Embracing hydrogen Flameless Oxyfuel for CO_2-free heating

Ovako's ambitious environmental targets led the Swedish company to move over to Linde's Flameless Oxyfuel solutions, including the innovative use of hydrogen as a fuel

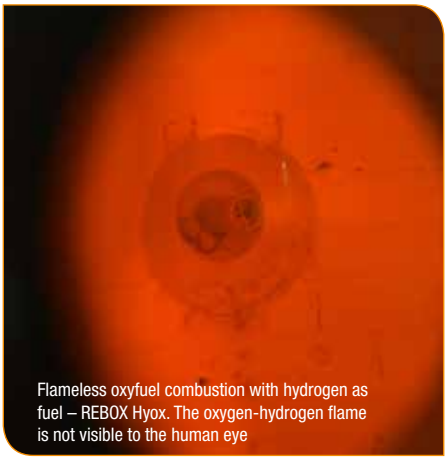
As the challenges of increasing use of energy and industrial pollution grow into one of the biggest issues of our time, the modernisation of industrial heating systems becomes increasingly important and a centre of attention. One known method to combat this problem, is the modification of the combustion system by using oxygen instead of air as the primary oxidiser. This technology, called Oxyfuel combustion, has been extensively investigated and gradually employed in industry. In general, it has the potential to substantially decrease both energy use and emissions. If we were to fully implement existing Oxyfuel technologies in the steel industry, the sector's total CO_2 emissions use could be decreased by more than 100 million tonnes annually.

Linde's experience of converting reheating furnaces into complete Oxyfuel operations, show energy savings ranging from 20% to 60%. It should be noted that the total energy saving is greater than simply reading a meter at the furnace. The energy needed to bring the natural gas, for example, to its use in the furnace is of course also saved. In the mid-1980s Linde began to equip the first furnaces with oxygen-enrichment systems. These systems increased the oxygen content of the combustion air to 23-24%. The results were encouraging as fuel consumption was reduced and the output, in terms of tonnes per hour, increased. In 1990 Linde converted the first furnace to operation with 100% oxygen, that is full Oxyfuel combustion, at Timken in the US. Today, the total number of installations exceed 170.

Flameless Oxyfuel

Increasingly stricter legislation on emissions led to the development of Flameless Oxyfuel. Linde introduced it for the first time in 2003 at Outokumpu, in continuous furnaces for strip annealing and slab reheating. The expression

Discharge of a steel slab from a 300t/h walking beam furnace after being uniformly heated using a Flameless Oxyfuel solution with natural gas as fuel, which in future could be partially or fully replaced by hydrogen



Flameless oxyfuel combustion with hydrogen as fuel – REBOX Hyox. The oxygen-hydrogen flame is not visible to the human eye

'Flameless combustion' communicates the visual aspect of the combustion type, that is, the flame is no longer seen or easily detectable by the human eye. Another description might be that the combustion is extended in time and space – it is spread out in large volumes, therefore it is sometimes referred to as 'volume combustion'. Such a flame has a uniform and lower temperature, practically the same temperature as air-fuel combustion, yet contains the same amount of energy as conventional Oxyfuel. In Flameless Oxyfuel the mixture of fuel and oxidant reacts uniformly through the reaction flame volume, with the rate controlled by partial pressures of reactants and their temperature. Fundamentally here, using burners or lances or a combination of the two, utilises velocity in a beneficial way whilst at same time separating the injection points of the fuel and the oxidant, leaving the traditional design of a burner in tact.

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In Flameless Oxyfuel, the combustion gases are effectively dispersed throughout the furnace, ensuring more effective and uniform heating of materials even with a limited number of burners installed. Although the first installations took place in reheating and annealing, Flameless Oxyfuel was quickly adopted for the preheating of ladles and converters where it has also demonstrated great results. The next area to be exploited, with substantial positive impact, could be the blast furnace hot stoves. Recently there has been an emphasis on the use of low calorific fuels, for example blast furnace top gas. Oxyfuel strongly supports the use of such low calorific gases.

Ovako's green journey

The Swedish industry has set ambitious environmental targets and there are several promising initiatives to reduce the emission of greenhouse gases within the steel industry. Most projects are focusing on replacing fossil coal and coke in the reduction of iron ore, which is the main source for CO_2 emissions in ore-based steel production.

Scrap-based steel producers focus on their processes that create CO_2 emissions, these are mainly melting in the electric arc furnace and heating before hot rolling and heat treatment. In addition, it is also considered critically important to focus on all upstream supplies in order to generate a full 'cradle to gate' perspective. To make beneficial environmental changes on a large scale, it is important that all participants in the value chain carry this perspective.

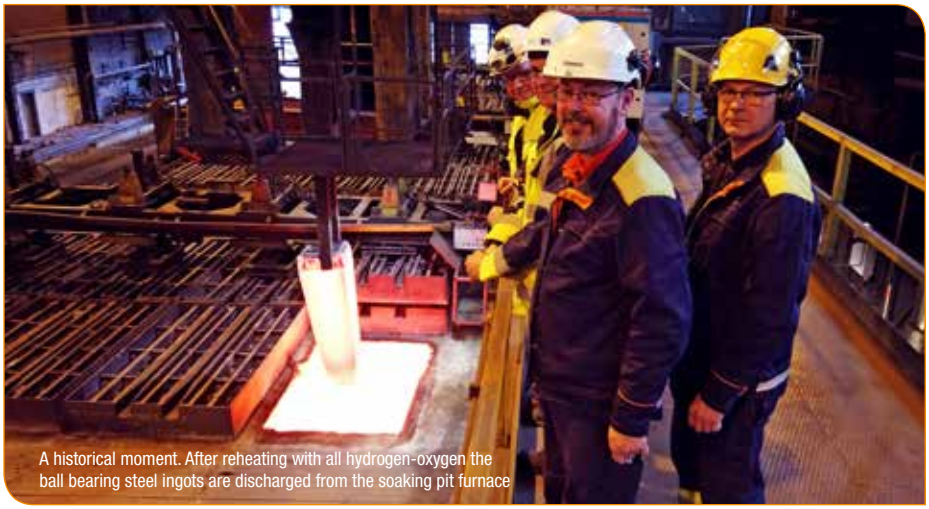
Ovako is a scrap-based European engineering steel company with sites in Sweden and Finland. It is a subsidiary of Sanyo Special Steel and a member of Nippon Steel group. Ovako produces high quality special steel with a low $C0_2$ 'cradle to gate' footprint. Due to years of solid sustainability work, Ovako has already achieved a carbon footprint 80% lower than the global industry average, but it is continuously working to get even better.

While energy production in Sweden has a low average of 12g CO_2/kWh, it is important to go beyond such simple analyses. Instead, it is the certified source of electricity that needs to be tied to your own consumption. Electricity is a traded commodity and unless the source is clearly specified it will be easy to draw the wrong conclusions. Ovako purchases 100% fossil-free electricity from Nordic power suppliers.

Over recent years Ovako has invested in replacing fossil fuels with electricity where possible. The heat treatment furnaces have been converted to electric for all furnace temperatures lass than 1000°C. In the hot rolling mill hot charging is used as much as possible, enabling significant savings in fuel and CO_2 emissions. Ovako has also changed fuel from oil to liquified petroleum gas (LPG) resulting in lower emissions of CO_2, SO_2 and particulates, facilitating the possibility to change to other CO_2-free fuels, such as green hydrogen produced by electrolysis of water.

Linde and Ovako have cooperated for almost 30 years to develop, implement and upgrade the Oxyfuel technology along with other uses

Discharge of test pieces heated by Flameless Oxyfuel with hydrogen (REBOX Hyox). The test pieces were of different grades, from four different steel companies



A historical moment. After reheating with all hydrogen-oxygen the ball bearing steel ingots are discharged from the soaking pit furnace

of industrial gases, to fit various applications and demands relating to economy, quality and emissions. Originally using conventional Oxyfuel to replace air-fuel combustion, Ovako has moved over to Linde's Flameless Oxyfuel solutions in the REBOX portfolio to increase temperature uniformity and reduce NOx emissions.

Hydrogen: the next step

To further reduce the emission of greenhouse gases Ovako and Linde decided to explore the possibility of using hydrogen-Oxyfuel technology for reheating the steel before hot rolling and forging, applying the REBOX Hyox concept. It is important to maintain all the great benefits of the Flameless Oxyfuel combustion when adding hydrogen to it. In the hydrogen-Oxyfuel combustion the flue gas formed is water vapour.

To be able to heat steel of different grades in a viable way in a 100% H_2O atmosphere, a number of questions have to be answered regarding potential quality impact on the steel, capacity and uniformity in the reheating process, NOx emissions, safety issues and changes in the combustion system.

To evaluate the scaling, de-scaling, decarburisation, hydrogen embrittlement, heating capacity, temperature uniformity and NOx formation, a pilot test campaign was carried out. The pilot tests were made in Linde's Technology Centre near Stockholm, Sweden. These tests involved heating smaller pieces of different steel grades with hydrogen Flameless Oxyfuel and comparing the results with the established Flameless Oxyfuel combustion used at Ovako with LPG as fuel.

After thorough analyses, it could be concluded that all results were encouraging. No negative impact could be identified related to the material, combustion, or emissions.

A World first

Based on the positive outcome from the pilot tests, Ovako and Linde decided to make a full-scale demonstration at Ovako's Hofors mill in Sweden by applying a 100% hydrogen-Oxyfuel heat in full scale in one of the pit furnaces in Hofors. The existing combustion system at Horos was upgraded to handle hydrogen and LPG as fuels. The changeover between the fuels can be done in just one second with complete safety, following all regulations.

The full-scale demonstration was carried out in March 2020, when 24 ball-bearing steel ingots from the steel plant were charged into four pits. One pit was fired with hydrogen-Oxyfuel using REBOX Hyox, whilst the other three operated with their normal LPG-Oxyfuel.

All relevant data (flows, temperatures, oxygen levels in the flue gases etc) were logged. The data indicated that the capacity, temperature uniformity and controllability of the combustion system worked just as well as during normal operation.

After heating and soaking, the ingots were successfully rolled to bars in the rolling mill. Rolling forces, dimensions, scale and temperature uniformity were at the same high level of quality as always. A thorough inspection and analysis of the final bars showed that heating using hydrogen as fuel does not impact the quality.

World's first all hydrogen-oxygen heated steel being successfully rolled

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Following the full-scale demonstration, Ovako has concluded it is now confident hydrogen can be used simply and flexibly, with no impact on steel quality, meaning a very large reduction in the carbon footprint. According to a first estimate, an initial investment would save 20,000 tonnes of carbon dioxide each year, but with much more to come. The full-scale demonstration was carried out in such a way that it can be reproduced at full-scale in Hofors and other rolling mills within Ovako.

Author

Joachim von Scheele
Director global commercialisation
Linde Technology
Linde PLC
www.Linde.com

Building a better future

The world's first full-scale demonstration of the use of hydrogen as fuel when reheating steel, was proven completely successful. It can be applied safely in normal operation and with no negative impact on the operation and the steel quality. With green hydrogen and oxygen from electrolysis of water, combined with a flexible Flameless Oxyfuel system, the CO_2 emissions associated with reheating may be eliminated. The use of hydrogen in combustion is very positive for the environment, as the only emission generated is water vapour.

Ovako is now looking to complete the financing with industrial partners, along with support that may be needed from financial institutions. Full-scale operations could be a reality within the near future, and this would be an important learning ground for the increased use of hydrogen across many industries. It could possibly even be an enabler for fuel cells in transport industries.

Through this cooperation and development work, Linde and Ovako have agreed that their ambition is to help other industry companies gain insight. Innovative steel, and innovative steelmaking, can help to build a better future. With this vision in mind both companies aim to make the world more productive, helping to sustain and protect the planet. Making the first ever steel reheating operation using green hydrogen – and oxygen – is proof of this.