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Effect of Stopper Rod Movement on Mould Fluid Flow and Sliver Formation (at ArcelorMittal Dofasco No. 1 Continuous Caster)

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Objectives

Overall: To study detailed effect of transient flow phenomena on defect formation, to enable better methods to predict & improve product quality

Plant Measurements:

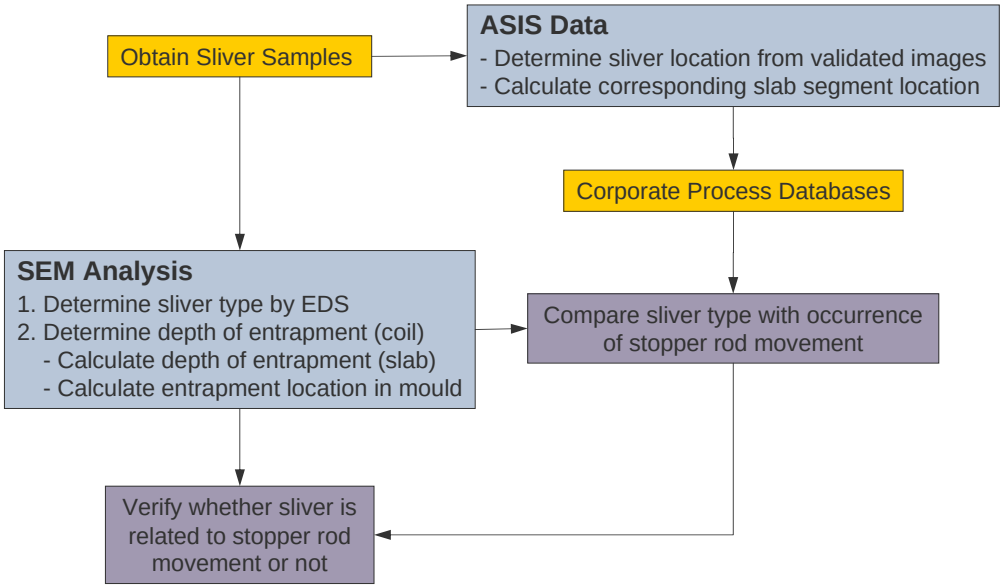
To correlate the change of stopper rod position with sliver defects on ULC steel coils by analyzing:

- Validated ASIS™ images of slivers after downstream processing
- SEM Images of cross-sections of sliver samples
- Process data from corporate databases

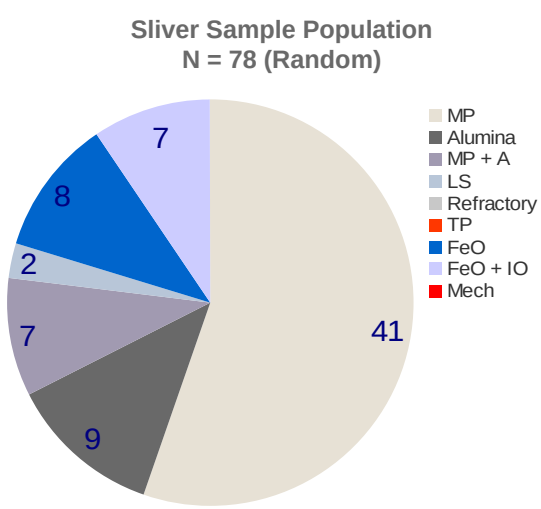
Computational Models:

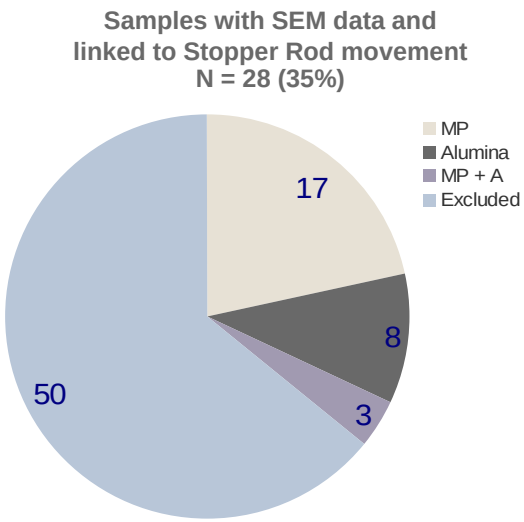
•Develop accurate transient models of 3-D flow to simulate specific measured mold events, in order to quantify conditions for defect formation

Methodology



Sliver Sample Population

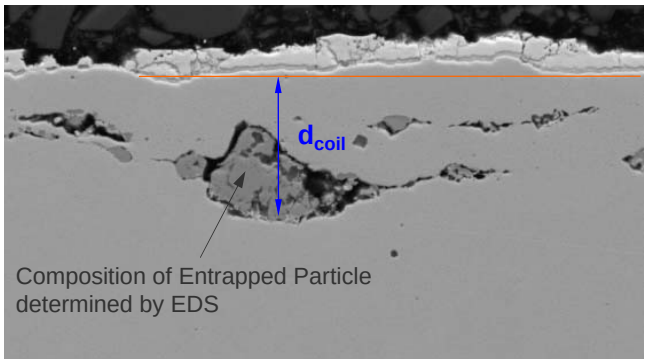




Sliver samples were obtained from coils processed at Dofasco's HDG Lines & analyzed at Global R&D Hamilton

Estimation of Depth of Particle Entrapment

Typical Sliver SEM Micrograph



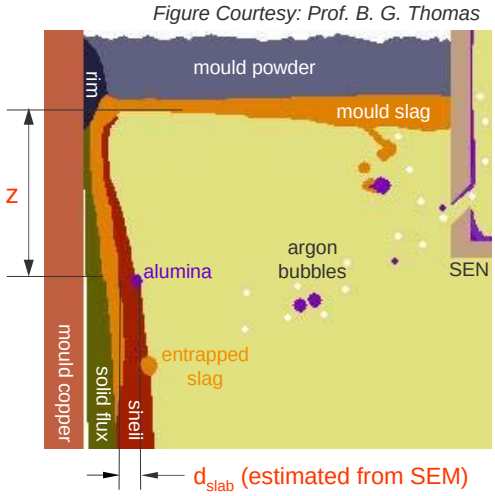
d_{slab} = Depth of entrapment in slab (mm)
T_{coil} = Coil thickness (mm)
d_{coil} = Depth of entrapment in coil (mm)
T_{slab} = Slab thickness (mm)
T_{scale} = Scale thickness (mm)
Assumed to form in Hot Mill Reheat Furnace based on Dofasco's historical data

Depth of entrapment in slab after casting is given by: (in mm)

$$d_{slab} = \frac{T_{slab} * d_{coil}}{T_{coil}} + T_{scale}$$

Estimation of Particle Entrapment Location in Mould

Figure Courtesy: Prof. B. G. Thomas



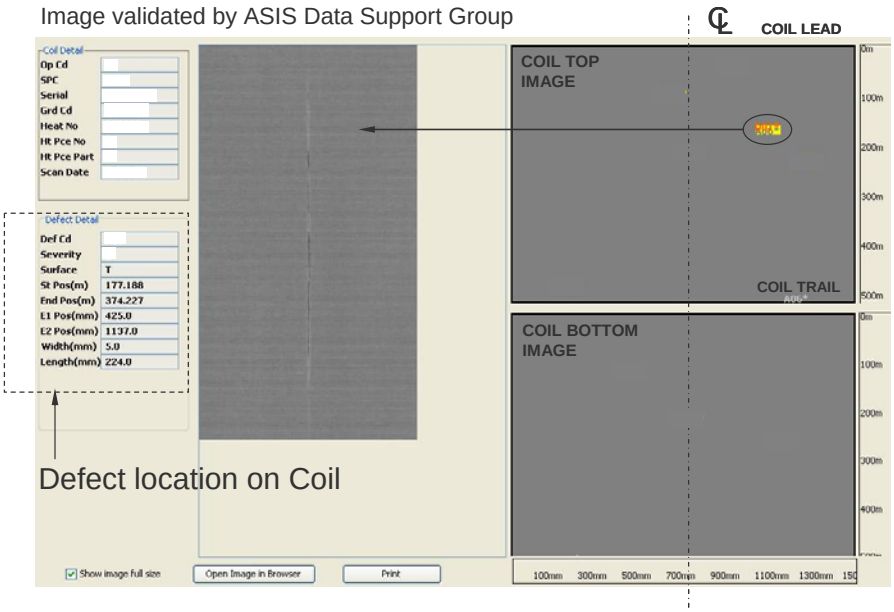
z = Distance of entrapment from meniscus (mm)
d_{slab} = Depth of entrapment in slab (mm) → from SEM
V_c = Casting speed (mm/min) → from Process Database
k = solidification constant (mm/min$^{0.5}$) → from CON1D

Location of entrapment in mould is given by: (in mm)

$$z = \frac{V_C * d_{slab}^2}{k^2}$$

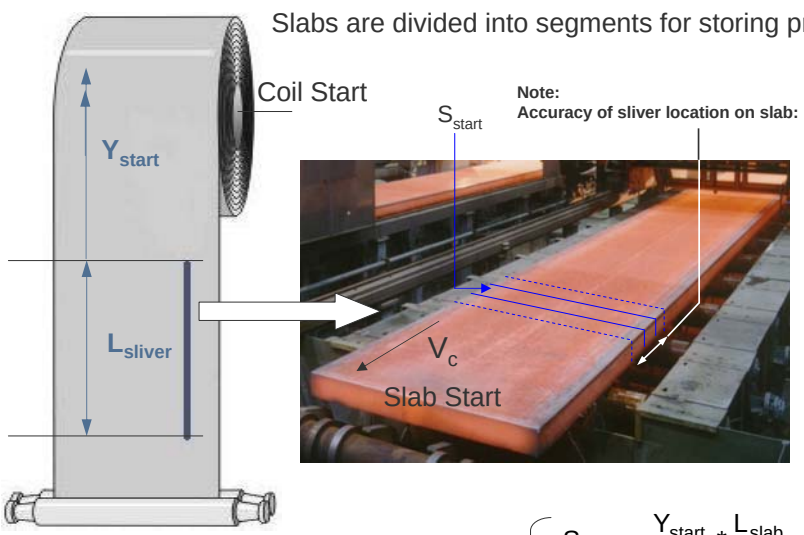
Example of ASIS™ Image

Image validated by ASIS Data Support Group



Estimation of Defective Slab Segment

Slabs are divided into segments for storing process information in Level II



Note:
Accuracy of sliver location on slab: ± 1 slab segment

L_{coil} = Coil length (m)

Y_{start} = Sliver start position from Coil Start (m)

L_{sliver} = Sliver length (m)

L_{slab} = Slab length (m)

S_{start} = Defect slab segment (start)

S_{end} = Defect slab segment (end)

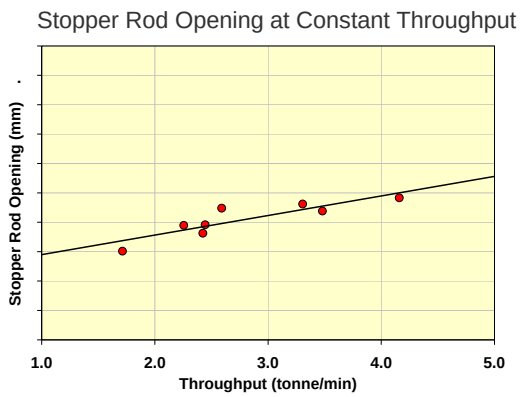
ΔL = Slab segment length (m)

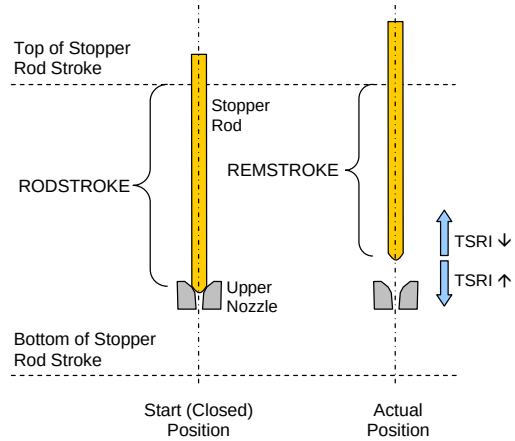
Start and End Slab Segments "containing" the sliver given by:

$$S_{start} = \frac{Y_{start}}{L_{coil}} * \frac{L_{slab}}{\Delta L}$$

$$S_{end} = \frac{Y_{start} + L_{sliver}}{L_{coil}} * \frac{L_{slab}}{\Delta L}$$

Definition of Stopper Rod Index

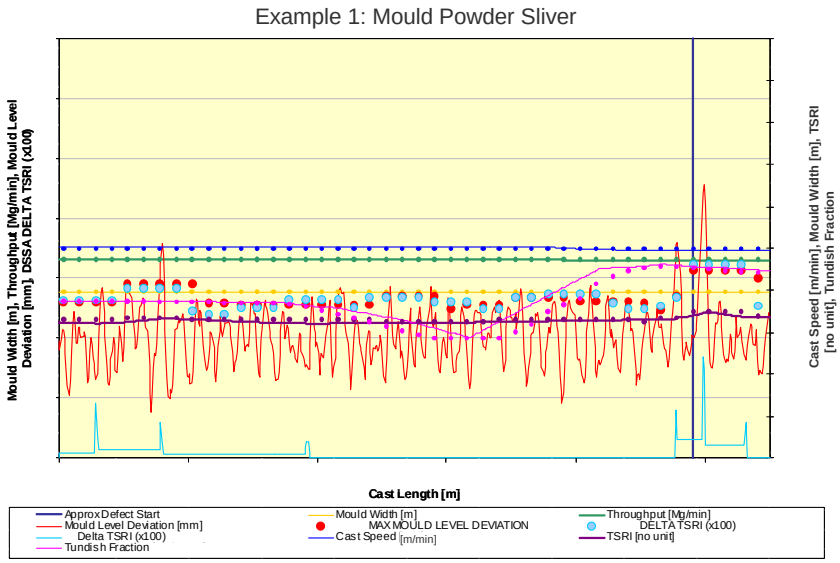


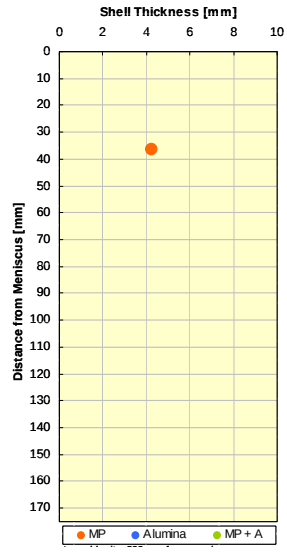


$$\text{TSRI} = \frac{\text{REMSTROKE}}{\text{RODSTROKE}}$$

$$\Delta\text{TSRI} = \left|\text{TSRI}_{t-1} - \text{TSRI}_t\right|$$

Process Data & Defect Entrapment

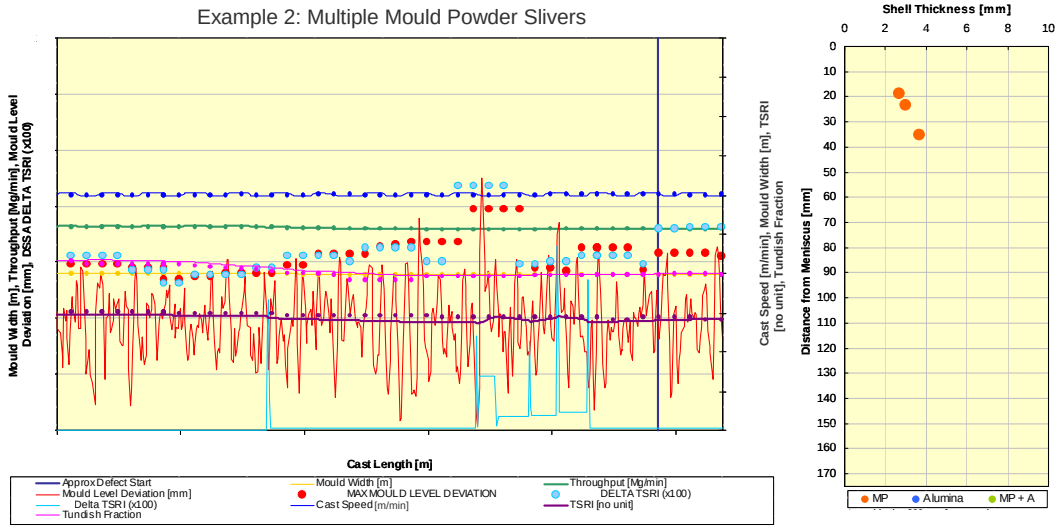




A stopper rod movement caused spikes in mould level and subsequent mould powder entrapment.

Process Data & Defect Entrapment

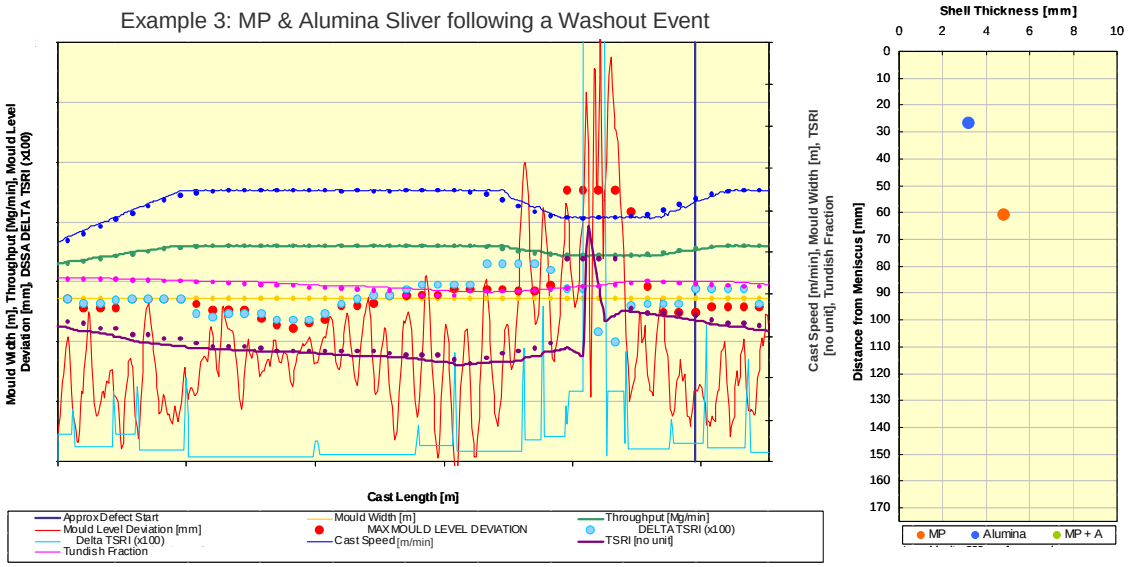
Example 2: Multiple Mould Powder Slivers



Multiple stopper rod movements caused several mould powder entrapments.

Process Data & Defect Entrapment

Example 3: MP & Alumina Sliver following a Washout Event



A “wash-out” event caused mould powder & inclusion entrapments.

Summary

- Sliver formation on ULC coils for has been correlated with stopper rod movement at No. 1 CC under constant throughput casting conditions
- In some cases, a stopper rod movement was associated with mould level fluctuation under constant throughput conditions
  - Both mould powder and alumina type slivers were associated with stopper rod movement in above cases
- In other cases, slivers were associated with stopper rod movement + factors such as, speed change etc.

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