

Ovako, Hofors Works — 13 Years' Experience of Using Oxyfuel for Steel Reheating: Background, Solutions and Results

Since the very first oxyfuel installation (1994) in a revamped reheating furnace at Ovako, Hofors Works, Sweden, the technology has shown interesting results. Ovako can now present the results of oxyfuel installed in 48 pit and two rotary hearth reheating furnaces (Figure 1), an increased throughput of 30–50%, fuel savings in the order of 30–45%, more uniform heating, less scale formation, and reduced CO₂ and NO_x emissions.

This paper will also discuss how oxyfuel combustion requires both correct technical application and control in order for such results to be achieved. In this context, oxyfuel combustion is defined as a replacement for all combustion air, containing 78% nitrogen, with industrial-grade oxygen. When combusted with a fuel, gaseous or liquid, this is then referred to as “all oxyfuel.”

Ovako — Leader in the Field of Bearing Steels

Ovako is a leading European producer of long special steel products for the roller bearing, heavy vehicle, automotive and general engineering industries. Production consists of low-alloy and carbon steels in the forms of bar, wire and wire rod, tubes, rings and pre-components. The company has 16 production sites, nine of them in Sweden, three in Finland, two in The Netherlands, and one each in France and Italy. Total turnover is close to €1.7 billion. The company employs 4,600 people. Total steel production is 2.2 million tons, whereas the reheating volume is 780,000 tons/year. Ovako's Hofors plant provides steelmaking, ingot casting, billet and heavy bar mills (Figure 2), and tube and ring-rolling mills. Billets, heavy bars, tubes, rings

and pre-components from tubes and rings are produced there. The Hofors plant has about 1,400 employees.

The use of oxyfuel technology at Ovako's Hofors Works has led to increased throughput, fuel savings and reduced emissions. This paper describes background, solutions and results of Ovako's oxyfuel reheating installations.

In the early 1990s, Ovako set out to lower fuel consumption and raise heating capacity in their reheating operations. Local authorities were positive about the planned increases but imposed further reductions in NO_x emissions. The search for alternatives led to Ovako defining some important parameters for such a project:

- **Product quality:** It is unacceptable for a supplier of bearing and special engineering steel to reduce product quality. An improvement in quality should be sought, if possible.
- **Productivity:** More production capacity was needed to meet market needs and facilitate a more flexible approach.
- **Cost reduction:** Any employed method should reduce the cost of fuel, maintenance, equipment, and emissions management.
- **Environment:** Ambitious goals were to be set to reduce NO_x and CO₂ emissions — an extra tax had already been added to the fuel cost in Sweden.

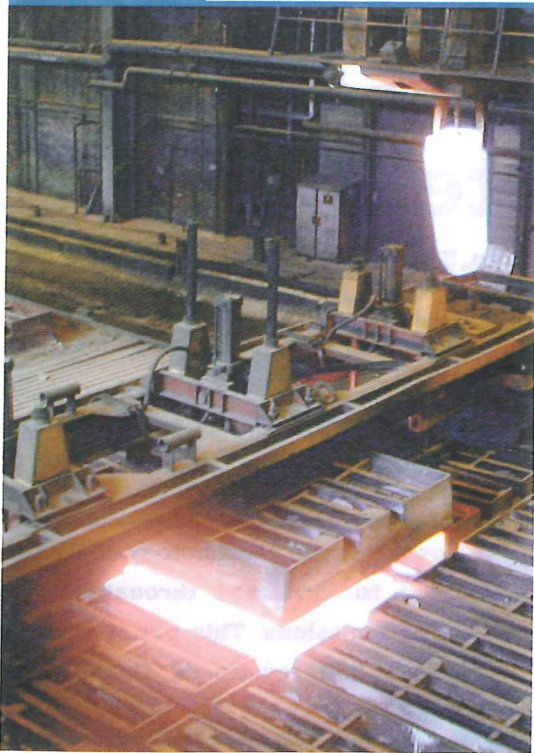


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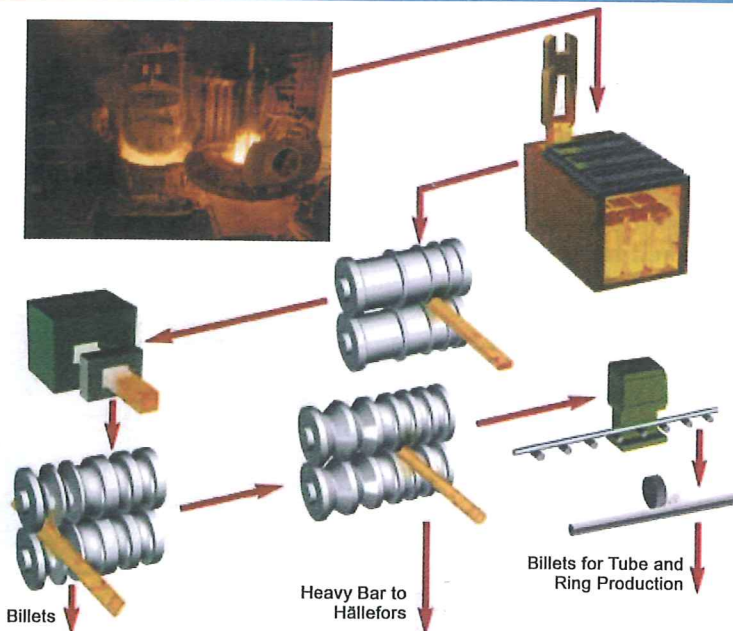


Figure 1



Since 1994, Ovako, Hofors Works, Sweden, has implemented oxyfuel in 48 pit and two rotary hearth furnaces for greater throughput capacity, providing flexibility, fuel savings and reduced emissions.

Figure 2



At Ovako Steel, cast ingots are reheated in 48 pit furnaces before being rolled in the billet mill. The billets are later reheated in two rotary hearths prior to the tube mills. All furnaces are oxyfuel equipped.

Linde was approached due to their knowledge of oxyfuel in reheating applications, including bearing steels. In 1990, Linde had installed “all oxyfuel” at The Timken Co. with several interesting results, including a 63% reduction in specific fuel consumption, 74% less flue-gas emissions, and a reduction in heating time from 5 hours to 2.5–3 hours.¹

More Heating Capacity, Less Energy and Reduced Emissions

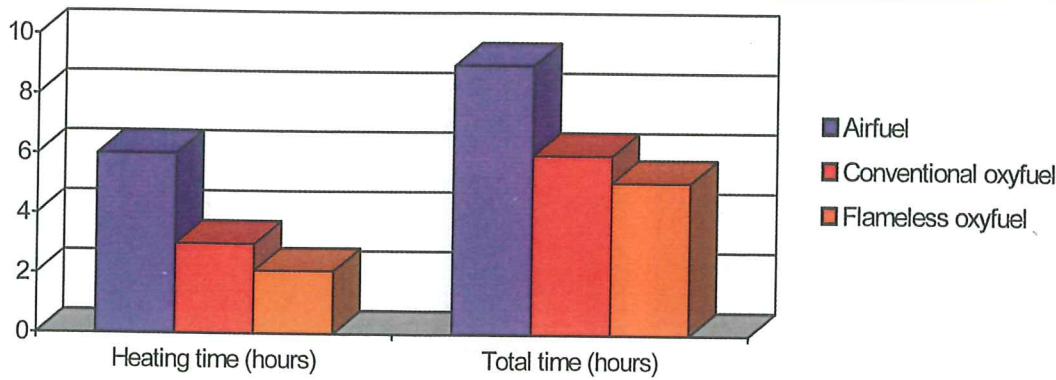
The first oxyfuel installation at Ovako in a reheating furnace took place in 1994. They wanted to test and evaluate the technology supplied by Linde. The installation replaced existing airfuel burners, a recuperator and an electrical ventilator fan. Oxyfuel was installed in a soaking pit battery of four soaking pits. The results were rewarding, and thus far a total of 48 pit and two rotary hearth furnaces have been converted to oxyfuel. Ovako has achieved a 30–50% increase in heating capacity in the existing furnaces. Heating time reductions for pit furnaces are shown in Figure 3. These results are coupled with a 30–45% reduction in specific fuel consumption. This has had the same CO₂-reducing effect. The extra throughput capacity has provided Ovako with greater flexibility, enabling them to follow variations in order intake and business cycles, and facilitating better-planned maintenance stoppages.

The rotary hearth furnaces today have a fuel consumption of 0.9 mmBtu/ton heated steel, effective for cold-charged material during manned hours at a temperature range of 2,050–2,320°F. When a new tube mill was erected in 1998, a new rotary hearth furnace was needed. Ovako instructed the furnace supplier to equip it with oxyfuel for optimum performance and to maximize furnace output for the possible furnace size. The oxyfuel technology used has undergone several shifts in technology: initially conventional oxyfuel and later staged combustion, which has been continuously upgraded when necessary.

Further Reduced Heating Time, More Uniform Heating and Less Scale Formation

— In 2006, Ovako installed flameless oxyfuel in the remaining eight pit furnaces, replacing airfuel burners and recuperators, for even better uniform heating and lower NO_x emissions. At this occasion, several tests were performed at the billet mill to monitor the changes in rolling force, scale formation, heating times, soaking times and billet temperature out of the rolling mill, as well the levels of NO_x emissions. It was seen that the flameless oxyfuel technology offered a further reduction in heating time compared to conventional oxyfuel (Figure 3).

Figure 3



With the installation of oxyfuel in the pit furnaces at Ovako, the heating time was reduced from 6 hours to 3 hours. More uniform heating of flameless oxyfuel has further reduced the heating time down to 2.1 hours. Total time, which includes the soaking, has been reduced from 9 hours to 5.1 hours with flameless oxyfuel.

Shorter heating cycles are the result of more uniform heating conditions. This is possible by the lower flame temperature of flameless oxyfuel, created by diluting the flame with the hot furnace gases (Figure 4), and because the dilution promotes an effective stirring of the flue gases, which in oxyfuel combustion contains no nitrogen ballast.

The more uniform heating of the ingots was first recognized and later confirmed by billet temperature measurements. The decrease in heating and soaking time creates not only a decrease in media input, but also a reduction in scale formation. Scales from ingots from both conventional oxyfuel and flameless oxyfuel were sampled. The results indicate a reduction in thickness of several percent without any difference in chemistry.

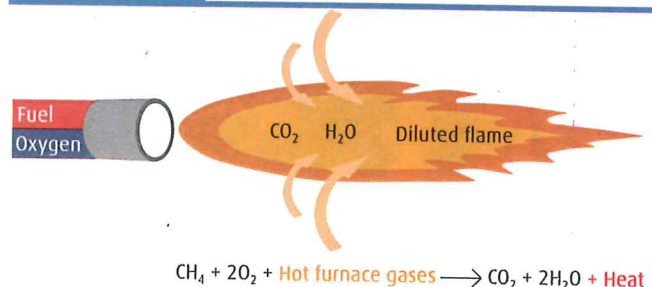
Oxyfuel to Reduce NOx Emissions — Ovako in Hofors is a minimill where most of the CO₂ and NO_x emitted originate from the reheating and annealing processes. When Ovako revamped their reheating furnaces from airfuel into oxyfuel combustion, the emissions of NO_x, measured in the flue gases, dropped below the Swedish legislation's levels of 0.348 lb/mmBtu for liquid fuels and 0.232 lb/mmBtu for gaseous fuels. In parallel to the frequent measurements taken by Ovako, the local authorities of Hofors town have been running air-quality tests since 1993. These tests have been repeated at intervals of several years at locations around the town of Hofors, involving measurement just outside the Ovako Works.² Oxyfuel reduces NO_x emissions first by reducing the fuel consumption, and second by having no nitrogen present in the combustion. In 2006, installed flameless oxyfuel had a lower flame temperature, thus avoiding the creation of thermal NO_x. This and other measures at Ovako — tight furnaces, pressure control and short furnace opening intervals

— have improved the situation. The low NO_x emission levels have been confirmed in an investigation carried out by the Royal Institute of Technology in Stockholm, Sweden.³

Flameless Oxyfuel — State-of-the-art Combustion Technology — Since 2003, industrially employed flameless oxyfuel combines the benefits of conventional oxyfuel combustion — powerful and compact burners for easy installation, high thermal efficiency for reduced fuel consumption, lower levels of CO₂ and NO_x emissions, increased heating capacity for higher furnace throughput in existing furnaces — with the features of the flameless combustion technology for a well-distributed combustion and lower flame temperature, achieving ultralow emissions of NO_x and a more uniform heating of the material.

“All oxyfuel” installations of flameless oxyfuel have already been implemented in 30 furnace installations, e.g., Outokumpu, Ascometal, Uddeholm Tooling, Scana, AreclorMittal Shelby and now also at Ovako.⁴

Figure 4



In flameless oxyfuel, the flame is diluted by the hot furnace gases. This effectively lowers the flame temperature, still having the same energy content for a more homogenous heating of the steel.

Figure 5



In the rotary hearth furnaces, the heating zones and burner positions were reviewed to achieve optimum heating conditions. Refractory was not altered. The picture to the right shows the flue gas channels of eight soaking pit furnaces with individual pressure control exiting via one common stack.

Ovako and others have also implemented flameless oxyfuel in vessel-preheating operations, showing similar and important results valid for this application: faster and more uniform heating of the vessel, including low emissions levels of NO_x.

Successful Application of Oxyfuel

With oxyfuel, it is possible to operate at higher heat-transfer rates, thus creating a higher speed for increased furnace throughput, lower fuel consumption and lower emissions than with airfuel systems. In order to achieve such results, several factors must be taken into consideration. These factors are discussed below.

Figure 6



Oxyfuel burners are both compact and powerful. In this boosting application, an additional 6.8 mmBtu/hr oxyfuel burner (left) is placed next to an existing 1.7 mmBtu/hr airfuel burner (right).

Requisite Production Capacity — Redefining the Heating Profile — Often, old metallurgical standards and what has been technically and economically feasible with airfuel technology have defined existing heating profiles for the various steel grades. In more than 110 installations since 1990, Linde has proved that these heating profiles can be challenged and that, with oxyfuel combustion, it is possible for such a challenge to be successful. This experience and knowledge is based on thorough understanding of the metallurgical considerations, customer processes and constraints; application expertise regarding oxyfuel burners and the control system gained through close cooperation with customers such as Ovako; and development, testing and implementation, with follow-up for feedback for improvements. However, with oxyfuel, it is often economically viable to add extra furnace power because of the efficient combustion and the beneficial heat-transfer process, with moderate losses of the exhaust gases.

Power Input — Defining Heating Zones, Burner Sizing and Position — The defined heating profiles are used when deciding on the requisite heating zones, positioning of burners and the requisite power input (Figure 5). Furnaces rather frequently do not require the same burner-power input as the once-specified nominal value. On many occasions, this level has never been reached or used, owing to poor performance or other malfunctions of the airfuel systems, recuperators, regenerative systems, air blowers, etc. One should also bear in mind that a 10 mmBtu airfuel and recuperator system can be replaced by a 6.7 mmBtu oxyfuel system. The maximum power of a burner cannot always be used, unless for short periods. It may thus be appropriate to

choose a somewhat smaller burner. It will then more often operate close to its nominal setting, which is more advantageous regarding both fuel savings and emissions. To further optimize combustion, the turndown ratio is limited, and on/off regulation is used to reach furnace-temperature setpoint.

Definition of the heating zones and burner positions depends on the type of furnace and its specific design and function. This is achieved by experience and calculation tools, which Linde has based on data from more than 110 furnace installations, numerous laboratory tests and various combustion solutions. Positioning of oxyfuel burners is normally easier with the small, powerful oxyfuel burners (Figure 6), with no need for any bulky combustion air ducting.

A water-cooled flameless oxyfuel burner, with integrated UV sensor and ignition for a maximum power of 8.5 mmBtu/hr, has a burner diameter of 4.25 inches and a weight of 22–44 pounds, depending on refractory thickness.

Correct Inputs — Temperature and Pressure

— In order to achieve the desired and defined heating profiles in accordance with set targets, feedback on supervision, control and safety is needed. Positioning of the thermocouples and the various measurement strategies must be defined for the furnace and process in question.

Temperature measurement to comply with safety regulations is equally important — e.g., with regard to overheating, flue-gas temperatures, and maximum temperature at old and unused but still remaining recuperators.

For instance, it is vitally important to keep furnace pressure under strict control; otherwise, NO_x emissions will rise to high levels. However, flameless oxyfuel has proved to be almost insensitive to ingress air, as has been demonstrated in pilot-scale testing and verified in full-scale production furnaces. It is vital for anyone interested in the energy efficiency of any kind of combustion system to keep track of the furnace pressure (Figure 5). Specially designed pressure transmitters must be used to be able to measure and control furnace pressures less than 10 Pa.

Flow Trains — Correct Dimensioning, Measurement and Control — Choosing the correct power input would affect the design and dimensioning of the requisite flow trains. Excessively large burners, whereby the nominal maximum power is never or seldom used, also cause an over-dimensioning of the flow trains, and the total system performance will suffer.

In order to get the best out of a burner system, accurate flow measurements are needed.

Of course, this is also of great importance for good performance in an airfuel system. However, with an oxyfuel system in which a deviation of lambda with 1/100 will affect the excess oxygen level in the furnace atmosphere by over 1%, it is even more important. In an airfuel system, the same deviation will instead have an effect of approximately 0.2%. Using a V-cone flowmeter results in good measurements, but accuracy of all other sensors — such as differential pressure transmitter, pressure reducer, control valve, temperature and pressure measurement — will also affect the accuracy of the system.⁵ However, in oxyfuel combustion, both media are more accurately measured in terms of flow and pressure compared to what is normal in airfuel combustion. In the case of airfuel, an electric fan blows the large volumes of normally preheated combustion air through large ducts to the burner. This results in temperature variations in the preheated air as well the flow and pressure. The nitrogen ballast, present in airfuel combustion, conceals such malfunctions and makes quick corrections difficult.

The introduction of limited turndown ratio in combination with on/off regulation of the burners, already mentioned with regard to maintenance of optimal combustion and limited emissions, keeps regulation of the flow train within a limited range, thus creating better accuracy and control. For future adjustments, flow trains could be adapted using orifice plates, depending on the new requests for possible drastically different heating profiles. Superior and more advanced control systems are today often integrated; with preset heating profiles and logging functions and in continuous furnaces, they normally monitor and adjust for new steel grades, different sizes and temperature setpoints. FOCS (Furnace Optimization Control System) is one such system that has been implemented in one of the rotary furnaces at Ovako in Hofors.

Maintenance — Monitoring the Process

— Ovako has applied a strategy where the furnace status is frequently monitored, thus providing an early indication to facilitate rapid actions. This saves fuel, maintains the quality of the product, keeps emissions below set requirements, and avoids a sudden and much more costly unplanned production stoppage. Furnace lids, refractory, openings, dampers and burners should be kept well-fitting, tight and properly working for optimal performance and safety. With increased production capacity in an existing furnace, this implies more frequent charging and discharging of the furnace in question, thus more tonnage passing through the furnace, which eventually means some more physical wear and tear on

Figure 7



Rotary hearth furnace at Ovako in Hofors. Here, billets for tube rolling are heated with oxyfuel to a temperature of 2,200°F. The heating properties of oxyfuel minimize the temperature deviation of max. 9°F necessary for a good piercing operation.

the furnace. With properly installed oxyfuel combustion, there has been no reported wear on the furnace. Furthermore, cleaning and maintenance of recuperators or regenerative solutions are not required, thus also no degeneration in performance of combustion and heat-transfer processes.

Not only does the reduced scale formation reduce the cost of lost material, but there will also be less maintenance work in ridding the rolling mill from scale, and reduced costs for depositing this scale.

Summary

The advantages mentioned regarding oxyfuel in reheating and annealing operations can be fully attained only by continuously treating all the operations as an integrated process. To exploit the faster heating capacity of oxyfuel, it is necessary to apply constraint management and throughput issues in all the operations — this is demanding but highly rewarding. At Ovako, increased furnace throughput of 30–50%, fuel savings in the order of 30–45% and reduced NOx emission levels are possible with

oxyfuel and if the furnace and measurement systems are well-engineered and in good condition. This is valid for both batch and continuous-type furnace operations, as in the 48 soaking pit and two rotary hearth furnaces (Figure 7). Ovako Hofors Works has recently awarded Linde a turnkey contract for a third, completely new, flameless oxyfuel rotary hearth furnace.

With 13 years of operation of the oxyfuel process, Ovako has shown that oxyfuel in reheating and annealing leads to economically viable results when it comes to expanding business and creating more production capacity and requisite flexibility, improving and maintain-

ing profit margins, and meeting environmental targets. The introduction of flameless oxyfuel already constitutes an established new generation of solutions that combines the efficiency of oxyfuel with low flame temperatures and effective stirring, thus resulting in more rapid and uniform heating of the steel and ultralow levels of NOx emissions.

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