MANUFACTURING OF LARGE AND HEAVY CLAD PLATES BY EXPLOSION CLADDING

STEPHANE PAULY
Agenda

1. Introduction to Dynamic Materials Corporation
2. Explosion cladding / welding process (DETAACLAD®)
3. Manufacturing of large and heavy clad plates
4. DMC experience on heavy clad components
Corporate overview

- Founded in 1965, Manufacturers of DETACLAD® plates for over 40 years
- Public Company, NASDAQ symbol ‘BOOM’
- Headquartered in Boulder, Colorado USA
- ~226 M USD$ - 400 Employees in 10 Countries
- 3 different divisions
DMC - clad metal locations

CLADDING CAPACITY = 75,000 m² (~30,000 tons/yr with 50mm base)
DMC Manufactures Detaclad® Explosion Clad

A unique, robust technology for welding plates together using the energy of an explosive detonation.
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DETACLAD® welding process

**Pre cladding Assembly**

- Cladding and Base Metal Plates are positioned parallel with a preset separation distance (1).
- Explosive is placed on top

**Explosion cladding event**

- Detonation sweeps across the plate at ~2000m/sec (2 & 3)
- Solid state welding process
- Essential variables are:
  1. Stand Off Distance (mm)
  2. Detonation velocity (mm/s)
  3. Explosive load (kg/sqm)
Explosion clad plate manufacturing

Pre-clad Operations

1. Plain Material Inspection
2. Grind Mating Surfaces
3. Assembly: Backer, Cladder

Cladding

4. Explosion
5. Flattening and Cutting

Post-clad Operations

6. Testing and Inspection
   Ultrasonic Examination of Bond, Mechanical Tests, Physical Measurement, Certifications
DMC capacity - Clad Plate sizes

Thicknesses:
Cladder: 1 to 30 mm
Base: 1 to 500 mm

Titanium clad plates for Ni autoclaves
9m x 2m x 140 mm

Forged Ti clad tubesheets for Urea Strippers
(diam 2.3 m x 400 mm)
Metals typically clad

**Cladding Metals**

**Ferrous Metals:**
- Carbon Steels
- Stainless Steels

**Non Ferrous Metals:**
- Ni & Ni alloys
- Aluminum & Al Alloys
- Copper & Cu Alloys

**Reactive Metals:**
- Tantalum
- Titanium
- Zirconium

**Base Metals***
- All Metals
- Alloy Steel
- Carbon Steel
- Stainless Steel
*Plate or forgings
316L - Explosion clad interface

EDX scan of the Stainless Steel–Mild Steel bond interface which is approx 20 nm.

=> ATOMIC SHARING BOND
Ti Grade 1 – Explosion Clad Interface

interface-100nm

=> ATOMIC SHARING BOND
Alloy 825 cladded on A 516 G70 HIC (4,5 mm)

Cladding thickness of 4,5 mm

=> CLADDING THICKNESS IS GARANTY
Explosion cladding attributes

✓ **Solid state welding process** that does not modify:
  • Corrosion and thermal resistance of clad metal (no dilution, No HAZ)
  • Base metal properties meets Code requirements.

✓ Virtually **any metal combination** can be welded
  • Similar alloys, such as Stainless Steel to Steel
  • Dissimilar alloys, such as Ti or Al to Steel

✓ **Plates & forgings** can be cladded

✓ **Flexible** is sizes and quantities

✓ **DETACLAD® process** is **reliable**: 0.005% rejectable area of production area
DETA CLAD’S® plates vs other processes (1/2)

GREATER BOND STRENGTH

✓ Stainless & Ni alloys:
  • Shear strength ≈ 400 Mpa
  • Tear strength ≈ 500 Mpa

✓ Ti & Zr clads
  • Shear strength ≈ 200 Mpa

✓ Attachments can be weld directly to Detaclad

Shear test – SSteel/Csteel
UNCHANGED MATERIAL CHEMISTRY (no dilution)

- Corrosion resistance is constant over full thickness
- HIC properties of the steel are conserved
- DETACLAD is resistant to Hydrogen induced disbonding (HID)

Tests in accordance with ASTM G146
- SA387-Grade 22 Cl 11 with 316L (40+6 mm)
- $PH_2=15 \text{ bars at } T^\circ 450^\circ C \text{ for } 48 \text{ H}$
- Cooling rate= $150^\circ C/h$
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Manufacturing of Large and heavy clad plates

CLADDING CAPACITIES

Underground Chambers
Detonations to 8 tons

Open Air
Detonations to 1 ton

Operations capable of 13m long and heavy clad plates (50 tons)
Manufacturing of Large and heavy clad plates

**PREWELDING**

- Plasma and TIG Keyhole bench up to 7,6 m
- Necessary for long and Large cladding plates
- Allow the use of coils for shorter deliveries
- Welding process qualified by ASME section IX and/or european codes
- Over 20 years of experience inside DMC group
- Welding engineers

Typical cross welds on cladding alloy

Typical cladding alloy prewelded
Manufacturing of Large and heavy clad plates

**FLATENING**

- Large & specialized flatening equipements
- Typical flatness of 5 mm/m achieved
- Rolling or pressing

2 presses – 1500 & 1800 Tons in USA
Up to 200 mm

Roller leveller 4m wide
Up to 75 mm
Manufacturing of Large and heavy clad plates

HANDLING

✓ Internal cranes up to 50 T
✓ Forklift of 20 T each
✓ Skilled and qualified operators
✓ Special procedures to avoid contamination or Deterioration during handling
Manufacturing of Large and heavy clad plates

SUPPLY CHAIN

- Large yards for the storage
- Dedicated personnel for transportation
- Qualified personnel (COFREND, ASNT) for inspections
- Capacity reservations
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DETA CLAD® applications

Transition joints
(ships, Aluminium pots, train)

Clad plates for pressure vessels
(reactors, hydrotreaters, heat exchangers)
Explosion Clad Market sectors

- Armouring
- Shipbuilding
- Railway industry
- Electrochemical processing
  - Chlorine cells
- Hydrometallurgy
  - Aluminum
  - Nickel
  - Magnesium
- Energy
  - Upstream Oil and Gas
  - Refineries
  - Power Generation
  - Coal Gasification
  - LNG
  - Alternative (ITER, solar)
- Chemical & Petrochemical Industry
- Refrigeration
- Steel mills
DMC experience in Heavy clad component

Desulfurization units, hydrotreaters:
Stainless steel clad refinery column

- Cr-Mo steel + Stainless 321 (102 mm + 3 mm)
- 5 m diam x 35 meters long
DMC experience in Heavy clad component

Oil & Gas Separation units:
slug catchers, separators, acid gas removal

- Steel SA516 G70 HIC + 316 L or 825 or 625
- Sizes range: 8 m x 2 m x (150 + 3 mm)
- Slug catchers (Wasit Gas)
DMC experience in Heavy clad component

Oil & Gas Separation units:

Clad Pipes - Finger type slug catchers

✓ Steel SA516 G70 HIC + 316 L or 825 or 625
✓ Sizes range : 12 m x 3,8 m (40 + 4 mm)
✓ Slug catchers (Gorgon, Australia)
DMC experience in Heavy clad component

Hydrometallurgy (Pressure Acid Leaching):

Nickel leaching autoclaves

- Steel SA516-70 + Ti GR 17 (120+8.50 mm /60+9 mm)
- 4-5 m diameter x 30 m long
DMC experience in Heavy clad component

PTA plants (Purified Terephthalic Acid):

Ti clad reactor column

- Steel SA516-70 + Ti Gr 1 Thickness (38 to 75+3 ; 117+12)
- 73 m high and 6 m diameter
DMC experience in Heavy clad component

Urea processing:
strippers, heat exchangers

✓ Steel SA508 + SA 533 + Titanium SB 265 Gr 1 (or zirconium)
✓ Sizes range: 7,6 m x 2,2 m x (80+3 ; 400 + 12 mm)
Conclusions

- Detaclad technology is proven robust and reliable
- Detaclad products have extensive performance experience in the heavy clad applications
- Fast delivery is possible when needed
Conclusions

THANK YOU FOR YOUR ATTENTION

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