace by increasing the flow of electrode spray water from the normal amount of 30l/min to 60l/min. In most heats an increased alert on time was noted.

Following the slag door water detection trials, a water leak occurred in the furnace and the heat number was noted by the operator. Further analysis of the data revealed that the alerting increased significantly two heats before the operator noted the leak was present. Due to the fact that the water detection alerts were not online for the operator to use, it cannot be 100% certain that the system detected the leak in real time, but it is highly likely that the system accurately detected the water leak.

CONCLUSIONS

The use of EFSOP® resulted in an overall reduction in consumption costs, especially methane and electrical consumptions, more efficient post-combustion and hence a more efficient furnace operation. The Water Detection Technology™ was tested via controlled water injection...
trials through the slag door and increased electrode spray water trials. The technology was able to distinguish charges with water injection from those without. As a result of the position results from the trials, the system is currently being tuned to understand the false alert rates before being implemented by the plant for online, real-time abnormal water event detection.

ACKNOWLEDGEMENTS
The authors would like to thank the maintenance, operators and production personnel at Ferriera Valsabbia for their support during the optimisation and water detection testing phase. In particular to Franco Fusi for providing maintenance to the system and for his help during water trials. 

Nadia Boin and Armando Vazquez are with Tenova Goodfellow Inc., Mississauga, Canada. Pierluca Levrangi is with Ferriera Valsabbia S.p.A. Brescia, Italy.

CONTACTS: goodfellow@ca.tenovagroup.com
LLevrangi@ferriera-valsabbia.com

This paper is based on a presentation to CONAC 2010, 4th Steel Industry Conference & Exposition, Oct 2010, Centro Convex, Monterrey, NL, Mexico

Additional information about the Tenova Goodfellow EFSOP® system can be found in other technical papers below.

REFERENCES