Effect of Oscillation Marks on Billet Casting

Ya Meng

Department of Materials Science & Engineering
University of Illinois at Urbana-Champaign

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Effect of Carbon Content on Oscillation Mark Depth

[Graph showing the relationship between carbon content and oscillation mark depth for different materials and conditions.]
Effect of Negative Strip Time on Oscillation Mark Depth

![Graph showing the relationship between negative strip time and oscillation mark depth for various materials and conditions.](image-url)
Effect of Oscillation Mark Depth on Average Mold Heat Flux

![Graph showing the effect of oscillation mark depth on average mold heat flux](image)

- **Lasco** ($V_c = 1.99 \sim 2.26 \text{ m/min}$)
- **CON1D Others** ($V_c = 2.2 \text{ m/min}$)
- **CON1D 0.27\%C, $d_{air} = 35 \mu\text{m}$ ($V_c = 2.2 \text{ m/min}$)

- **0.08\%C, $d_{air} = 39 \mu\text{m}$$
- **0.16\%C, $d_{air} = 30 \mu\text{m}$$
- **0.16\%C, $d_{air} = 39 \mu\text{m}$$
- **0.767\%C, $d_{air} = 30 \mu\text{m}$$

Average Mold Heat Flux (MW/m²)

Oscillation Mark Depth (mm)
Effect of Oscillation Mark Depth on Average Mold Heat Flux

Heat Flux (MW/m²) vs Oscillation Mark Depth (mm)

- Lasco (converted)
- Georgetown
- Georgetown (converted)
- Sidbec
- Sidbec (converted)
- CON1D Others
- CON1D 0.27%C, $d_{air}=35\mu m$
- 0.767%C, $d_{air}=30\mu m$
- 0.04%C, $d_{air}=39\mu m$
- 0.08%C, $d_{air}=39\mu m$

$V_c=3.4\text{m/min}$
Effect of Oscillation Mark Depth on Average Mold Heat Flux

![Graph showing the relationship between Oscillation Mark Depth and Heat Flux. The graph includes data points for different casting velocities and mold conditions, such as Losco, CON1D, and Georgetown. The data shows a decreasing trend in heat flux as the Oscillation Mark Depth increases. The graph helps in understanding how varying mark depths affect the heat flux during continuous casting.]
Effect of Oscillation Mark Area/Unit Length on Average Mold Heat Flux

![Graph showing the relationship between oscillation mark area/unit length and average mold heat flux.](image)

- **Graph Details:**
  - **Axes:**
    - Y-axis: Average Mold Heat Flux (MW/m²)
    - X-axis: Osc. Area/unit Length (mm)
  - **Data Points:**
    - Frequency = 1.0 Hz
      - Osc. Area/unit Length: 0.27°C, d₂₅ = 35µm
      - Vc = 2.2 m/min
      - Osc. Area/unit Length = 0.05 mm
    - Frequency = 1.5 Hz
      - Osc. Area/unit Length: 0.27°C, d₂₅ = 35µm
      - Vc = 2.2 m/min
      - Osc. Area/unit Length = 0.1 mm
    - Frequency = 2.0 Hz
      - Osc. Area/unit Length: 0.27°C, d₂₅ = 35µm
      - Vc = 2.2 m/min
      - Osc. Area/unit Length = 0.15 mm
  - **Equations:**
    - Osc. Area/unit Length ∝ w₁₅ Hz ∝ d₁₅ Hz
    - freq ↑, w₁₅ Hz × d₁₅ Hz = 0.4 mm × 8 mm
    - freq = 1.5 Hz, w₁₅ Hz ∝ d₁₅ Hz
Effect of Oscillation Mark Size/Frequency on Mold Heat Flux and Taper

0.27C%, $V_c = 2.2m/min$, $120mm \times 120mm$ Billet

Working Mold Length : 700mm,

$d_{air} = 35 \mu m$, $\Delta T_{sup} = 50^\circ C$
Comparison of CON1D and CON2D Results

\[ V_c = 2.2 \text{m/min}, \Delta T_{\text{sup}} = 50^\circ \text{C}, \]

120mm × 120mm Billet

Working Mold Length : 700mm
Effect of Steel Grade on Mold Heat Flux and Taper

\[ V_c = 2.2 \text{m/min}, \Delta T_{\text{sup}} = 50^\circ \text{C}, 120\text{mm} \times 120\text{mm Billet} \]

Working Mold Length : 700mm,

\[ d_{\text{osc}} \times w_{\text{osc}} = 0.4\text{mm} \times 8\text{mm}, \quad d_{\text{air}} = 35\mu\text{m} \]
Casting speed: 1.2m/min; time: 1.5sec
<table>
<thead>
<tr>
<th>Carbon content</th>
<th>0.04</th>
<th>0.07</th>
<th>0.13</th>
<th>0.27</th>
<th>0.47</th>
</tr>
</thead>
<tbody>
<tr>
<td>Other components</td>
<td>0.04%C, 1.52%Mn, 0.34%Si, 0.012%P, 0.015%S</td>
<td></td>
<td></td>
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<tr>
<td>Segregation model</td>
<td>No</td>
<td></td>
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<tr>
<td>Ferrostatic pressure</td>
<td>Yes</td>
<td></td>
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<tr>
<td>Mold Oscillation (mm)</td>
<td>d = (6<em>cos(1.66667</em>time*3.141593)</td>
<td></td>
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<td></td>
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</tr>
<tr>
<td>Stroke (mm)</td>
<td>12</td>
<td>12</td>
<td>12</td>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td>Frequency (cpm)</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
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<tr>
<td>Superheat (C)</td>
<td>30</td>
<td>30</td>
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<td>30</td>
<td>30</td>
</tr>
<tr>
<td>T liquidus (C)</td>
<td>1533</td>
<td>1530</td>
<td>1526</td>
<td>1515</td>
<td>1444</td>
</tr>
<tr>
<td>T solidus (C)</td>
<td>1518</td>
<td>1504</td>
<td>1495</td>
<td>1478</td>
<td>1499</td>
</tr>
<tr>
<td>Heat flux below meniscus</td>
<td>Qflux = 4000*(250-t(n1))</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heat flux above meniscus</td>
<td>Qflux = 0.0</td>
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</tr>
<tr>
<td>Temperature of the mold</td>
<td>250 C</td>
<td></td>
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<tr>
<td>Mesh size</td>
<td>30 mm x 3 mm</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Number of nodes</td>
<td>91 x 31</td>
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<tr>
<td>Mesh grading ratio along the shell</td>
<td>1.1</td>
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<tr>
<td>Time step</td>
<td>0.001 s</td>
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<tr>
<td>Simulation time</td>
<td>1.5 s</td>
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<tr>
<td>Constitutive law</td>
<td>Kozlowski Model III and Power Delta law</td>
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<tr>
<td>Mold taper</td>
<td>Linear, 0.75 %/m</td>
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<tr>
<td>Mold friction</td>
<td>No</td>
<td></td>
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</tr>
</tbody>
</table>

Max. displacement

| At 0.9 s | 0.023 | 0.023 | 0.035 | 0.004 | 0.003 |
| At 1.2 s | 0.047 | 0.17 | 0.24 | 0.01 | 0.007 |
| At 1.5 s | 0.054 | 0.31 | 0.38 | 0.02 | 0.017 |