Innovative and Efficient Technologies for Industry

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What priorities for R&D on industrial gas uses today?

- To remain at a level consistent with high prices and volatility
  - It’s the worst time to reduce R&D efforts on industrial energy uses

- To meet the issues of industrials users
  - Compromise between flexibility and global efficiency of industrial tools
    - to adjust production level vs. energy prices
    - to allow arbitrages between energies
  - To suppress plant bottlenecks
  - To adapt industrials plants to environment constraints
    - in order to match regulation
    - and face opportunities and risks from CO2 markets

For all these issues the key word is flexibility

GDF SUEZ has launched R&D projects to develop energy-efficient solutions that comply with the problem of global warming, directly linked to the energy consumption
INNOVATIVE FLAMELESS REGENERATIVE BURNERS FOR DIRECT FIRED FURNACES ON HOT DIP GALVANIZING LINES - UP TO 15% LINES PRODUCTIVITY INCREASE

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What is a continuous galvanizing line?

**WHY IS STEEL GALVANIZED?**

**Objective:** to protect actively the steel against oxidation

**Way & Mean:** Many protective forms exist: varnish, paints, organic coatings, … but the most efficient and stable is the deposit of ZINC layer. That is the coating layer which will suffer the oxidation (very low oxidation kinetic towards the Fe oxidation kinetic)

**Advantages:** the steel pieces are easy to press (specific forms). Aesthetic qualities.
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**PROCESS:**

→ Continuous annealing thermal treatment (Strip T ~ 850-950° C)

→ Zinc coating deposit through a liquid zinc bath (Tbath ~ 460° C). An intermetallic appears between the steel (substrate) and coating so that the adherence is ensured. Control of the Coating thickness through the wiping section.

→ Coating solidification & final surface treatment (chromatation, organic coating,...)
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**The annealing furnace:**

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What is a direct flame furnace?

The direct flame furnace (DFF):

Hot dip galvanizing lines are equipped with preheating sections (Tstrip: 25°C to 750°C). 2 kinds of preheating sections:

- **Direct Fired Furnace** — the heating burners are direct flame burners
- **Radiant Tube Furnace** — the burners are introduced into radiant tubes. The strip is heated through the tubes radiation.
The direct fired furnace (DFF) :
The direct fired section is divided in 2 zones:

→ a post-combustion section (for residual gas power recovery to start the preheating of the strip)

→ a heating zone equipped with direct fired burners managed with sub-stoechiometric gas combustion conditions

Most of the time, for energy efficiency issues, there is a heat recovery of fumes for air preheating (up to 450°C)
Why innovative burners for the DFF section?

**Industrial needs:**

→ *Strong demand on the markets for high added value steel grades* like the hot stamping “Usibor” grade (automotive & industry applications)

→ *Respect of strip surface oxidation kinetics and oxide nature*

→ Identified lines require corresponding *productivity increase*

→ *Direct fired furnace preheating section encountered bottlenecks issues* to increase their productivity thanks classical heating power boosting (initial nominal condition design)

**Technological solution:**

→ *Regenerative burners* adapted to the *sub-stoechiometric combustion* conditions

→ existing heating power kept identical (few additional fumes for existing exhauster and heat recovery system)

→ *strong heat efficiency* thanks high preheated combustion air (~1000°C vs ~450°C for classical solutions)

→ *energy savings* & production costs reduction (in case of identical productivity ratio)

→ *productivity increase* (in case of identical energy consumption)

→ *Flameless combustion* for homogeneous heating

→ Pollutants emission mastered (NOx)

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Innovative flameless burners for galvanizing lines
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Flameless regenerative burners adapted to direct fired furnaces

- The **innovative burning technology** dedicated to non-oxidizing heating atmospheres consists on a combination of:
  - a **regenerative system** and
  - a **flameless combustion technology**.
  - an **integrated post-combustion system**

  ➔ Fumes in the DFF section are products of sub-stoechiometric gas combustion, with residual gas power.

- The **association of those three principles** should allow meeting the following requirements:
  - to guarantee a **complete combustion** at the furnace exit
  - to lead to **high energy efficiency** (all residual gas power recuperated within the burner ➔ maximum temperature air preheating)
  - to achieve a **cleaner process** (NOx & CO emissions)
  - to obtain an **homogeneous heating temperature**
Three complementary work axes to prepare a demonstration operation on an ArcelorMittal plant

To answer these questions, the project was set-up following three work axes:

- Experimental characterization of the combustion efficiency and the gas atmosphere generated within an semi-industrial scale furnace, optimization of operating conditions;

**Burner test**
- Atmosphere characterisation
- Operating condition optimisation

**Target** demonstration operation
Three complementary work axes to prepare a demonstration operation on an ArcelorMittal plant

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Three complementary work axes to prepare a demonstration operation on an ArcelorMittal plant

- To answer these questions, the project was set-up following three work axes:
  - Experimental characterization of the combustion efficiency and the gas atmosphere generated within an semi-industrial scale furnace, optimization of operating conditions
  - Based on previous results, impact of the generated gas atmosphere to the steel surface
  - Evaluation of the energy savings, the environmental impact and costs savings for specific ArcelorMittal hot dip galvanizing lines with dedicated numerical tools
Innovative burner’s design and optimization of high efficient regenerative solution

- Reference case: Hot Dip Galvinizing line A of ArcelorMittal

- Parametric study in the semi-industrial furnace of GDF SUEZ
  - Prototype burner gas power input (from 100 to 400 kW),
  - Furnace temperature (up to 1300°C),
  - Air gas ratio in the furnace (from 0.85 to 0.95),
  - Oxygen content in fumes after regenerator (from 0.5% to few %),
  - Regenerative burner cycling time (from 1 to 2 min),
  - Extraction rate of fumes inside the regenerator (from 50 to 90%).

- Criteria for the technology evaluation and operating parameter optimisation
  - Burner stability, for ignition and nominal use of the technology
  - Energy efficiency of the technology
  - NOx and CO emissions
  - Impact on the strip quality
Semi-industrial scaled pilot facility to optimize the combustion parameters

A 500 kW furnace has been designed and set up at GDF SUEZ Research Centre
- representative of metallurgy processes (up to 1350°C)
- One specific parameter varies while keeping constant the other operating conditions
- Every relevant parameter such as combustive temperature, input power, air ratio can be separately controlled

These experimental data have been used
- to characterize the energy and environmental performances of the burner
- for the validation of the numerical tools
Encouraging and suitable results for industrial use

- **Burner stability** achieved, for ignition and cycling use of the technology
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- **High energy efficiency of the technology with homogeneous temperature field near the strip**
  - 1000°C preheated air, exhaust fumes temperature at around 250°C, increase by more than 150°C because of the post-combustion heat. Vault temperature can achieve 1300°C instead of 1200°C with the same energy feeding.
  - A better control of the strip quality and more specifically to the strip flatness are expected.

- **Performances in terms of NOₓ and CO emissions need a set of optimised values of the operating parameters but already satisfactory levels for an industrial use**
  - NOₓ contents measured are under the today’s regulation requirements with an appropriate set of operating parameter, (around 200 mg/Nm³ @3%O₂ inside the furnace).
  - A complete combustion (minimum CO level) and all sucked elements (CO, H₂) can be burnt.

- **The contents of H₂, CO₂, CO, H₂O is quite equivalent in both conditions.**
  - The main difference is the O₂ content detected, especially the O₂ peaks observed during the switch time of the regenerative burners.

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\text{temperature field close to the strip}
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Laboratory scale preheating pilot to investigate the impact on product quality

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*Image of laboratory scale preheating pilot setup with labeled components.*

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- Traditional surfaces observations (Glow Discharge Optical Emission Spectroscopy or GDOES) to characterize the effect of the furnace atmosphere and temperature on the product quality
• Based on the line A order book, two sensitive steel grades (AlK and IF) and their critical formats have been selected to conduct the tests.
  – Three sample temperature studied: 600, 700 and 800°C. (line A, strip temperature around 700°C)
  – The industrial reference of line A is 1200°C - the vault temperature measured on the experimental cell equipped with the regenerative burners is 1300°C due to the high efficiency of the burners

• The thickness effect:
  – Surface oxidation and sample heating are coupled: heating kinetics is accelerated above ~700°C (as standard burners)
  – The heating kinetic of thin samples is quicker than the heating kinetic of the thick samples so that the oxidation occurred earlier.

• Effect of the vault temperature from 1200°C to 1300°C: a reduction of the required time to heat the sample at the desired final temperature. The potential gain on the heating kinetic observed on laboratory conditions and for this sample can reach 20%

• Minor effect of higher O2 content: the classical reaction between the steel and the gas is lightly modified but does not induce significant damages on the sample surface)
• The industrial lines are interested to implement regenerative burners within their preheating sections equipped with direct fired section.

It requires pre-dimensioning investigations to evaluate the new furnace design (burner’s location, power…) and to estimate the expected energy savings and productivity stakes

• Baseline configuration of two ArcelorMittal lines for validation

• Specific subroutines for regenerative system (including post combustion within the burner) have been carefully qualified, based on experimental data measured within these particular burners on GDF SUEZ semi-industrial scale furnace
Energy savings stakes for line A:
for that case, a full conversion from standard burners to the innovative burners has been analysed.

Provided the innovative burners are located at an optimised place on the line, not simply replaced at the location of the existing burners, we can then have

- significant energy savings (up to 14% for thick strip)
- while respecting the constraints of the furnace such as the maximum temperature of the roof.
Flameless regenerative burners
Productivity increase at lower investment costs

• **A productivity increase issue for line B:**
  For that case, a retrofit of one combustion zone has been studied.
  Power limitation due to recuperator design implies a bottleneck in term of production.
  No existing technology meets the issue except the full retrofit of the recovery system.

• The computations performed show
  – a maximum **productivity increase of 15%** for the considered product order book and **specific gas consumption reduction can reach 5%**
  – The **strip thermal profile** and **target temperature at the exit of the preheating furnace** are respected as well the acceptable **roof temperature and fumes temperature at the exhauster**.

• In that second industrial case
  the **regenerative burners is the optimal candidate to solve the furnace bottleneck** in order to increase productivity at lower investment’s costs.
Flameless regenerative burners already suitable for industrial use on HDG lines

- GDF-Suez and ArcelorMittal identified the potential interest to apply flameless regenerative burners to the specific conditions of preheating section on HDG lines.

- They joined their complementary competencies within a collaboration to test and to characterize in semi-industrial conditions the performances of this innovative solution, and finally to prepare the first industrialisation.

- Resulting from characterization campaigns, the performances of the tested burners are very encouraging and already suitable for industrial use:
  - No operating problem has been detected.
  - Performances in terms of NO$_x$ and CO emissions need a set of optimised values of the operating parameters, but have already satisfactory levels for an industrial use.
  - Combustion efficiency of this innovative technology is very high and promises to reach a more energy efficient furnace compared to current technology.
  - Temperature field within the furnace, and particularly in the strip neighbourhood, is quite homogeneous, leading to a better heating quality.
  - There is no impact of the generated atmosphere on the quality of the surface of the strip.
Next step: flameless regenerative burners implemented on HDG lines

- Expected energy savings, pollutant emissions and productivity gains in the case of an industrial implementation:
  - A saving up to 15% on gas consumption and associated CO2 emission,
  - A decrease of 10% on CO emission
  - A low level of NOx emission: 200 mg/Nm3 @ 3% O2
  - No impact on product quality

- These encouraging results allow us to predict a productivity increase up to 15% on the studied bottlenecks of HDG lines, especially dedicated to high added value steel grades.

- Complementary measurements and tests will be conducted in real production conditions on the industrial line where the first implementation of developed flameless regenerative solution will be done to assess the performances measured in the semi-industrial conditions and the estimated associated gains.
THANK YOU FOR YOUR ATTENTION

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