Simulation of carbide dissolution in hot-work tool and corrosion-resistant steels using DICTRA

Thermo-Calc Anwendertreffen
09-10. September 2011
Aachen
Content

- Presentation of Deutsche Edelstahlwerke GmbH

- Simulation of $M_6C$-carbide dissolution in hot-work tool steel 1.2367

- Simulation of Nb(C,N) dissolution in corrosion-resistant steel 15-5PH
Presentation of Deutsche Edelstahlwerke GmbH
Short profile

- Leading company focused on the production und processing of specialty steel long products

- The company is headquartered in Witten, with production sites in Witten, Krefeld, Siegen and Hagen

- Main business sectors: machinery and plant engineering, automotive industry, aircraft and aerospace as well as distribution

- DEW is part of the SCHMOLZ + BICKENBACH Group with 10,000 employees located around the world
Presentation of Deutsche Edelstahlwerke GmbH
Production locations

Witten
~ 1700 employees

Krefeld
~ 670 employees

Hagen
~ 400 employees

Siegen
~ 1080 employees
## Presentation of Deutsche Edelstahlwerke GmbH
From steel production to machining

<table>
<thead>
<tr>
<th>Witten</th>
<th>Krefeld</th>
<th>Siegen</th>
<th>Hagen</th>
</tr>
</thead>
<tbody>
<tr>
<td>130t Electric-Arc-Furnace</td>
<td>Electro-Slag-Remelting (ESR) Vacuum-Arc-Remelting (VAR)</td>
<td>120/140 t Electric-Arc-Furnace</td>
<td>Rolling mill for wire and steel bars</td>
</tr>
<tr>
<td>Vertical Continuous Casting / Ingot casting</td>
<td>33-MN-Forging press</td>
<td>Continuous casting plant Bow type</td>
<td>Wire drawing</td>
</tr>
<tr>
<td>Forging machine LSX 25</td>
<td>Forging machine RF 70</td>
<td>Electro-Slag-Remelting (ESR)</td>
<td>Milling /grinding/ polishing</td>
</tr>
<tr>
<td>Rolling mill</td>
<td>Heat treatment</td>
<td>Ingot casting</td>
<td>Pickling lines</td>
</tr>
<tr>
<td>Heat treatment</td>
<td>Machining</td>
<td>Rolling mill</td>
<td>Heat treatment</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Single bar heat treatment unit</td>
<td>Bright steel unit</td>
</tr>
</tbody>
</table>
Presentation of Deutsche Edelstahlwerke GmbH
Product highlights of DEW

Ferro-Titanit
Wire casting
Non-magnetic drill collars
Aircraft materials

Armoured plates
Cold rolls
Mandrels
Presentation of Deutsche Edelstahlwerke GmbH
Research and development department

- team engineering steels
- team corrosion-resistant steels
- team tool- and high-speed steels
- team material simulation
- team process simulation
- cooperations (universities, institutes, …)
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Simulation of $M_6C$-carbide dissolution in hot-work tool steel 1.2367

- Hot-work tool steels are used for chipless forming of metallic and non-metallic materials
- These materials will be deformed or casted at high temperatures and/or high pressures

- Requirements on hot-work tool steels
  - tempering resistance
  - strength
  - ductility
  - wear resistance
  - resistance to thermal shock

especially at high temperatures

<table>
<thead>
<tr>
<th>Chemical composition in mass-%</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
</tr>
<tr>
<td>------</td>
</tr>
<tr>
<td>0,37</td>
</tr>
</tbody>
</table>
Simulation of $M_6C$-carbide dissolution in hot-work tool steel 1.2367

Input-data (light microscope, scanning electron microscope, microprobe, Thermo-Calc)

$r_{M6C} = 30 \, \mu m$, $r_{\text{matrix}} = 184 \, \mu m$

molefraction in FCC (austenite) and carbide ($M_6C$) vs. temperature [°C]

molefraction Fe, C, Cr, Mo … in matrix (FCC = $\gamma$) and carbide ($M_6C$)
Simulation of $M_6C$-carbide dissolution in hot-work tool steel 1.2367
Possible DICTRA-models
Simulation of $M_6C$-carbide dissolution in hot-work tool steel 1.2367
Example: Dissolution of a spherical $M_6C$-carbide in an austenite-matrix

$r_{M6C} = 30 \, \mu m$, $r_{\text{matrix}} = 184 \, \mu m$

Conclusion:
Good agreement in time and temperature at 35h / 1260°C
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Simulation of Nb(C,N) dissolution in corrosion-resistant steel 15-5PH

- typical applications:
  - high-pressure valves and pumps
  - sensors
  - aerospace
  - ...

<table>
<thead>
<tr>
<th>Chemical composition in mass-%</th>
<th>C</th>
<th>Si</th>
<th>Mn</th>
<th>Cr</th>
<th>Mo</th>
<th>Ni</th>
<th>N</th>
<th>Cu</th>
<th>Nb</th>
</tr>
</thead>
<tbody>
<tr>
<td>0,05</td>
<td>0,70</td>
<td>0,70</td>
<td>15,00</td>
<td>0,35</td>
<td>4,50</td>
<td>0,015</td>
<td>3,50</td>
<td>0,10</td>
<td></td>
</tr>
</tbody>
</table>

removes carbon by chemical combination
Corrosion-resistance
Hardness by aging

pump
valve
airspace
Simulation of Nb(C,N) dissolution in corrosion-resistant steel 15-5PH
Metallographical analysis of an high-niobium melt

**EFTEM-analysis**
(aging at 420°C/8h/air)

**EDX-analysis**
(fraction surface)

<table>
<thead>
<tr>
<th>Element</th>
<th>Massen%</th>
<th>Atom%</th>
</tr>
</thead>
<tbody>
<tr>
<td>N K</td>
<td>1.55</td>
<td>8.09</td>
</tr>
<tr>
<td>Cr K</td>
<td>5.65</td>
<td>7.95</td>
</tr>
<tr>
<td>Fe K</td>
<td>19.87</td>
<td>26.01</td>
</tr>
<tr>
<td>Ni K</td>
<td>1.27</td>
<td>1.58</td>
</tr>
<tr>
<td>Nb L</td>
<td>71.66</td>
<td>56.38</td>
</tr>
</tbody>
</table>
Simulation of Nb(C,N) dissolution in corrosion-resistant steel 15-5PH
Thermo-Calc – “Scheil-calculation“ → solidification
Simulation of Nb(C,N) dissolution in corrosion-resistant steel 15-5PH
Thermo-Calc – “Step-calculation“ → equilibrium
Simulation of Nb(C,N) dissolution in corrosion-resistant steel 15-5PH
DICTRA-simulation

- possible temperature range
  ~ 1220 – 1360 (according to Thermo-Calc)

- compositions of Nb(C,N) and austenite
  → Thermo-Calc (Scheil)
  → scanning electron microscope (EDX)

- size of Nb(C,N) and austenite
  → scanning electron microscope (EDX)
Thank you for your attention!

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