EternAloy

TCHP technology

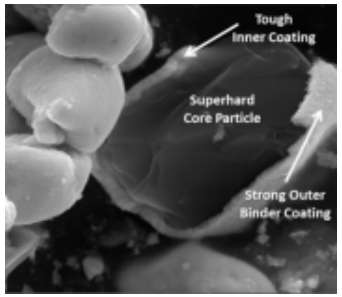
Expertise in the encapsulation of hard particles

Proprietary, patented TCHP Technology

- EternAloy® products are produced using a patented technology known as TCHP (Tough Coated Hard Powder).
- TCHP enables the precision encapsulation of extremely small hard particles with a tough protective shell and a very thin and strong binder layer.
- This game-changing technology establishes an entirely new class of powdered metals with extreme combinations of hardness, toughness, and wear-resistance over a wide temperature range – up to 600°F (316°C)
- EternAloy utilizes a flexible, proprietary, globally-patented powdered metal processing technology to carefully coat 2 to 50 micron-sized hard core particles of any shape with 50 to 500 nanometer-thin tough coatings to create TCHP.
- Customized coating thicknesses are available to meet specific requirements.
- Coating options include WC, Co and Ni, with others possible.

Precision encapsulation of a hard core particle with a tough and uniform shell protects particles during heating and delivers extreme wear resistance performance in sintered solid body or surface coating applications.

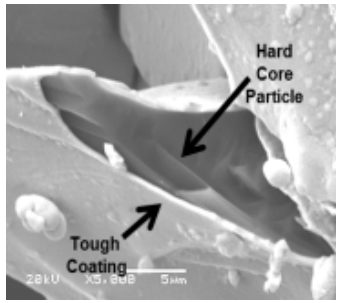
Examples



Diamond-WC-Co

Current hard core particles

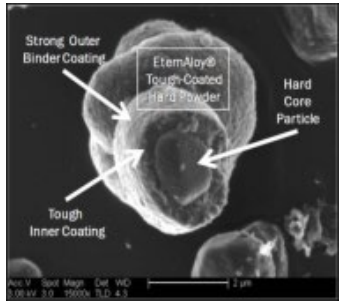
- Aluminum Oxide [Al_2O_3]
- Titanium Carbo-Nitride [Ti(C,N)]
- Silicon Carbide [SiC]
- Cubic Boron Nitride [cBN]
- Diamond



SiC-WC

Other Core Particles

- Titanium Diboride [TiB_2]
- Silicon Nitride [Si_3N_4]
- Zirconium Dioxide [ZrO_2]



Al_2O_3-WC-Co

Note:

- more than 30 other particles included in patent

Customer Benefits

Unique Selling Propositions (USP) of TCHP metal powder and finished products for high-value applications

A unique combination of hardness and toughness leading to:

- Extreme wear resistance
- Increased durability
- Erosion protection
- Heat resistance

Customer benefits

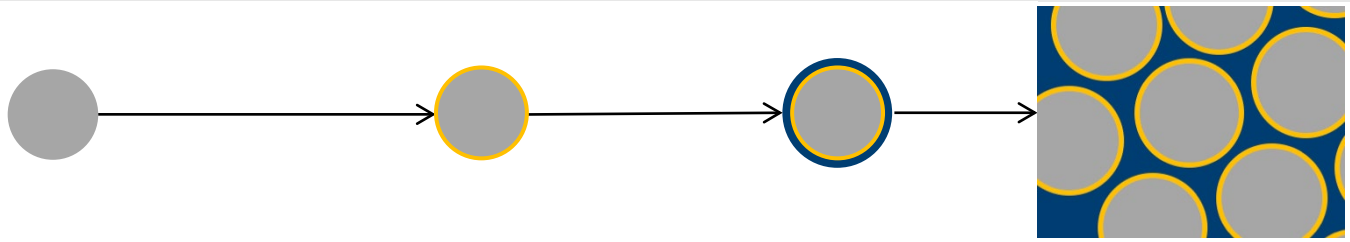
- Increased longevity (1.5-40X compared to the current industry standard - depending on the application):
  - Reduce machine downtime
  - Extend maintenance intervals
  - Increased productivity
- More efficient use of labor

Reduction of operating costs & increased productivity

TCHP-production concept (simplified)

Produced at EternAloy facility using proprietary equipment designs

Raw material - Core Particle Size range from 2 to over 50 µm	**Step 1 – Coating Custom coating thicknesses From 50 to 500nm**	**Step 2 – Coating Custom coating thicknesses From 50 to 500nm**	**Final Product**	**Applications**
Wear resistant core particles (e.g. cBN, Ti(C,N), Al_2O_3, …)	+ tungsten carbide (WC) coating	+ cobalt, nickel or other coating	= TCHP powders	Sintering or consolidation



Hardness component	Toughness component	Outer coating for final powder		
Numerous suppliers			One supplier (EternAloy)	Numerous customers

Applications

TCHP powders can be sintered into solid shapes in conventional sintering furnaces commonly used to sinter industrial tungsten carbide (WC) powders. Methods for sintering TCHP include sinterHIP, vacuum HIP, and spark plasma sintering.

TCHP Powder Attributes

Sizes of the “core” particles in EternAloy® TCHPs range from 2 µm (e.g., Al_2O_3, or Ti(C,N)) to 50 µm (e.g., SiC). The core particles are coated atom-by-atom with, for example, an intermediate encapsulating layer of WC and an outer encapsulating nanolayer of Co binder. When sintered or applied using thermal spray methods, the tough outer layers chemically bond in the sintered article or deposited coating, **combining high strength, heat resistance, and toughness** of cemented carbides with the chemical and abrasion wear resistance of the harder core particles.

TCHP-production: cBN core encapsulated with WC

Example images of uncoated particles and WC-coated particles

TCHP cBN-Superhard Material

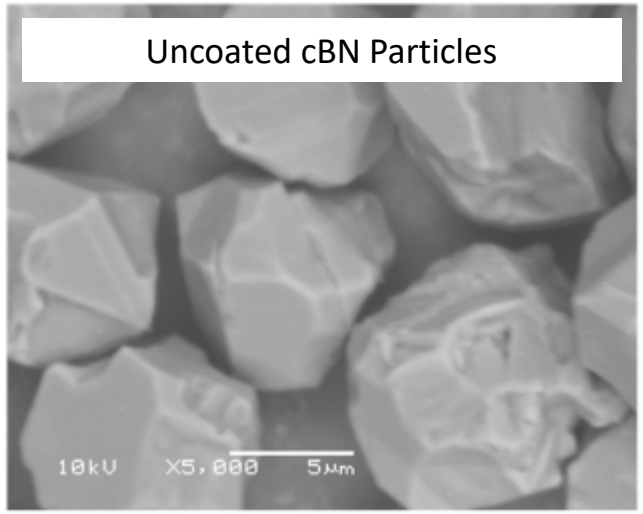


Image of raw Uncoated 8 to 16 micron cBN Particles

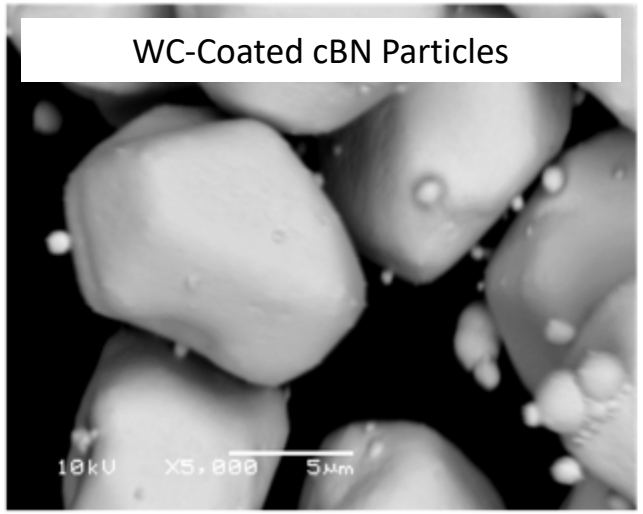


Image of cBN Particles encapsulated with WC using EternAloy's coating technology

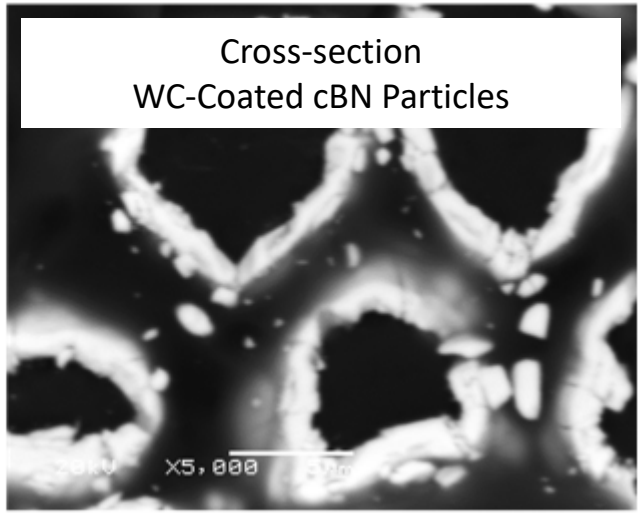


Image showing cross-sections of the WC-coated cBN Particles. Each particle is uniformly encapsulated with WC. The internal black areas are cBN particles. The light gray areas are the WC coating.

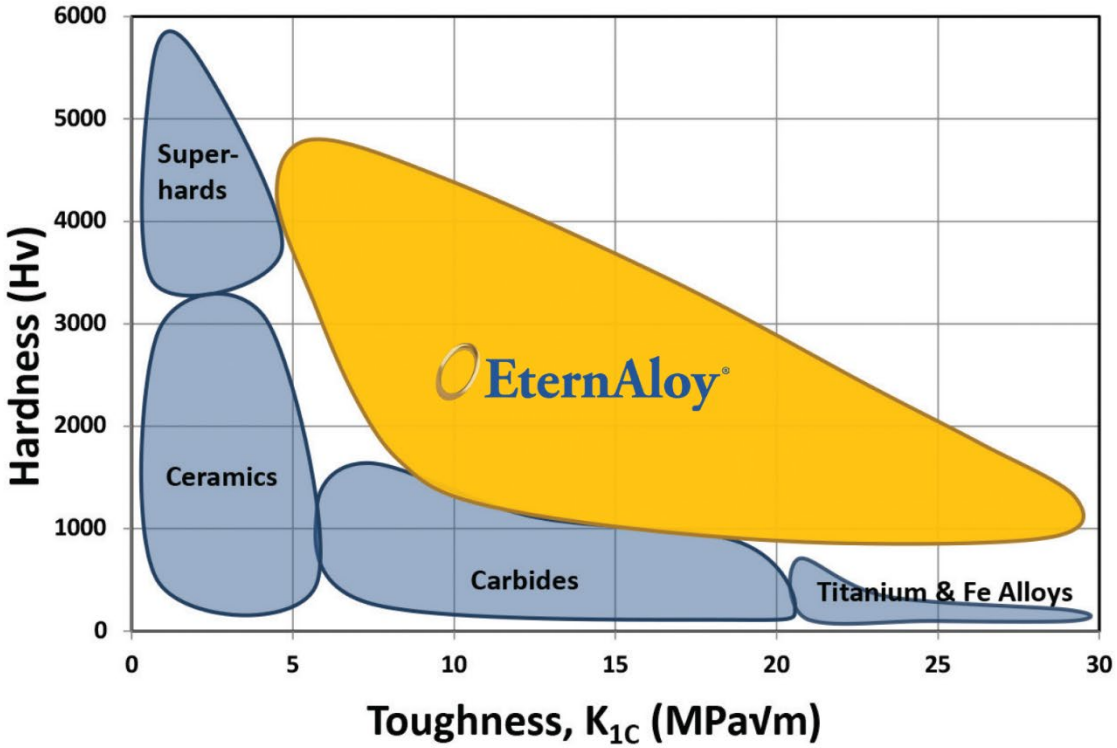
5000X SEM Magnification

Revolution in powder metallurgy: Tough-Coated Hard Powder (TCHP Products)

Overcoming conventional materials' trade-off between Hardness and Toughness

- The EternAloy® TCHP technology allows for the development of novel composite materials with unique hardness and toughness combinations.
- The combined hardness and toughness of EternAloy® TCHP creates an ideal solution for many high-value, extreme wear-resistance applications.

EternAloy® Hardness / Toughness Comparison:



Products

Metal Cutting Components

- Turning and Threading Inserts (blanks and finished)
- Rod Blanks
- Single Point Tools
- Finished Drills/End Mills
- Tips
- Disks (40mm Diameter), various thicknesses

Metal Cutting Powders

- HNT Carbide [Ti(C,N) core, WC-Co]
- HNT CarbideMax [cBN core, WC-Co]

Wire Drawing Dies

- Sizes available upon request

Customized Products

- Over 30 different core particles
- WC, Co or Ni coatings
- Flexible coating thickness
- Toll service development opportunities

Products Under Development

- Laser Metal Deposition (including Diamond)
- Sintered Diamond Disks
- Additive Manufacturing

Product Patents

- Over 30 core particle types are covered under patent
- Over 50 patents in place in more than 30 countries around the world
- More than 25 additional patents pending at this time
- Unique equipment is designed and constructed solely using EternAloy in-house expertise

Plant & Equipment Overview

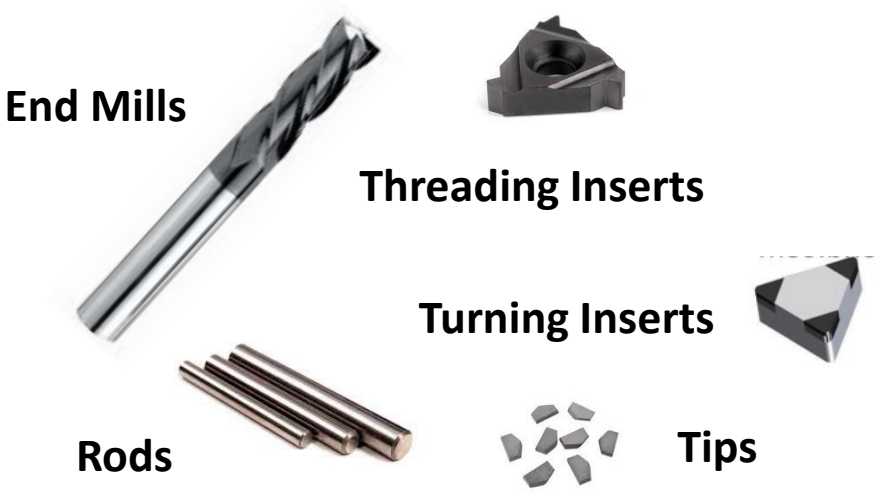
- Headquarters and Plant (32,000 ft^2), located in North Huntingdon, PA, USA
- All production equipment is uniquely designed with very tight tolerances to meet precise TCHP production requirements

EternAloy® is uniquely positioned as the only developer and producer of nano-scale Tough-Coated Hard Powder (TCHP)

Metal Cutting

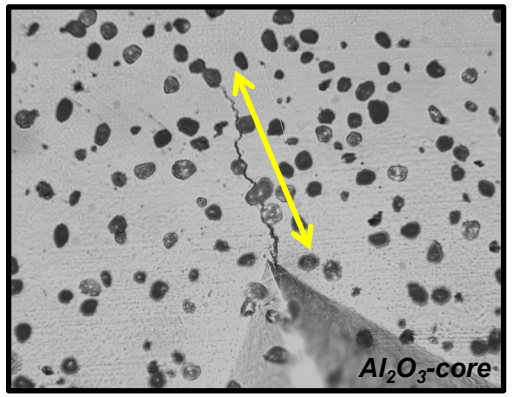
Products

- Turning and Threading Inserts (blanks and finished)
- Rod Blanks
- Single Point Tools
- Finished Drills/End Mills
- Tips
- Disks (40mm Diameter), various thicknesses



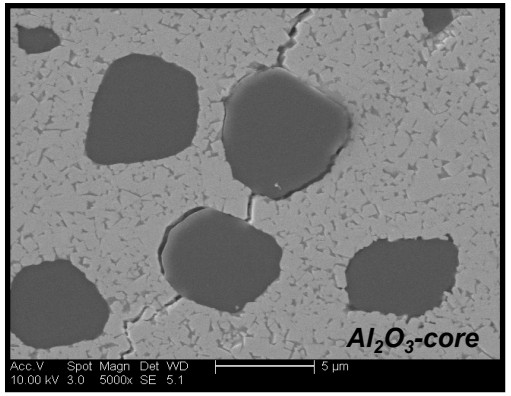
Technical Differentiators of TCHP

- Uniform distribution of hard particles in sintered (solid body) microstructure
- Overcome the inherent statistical limitations of mixing or blending powders and permits improved homogeneity in sintered microstructure
- TCHP offers high uniformity of Co binder distribution
- Encapsulation protects particles from reacting during sintering or consolidation
- Unique design inherently enables crack arrest, as propagating cracks are deflected by, into and around “core” particles, creating increased toughness

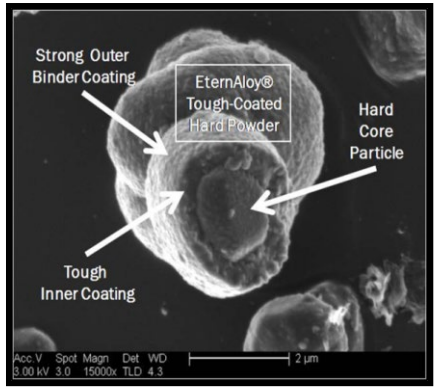


Microstructure at 500X

Crack intentionally introduced



Microstructure at 5000x



TCHP Particle at 15000x

Metal Cutting

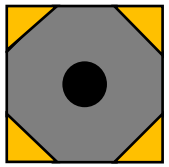
EternAloy's Patented Co-Sintering Technology

- An indispensable and highly valuable add-on to the TCHP patents and is proving key to commercialization of EternAloy's TCHP metal powder grades.
- Reduction of TCHP powder needed for applications – creates compelling value proposition for user.
- Opening the door to new target markets and applications.

Example application – metal cutting tools

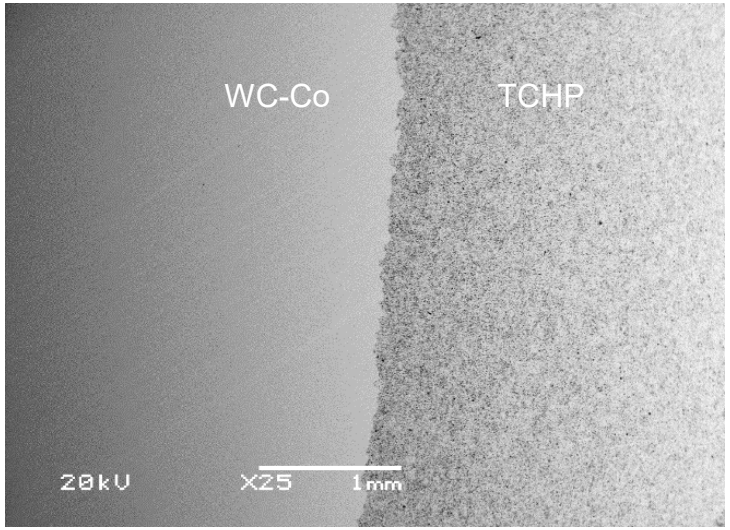
Solid Blank for Rotary Tools

TCHP-Tipped Indexable Tools



TCHP

WC-Co

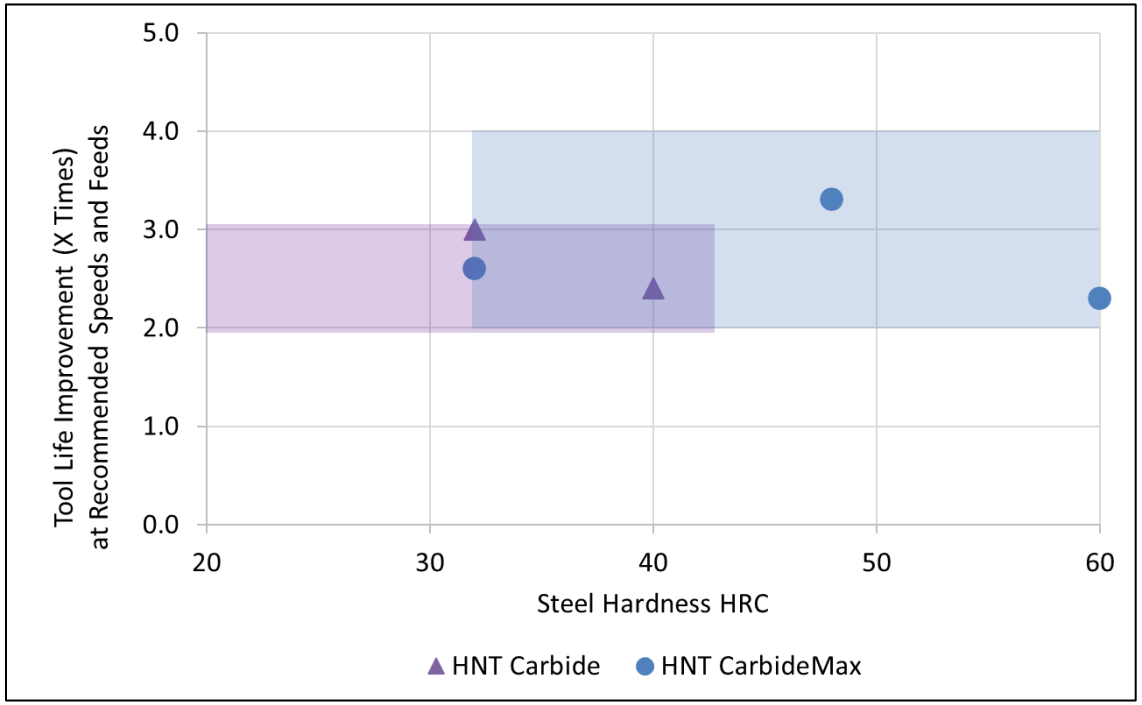


EternAloy's proven and patented co-sintering of TCHP with WC-Co enables a method for the EternAloy TCHP to be able to achieve a value proposition in industrial cutting tools

EternAloy Grades HNT Carbide and HNT CarbideMax

- Provide up to 4X longer tool life in general purpose machining Rc 18 to Rc 60 and 316SS HRA69
- “Tips” can be brazed onto tungsten carbide blanks (i.e. turning inserts, single point tools, drills, etc.)
- HNT Carbide can be co-sintered into bi-material parts with tungsten carbide powder and conventional press and sinter processes.
- HNT CarbideMax co-sintering capability with tungsten carbide powders is anticipated.

EternAloy® HNT Performance Advantage in Turning
Compared to Market Leading Fine Grain WC-10Co Inserts

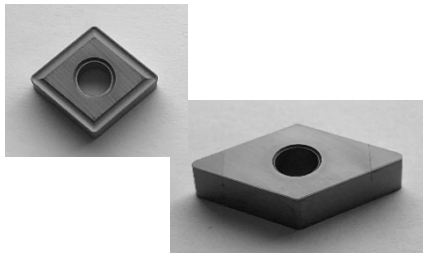


Metal Cutting Inserts

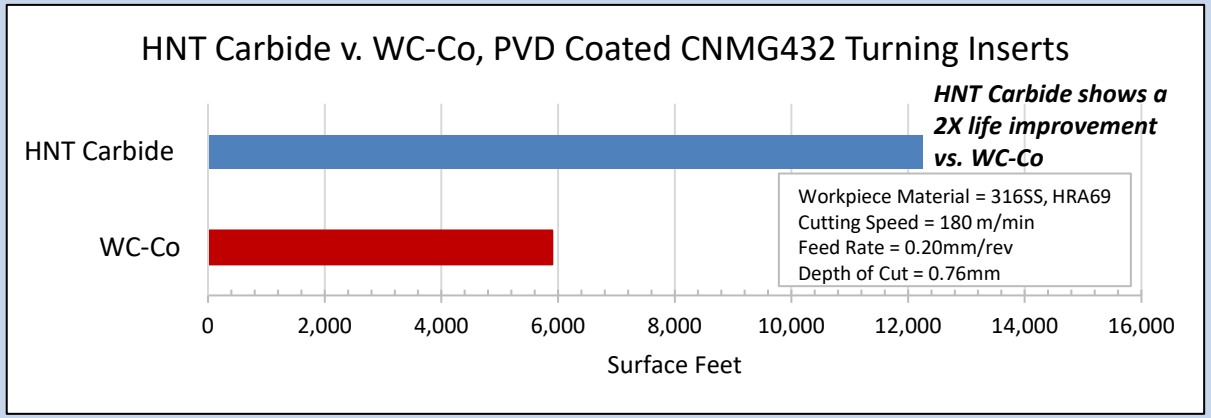
Turning Studies

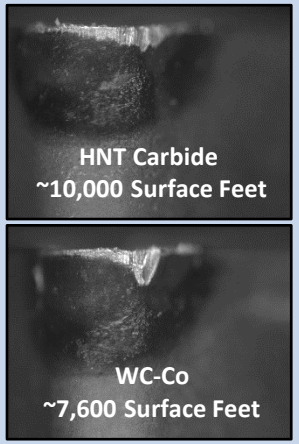
EternAloy Insert Turning Performance

- EternAloy® **HNT Carbide and HNT CarbideMax** provide increased tool life and higher productivity when compared to market leading tungsten carbide cutting tools.

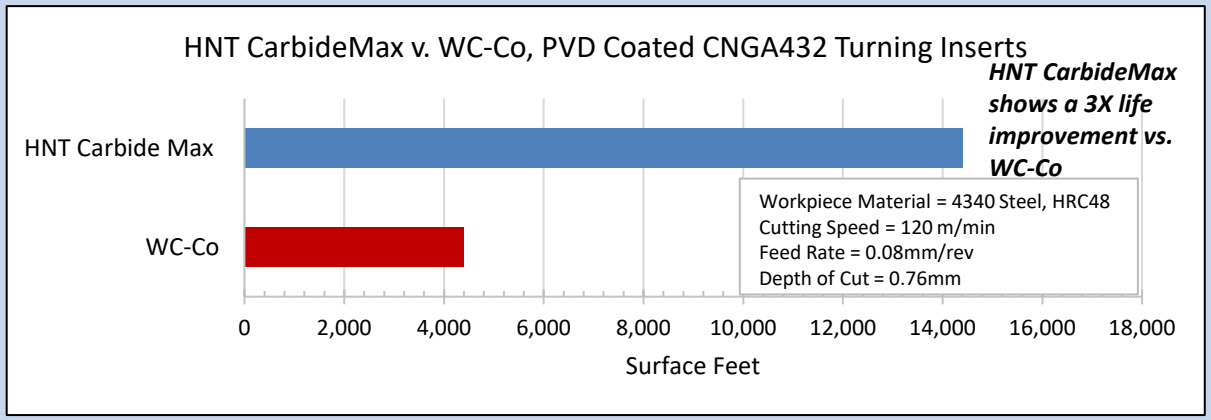


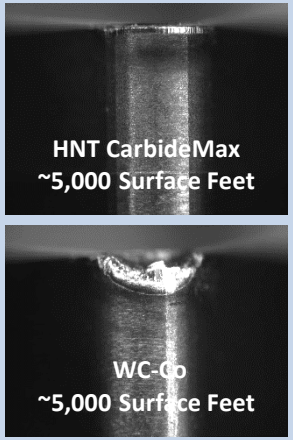
HNT Carbide





HNT CarbideMax

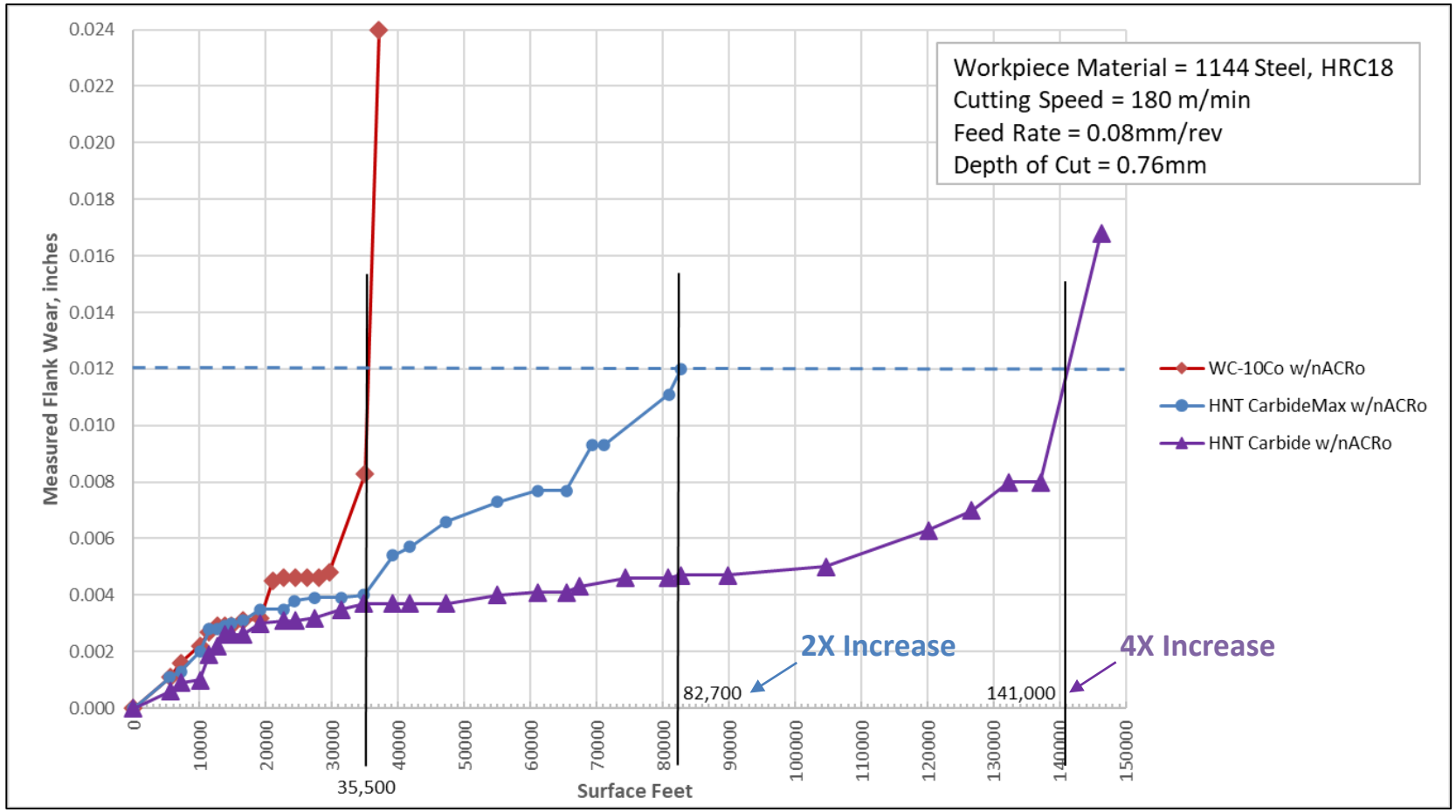


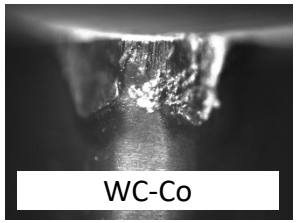


Metal Cutting Inserts

Turning Studies

HNT v. WC-Co, PVD Coated CNGA432 Turning Inserts: Results in 1144 Steel, HRC18
Cutting Speed = 180 m/min (590 sfm)





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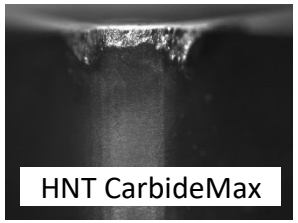

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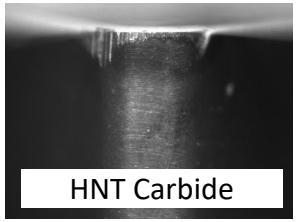

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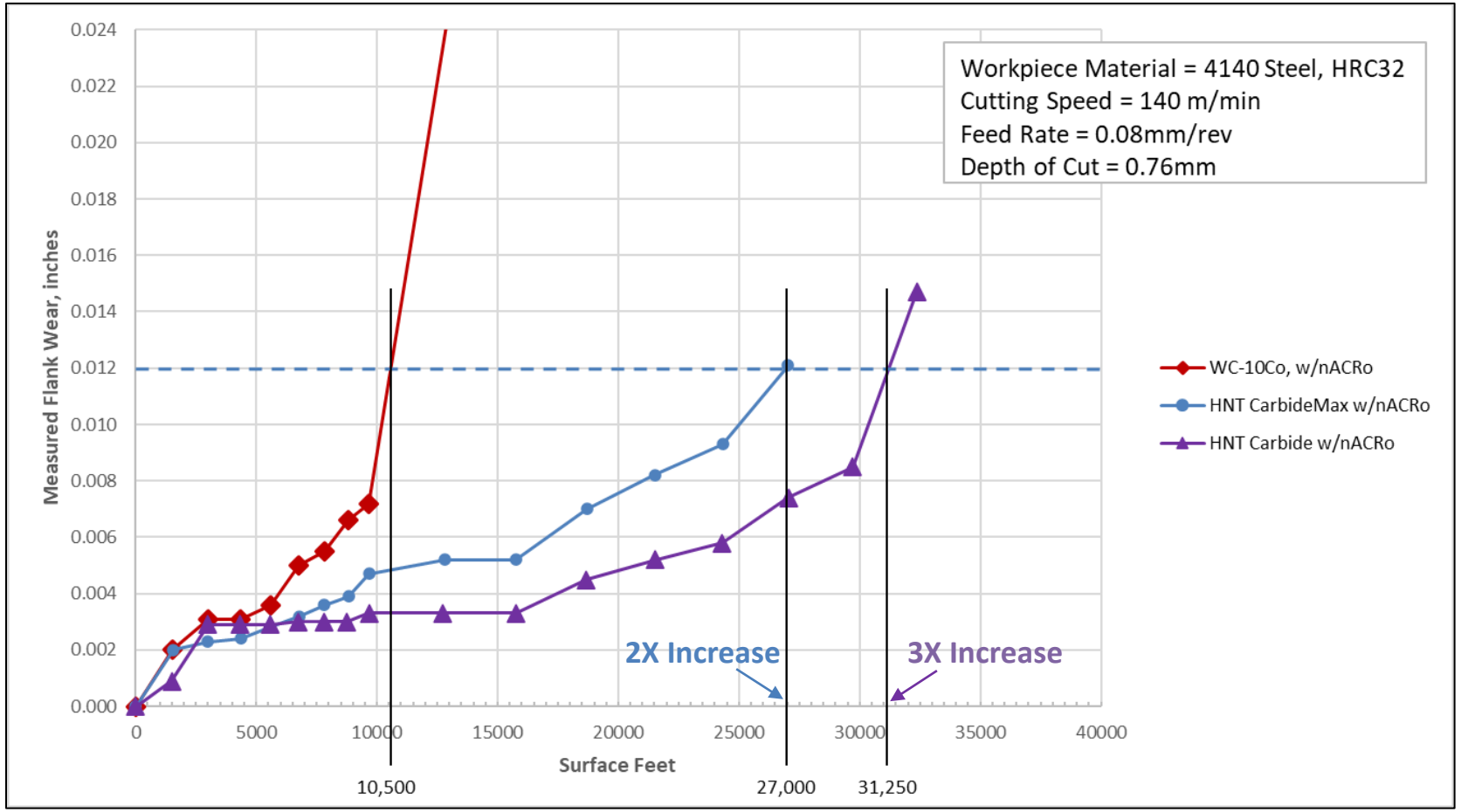
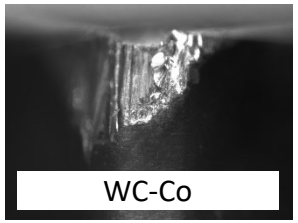
Corner After Machining,
Linear Surface Feet Cut

Metal Cutting Inserts

Turning Studies

HNT v. WC-Co, PVD Coated CNGA432 Turning Inserts: Results in 4140 Steel, HRC32
Cutting Speed = 140 m/min (459 sfm)





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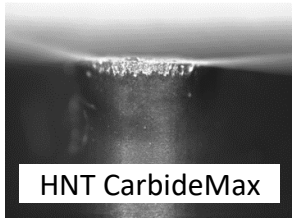

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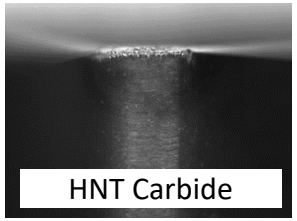


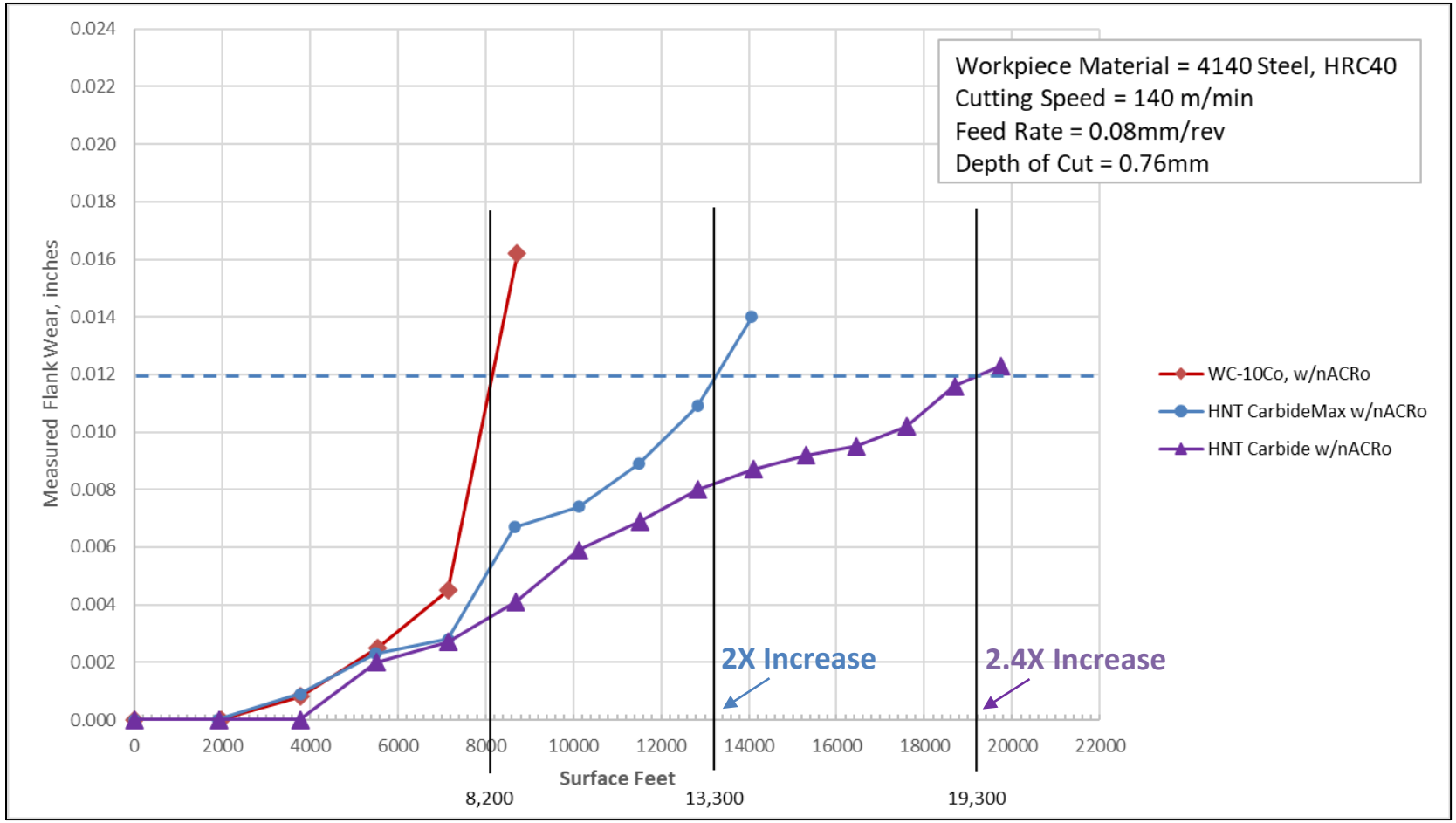
15,769

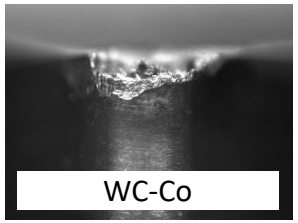
Corner After Machining,
Linear Surface Feet Cut

Metal Cutting Inserts

Turning Studies

HNT v. WC-Co, PVD Coated CNGA432 Turning Inserts: Results in 4140 Steel, HRC40
Cutting Speed = 140 m/min (459 sfm)





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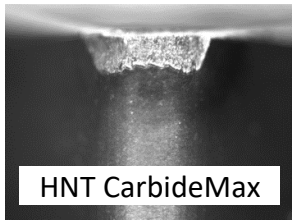

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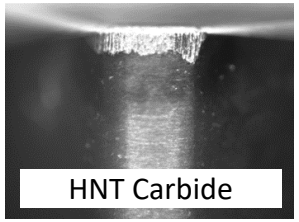


14,100

Corner After Machining,
Linear Surface Feet Cut

Metal Cutting

End Milling Studies

High Speed Profiling of H13 Tool Steel

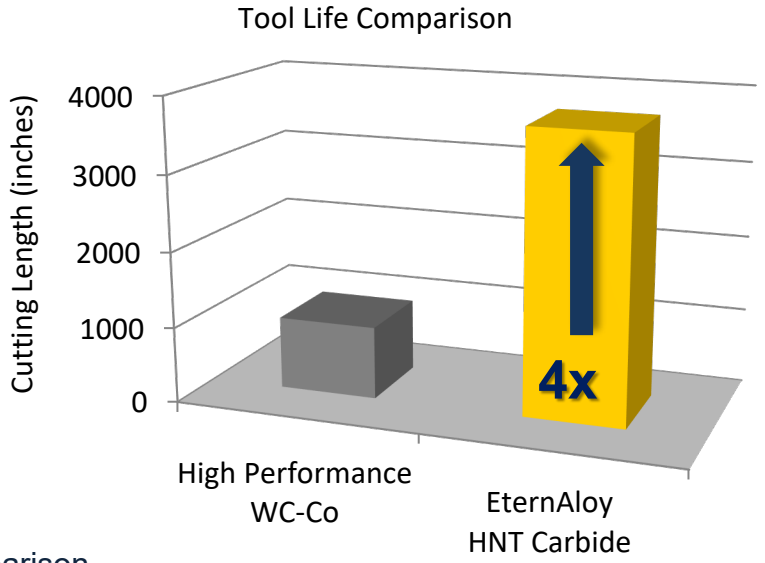
- Exceptional hardness and toughness
- Outstanding edge wear resistance
- Enhanced thermal conductivity

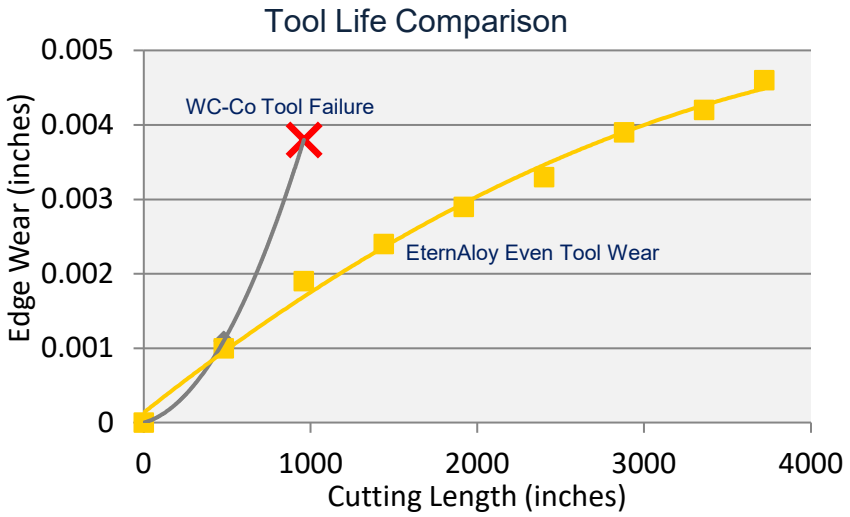
Performance Benefits

- Greater productivity
- Higher metal removal rates
- Increased feed rates
- Significant economic savings

Recommended Applications

- High carbon and tool steels
- High-speed profiling

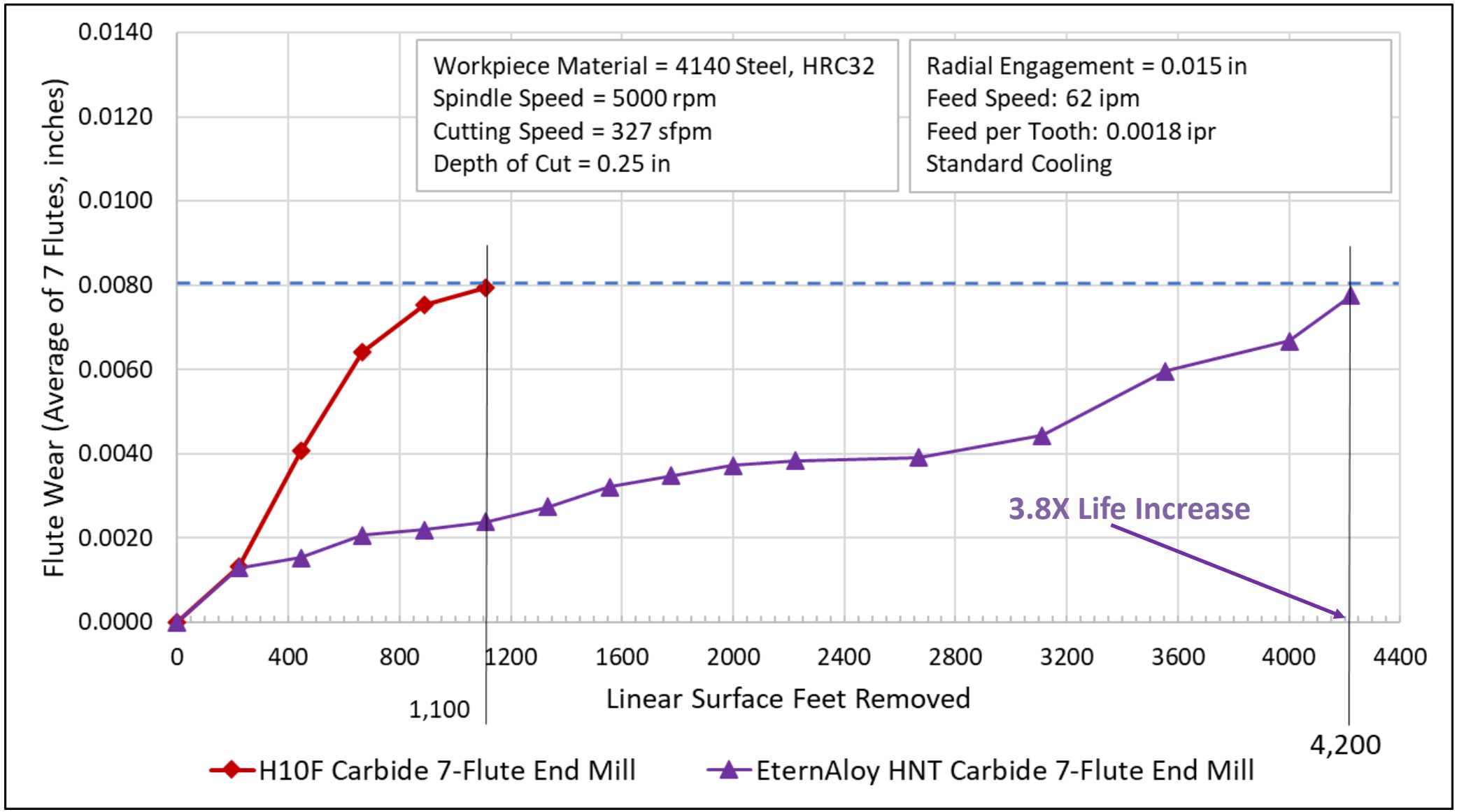




EternAloy HNT Carbide delivers 4X life improvement over high-performance carbide end mills.

End Mill Wear Testing

EternAloy HNT Carbide v. H10F Carbide
AlTiN Coated, 7-Flute, ¼"D End Mill Wear Testing
(Average measured wear of 7 Flutes)

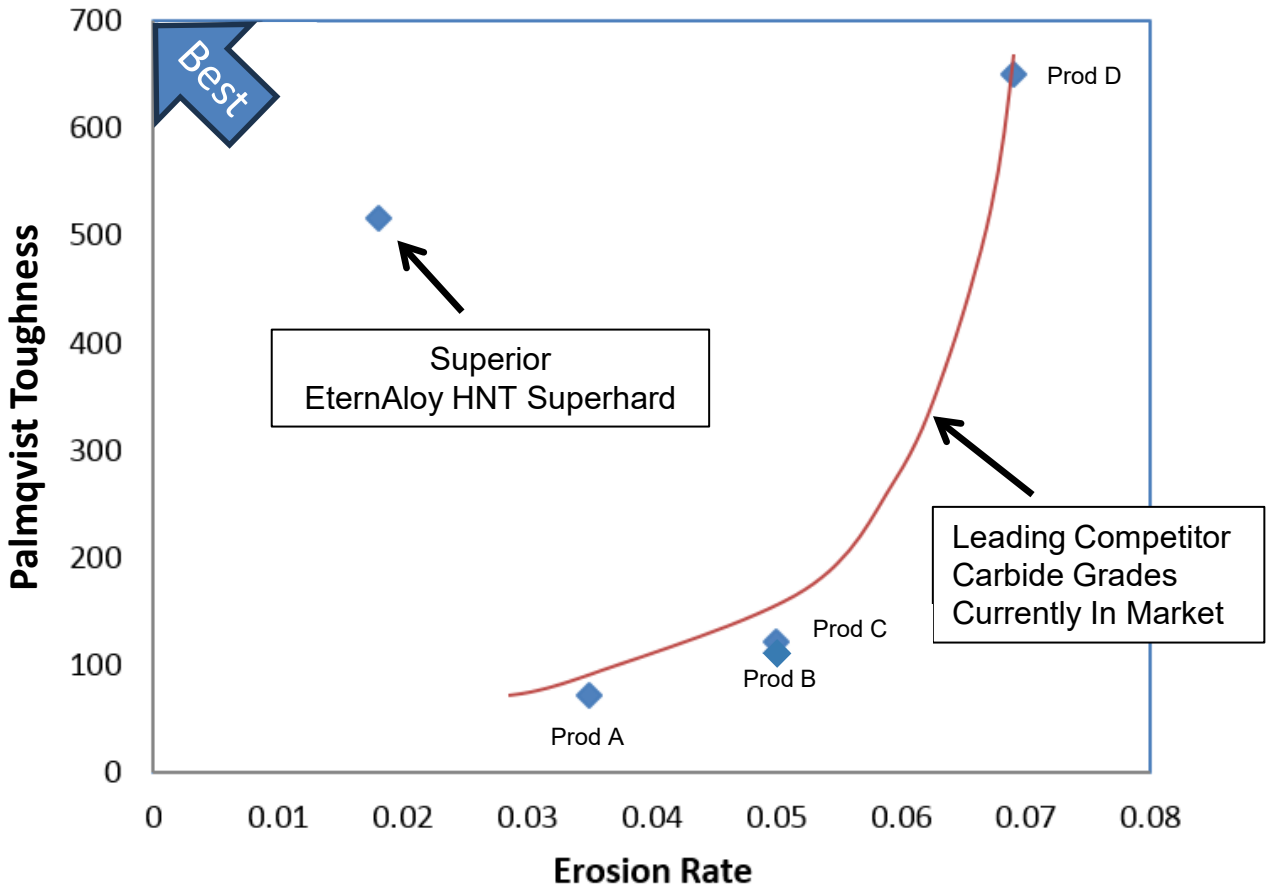


Metal Cutting

Erosion Studies

EternAloy HNT Superhard Materials

- Initial testing demonstrates that HNT Superhard materials offer far superior performance than existing superhard materials for cutting tool, mining, and drilling applications.

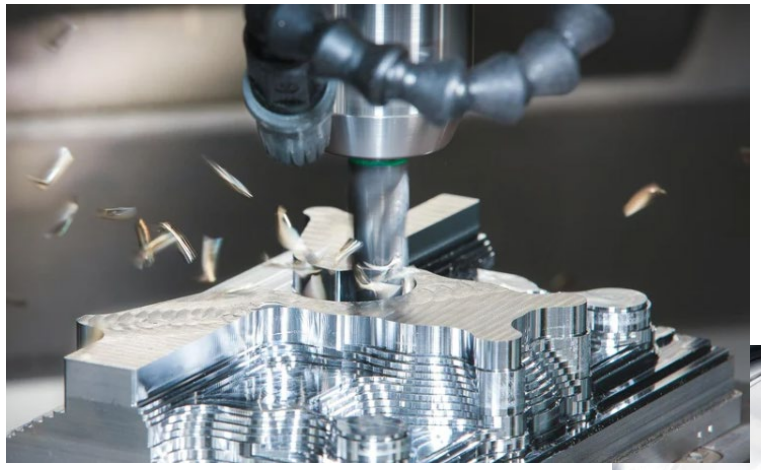


High-Value Flexibility Offered by EternAloy TCHP Technology

- EternAloy's patented encapsulation process can be applied to a wide variety of core particles – for example alumina, Ti(C,N), silicon carbide, cBN, diamond, etc.
- TCHP composition can easily varied to adjust volume proportions of core particle to outer layers
- TCHP's unique design inherently ***enables crack arrest and*** increased material toughness - propagating cracks are deflected by, into and around the "core" particles
- TCHP can be consolidated by numerous techniques, including sintering and spark plasma sintering
- TCHP materials offer ***thermal conductivity management alternatives*** to target different applications
- TCHP ***encapsulation technology*** protects particles from reacting during sintering or consolidation

*These performance characteristics allow for superior performance in the **Cutting Tool Industry** where abrasive wear mechanisms dominate.*

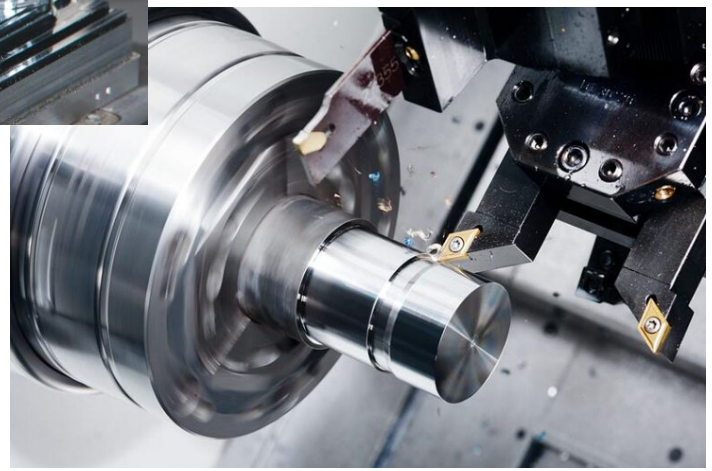
Metal Cutting Applications



Metal Cutting

EternAloy milling and turning tools operate up to 4 times longer when compared to popular tungsten carbide cutting tools.

Applications range from general purpose to high efficiency machining in steels and stainless steels.



End Mills

Threading Inserts

Turning Inserts

Rods

Tips

EternAloy materials:

- Can be co-sintered with WC-Co
- Can be brazed onto WC-Co or other braze compatible materials
- Can be ground on existing carbide tool grinding machines

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