Tenova TRGX regenerative and TRGSX self-regenerative flameless burners: The reliable technology for an immediate CO₂ footprint reduction through improved combustion efficiency

By Michele Roveda* and Davide Astesiano **

Introduction

The current discussion about energy transition and transformation of the steel industry into a climate-neutral sector by 2050 is mainly focused on the decarbonisation of steel production, where fossil raw materials and fuels contribute to the CO₂ direct emissions. In hot rolling processes, fossil feedstock is used as a fuel and it is responsible for the carbon footprint of final steel products from about 100 to 250 kgCO₂/tCS respectively for billets and plates.

In order to be in line with industry’s long-term vision and to contribute to the worldwide general targets of GHG emission reduction, it will be of fundamental importance to adopt a holistic approach that includes low carbon technologies for heating processes associated with the steelmaking downstream furnace operations.

The availability of green electricity is of course crucial to this end, both to reduce emissions and to produce green fuels such as hydrogen in order to replace fossil sources.

As green fuels are still not giving enough returns in terms of profitability besides hydrogen availability which remains still to be exploited, an immediate step towards decarbonisation can be considered in the new capital investment by adopting those technologies which assure the highest level of fuel efficiency which is mainly reached by increasing the combustion air temperature recovering the residual heat stored in the waste gases. These technical goals motivated Tenova, a leading developer and provider of sustainable solutions for the green transition of the metals industry, to develop the regenerative and self-regenerative burners which were released in early 2008. Since then more than 500 regenerative/self-regenerative burners have been installed at nine different industrial plants.

Tenova’s approach to being a valuable partner in providing sustainable solutions for end users is part of the continuous development strategy towards the next generation combustion systems: a comprehensive approach to sustainability providing the combustion system with hydrogen ready burners, smart equipment for a flexible operation obtained from the synergy between automation process control and AI platform based algorithms. The most recent Tenova SmartBurner platform installation represents the framework in which IoT solutions are leveraged in order to monitor and improve key performance indicators (KPIs) and key health indicators (KHI) of each single burner unit.

Technology assessment

There are several drivers that are considered during the assessment phase for a new installation or plant modernisation combustion system technology project. Ultimately, the selection of the combustion system is based on the key drivers of high product quality, minimum energy consumption, compliance with environmental regulations, and the achievement of minimum CAPEX.

Minimum energy consumption is normally synonymous with minimum OPEX.

Regenerative burners work in pairs (see Figure 1) with typical cycles of about 60 secs, and are controlled by automatic valves installed into the piping lines. They are able to preheat combustion air up to 1000 - 1150 °C for reheating process while for self-regenerative burners used in heat-treatment the air pre-heat is up to 750 °C. Considering the fixed furnace length, the regenerative systems are able to provide higher available heat to the process thus implying a productivity improvement of about 20 - 25%. This is particularly effective for plant modernisation where a significant increment of production rate can be achieved while minimising the impact of the revamping operations.

In the other hand, a regenerative furnace is 20-25% shorter in length than a conventional one and the higher available heat to the process implies reduced fuel consumption thus the carbon footprint is significantly reduced.

The regenerative burner combustion system are an immediate solution to reduce CO₂ emissions of about 10% compared to CO₂ emission rate of recuperative systems which is today the largest adopted technology on hot rolling mill and heat treatment lines. CO₂ emission drops immediately despite the high temperature in the flue gas which is suitable for clean fuels and mixtures having high hydrogen content. The effect of hydrogen is to reduce the flame length, higher intensity implying higher peak temperature which enhance the NOx formation reactions. For this reason, Tenova regenerative burners adopt flameless technology to reduce temperature peaks and reduce NOx emissions.

Tenova tradition on regenerative burners

Tenova has a long tradition in leading edge combustion technology and developed an interdisciplinary design process including Computation Fluid Dynamics (CFD) modeling (Figure 3), industrial scale test and industrial applications. The consolidated workflow (figure 2) allows Tenova to drastically reduce the time it takes to develop new burners and combustion systems for the market. Experimental tests are also focused on providing reliable and high endurance equipment, which are of paramount importance to assure combustion performances. In fact, the high combustion air temperature reached inside the regenerator requires a precise design and material selection for the internal refractory lining. Similarly, the automatic valves and field equipment to properly control the cycling operations between the two subsequent working modes (flame-regeneration) have to provide top operating and long lasting performances keeping into consideration the extremely high amount of manoeuvres which are required during the burner lifetime.

Subsequent to the laboratory tests, the test campaign on full sized industrial furnaces was done from 2008 to 2010 by replacing some burner units on existing recuperative type furnaces. Two different types of regenerative media for combustion air have been assessed: honeycomb type and ball type. The honeycomb is suitable for clean fuels and clean furnace chamber atmospheres while the latter can be adopted where dust and gases contamination is present.

While TRGX are used in reheating furnaces, for heat treatment furnaces Tenova has developed, in 2012, TRGSX self-regenerative flameless burners. These burners adopt the
same concepts of the regenerative type provided that a double set of regeneration media is installed on the unique burner so the regeneration of one set of media is done in the burner while the burner itself is firing using pre-heated air from the second set of regenerative media. This allows the burner to always be in operation with the drawback of an increased complexity of the burner system.

The portfolio was enlarged in 2015 by the double regenerative burner, TRGD, which is able to preheat both air and gas by using two different regenerators. The TRGD are suitable for the application where the gaseous fuel has a low net heating value as for example Blast Furnace Gases where increasing the flame temperature is necessary. It is important to underline that the burners are able to work with BFG starting from cold conditions assuming extremely low CO emissions.

Smart packages and hydrogen ready burners
Considering the complexity of the regenerative system, for maintaining burner performances at nominal levels throughout its life, in recent years Tenova has introduced the concept of SmartBurner where the burner status is monitored, controlled and integrated with the furnace process parameters.

The SmartBurner IIoT framework offers a complete set of process diagnostics, KPIs and KHIs that allow controlling the status of important process burner parameters (i.e combustion ratio, leakage of switching valves, combustion quality) and carrying out easier burner inspection and maintenance interventions.

Process performance measures and health status of single critical components can be continuously monitored with the final aim to simplify and support any personnel intervention on field.

The recent development program relates to the optimisation of regenerative burners powered with hydrogen or with natural gas and hydrogen mixtures.

The flexibility of the hydrogen ready burners permits to maximise the consumption of the available amount of hydrogen on Customer plants through the possibility to work with variable mixtures of NG and H₂.

The optimised hydrogen flameless combustion allows maintaining NOₓ emissions always below the future stringent limits (< 80 mg/Nm³) in combination with a potential carbon free quantity of waste gases.

Operation results
Since the first industrial installation of a whole furnace combustion system made by regenerative technology in 2009 till 2019 more than 600 Tenova TRGX regenerative and TRGSX self-regenerative flameless burners units have been put in operation contributing to an approximately reduction of 250,000 tons of CO₂ as summarised in the Table 1 and Table 2.

**Conclusions**

Many well-known potential drawbacks (cost, complexity, control) that affect implementation of regenerative burner technology, are now being overcome by Tenova, with specific technological solutions, such as flameless technology, correct material choice, burner design, control strategy, and overall furnace design, from knowhow derived from more than 40 years’ experience.

Tenova regenerative flameless burners combine the lowest NOₓ emission level with high temperature combustion air preheating, which allows an important reduction of CO₂ emissions through high combustion efficiency. Hence the sustainability of the steel plant can be immediately improved even for those sites where green hydrogen is not available yet, keeping into consideration that the Tenova burners are hydrogen ready so whenever hydrogen will be available a further step towards carbon neutrality can be taken without any modification to the burner.

<table>
<thead>
<tr>
<th>Customer</th>
<th>Country</th>
<th>Year</th>
<th>Furnace type</th>
<th>Fuel</th>
<th>Burners</th>
<th>Regen.</th>
<th>CO₂ saved</th>
</tr>
</thead>
<tbody>
<tr>
<td>Customer F</td>
<td>India</td>
<td>2019</td>
<td>WBF 30t/h</td>
<td>NG</td>
<td>#20 TRG12</td>
<td>HC</td>
<td>N.A.</td>
</tr>
<tr>
<td>Customer E</td>
<td>Germany</td>
<td>2016</td>
<td>WBF 360 t/h</td>
<td>NG</td>
<td>#14 TRGX22 #6 TRGX18 #8 TRGX 16</td>
<td>B</td>
<td>&gt; 25,000 tons</td>
</tr>
<tr>
<td>Customer D</td>
<td>TX (USA)</td>
<td>2014</td>
<td>RHF 170 t/h</td>
<td>NG</td>
<td>#38 TRGX16 #8 TRGX14 #8 TRGX12 #8 TRGX10</td>
<td>B</td>
<td>&gt; 30,000 tons</td>
</tr>
<tr>
<td>Customer C</td>
<td>PA (USA)</td>
<td>2012</td>
<td>#4 Car Bottom Furnaces</td>
<td>NG</td>
<td>#32 TRG12</td>
<td>HC</td>
<td>&gt; 25,000 tons</td>
</tr>
<tr>
<td>Customer B</td>
<td>Italy</td>
<td>2010</td>
<td>RHF 220 t/h</td>
<td>NG</td>
<td>#35 TRGX16 #20 TRGX14</td>
<td>B</td>
<td>&gt; 60,000 tons</td>
</tr>
<tr>
<td>Customer A</td>
<td>CA (USA)</td>
<td>2009</td>
<td>WBF 270t/h</td>
<td>NG</td>
<td>#16 TRGX20 #16 TRGX14</td>
<td>B</td>
<td>&gt; 90,000 tons</td>
</tr>
</tbody>
</table>

Table 1. Operating results TRGX regenerative burner - HC = Honeycomb Type Regenerator B = Ball Type Regenerator

<table>
<thead>
<tr>
<th>Customer</th>
<th>Country</th>
<th>Year</th>
<th>Furnace type</th>
<th>Fuel</th>
<th>Burners</th>
<th>Regen.</th>
<th>CO₂ saved</th>
</tr>
</thead>
<tbody>
<tr>
<td>Customer C</td>
<td>TX (USA)</td>
<td>2013</td>
<td>Heat-treatment Line</td>
<td>NG</td>
<td>#80 TRG52 #60 TRG54 #60 TRG56</td>
<td>SR-HC</td>
<td>&gt; 11,000 tons</td>
</tr>
<tr>
<td>Customer B</td>
<td>Mexico</td>
<td>2013</td>
<td>Heat-treatment Line</td>
<td>NG</td>
<td>#22 TRG52 #40 TRG54 #40 TRG56 #20 TRG58</td>
<td>SR-HC</td>
<td>&gt; 8,500 tons</td>
</tr>
<tr>
<td>Customer A</td>
<td>Mexico</td>
<td>2013</td>
<td>Heat-treatment Line</td>
<td>NG</td>
<td>#20 TRG52 #40 TRG54 #20 TRG56</td>
<td>SR-HC</td>
<td>&gt; 5,000 tons</td>
</tr>
</tbody>
</table>

Table 2. Operating results TRGS self-regenerative burner HC = Honeycomb Type Regenerator