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Mario Taddeo
Sales Manager (ISOMAG) Asia Pacific
Relationship between Refractory Lining Design & Liquid Steel Temperature at the Ladle Furnace
Saving Energy at the Ladle Furnace

Reducing Energy consumption of the Ladle Furnace is the goal of every steelmaker

• It can be achieved through:
  ◦ **Process Improvement and/or**
  ◦ Capital Upgrades

This Presentation solves this problem by reducing the heat loss through optimised refractory lining design
Introduction

Case Study:
Thai Steel plant optimized the Ladle Refractory Lining by using 13mm Structural Insulation

Quantify the Efficiency by comparing
1. Refractory Lining Design
2. Theoretical Heat Loss Analysis
3. Ladle Thermovision
4. Liquid steel temperature improvement at Ladle Furnace (LF)
5. Energy savings at the LF.
QUESTION ????

HOW DOES THE REFRACTORY LINING AFFECT:

• Liquid Steel Temperature, &
• Electricity Consumption at the Ladle Furnace

ACTION: !!
Reduce the heat loss through the refractory lining of 1 ladle and compare this to the rest of the fleet.
How to Reduce Refractory Heat Loss

1. **Use a thicker refractory lining**
   - **Check:** Compromises Vessel Capacity, Productivity and Refractory Costs

2. **Use a Less Conductive Refractories**
   - **Check:** Compromise Refractory Performance & Lining integrity

3. **Use Structural Insulation (~13mm)**
   - **Check:** Heat Loss Analysis (within Max Service Temp) & Permanent Lining Campaign Performance
Customer Chose Insulation – What Type / Why

• High Temperature Load Bearing Application:
• Requires Excellent Thermomechanical properties

<table>
<thead>
<tr>
<th>Product</th>
<th>Cont. Service Temp. Limit</th>
<th>Porosity</th>
<th>Hot Crushing Strength at 5% Strain at 500°C</th>
<th>Thermal Conductivity at 500°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>ISOMAG® 70</td>
<td>1000°C</td>
<td>54%</td>
<td>17 MPa</td>
<td>0.29 W/m.K</td>
</tr>
<tr>
<td>ISOMAG® 55</td>
<td>1000°C</td>
<td>63%</td>
<td>6 MPa</td>
<td>0.25 W/m.K</td>
</tr>
</tbody>
</table>
ISOMAG 70 Hot Stress Cycle Test @ 500°C
ISOMAG Durability – 500,000 tonnes. LADLE

170t Ladle
WL = 125 heats
PL = 23 x WL campaign
ISOMAG = 489,000t
Case Study: Thailand Steel Plant

6 x 70t Ladle - 4 Strand Billet Caster

Lining Design Changes – (1)

- Replace 32mm Alumina Brick with 13mm ISOMAG
- **19mm Lining thickness Saving – Increase Capacity & Productivity**

<table>
<thead>
<tr>
<th>Lining Material</th>
<th>Current Practice</th>
<th>New (Insulated) Lining</th>
</tr>
</thead>
<tbody>
<tr>
<td>Working Lining (WL)</td>
<td>150mm: MgO-C Brick</td>
<td>150mm: MgO-C Brick</td>
</tr>
<tr>
<td>Permanent Lining 1 (PL1)</td>
<td>75mm: 65% MgO Brick</td>
<td>75mm: 65% MgO Brick</td>
</tr>
<tr>
<td>Insulation Lining (IL)</td>
<td>32mm: 65% Alumina Brick</td>
<td><strong>12.7mm: ISOMAG® 70</strong></td>
</tr>
<tr>
<td>Total Thickness</td>
<td><strong>257mm</strong></td>
<td><strong>238 mm</strong></td>
</tr>
</tbody>
</table>
ISOMAG Thermal Profile Comparison – New Lining

**Current Practice**
- Shell
  - 65% Alumina Brick
  - 65% MgO Brick

**Recommendation #1**
- Shell
  - ISOMAG 55👍
  - 65% MgO Brick

**Temperature (°C)**
- Shell: 377°C
- 65% Alumina Brick: 588°C
- 65% MgO Brick: 811°C
- MgO-12% Brick: 1084°C

**Steel Ladle / METAL Zone / Slag Zone**

**NEW LINING**

**Lining Thk:**
- Current: 258 mm
- Recommendation: 239 mm

**Heat Loss:**
- Current: 11827 W/m²
- Recommendation: 9509 W/m²

**Delta Thk:**
- -19 mm

**Delta T:**
- -37°C

**Loss Variation:**
- -20%
ISOMAG Thermal Profile Comparison – Worn Lining

Steel Ladle / METAL Zone
WORN LINING

Lining Thk = 183 mm
Heat Loss = 14708 W/m²
Shell Temp. = 415 °C

Lining Thk = 184 mm
Heat Loss = 11542 W/m²
Shell Temp. = 373 °C

ΔThk = -19 mm
Loss Variation = -22%
ΔT = -42 °C
ISOMAG Installation into Refractory Lining
Thermovision Comparison

**Measurements**

<table>
<thead>
<tr>
<th>Parameters</th>
<th>9/02/2012 2:08:03 PM</th>
<th>9/02/2012 1:46:26 PM</th>
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</thead>
<tbody>
<tr>
<td>Ar1 Max</td>
<td>391.8</td>
<td>387.0</td>
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<tr>
<td>Ar1 Min</td>
<td>286.0</td>
<td>285.3</td>
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<tr>
<td>Ar1 Average</td>
<td>363.7</td>
<td>339.1</td>
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<tr>
<td>Ar2 Max</td>
<td>407.0</td>
<td>357.5</td>
</tr>
<tr>
<td>Ar2 Min</td>
<td>245.6</td>
<td>182.0</td>
</tr>
<tr>
<td>Ar2 Average</td>
<td>363.7</td>
<td>313.8</td>
</tr>
<tr>
<td>Sp1</td>
<td>398.9</td>
<td>337.4</td>
</tr>
</tbody>
</table>

**Parameters**

- Emissivity: 0.9
- Refl. apparent temp.: 28 ºC

**Ladle 3 - Skulling Area**

**STANDARD REFRACTORY LINING**

**ISOMAG INSULATION**

40ºC Saving
QUESTION ??

Insulating the Refractory Lining Reduces Shell Temperature

Does a lower shell temperature result in Hotter Steel Arriving at the Ladle Furnace.

If so – How much??
Calculating Liquid Steel Temperature Loss

LIQUID STEEL TEMPERATURE LOSS = 

\[ \frac{EAF_{(\text{tapping temperature})} - LF_{1_{(\text{LF Arrival Temperature})}}}{\Delta t_{(EAF-LF1)} \ (\text{PARKING TIME})} \]
### Liquid Steel Temperature Loss Comparison - Data

**• All Ladle Comparison with Insulated Ladle 8**

<table>
<thead>
<tr>
<th>Ladle</th>
<th>Ladle life</th>
<th>Ladle tap weight</th>
<th>Tapping temp.</th>
<th>Parking time (min)</th>
<th>1st LF temp.</th>
<th>Exit LF temp.</th>
<th>Heat loss deg.C/min</th>
<th>Power cons. (kwh)</th>
<th>Power on time (min)</th>
<th>Power cons. kWh/gbt</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>33</td>
<td>70.5</td>
<td>1629</td>
<td>5.5</td>
<td>1571</td>
<td>1603</td>
<td>10.7</td>
<td>2881</td>
<td>19.2</td>
<td>41</td>
</tr>
<tr>
<td>3</td>
<td>11</td>
<td>70.6</td>
<td>1626</td>
<td>5.5</td>
<td>1554</td>
<td>1602</td>
<td>13.8</td>
<td>3164</td>
<td>21.4</td>
<td>45</td>
</tr>
<tr>
<td>4</td>
<td>50</td>
<td>70.6</td>
<td>1625</td>
<td>5.2</td>
<td>1567</td>
<td>1603</td>
<td>11.4</td>
<td>3012</td>
<td>20.3</td>
<td>43</td>
</tr>
<tr>
<td>6</td>
<td>26</td>
<td>70.7</td>
<td>1624</td>
<td>5.5</td>
<td>1560</td>
<td>1604</td>
<td>12.5</td>
<td>3073</td>
<td>20.5</td>
<td>43</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td><strong>30</strong></td>
<td><strong>70.7</strong></td>
<td><strong>1627</strong></td>
<td><strong>5.5</strong></td>
<td><strong>1567</strong></td>
<td><strong>1604</strong></td>
<td><strong>11.9</strong></td>
<td><strong>2973</strong></td>
<td><strong>19.9</strong></td>
<td><strong>43</strong></td>
</tr>
<tr>
<td>8</td>
<td>37</td>
<td>70.4</td>
<td>1623</td>
<td>5.1</td>
<td>1575</td>
<td>1603</td>
<td>9.7</td>
<td>2876</td>
<td>19.5</td>
<td>41</td>
</tr>
<tr>
<td><strong>ISOMAG Advantage</strong></td>
<td><strong>7</strong></td>
<td><strong>0.3</strong></td>
<td><strong>4</strong></td>
<td><strong>0.4</strong></td>
<td><strong>-8</strong></td>
<td><strong>1</strong></td>
<td><strong>2.2</strong></td>
<td><strong>97</strong></td>
<td><strong>0.4</strong></td>
<td><strong>2</strong></td>
</tr>
</tbody>
</table>
Factors Affecting Energy Consumption at the LF

- Steel Grade Type
- Plant Operations
- Time between EAF and LF (Parking Time)
- Treatment Time
- Conductivity of Refractory Lining:
## Liquid Steel Temperature Loss Comparison - Data

### Ladle in Sequence/Grade vs Insulated Ladle 8

<table>
<thead>
<tr>
<th></th>
<th>Ladle life</th>
<th>Ladle tap weight</th>
<th>Tapping Temp.</th>
<th>Parking time (min)</th>
<th>1st LF temp.</th>
<th>Exit LF temp.</th>
<th>Heat lost (C/min)</th>
<th>Power cons. (kwh)</th>
<th>Power cons. (kwh)/GBt</th>
<th>Power on time (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>STANDARD</td>
<td>26</td>
<td>70</td>
<td>1,633</td>
<td>5</td>
<td>1,560</td>
<td>1,625</td>
<td>14</td>
<td>4,040</td>
<td>58</td>
<td>27</td>
</tr>
<tr>
<td>ISOMAG</td>
<td>33</td>
<td>70</td>
<td>1,636</td>
<td>5</td>
<td>1,590</td>
<td>1,632</td>
<td>9</td>
<td>3,631</td>
<td>52</td>
<td>24</td>
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<tr>
<td>ISOMAG Benefit</td>
<td></td>
<td></td>
<td>-3</td>
<td>0</td>
<td>-30</td>
<td>-7</td>
<td>5</td>
<td>409</td>
<td>6</td>
<td>3</td>
</tr>
</tbody>
</table>

- Steel Grade affects LMF Energy Consumption
- 10% Energy Saving using ISOMAG when compared with the same grade
Steel Temperature vs Time after EAF Tapping - Dolomite

Heat Loss through Refractory Absorption

Heat Loss through Ladle Shell
Liquid Steel Temperature Loss to LF vs Lining - Predicted

Steel Temperature vs Time after EAF Tapping - MgO-C v Dolomite Lining

Increase Superheat for high conductive lining

Liquid Steel Temperature °C

Time After Tapping into EAF

MgO-C
Dolomite
Steel Temperature vs Time after EAF Tapping - With Insulation Lining

- **Dolomite + ISOMAG**
- **MgO-C + ISOMAG**
- **Dolomite**
- **MgO-C**

Time After Tapping into EAF

Liquid Steel Temperature °C

- 0
- 5
- 10
- 15
- 20
- 25
- 30
- 35
- 40

Liquid Steel Temperature Loss to LF vs Lining & ISOMAG - Predicted
THE POWER OF THE RIGHT INSULATION DESIGN

• Reduce Wall thickness by 19mm
  • Increase Vessel Capacity
  • Increase Wear Lining Thickness & Life

• Shell Temperature reduced by 30°C
• Better insulation of the lining keeps refractories hotter
• Hotter refractory lining results in hotter steel arriving at the LF
• LF Energy saving of 10% Achieved using ISOMAG
Thank you