Inter Stand Cooling in Hot Strip Mill
ISC Motivation

Reach the desired (target) Exit Rolling Temperature for the whole product mix

Keeping the constant temperature lengthwise (Elimination of skid marks and other temperature inhomogenities)

Increase of the productivity of the mill
Conditions for proper function of ISC

**Hardware** – Efficient cooling headers, water system

**Software** – Control system of ISC working either within Level 2 or separately
Demands on Cooling Headers

Sufficient Cooling Power (HTC)

Easy flow rate control

Long service life time

Easy maintenance
Investigation of cooling headers
Laboratory stand
Heat transfer coefficient

\[ HTC = f( T, x, y ) \]
Computer simulation of cooling abilities

Temperature [°C]

No cooling - Average
No cooling - Surface
No cooling - Center
Cooling - Average
Cooling - Surface
Cooling - Center

92°C
Headers with conical nozzles
Headers with nozzles (Solid Jet)
Designed upper cooling headers with conical nozzles
Control system of ISC

a) In existing Level 2, working on process computer

b) Independent control system working on separate computer
Scheme of the control system ISC

SET UP – ISC

Long term adaptation

Short term adaptation

V-Controller

T-Controller

Force

Torgue

Speed

Existing Level 2

PYRO 1

PYRO 2

strip

Roughing mill

Finishing mill

Force Torgue Speed
Setup of ISC

<table>
<thead>
<tr>
<th>Strip Length</th>
<th>Temperature (°C)</th>
<th>Flow rate (l/s)</th>
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</thead>
<tbody>
<tr>
<td>0.00</td>
<td>9.56</td>
<td>0.00</td>
</tr>
<tr>
<td>0.16</td>
<td>10.00</td>
<td>0.16</td>
</tr>
<tr>
<td>0.32</td>
<td>10.40</td>
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<tr>
<td>0.48</td>
<td>10.88</td>
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<tr>
<td>0.64</td>
<td></td>
<td>0.64</td>
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<tr>
<td>0.80</td>
<td></td>
<td>0.80</td>
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<tr>
<td>0.96</td>
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<td>0.96</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Temperature behind RM</th>
<th>Target exit Temperature</th>
<th>Exit temperature without cooling</th>
<th>Exit temperature with maximum cooling</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.00</td>
<td>4.00</td>
<td>0.00</td>
<td>0.00</td>
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<tr>
<td>4.00</td>
<td>2.00</td>
<td>0.16</td>
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<td>0.00</td>
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Pyro behind RM
Pyro behind FM
Practical Experience

(2000 mm hot strip mill)

1. Thin Strips
2. Thick Strips
3. Productivity
Thin strips (thickness 3 mm)

Behind RM

Without cooling

Full cooling

Target Temperature

Measured Temperature

Target Temperature +5°C
Thin strips (thickness 2.5 mm)

<table>
<thead>
<tr>
<th>Strip Relative Length (mm)</th>
<th>Exit Rolling Temperature (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>810</td>
<td>820</td>
</tr>
<tr>
<td>830</td>
<td>840</td>
</tr>
<tr>
<td>850</td>
<td>860</td>
</tr>
<tr>
<td>870</td>
<td>880</td>
</tr>
</tbody>
</table>

- **Computed ERT without cooling**
- **Target Temperature**
  - + 5°C
  - - 5°C
- **Target Tolerance (+10°C)**
- **Target Tolerance (-10°C)**
- **Measured ERT**
- **Computed ERT with max cooling**
Thick strips (thickness 16 mm)

Target Temperature

+10-12°C

Measured Temperature
Thick strips (thickness 16 mm)

Target Temperature: +10-12°C
Increase of productivity
Velocity 14 m/s (2mm strip)
Increase of productivity
Velocity 17.4 m/s (2mm strip)
Increase of productivity
Velocity 21 m/s (2mm strip)

+ 10°C
Comparison of cooling power (2mm strip)

Velocity 14 m/s  Velocity 21 m/s
Problems

Phase transformation during rolling:

Due to phase transformation an additional heat is generated, that depends on cooling rate, deformation and chemical composition of the steel. It is extremly complicated to reach the temperature tolerance in some steels rolled in party ferritic region.

Strong skidmarks (old type furnaces):

Temperature waves greater than 30°C can be eliminated but control range is considerably reduced.

Temperature waves greater than 40°C skidmarks cannot be fully removed especially in thick strips.
Recapitulation

Optimum solution of Cooling headers:

Nozzles with conical or flat beam

Effects of controlled ISC:

In thin strips (thickness less than 4mm) deviation +/- 7 °C
In thick strips (thicker than 10mm) deviation +/- 12 °C
Increase of rolling velocity in thin strips 30%