DEFECTS
ON & IN SLABS

Oh my GOD!
Ugly Cracks!!
Content

- Classification of defects
  - Type
  - Size
- Factors influencing the cracking susceptibility.
  - Material properties
  - External factors
- Short solidification theory
- Calculation of shell thickness
- Crack types & causes
- Actions to avoid cracking
Classification

Defect types

✓ Shape defects      kod 30-39
✓ Surface defects    kod 40-49
✓ Other actions      kod 50-59
✓ Internal defects   kod 60-69

Size

① Minor, relatively harmless defects (0-3mm)
② Semi deep defects  (4-11mm; treatment necessary)
③ Deep defects       (12-20mm; Heavy treatment)
④ Very deep defects  (> 20mm: could be scrap)
Factors influencing the cracking susceptibility.

- Material properties
  - Steel analysis
  - Temperature properties

- External factors causing tension in the strand
  - Mechanical
  - Thermal
Influence of analyses

- Low carbon, low alloy steel has low susceptibility for cracking.

- Steel with carbon ~0.08-0.14% is very susceptible to surface cracks.

- High carbon, high alloy steel has high susceptibility to internal defects.

- S, P, V, Nb normally increases the crack susceptibility.
Properties at different temperatures

The ductility varies during the solidification and cooling period.

- **AlN, BN, Nb(C,N)**
- **Cu, Sn, Sb**
- **(Fe, Mn)S-O**

**Diagram:**

- **Ductility**
- **Temperature (Ts):** 600, 900, 1200, 1500
Solidification theory

$Q = \frac{dq}{dt} = \frac{-k}{dx} dT$

Internal defects are created when the two-phase region is exposed to tensions exceeding the strength of the material.
Shell growth: 1

It is possible to calculate the approximate shell thickness with the following formula:

\[ s = Cs \sqrt{\frac{l}{V_c}} \]

- \( s \) = shell thickness [mm]
- \( Cs \) = solidification constant (~25-27)
- \( l \) = distance from meniscus [m]
- \( V_c \) = casting speed [m/min]

This relatively simple formula gives you a rough idea of the shell thickness. You must try to find out the Cs for different conditions.
If you want to know where in the machine a defect is created you can rearrange the formula as below:

\[ l = V_c \times \left( \frac{s}{C_s} \right)^2 \]

The length is not exact, but it will give you a hint where to search for problems in your caster.
External faktors

MECHANICAL
- Taper errors
- Bad mould lubrication
- Badly aligned rolls/segments
- Skidding rolls
- Strand unbending

THERMAL
- Uneven cooling
- Fast reheating
- To soft cooling
- To hard cooling
1. Longitudinal narrow face cracks
2. Longitudinal cracks
3. Corner cracks
4. Transversal cracks
5. Diagonal cracks
Longitudinal narrow face cracks

- Causes:
  - Bulging of broad side
  - Pressing of narrow face
  - Overcooling and reheating of the narrow face
Longitudinal cracks

- **Causes:**
  - Bulging of broad sides down in the machine
    - Bearing- or roll damage, misaligned rolls and/or segments.
    - Insufficient cooling

- Can extend to slab surface and cause a breakout
Corner cracks

Causes:

- Narrow face bulging
  - Insufficient taper
  - Insufficient cooling
- Reheating

Can extend to slab surface and cause a breakout
Corner cracks
Transversal cracks

**Causes:**
- Bulging
- Depression of shell
  - Roll alignment
- Unbending of the strand
- To high pressure from driven rolls
Transversal cracks
Diagonal cracks

”Triple-point cracks”

Causes:

- Sensitive analyses
- C-content >0.15 %
- Low Mn/S ratio
- Bulging
Surface cracks

1. Transversal cracks
2. Transversal corner cracks
3. Longitudional cracks
4. Short Longitudional cracks
5. Longitudional corner cracks
6. Star/net cracks
Transversal cracks

Causes:

- Large temperature gradients in the cooling zone.
- Straightening at low-ductile temp.
- Misaligned/damaged/skidding rolls can be the cause.

The cracks are normally situated in oscillation marks.
Transversal corner cracks

Causes:
- Large temperature gradients in the cooling zone.
- Straightening at low-ductile temp.

The cracks are normally situated in oscillation marks
Longitudional cracks

- Long, deep "mid face cracks"

Causes:
- Uneven shell growth due to bad mould powder function.
- Tensions generated in the mould ie. bad lubrication, scratches, insufficient taper.
Short Longitudional cracks

Causes:

- High casting temperature => thin shell.
- Uneven shell growth.
Longitudinal corner cracks

- Causes:
  - Uneven corner cooling.
  - Bulging below the mould.
  - Due to insufficient narrow face cooling and/or taper

- This type of crack can some time cause severe breakouts.
Star/net cracks

Cause:

- Cupper pick-up from the mould due to bad powder function causes "hot shortness". This is cupper entrained in the grain boundaries that cause low ductility => cracks.
Countermeasures

- Avoid tension in problem areas.
  - Temperature & analysis
- Good steelmaking practice => less casting problems => better quality.
- Continuous supervision of the mould area.
- Always keep the casters in top condition.
  - Mould conditions
  - Segment/roll alignment
  - Secondary cooling