

Standard Tungsten Carbide Cladding Formulas – Power Generation

Engineering Formulas

Kennametal Conforma Clad has compiled over 20 years of scientific testing to develop three standard tungsten carbide cladding formulas that meet most of your severe wear protection needs. Our standard cladding formulas are designed to protect equipment from multiple modes of wear including abrasion, erosion, corrosion or any combination of the three. Kennametal Conforma Clad engineers evaluate individual components and their operating environments in order to recommend a standard cladding formula, or create a custom cladding to meet customer-specific requirements.

Our unique infiltration brazing process combines the hardness of tungsten carbide with the corrosion resistance of nickel chrome boron to create a protective barrier with unmatched wear-resistant properties. With a metallurgical bond strength in excess of 70,000 psi, our cladding is extremely resilient to chipping, cracking and flaking.

Cladding Specifications

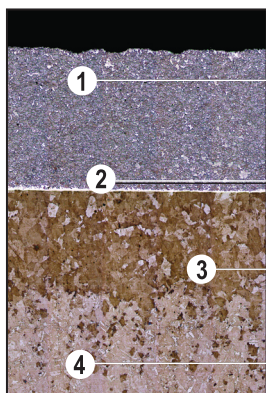
| Cladding Composition (Weight Percentage) | | | |
|--|--------|--------|--------|
| | WC 200 | WC 210 | WC 219 |
| Tungsten Carbide* | 62% | 55% | 48% |
| Nickel | 30% | 34% | 39% |
| Chromium | 6% | 7% | 8% |
| Other | 2% | 4% | 5% |
| Total carbide loading from other carbide formation | 68% | 66% | 62% |

*Tungsten Carbide (WC) includes cobalt-bonded WC.

| Cladding Properties | | | |
|---|---------|---------|---------|
| | WC 200 | WC 210 | WC 219 |
| Density (lb/in ³) | 0.44 | 0.42 | 0.40 |
| Thermal Conductivity (BTU in/h•ft ² •°F) | 230 | 200 | 170 |
| Metallurgical Bond Strength (psi) | >70,000 | >70,000 | >70,000 |
| Porosity | <3% | <3% | <3% |
| Rockwell Hardness (HRC)** | 64-70 | 60-66 | 56-62 |

**Cladding is a composite of tungsten carbide particles dispersed in a nickel-based alloy matrix. The extremely hard carbide particles, with a Vickers Diamond Pyramid Hardness of about 2000 DPH_{50g} (1865 DPH_{50g} is equivalent to 80 Rockwell C Hardness (HRC)), are surrounded by a two-phase matrix (300-800 DPH_{50g}, equivalent to 30-64 HRC). Because of the heterogeneous structure of the cladding, direct Rockwell hardness measurements are an average of the hard particles and matrix, and are not representative of the individual components of the composite.

Cladding Photomicrograph



Cladding

Dense tungsten carbide loading with uniform carbide distribution - high wear resistance with predictable wear rates and continuous operation up to 1900°F

No interconnected porosity - superior corrosion and impact resistance

Bond Line

True metallurgical bond (>70,000 psi) with high interparticle bond strength - provides unsurpassed strength and prevents chipping, flaking and check cracking

Diffusion Zone

Minimal dilution - substrate retains uniform properties in diffusion zone

Substrate

Heat treatable - can be heat treated after cladding process to restore substrate's mechanical properties

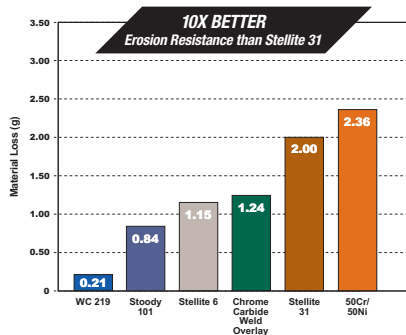


Performance Data

EPRI field studies verify that 1/16" of Kennametal Conforma Clad® tungsten carbide cladding provides the same erosion protection as approximately 1" of chrome carbide weld overlay or 3" of carbon steel.

Black Beauty Coal Slag Erosion Test

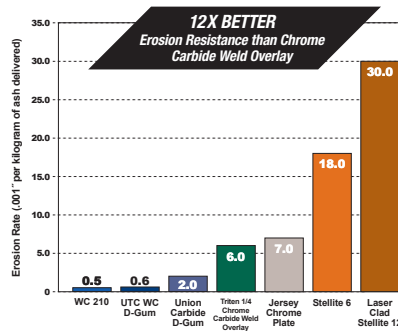
90° Impingement Angle, 240 ft/sec - 30 Minute Test



Laboratory testing, following ASTM G73 standards, on low swirl coal spreaders determined Kennametal Conforma Clad's WC 219 provides the best erosion protection from fine grit black beauty coal slag.
Babcock Power, CCV-DAZ Development Project

Fly Ash Erosion Test

40° Impingement Angle, 550 ft/sec - 30 Minute Test

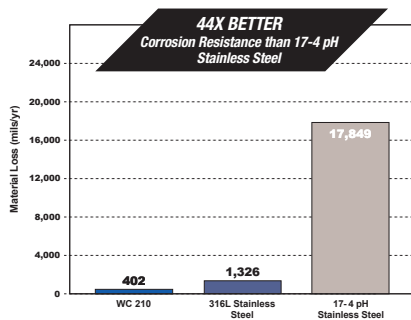


EPRI testing found that Kennametal Conforma Clad's WC 210 provides superior erosion protection for power boiler fan blades exposed to high-velocity bituminous coal fly ash.

EPRI CS - 6068, Project 1649-4

Corrosion Test

10% Sulfuric Acid at 212° F (100° C)

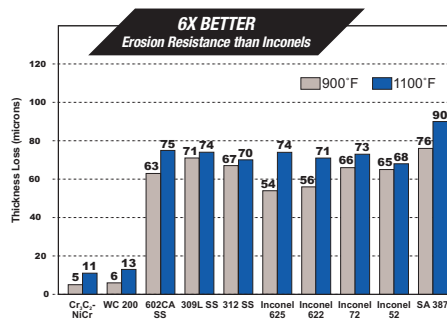


ASTM G31 testing shows Kennametal Conforma Clad's WC 210 provides superior corrosion resistance.

Laboratory Testing, ASTM G31 Standards

Hot Erosion Test

30° Impingement Angle, 141 ft/sec - 180 Minute Test



EPRI testing at elevated temperatures confirms that Kennametal Conforma Clad's WC 200 protects boiler tube applications from erosive wear better than other accepted alternatives.

EPRI Report 1008037

Cladding Properties

| Properties | Kennametal Conforma Clad® | Thermal Spray | Weld Overlay | Wear Tiles | AR Plate |
|--------------------------------|---------------------------|-----------------|--------------|------------|----------|
| Bond Strength | Very High | Very Low | High | Low | N/A |
| Complex Geometries | Yes | No | Difficult | Difficult | Very Low |
| Abrasion Resistance | Very High | Moderate | High | Very High | Very Low |
| Erosion Resistance | Very High | Low to Moderate | Low | Low | Very Low |
| Corrosion Resistance | High | Low | Low | Low | Low |
| Impact Resistance | Moderate | Low | Moderate | Very Low | Low |
| Oxide Level | Low | High | Low | Low | Low |
| Temperature Resistance | High | Moderate | Low | Very Low | High |
| Resists Multiple Modes of Wear | Yes | No | Yes | No | No |

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