Achieving EAF environmental and process synergy with Tenova Technologies

Technologies and tools exist that can achieve synergy between the EAF process and reduced environmental impact. The important principle is to combine all technologies into a single operating system and ensure balanced production operations. By using Tenova’s proprietary EFSOP® as the cornerstone for process optimisation, steelmakers can be confident of achieving improved total business performance through increased production, lower conversion costs and improved process efficiency, as well as reduced environmental impact.

We can say with confidence that an Electric Arc Furnace (EAF) is much more environmentally friendly today than in the past, however, in many cases, we are still far from reaching total synergy between the process and the environment.

Historically, the two main parameters for steel production were speed (tonnes) and related cost (the bottom line $/t). During periods of strong economic growth, the focus was on achieving the main financial gains through increased output. However, during economic downtimes, the focus shifts to the bottom line with more emphasis being placed on process optimisation and overall efficiency.

Environmental concerns gained much strength in the late 1980s and early 1990s and today are treated with equal importance to the others. For example, if environmental parameters are not satisfactory, plants can be fined and production halted, so directly impacting the bottom line. Initially, the key concerns for achieving stricter environmental compliance were related to:

- Meltdown visual opacity of fumes (outdoor), typically related to EAF charging, melting and tapping and influenced by meltdown openings or poor fume control systems.
- Shorter furnace Power-ON time cycle (indoor), typically related to more efficient chemical packages and poor fume control systems.

The focus was clearly put on fume control systems to solve environmental issues, yet furnace-related equipment and plant practices were still not directly related to the environmental issues. Therefore, as long as there were no environmental emergencies, the furnace was always pushed as hard as possible to achieve faster production, even though this created greater environmental impact.

Around the year 2000, advanced chemical packages added significantly to improved production methods and changed completely the required design parameters for the fume control system. This was supposed to trigger a complete revamp of the fume control system to match the worst cases, but typically these improvements were much delayed or only minimum steps were taken.

In some cases where the fume control system did not match furnace capacity, the potential solution to minimise fume issues was to strictly optimise the furnace practice to match capacity of the existing fume control system.

Many successfully completed projects confirmed that the best optimisation scenario for production efficiency ($/t) is also the best scenario related to the environmental...
Reducing energy loss, overdraft and related emissions is directly related to a reduction in environmental issues. Due to a slowing economy over the past 5-10 years, production capacity became slightly less important than efficiency optimisation, and dynamic controls and flexibility issues gained significant importance, which was also directly related to the environmental parameter improvements.

As a global leader in EAF process control, Tenova has developed proprietary technologies such as EFSOP® and iEAF® to provide a clear path for achieving and maintaining the synergy balance between the EAF and the environment. This is achieved through use of more complete off-gas analysis and dynamic modules for greater chemical energy, melting and endpoint control. The key aspects of EFSOP® are shown in Figure 1.

**Table 1 EAF production and environmental benefits**

<table>
<thead>
<tr>
<th>Optimisation/Synergy Action Plan</th>
<th>Production &amp; S/t (Overall)</th>
<th>Environment Comments</th>
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</thead>
<tbody>
<tr>
<td><strong>Step 1 (Primary parameters)</strong></td>
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<td></td>
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<tr>
<td>kWh/tonLS</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>O₂ usage</td>
<td>Yes</td>
<td>Yes</td>
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<tr>
<td>Natural Gas usage</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Charged/Inoculated C usage</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Material additives, Oils usage</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Scrap usage</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Slag practice/composition</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Yield</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td><strong>Step 2 (Secondary parameters)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EAF Draft (off-gas) &amp; Quality</td>
<td>Yes</td>
<td>Yes</td>
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<tr>
<td>Furnace Geometry &amp; Openings</td>
<td>Yes</td>
<td>Yes</td>
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<tr>
<td>EAF exhaust/air intake ratio</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Electrode consumption</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Off-gas system maintenance</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Pump/Fan energy usage</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Filtering Efficiency/Condition</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Cooling Water usage</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

As an example, we can single out a secondary parameter like EAF exhaust vs air intake ratio and discuss its relationship. Figure 2 shows a typical North American operating scenario of the downstream (DS) oxygen.

**Fig 2 Typical uncontrolled O₂ profile in water cooled ductwork**
reading, calculating excess air and resulting importance to the EAF environmental synergy. In the case of excess air leakage, either as combustion air requirement or false air, this affects environmental issues in many ways. It is directly related to loss of exhaust and capture capacity, so causing either excess fugitive emissions or boosting requirements for a much larger baghouse system, including fans. This can significantly increase investment and operating cost. Also, indirectly it is related to the heat removing efficiency, increased maintenance and reduced equipment life expectancy due to higher than required exhaust volume, high abrasion and erosion. The resulting conditions are poor mixing and combustion efficiency, potential for dry quench, excess fugitive emissions, poor indoor air quality, poor heat transfer and higher energy usage.

EAF FUME CONTROL SYSTEM EQUIPMENT

The EAF is typically the main source of emissions in the meltshop and is served by a dedicated fume control system. Depending on the layout and process specifics, fume control systems can have different elements, but typically consist of:

- Primary (4th hole) system (roof elbow, combustion chamber/drop out box, water cooled duct, spray chamber or radiant cooler, dry ductwork, and flow control damper),
- Secondary system (canopy hood, dry ductwork and flow control damper),
- Combined system (mixing chamber and baghouse system with fans, either positive or negative pressure type).

Figure 3 shows the typical EAF fume control system elements. Each element is directly related to the environmental parameters, where design and operations could be optimised to achieve further synergy. However, as everything is related to the source of generation, the main focus should always be on the furnace.

EAF OPTIMISATION EXAMPLE

The fume control system starts at the furnace which is the
critical optimisation step to achieve the best environmental parameters. In order to allow appropriate optimisation, off-gas composition must be accurately and continuously measured.

Off-gas energy, as input for the fume control system design represents up to 70% of the total EAF energy loss. An optimised furnace would have less energy loss and smaller requirements for the fume control system. The typical off-gas composition is CO 25–40% and H2 15–20%, but occasional peaks could be larger. About 50% of off-gas energy consists of un-combusted CO and H2, but these values vary with the furnace draft efficiency, which is critical for environmentally friendly operations.

It is important to clearly understand that post combustion of CO to CO2 and H2 to H2O generates about four times more energy than the conversion of C to CO, which typically occurs in the furnace. This is a critical component of the fume control system design since it is used as an input for its design parameters. Figure 4 shows a typical off-gas energy profile.

The EAF typically operates under either oxidising or reducing conditions, but only balanced conditions between those two scenarios will generate full synergy with the environment (see Figure 5). Continuous off-gas composition measurements clearly indicate conditions inside the furnace and allow necessary adjustments to achieve a balance set point. However, it is critically important to fully understand the measurements and their related implications.

For example, in cases where the off-gas consists of low CO/H2 and high O2 levels, conditions are typically too oxidising. There are many possible causes, such as over-drafting the furnace with the fume control system or too large gaps.

If the off-gas contains high CO/H2 and low O2, conditions are typically too reducing so it is possible to have too much un-combusted CO and H2, causing high energy loss which could overwhelm the fume control system.

The fastest way to achieve EAF environmental synergy is with the use of off-gas composition readings to directly adjust operations with closed loop controls. This should be used in conjunction with slag composition analysis to determine the optimum operating points for each individual operation and each scrap mix type. Closed loop controls should work during EAF Power-ON time to optimise post combustion oxygen, natural gas usage, charged/injected carbon and lance oxygen, as well as to optimise EAF draft and fume evacuation with minimum energy loss.

The main goal, as shown in Figure 6, is to maintain a modestly reducing off-gas chemistry to maximise energy efficiency (C, natural gas, electricity and O2), maximise yield, minimise Power-ON and tap to tap times, minimise
refractory wear, electrode consumption and tap alloy additions.

A well-operated EAF will generate downstream benefits such as reduced energy loss and reduced requirements for the fume control system operation. This scenario would need a smaller fume control system, which is equivalent to savings and a more environmentally friendly operation.

In cases where the fume control system is under-designed, revamping could be possibly delayed or may not be required at all if the plant operation were optimised. In cases where the fume control system is large enough, EAF optimisation would allow further optimisation of the fume control system resulting in savings such as energy, maintenance and useful equipment life.

**EAF ENVIRONMENTAL TECHNOLOGIES**

There are many techniques and technologies today that could improve environmental conditions of typical EAF operations. In recent history, significant improvements occurred in relation to furnace practice, static and dynamic models, chemical packages, off-gas analysis and closed loop controls for various scrap compositions.

One of the most influential parameters for related environmental effects was found to be EAF dynamic draft. Overall process understanding, fume control system design and control improvements significantly benefited when computational fluid dynamics (CFD) modelling was used. Advances in computational power allowed full integration of CFD modelling in every aspect of the steel industry, with full understanding of issues and solutions, which directly promoted EAF process and environmental synergies.

For example, direct effects of EAF exhaust draft, gaps, slag door, injection lances, water leaks, etc, should always be fully evaluated, understood and optimised with use of effective CFD modelling. Examples of EAF temperature profile, injection and slag door effects are shown in Figure 7.

**OPTIMISATION EXAMPLES**

Two case study examples are shown below where the first step of EAF optimisation was achieved. Both projects occurred in Japanese steel plants, Kanto Steel and Topy Industries.

**Kanto steel**

Kanto Steel is part of the Kyoei Steel Group and was established in 1994, producing rebar and round bar products. The existing 86t EAF practice was reviewed and direct Step 1 parameters were optimised. The initial off-gas analysis review indicated both reducing and oxidising chemistry during melting/refining as shown in Figure 8.

High variability in off-gas conditions during melting phase required optimisation steps that include post-combustion adjustments, adjustment of oxygen and gas set points, modified main O2, O2 shroud and fuel set points for the burner to dynamically control injection. Therefore, the usage of chemical energy during the burner period was optimised to maximise efficiency, as illustrated in Figure 9.

Injected carbon analysis was also performed. Data analysis indicated an immediate increase in CO readings when injecting carbon via the door lance was in use, indicating poor penetration into the steel bath. Optimisation of the injection process included reducing the use of C injectors during intermediate charges unless high carbon in steel was desired, as well as increased use of wall carbon injectors during the defining phase.

Oxygen lancing optimisation included an increased
lance oxygen flow rate when intermediate scrap baskets were charged, in order to start the decarburisation process earlier, so releasing latent chemical energy and charging the subsequent basket faster. During the optimisation process, the EAF draft was reviewed and adjusted to minimise the overall draft and energy loss.

Results of optimisation are shown in *Figure 10*, indicating that both reduced energy consumption and improved yield were achieved, but with an increase in injected carbon.

Comparing before and after optimisation, the economic savings were in the range of $Yen200/t (~$CAN2.4/t), illustrating that this Step 1 EAF optimisation case was both financially and environmentally beneficial.

**Topy Industries Ltd**  The potential next improvement is Step 2 optimisation, which includes indirect parameters related to design and operations. The Topy Industries Ltd, Toyohashi 150t EAF plant produces general and asymmetric sections as well as deformed bar steel products for the domestic, North American and Asian markets. Topy Group is certified by ISO and committed to enviro-friendly operations. *Figure 11* shows examples of the off-gas composition before (top figures) and after optimisation (lower figures) as modelled, and as actually measured by the analyser in the off-gas system.

The achieved optimisation benefits are shown in *Figure 12*, leading to annual savings of $CAN1.5 million.

In summary, the results shown in these two Tenova EFSOP® projects are evidence that EAF operations, the bottom line and the environment were all positively impacted.

**CONCLUSIONS**

Technologies and tools exist that can achieve very good or, in some cases, the best possible synergy between the EAF process, design, operation and environment. The important principle and critical step is to combine all technologies into a single operating system and ensure balanced production operations. Unfortuately, in some cases due to recent the economic conditions and other obstacles in our industry, there is still a long way to go, although many of these obstacles could be overcome with further education about the issues and their inter-relationship.

By utilising EFSOP® as the cornerstone for EAF process optimisation, steelmakers can be confident of achieving benefits such as increased production, improved process efficiency and consistency, improved environmental conditions, improved flexibility for changing market conditions, lower conversion costs, better control of process variables, reduced risk of furnace control system explosions and deflagrations, as well as improved total business performance.

All environmental benefits start with EAF optimisation, but are fully achieved with tuning of the entire fume control system. There are many related environmental benefits that are typically not tracked, which include less off-gas volume to evacuate or filter, fewer dioxins/furans/mercury/VOCs, reduced requirements for prolonged post-combustion, less cooling water, less energy used in a baghouse system, less maintenance and prolonged equipment life.

A perfect synergy between EAF process and environment can be achieved only if all primary and secondary parameters directly or indirectly related to a specific furnace are recognised and optimised. **MIS**

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