Platemod: A model-based production system

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The Industrial Problem
How can one predict mechanical properties (e.g., strength and toughness) in heavy steel plate production, on the basis of thermomechanical history and (known) chemical composition?

MathConsult GmbH, Linz, Austria,
uni software plus GmbH, Austria.

voestalpine Grobblech, Austria.
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The challenge:

Heavy steel plates (e.g., in pipelines for natural gas) need to withstand mechanical and thermal extremes, and chemical loads.

To obtain a highly resistant plate: the crystallization and the history of phase changes between different steel phases must be tightly controlled.

Desirable: Prediction of the mechanical properties on the basis of thermomechanical history and (known) chemical composition.
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Platemod:

PlateMod is a system that facilitates simulation of the production process.

PlateMod covers the whole process chain.

PlateMod dynamically controls the process parameters and improves the accuracy of reaching the desired mechanical properties.
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Linz Industrial Mathematics Competence Center (IMCC):

• Cooperative framework for industrial mathematicians.
• Three partner institutions.
• Department of Industrial Mathematics at Johannes Kepler University Linz (head: Ronny Ramlau; ~5-10 scientists)
• MathConsult GmbH (head: Andreas Binder; ~20 scientists)
• Transfer Group at the Johann Radon Institute (head: Ronny Ramlau; ~10-15 scientists)
• Focus: development and transfer of mathematical methods to industry and other scientific partners.
• International and regional industrial partners.
• All three institutions located at JKU Science Park.
voestalpine:

- One of Austria's leading industry enterprises, headquartered in Linz, Austria.
- 500 group companies and locations in more than 50 countries on 5 continents.
- In the business year 2015/16, voestalpine Group reported revenue of EUR 1.11 billion.
- Around 48,500 employees worldwide.
- One of the biggest steel producers in the world.
- Produces about 5 Mio. tons of steel per year (in Linz).
- VAGB: voestalpine Grobblech: heavy plate production.
Conversion of pig iron to steel:

- Blast furnace produces pig iron (high Carbon content, very brittle)
- Converted to steel, most prominent process is “basic oxygen steelmaking” or “LD (Linz-Donawitz) process” (Robert Durrer)
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Steel plate production:

- Reheating furnace
- Accelerated cooling
- Rolling stand
Steel plate production - main steps:

- Heating of steel slabs in reheating furnace,
- Hot rolling (several passes),
- Accelerated cooling,
- Leveling to obtain flat plates,
- Edge trimming, cutting, inspection and evaluation.
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Highly resistant plates are needed for:

- Offshore applications
- Pressure vessels
Highly resistant plates are needed for:

- Deepwater and sour service applications
- Yellow goods
Plate thickness:

Typically up to 40mm for, e.g., line pipes, up to 150 mm for, e.g., offshore productions.

Desired mechanical properties:

Great Strength

AND

Great Toughness
Mechanical properties are dependent on:

- **Chemical composition** (such as alloying elements, especially niobium)

- **Thermomechanical history** (recrystallization and softening behavior, influenced by strains and strain rates and temperature history)
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Thermomechanical history:

Only surface temperature can be measured -> Prediction of temperature history in bulk?

Coupling between thermal history and mechanical behavior during each rolling pass.

Prediction of the mechanical properties on the basis of thermomechical history and (known) chemical composition.
Thermomechanical history:

- For control and prognosis of temperatures at different locations on the surface and in the plate, solver for the nonlinear heat transport equation is needed.

- Solver should be fast and reliable.

- Need to resolve the massive temperature drops at the surface when entering the cooled rollers of the stand.
Thermomechanical history: rolling (several rolling passes)
Thermomechanical history: cooling
Platemod concept:
Platemod simulation:

- Pre-production calculations to optimize the initial plate (chemical composition, dimensions of plate)
- Pre-production calculations to optimize the initial setup of the process (number of roll passes, cooling temperature, ...)
- Both calculations target the mechanical properties of the product using the PlateMod Control functions for prediction
- Special R&D mode to perform parameter studies and to test new material laws (rapid prototyping of new functions; dll calls Mathematica functions via Notebooks)
- Domain Specific Language developed in Mathematica for metalurgical engineers
Platemod online:

Calculations triggered during the process are performed

Adaption of Parameters to obtain coincidence with temperature measurement at surface

Prediction of properties based on a simulation starting from the current process step
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Results & Benefits to the company / Summary:

- PlateMod enables model based production by unifying the algorithmic framework used in R&D and automatization
- PlateMod covers the whole process chain from reheating furnace to cooling bed
- PlateMod Control dynamically controls the process parameters and improves the accuracy of reaching the desired mechanical properties
- PlateMod Simulation allows for contract-specific determination of process parameters
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Thank you for your attention.