Explosion Cladding
An Enabling Technology for Zirconium in the Chemical Process Industry

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Zirconium and the Chemical Process Industry (CPI)

- Corrosion is a major equipment concern in many CPI facilities
- Zirconium exhibits superior corrosion resistance over a broader range of chemical environments and temperatures than virtually any other metal
  - Acids – both organic and inorganic
  - Strong Alkalis
  - Salt solutions
In Severe Corrosion Environments-

- Zr 702 and 700 are commonly used
- Zr is the material of choice for
  - Tanks, Columns, Heat Exchangers, Autoclaves, Reactors, Valves, Pumps...
- In conditions requiring thin wall equipment, Zr 702 is clearly a better value than other, often much lower cost Corrosion Resistant alloys
For Heavier Wall Equipment-

The cost/benefit justification for Zr is often more challenging.

Table 1: Comparative Costs of some Corrosion Resistant Alloys

<table>
<thead>
<tr>
<th>Alloy</th>
<th>Cost Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>S31603 (Stainless Steel)</td>
<td>1.0</td>
</tr>
<tr>
<td>R50400 (Titanium)</td>
<td>3.0</td>
</tr>
<tr>
<td>N10276 (Hastelloy)</td>
<td>5.0</td>
</tr>
<tr>
<td>R60702</td>
<td>8.0</td>
</tr>
<tr>
<td>R05200 (Tantalum)</td>
<td>20.0</td>
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</tbody>
</table>
Clad Can Significantly Improve Competitive Position for Thicker Applications

3 mm Zr
30 mm Steel
Cost Savings – Zr Clad vs Solid Zr 702

The graph shows the cost savings of Zr Clad vs Solid Zr 702. The x-axis represents the thickness of the equipment when designed with solid R60702, while the y-axis represents the cost savings (% of cost of R60702) for two different thicknesses: 3 mm Zr + steel and 8 mm Zr + steel.
Explosion Cladding

- The only proven industrial technology for joining Zr to Steels and most other metals
- Highly robust and reliable technology
- Broad range of metal combinations
- Discovered and industrialized in 1960’s
- Over 30 explosion cladding companies produce over 200,000 mt of clad worldwide today
- Zr clad is the most challenging to make
- Dynamic Materials Corp. developed Zr cladding technology and is World Leader today
The energy of an explosive detonation accelerates the Zr and base metal plates together causing a high velocity collision. The momentum exchange creates conditions which result in metallurgical welding.

**Explosion Cladding Process**
Explosion Weld Interface

![Image of Explosion Weld Interface]

- **Ti**: 500 nm
- **Low carbon steel**:

![At. % vs Distance (nm) graph]

- **Ti**
- **Fe**
Zr – Steel Explosion Weld Interface

- Diffraction studies indicate interface layer is amorphous
- Result of very fast heating and cooling, estimated to be $> 1 \times 10^7$ °C/sec
- Thermodynamically stable intermetallic compounds do not have time to form.
- Zr-Steel interface typically $> 200$ MPa shear strength, highly resistant to disbonding in fabrication and service
Heat Exchanger – Nitric Acid - 200°C

- Stainless Steel Shell
- Zr Tubes
- Zr – Stainless Steel Explosion Clad Tubesheet
Zr Clad Pressure Vessel

- 50,000 liter reactor
- 3 mm Zr cladding on inside for corrosion resistance
- 30 mm Carbon Steel shell for pressure containment
- Steel water jacket on outside for temperature control
Tube Coupling: Zr-to-Stainless Steel

12 mm long Zr

Explosion weld Zr to Stainless

38 mm long stainless steel
Conclusion

- Explosion cladding enables the cost effective use of Zr as a corrosion resistant material in many severe CPI applications.
- Today virtually all Zr CPI equipment requiring wall thickness > 20 mm is explosion clad.
Acknowledgments

- ATI Wah Chang, especially
  - Terry Webster
  - Richard Sutherlin
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Thank You

For More Information about Explosion Cladding please visit www.dynamicmaterials.com