Stress Distribution and Crack Formation on Sliding Gate

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Patterns of Cracks Formed on Sliding Gate Refractory

Service life of sliding gate plate acts as a limiting factor to achieve the expected SEN performance on continuous caster

<table>
<thead>
<tr>
<th>Types of crack</th>
<th>Caused by</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outside cracks</td>
<td>Thermal expansion</td>
</tr>
<tr>
<td>Longitudinal cracks</td>
<td>Thermal expansion</td>
</tr>
<tr>
<td>Transversal cracks</td>
<td>Plate support load</td>
</tr>
</tbody>
</table>

“Steel and Refractory Chemical Interactions and Mechanical Behavior of Plates for Sliding Gate during Steel Continuous Casting”, V. Munteanu, 2008

Why Cracks are Formed in Sliding Gate

- **Thermal stress** induced by temperature distribution of sliding plate with pre-heating and molten steel temperature

- **High surface pressure** from cassette supporting 3 sliding gate plates

- **Ferro-static pressure** due to height difference between tundish free surface and sliding gate location

- **Friction force** caused by mechanical movements for stabilizing the mold meniscus level
Components of Sliding Gate

- Upper cassette
- Lower cassette
- Upper plate
- Middle plate
- Lower plate
- Steel bend
- Jig
- Bolt

[Schematic of sliding gate parts drawing by Abaqus]
**Plate Contacting Geometry with Cassette**

<table>
<thead>
<tr>
<th>Plate Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Upper plate</strong></td>
<td>Cylinder is connected to middle plate via jig. Each plate enclosed by steel bend is fixed by forced clamp.</td>
</tr>
<tr>
<td><strong>Middle plate</strong></td>
<td>Steel bend</td>
</tr>
<tr>
<td><strong>Lower plate</strong></td>
<td>Steel bend</td>
</tr>
</tbody>
</table>

**Schematic of sliding gate plates contacting geometry (top view)**

- Cylinder is connected to middle plate via jig.
- Each plate enclosed by steel bend is fixed by forced clamp.
Parameters Considered for Computational Modeling

- **Temperature**

  - Pre-heating temp. :
    Sliding gate is heated from room temp. to pre-determined temp.

  - Molten steel temp. :
    Molten steel flows through sliding gate hole, during continuous casting
Parameters Considered for Computational Modeling

- **Load imposed on sliding plate**
  
  Cassette is loaded by 3.5 ton weight through 4 screws bolted from bottom to top
  
  \[
  \text{bolt load} : \frac{3500 \text{ kg} \times 9.81 \text{ m/s}^2}{4 \text{ screws}} = 8583.75 \text{ N}
  \]

- **Ferro-static pressure**
  
  \[
  P_{SG} = \gamma h + P_{atm}
  \]

  "Ferro-static Pressure"

  - \(\gamma\): Specific Weight (kN/m\(^3\))
  - \(h\): Molten Steel Depth (m)
  - \(\rho\): Density (kg/m\(^3\))
  - \(g\): Gravitational Acceleration (m/s\(^2\))

  \[
  \gamma h = \rho gh = 7020 \text{ kg/m}^3 \times 9.81 \text{ m/s}^2 \times 1.8 \text{ m} = 123959.16 \text{ kg/m} \cdot \text{s}^2 \cdot \text{m} = 123959.16 \text{ N/m}^2 = 123959 \text{ Pa}
  \]

  \[
  P_{atm} = 101325 \text{ Pa}
  \]

  \[
  P_{SG} = 123959 \text{ Pa} + 101325 \text{ Pa} = 225284 \text{ Pa}
  \]
Parameters Considered for Computational Modeling

- Mechanical movement (Friction force)

Cylinder is working back and forth to stabilize the mold meniscus level with velocity of approx. 0.025 m/s

![Diagram showing mechanical movement and components]
Future Plan

- **Stress distribution** will be investigated considering 5 different parameters on sliding gate plates with different opening ratio

- **Crack Initiation and propagation** will be investigated

- **How stresses are affected on plates depending on different pre-heating temperature** will be considered
Acknowledgements

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