Cast Components for High Temperature CSP Thermal Systems

Oak Ridge National Laboratory
MetalTek International
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G. Muralidharan (ORNL), Jim Myers (MetalTek International)
Low-cost Components are Required for Gen 3 CSP Systems

- Components for Gen 3 systems are targeted for >700°C operation to achieve improved efficiencies
- High temperatures and harsh environments typically demand the use of high performance and more expensive Ni-based alloys (example: Haynes® 230, Haynes® 282, or IN® 740H)
- Low-cost components are required to achieve to achieve the Sunshot goal of 6 ¢/ kWh
High Component Costs Are Due to Alloy and Processing Costs

• Both alloy cost and processing costs contribute to component costs
• Alloys such as Haynes® 282, or IN® 740H have excellent high temperature strength, creep and oxidation resistance
  • Relatively high materials cost due to high levels of Ni and Co

<table>
<thead>
<tr>
<th>Alloy</th>
<th>Ni</th>
<th>Co</th>
<th>Cr</th>
<th>Fe</th>
<th>W</th>
<th>Mn</th>
<th>Mo</th>
<th>Nb</th>
<th>Al</th>
<th>Ti</th>
<th>Si</th>
<th>C</th>
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<tbody>
<tr>
<td>Haynes® 230</td>
<td>Bal (~59)</td>
<td>5 Max</td>
<td>22</td>
<td>3 max</td>
<td>14</td>
<td>0.5</td>
<td>2</td>
<td>0.5 Max</td>
<td>0.3</td>
<td>0.1 Max</td>
<td>0.4</td>
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<tr>
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<td>20</td>
<td>1.5 Max</td>
<td>-</td>
<td>0.3 Max</td>
<td>8.5</td>
<td>-</td>
<td>1.5</td>
<td>2.1</td>
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<td>24.5</td>
<td>3 Max</td>
<td>-</td>
<td>1 Max</td>
<td>1 Max</td>
<td>1 Max</td>
<td>1.35</td>
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<td>0.15</td>
<td>0.03</td>
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</tbody>
</table>

• Multiple wrought processing steps required for fabrication of components such as seamless tubes
Casting Components Offers a Route for Cost Reduction

- Certain component geometries can be cast with cost savings
  - Example: Cylindrical objects (pipes) can be centrifugally cast
  - Complex valve bodies can be fabricated using the casting process

- Other benefits can be anticipated with castings
  - Customized material choice and component design, smaller order quantities, potentially lower lead-times

- ORNL has a history of successful development and collaborations on centrifugal cast components

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ORNL Alumina Forming Austenitic tubes fabricated using centrifugal casting in air (ARPA- E OPEN 2015)

Furnace roll fabricated using centrifugal casting of ORNL alloy has been successfully operating in heat-treat furnace at 900° C for more than two years (ARPA- E OPEN 2015)
Use of Alternate Alloys May Offer Additional Cost Savings if Properties Are Adequate

- ORNL funded by EERE, Vehicle Technologies Program, has developed high strength alloys with Ni+Co ~ 50 wt. %
  - US Patents 9,605,565 B2, 9,752, 468 B2
- Creep properties in cast + heat-treated condition will be evaluated to determine if alloys will meet property requirements

<table>
<thead>
<tr>
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<th>Fe</th>
<th>Mn</th>
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<th>Nb</th>
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<tr>
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<td>1 Max</td>
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Project Objectives

• Evaluate the feasibility of using a centrifugal casting process to lower manufacturing cost of piping fabricated using Ni-based alloys including Haynes®230, Haynes ® 282, or IN ® 740H

• Evaluate properties of cast and heat-treated alloys fabricated using this process
  • Investigate properties of alternate alloys with lower raw material costs

• Knowledge would be applicable to the design of piping, valve fittings, valve bodies along with those of turbo-machinery
Approach

• Fabricate laboratory scale castings, develop heat-treatment processes and measure high temperature mechanical properties

• Verify high temperature mechanical properties using small industrial scale castings and down-select alloys for centrifugal casting trials

• Fabricate pipes using centrifugal casting and verify that target properties are met
Anticipated Outcomes

- Centrifugal casting process will be developed for selected alloys that meet high temperature mechanical property targets
- Mechanical properties of selected alloys in cast + heat-treated condition
- Provide information on suitability of alternate alloys
- Develop a supplier base for lower cost, cast components