State-of-the-art oxyfuel solutions for reheating and annealing furnaces in steel industry

Axel Scherello[1], Werner Högner[2], Erik Claesson[3], Pete Bamforth[4] and Christophe Mercier[5]

[1]Gaswärme-Institut e. V., Hafenstr. 101, 45356 Essen, Germany
[2]ThyssenKrupp Steel AG, Kaiser-Wilhelm-Str. 100, 47166 Duisburg, Germany,
[3]Ovako Steel AB, SE-813 82 Hofors, Sweden
[4]Outokumpu Stainless AB, SE-644 80 Torshälla, Nyby, Sweden
[5]Ascométal S.A., B.P. 40030, 13771 Fos-sur-Mer, France

Summary

This paper presents an overview of oxyfuel techniques with special attention to the payback of oxyfuel implementation projects. To evaluate the possibilities and the advantages of oxyfuel solutions in steel reheating and annealing, Gaswärme-Institut (GWI) has acquired information from installations in a number of European countries. Thus it also includes practical experiences from plant operating teams. Important parameters for the economics here are: higher heating rates for more furnace throughput and flexibility, lowered specific fuel consumption, pollutant formation, product temperature homogeneity, installation cost, maintenance reduction, and cost of industrial grade oxygen.

Among the oxyfuel techniques in this context, in addition to flameless oxyfuel combustion, another interesting solution is the so-called direct flame impingement, already in use for steel strip heating. The paper ends with an outlook to future aspects of oxyfuel utilisation for reheating and annealing furnaces in steel industry.

Key words: Oxyfuel, flameless combustion, direct flame impingement, thermal efficiency improvement, scale reduction,

1. Introduction

Process improvement of reheating and annealing furnaces in the steel industry is based on both energy and production costs savings and at the same time observing product quality standards. Therefore in the past waste heat recovery methods were realised in order to increase the utilisation of the fuels energy content. Methods such as self recuperative burners and regenerative combustion are established.

In contrast to these methods there exists the possibility to minimize the flue gas losses using pure oxygen as an oxidator. Without the combustion air nitrogen content the efficiency of oxyfuel combustions is already as high as 72 % without heat recovery methods [1].

Due to the fact that the maximum flame temperature of oxyfuel combustion is higher than using air the misleading assumption might be that damages at the product may occur. Another misconception regarding oxyfuel is that scale formation is increased based on the assumption that the oxygen partial pressure is raised.

Based on modern combustion principles these prejudices can be cleared. Due to the high stirring rates and the internal recirculation of flue gases temperature peaks can be avoided if advanced burner techniques – such as flameless oxyfuel – are applied. At the same time the free oxygen content inside the flames can be reduced to moderate levels. Furthermore it is proven that scale formation is dependent on the residence time and the temperature level [2]. Due to the more effective heat transfer of oxyfuel flames, which is based on the absence of the diluting nitrogen content of combustion air, shorter throughput times and therefore decreased scale formation levels can be reached.

In addition steel production is a complex combination of several process steps which have to be combined with each other, such as steel making, hot rolling, annealing, galvanizing etc. Due to the higher flexibility when it comes to a change of process parameters using oxyfuel combustion is advantageous towards airfuel systems.

Besides these benefits of using oxygen instead of air it has not to be neglected that oxygen has to be produced first. The savings resulting from improved process parameters, such as production capacity and flexibility, scale formation, heating rates, energy consumption and reduced emissions (CO_2 and NO_x), have to be advantageous in comparison with the oxygen costs. In addition airfuel combustion together with heat recovery methods needs bigger and insulated air/exhaust gas ducts. Together with the heat exchangers the capital investment and maintenance costs in the airfuel case are larger compared with an oxyfuel application.

The following sections will describe some examples of oxyfuel applications. Advantages and disadvantages were listed and evaluated regarding production flexibility, energy consumption and product quality. The evaluation includes the experiences of the plant operators.

2. Soaking pit furnaces

At Ovako Steel works in Hofors, Sweden high quality steels are produced with in electric arc furnaces. To reheat the caste ingots prior to the downstream billet production soaking pit furnaces are used to reach a proper ingot rolling temperature.

The demands for these reheating furnaces can be described as follows. The operation needs a huge flexibility due to the capacity shifting position between steel production and ingot rolling. Depending on different situations high reheating ranges are required if large capacities at the downstream processes (billet rolling and tube production) are needed. On the other side low energy consumption during stand by periods has to be realised. These criteria have to be fulfilled parallel with a low scale formation rate in order to reach a good surface quality, which avoids unnecessary excessive grinding.

In 1994 Ovako first installed oxyfuel technology at four soaking pit furnaces [3]. Based on the operation experience in total 40 pit furnaces were converted to oxyfuel firing. In 2006 the remaining 8 pit furnaces were revamped from airfuel into flameless oxyfuel.

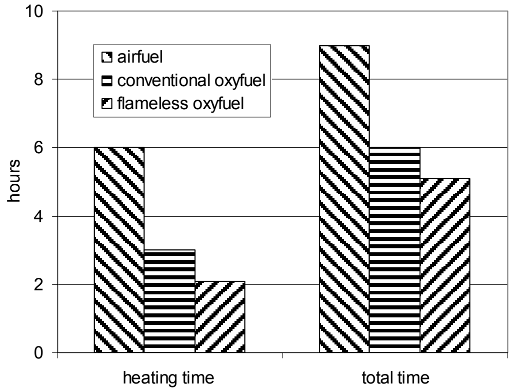

Figure 1: reheating times for different process paramerters

With the installation of oxyfuel in the pit furnaces at Ovako, the heating time was reduced from six to three hours (see **figure 1**). The more uniform heating of flameless oxyfuel has further reduced the heating time down to 2.1 hours. Total time, which includes soaking, has been reduced from nine to 5.1 hours with flameless oxyfuel.

Figure 2 shows an overview (left) and the flue gas system (right) for eight pit furnaces, which points out that the constructive amount for oxyfuel installations can be reduced to a minimum. Compared with airfuel combustion, where in addition recuperators and electrical ventilators were used, the investment costs for oxyfuel systems are decreased.

Figure 2: Ovako operates a total of 48 oxyfuel fired soaking pit furnaces (left). The compact exhaust system with chimney for two furnace batteries with 8 furnaces in total (left)

Ovako has achieved a remarkable increase in heating capacity coupled with a more than 30 % specific fuel consumption reduction. At the same time the amount of pollutant emissions – CO_2 and NO_x – was reduced. In addition the above listed operating demands were fulfilled.

The same situation exists at Ascometal, Fos-sur-Mer, France where also soaking pit furnaces are used to reheat ingots prior to rolling. Since the first flameless oxyfuel installation in 2004 they now benefit from 33 % shorter heating cycles, 40 % reduced specific fuel consumption and 40 % decreased NO_x emissions. At the same time uniform heating characteristics and less scale formation can be performed. Due to this only 9 instead of 13 furnaces deliver the same production rate which results in savings of energy costs, reduced maintenance and improved logistics [4].

In the both case for Ovako and Acometal the fast and effective oxyfuel heating process has improved the mill availability, enabling a higher throughput tonnage.

3. Rotary hearth furnaces

In order to reheat the billets prior to piercing Ovako, Hofors site is operating two rotary hearth furnaces (see **figure 3**) equipped with oxy fuel burners. The specific fuel consumption is 290 kWh/t for cold charged material, which is heated up to 1120 to 1270 °C. Compared to airfuel operation again higher throughputs, lower emission levels, decreased energy consumption and more uniform heating were reached. Until now oxyfuel burners with staged combustion are in operation. Ovako is now evaluating flameless oxyfuel combustion to see if a more uniform heating and even lower NO_x emissions can be realised.

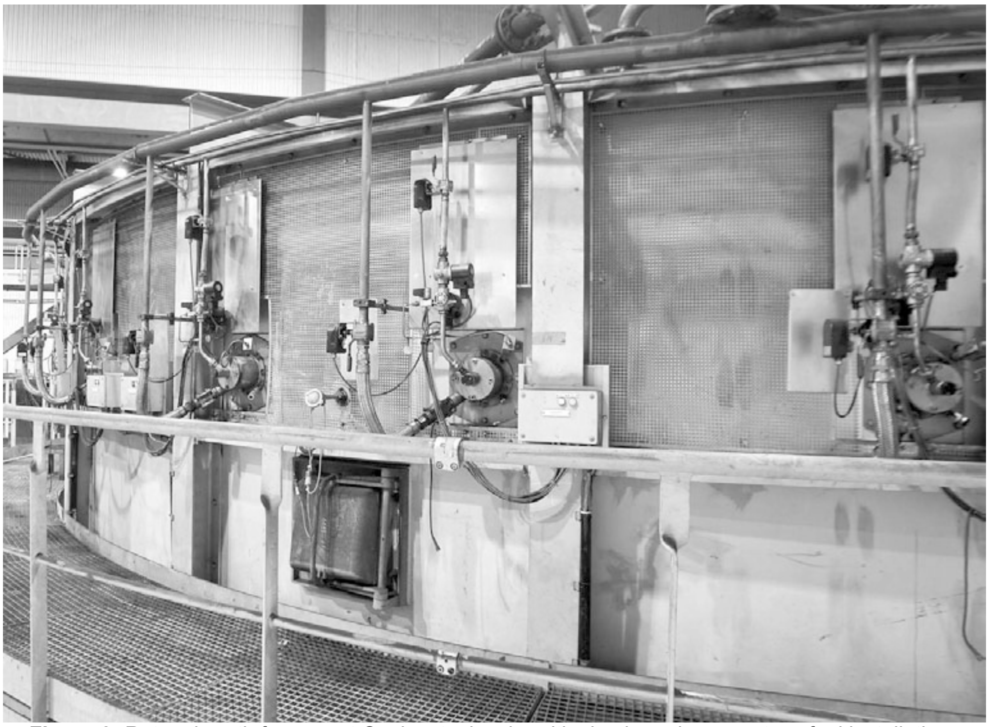

Figure 3: Rotary hearth furnace at Ovako steelworks with simple and compact oxyfuel installations

4. Stainless steel annealing

In order to reach increased production rates, to minimise fuel consumption and to meet stricter environmental legislation pollutant emission limits Outokumpu Stainless, Coil Products, Nyby plant (stainless steel strip production capacity 150.000 t/a), Sweden, converted the catenary furnace on the preparatory annealing line for hot rolled strips to oxyfuel firing.

The airfuel burners at this 18 meter furnace were exchanged with flameless oxyfuel burners, which produce high stirring rates of furnace atmospheres and at the same time increased heat transfer rates towards the product on a small level of NO_x formation. Using the same power input of 16 MW converting from airfuel to oxyfuel the heat transfer efficiency as well as the production capacity were increased. The throughput growth of about 55 % was realised without any geometry changes at the furnace whereas the NO_x emissions were kept below 70 mg/MJ. But not only emissions and capacity advantages were achieved. Also the flexibility was improved, in order to react on changes in capacity requirements. Outokumpu co-workers compared the differences resulting from the furnace modification with a modern turbo diesel engine in comparison with old fashion diesel car performance. In addition the remaining heat form the flue gas volume flow, which was reduced about 70 % compared with airfuel combustion, is extracted and used in a heat recovery system in order to produce hot water.

Within the finish annealing line at Nyby another catenary furnace is in operation. The complete change from airfuel to oxyfuel leads to a production capacity increase from 11 to 23 tons per hour. Due to the demand of additional capacity without the possibility of a furnace enlargement Outokumpu together with Linde installed the so called Direct Flame Impingement (DFI) technique at the furnace entrance side [5].

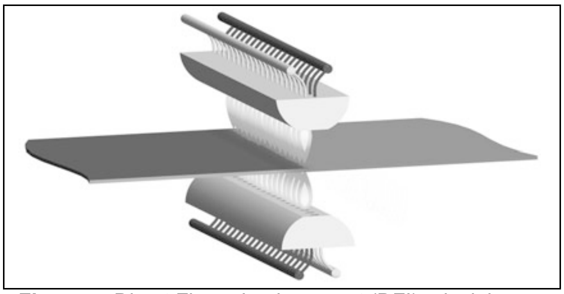

Figure 4: Direct Flame Impingement (DFI) principle

DFI is based on a large number of small oxyfuel burners which are positioned in rows close to the strip in order to realise oxyfuel flames that are directly impinging the strip. **Figure 4** shows the DFI principle which realises a distinct higher amount of heat transfer from the oxyfuel flames into the strip.

Figure 5: Compact DFI Unit at Outokumpu Nyby site

At the Outokumpu Nyby site a DFI oxyfuel unit containing 120 burner nozzles in 4 burner rows with a heat input of 4 MW was installed. Using this 1.8 m unit (see **figure 5**) not only an additional capacity increase of about 50 % but also an improved temperature control possibility was realised.

5. Carbon steel galvanising

In co-operation with Linde ThyssenKrupp Steel installed a DFI oxyfuel unit at the entry side of a reheating furnace in order to increase the galvanizing capacity of an existing production line at the Finnentrop works [6]. A total of 5 MW was installed in a DFI unit similar to that of Nyby. Tests have proven that at a production rate of 105 tons per hour a temperature increase of about 200 °C can be reached. Not only the increased throughput of about 30 % but also the compact design, that makes it possible to install DFI at the existing galvanizing line, is advantageous. In total the DFI oxyfuel unit saves energy and at the same time it allows to tune the necessary strip characteristics concerning surface properties and inner temperature distribution precisely.

The unit burns off residues, particles, grease and oil from the hot rolled strip, providing it cleaner than an existing 25 m long pre-cleaning section. By removing this section costs for maintenance and materials as well as electricity could be saved. Taking the capacity and quality advantages as well as energy savings together with reduced pre-cleaning costs into account, the oxygen supply costs are judged to be smaller.

6. Conclusion

The thermal efficiency of oxyfuel combustion is rather high. Therefore heat recovery systems are not necessarily required. This simplifies the heating system and minimises maintenance. Energy savings in combination with increased capacity, lower pollutant emissions and improved product quality are resulting in the statement, that an oxyfuel application is advantageous independent from the fuel used. Nevertheless the combination of combustion process knowledge and production experience is an important basis of a successful oxyfuel application.

7. References

[1] Scherello, A.: Self recuperative burners, Heat Processing – international magazine for industrial furnaces, heat treatment plants and equipment. Page 51 – 53, Issue 1, 2007.

[2] Adolfi,, J.; Ekman, T.; von Schéele, J. and Blasiak, W.: Scale formation and surface quality of carbon steel at oxyfuel heating. Steel Rolling, Paris 2006.

[3] Fredriksson, P.; Claesson, E.; Vesterberg, P.; Lugnet, A.; Ritzén, O.: Application of oxyfuel combustion in reheating at Ovako, Hofors works, Sweden – Background, solutions and results. Steel Rolling, Paris 2006.

[4] Vesterberg, P.; Moroz, G.: Flameless oxyfuel for highly visible results. AISTech 2006, Cleveland, Ohio, USA, 1-4 May 2006

[5] Ljungars, S.; Gartz, M.; von Scheele, J.: Boosting Heating Capacity Using New Technology. Nordic steel and mining review, 2004

[6] Eichelkraut, H.; Heiler, H.-J.; Högner, W.; Paul, R.; Ritzén, O.; Vesterberg, P.: DFI oxyfuel solution boost galvanizing capacity at ThyssenKrupp Steel. ATS/JSI 2006, Session 16, Galvanization, Paris, 14 - 15 December 2006.