EXPERIENCES AND RESULTS FROM USING OXYFUEL IN STEEL REHEATING AT OVAKO STEEL, HOFORS WORKS, SWEDEN[1]

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Abstract

No steel mill has more oxyfuel installations running than Ovako Steel at Hofors. There are today installations in 50 different reheat furnaces, in addition to what is used in the steel-making for melting and ladle preheating. The paper describes how Ovako Steel has worked with these installations over a period of 13 years, which the demands were and how they were met. It informs about the astonishing results achieved, including increased throughput (35-100%), fuel savings (30-45%), decreased emissions, less scale formation, more uniform heating. The challenges with this demanding but highly rewarding technology are described, including how Ovako has learnt to work with it successfully. Ovako Steel has always applied the latest technology, now it is flameless oxyfuel.

Keywords: Reheating, oxyfuel; Fuel savings; Production increase; Environment; Flameless; Uniform heating; Thermal efficiency.

EXPERIÊNCIAS E RESULTADOS DO USO DA TECNOLOGIA OXYFUEL NO REAQUECIMENTO DO AÇO NA OVAKO STEEL, HOFORS WORKS, SUÉCIA

Resumo

Nenhuma aciaria tem mais instalações com queimadores oxyfuel funcionando do que a Ovako Steel em Hofors. Existem hoje instalações em 50 diferente fornos de reaquecimento, adicionalmente ao que já é usado na fabricação do aço propriamente dito, como, fusão e preaquecimento de panelas. O trabalho descreve como a Ovako Steel tem trabalhado com essa tecnologia por mais de 13 anos, e como tais exigências foram atingidas. O trabalho informará sobre os surpreendentes resultados atingidos, incluindo aumento de capacidade de aquecimento de 35 à100%, economia de energia térmica de 30 à 45%, menores emissões para atmosfera, menor formação de carepa e maior uniformidade de aquecimento. Os desafios e os benefícios encontrados serão descritos, incluindo também, como a Ovako aprendeu com sucesso a trabalhar com a referida tecnologia tirando proveito dos seus benefícios. Ovako Steel tem sempre aplicado as últimas tecnologias disponíveis no mercado, que nesse momento é a tecnologia de queimadores oxyfuel "Flameless" (sem chama).

Palavras-chave: Aquecimento; Oxyfuel; Economia de combustível; Aumento de produção*; Flameless* (sem chama); Aquecimento uniforme; Eficiência térmica.

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INTRODUCTION

Since the first oxyfuel installation at the Hofors works, in 1994, the technology has shown excellent results. Ovako can now present the results of oxyfuel installed in totally 48 pit and 2 rotary hearth reheating furnaces (Figure 1), an increased throughput of 35-100%, fuel savings in the order of 30-45%, more uniform heating, less scale formation and reduced CO_2 and NO_X emissions.

Figure 1. Ovako, Hofors works, Sweden, has since 1994 implemented oxyfuel in 48 pit and 2 rotary-hearth furnaces for greater throughput capacity, providing flexibility fuel savings and reduced 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, and 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 two million tonnes. Ovako's Hofors plant provides steel-making, 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 here. The Hofors plant has about 1,400 employees.

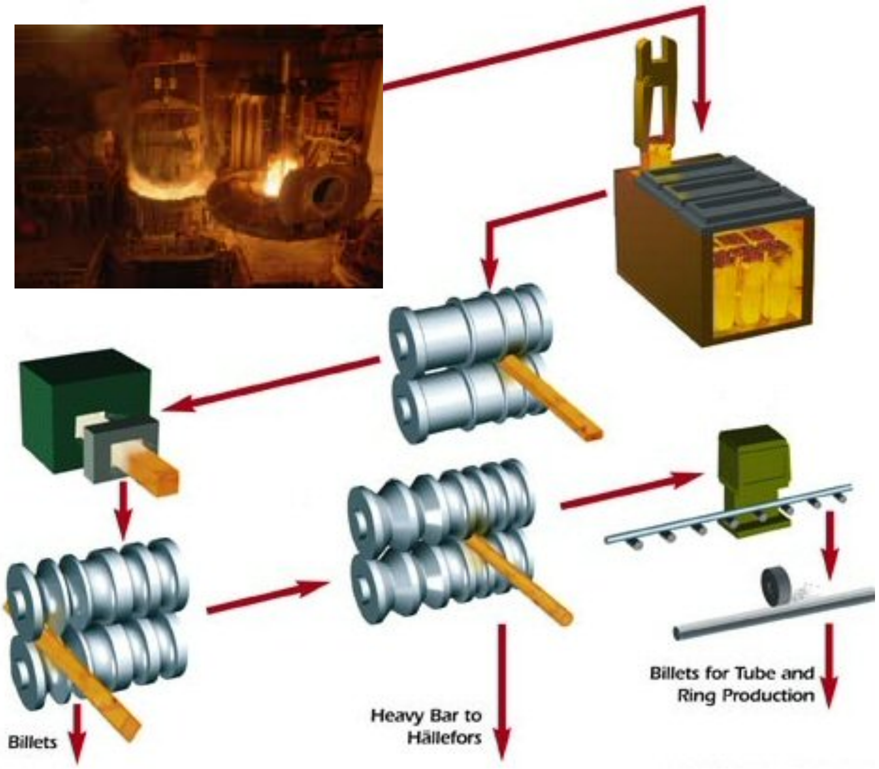

Figure 2. At Ovako Steel cast ingots are reheated in 48 pit furnaces before being rolled in the billet mill. The billets are later reheated in 2 rotary hearths prior to the tube mills. All furnaces are oxyfuel equipped.

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 to a solution to this led to Ovako defining some important parameters for such a project.

1. **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.
2. **Productivity** – More production capacity was needed to meet market needs and facilitate a more flexible approach.
3. **Cost reduction** – Any employed method should reduce the cost of fuel, maintenance, equipment, and emissions management.
4. **Environment** – Ambitious goals were to be set to reduce NO_X and CO_2 emissions - an extra tax had already been added to the fuel cost in Sweden.

Linde, was approached due to their knowledge of oxyfuel in reheating applications, including bearing steels. Linde had in 1990 installed all oxyfuel at TIMKEN, USA 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 hr to 2.5-3 hr.(1)

MORE HEATING CAPACITY, LESS ENERGY AND REDUCED EMISSIONS

The first oxyfuel installation at Ovako in a reheating furnace took place in 1994. Ovako wanted to test and evaluate the technology supplied by Linde. The installation replaced existing airfuel burners, recuperator and 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 2 rotary-hearth furnaces have been converted to oxyfuel. Ovako has achieved a 35-100% increase in heating capacity in the existing furnaces. Heating time reductions for pit furnaces are showed in Figure 3. These results are coupled with a 30-45% reduction in specific fuel consumption. This has had the same CO_2-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.

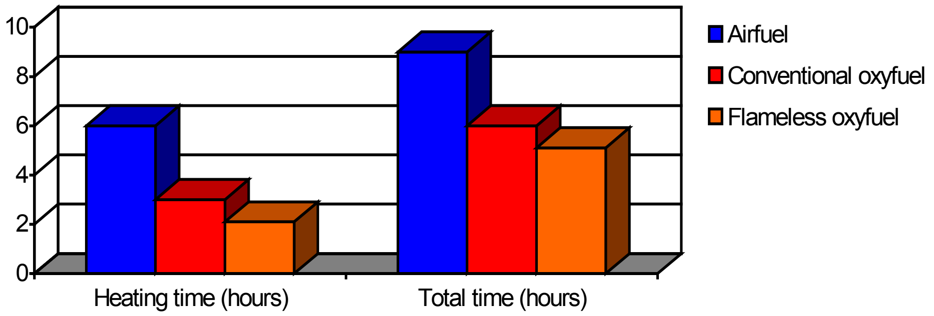

Figure 3 With the installation of oxyfuel in the pit furnaces at Ovako, the heating time was reduced from 6h to 3h. The more uniform heating of flameless oxyfuel has further reduced the heating time down to 2.1h. Total time, which includes the soaking, has been reduced from 9h to 5.1h with flameless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

The rotary-hearth furnaces today have a fuel consumption of 280 kWh/t heated steel, effective for cold-charged material during manned hours at a temperature range of 1,120-1,270°C. 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 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).

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 furnace gases (Figure 4) and that the dilution promotes an effective stirring of the flue gases, which in oxyfuel combustion contains no nitrogen ballast.

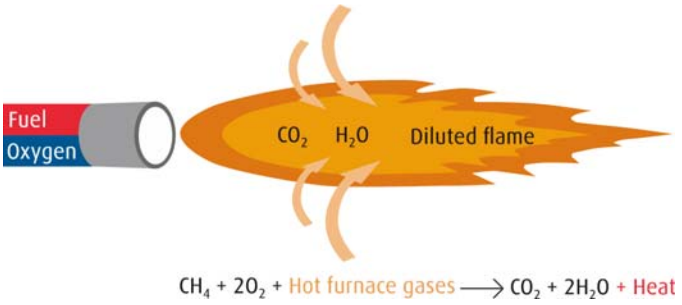

Figure 4. In flameless oxyfuel the furnace gases dilute the flame. This effectively lowers the flame temperature, still having the same energy content for a more homogenous heating of the steel.

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 from flameless oxyfuel were sampled. The results indicate a reduction in thickness of several percent without any difference in chemistry.

Oxyfuel to reduce NO_X emissions

Ovako in Hofors is a mini-mill where most of the CO_2 and NO_X emitted originates 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 150 mg/MJ for liquid fuels and 100 mg/MJ 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 by first reducing the fuel consumption and secondly 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 CO_2 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 a lower flame temperature, achieving ultra-low emissions of NO_X and a more uniform heating of the material.

So called all oxyfuel installations of flameless oxyfuel has already been implemented in 22 furnace installations, e.g. Outokumpu Stainless, Ascométal, Bohler-Uddeholm, Scana and now also at Ovako.(4) 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 and lower fuel consumption and lower emissions than with airfuel systems. In order to achieve such results several factors must be taken into consideration.

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 over 100 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 control system gained through close cooperation with customers such as Ovako, 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 & position

Figure 5. In the rotary hearth furnaces the heating zones and burner positions were reviewed to achieve optimum heating conditions. Refractory was not altered. Picture to the right shows the flue gas channels of 8 pit furnaces with individual pressure control exiting via one common stack.

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 MW airfuel and recuperator system can be replaced by a 6.7 MW 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 set point.

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 over 100 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.

Figure 6 Oxyfuel burners are both compact and powerful. In this boosting application an additional 2 MW oxyfuel burner (left) are placed next to an existing 0.5 MW airfuel burner (right).

A water-cooled flameless oxyfuel burner, with integrated UV sensor and ignition, for a max power of 2.5 MW has a burner diameter of 105 mm and a weight of 10-20 kg depending on refractory thickness.

Correct inputs – temperature & 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 close control otherwise NO_X emissions will raise to high levels. Flameless oxyfuel has however proven to be almost insensitive to ingress air, as has been demonstrated in pilot-scale testing and verified in full-scale production furnaces. But 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 & 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 causes 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, but 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 flow meter 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 medias 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 turn-down 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 set points. FOCS (Furnace Optimization Control System) is one such a system, which 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 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 only be fully attained 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 35-100%, fuel savings in the order of 30-45% and reduced NO_X emission levels are possible with oxyfuel and if the furnace and measurement systems are well engineered and in good condition. This is valid both for batch and continuous type furnace operations, as in the 48 pit and 2 rotary hearth furnaces.

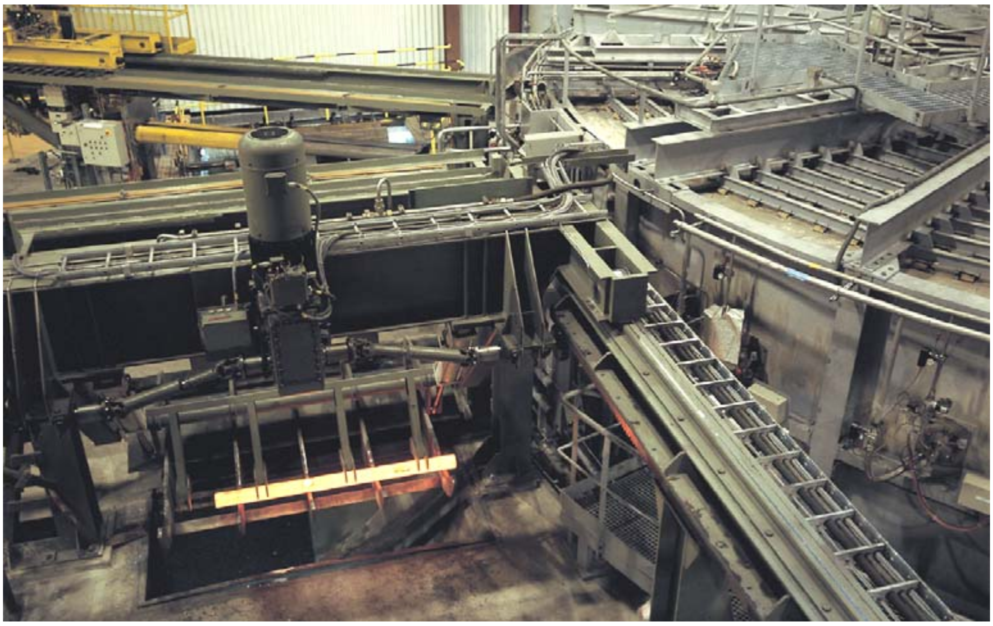

Figure 7. Rotary hearth furnace at Ovako in Hofors. Here billets for tube rolling is heated with oxyfuel to a temperature of 1200°C. The heating properties of oxyfuel minimizes the temperature deviation of max 5°C, necessary for a good piercing operation.

Ovako has with 13 years of operation of oxyfuel process 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 maintaining 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 ultra-low levels of NO_X emissions.

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