Microwave Assist Technology for Ceramic Production

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Outline

- MAT Introduction
- MAT Firing
- Implementation
- Summary

MAT Kiln Tour at MS&T 2008
Microwave Assist Technology (MAT)

- Combination of radiant heat (gas or electric) with microwave energy
- Separately control microwave and radiant
- Uniformity allows faster firing → energy savings

Temperature profile across part thickness

MAT is a patented technology. Ceralink has exclusive license in North America, sublicensed exclusively to Harrop Industries for industrial MAT kilns.
MAT Development

- EA Technologies
  - Investment from British government
  - Proven technology - international consortium
  - Energy savings
- Spun off to C-Tech Innovations
- Licensed to Ceralink in NA and Carbolite in Europe
  - Tech transfer
  - Standardization, documentation, SOPs
  - Work out the kinks and make it user friendly

MAT Commercialization

- Carbolite Laboratory MAT
  - Available in NA through license agreement with Ceralink
- Harrop MAT Production Kilns
  - Ceralink grants exclusive license to Harrop for Industrial MAT
  - Scale up demonstrations
MAT Background

- 3 stages firing trials
  - Lab
  - Batch
  - Tunnel
- Consortium for MAT processing
- Scalable Technology
MAT Gas Tunnel Kiln

- M/W Ports
- Gas Burners
- Air Jets
- Extract

Scale 1:81

Lengths:
- 13.5 m
- 14.5 m

Ceralink Inc.
MAT Consortium
Production Firings

- Pilot scale production: tons of product fired
- Materials fired: advanced ceramics, refractories, abrasives, clay bricks, sanitary-ware, tableware, tiles, ceramic powders, foundry products
- All showed benefit from MAT firing
MAT Processing
Drying, Calcining, Sintering

Considerations:

- Microwave heat targets product → Less energy wasted in non-product
- Faster ramp rates, shorter dwell times → Time and energy savings
- Thermal conduction not as significant → Fast, uniform heating
- Dielectric properties → Material heating temperature dependent
Enhanced Densification
Microstructure Uniformity

- MAT- more uniform grain size across part
MAT Firing Data
Clay Bricks - temperature uniformity

MAT firing
25 hrs total

Conventional firing
70 hrs total
MAT Firing Data
Clay Bricks – time savings

Cycle time reduction for product load
MAT Firing Data

Clay Bricks – energy savings

- Energy reduction for same throughput of bricks
  - 20 mil BTU vs. 40 mil BTU

- 2006 study showed ROI 13-18 months*

MAT Firing Data
Refractories – time and energy savings

Total Firing Time
MAT: 22 hrs total
Conventional: 45 hrs total

Energy consumption
MAT: 60 mil BTU
Conventional: 110 mil BTU
MAT Firing Data
Advanced Ceramics

Faster MAT heating with improved temperature uniformity throughout product load

<table>
<thead>
<tr>
<th></th>
<th>Conventional</th>
<th>MAT</th>
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<tbody>
<tr>
<td>Heating &amp; Dwell Time (hrs)</td>
<td>15</td>
<td>9</td>
</tr>
<tr>
<td>Total Firing Time (hrs)</td>
<td>23</td>
<td>17</td>
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Ceralink
Microwave Assist Technology

MAT Lab Kilns

CerMAT
atmosphere controlled
1700 °C kiln

Carbolite MAT
1600 °C air kiln
Proof of Concept
MAT Sintering
Blasch Precision Ceramics
Alumina-SiC Corrosion Resistant Sleeve

Test bars
Sleeve Section

High Temp 1700 °C Microwave Assist Technology Electric
CerMAT 1700 °C
MAT Kiln Scale-up Testing

Compatible with microwave?

- Evaluate in MAT lab kiln
  - insulation, setters, kiln furniture
- Measure dielectric properties

Refractory assemblies tested using MAT lab kiln
MAT Scale-up

Blasch Precision Ceramics
Alumina-SiC sleeves
Scale-up test

Harrop Industries
MAT Elevator Kiln
inert atmosphere, 1620 °C
MAT vs. Conventional Blasch Alumina-SiC

- Saved 16 hrs on heat up
- Saved 30 hrs total run time
MAT Property Results

Blasch Alumina-SiC

- Equivalent properties
- Faster turn-around time
- Less product in process
- 80% energy savings

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<th>Conv.</th>
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<tbody>
<tr>
<td><strong>Bulk Density g/cc</strong></td>
<td>2.69 ±0.01</td>
<td>2.68 ± 0.1</td>
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<tr>
<td><strong>Open Porosity %</strong></td>
<td>17.2 ± 0.3</td>
<td>14 ± 0.1</td>
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<tr>
<td><strong>Modulus of Rupture psi</strong></td>
<td>5275</td>
<td>5300</td>
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**Blasch** ± 2 S.D.

**Modulus of Rupture**

**Shear Modulus**

- 15 °C/m, 5 °C/m, 5 °C/m, 15 °C/m, 5 °C/m, 15 °C/m, 5 °C/m, 5 °C/m, 60% 60-100% 60-100% Blasch ± 2 S.D.
MAT Implementation

Cost benefit needed to show ROI for each product

What is important to the manufacturer?

- Energy savings
- Increased throughput
- Decrease equipment footprint
- Faster turn-around time
- Improved materials properties
- New materials
Summary

- MAT proven to
  - Reduce firing time
  - Reduce energy consumption
  - Maintain uniform temperature profile
  - Improved properties
- Readily scalable microwave technology
- Cost benefit
- Available now
Acknowledgments

C-Tech Innovation
...advantage through technology

Dave Ellis
Norman Maloney
Ruth Wroe

Please visit us at the
Harrop Industries - Thermex Thermatron
Expo Booth # 200-202