Advanced heat recovery for oxy-fuel fired glass furnaces

H Kobayashi et al present the latest developments in OPTIMELT Plus technology, which delivers advanced heat recovery for oxy-fuel fired glass furnaces.

The OPTIMELT thermochemical regenerator (TCR) process is an advanced heat recovery technology for oxy-fuel fired glass furnaces. It has been demonstrated in a 50 tonnes/day glass furnace at Pavisa since September 2014 and the system is in commercial operation.

A larger system will be installed at Libbey Glass, Leerdam, The Netherlands in 2017, partly funded by EU (LIFE15 CCM- NL-000121 - LIFE OPTIMELT). The technology utilises conventional regenerators and endothermic reforming reactions between fuel and recycled flue gas (RFG) to recover flue gas exhaust heat.

For a larger scale commercial furnace, expected fuel savings are about 30% compared to oxy-fuel and about 30% compared to air-regenerator furnaces.

The technology heats and reforms fuel and RFG mixture in a hot checker pack of the regenerator without catalysts or separate steam generation. H₂O and CO₂ in the oxy-fuel combustion flue gas are syngasically utilised as reactants. The syngas created from the reforming of the natural gas contains hydrogen, carbon monoxide and soot, which produces a highly luminous flame and transfers heat efficiently to the glass melt.

Regenerators are similar in design to conventional air heating regenerators but only one third the size in the checker volume due to the small flue gas volume of oxy-fuel combustion, making the retrofit or rebuild an economically attractive option, especially when the available space for a larger furnace is limited. The TCR system is integrated into the oxy-fuel combustion system and the furnace can be operated either in oxy-fuel firing or TCR firing mode. The transitions between oxy-fuel and TCR operation are fully automated in the PLC control.

**ADVANCED HEAT RECOVERY OPTIONS**

Current TCR design recovers about 80% of the sensible heat from furnace hot flue gas at about 1500°C and cools it to about 660°C. Cooled gas still contains about 40% of the flue gas sensible heat and additional heat recovery is possible by combining TCR with another heat recovery unit.

Two examples are shown schematically in figure 1. A cullet or batch preheater can be installed to preheat batch/cullet and to cool down the flue gas further from 660°C to a 200°C range. Fuel savings can increase to about 29% relative to the oxy-fuel baseline with this combination. A waste heat boiler can be installed to generate steam for power generation and as the reforming reactant, eliminating RFG. An organic flue gas cycle can also be used for power generation. Another option is to combine oxygen preheating using regenerators in parallel to TCR.

In table 1, calculated fuel savings for various combinations of heat recovery systems for generic 300 tonnes/day oxy-fuel fired container glass furnaces are summarised. TCR saves about 20% of the fuel consumption of the baseline oxy-fuel furnace. When oxygen heating regenerators are combined with TCR, the fuel savings increase to about 25%.

By combining a cullet preheater with TCR, fuel savings as high as 29% are possible. However, the value of additional fuel savings have to be compared to the incremental capital investment required to determine the most economic and practical option. Based on cost-benefit considerations and commercial operating and maintenance experience, the combined TCR-O₂ regenerators and the combined TCR-cullet preheater systems were selected as most economic options for additional fuel savings in the analysis.

The dual TCR and O₂ regenerator system, termed OPTIMELT Plus technology, was chosen for detailed engineering and economic analysis of a 240 tonnes/day oxy-fuel fired container furnace. A second set of regenerators arranged in parallel to the TCR regenerators is used to accomplish the oxygen preheat to about 2200°F (1200°C).

Since the total flue gas flow rate is reduced by the additional fuel savings and the flue gas is split into two chambers, the combined checker volume of the TCR and O₂ preheating chambers becomes about 5%-10% smaller, which makes the additional capital cost of this combined heat recovery system relatively small as compared with the baseline TCR system. A simplified process sketch is shown in figure 2. Both hot syngas and hot oxygen are

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**Figure 1:** Combined heat recovery options for oxy-fuel furnaces.

**Table 1:** Calculated fuel savings with heat recovery systems for a 300 tonnes/day container glass furnace.

<table>
<thead>
<tr>
<th>Case</th>
<th>Heat recovery system</th>
<th>Fuel savings (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Oxygen</td>
<td>21</td>
</tr>
<tr>
<td>2</td>
<td>OPTIMELT Thermochemical Regenerator (TCR)</td>
<td>31</td>
</tr>
<tr>
<td>3</td>
<td>OPTIMELT Plus (dual TCR, O₂ regenerator)</td>
<td>25</td>
</tr>
<tr>
<td>4</td>
<td>OPTIMELT TCR + cullet</td>
<td>14</td>
</tr>
<tr>
<td>5</td>
<td>O₂ regenerator (100% O₂ purity, PH temp 1200°C)</td>
<td>11</td>
</tr>
<tr>
<td>6</td>
<td>O₂ regenerator + cullet</td>
<td>17</td>
</tr>
<tr>
<td>7</td>
<td>O₂ regenerator + batch cullet</td>
<td>22</td>
</tr>
</tbody>
</table>

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**Figure 2:** OPTIMELT Plus regenerative heat recovery for oxy-fuel furnaces.

**Table 2:** Example comparison of the two OPTIMELT heat recovery technologies.

<table>
<thead>
<tr>
<th>Oxy-fuel baseline</th>
<th>OPTIMELT TCR</th>
<th>OPTIMELT Plus</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel input</td>
<td>4</td>
<td>3.2</td>
</tr>
<tr>
<td>Soot emissions</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Fuel savings</td>
<td>2.8</td>
<td>2.6</td>
</tr>
<tr>
<td>Run gas temperature</td>
<td>1200°C</td>
<td>1200°C</td>
</tr>
<tr>
<td>NG (CH₄)</td>
<td>1200°C</td>
<td>1200°C</td>
</tr>
</tbody>
</table>
FLAME DESIGN CONSIDERATIONS

The hot oxygen and syngas have relatively low velocity when they enter the furnace through the ports. The OPTIMELT technology makes use of a special burner design feature to produce desirable long flame shapes. An example of CFD simulation for the syngas-hot oxygen flame is presented in figure 3 on the temperature contours in a 240 tonnes/day furnace. Both syngas and oxygen enter the furnace at about 2200°F (1200°C) from two separate ports, mix inside the furnace and form a long flame that shows the desired U-shaped profile.

SUMMARY

Praxair is developing an advanced heat recovery technology, OPTIMELT Plus. In addition to recovering energy through reforming of natural gas to syngas, this technology preheats the oxygen to improve energy recovery by an additional 5% to a total of 25% compared with the oxy-fuel furnace and 36% when compared to a typical air regenerative furnace. Preliminary engineering and costing for a 240 tonnes/day end-port furnace is complete.

ABOUT THE AUTHORS:

H Kobayashi is Corporate Fellow and J de Diego is European Manager Combustion Market Applications at Praxair. Their Praxair colleagues J Vetter, J Pedel, S Laux, R Bell, A Francis and K T Wu also contributed to this presentation.

FURTHER INFORMATION:

Praxair Inc, Danbury, CT, USA
Tel: +1 203 837 2652 / +34 609848813
Email: Sho_kobayashi@praxair.com / Joaquin_de_Diego@praxair.com
Web: www.praxair.com

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