Promotion of Alumina Scale Protected Iron-Base Oxide Dispersion Strengthened Alloys


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Objective

Investigate alloying additions to promote highly stable oxide dispersoids while maintaining alumina scale formation, where internal oxidation studies simulate exchange reaction effects of a single particle.

Background/Motivation

- Advanced—ultra supercritical (A-USC) coal fired plants will operate at 760°C and 35 MPa, which will require oxide dispersion strengthening (ODS) for Fe-based materials with superior oxidation resistance (AlO).

- Gas Atomization Reaction Synthesis (GARS) has previously been shown viable to make simplified nanopowders without Al. Fe-based ODS utilizing complex Y-Hf or Y-Ti dispersoids

- In order to test these alloying additions, chill cast alloys, compositions shown in Table 1, were created to simulate a powder particle

<table>
<thead>
<tr>
<th>Sample ID</th>
<th>Fe</th>
<th>Cr</th>
<th>Al</th>
<th>Y</th>
<th>Ti</th>
<th>Hf</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (Base Alloy)</td>
<td>Bal</td>
<td>16</td>
<td>10</td>
<td>0.2</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2 (Ti Addition)</td>
<td>Bal</td>
<td>16</td>
<td>10</td>
<td>0.2</td>
<td>0.25</td>
<td>-</td>
</tr>
<tr>
<td>3 (Hf Addition)</td>
<td>Bal</td>
<td>16</td>
<td>10</td>
<td>0.2</td>
<td>-</td>
<td>0.25</td>
</tr>
</tbody>
</table>

Table 1: Sample identification and additions in wt.%

- Chill cast microstructures have been shown through previous work to be analogous to a powder particle

Figure 1: GARS processing diagram

Figure 2: GARS exchange reaction: initial consolidation (left), prior particle boundary oxide dissociation (middle), dispersoid formation (right).

Figure 3: Oxide map for Fe-0.1Al Alloys at 800°C, in oxygen at 200 Torr.

- In order to operate at A-USC conditions, additions of Al are necessary for oxidation protection (See Figure 3)

- Hf has been shown to promote complex Y-Hf oxides, in Co-base alloys, suppressing less stable Y-Al oxides.

- X-ray samples were then machined from the bars and polished to a 1 μm finish using silicon carbide and diamond suspensions

- All samples were heat treated in air at 1600°C for 10 hours

- Serial grinding and x-ray analysis (Cu-Kα radiation) to determine a depth profile of phases

- In order to ensure even grinding, a polishing apparatus seen to the right was used

Figure 4: Powder particle from GARS produced Fe-base ODS alloy (left). As-cast structure from chill cast bars

Figure 5: X-Ray sample geometry (top left); mounted sample (bottom left); polishing apparatus (right)
OUTSTANDING POSTER AWARD

Results/Analysis

(1) Base Alloy (Fe-16Cr-10Al-0.2Y at%)

- Surface
- 25 µm
- α-Alumina
- α-Iron
- YAlO₃
- Fe₃Y₃

Both base alloy and titanium addition samples formed surface alumina followed by an undesirable layer of YAlO₃ highlighted by red ovals and arrows.

(2) Titanium Addition (Fe-16Cr-10Al-0.2Y-0.25Ti at%)

- Surface
- 25 µm
- α-Alumina
- α-Iron
- YAlO₃
- Fe₅Y₅

(3) Hafnium Addition (Fe-16Cr-10Al-0.2Y-0.25Hf at%)

- Surface
- 150 µm
- 400 µm
- α-Alumina
- α-Iron
- HfO₂
- Y₂HfO₇
- Fe₅Y₃

In hafnium addition Y₂HfO₇ dispersoids, noted with red boxes and arrows, formed throughout with an initial region of alumina and hafnia followed by hafnia. These properties are preferred for Al₂O₃ scale protected Fe-ODS alloys.

Future Work

- Calculate diffusion constants for Hf alloy through Rhine's packs to find heat treatment times for consolidated powders
- Using Hf alloy design create powders through GARS processing
  - Determine surface oxide formed during rapid solidification
  - Consolidate powders to form specimen for sample testing
- Oxidation and creep testing of consolidated alloys

References