Current status of the KIT ODS steel development programme

Jan Hoffmann, Michael Rieth, Rainer Lindau, Michael Klimenkov, Anton Möslang, Dave Armstrong, Ben Britton
Contents

- latest production of ODS alloys
- microstructural characterization
- mechanical tests
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

Fe13Cr1W0.3Ti
Y$_2$O$_3$

mechanical alloying
Production of ODS alloys

Fe13Cr1W0.3Ti → Y2O3

mechanical alloying → compressing into capsules
Production of ODS alloys

Fe13Cr1W0.3Ti

Y2O3

mechanical alloying

compressing into capsules

100 Mpa 1100°C

hot consolidating (HIP)
Production of ODS alloys

Fe13Cr1W0.3Ti

Y2O3

100 Mpa 1100°C

mechanical alloying

compressing into capsules

hot rolling / heat treatment

hot consolidating (HIP)
Alternative ODS particles

Pre-alloyed powder:

Fe$_{13}$Cr$_1$W$_{0.3}$ + 0.3 wt.% oxide

<table>
<thead>
<tr>
<th>oxide</th>
<th>Y$_2$O$_3$</th>
<th>La$_2$O$_3$</th>
<th>Ce$_2$O$_3$</th>
<th>ZrO$_2$</th>
<th>MgO</th>
</tr>
</thead>
<tbody>
<tr>
<td>atomic weight of oxide [g/mol]</td>
<td>225.8</td>
<td>325.8</td>
<td>328.2</td>
<td>123.2</td>
<td>40.3</td>
</tr>
<tr>
<td>atomic percent of oxide in alloy [at.%]</td>
<td>0.074</td>
<td>0.051</td>
<td>0.051</td>
<td>0.136</td>
<td>0.414</td>
</tr>
</tbody>
</table>

0.3 wt% of oxide powders added for mechanical alloying
Alternative ODS particles - FIB

- **Y$_2$O$_3$**
- **La$_2$O$_3$**

- bi-modal microstructure
- elongated + equiaxed grains
Alternative ODS particles - FIB

- recrystallized grains surrounding elongated, unrecrystallized grains

Y$_2$O$_3$  La$_2$O$_3$
Alternative ODS particles

Fe$_{13}$Cr$_{1}$W$_{0.3}$Ti + La$_2$O$_3$
Alternative ODS particles - FIB

ZrO$_2$

Ce$_2$O$_3$
Alternative ODS particles

- (nearly) fully recrystallized structure
- only very little elongation visible
Alternative ODS particles - EBSD

Fe$_{13}$Cr$_1$W$_{0.3}$Ti + ZrO$_2$
Alternative ODS particles - TEM

- formation of ODS particles with La$_2$O$_3$
- fine distribution of the oxides (inside grains$^1$ and on GB$^2$)
Mechanical tests (charpy-impact test)

- Y2O3
- La
- Zr
- Ce
- Mg
- Y2O3-HIP

All specimens in LT- orientation

rolling direction

impact-energy (J)

temperature (°C)
Mechanical tests (charpy-impact test)

Y$_2$O$_3$  MgO
Mechanical tests (charpy-impact test)

Y$_2$O$_3$  MgO

RT

300°C
Mechanical tests (tensile tests – yield strength)

- Y-containing alloys show the best results
- Most alloys perform in a similar way
Mechanical tests (tensile tests – total elongation)

- Y2O3
- La2O3
- Zr2O
- Ce2O3
- MgO
- FeY

The graph shows the total elongation (%) of various materials (Y2O3, La2O3, Zr2O, Ce2O3, MgO, FeY) as a function of test temperature (°C). At higher temperatures, the total elongation increases significantly for some materials, indicating their mechanical properties change with temperature.
Comparison of 12Cr, 13Cr and 14Cr ODS

- GETMAT
  - 12Cr2W0.3Ti 0.2 Y$_2$O$_3$
- ORNL
  - 12Cr3W0.4Ti 0.25 Y$_2$O$_3$
  - 14Cr3W0.4Ti 0.25 Y$_2$O$_3$
- KIT
  - 13Cr1W0.3Ti 0.3 Y$_2$O$_3$
  - 13Cr1W0.3Ti 0.3 La$_2$O$_3$
  - 13Cr1W0.3Ti 0.3 Ce$_2$O$_3$
  - 13Cr1W0.3Ti 0.3 Fe$_2$Y

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

Alternative oxides for ODS steels

- Formation of nano-oxides is possible with alternative oxides

- Two major types of microstructures evolved (Elongated bi-modal / Recrystallized)

- Tensile properties of different oxides are comparable to yttrium-alloys

- Improved charpy-impact properties for Ce₂O₃ and MgO
Thank you for your attention!