Effect of deformation and cooling path on phase transformation and hardness

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Research subjects:

– Effect of deformation on phase transformation phenomena
– Computational modelling of phase transformation phenomena for steels
– Estimate for final mechanical properties of hot rolled steels
Methods and materials

- JMAK equation for calculation of austenite to ferrite and bainite transformations
- Koistinen-Marburger type equation for calculation of austenite to martensite transformation
- Own finite element code for full coupling of heat conduction/transfer and own phase transformation code
- Abaqus finite element software for deformation and heat conduction/transfer which can be coupled with own phase transformation code
- Matlab is used for fitting of model parameters
- The model has been fitted to the CCT data of 960 QC steel (data from Antti Kaijalanen), Raex 400 (Antti), and 700+MC (Juho Mourujärvi), as well as two steels from Mahesh.
Connection to SSAB product/process

- Strip and plate mills and water cooling
- Model can be fitted to different steels/deformation schedules when following data is available:
  - CCT data with kinetics
  - Estimate of the final phase fractions after cooling with different cooling rates
- Currently fitted steels: The model has been fitted to the CCT data of 960 QC steel (data from Antti Kaijalainen), Raex 400 (Antti), and 700MC+ (Juho Mourujärvi)
Purpose

• Computer simulation of factors influencing final properties of finished steel product
  – Influencing factors:
    • Steel composition
    • Deformation
    • Cooling path
  – Final properties:
    • Hardness and other mechanical properties
    • Flatness
Some recent results
Phase transformation model fitting on experimental CCT (1% transformed)
Phase transformation model fitting on CCT data (kinetics), steel 1

a) Steel 1, no deformation

b) Steel 1, deformed at 850 °C
Phase transformation model fitting on CCT data (kinetics), steel 2

c) Steel 2, no deformation
d) Steel 2, deformed at 850 °C
Kinetics

Steel 1, no deformation

Steel 1, deformed at 850 °C
Calculation of product phases and hardness for any cooling path

Results:
- Ferrite fraction: 0.0000000000000000
- Bainite fraction: 0.44358130296567261
- Martensite fraction: 0.55642069606419509
- Hardness: 405.04786235879476
Austenite transformation to bainite and martensite during cooling in collaboration with PhD student Oskari Seppälä
Austenite transformation to bainite and martensite during cooling in collaboration with PhD student Oskari Seppälä
Heat conduction and phase transformation simulation:
- Simulation setting

W = \[10 \cdot 10 \sin \left(\frac{2 \cdot t}{1.5s}\right)\] \(\text{W/m}^2\text{s}\)

Pulsed water flows

Calculate:
1. Time dependent temperature distribution
2. Phases transformed as function of time
   - on surface
   - on \(\frac{1}{4}\) thickness
Heat conduction and phase transformation simulation:
- Time dependent temperature distribution

Pulsed water flows
Heat conduction and phase transformation simulation:
- Temperature at surface
- Temperature at $\frac{1}{4}$ thickness

- Fractions of ferrite and bainite formed on surface and on $\frac{1}{4}$ thickness
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Timetable

• Q3 & Q4:
  – Submit article on deformation effect on bainite/martensite formation
  – Finalize coupled heat conduction phase transformation code
  – Phase transformation code as Abaqus subroutine
  – Collaboration with Joonas Ilmola & Olli Leinonen (Hot rolling and phase transformations), Oskari Seppälä (detailed microstructure code), Joni Paananen (welding simulations)
  – Improve model fitting procedure
  – Publication of results from these studies as soon as possible (probably not possible until early 2018)
Milestones

- Publish phase transformation model results
- Finalize phase transformation code coupling with heat conduction code
- Phase transformation code as subroutine in Abaqus FEM software
- Application of the model in thermomechanical rolling