FusionStell™ Cladding

Coking Safety and Reliability Seminar
Galveston, TX, 2 – 4 May 2012

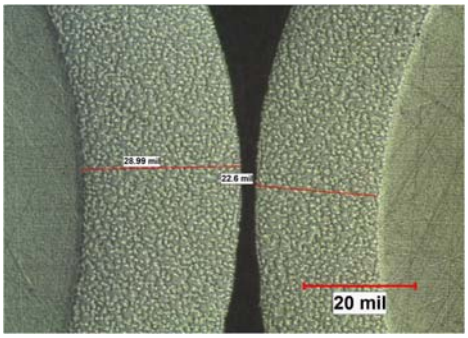
Deloro Stellite Group

Deloro Stellite is a global provider
of innovative solutions to challenging wear problems.

We deliver advanced wear protection
to extend the life of components
in demanding environments
where heat, corrosion and abrasion
are prevalent.

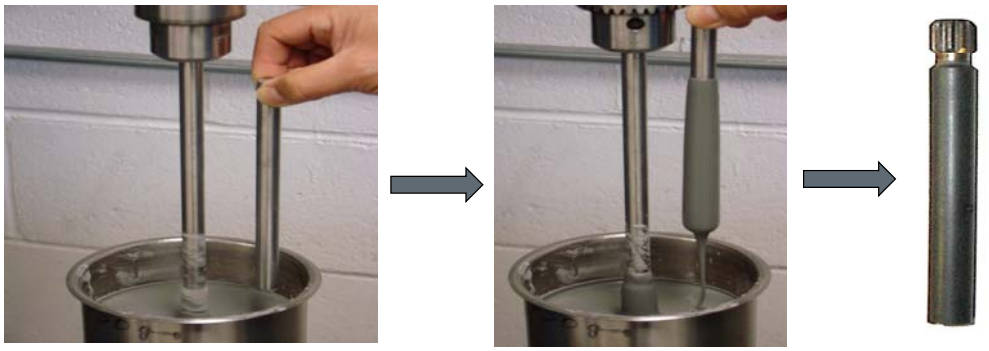
FusionStell™ Cladding process

- A novel technology to metallurgically bond a thin layer of Stellite with full density onto metal substrates
- The coating offers the wear resistance of a cast cobalt component on a non-cobalt substrate, typically steel
- Properties of the FusionStell™ coating the same as cast alloy
  - Chemical composition identical
  - Hardness the same
  - Finish the same as equivalent cast alloys
- No Fe-dilution or heat affected zone as in hardfacing of Stellite
- More consistent coating quality than spray & fuse coatings



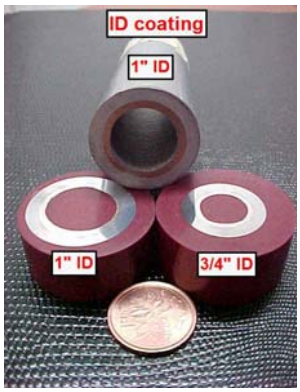
FusionStell™ Process

- Stellite powder is mixed with water, organic binder, and various additives to form a slurry
- Substrate components are dipped into the slurry and the metal coating adheres to the component surface
- The coating is air dried, before sintering in a vacuum furnace



FusionStell™ samples

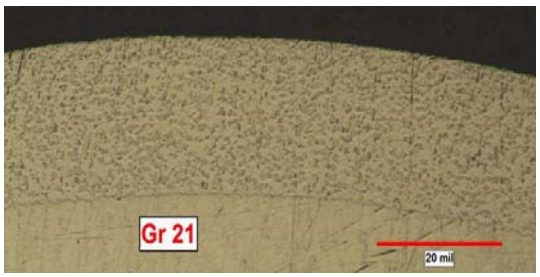
Outside diameters



Inside diameters

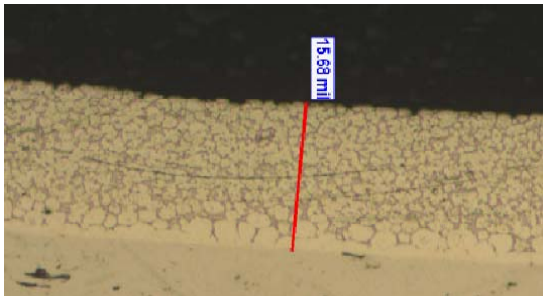
Complex shapes

Metallurgically bonded coatings

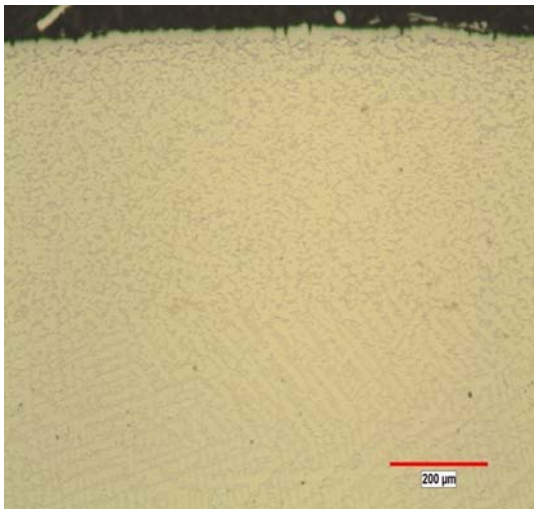


Outside diameter

Inside diameter

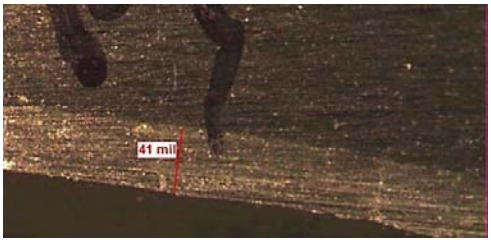


Stellite 720 on ID of 9Cr1Mo pipe



Stellite 12 coating on Stellite 12 casting

FusionStell™ Coated 9Cr-1Mo Return Bends



FusionStell™ Applications

Good Coating Bond Strength

- Bend test showed good bonding of FusionStell™ Stellite 720 coating onto 9Cr-1Mo with no coating delamination

Bend test sample & set-up

Bend test results

Substrate compatibility

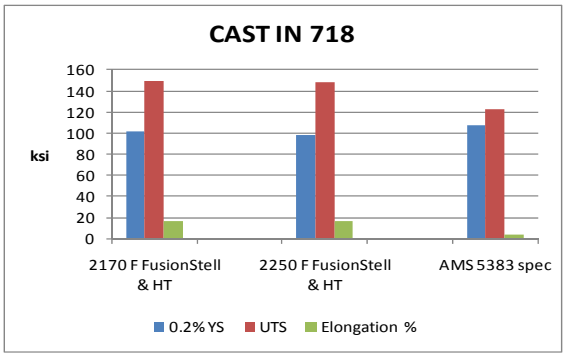
- Certain substrates cannot be subjected to high temperature sintering
- No problems with Stellite 6 & 12, but very hard coatings have limitations

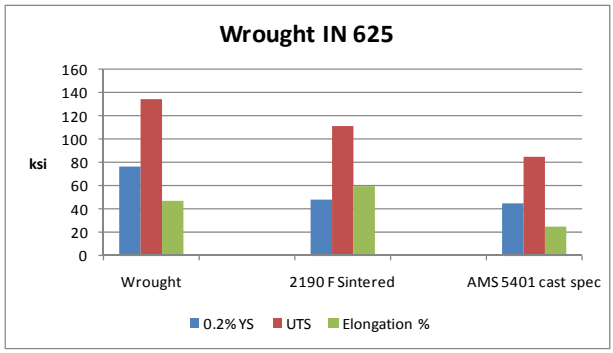
	Carbon steels (1026, 4130, 1018)	**Austenitic stainless steels** (316, 304, 308, 303, 347)	**Precipitation hardened steels** (17-4 PH)	**Martensitic steels** (410, 420, 440C, 9Cr1Mo, F9, F91)	**Ni-based alloys** (C276, 800H, 718)
Common Stellite Stellite 6 & 12 (hardness range 40 – 48 HRc)	✓	✓	✓	✓	✓
Very hard Stellite Stellite 720, Star J (hardness range 53 - 58 HRC)	✓	✓	✓	440C ✓ 9Cr1Mo* ✓	✓
Tribaloy alloys T400, T800 (hardness range 53 - 56 HRC)	✓	✓	✓	440C ✓ 9Cr1Mo ✗	C276 ✓ 800H IN718 ✗

* fine cracks in the coating

Substrate Mechanical Properties

- Mechanical properties of steels recovered with post-coating heat treatment
  - Austenitic steels unaffected
  - Precipitation hardened and martensitic steels fully recovered
- Most cast alloys properties not significantly affected
  - Typically a slight reduction in yield strength
- Wrought alloy properties reduced between 15 - 25% due to grain growth
  - Yield strength mostly affected





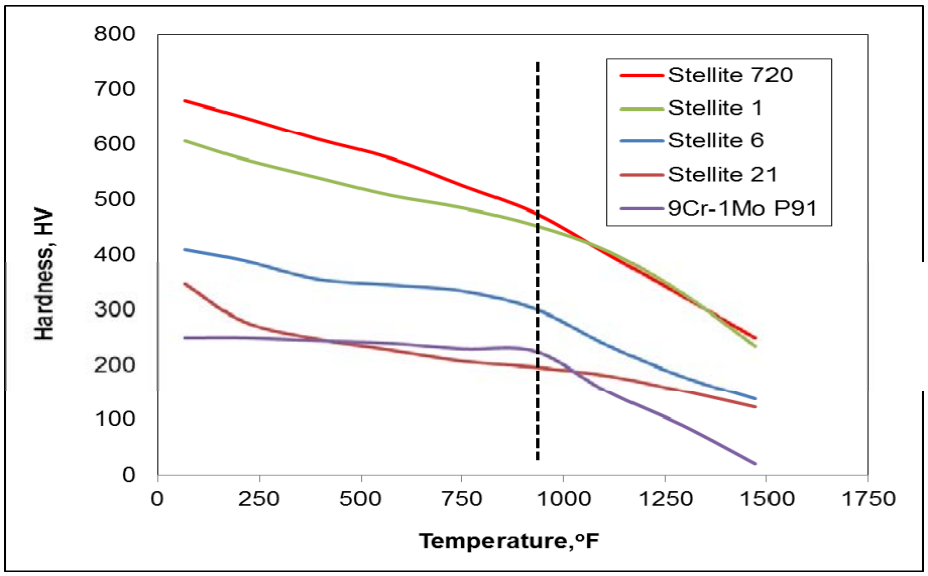
Stellite Alloy Chemistries

Alloys	Cr	W	Mo	C	Hardness, HRC
Stellite 6	29	4.5	-	1.2	39 - 43
Stellite 12	29	8	-	1.8	47 - 51
Stellite 1	31	12.5	-	2.5	51 - 58
Stellite 720	33	-	18	2.5	55 - 60

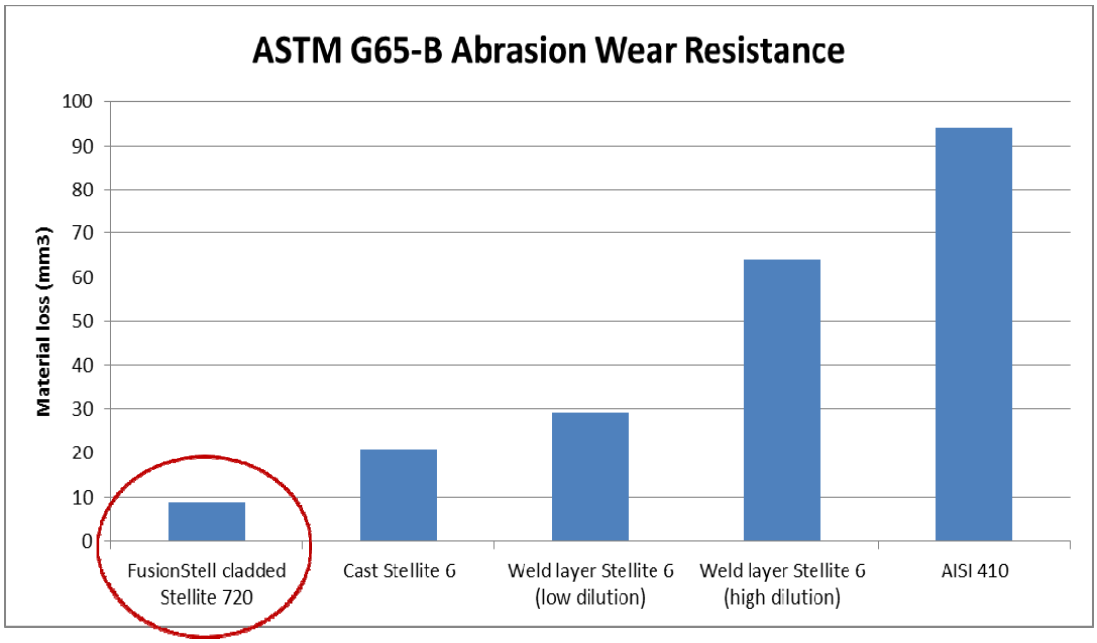
- Wear properties of the coating is determined by both the alloy chemistry and manufacturing process

High Temperature Hardness

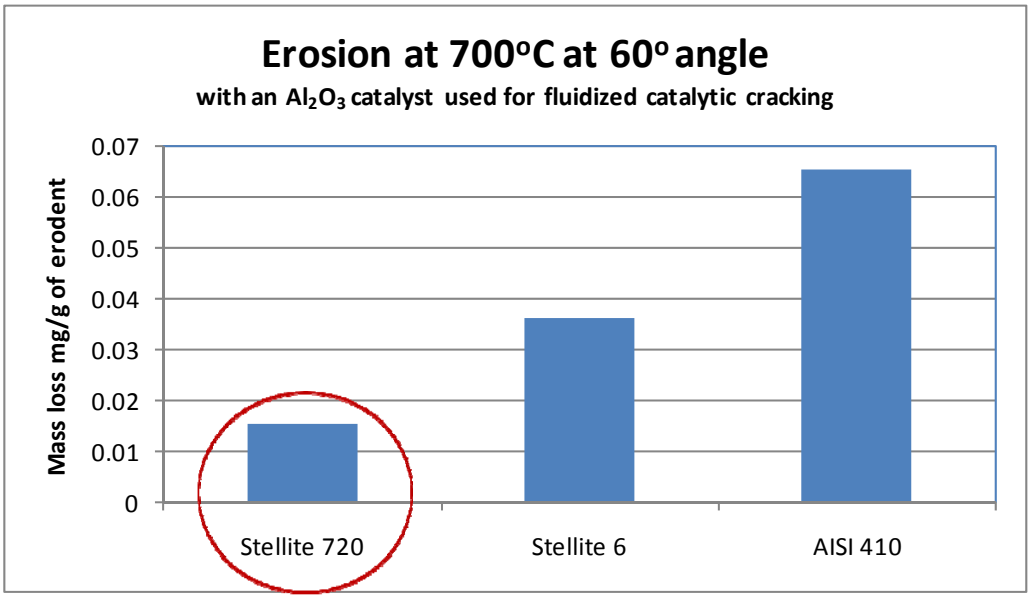
- Stellite alloys retain hardness above 900ºF better than 9Cr1Mo



Better Wear Resistance than Hardfacing



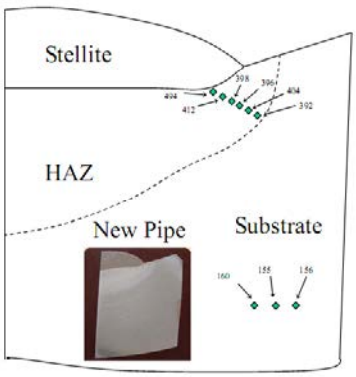
High Temp Erosion in FCCU environment



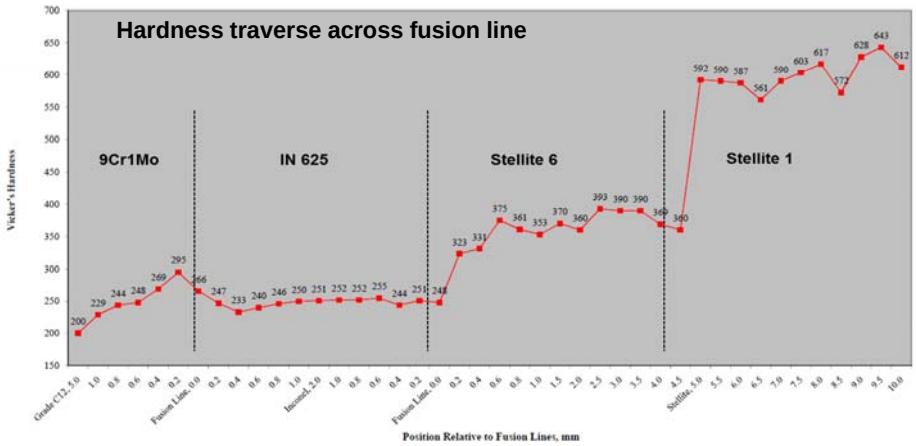
Weld Overlays in Return Bends

Limitations of Stellite weld overlays

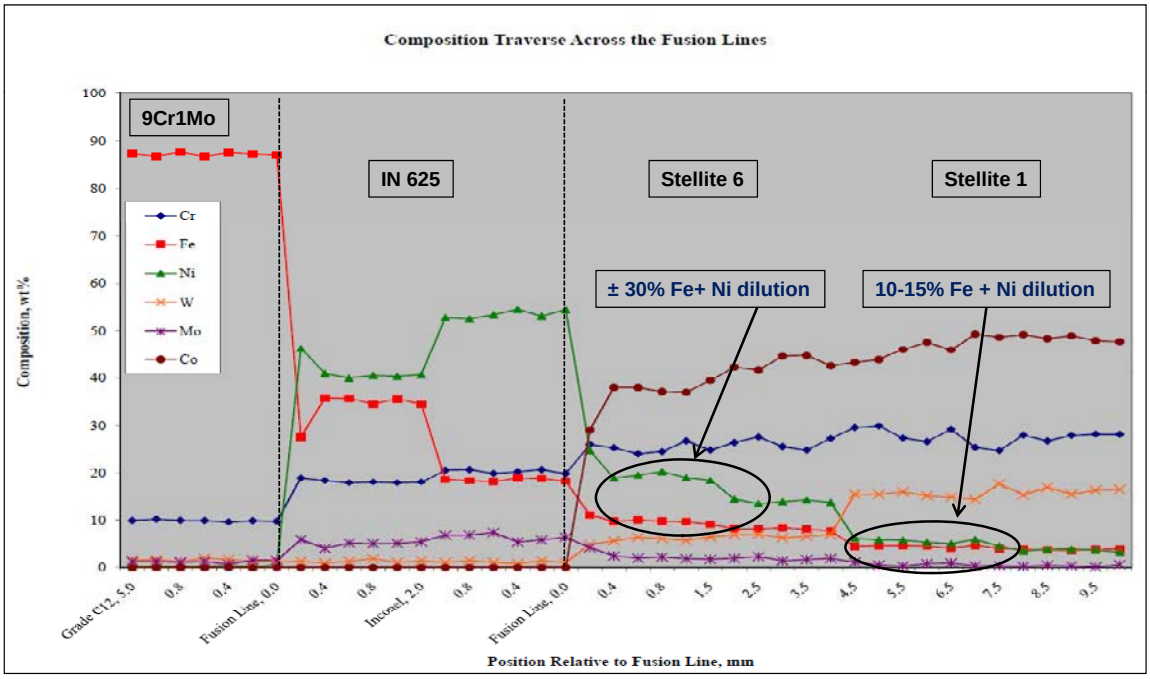
- Over-heating of substrate
- High welding rate cause large HAZ
- High Fe-dilution & Ni-dilution reduce wear properties of Stellite
- Irregular surface effect flow rates



Return Bend with Weld Overlay

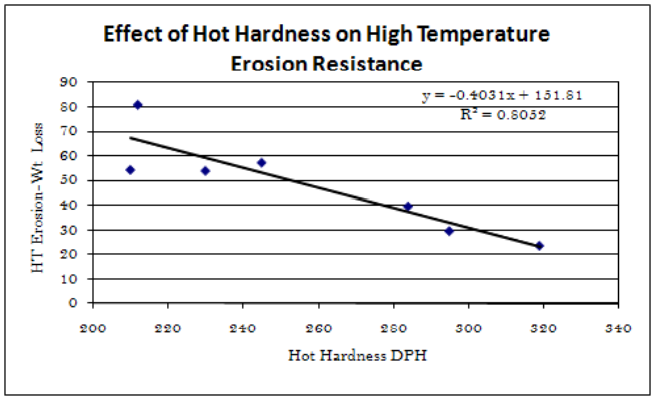


Dilution in Weld Overlays



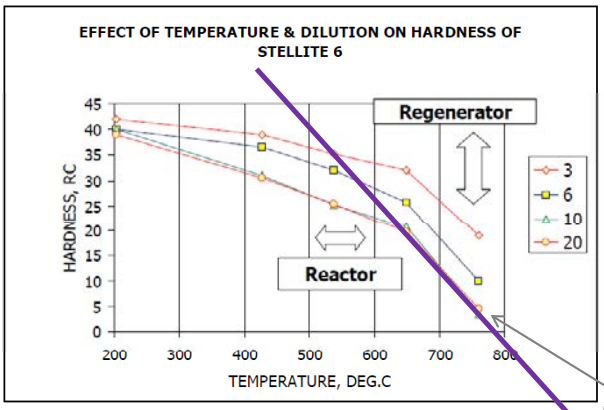
Why is Dilution important?

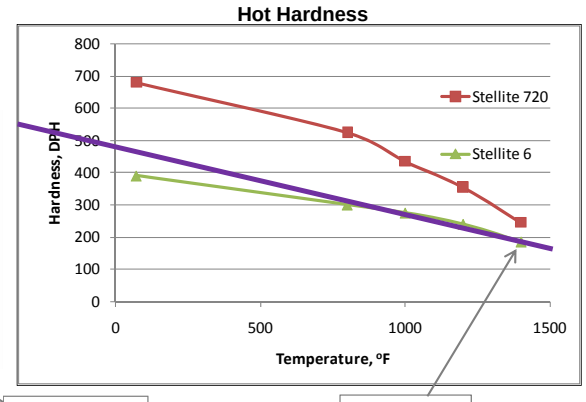
- Dilution of Stellite weld overlays from substrate is inevitable
  - Dilution is amount of Fe or Ni (when using IN625 butter layer) in the Stellite
- Dilution in Stellite generally has the following effect:
  - Decreases hardness – more pronounced at higher temperatures
  - Decreases corrosion resistance
  - Decreases wear resistance
- Erosion rate doubles when hardness decrease from 320 to 200 DPH



Hot Hardness and the Effect of Dilution

- Hot hardness is very important to ensure good wear resistance at higher operating temperatures
- Hardness drops rapidly with increased Fe dilution, as shown by change in gradient



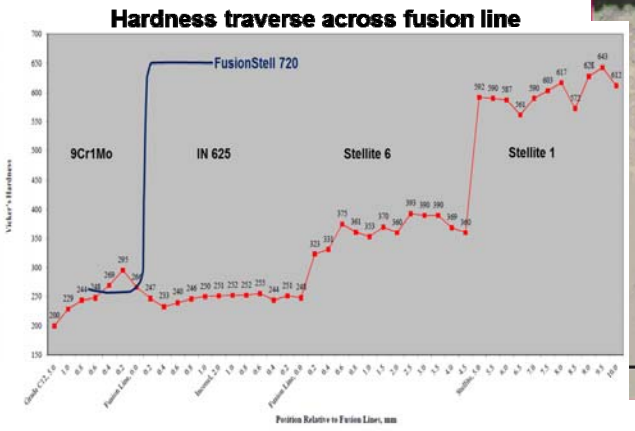


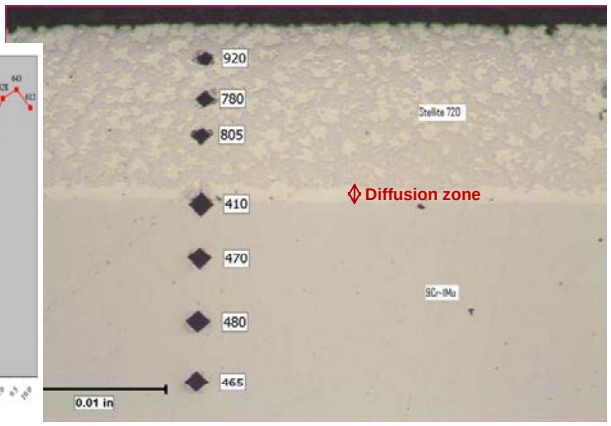
10% dilution

No dilution

FusionStell™ 720 cladding on 9Cr1Mo

- The FusionStell™ process produce a 'pure' Stellite coating
- Dilution only occur in diffusion zone ensuring a metallurgical bond
- Diffusion zone is typically 0.001" thick



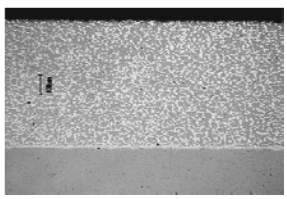


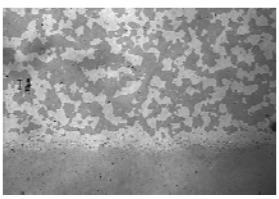
The hardness values of the 9Cr1Mo substrate are higher than normal as this sample did not receive full HT cycle

FusionStell™ coated Thermowells

- Thermowells for bitumen upgrading service coated with Stellite 720
  - Coating thickness 0.040" on 300 series SS base
  - Higher hot hardness than Stellite SF12

Coated Thermowell sheath after metallurgical analysis





Damaged spray & fuse thermowell

Ultrasonic Testing of FusionStell coatings

- No reliable method available to measure thickness and integrity of weld overlay Stellite coatings on ID's of return bends
- UT results of FusionStell™ coated 9Cr1Mo demonstrated that coating thickness can be measured successfully
- FusionStell™ process provides smooth surface for intelligent pigging
- It is possible to inspect coating thickness of FusionStell™ return bends in-situ at regular intervals to determine remaining wear life

Weld overlay vs. FusionStell™ cladding

- Limitations of Stellite weld overlays on return bends
  - Welding parameters are 'hot' due to limited access and need for thick coatings
  - These 'hot' welding parameters results in very high dilution levels
  - Fe & Ni-dilution reduces the wear resistance of Stellite significantly
  - Weld overlay coatings cannot be inspected with UT due to cracking
- FusionStell™ offers superior coating properties
  - Demonstrated uniform coating deposition on various sizes of ID's
  - Coating integrity demonstrated – diffusion bonded to the substrate
  - No Fe-dilution – wear resistance superior to a weld overlay
  - Process repeatability will ensure consistency – can be measured with UT
  - Enable pigging of the system with consistent coatings in the return bends

Benefits of FusionStell™ Technology

- The process can produce coated solutions not possible with any other technology such as internal diameters
- Metallurgically bonded coatings with excellent wear and corrosion resistance
- Engineered materials solutions for severe service environments
  - Select optimum coating compositions for a specific application

Overview of Deloro Stellite Group

- The company dates back to 1907 with the invention of a family of cobalt based alloys called “Stellite”, known for its superior wear resistance
- Today it is a global company with sales over $300 million, operating out of 6 countries, employing around 1,300 people
- Industry leader for solving wear and corrosion problems, and a supplier to diverse industry sectors
- Provider of a wide range of alloys and coatings that can resist aggressive and demanding environments

Kennametal has acquired the Deloro Stellite Group in March, and the company is now called Kennametal Stellite

Where are Stellite® Alloys Used?

- Family of alloys that exhibit excellent resistance to wear and corrosion
  - Main constituents of Stellite alloys are Co, Cr, W, Mo, C
  - Hardness from 32 – 63HRC
- Stellite® alloys out-perform other materials under conditions when two of the following three conditions are present:
  - Wear
  - Corrosion
  - High temperatures
- Good corrosion resistance due to high Cr content (28 – 32%)
  - Corrosion behaviour similar to 316 stainless steel
- Can be produced with a variety of manufacturing methods, including various casting and surfacing proceses

Suite of Manufacturing Processes

Manufacture of components for high wear applications

- Variety of casting processes available within our network of six foundries
  - Sand casting
  - Centrifugal casting
  - Investment casting
  - Resin shell casting
  - Vacuum casting
- Machining and finishing of hard alloys to high surface finish specs
  - Modern machine shops at various locations
- Powder metallurgy products
- Wrought products
- Prototyping and Rapid Product Development




Suite of Manufacturing Processes

Wear-Resistant Coatings

- HVOF coatings
- Plasma Transferred Arc (PTA) welding
- Tungsten Inert Gas (TIG) Welding
- Submerged Arc Welding
- Metal Inert Gas (MIG) Welding
- FusionStell™ coatings

Wear-resistant materials

- Cobalt and Nickel welding consumables
  - Power, rod, wire & electrodes
- HVOF thermal spray powders

Coating equipment systems

- Jet-Kote® HVOF coating systems
- Starweld® & Hettiger® Plasma Transferred Arc (PTA) welding systems

Contact Details

- Daniel De Wet
  VP: Technology & Business Development
  Deloro Stellite Group
  471 Dundas Street East
  Belleville, ON, K8N 1G2
  Canada

  Tel: +1 (613) 968 3481
  E-mail: ddewet@stellite.com
  Web site : www.stellite.com

- Louw De Jong
  Sales Manager & Refinery Specialist
  Deloro Stellite Inc.
  471 Dundas Street East
  Belleville, ON, K8N 1G2
  Canada

- Tel: +1 (604) 328 9723
  E-mail : ldejong@stellite.com
  Website : www.stellite.com