THERMO-CALC® AND DICTRA® SIMULATIONS OF THE SOLUTION HEAT TREATMENT OF SUPERDUPLEX STAINLESS STEELS

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M. T. M. Fiorante
Introduction

**Duplex Stainless Steels (DSS)**

Approximately equal amounts of ferrite (α, BCC) and austenite (γ, FCC)

Corrosion resistance, mechanical strength, toughness

Properties are determined by the correct balance of α and γ

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Introduction

**Balance between ferrite and austenite depends of:**

 ✓ Chemical composition
 ✓ Solution heat treatment

ferrite (α, BCC) between 45 and 55%v is acceptable

typical solution treatment temperature lies between 1050 and 1150 °C

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Introduction

**Balance between ferrite and austenite depends of:**

✓ Chemical composition
✓ Solution heat treatment

small amounts of Cr$_2$N can be formed depending on chemical composition

Thermodynamic simulations only predicts the equilibrium phase content: what about kinects?

Objectives

Computational simulations of the equilibrium and phase transformation kinetics of a superduplex stainless steel UNS S32750 in two different heat treatment cycles:

- Isothermal at 1250 °C (a possible hot work temperature)
- Isothermal for generation of duplex structure after a 1250 °C temperature hold
Computational modelling

TCFE8
Only using Fe, Cr, Ni, Mo, N

<table>
<thead>
<tr>
<th></th>
<th>Cr</th>
<th>Ni</th>
<th>Mo</th>
<th>N</th>
<th>Mn</th>
<th>W</th>
<th>C</th>
<th>Fe</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>25.17</td>
<td>6.88</td>
<td>3.61</td>
<td>0.25</td>
<td>0.60</td>
<td>0.69</td>
<td>0.01</td>
<td>balance</td>
</tr>
</tbody>
</table>
### Computational modelling

<table>
<thead>
<tr>
<th>Simulation time</th>
<th>Temperature</th>
<th>Geometric model</th>
<th>$\alpha$ length</th>
<th>$\gamma$ length</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 h</td>
<td>1250 °C</td>
<td>Planar</td>
<td>10 $\mu$m</td>
<td>10 $\mu$m</td>
</tr>
<tr>
<td>16 h</td>
<td>1250 °C</td>
<td>Spherical</td>
<td>1.3 $\mu$m (thickness)</td>
<td>5 $\mu$m (radius)</td>
</tr>
</tbody>
</table>

![Diagram showing $\alpha$ and $\gamma$ lengths]

**MOBFE3**

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<th>$\alpha$ length</th>
<th>$\gamma$ length</th>
</tr>
</thead>
<tbody>
<tr>
<td>1000 h</td>
<td>1088 °C</td>
<td>Planar</td>
<td>67 $\mu$m</td>
<td>28 $\mu$m</td>
</tr>
<tr>
<td>20 h</td>
<td>1088 °C</td>
<td>Spherical</td>
<td>6.9 $\mu$m</td>
<td>14 $\mu$m</td>
</tr>
</tbody>
</table>

*only using Fe, Cr, Ni, Mo, N*
**Experimental procedure**

<table>
<thead>
<tr>
<th>Initial condition</th>
<th>Temperature</th>
<th>Holding time</th>
</tr>
</thead>
<tbody>
<tr>
<td>As received</td>
<td>1250 °C</td>
<td>1 min, 2 min, 40 min, 3 h</td>
</tr>
<tr>
<td>3 h @ 1250°C, water quenched</td>
<td>1088 °C</td>
<td>2 min, 30 min, 3 h, 12 h, 36 h</td>
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➢ Water quenching after all isothermal heat treatments

➢ Optical Microscopy (OM) after modified Beraha etching
  ➢ Quantitative analysis of ferrite, 20 random fields at 100x magnification

➢ Optical Microscopy (OM) after oxalic acid electrolytic etching (6 Vdc, 30 s)
  ➢ Linear intercept mean grain size measurements of the two initial conditions
  ➢ Data used for estimation of the $\alpha$ and $\gamma$ lengths in DICTRA models
Results and Discussion

1 min  
@ 1250 °C  
Beraha

2 min  
@ 1250 °C  
Beraha

40 min  
@ 1250 °C  
Beraha

3 h  
@ 1250 °C  
oxalic
Results and Discussion

2 min @ 1088 °C
Beraha

3 h @ 1088 °C
Beraha

30 min @ 1088 °C
Beraha

36 h @ 1088 °C
Beraha
Results and Discussion

[Graph showing the ferrite volume fraction (%) over time at 1250 °C [s] for Planar, Spherical, and Experimental phases.]
Results and Discussion

Cr and Mo gradients only vanishes after 1800 s (30 min) of heat treatment @ 1250 °C
Results and Discussion
Planar model used in DICTRA® simulations is the one that better assess the behaviour of volume fraction phase’s changes for both heat treatments.
Conclusions

Ferrite and austenite volume fractions stabilize after 30 min of heat treatment, obtaining 71% of ferrite at 1250 °C and 51% of austenite at 1088 °C; simulations are in accordance with experimental validations.
Equilibrium of chemical composition, marked as the absence of compositional gradients, is established long after the achievement of the equilibrium volume fraction of phases, reached after 30 min.

The information about total attenuation of gradient profiles can only be obtained in DICTRA® simulations.
Acknowledgements

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