Maintaining Aging Titanium Clad Equipment

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Reactive Metal Clad in CPI

- Typically Ti, Zr, Ta, Nb – Ti Dominates, presentation focus’ on Titanium but generally applicable to all four metals
- Clad is commonly used in stationary CPI equipment---pressure vessels, columns, heat exchangers
- For over 50 years, >95% of titanium clad has been made by Explosion Cladding
Preventive Design: a Head Start on Aging Equipment Management

- History shows 50+ years good Ti Clad experience, yet... NOT Ti-clad is still not your everyday commodity material
- When equipment production team is adequately experienced, performance issues with clad are rare-
- When properly designed, constructed and operated this equipment is highly robust, typically providing problem-free performance for 25 to 50 years

Preventive Design: a Head Start on Aging Equipment Management - continued

- Knowledgeable, experienced design, fabrication, clad manufacture are critical-
- Few applications are Cookie Cutter (even ones that seem to look alike)
- Alloy selection must be appropriate for the application – CP Ti vs Ti-Pd vs Ti-12 vs ???
- Materials thicknesses – appropriate for fabrication and service
- Dissimilar metal concerns & manufacturer understanding- this is not stainless steel
- Limited breadth of supply chain-
  - Explosion Clad Producers- Over 50 globally, yet ~10 are OK for Ti clad tubesheets, ~5 for Ti clad vessel plates
  - Fabricators- many reliable for HX tube bundles- far fewer for Ti-clad vessel fabrication
- Limited availability for 3rd Party Inspectors knowledgeable Ti Clad projects... not so critical with experienced producers, but very important for newbes and wannabes
Typical Ti-Clad Equipment

Ti Clad Equipment Reliability

- Diligence during clad equipment selection, design and manufacture has assured very low clad equipment maintenance concerns

- When there are failures they typically result from:
  - Fabrication weld quality- primarily in batten strip welds or similar nozzle liner closure welds
  - Loss of cladding thickness due to corrosion, erosion or mechanical damage
  - Design
Ti Clad Equipment Risk

- Clad equipment relies on-
  - The cladding layer for process **corrosion containment**
  - The base metal layer for process **pressure containment**

- A through-thickness cladding metal failure can result in aggressive corrosion of the base metal layer.

- The resulting Risk is loss of the equipment and further potential damage from a high pressure release of the process media. How big is it?

When Problems Arise

- Ti-Steel Clad fabrication requires batten strip weld designs
- Titanium batten weld cracks are the most common cladding defect
- Properly made batten welds very rarely crack

>90% of Ti Clad Equipment Fabrication

Preferred when clad is thicker, erosion or corrosion are expected

Surface Mount Batten Picture Here

Other specialized batten designs
Inspection for Batten Weld Defects

- There are currently no reliable NDE methods for detecting purely subsurface partial penetration batten strip weld defects.
- Batten strip fabrication welds should be examined by penetrant testing (PT) and helium leak testing (HLT) as part of the fabrication ITP.
- On-site re-test of by PT and HLT is recommended pre-startup and/or post startup, with ongoing frequency depending upon the reliability record of the Fabricator and the Risk Assessment.
- Periodic inspections throughout the equipment lifetime should be addressed in the Risk Based Inspection Plan.

In-Service Detection of Batten Weld Defects

- Telltale inspection access to the hidden backside of the batten strip is an important feature of the design
  - Batten strip fabrication welds necessitate backside inert gas purge
  - The purge is achieved via a hole drilled through the steel backing metal to access the titanium weld root
  - This same hole provides a non-intrusive “telltale” monitoring tool during operation.
- When properly maintained and monitored, the telltale’s will reliably provide early warning of a weld failure.
Telltale Detection of Batten Weld Failure

- Tubes attached to the telltale ports can be located where frequent monitoring is easy.
- Modern, automated monitoring systems can be used.

- This photo shows a poorly managed telltale monitoring bank. Regrettably the importance of telltale tube maintenance if often not understood by operators.

Repair of Batten Weld Defects

- When found early, batten repairs can be made without major complications

- Repairs should be made on-site by an experienced titanium clad fabricator using best titanium welding, fabrication and inspection practice

- It is critical to fully clean the area behind the failure prior to installing a new batten strip.
Titanium cladding is typically chosen for its corrosion resistance.

As with solid titanium equipment, titanium cladding is generally selected only if the corrosion rate is predicted to be zero. A corrosion allowance is rarely considered necessary in the titanium thickness decision.

Titanium thickness has traditionally been established by cost and manufacturing/fabrication limitations on the rule “less is better”.
Historical Cladding Metal Thickness

- In 1960’s 2mm (0.078 in) titanium cladding thickness was established as the best “practical” thickness for clad manufacture and fabrication
  - Most titanium clad vessels produced between 1960 and 1990 used 2mm nominal cladding thickness

- In 1990’s the industry began to realize that 3mm (0.118-in) cladding was actually **lower initial cost, lower damage risk and more easily repaired when needed**.
  - Since 1990 the standard has gradually transitioned toward 2.5 to 3.5 mm (0.10 to 0.14 in) thick cladding.
  - When erosion or mechanical damage is considered a possibility additional thickness is added.
  - For example, in hydrometallurgical process equipment the cladding thickness is typically increased to the 6 to 8mm range (0.25 to 0.31 in)

Cladding Metal Thickness Damage

- Rare but Real operational problems can cause cladding metal thickness loss
  - Corrosion- most commonly pitting/crevice
  - Erosion
  - Mechanical damage –

- In the absence of proper design and/or monitoring, full thickness cladding loss can result.
Repair of Cladding Loss

- When the thickness monitoring proves provides early warning, areas of reduced cladding thickness can be repaired by overlay welding. Typically OK when around 1.5mm (0.060 in) cladding remains.

- Defects shown in the prior photo are more challenging:
  - Cladding alloy patches have been used successfully. See photo on following sheet.
  - In worse cases, full through-thickness vessel sections have replaced to salvage the equipment.

Technique for Patching Larger Areas of Cladding Metal Loss

- Steel overlay repair
- Titanium filler plate
- Titanium cladding
- Steel base metal
- Titanium patch plate
- Purge/Vent/Telltale
- Titanium seal weld
Heat Exchangers

- Clad metal is primarily used for
  - Tubesheets
  - Shells
  - Bonnets
- Issues with shells and bonnets is similar to the vessel discussion above

Clad Tubesheets

- Issues with clad tubesheets has typically been related to
  A. Improper tubesheet and exchanger design
  B. Inadequate tubesheet metal thickness selection
  C. Improper fabrication
Heat Exchanger Failure #1

- Designed as shown on left with clad interface exposed to process media.
- Bimetal corrosion caused titanium hydriding and eventual bond failure.
- Preferred design is shown on right.

Heat Exchanger Failure #2

- Zirconium-Stainless clad tubesheet + Zirconium Tubes
- 5mm (0.19 in) Zr as clad
- Face machining reduced Zr to 2mm thick (0.080 in)
- Tubes were fully welded to Zr face, very significant weld cracks
- Cracks masked with “seal welds”.
- Failed after 12 years service.
- RBI penetrant inspections would have sent up Concern Flags years earlier.
Conclusions

- When properly designed, manufactured and fabricated clad equipment performs highly trouble free
- Without all 3 of the above, clad can fail
- A well established Risk Based Inspection Plan will greatly reduce unanticipated problems
- If detected early, most clad equipment defects can be repaired

Thank You

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