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Roll Cooling in Novelis Aluminum Hot and Cold Rolling Mills

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Acknowledgement: The work of many former and current colleagues in Alcan and Novelis is presented here

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Overview

Objectives of Roll Cooling

Roll Cooling Systems and Spray Nozzles

Coolant Types

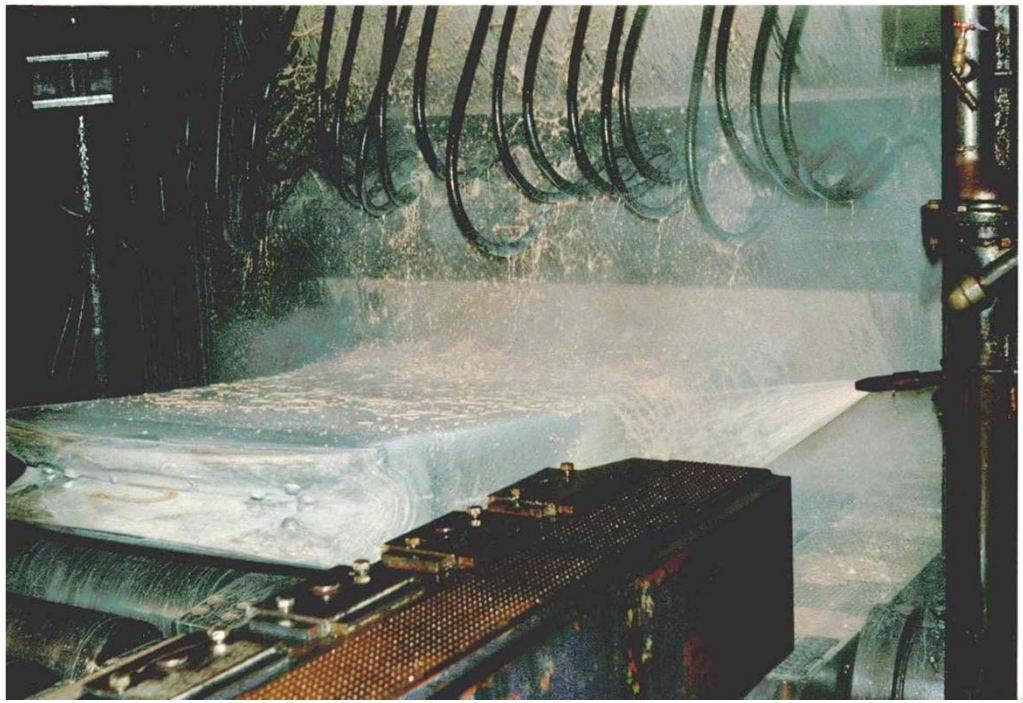
Roll cooling measurements

‘Footprint’ Roll Cooling Design Model

Design guidelines

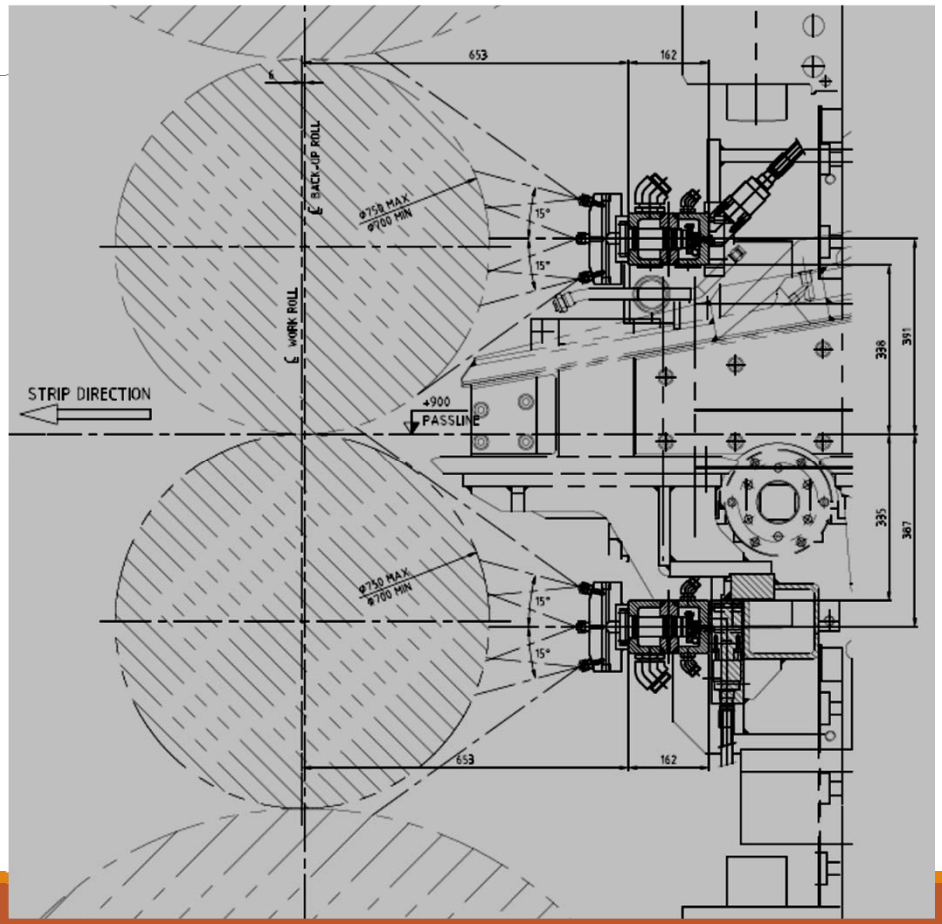
Objectives of Roll Cooling

- Reduce friction and wear
  - Roll force, Surface quality, Refusals
- Remove excess heat
  - Avoid damage to roll
- Control thermal crown on roll
  - Strip thickness profile and flatness
- Wash away wear debris



Roll Cooling Systems

- Several rows of spray nozzles, spaced 1-3inches apart across the width of the roll
- Valves switch nozzles individually or in zones to selectively cool the roll



Spray Nozzles

- Nozzles deliver spray with a defined flow rate and geometry
- Two main types are used
  - Flat spray – narrow elliptical pattern
  - Full cone – circular pattern

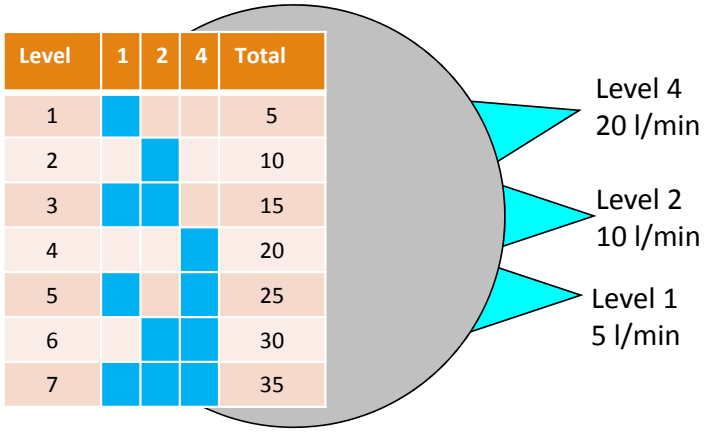
Flat spray nozzle
(Pictures: Spraying Systems Company)

Full cone nozzle
(Pictures: Lechler)

Valves and Cooling Control

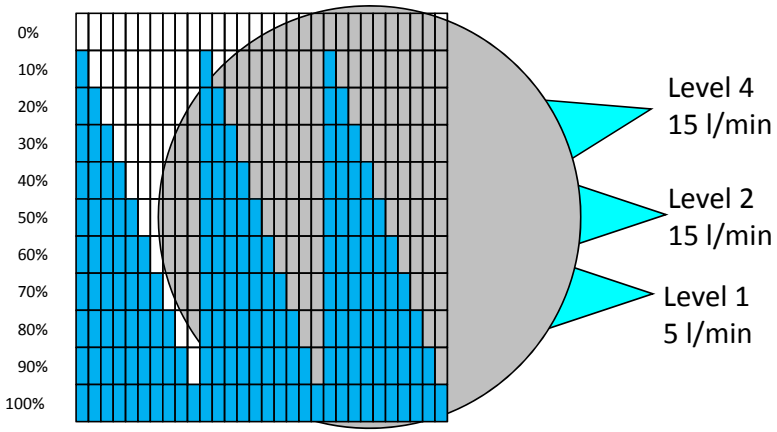
- Control the level and distribution of cooling on roll
- Pulse or Level control strategies

Mill coolant valves
(Picture: Primetals Technologies)



Level	1	2	4	Total
1	■			5
2		■		10
3	■	■		15
4			■	20
5	■		■	25
6		■	■	30
7	■	■	■	35

Level control

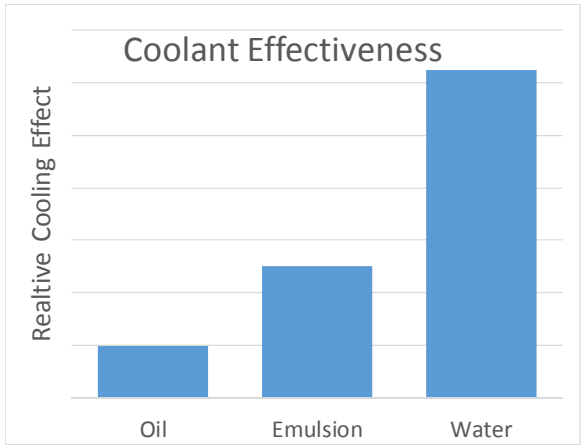


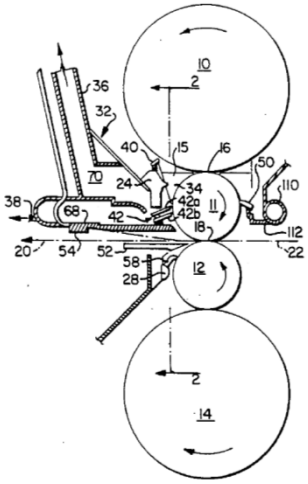
Pulse control

Aluminum Rolling Coolants

- Hot rolling emulsion
  - Naphthenic or paraffinic mineral oils
  - Emulsifiers (metal and amine soaps and/or nonionic surfactants)
  - Load-bearing additives (fatty acid, alcohol, ester)
  - Other additives (anti-oxidant, anti-corrosion, biocide,…)
  - Water
- Cold rolling oil
  - Base oil (hydrodynamic lubrication)
  - Additives
- Novelis patented technology for water-based roll cooling

Process	Metal temperature	Metal thickness	Coolant	Lubricant
Hot rolling	300-500C	2-500mm	Emulsion	
Cold rolling	20-200C	<0.1-4mm	Mineral oil	
			Water	Mineral oil

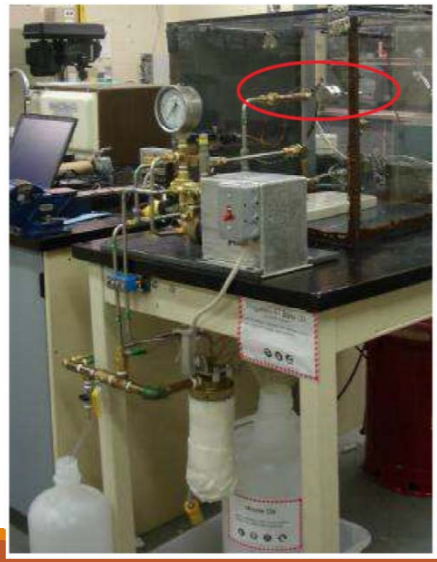




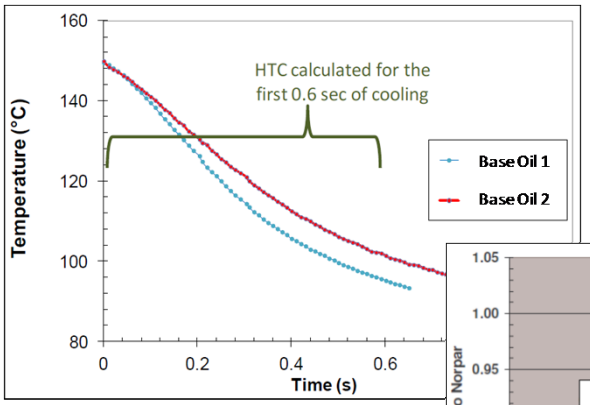
Roll cooling sprays within a coolant containment box (CCB) at exit side; Coolant drainage inside the CCB and CCB is under vacuum

Coolant Effectiveness

- Relative measurement of cooling performance of different Cold Mill Lubricants
  - Heated aluminum block, instrumented with thermocouples, was cooled in a standard test using sprays of various lubricant oils
  - Measured up to 25% reduction in htc compared to normal paraffin

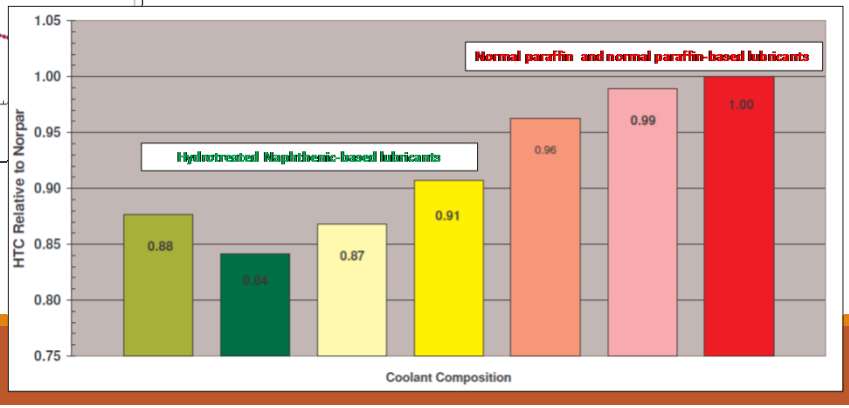


Lab rig for measuring cooling performance of lubricants



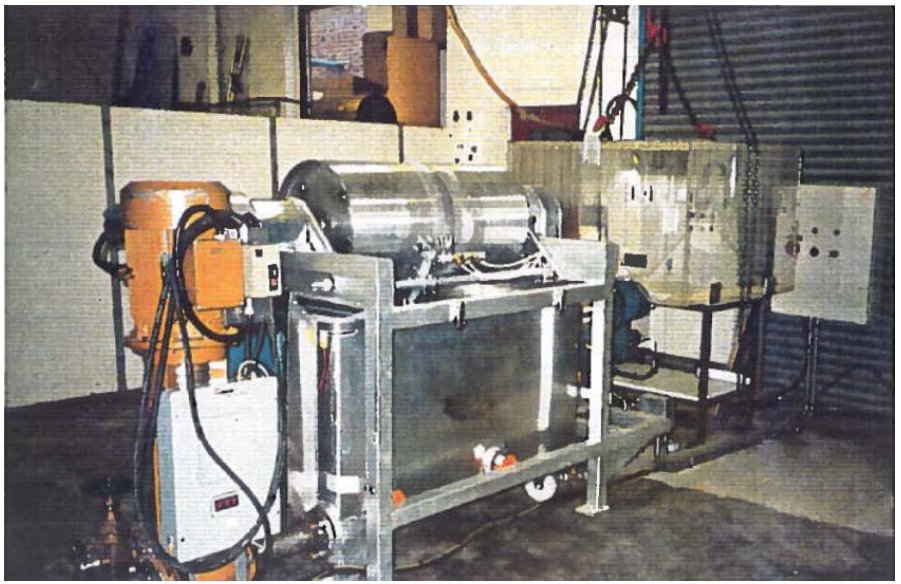
Cooling curves measured with two base oils

Cooling htc with normal paraffin and hydrotreated naphthenic-based oils



Cooling Measurements

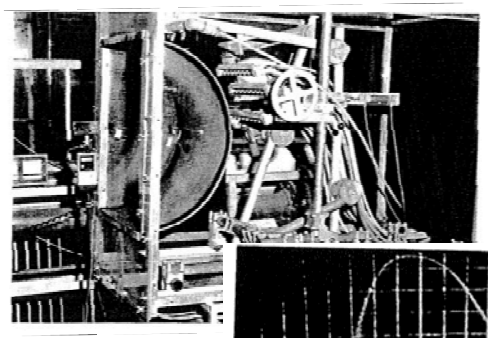
- Measurement of cooling effect of spray
- Heated rotating roll rig
  - Central section with cartridge heaters, instrumented with thermocouples, cooled by spray
- Measured the effects of flow rate, pressure, nozzle type, spray geometry, roll speed, coolant type
- More significant factors are extent of spray coverage area, flow rate and roll speed
- Correlations developed for design of cooling systems



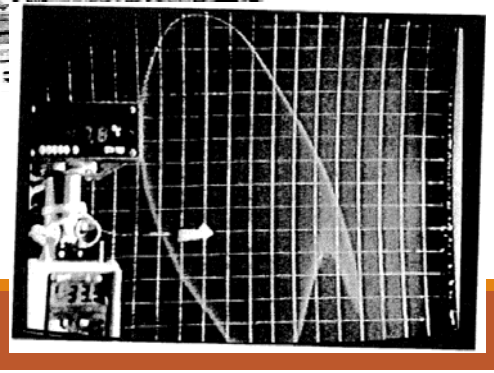
Rotating roll rig for roll cooling measurements

Cooling Distribution

- Measurement of cooling distribution by liquid crystal technique
  - An aluminum sheet, with the back surface painted black and with a film of liquid crystal coating, was initially cooled to uniform ambient temperature
  - Hot water sprays were impinged on the front surface. Lines of color change were video recorded then analysed to yield contour maps of htc value



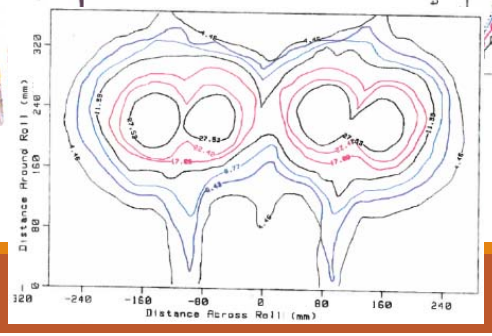
Liquid crystal rig



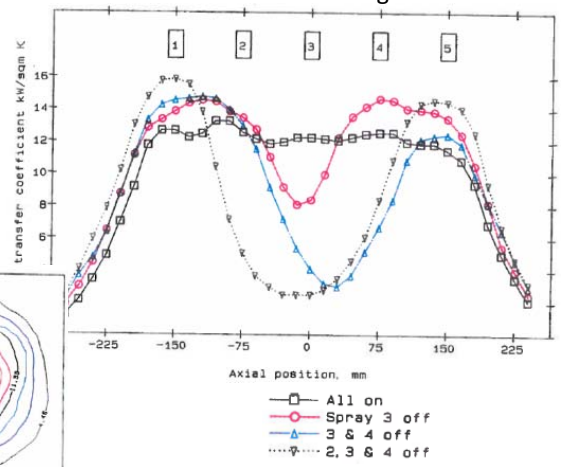
Isotherm on test sheet

Cone spray patterns viewed through Plexiglass

Htc contour map



Plots of circumferential average htc

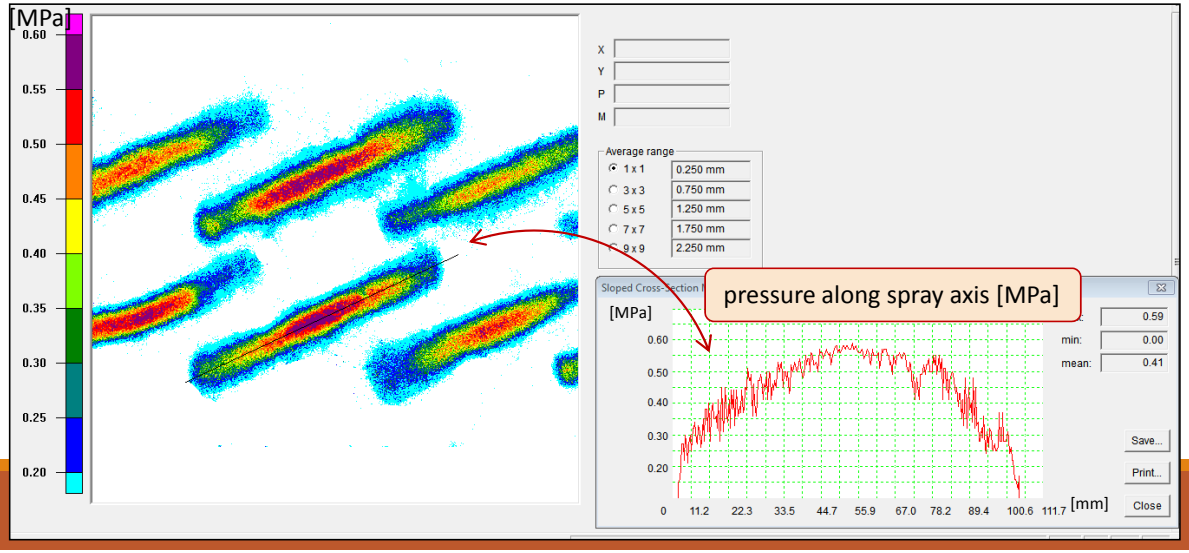


Spray Footprint Measurements

- Spray footprints measured with Fujifilm pressure-sensitive film
  - Film attached to an arc of mill roll circumference, where sprays impinge, and covered with ‘water-proof’ plastic sheet
  - Sprays are operated for 10 seconds and film color changes to red, depending on the pressure
  - Films can be scanned with Fuji analyser to determine the impingement pressure distribution
  - Measurement reveals blocked, misaligned or damaged nozzles etc

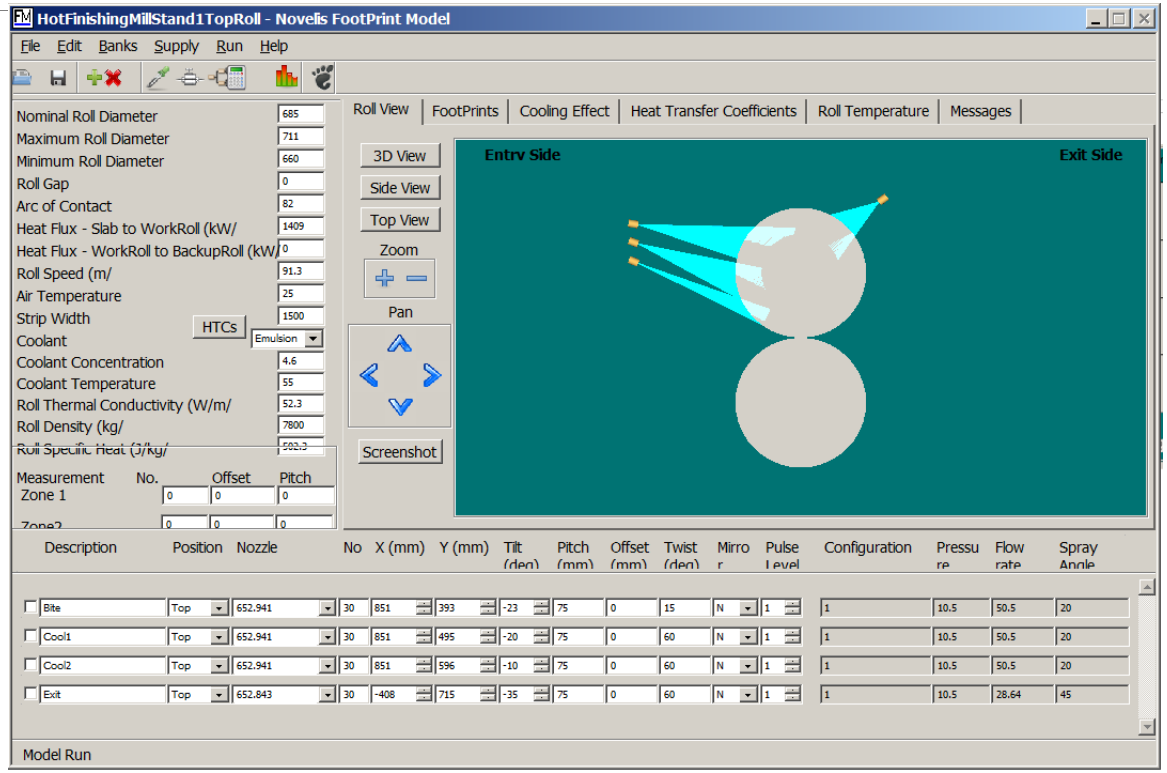
Mill roll wrapped with Fujifilm pressure sensitive film

Analysis of Fujifilm pressure footprints



Roll Cooling Design

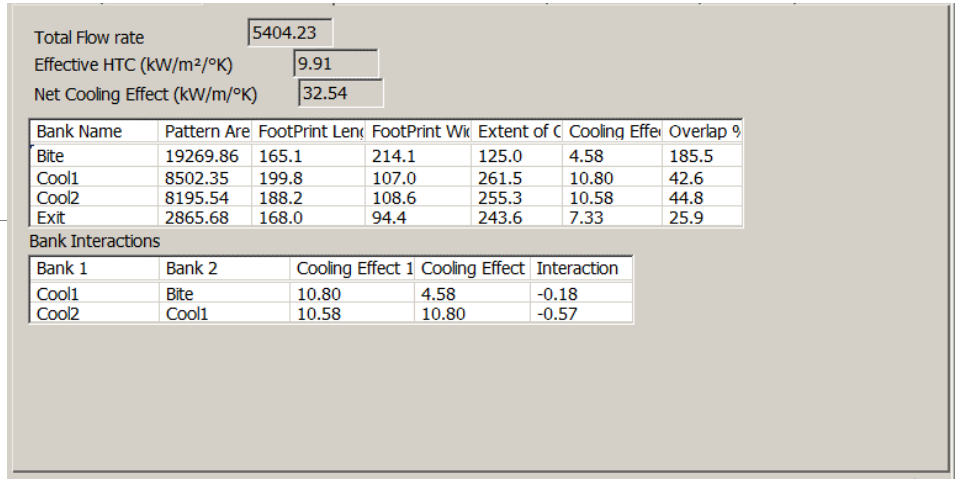
- Design model incorporates knowledge from roll cooling measurements
- Model input parameters:
  - Roll and spray bars
  - Nozzle types and flow characteristics
  - Valve characteristics
  - Coolant type
  - Strip and rolling



Interface for Footprint roll cooling design model

- Design guidelines
  - Large spray coverage on rolls and space spray bars around circumference
  - Cool exit side unless carryover is an issue
  - Position spray bars not too close to roll and aim near perpendicular to roll (sensitivity to roll diameter)
  - Target 10-50% spray overlap for full range of roll diameters

Cooling effect and spray overlap



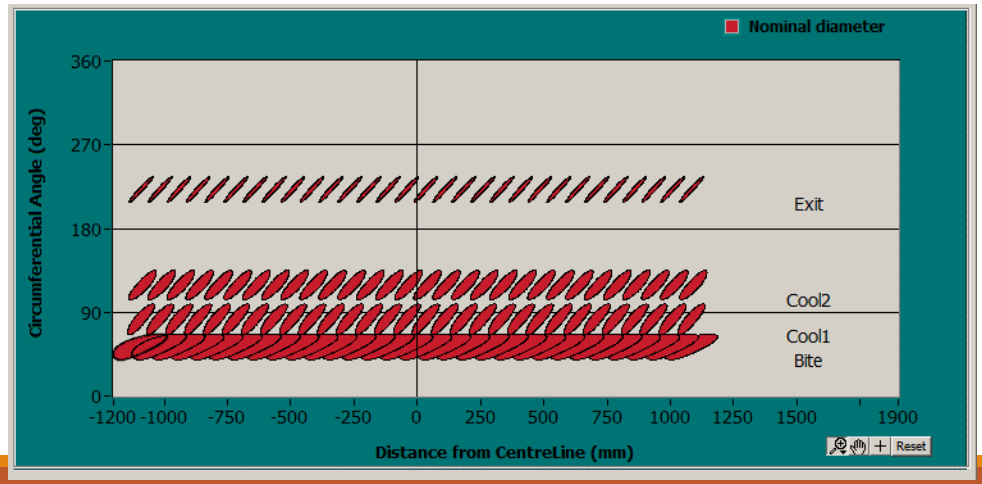
Total Flow rate	5404.23
Effective HTC (kW/m²/°K)	9.91
Net Cooling Effect (kW/m/°K)	32.54

Bank Name	Pattern Are	FootPrint Len	FootPrint Wi	Extent of C	Cooling Effe	Overlap %
Bite	19269.86	165.1	214.1	125.0	4.58	185.5
Cool1	8502.35	199.8	107.0	261.5	10.80	42.6
Cool2	8195.54	188.2	108.6	255.3	10.58	44.8
Exit	2865.68	168.0	94.4	243.6	7.33	25.9

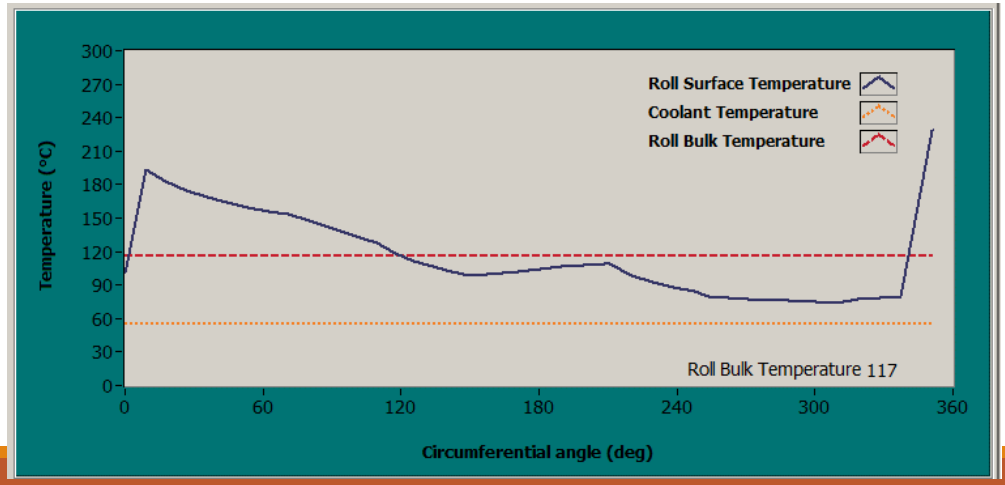
Bank Interactions

Bank 1	Bank 2	Cooling Effect 1	Cooling Effect	Interaction
Cool1	Bite	10.80	4.58	-0.18
Cool2	Cool1	10.58	10.80	-0.57

Spray footprint patterns



Roll temperature



SUMMARY

- Multiple functions of roll coolant
- Zoned application and controlled level of cooling
- Different coolant types
- Measurements for roll cooling design and process development

Thank you

Questions ?