

Flatness Prediction in Multi-pass Hot Rolling

- Gränges user case in VMAP2.

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- Independent research institute
- 190 Co-workers
- Main facilities in Luleå and Stockholm
- Customers all over the world
- Co-owned by the industry (80 %) and RISE (20 %)



Long traditions– The oldest part was funded 1921 (The Metallographic institute).

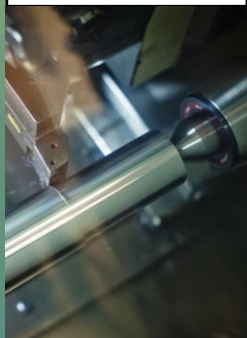
Research areas

Joining



Process optimization
Construction
Light materials
Weldability
Product development
Additive manufacturing

Machining



Method development
Modelling
Machinability
Tool wear
Material characterization

Heat treatment



Material influence
Material characterization
Process simulation
Properties after heat treatment

Mechanical properties



Custom made
Extreme environments
Material data for simulations
Fracture mechanics
Creep

Metal working



Rolling and forging
Process modelling
Online measuring
Piloting
Flatness, wear, oils dimensioning

Heating



Modelling process and temperature
Alternative fuels
Electricification
Online measuring
Pilot furnaces

Process monitoring



Sensor development for online monitoring
Optics and laser
Spectroscopy
Ultrasonics
LIBS, LUS
Data and signal analysis

VMAP Analytics concept

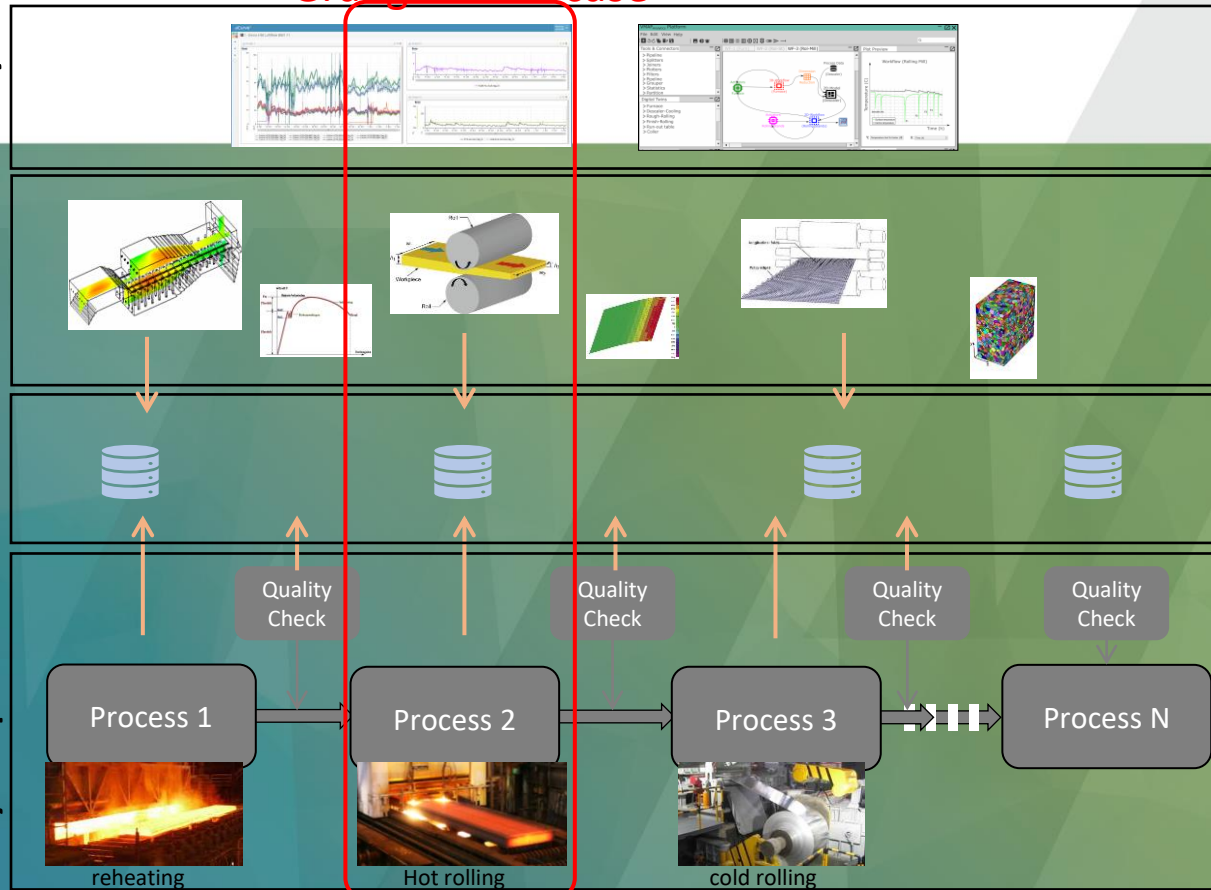
Gränges User case

Physical process

Data

Virtual process

Analytics



VMAP2

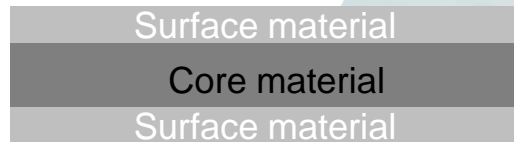
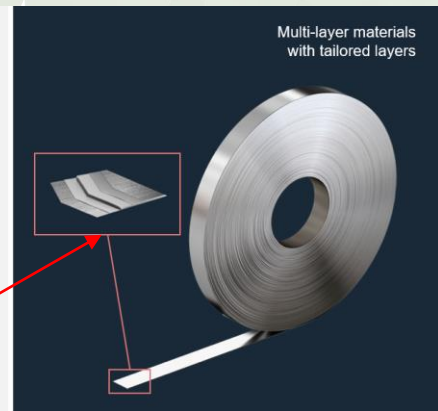
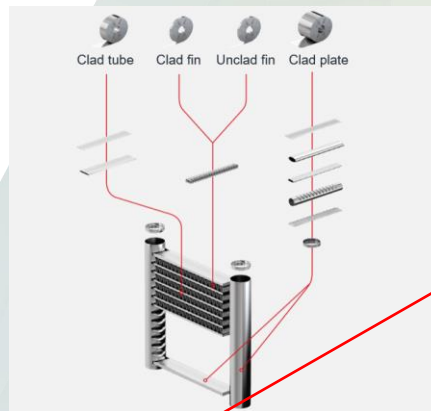
VMAP1

VMAP 1

- Standardized nomenclature
- Network of 40 companies (VMAP standards association)

Gränges usecase

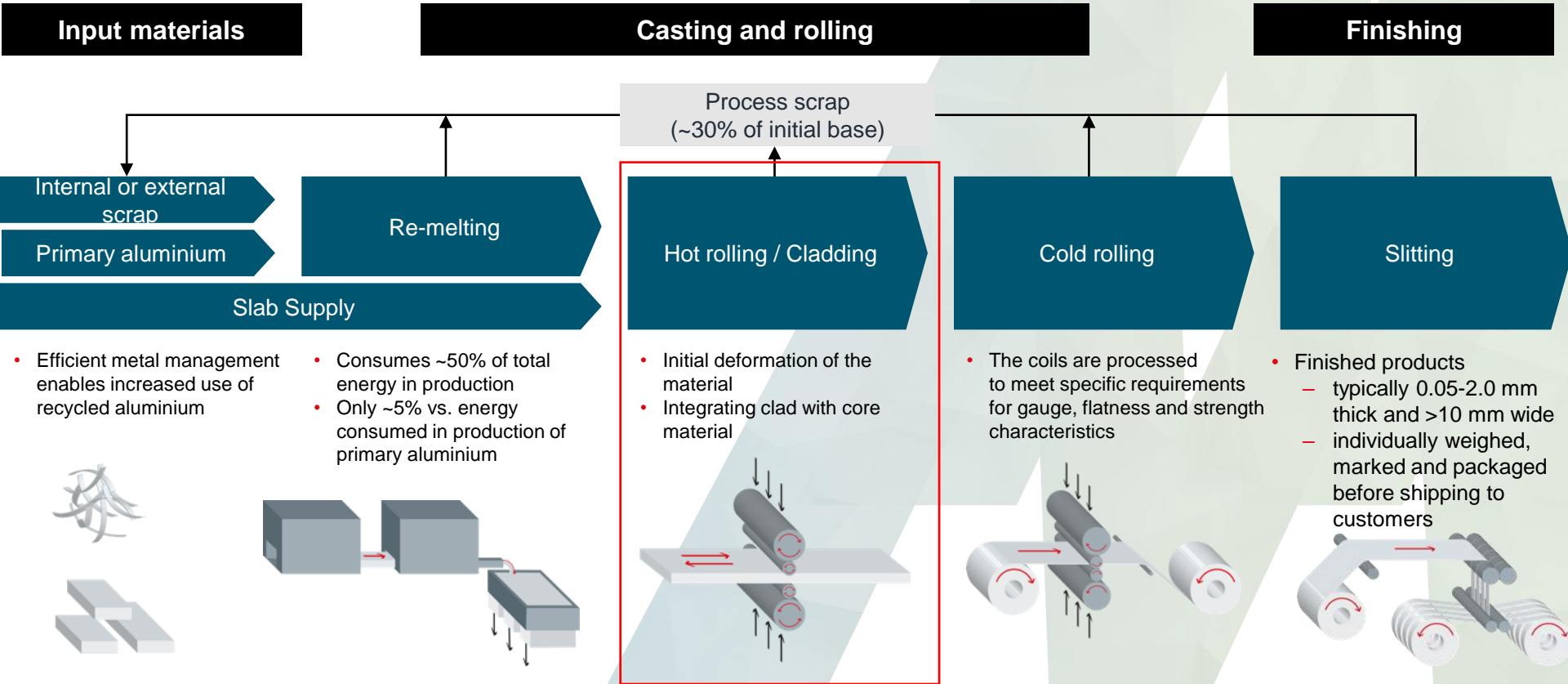
- Creates material for aluminium heat exchangers.
- Rolls long and thin strips of aluminium.
- Clad materials.
- 25% of the global market.
- 570 000 tonnes/year.



GRÄNGES

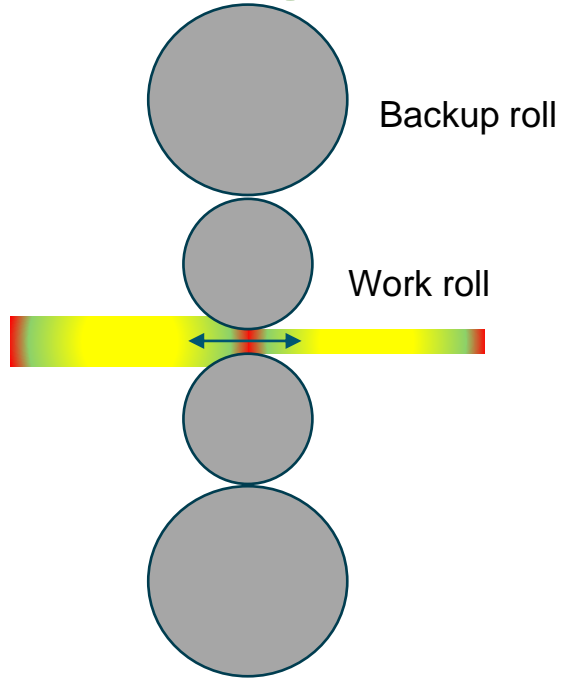
Main stages in the production process, Europe and Asia

Overview of the production process

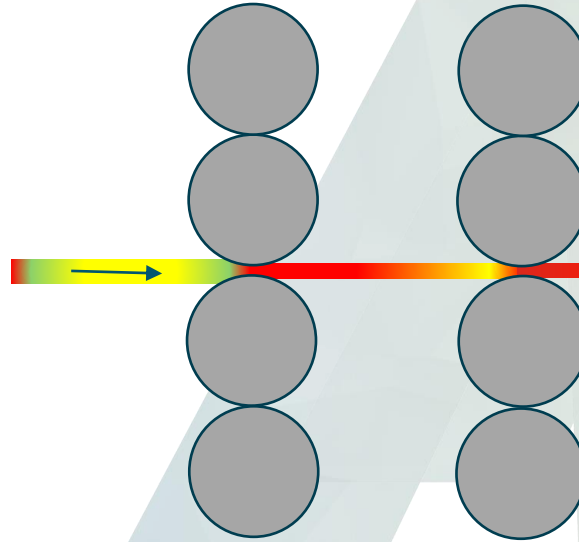


Hot Rolling process

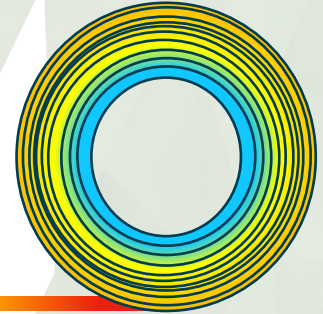
Reversing mill



Tandem mill



Coil box



Hot rolling process

Reversing mill

- Reduction from ~600 mm to ~18 mm
- Trimming operation
- Cooling
- From 25 and to 70 passes for clad materials.
- No temperature measurements.

Tandem mill

- Reduction to ~3 mm in 2 steps.
 - Cooling.
 - Tension.
 - High speeds
-
- Forces over 10 000 kN.
 - Roll bending – Uneven sheet profile.
 - Sheets ~600 m long.



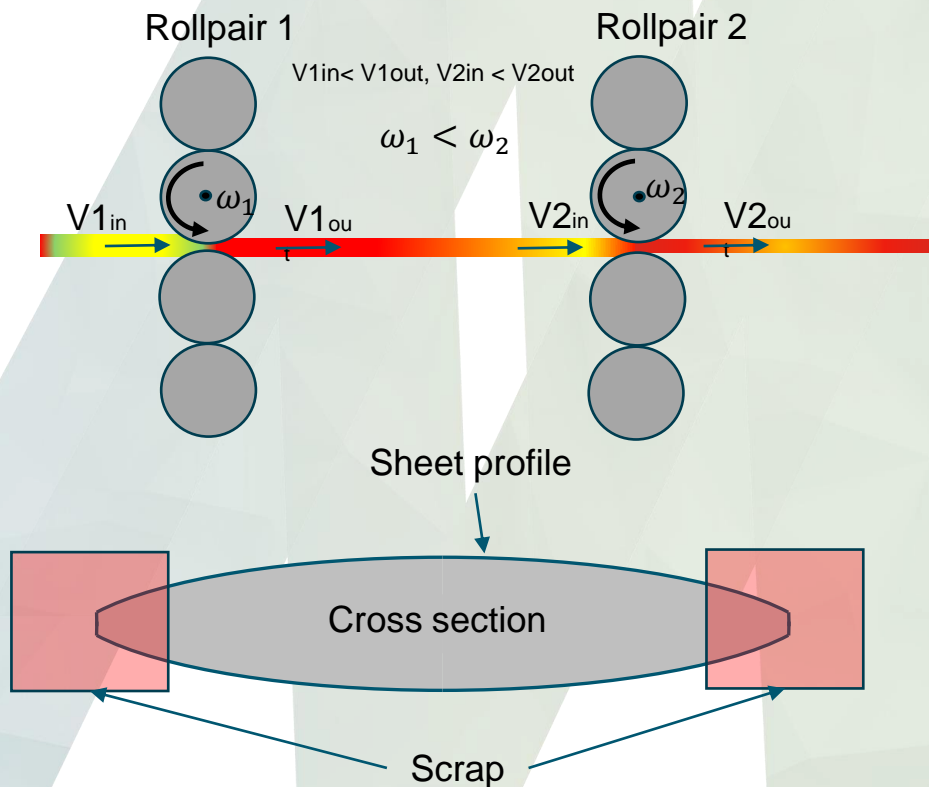
Hot rolling process

Reversing mill

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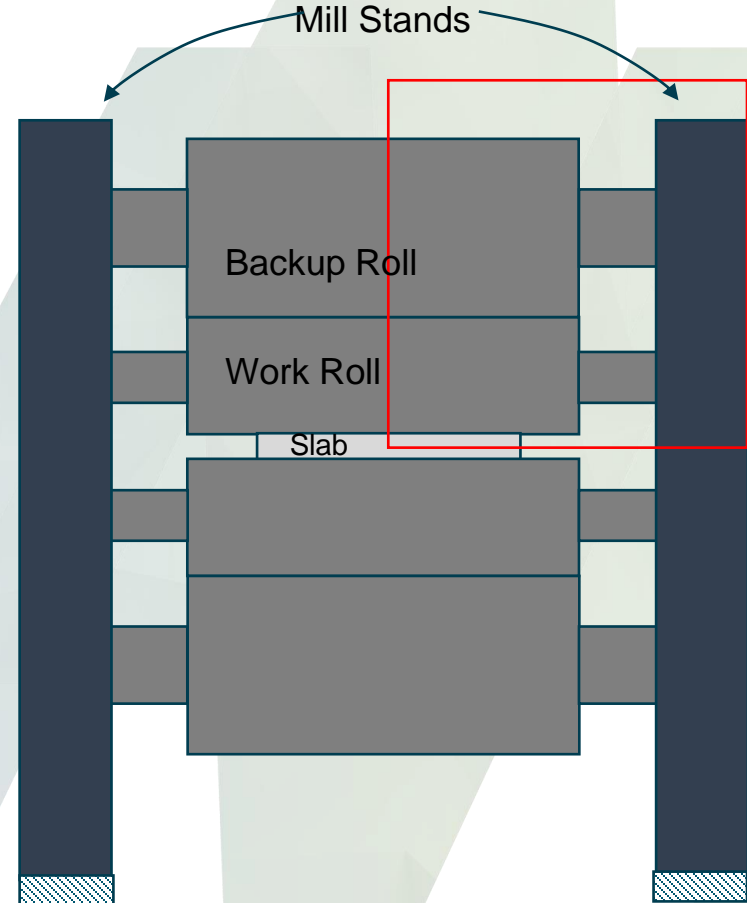


Summarization

- Unknown temperatures.
- Unknown sheet profiles.
- Unknown rollbending.
- Different speeds and strain rates.
- What happens at the early stages of the process will influence the end result!

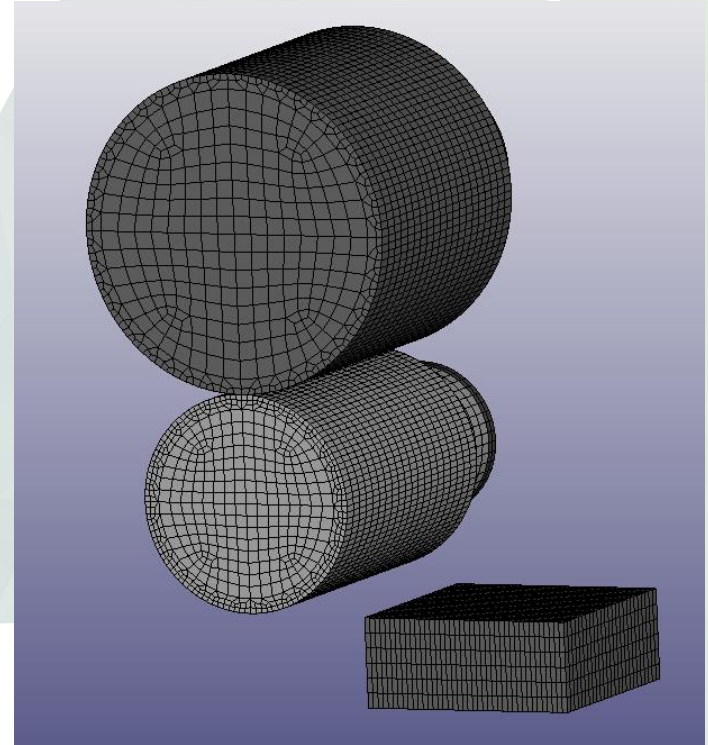
Modelling approach

- Large system with many elements.
 - Use quarter symmetry.
 - Only simulating a 5th of the total slab length
 - Hex elements.



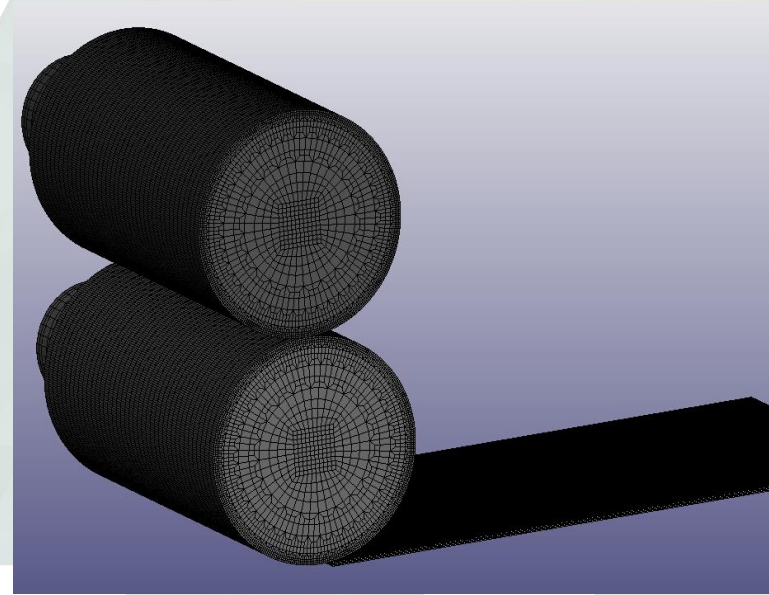
Modelling approach

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 - Hex elements.
- Reversing mill model has ~31k.



Modelling approach

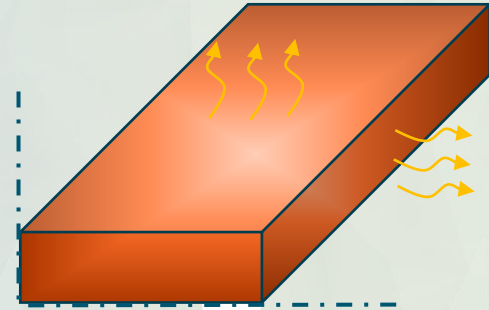
- Large system with many elements.
 - Use quarter symmetry.
 - Only simulating a 5th of the total slab length
 - Hex elements.
- Reversing mill model has ~31k elements.
- Tandem mill model has ~611k elements.
- Forming surface to surface contacts.



Modelling approach

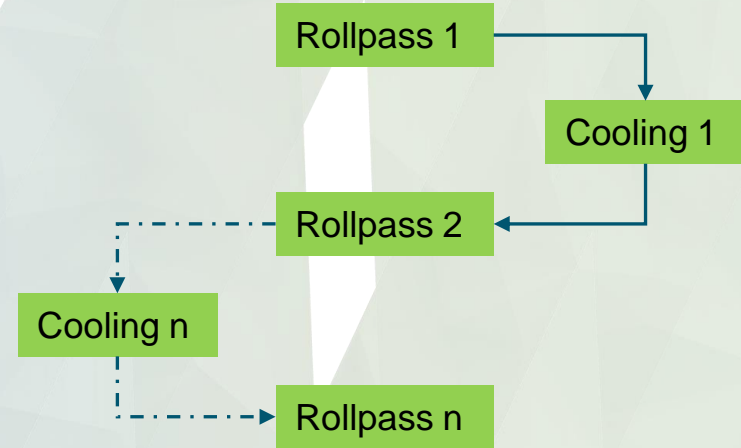
- Non existing temperature measurement.
 - Coupled thermomechanical analysis
 - Convection and radiation
 - Heat transfer to rolls
 - Cooling
 - Strain-rates from 0.1 to 20 1/s
 - Johnson-Cook material model!

Boundary Prescribed radiation set
Boundary Prescribed convection set
Boundary flux set for cooling

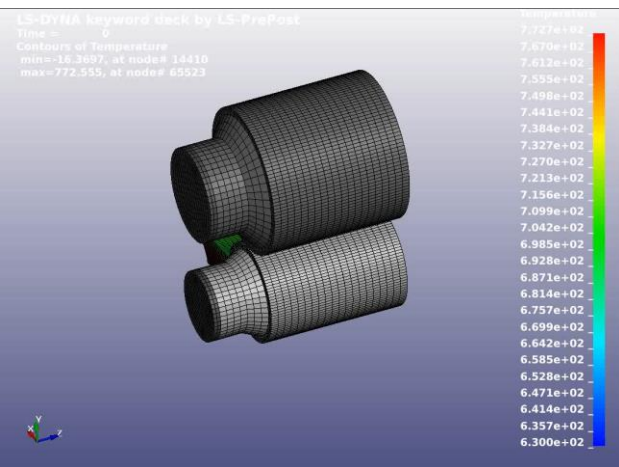


Modelling approach

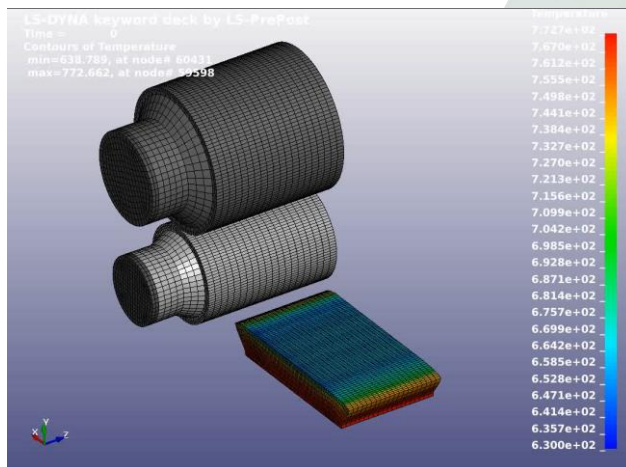
- One pass at a time.
 - Python is used to write parameter keywords and execute start commands.
 - Save and store data in a file system.
 - Use implicit_springback to generate dynain file with node positions, stress and temperature distribution for next pass.



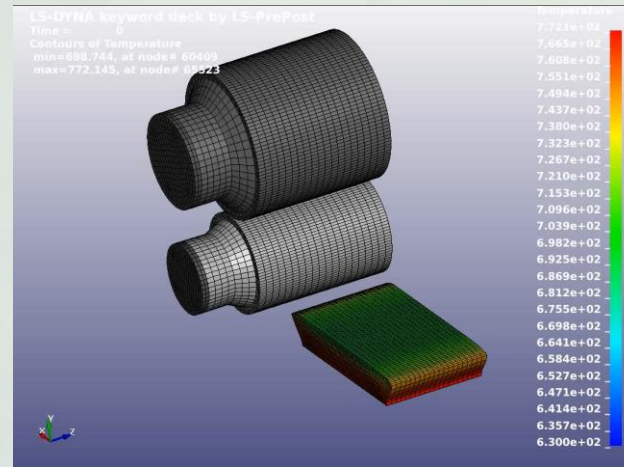
Modelling approach



Pass simulation n



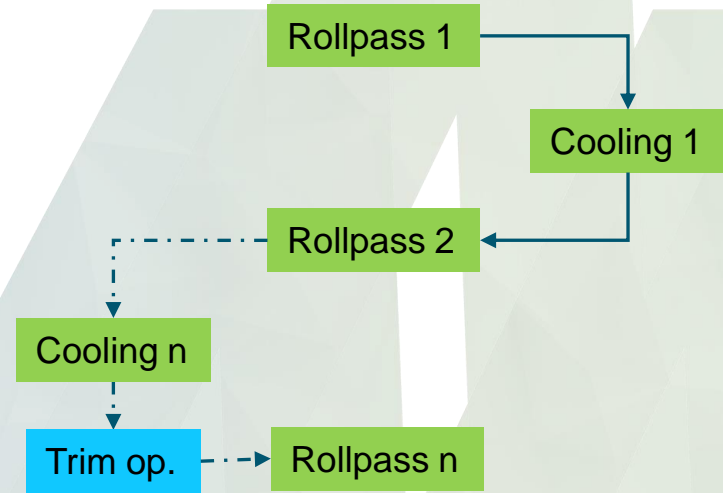
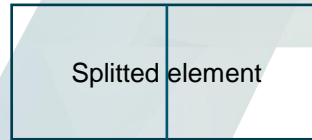
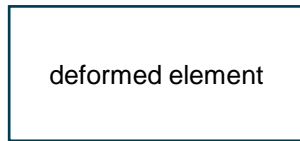
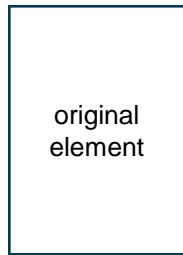
cooling simulation n



Pass simulation n+1

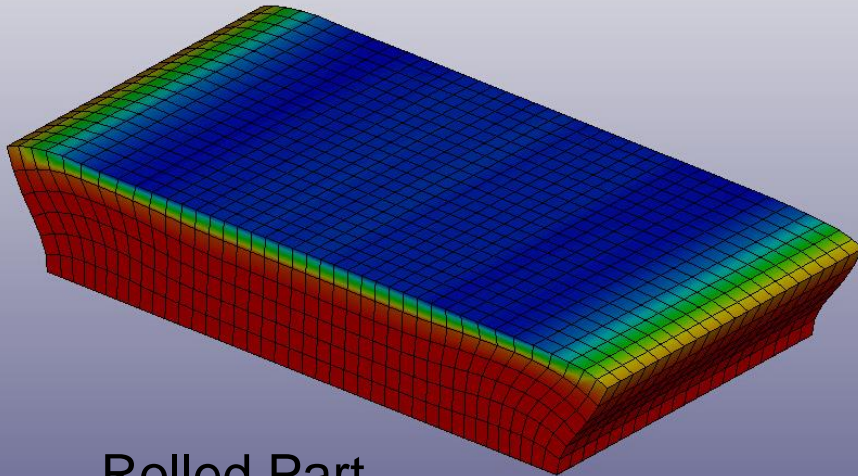
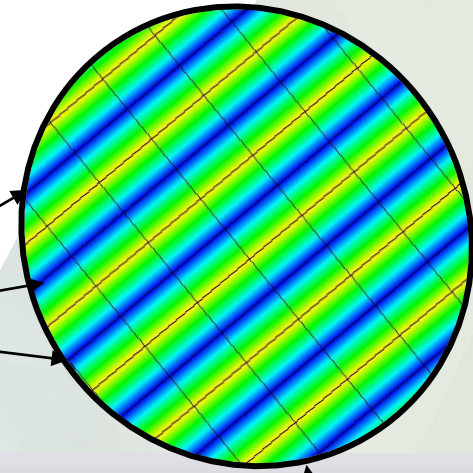
Modelling approach

- Mesh degradation.
 - Split mesh lengthwise or remesh if necessary.

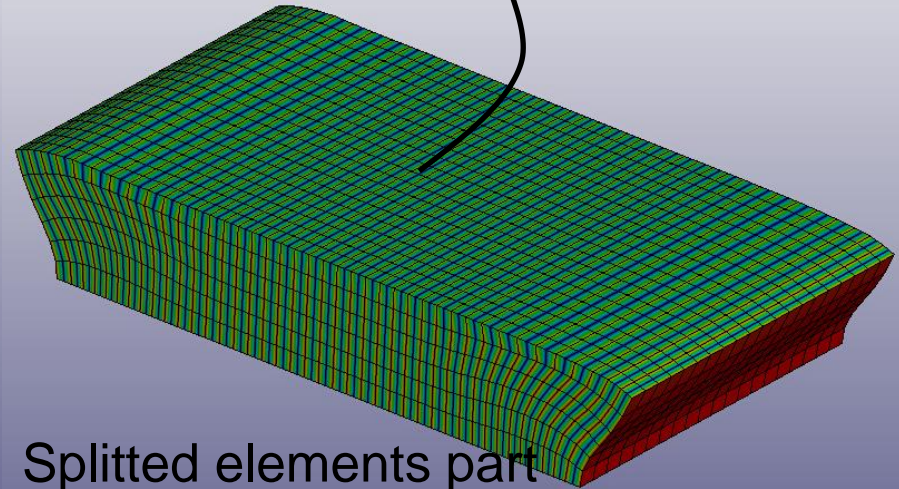


Temperature Mapping

$T = 0 \text{ K! ?}$



Rolled Part

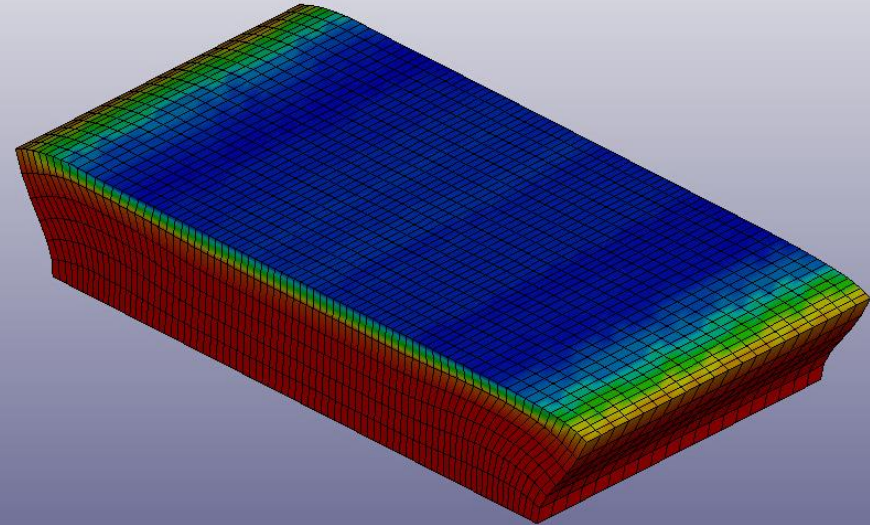
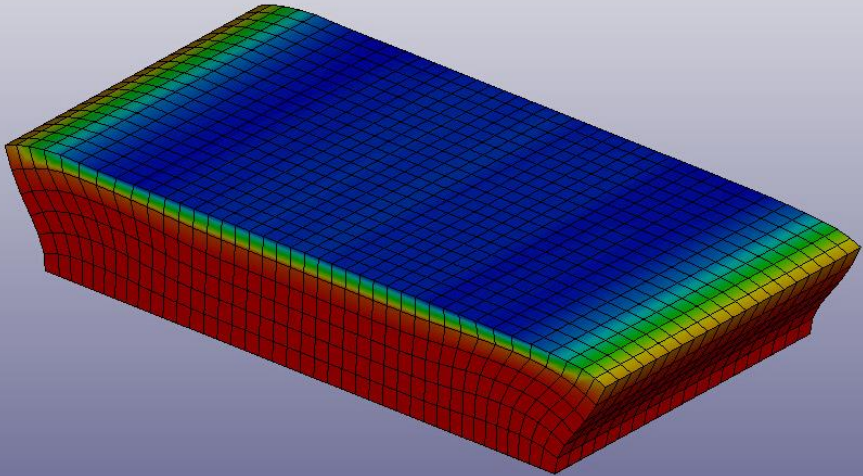


Splitted elements part

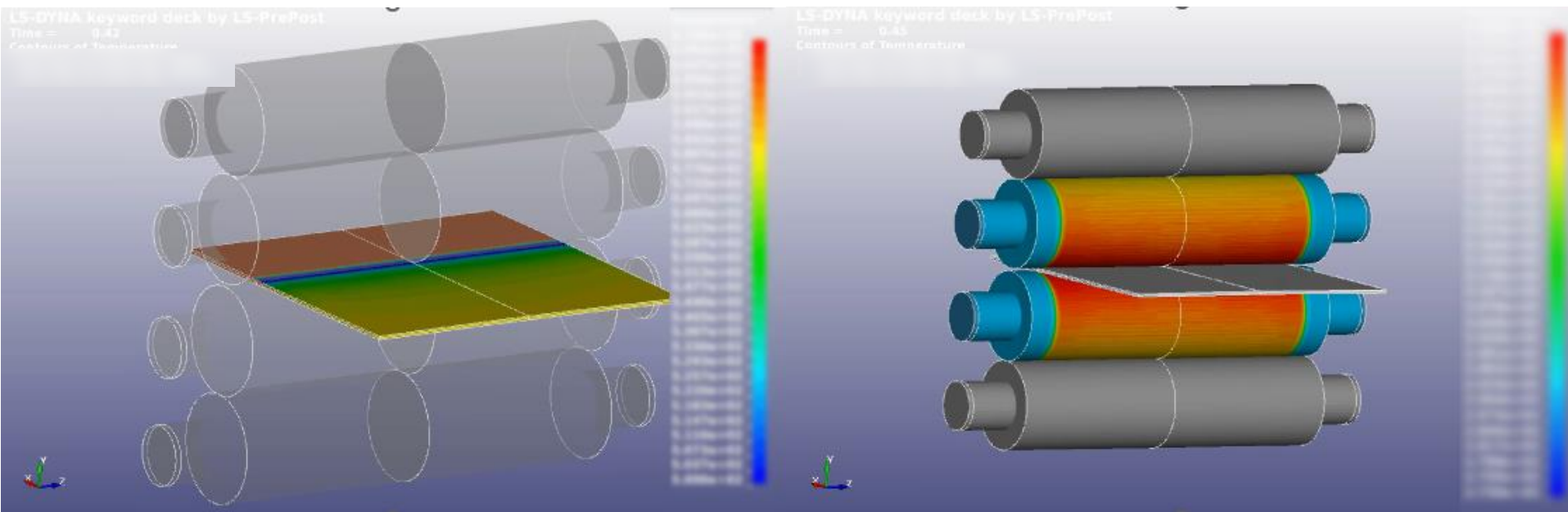
Temperature Mapping

Rolled Part

Splitted elements part with mapped temperatures



Heat development and transfer

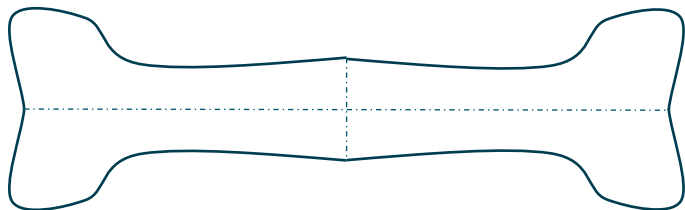


Heat development in sheet

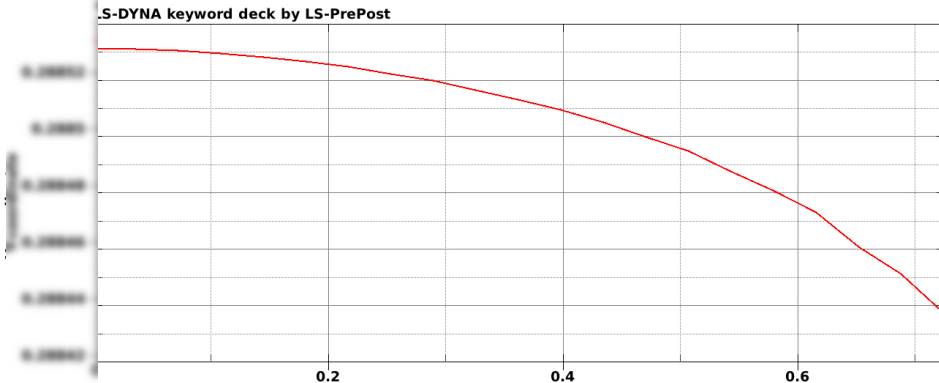
Heat development work roll.

Sheet crown

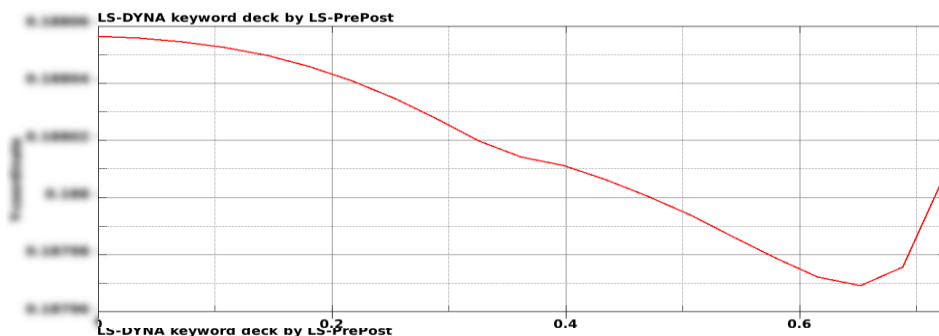
- Using LS-Prepost we can plot and see the sheet profile and crown.
- Interesting behaviors such as dog bone effects.



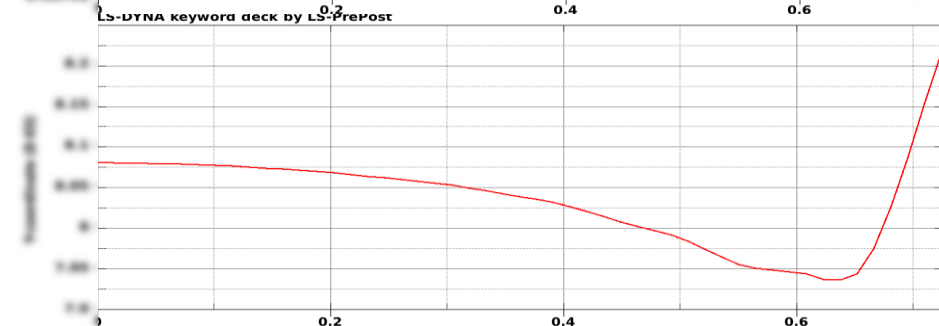
Pass 1



Pass 10

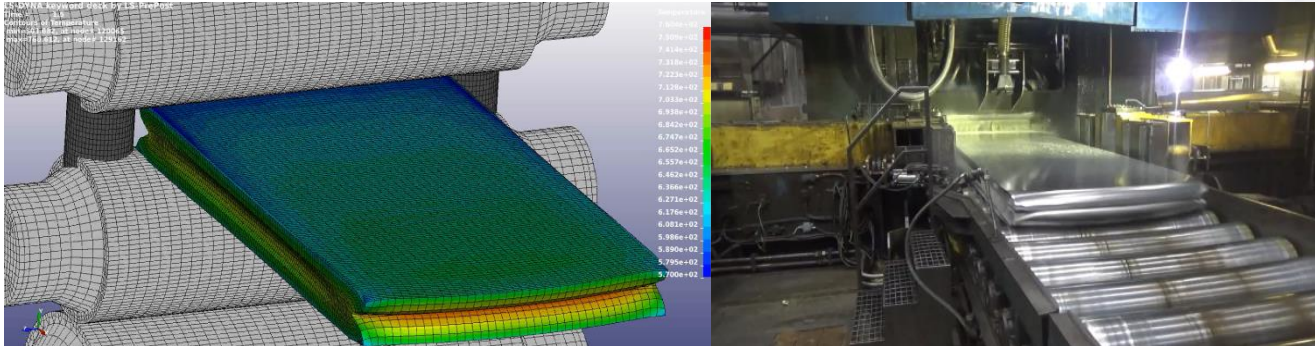


Pass 25



Summary

- Interesting data is generated.
- We can now see what is not measured.
 - Temperature, stress, and shape evolution can be tracked from the early stages of the process.
- Model shows great resemblance to reality
- Project benefits from LS-Dynas thermomechanical capabilities!



Future work

- Updated materialmodel
- Simulate clad materials
- Converting result data to VMAP standard for analytics
- Intertwine result data with factory sensors.



Thanks!

- Vinnova
- Gränges AB
- Dynamore Support



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