A CFD Study of Heating Steel Bar End-face to Allow Machinability
Content

- Company
- Market and Products
- Technology
- CFD at Georgsmarienhütte GmbH
## History

<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>1856</td>
<td>Founded as an iron production plant located in the South of Osnabrück. Its name derived from the last rules of the Hannover dynasty, King George V. and Queen Marie.</td>
</tr>
<tr>
<td>1993</td>
<td>Dr. Jürgen Großmann and Drueker &amp; Co. GmbH buy and incorporate Georgsmarienhütte.</td>
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<tr>
<td>1994</td>
<td>The blast furnace-converter was replaced with a DC electric arc furnace.</td>
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<tr>
<td>1997</td>
<td>Georgsmarienhütte Holding GmbH was created.</td>
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<tr>
<td>2006</td>
<td>A new walking-beam furnace replaces both of the 40+ year old walking-hearth furnace.</td>
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<tr>
<td>2007</td>
<td>A second ladle furnace is installed to expand secondary metallurgy.</td>
</tr>
<tr>
<td>2009</td>
<td>The rolling mill is modernised.</td>
</tr>
</tbody>
</table>
Company

- Manufacturer of quality and engineering steels
- Market leader in Germany
- Among the top European manufacturers
- Key Data 2010:
  - 630 mil. Euro Turnover
  - 1,320 employees
International Sales Offices
Our Vision

BEING PROMPT …

... MEANS REACTING WITH MAXIMUM PRECISION IN THE SHORTEST TIME POSSIBLE. CHALLENGE US!

- Melt and treat in the morning
- Cast at noon
- Roll in the evening
- Finish over night
- Ship the next day!
Market

Our steel drives you forward

- Powertrain, engine, transmission, steering and chassis components of cars and trucks
- End use of 80% of our products in the automotive industry
References
Applications

**ENGINE**
- Fracture-split conrod
- Camshaft
- Common-Rail Injector Nozzle
- Piston
- Crankshaft

**TRANSMISSION**
- Gear shaft
- Cardan shaft

**CHASSIS**
- Steering rack
- Knuckle

**BEARINGS**
- Wheel hub
- Ball bearings
DC electric arc furnace – 130 MW
Production process

1. Scrap
2. DC electric arc furnace
3. Ladle furnaces
4. Vacuum degassing
5. Conditioning and trimming
6. Ingot casting
7. Continuous casting (6 strands)
8. Straightening lines
9. Cooling bed
10. Rolling mill medium-section mill with Kocks PSB and RSB
11. Annealing furnaces
12. Surface test
13. Internal flaw detection
14. Material identity check
15. Bright bar production
16. Walking-beam furnace
17. Shipping
CFD at Georgsmarienhütte GmbH

- Wide field of application due to different production processes
- CFD since May/August 2011
- Until now: Simulation of air and water flow as well as heat transfer

**Hardware & OS:**

- Workstation: Windows 7 64bit @ 8 cores, 3.6 GHz, 48GB
- Cluster: Windows Server 2008 R2 @ 192 cores, 2.4 GHz, 24GB/core
- HPC Cluster Manager
Air flow

- Analysis of an axial fan
- Steady and unsteady, rigid body motion
- Comparison with measured data
steady vs. unsteady
Air flow
CFD Simulation vs. measured data

Luftgeschwindigkeitsprofil (Auslass)

10 [m/s]  15 [m/s]  20 [m/s]  25 [m/s]  30 [m/s]

measured data
Heat transfer

- Heating-up the end face of a steel bar followed by cooling in still air
- Unsteady
- Free convection
- Thermal conductivity as a function of chemical composition and temperature
- Temperature curves plotted by the use of point probes
Heat transfer

- Simplified setup
  - Induction heating is not considered
  - A small volume is uniformly heated by the energy input

- Polyhedral Mesher & Prism Layer Mesher

- Volumetric Control for refining the mesh at the bar end

- Approx. 3 mil. cells
CFD

Temperature range

Chemical composition

JMatPro

Calculated thermal conductivity

Fe C Cr

Al Ni Mn Mo

Temperature range

Graph showing thermal conductivity vs. temperature (°C)
JMatPro

JMatPro: The materials property simulation software.

General Steel

Thermodynamic Properties:
- Step Temperature
- Step Concentration
- Profile
- Single

Solidification:
- Phases and Properties

Thermo-Physical Properties:
- Stacking Fault Energy

Mechanical Properties:
- Jominy Hardenability
- High Temperature Strength
- Flow Stress Analysis
- Fatigue Related

Phase Transformation:
- TTT/CCT Diagrams
- Quench Properties
- Welding Cycle
- Martensite
- Energy Changes
- Simultaneous Precipitation
- Reaustenitisation
- TTA Diagram
- Transformation Plasticity
- Advanced CCT

Data Export:
- Heat Treatment Data
- FORGE by Transalor
- DEFORM Forging
- DEFORM-HT

Others:
- Carburisation

Waiting for the user to pick a property...
### JMatPro

**Thermo-Physical Properties:**
- **Extended General**
- **Stacking Fault Energy**
JMatPro

JMatPro the materials property simulation software.

General Steel

Thermo-Physical and Physical Properties

Temperatures (C)

Heat treatment: 100
Upper limit: 1600
Step: 10

Phases

Take all phases into account

Start calculation

100CrMnSi6-4

waiting for user input...
100CrMnSi6-4 Physical properties

Temperature (°C) vs. Thermal conductivity (W/m*K)

COMPOSITION (Wt%)
Fe: 95.5915
C: 0.9357
Si: 0.6125
Mn: 1.0467
P: 0.0154
S: 0.0067
Cu: 0.1569
Al: 0.011
Cr: 1.4418
Mo: 0.0307
Ni: 0.112
V: 0.0076
Ti: 0.0022
Nb: 0.0034
B: 4.0E-4
N: 0.0079
W: 0.0062
Co: 0.0114
interpolateTable(@Table("thermal_conductivity"), "Temperature", LINEAR, "ThermalConductivity", $Temperature)
$(\text{Time} < 2) \ ?
(6000/4.874361e-06) : 0
Point Probes
Solution Time = 2 s
Solution Time = 5 s

Solution Time = 60 s
Temperature curves 0 to 10 s
Temperature curves 0 to 60 s
Conclusion

- Material database of STAR-CCM+ expandable by the use of JMatPro (thermal conductivity $= f(\text{chemical composition, } T)$ of steel).

- An idealized inductive heat treatment could soften the hardened surface.

- Almost identical temperature profile at different bar diameters; energy input is scaled linear to the heated volume.

- More time is needed than the process permits.

- A different method of getting rid of surface hardening is needed.
Outlook

- Calculated specific heat capacity as $f(\text{chemical composition, } T)$
  JMatPro and Thermocalc

- Different steel grades
  JMatPro and Thermocalc

- Induction heating (STAR-CCM+)

- Forced air cooling (STAR-CCM+)
Outlook

- Rolling Mill
- Cooling Bed
- Ladle
- Tundish
- Continuous Casting

Source: Brian G. Thomas, University of Illinois at Urbana-Champaign