WEAR REDUCING TECHNOLOGY NEWLY APPLIED TO SEVERE PUMPING SERVICES

TAMU Case Study 2011

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ABSTRACT

• A U.S. Gulf Coast refinery had experienced accelerated internal wear of FCCU cycle oil pumps, often requiring entire case replacements. Compared to typical industry pump performance, run lengths were shorter, and cost per installed was higher. The application requires pumps capable of withstanding significant catalyst fines.

• Several wear resistant products have been used in pumps. However, all are limited due to the nature of the technologies. Thermal spray coatings and weld overlays can be used in “line of sight” applications, but not for small interior surfaces. Thermal sprays suffer from failures of the mechanical bond. There is preferential erosion of the soft matrix between the hard particles in weld overlays. Hard diffusion coatings (boronizing) are very thin and can be punctured by large abrasive particles.

• Infiltration brazed tungsten carbide cladding (IBTCC) solves many of these issues. IBTCC was developed for extreme wear applications with difficult geometries such as downhole drilling tools and coal fired power plants. IBTCC combines a true metallurgical bond and a dense, uniform distribution of tungsten carbide particles throughout the coating, to create excellent erosion resistance and toughness in complex geometries.

• After 13 months in service, an IBTCC cycle oil pump showed no significant signs of internal erosion. This technology has also been applied to FCCU fractionator bottoms and debutanizer reboiler services, with no signs to date of increased vibration or loss of hydraulic performance.

• The case study will show how internal material changes can improve pump longevity and produce maintenance cost savings.
Introduction

• **Current Hardware**
  P-8A/B, P-9A/B overhung API pumps
  P-3A/B, P-518A/B between bearings, top suction API pumps

• **Previous Run Lengths, MTBRs**
  P-8A/B, P-9A/B with 12% chrome case average life was 1 month, with tungsten carbide HVOF averaged 8-12 months.
  P-3 A/B with WC HVOF would run for about 2.5-3 years before complete failure, 4.5-5 years with Boron Diffusion.
  P-518 A/B developed severe vane pass vibration in 1 – 1.5 years.
    Lasted 3 years maximum before total loss of impeller and case.

• **Pump Operating Conditions**
  P-8, P-9 FCCU Cycle Oil Pumps
  Clarified Oil at 650 F, 0.75 SG, with significant catalyst fines – like sand, but very fine
  30 psig suction, 400 gpm, 350 feet of head
  4x3-10.5 pumps at 3600 rpm – small size/high speed not ideal for erosive service

  P-3 FCCU Fractionator Bottoms Pumps
  FCCU Catalyst Slurry at 680 F, 0.87 SG, with 0.1 to 0.3 wt% solids
  25 psig suction, 3500 gpm 440 feet of head, 5000 gpm 400 feet of head
  16x12-20 pumps at 1800 rpm

  P-518 Cat Light Ends Debutsanizer Bottoms Pumps
  Cat Naptha (Butane) mix at 460 F, ~0.55 SG, with significant catalyst fines
  195 psig suction, 2950 gpm, 419 feet of head
  12x8-23 pumps at 1800 rpm
Problem Description

• P-8 case wear ring after 10 months
  – May 2005
• P-8 case gouge after 8 months
  – Oct 2008
• 1 unit shutdown, lost both pumps
Problem Description

- Shredded P-3 wear plate
  - December 2007
  - Spare strategy left unit vulnerability
  - Unable to maintain top rate
- P-3 impeller, cut to ribbons
  - May 2009
Existing Technology – Erosion Resistance for Pumps

- Tungsten Carbide (WC) Spray, HVOF
  - Line of site process
  - Low bond strength (10,000 – 12,000 psi) – easily undermined
- Boron Diffusion (BD)
  - Only 0.008-0.010” thickness on carbon steel
  - Even thinner ~0.003” on 12-chrome
  - Large abrasive particles can puncture the coating
  - Once thin coating punctured, the substrate is left without wear protection
- Weld Overlay
  - Soft binder holding carbide particles
  - Uneven carbide distribution in the matrix – Preferential erosion path
- Solid Stellite impellers
  - Difficult to source consistent castings
- Welded Stellite
  - Delayed cracking potential
  - Low carbide content (12%-15%) – Not optimum protection for erosion wear
Flexible Tungsten Carbide cloth can conform to complex geometries.

Provides premium wear protection in previously difficult to reach locations.

Not limited by “line of sight” application.
Infiltration Brazed Tungsten Carbide Cladding Process

- **POWDER MIXING**
  - Abrasion Resistance
  - Corrosion Resistance
  - Impact Resistance
  - Erosion Resistance
  - Selected powders and organic binders

- **CLOTH FORMATION**
  - Material rolled to predetermined thickness and density

- **CLOTH APPLICATION**
  - Selected Hard Particle Cloth

- **FURNACE BRAZING**
  - Applied with Low Temp Adhesive
  - Controlled Inert Environment Furnace Brazing at >1093 °C
Infiltration Brazed Tungsten Carbide Cladding Characteristics

*Can be applied to most steels: Carbon, Stainless, Nickel Alloys
*0.030” to 0.060” thickness
*Hardness up to 70 HRc
*High Inter-Particle Bond Strength
*Controlled Cladding Thickness
*Minimal Dilution from substrate

*Metallurgical Bond (70 KSI + bond strength)
*High Tungsten Carbide Loading (70% by wt.)
*Uniform Carbide Distribution & Microstructure
*No Oxide Contamination
*Minimal Porosity
Finishing

• Parts should not be finished prior to cladding, due to distortion during brazing process.

• 0.125-0.25” Extra material needs to be left for important features (head & wear ring fits, etc.) to be finished after cladding.

• Ultra tight tolerances and fine finishes are possible with CNC machining centers and vertical grinders.
Abrasion Resistance (ASTM G-65)

6000 Revolutions with Sand
(coatings applied on 1018 carbon steel)

*Boron Diffusion results extrapolated from 1000 revolution test due to coating thinness
Erosion Resistance

Erosion

- If high erosion-resistant particles exist in low erosion resistant or soft matrix, the impacting particles can undercut and remove portions of the material (Figure 1).

- However, if the high erosion resistant particles such as tungsten carbide are densely packed in a matrix material that causes the impacting particles to impinge on a greater percent of the hard particle, the erosion resistance increases dramatically (Figure 2).

*Hard particle density key to erosion resistance*
Erosion Resistance (ASTM G76)

- 60 Micron angular Al₂O₃,
- 2 g/min feed rate,
- 230 ft/sec velocity

(coatings applied on 1018 carbon steel)
Erosion Resistance

1/16” of IBTCC provides equivalent erosion protection to 1” of chrome carbide weld overlay or 3” of carbon steel.
Comparative Microstructures

IBTCC (reference = 500 μm)

Boron Diffusion
(reference = 200 μm)

12% Co WC HVOF Spray
(reference = 200 μm)

Cobalt Alloy
Comparative Microstructures

IBTCC  50 $\mu$m and 100 $\mu$m

Boron Diffusion  40 $\mu$m and 20 $\mu$m

12% Co WC HVOF Spray  200 $\mu$m and 10 $\mu$m
Improvement Projects

- IBTCC applied to new P-3 cases, heads, impellers, wear plates.

- Manufacturing Considerations: To machine or grind
  - Areas to be clad need generous radii underneath, prefer 1/8” min.
  - Weld balance pads on impellers or extra layer all around
  - Build up to-be-ground areas to 0.06-0.08”, leave nominal 0.030”
  - Adjust casting patterns for more axial clearance
  - Coating thickness – not much effect on large pump efficiency
Improvement Projects

- New P-3 “drop-in” pumps with IBTCC internals on all wetted parts - case, heads, impeller, and wear plate surfaces. Integral wear rings.
- Adds ~8 weeks to lead time. Slightly more expensive than BD.
Hydraulic Performance

- OEM original 22” impeller vs. IBTCC with 20.625” impeller
- Measured thickness applied to various components 0.030-0.060”, falls within typical casting tolerances.

- No signs of performance or mechanical degradation so far, ~1 and ~2 year ongoing run lengths
Mechanical Performance

- Can balance to common specifications: 4W/N, ISO G2.5, etc.
- P-8 Clarified oil pump after one year of service with infiltration brazed tungsten carbide cladding, 0.004-0.008” at most material loss. See below. Did a slight cladding repair.
- Projected life extended to 3-4 years, from ~12 month max run with WC HVOF.
- Pump pulled due to strainer plugging. Impeller ran 3 months on the key alone, metal/metal against case. Could have reused except for oversize impeller bore.

- Separate Houston area Olefins plant applied IBTCC inside a tar pump. Internal inspection showed no wear after 5 months. The pump required repair every 4-6 months with previous coatings.
Mechanical Performance

- Both P-518A/B IBTCC cases running ~4 years - no signs of vane pass vibration yet.

0.24 ips @ 7125 cpm = 4X running speed
BEFORE - in 2007

0.02 ips @ 119 Hz = 4X running speed
AFTER - in 2011
Comments and Questions?
Backup Material
Bond Strength

Reported bond strengths of flame spray processes compared to brazed claddings.
Bond Strength Evaluation

Threaded tensile specimens were made from hardened 4140. The “halves” were brazed together using the braze alloy and typical brazing cycle.

Specimens were tensile tested by an outside lab. All samples broke at the braze joint (as was intended). The average tensile strength from 26 pieces was 72,000 psi.
Fly Ash Erosion Test

EPRI (Electric Power Research Institute) testing found that IBTCC WC 210 provides superior erosion protection for power boiler fan blades exposed to high-velocity bituminous coal fly ash.

Erosion Resistance

EPRI CS - 6068, Project 1649-4
Corrosion Resistance

Laboratory Testing, ASTM G31 Standards

Corrosion Resistance
than 17-4 pH Stainless Steel

Material Loss (mils/yr)

<table>
<thead>
<tr>
<th>Material</th>
<th>Loss (mils/yr)</th>
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<tbody>
<tr>
<td>WC 210</td>
<td>402</td>
</tr>
<tr>
<td>316L Stainless Steel</td>
<td>1,326</td>
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<tr>
<td>17-4 pH Stainless Steel</td>
<td>17,849</td>
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10% Sulfuric Acid at 212°F (100°C)
New IBTCC P-3 Pump
Damage to Previous Pumps

Boron Diffusion worn through (wear plate closeup)

25 Chrome iron impeller tip wear