Investigation on different oxides as candidates for nano-sized ODS particles in reduced-activation ferritic (RAF) steels

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Introduction

What are ODS alloys?

Oxide Dispersions-Strengthened alloys

Nano-sized oxide-particles 10-20nm

- good corrosion-resistance
- excellent high-temperature properties
- improved creep-strength
- material tends to be brittle
- high production costs
Production of ODS alloys

**Mechanical alloying**

→ compressing into capsule

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**Production of ODS alloys**

**Compacting of the powders containing the different oxides:**

- HIP at 1100°C / 100 MPa for 2 hours
- Hot-rolling at 1100°C
- Reduction from 45 mm diameter to 6 mm thickness
- 5 passes needed for final shape, with reheating after each pass
Production of ODS alloys

<table>
<thead>
<tr>
<th>No.</th>
<th>Composition</th>
<th>Milling-speed</th>
<th>Milling-time</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Fe13Cr1W0.3Ti + La₂O₃</td>
<td>1200 / 800</td>
<td>80h</td>
</tr>
<tr>
<td>2</td>
<td>Fe13Cr1W0.3Ti + Ce₂O₃</td>
<td>1200 / 800</td>
<td>80h</td>
</tr>
<tr>
<td>3</td>
<td>Fe13Cr1W0.3Ti + MgO</td>
<td>1200 / 800</td>
<td>80h</td>
</tr>
<tr>
<td>4</td>
<td>Fe13Cr1W0.3Ti + ZrO₂</td>
<td>1200 / 800</td>
<td>80h</td>
</tr>
<tr>
<td>5</td>
<td>Fe13Cr1W0.3Ti + Fe₂Y</td>
<td>1200 / 800</td>
<td>80h</td>
</tr>
<tr>
<td>Ref</td>
<td>Fe13Cr1W0.3Ti + Y₂O₃</td>
<td>1200 / 800</td>
<td>80h</td>
</tr>
</tbody>
</table>

- milling in argon-atmosphere
- ball to powder ratio 10:1 (2000g : 200g)
- complete production in argon (glove-box)

Characterization (FIB/TEM)

- Fe13Cr1W0.3Ti + Y₂O₃ rolled
- Fe13Cr1W0.3Ti + La₂O₃ rolled

Characterization (microstructure)

- clearly visible rolling texture
- grain size approx. 400 to 800 nm width, but micrometer-sized length

Characterization (oxides)

- formation of ODS particles with La₂O₃
- fine distribution of the oxides (inside grains and on GB)
Characterization (oxides)

- Formation of ODS particles with La2O3
- Fine distribution of the oxides (inside grains and on GBs)

EBSD Measurements

- Fe13Cr1W0.3Ti + Y2O3

Results from EBSD Measurements

- A bimodal grain size distribution is visible
- Grains with <110> parallel to the rolling direction
- Predominance of (001) <110> rotated cube (α-fiber) typical texture in bcc metals
Fine recrystallized grains are surrounded by coarser elongated ones.

All specimens in LT-orientation.
Y-containing alloys show the best results.
Most alloys perform in a similar way.

Performance in tensile tests is comparable to alloys produced at other facilities.

Formation of nano-oxides is possible with alternative oxides.
Tensile properties of different oxides are comparable to yttrium-alloys.
Improved charpy-impact properties for Ce₂O₃ and MgO.

Detailed TEM Characterization of nano-oxides is still in progress.
EBSD mappings of selected oxides (other than Y₂O₃).
4-point-bending-tests (fracture-toughness)

planned work at the Materials Department

FIB (Channeling) microstructure char.

EBSD on rolled and extruded materials

Conclusion and Outlook

Fig. 1. Microstructure of (a) and (b) 14YWT1000 and (c) and (d) 14YWT1150 at low (a and c) and medium (b and d) magnification.

Fig. 2. The effect of the HIPing temperature on microhardness.

Fig. 3. The variation of $K_q$ with temperature for 14YWT1000 and 14YWT1150.

Discussion

The breakdown in the usual higher strength/lower toughness relation in the NFA alloys is not fully understood. One possibility is that dislocation pile-ups in the larger and softer coarse grains trigger cleavage, perhaps by fracturing smaller harder grains or brittle particles. In this case, differences in the average strength of the alloy may be less significant than similarities in the grain structures. Indeed, if the larger grains are softer, the effect on the size of the pile up may offset the corresponding effect of higher strength.

Thank you for your attention!