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

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Introduction – advantages & disadvantages

- no nitrogen ballast
- high efficiency – no heat recovery equipment
- moderate peak temperatures even using oxygen
- reduced scale formation
- steel production is a combination of process steps – demand for flexibility
- increased throughput capacity and higher flexibility using oxyfuel

- costs for $O_2$

explanations & examples
Introduction - temperatures

Theoretical adiabatic combustion temperature using high calorific natural gas and different oxidators.

- \( T_{\text{ad}} \) in °C
- Oxidation ratio
- \( T_{\text{Ox}} = 25 \) °C
- \( O_{\text{2,Ox}} \) Vol.-%

- Oxygen: 21, 29, 35, 100
- Air: 21, 29, 35, 100
Introduction - temperatures

- standard combustion
- moderate temperatures based on internal flue gas recirculation
- state of the art
  - diluted combustion
  - mild combustion
  - flameless oxidation
  - flameless oxyfuel
- internal flue gas recirculation
Introduction - temperatures

oxyfuel staged combustion with 5 % primary oxygen

flameless oxyfuel
Introduction – scale formation

\[ m_{\text{scale}} = f (p_{O_2}, \Delta t, ...) \]

- recirculation and dilution due to flue gas entrainment
- reduced local partial pressures of \( O_2 \)
- avoiding temperature peaks
- reduced resident time of product in furnace

reduced scale formation
Introduction - energy

High efficiency for oxyfuel - even without heat recovery

- Energy efficiency for oxyfuel - even without heat recovery

Graph showing the relationship between thermal efficiency and oxidant preheating temperature. The graph includes lines for different oxygen concentrations in the oxidant (O₂ Concentration in the oxidant in Vol-%) at various temperatures. The natural gas H oxidation ratio is given as λ = 1.0, and the exhaust temperature is T_exhaust = 1500 °C.
Ovako – soaking pit furnaces

48 furnaces converted to oxyfuel combustion at Ovako Steel, Horfors works, Sweden
Ovako – soaking pit furnaces

- from electric arc melting
- stripping/mould removal
- oxyfuel fired soaking pit furnace
- increased throughput (> 30 %)
- decreased scale formation rate – especially for flameless oxyfuel
- flexibility – buffer between steel production and rolling mill
  - low energy consumption

to tube production

billet rolling
Ovako – soaking pit furnaces

6 → 2 reduction of heating time  
9 → 5 reduction of total time

- **airfuel**
- **conventional oxyfuel**
- **flameless oxyfuel**

![Bar chart showing reduction in heating and total times](chart.png)
Ovako – soaking pit furnaces

advantages

- compact exhaust gas system
- reduced constructive amount
- decreased and simplified maintenance
- lower investment costs
- no recuperators and electrical ventilators
- 30-45 % ↓ specific fuel consumption
- pollutant emissions reduction *
digression – emission units – rough example

**airfuel**
- 1 m³/h natural gas, 35 MJ/m³
- 9.5 m³ air (2 m³ O₂, 7.5 m³ N₂)
- hypothetic NOₓ formation
  - 2000 mg/h absolute
- flue gas 10.5 m³/h
  - 1 CO₂, 2 H₂O, 7.5 N₂
- dry flue gas 8.5 m³/h
- 235 mg/m³ NOₓ

2000 mg/h : 35 MJ/h = 57 mg/MJ NOₓ

**oxyfuel**
- 1 m³/h natural gas, 35 MJ/m³
- 2 m³ oxygen
- hypothetic NOₓ formation
  - 2000 mg/h absolute
- flue gas 3 m³/h
  - 1 CO₂, 2 H₂O
- dry flue gas 1 m³/h
- 2000 mg/m³ NOₓ

2000 mg/h : 35 MJ/h = 57 mg/MJ NOₓ

not comparable!
Ascometal – soaking pit furnaces

- soaking pit furnaces used to reheat ingots prior to rolling
- first flameless oxyfuel installation in 2004 – replacing airfuel equipment like burners, air ducts, recuperators and blowers
- targets
  - 33 % shorter heating cycles
  - 40 % reduced specific fuel consumption
  - 40 % decreased NO\textsubscript{x} emissions
- improved heating characteristics
- less scale formation
- only 9 instead of 13 furnaces deliver same production rate
- energy cost savings, reduced maintenance and improved logistics
- 290 kWh/t for cold charged material
- 1120 to 1270 °C final product temperature
Ovako – Rotary hearth furnaces

- simple and compact oxyfuel installations at Ovako rotary hearth furnace
Ovako – Rotary hearth furnaces

Compared with airfuel operation

- higher throughputs
- lower emission levels
- decreased energy consumption
- more uniform heating

> 30 %

< 100 mg/MJ with staged oxyfuel

< 10 °C from top to bottom

Until now oxyfuel burners with staged combustion

- flameless oxyfuel combustion for
  - further more uniform heating
  - higher throughputs
  - lower NO\textsubscript{x} emissions
Nyby works, SE, catenary furnace on the preparatory annealing line

- equipped with flameless oxyfuel burners
- high stirring rates of furnace atmospheres
- increased heat transfer rates towards the product
- small level of NO\textsubscript{x} formation
- flexibility

- throughput growth of about 55 %
- same pickling amount – decreased scale formation
- NO\textsubscript{x} emissions were kept below 70 mg/MJ
- specific fuel consumption reduction 40 %
second catenary furnace at finish annealing line

- change from airfuel to oxyfuel
- production capacity increase from 11 to 23 tons per hour

additional capacity demanded

- direct flame impingement (DFI) installed
DFI unit: 120 burner nozzles, 4 burner rows
heat input 4 MW
length 1.8 m
50 % additional capacity increase
even for highly reflecting stainless steel strip
improved temperature control
flexibility
- DFI oxyfuel unit 5 MW
- additional heat input: $\Delta T$ 200 °C at 105 t/h
- 30 % throughput increase
- compact design 3 m
- unit fits into existing line
- instead of recuperative zone
ThyssenKrupp Steel – Carbon steel galvanising

- precise tuning of strip characteristics
  - surface properties
  - inner temperature distribution
- 25 m pre-cleaning section not necessary any more
- advantages
  - capacity and quality
  - energy savings
  - no pre-cleaning costs
- oxygen supply costs small compared with advantages
Conclusions 1

- advantages told by plant operators:
  - energy savings
  - increased capacity
  - lower pollutant emissions
  - less but correct scale formation
  - uniform product temperature distribution
  - improved product quality
Conclusions 2

- oxyfuel combustion with high thermal efficiency
- easy to set up heating systems – reduced maintenance
- oxyfuel application advantageous independent from the used fuel – also for low-calorific fuels
- using combustion knowledge and production experience oxyfuel can be applied with additional economical benefits