Use of Numerical Simulations for Improving Color Changes on a New Float Glass Furnace

AGC Europe R&D center, Gosselies
F. Bioul, V. Vandenberghe, S. Drugman, A. Contino
Outline

1. Economical context of flat glass sector in EU
2. New technology for flat glass furnace
3. Color change numerical study
4. Conclusions
Economical context

- Flat glass business in Europe is in over-capacity
- Low selling prices (from NW-EU to Russia) for commodities and specialties to some extends
- Adaptation of production capacities to match demand
- Huge pressure to reduce costs:
  - Raw materials
  - Manpower
  - Investments
  - Energy
Overview of actions for cost reduction

Classification in 4 main categories of actions

**New technologies**
« Let’s change it »

**Third order**
« Let’s do better »

**Second order**
« Let’s do things right »

**First order level = core technology**
« Let’s get the best »

- **For stronger improvement steps but case by case profitability contexts**
- e.g. « Smart » furnace control
- Accurate sensors installation and use to monitor and optimize operations
- Furnace specifications, furnace design and standardization of operations

Furnace specifications, furnace design and standardization of operations
Energy use trend in flat glass sector

Thanks to combined effect of specific actions we see over time big improvement of energy consumption to produce glass nevertheless….

With classical technology we are reaching a threshold. To go further we need disruptive actions: Let’s change it!
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New technologies: Let’s change it

AGEU investigated **oxycombustion** for flat glass process as a breakthrough technology to

- Decrease Nox
- Decrease energy consumption
- Decrease investment (no regenerators)
- Increase stability of production (no reversal time) → Improve quality

Nevertheless the only use of cold oxygen instead of air as oxidizer

- Showed a negative profitability
- Generated huge lost of energy in waste fumes

Why not to recover it To preheat Oxygen/ Fuel?

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New technologies : Let’s change it

- Energy of waste fumes is used to preheat air
- Preheated air is used to heat oxygen to 550°C and gas to 450°C

* Technology developed with AIR LIQUIDE
New technologies : Let’s change it

- Hot oxygen combustion technology has to be validated on a real furnace for flat glass production

- Two-step project
  - 1st step*: furnace started in 2008 - France
    - Hybrid fuel: natural gas and heavy oil as combustible
    - Architectural clear glass

* Project founded by EC Program Life+: LIFE07 ENV/F/000179
New technologies : Let’s change it

- Hot oxygen combustion technology has to be validated on a real furnace for flat glass production

- Two-step project
  - 2nd step*: furnace started April 2014 – Czech Republic
  - 100 % natural gas as combustible

Automotive colored glass

New challenges are, for each color produced, from lighter to darker one
- Manage the foam
- Optimize furnace operation (crown temperature, burners, fire curve, …)
- Reach good glass quality with higher level of requirement for automotive
- Reach energy and environmental theoretical expectation

  NOX: - 79.2% ; SOX: - 34.5% ; Energy : - 19.7% vs Air/Gas furnace

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Automotive colored glass

Context

- The new Czech furnace produces several glass colors for automotive, requiring frequent color changes
- During each color change, glass cannot be sold because out of specifications (color, quality)

- In addition to challenges directly related to Hotox technology, one key challenge for this new furnace was to manage color changes on a new type of furnace
Color change study

Why numerical simulation of color changes?
- To improve our understanding of colorant mixing in the new furnace
- To prepare each new color change on the furnace
- To provide information for colorant adjustments during production

Methodology
- Validate a 3D coupled model (glass-combustion spaces) in *steady state conditions* as initial state
- Perform *transient simulation* of a color change with the 3D model
- Set-up a *simplified model* based on perfect mixer models
Color change – Starting condition

- Steady-state numerical model validation
  - GFM model including glass and combustion domains
  - Validation at furnace start based on bottom and crown thermocouple measurements
Color change – Transient simulation

Colorant average concentration at furnace exit

Colorant evolution

Colorant concentration

Time

- Inlet
- Outlet (GFM)
Color change – Transient simulation

Colorant average concentration at furnace exit

![Graph showing colorant evolution with deadtime and out of spec time]

- Colorant concentration
- Time
- Deadtime
- Out of spec
- Inlet
- Outlet (GFM)
Color change – Transient simulation

GFM model can also be used to analyze and get better understanding of colorant distribution inside the furnace.

Example of colorant concentration during one color change.

Old glass along the bottom center of the furnace.
Color change – Transient simulation

- GFM model can also be used to analyze and get better understanding of colorant distribution inside the furnace

- Example of colorant concentration during one color change

Old glass along the bottom center of the furnace
Color change – Simplified model

1-mixer model (2 parameters)

\[
\text{Time constant } \tau = \frac{\text{Melter Capacity}}{\text{Pull}} - t_d \quad \text{Deadtime } t_d
\]

2-mixer model (4 parameters)

Deadtimes can be adjusted by comparison with results of GFM model
Color change – Simplified model

Comparison between GFM model and 2-mixer simplified model in the melting zone

Evolution of averaged colorant concentration in the melting zone

Melting zone deadtime has been determined in order to fit GFM results. Melting zone is very close to a perfect mixer.
Color change – Simplified model

Comparison between GFM model and simplified model
- Very good fit between GFM and 2-mixer model
- 1-mixer model is able to reproduce asymptotic behavior
Color change – Practical examples

Tool validation: Example 1

- Very good fit between the 2-mixer simplified model and experimental data when increasing colorants
- The simplified model can be used to help for adjusting colorants during and after color change
Color change – Practical examples

Tool validation: Example 2

- Very good fit between the 2-mixer simplified model and experimental data when decreasing colorants
- The simplified model can be used to help for adjusting colorants during and after color change

![Colorant #1 evolution](chart1)

![Colorant #2 evolution](chart2)
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Conclusions

- In April 2014, the second furnace in AGEU using Hotox technology has been started with new challenges to face.

- One of these challenges was to manage color changes on a new type of furnace.

- Transient simulations of color changes have been used in order to improve our understanding of colorant mixing in the furnace and to fit a simplified color change model.

- This simplified model has been validated, and is successfully used in order to:
  - Prepare the settings of each color change
  - Adjust colorants during production
Thank you very much for your attention

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For any question, please contact
Antonella.Contino@eu.agc.com

And visit:
www.agc-hoxygas.eu