Cetek "Matrix Coating System" & It's Use at MiRO-Karlsruhe, Germany

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Overview

- Objective
- Key Coker Heater Operating Variables
- Benefits of Ceramic Coatings
- How Ceramic Coatings Improve Furnace Performance
- Coker Heater Coating Application
  - Impact of Refractory Coating
  - Impact of Process Tube Coating
  - Combined Impact
- Conclusions
- Q&A
Objective

- Identify a potential low cost, rapid payback project that improves a Coker heater and Coker unit performance.

Coker Heater: Key Operating Variables

- Residence Time
- Furnace Profile
  - Temperature Profile
  - Pressure Profile
  - Velocity Profile
- Coking Factor
- Heat Flux
- Peak to Average Flux
What Cetek Coatings Can Do

- Manipulate heat flux distribution in single fired heaters.
- Design coatings based on coking pattern of fire box.
- Measure true tube metal temperature by removing all scale and installing a uniform ceramic coating layer.
- Easy coking detection using infrared camera or pyrometer through the elimination of uneven scale delta T.

Benefits of Ceramic Coatings Applications

- Increased Throughput
- Longer Heater Run Lengths
- Lower Fuel Consumption
- Lower Bridgeway and Convection Section Temperatures
- More Reliable Infra-red Tube Skin Temperature Readings
- Longer Tube and Refractory Life
- Lower NOx Emissions
How Ceramic Coatings Improve Furnace Performance

Ceramic Coatings

- Theory & Applications on:
  - Refractories (high emissivity coatings)
    - NOx Emission Reduction (up to 30%)
  - Process Tubes (elimination of oxidation, scaling & fouling)
  - "Matrix Coating System" (manipulation of heat flux)
    - Application to MiRO's Coker Heaters

Furnace Radiation

The radiation from the burners goes in all directions.

- Some goes directly to the process tubes.
- How the tubes accept the radiation has an influence on the efficiency of radiant heat transfer.
- Some of the radiation goes to the refractory lining.
- How that interacts with the radiation also has an influence on the radiant heat transfer efficiency.
Radiant Heat Transfer Mode in a Fired Heater

\[
\text{Heat Flux} = C \times (T_s^4 - T_r^4) \times F_e \times F_a
\]

- \(T_s\): absolute temperature of radiation source
- \(T_r\): absolute temperature of radiation receiver
- \(F_e\): emissivity factor
- \(F_a\): furnace shape factor
- \(C\): constant

- It is therefore important to maintain the surface temperature of the tubes, \(T_r\), as low as possible.

- It is important to maintain the Emissivity Factor, \(F_e\) as high as possible

Cetek Ceramic Coatings

- Coatings for Refractories:
  - High Emissivity Properties
    - Increased Radiant Heat Exchange Efficiency
      - More Heat Available to the Process
      - Slightly Lower Flue Gas / Bridge Wall Temperatures
    - Higher Heat Flux to Back of Tubes in Single-Fired Heaters
      - Reduces Peak/Average Heat Flux
      - Increases "effective tube surface area"
    - More Uniform Heat Flux throughout the Heater
      - Helps to eliminate radiant "Hot Spots"
Cetek Ceramic Coatings

- Coatings for Process Tubes:
  - Elimination & Prevention of Oxidation (Scale) + High Emissivity
    - Increased Conductive Heat Transfer
      - More Heat Available to the Process
        » Lower Bridge Wall Temperatures
    - Back of Tubes Can Accept More Heat
      - In combination with high emissivity refractory coating
      - Reduces Peak/Average Heat Flux
    - No scale on tube surfaces to confuse thermography measurements

Matrix Coating System - Dual Emissivities

- Manipulate heat flux distribution in single fired heaters
- Design coatings application based on coking pattern of the fire box
- Measure true tube metal temperature by removal of all scale and install uniform ceramic coating layer
- Easy coking detection using infrared camera or pyrometer through the elimination of uneven scale delta $T$
Heat Flux Problems...?

For example:

Cetek Matrix Coating System (US Patent # 6,626,663B1)

- Differential Emissivity Tube Coatings
  - Increase, or Decrease Absorbed Heat Flux
  - Protects Tubes in High Flux Zones
  - Reduces Skin Temperatures

- Reduction of Peak/Average Heat Flux in Single – Fired Heaters
  - Use of Coatings on Both Refractory and Tubes
  - Reduces Heat Flux on Fired Side of Tubes
  - Increases Heat Flux on Back Side of Tubes
  - Increases “Effective Tube Surface Area”
  - Manipulates Heat Flux Zones
    - Reduces High Heat Flux
    - Increases Low Heat Flux
Cetek Matrix Coating System – Heat Flux manipulation

MiRO Coker Heater Application

Heater Schematic
IR Thermography Inspection

Observations:
- High Tubes Surface Temperatures on Lower Side Tubes
- Lower Tube Surface Temperatures on Upper Wall Tubes
- High Tube Surface Temperatures on Roof Tubes

Matrix Coating System Design

Heater Schematic

- High & Low Emissivity Tube Coating System
- High Emissivity Tube Coating
- High Emissivity Refractory Coating
Matrix Coating System

Heater Simulation Results

<table>
<thead>
<tr>
<th></th>
<th>Units</th>
<th>Before Coating</th>
<th>After Coating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Flux of the Upper 6 Wall Tubes</td>
<td>kW/m²</td>
<td>40.1</td>
<td>43.1</td>
</tr>
<tr>
<td>Average Flux of the 9 Roof Tubes</td>
<td>kW/m²</td>
<td>40.1</td>
<td>39.7</td>
</tr>
<tr>
<td>Average Flux of the Lower 10 Wall Tubes</td>
<td>kW/m²</td>
<td>40.1</td>
<td>38.8</td>
</tr>
<tr>
<td>Front 180° Tube Heat Flux - Upper 6 Wall Tubes</td>
<td>kW/m²</td>
<td>57.0</td>
<td>60.9</td>
</tr>
<tr>
<td>Front 180° Tube Heat Flux - Roof Tubes &amp; 10 Lower Wall Tubes</td>
<td>kW/m²</td>
<td>57.0</td>
<td>49.0</td>
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<tr>
<td>Flux Ratio of Front 180°/Average Flux</td>
<td>Ratio</td>
<td>1.42</td>
<td>1.25</td>
</tr>
<tr>
<td>Bridge Wall Temperature</td>
<td>°F</td>
<td>1503</td>
<td>1481</td>
</tr>
</tbody>
</table>
**Tube Skin Temperatures After Coating**

F-001: TMTs after ceramic coating was applied (adjusted for furnace duty)

TMT Increase Rate: 0.86°F/day Before Coating
TMT Increase Rate: 0.63°F/day After Coating

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**Flue Gas & Bridge Wall Temperature**

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IR Thermography Inspection Comparison

Before Coating  After Coating

Summary of Results & Conclusions

- Rate of TMT Increase Reduced from 0.86°F/day to 0.63°F/day
- Maximum TMT Reduced
- Increased Run Length, at Maximum Throughput
- Lower Flue Gas & Bridge Wall Temperatures
- Improved TST Uniformity
- Consistent Temperature Gradient across Coating
- More Accurate Determination of TMT & Coke Formation
Acknowledgements

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