Reducing energy consumption and CO_2 in fibreglass furnaces

Shrikar Chakravarti, Hisashi Kobayashi and Sireesha Aluri discuss heat recovery technologies for composite and insulation fibreglass furnaces offered by industrial gas and engineering company, Linde.

Process industries – refineries, steel mills, cement kilns and glass furnaces are looking for ways to substantially reduce CO_2 emissions from their operations. As part of the Science Based Targets initiative [the partnership between CDP, the United Nations Global Compact, World Resources Institute and the World Wide Fund for Nature that encourages companies to reduce emissions in line with the Paris Agreement goals], several glass companies have made commitments to sizeable reduction in CO_2 emissions by 2030[1].

Converting air-fuel furnaces to oxy-fuel furnaces with heat recovery provides an expedited and economical means to meeting all or a significant portion of the CO_2 reduction objectives. Oxy-fuel technology is commercially proven with over three hundred glass melting furnaces operating in this mode[2]. Flue gas typically exits the oxy-fuel soda lime silica glass furnaces at 1400–1500°C. With flue gas heat recovery, fuel consumption is estimated to decrease by 20–30% with a corresponding reduction in CO_2 emissions from fuel. Prior work has generally focused on soda lime silica glass – container and tableware.

This article focuses on fibreglass furnaces and discusses two commercially proven heat recovery technologies, offered by Linde, under the OPTIMELT trademark:

1. Thermo-chemical Regenerator Systems (TCR) for composite fibreglass furnaces.
2. Cullet Preheating (through an exclusive arrangement with Johansson Industries) for insulation fibreglass furnaces.

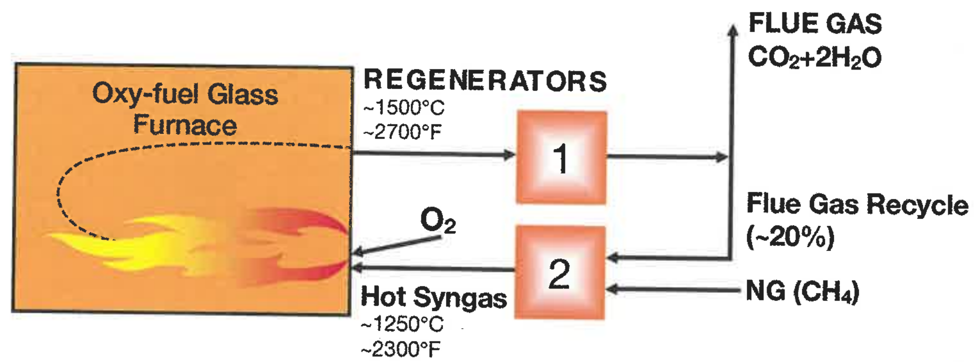

Figure 1: Schematic representation of Linde's OPTIMELT TCR process

Thermo-chemical Regenerator System Technology

Linde's OPTIMELT Thermo-chemical Regenerator (TCR) process is an advanced heat recovery technology for oxy fuel fired glass furnaces[3,4]. The technology is based on a unique waste heat recovery concept called thermo-chemical regeneration, in which heat stored in a regenerator checker during the flue gas exhausting cycle is recovered during the reforming cycle by preheating and reforming a mixture of natural gas and recycled flue gas. Figure 1 shows this cyclic heat recovery process.

The flue gas cycle in regenerator 1 is similar to the conventional regenerator heating cycle in which flue gas waste heat is transferred to and stored in the checker. The unique feature of the TCR process occurs during the reforming cycle where a portion of the cooled flue gas is recycled (Recycled Flue Gas or RFG) to the bottom of an already preheated regenerator (regenerator 2) and mixed with natural gas (NG) fuel. When the gas mixture is heated above a certain temperature, CH_4 is non-catalytically reformed by CO_2 and H_2O in the RFG to form H_2, CO and soot. The reformed gas or 'syngas' is combusted with oxygen in the glass furnace, thus providing thermal energy for glass melting. When the regenerator in reforming mode is getting colder, the regenerators are switched and the regenerator that was previously in reforming mode is heated with flue gas.

Installation at Libbey Leerdam

Following successful commercialisation on a 50tpd container glass furnace in Mexico, the TCR system has been ▸

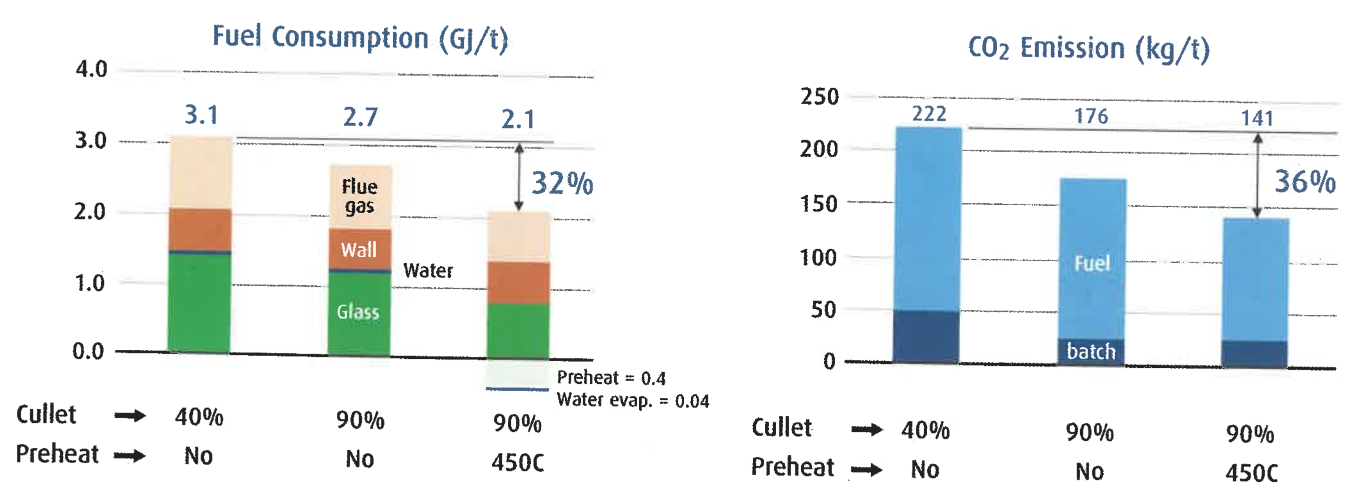

Figure 2: Impact of cullet preheating on 200tpd insulation fibreglass furnace.

Location	Pull Rate (t/d)	Year Installed	Glass	Cullet Ratio	Cullet Rate (t/d)
US	250	1997	Flint	50%	130
Europe	270	2014	Flint	50%	135
Europe	170	2015	Flint	80%	140
Europe	410	2016	Green/ Amber	75%	310
Europe	340	2017	Flint	70%	240

Table 1: List of commercial container glass references for cullet preheating from Linde and Johansson Industries.

in commercial operation on an oxy-fuel fired tableware glass furnace at Libbey Leerdam in the Netherlands since 2017[3,4]. TCR system operation commenced in late 2017. The three-year operating experience with the new furnace has reportedly been very positive; the TCR system has been in continuous operation meeting or exceeding Libbey's glass production and quality needs.

The regenerators are similar in design to conventional air heating regenerators and use similar materials, but the checker volume is only one-third to the size of the air-regen case.

Also, regenerators in air-fuel furnaces are prone to plugging due to formation of salt deposits in the checker channels. Alkali vapours in the flue gas such as NaOH and $NaBO_2$ react with SO_2 and oxygen upon cooling and form Na_2SO_4 (sodium sulphate) and other species, which condense and form liquid and solid deposits on heat exchanger surfaces. Even with periodic cleaning the plugging tendency remains, and heat recovery performance deteriorates significantly. However, with OPTIMELT thermochemical regenerators little deposit accumulation has been observed after multiple years of operation at Pavisa and Libbey. Recent inspection of regenerator refractory at Libbey's L1 furnace showed no degradation of the material due to reducing conditions that are present during the reforming cycle. In fact, these conditions seem to have a positive effect. Sodium sulphate deposited during the heating cycle is being vaporised during the reforming cycle. Evaporation rate of Na_2SO_4 was determined to be faster than its deposition rate under simulated regenerator conditions[5].

This 'self-cleaning' mechanism offers the long-term potential of lower maintenance requirements relative to conventional regenerators. This property should also facilitate the adoption of OPTIMELT TCR systems with fibreglass furnaces that tend to have higher levels of volatile species. Specifically, the TCR system could be an excellent fit for furnaces producing composite fibreglass, with or without boron. The TCR technology recovers energy from the flue gas. Since composite fibreglass furnaces typically operate at temperatures 50–100°C higher than soda lime silica furnaces, there is more energy in the flue gas available for recovery. For large soda lime silica glass furnaces, e.g. >300tpd, a TCR system reduces NG consumption by 18% vs an oxy-fuel system with no heat recovery. However, for composite fibreglass, preliminary calculations suggest that the NG savings on even smaller fibreglass furnaces, 200tpd, could be 18% vs oxy-fuel furnaces.

Cullet preheating

The cullet preheating system from Johansson Industries and Linde is designed to preheat cullet by direct contact with furnace gases, ensuring high heat transfer rates and high material preheat temperatures in the range of 400–450°C[6]. The preheated cullet is mixed with the batch directly above the charger, so normal furnace charging operations are maintained with little heat loss. Equipment size, cost and performance are significantly better with this approach versus indirect heat transfer. Long term reliability of these cullet preheaters is also well proven (see Table 1 for list of references[7]).

Besides the obvious fuel and oxygen savings to the furnace, another key benefit of this technology is the ability to handle post-consumer recycled cullet. Organic contaminants, e.g. paper, food residue, plastic, are pyrolysed and the fume is fully oxidised in the flue duct. This reduces the net carbon content of the cullet entering the furnace allowing for more stable glass redox control as well as no odour issues from the organic contaminants in the cullet[6].

Recently insulation fibreglass furnaces appear to be increasing cullet input[8]. The source of the cullet is mainly soda lime silica glass. The CPH technology, which has already been proven for soda lime silica, could be deployed in insulation fibreglass furnaces as well.

As shown in Figure 2, it may be possible to achieve greater than 30% reduction in fuel and oxygen consumption and CO_2 emissions by combining high cullet operation and cullet preheating under oxy-fuel firing.

Summary

This article discusses the potential of two commercially proven heat recovery technologies in the context of fibreglass furnaces. Depending on the project specifics, e.g. fuel prices, cullet rate, internal vs post-consumer recycled cullet, CO_2 avoidance costs and capital constraints, Linde can work with fibreglass furnace operators to cost-effectively achieve the near-term goal of 20–30% reduction in CO_2 emissions. Taking this step will also make the glass furnaces future-ready when low/zero carbon fuels like green H_2 become more economically viable. ●

References

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