Development of super low-level NOx RT-burner for annealing furnace

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Background of development

In the new furnace, we adopted only RT heating system. We need to achieve the NOx agreement value of 90ppm (11% O2 equivalent)

Outline of CGL

- Running direction of strip
- Pretreatment device
- Looper

Annealing furnace (RTFzone)

Main specification:
- Max speed: 180mpm
- Size: 0.4~2.3t × 610~1880w

Schema of RT burner

- RT burner: Capacity of combustion 140,000kcal/h
- Radiant tube: (COG)W model 7B (φ176mm)

※ Using about 200 RT burners

NOx regulation 90ppm (11%O2)
Type of furnace and NOx performance of RT burner

Existing furnace: 「DFF+RT」⇒NOx in concentric stack is 90ppm or less.
New furnace: 「Only RT」, NOx need to be 90ppm or less by using only RTF.

<table>
<thead>
<tr>
<th>Type of Annealing furnace</th>
<th>Existing annealing furnace in Fukuyama</th>
<th>Newly-established annealing furnace</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>「DFF + RTF」</td>
<td>「Only RTF」</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Type of Annealing furnace</th>
<th>(strip)</th>
</tr>
</thead>
<tbody>
<tr>
<td>#1</td>
<td></td>
</tr>
<tr>
<td>#2</td>
<td></td>
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<tr>
<td>#3</td>
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<tr>
<td>#7</td>
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<tr>
<td>#8</td>
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</table>

<table>
<thead>
<tr>
<th>Amount of NOx</th>
<th>0</th>
<th>100</th>
</tr>
</thead>
<tbody>
<tr>
<td>DFF</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RTF</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stack</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

【NOx agreement value】
【90ppm】

Need to reduce NOx
Only RTF≤90ppm
Comparison of the method to reduce NOx

We developed a new RT burner as a method to lower the NOx.

| How to reduce NOx | Exhaust gas denitration device
| SCR (Ammonia denitrification) |

**Schematic drawing**

- Install SCR in a bypass of exhaust gas duct
- Estimate the flow rate from differential pressures the before and after SCR and the inlet temperature of SCR
- Control the flow to SCR

**Cost increase**

+ about 70 million yen

**Low-level NOx RT burner (Need to develop)**

- Burner (new development - lower NOx)
- Main COG
- Main Air
- Exhaust gas
- recuperator
- Radiant tube

**Estimate the flow rate from differential pressures the before and after SCR and the inlet temperature of SCR → Control the flow to SCR**

**The goal is the same cost as the existing burner**
Goal of development (NOx of RT burner in CGL)

We control the controllable thermal NOx, and aim for low NOx emission

Thermal NOx: depending on flame temperature • • • controllable

Fuel NOx: depending on the amount of nitrogen components in the fuel • • • dyscontrol

The concentration of NOx in Exhaust gas

PPPm (at 11% O2)

Thermal NOx

Fuel NOx

Existing burner

New development burner

OK

NOx agreement value 90ppm (at 11% O2)

Suppression ∆ 60%
Method of reducing NOx

Optimizing the structure of RT burner by using Multi-stage combustion, Low excess air combustion and Exhaust gas recirculation.

⇒Aim to reduce thermal NOx

**<Inhibitory principle>**
- Reduction of O₂ concentration in combustion reaction zone
- Flame temperature reduction

**<Inhibitory combustion method>**
- Multi-stage combustion: ★New introduction
- Low excess air combustion: Adoption
- Exhaust gas recirculation: Adoption

**<Evaluation>**
- Reducing calories of fuel: × Lots of calories required
- Direct spraying of steam: × High waste heat loss
- Air temperature reduction: × High waste heat loss
- Thin film flame combustion: × Not enough space
- Denitration device
- SCR ammonia denitrification: × High cost

**Introductory technology in this time**
Suppress thermal NOx by reducing O\textsubscript{2} concentration of combustion

Reduce O\textsubscript{2} concentration of combustion area $\Rightarrow$ reduce flame temperature $\Rightarrow$ suppress thermal NOx

The relation between the oxygen in the combustion field and the theoretical adiabatic flame temperature

The relation of NOx value in the combustion exhaust gas, combustion time, and combustion temperature
We developed pre-combustion as one of the multi-stage combustion. The point of development are

1. to optimize pre-combustion
2. to optimize exhaust gas recirculation ratio

These optimizations reduce O2 concentration of combustion area, and flame temperature.
To reduce NOx by using pre-combustion

When the pre-combustion ratio is about 15%, NOx is reduced about 32.

⇒ We adopted pre-combustion as based technology to reduce NOx.

The relation between pre-combustion ratio and NOx value in exhaust gas
We found a structure which can achieve both NOx ≤90ppm and combustion cylinder temperature <1000℃.

Fig. The relation between the exhaust gas recirculation ratio and the NOx value

< Furnace temperature : 940℃ >

Fig. The relation between the air and the NOx value in the exhaust gas

However, localized heat occurred
Trouble: localized heat of RT burner

※localized heat of RT burner occurs

Localized heat occurs because COG for pre-combustion hits inside of the RT burner.

< Measures >
We aimed to reduce both NOx and localized heat by improving the structure of pre-combustion.

⇒ We optimized the structure of RT burner by combustion test
We evaluate NOx and localized heat, changing the structure of pre-combustion.

**Type E (original)**

<table>
<thead>
<tr>
<th>Holes position</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of holes</td>
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</tr>
</tbody>
</table>

**Type H**

※ Exhaust gas circulation rate 25%

<table>
<thead>
<tr>
<th>Holes position</th>
<th>1</th>
<th>2</th>
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</thead>
<tbody>
<tr>
<td>Number of holes</td>
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</table>

**Type L**

<table>
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<th>Holes position</th>
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<th>3</th>
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</thead>
<tbody>
<tr>
<td>Number of holes</td>
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<td>1</td>
</tr>
</tbody>
</table>

**Type K**

<table>
<thead>
<tr>
<th>Holes position</th>
<th>1</th>
<th>2</th>
<th>3</th>
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</thead>
<tbody>
<tr>
<td>Number of holes</td>
<td>6</td>
<td>3</td>
<td>1</td>
</tr>
</tbody>
</table>
Measures to reduce NOx and localized heat②
(NOx, Temperature of combustion tube)

NOx of 90ppm or less is achieved in Type E, L, and K

Type E (original)

- NOx ≤ 90ppm ◎
- Design limit 1000 ppm
- NOx (at 11% O2) ppm
- Temperature of the combustion tube °C
- Usage range

Type H

- High NOx ×
- Design limit 1000 ppm
- NOx (at 11% O2) ppm
- Temperature of the combustion tube °C
- Usage range

Type L

- NOx ≤ 90ppm ◎
- Design limit 1000 ppm
- NOx (at 11% O2) ppm
- Temperature of the combustion tube °C
- Usage range

Type K

- NOx ≤ 90ppm ◎
- Design limit 1000 ppm
- NOx (at 11% O2) ppm
- Temperature of the combustion tube °C
- Usage range
Considering localized heat, Type L is comprehensively best of four types.
We optimized the structure of RT burner, position of combustion and exhaust gas recirculation ratio. As a result, we reduced NOx and suppressed temperature of combustion tube.
The low NOx performance is stably maintained even after installation.
Thank you for your kind attention.

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