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Center Atlanta, GA

Cemented Carbides with Enhanced Functional Properties for Tooling used in Stamping Applications

Jim Cavanaugh
Manager of Technical Sales
General Carbide Corporation

Overview

- **Grade selection considerations**
- **Impact, Corrosion and Wear**
- **Grade recommendations for Stamping Tooling**
- **Case history……..350% increase in stamping productivity**
- **Summary**

Grade selection considerations:

How do we recommend or create a grade for a specific application such as Stamping?

What is the failure mechanism?

Wear, Chipping or…..

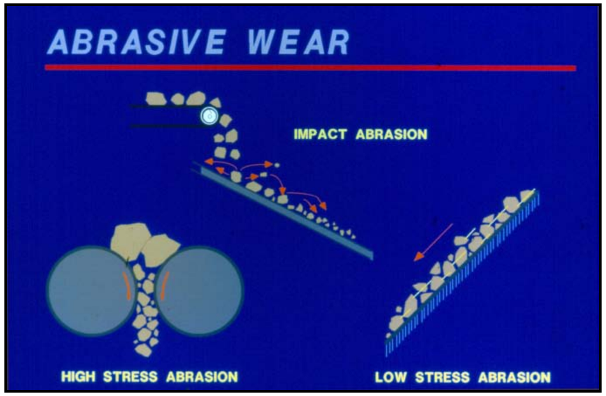
Is the answer a bigger hammer?

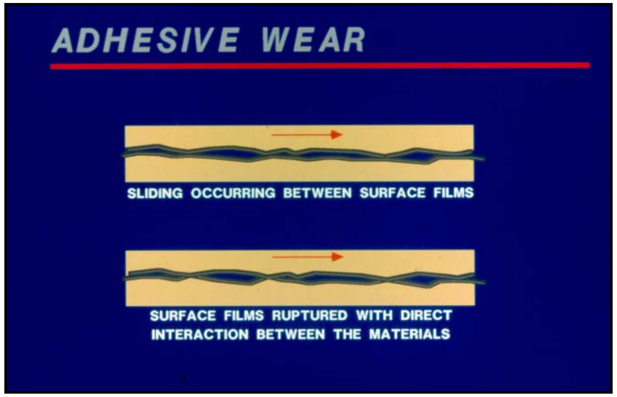
Requirements of each separate tool element within a Stamping Die Assembly….

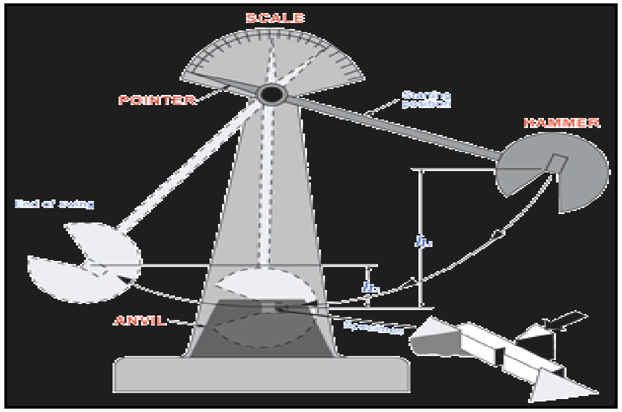
- **The whole <u>Die Set</u> must be able to withstand the radial pressure during operations to hold the tolerances in the horizontal cross-section of the component to be formed.**
- **<u>The Die</u> (Carbide Die Inserts and Punches) experiences impact and sliding wear and quite often sees abrasive wear patterns during progressive stamping, especially on thicker components. It also sees adhesive wear through friction because of the metal-to-metal motion of the top punch sections when leaving the Die.**

What are these wear patterns and how are they formed?…..

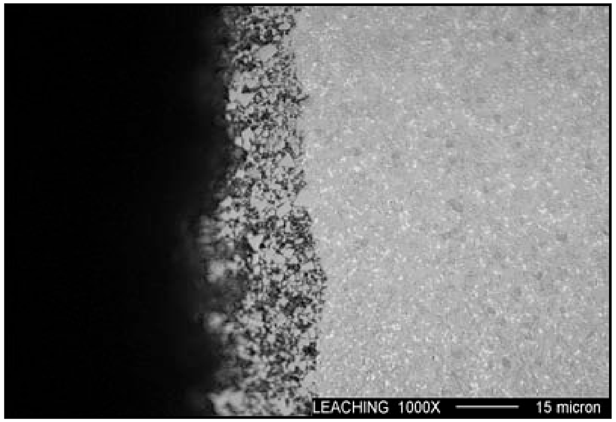
Stamping Dies can see these types of wear under normal working conditions:







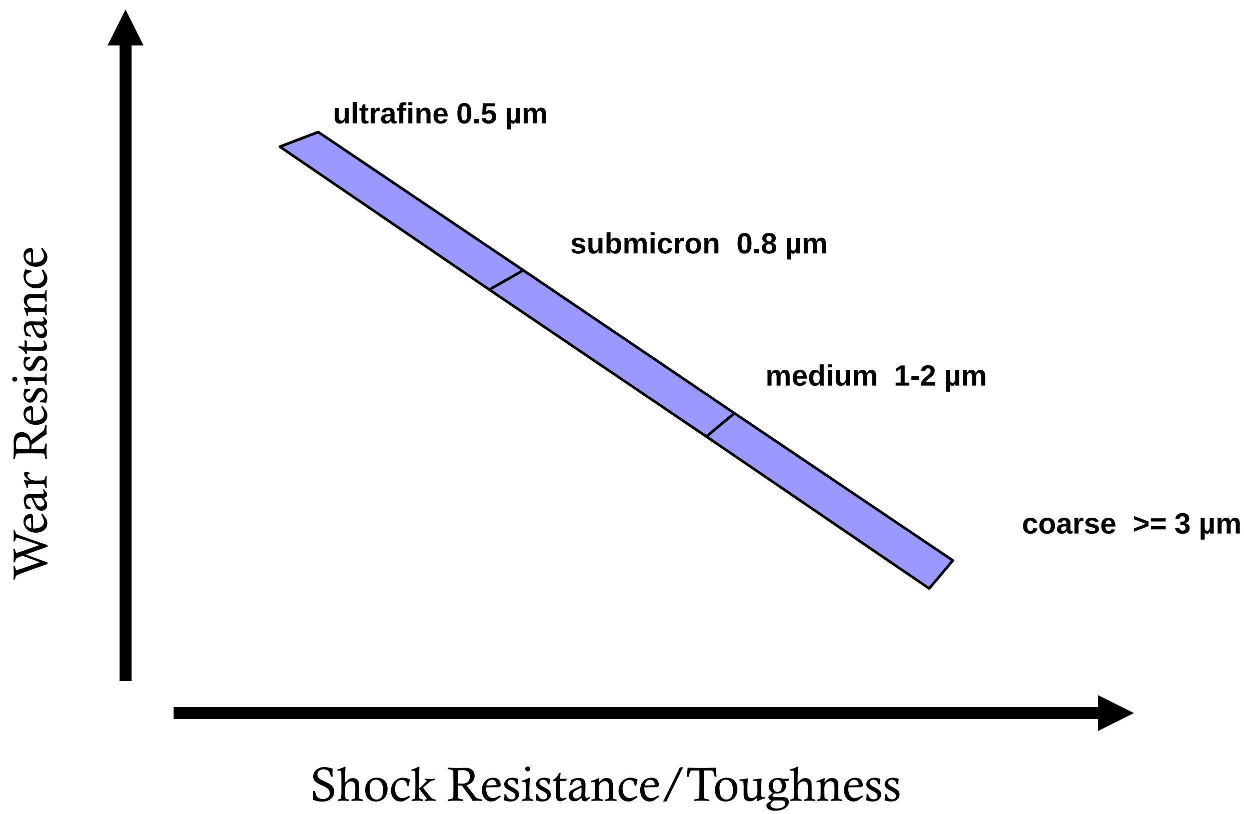
IMPACT



CORROSIVE WEAR

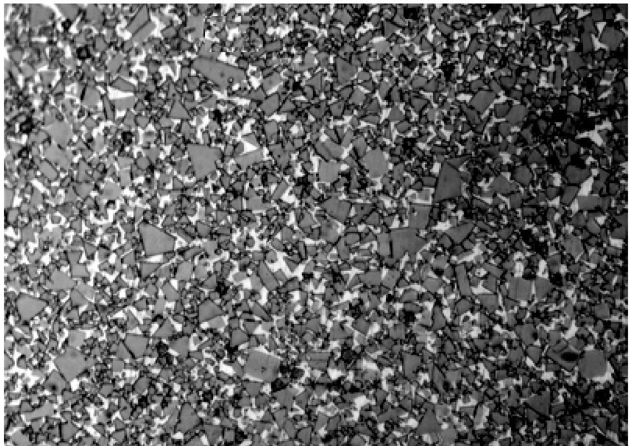
Therefore, tools should effectively resist wear, corrosion, galling and impact…

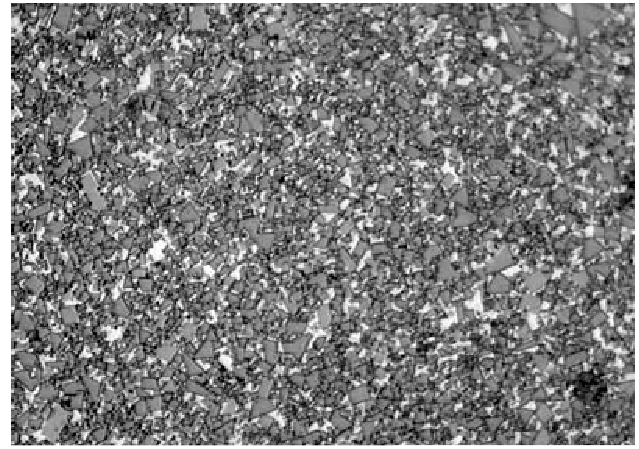
Effect of Grain Size



Constant binder content with varying grain size

4 µm

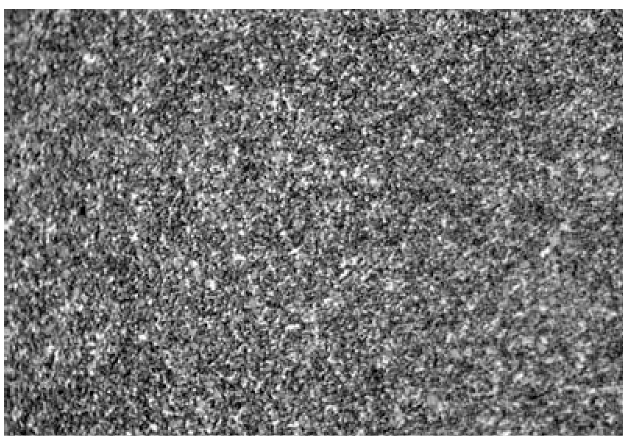


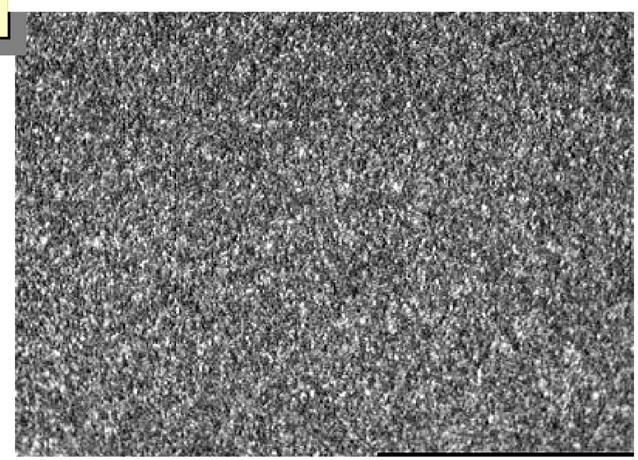


2 µm

1500x

0.8 µm



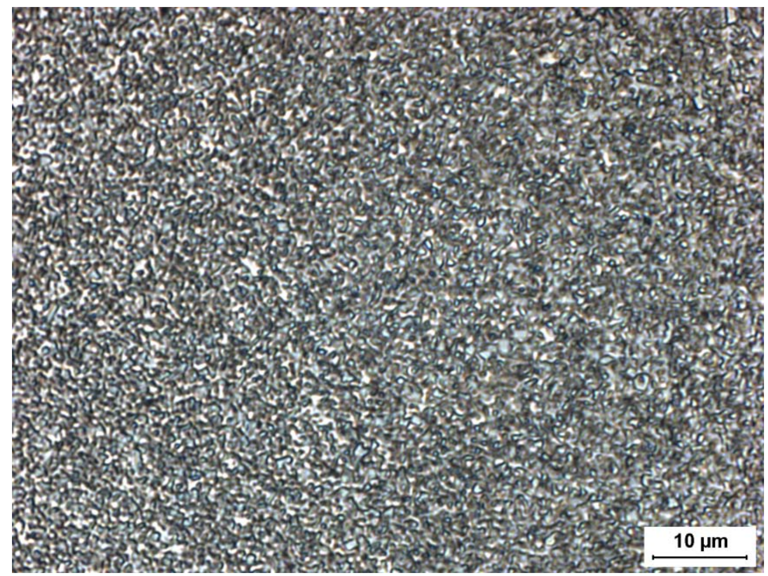


0.5 µm

Submicron grain formulation:

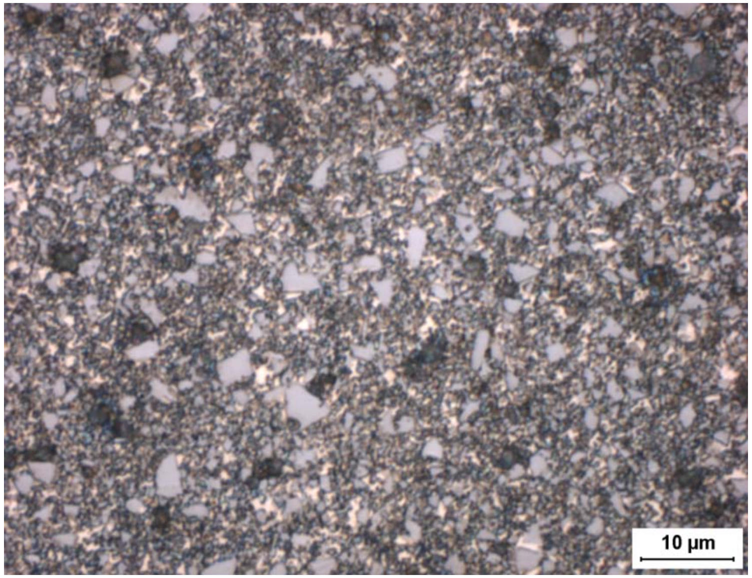
What does it do for Cemented Carbide ?

A submicron grain structure can achieve higher hardness with a given cobalt binder, but may reduce impact resistance resulting in chipping.



GC-010

Grain Size and Impact



GC-813CT

Hardness: 90.5 – 91.5

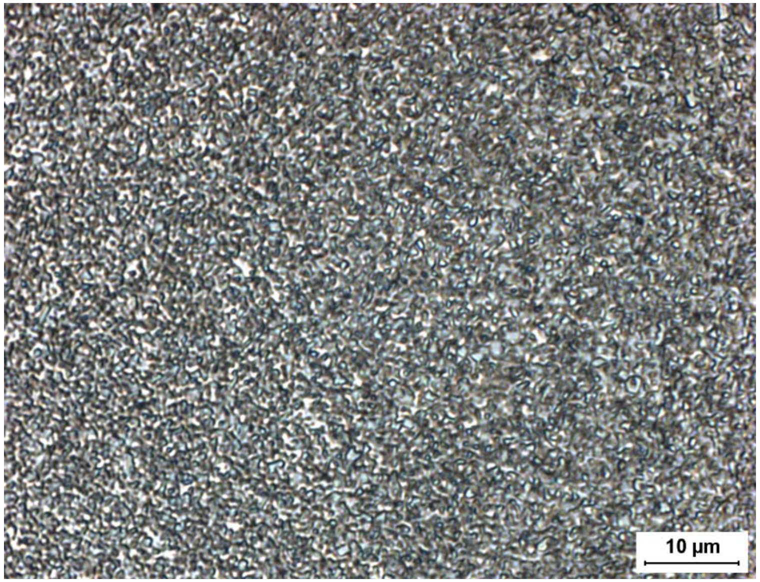
TRS: 460,000 psi

Average grain size: 1-3 micron

Galling Resistance: Moderate

Corrosion Resistance: High

Wear resistance: Good



GC-015

Hardness: 89.3 – 90.3

TRS: 535,000 psi

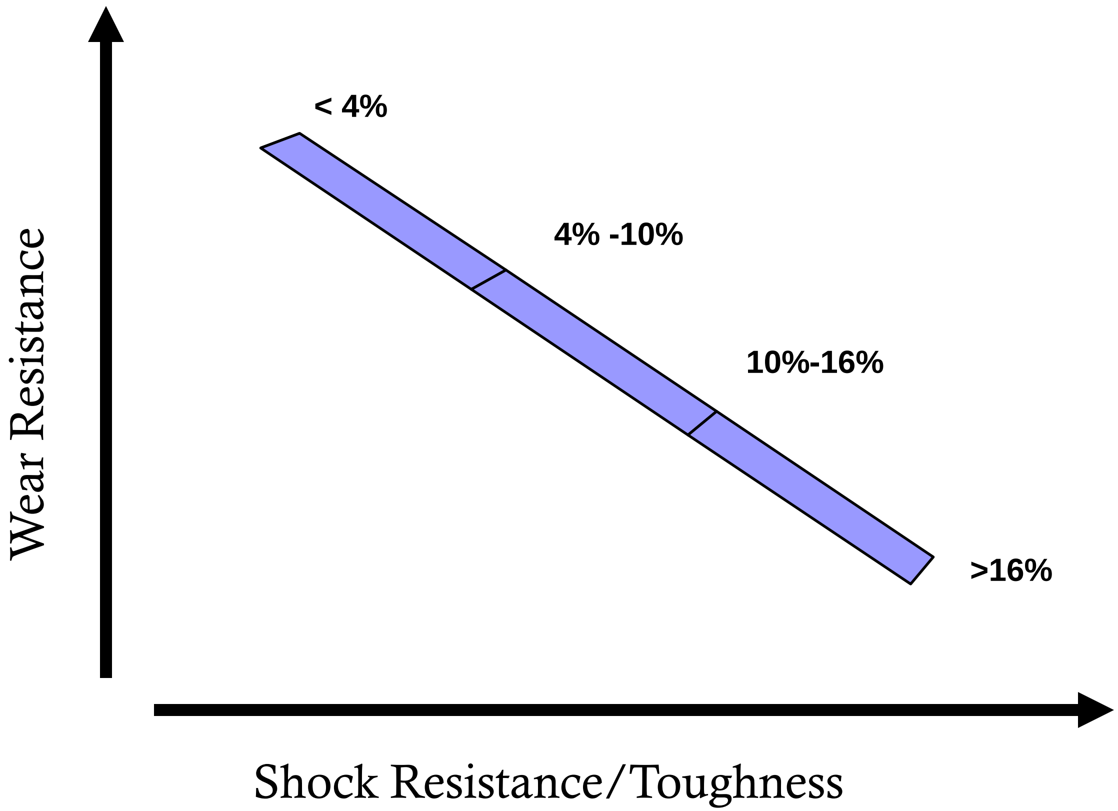
Average grain size: 0.8 micron

Galling Resistance: Low

Corrosion Resistance: Low

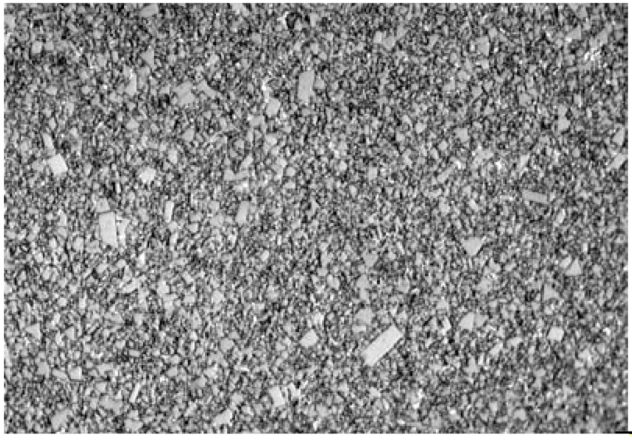
Wear resistance: Good

Effect of Binder Content.

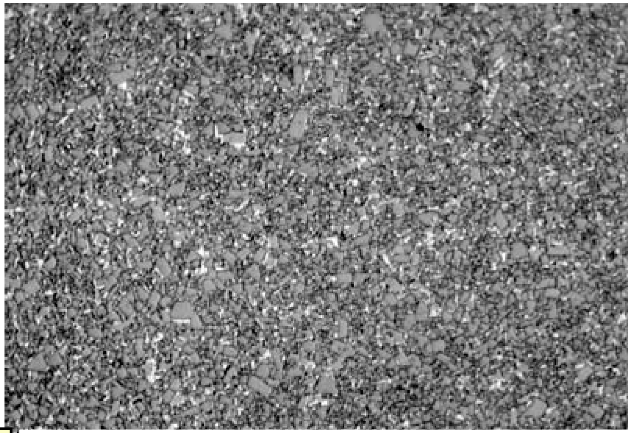


Constant grain size with varying binder content

6%

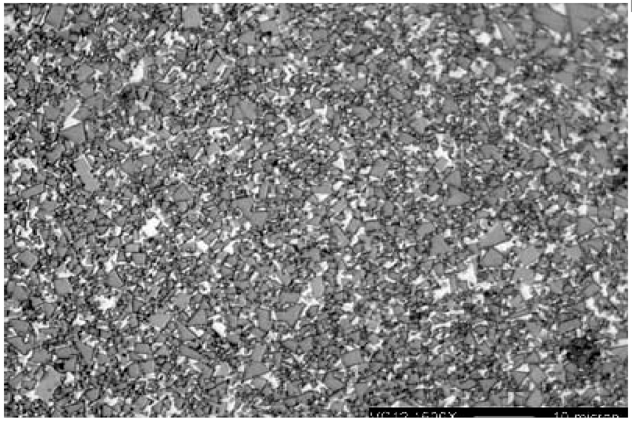


10%

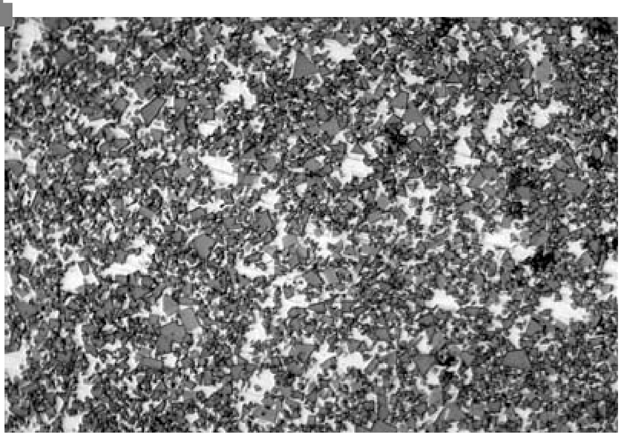


1500x

16%



24%



Our Mission

Objective #1

- Develop a superior Stamping grade that enhances impact strength and yet retains hardness to extend wear life.

Objective #2

- Develop a superior Stamping grade that exhibits enhanced corrosion resistance.

Objective #3

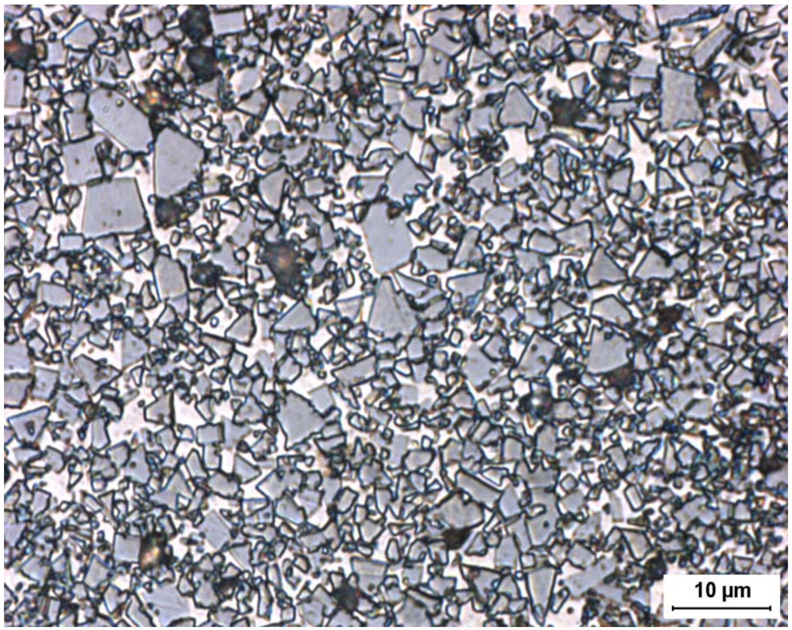
- Develop a superior Stamping grade that exhibits enhanced galling resistance to improve wear.

To achieve higher Mechanical Strength and Impact ....

Examples:

Pierce punches, dies.....

Unique Tungsten Carbide Powder



GC-411CT

GC-813CT

GC-613CT

GC-415CT

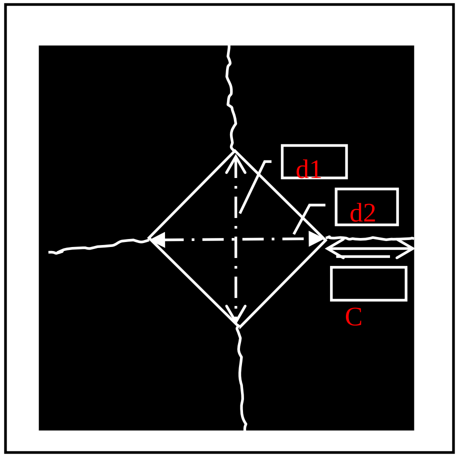
GC-425CT

Unique proprietary tungsten carbide grain has perfect stoichiometric carbon balance of 6.13 % throughout

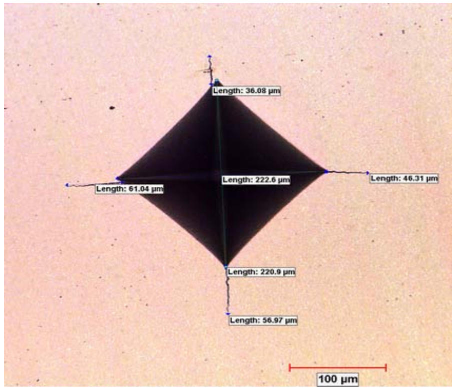
…can be alloyed with Tantalum Carbide and Corrosion Additives

Palmqvist Fracture Toughness Test:

Schematic of Palmqvist Test with Vickers indentation.



Vickers Indent with Crack Origination.



- **Palmqvist Toughness (W_G)**

$$W_G = \frac{P}{T}$$,where

P = load in Newtons

T = total crack length in mm (ΣC)

- **Palmqvist fracture toughness (W_K)**

$$W_K = A \times \sqrt{HV} \times \sqrt{W_G}$$

Where A-constant; HV-Vickers Hardness

New Grades Yield Impressive Palmqvist Results

Mechanical Properties for Selected Carbide Grades

GRADE	Rockwell Hardness (Scale A, HRA	HV (kgf/mm^2) HV	Palmqvist Fracture Toughness, W_K MN * (m^ (-3/2))	Average CTE 10^{-6} ^0C @ [RT- 800^0C]
GC-813CT	90.5 - 91.5	1420 - 1505	13	5.87
GC-313	88.1 - 89.1	1180 - 1280	18	6.26
GC-613CT	87.4 - 88.4	1110 - 1210	23	6.15
GC-411CT	88.5 - 89.5	1220 - 1320	17	6.29
GC-415CT	87.4 - 88.4	1110 - 1210	21	

Newly developed grades demonstrate high fracture toughness and yet retain high hardness values!

To achieve improved corrosion resistance ….

Examples:

Stamping lubricants, grinding fluids, WEDM fluids, electrolytic attack and residual lubricants which may remain on tools during storage.

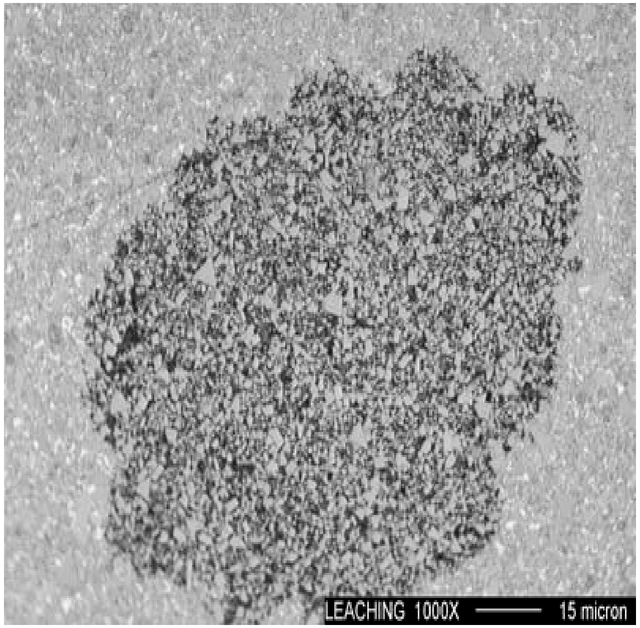
…especially, when lubricants may contain Chlorine or Sulfur radicals within it….

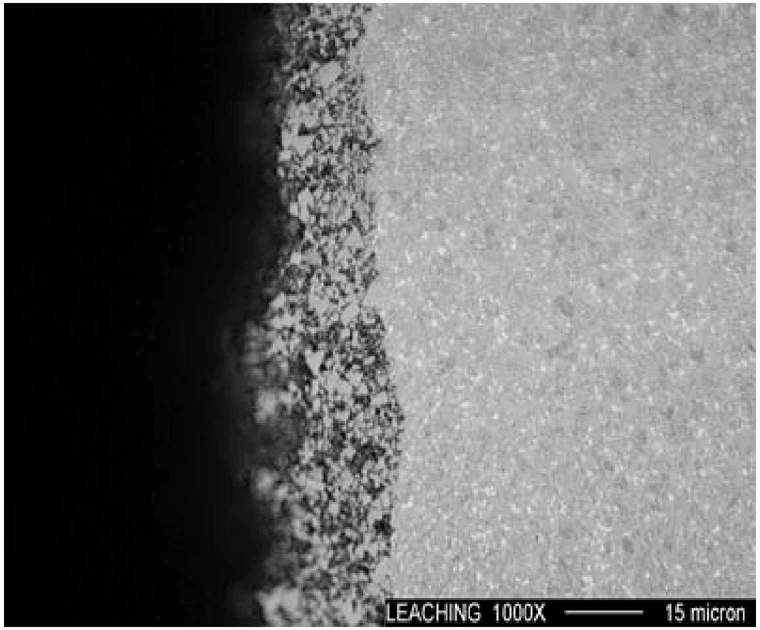
General Recommendations to Resist Corrosion:

- **WC with lower binder and finer grain size is better.**
- **WC grades with corrosion resistant nickel-based binder is better than straight cobalt binder.**
- **WC grades with cobalt-based binder plus corrosion resistant additives are superior to standard tungsten carbide grades.**

Typical corrosion/leaching conditions:

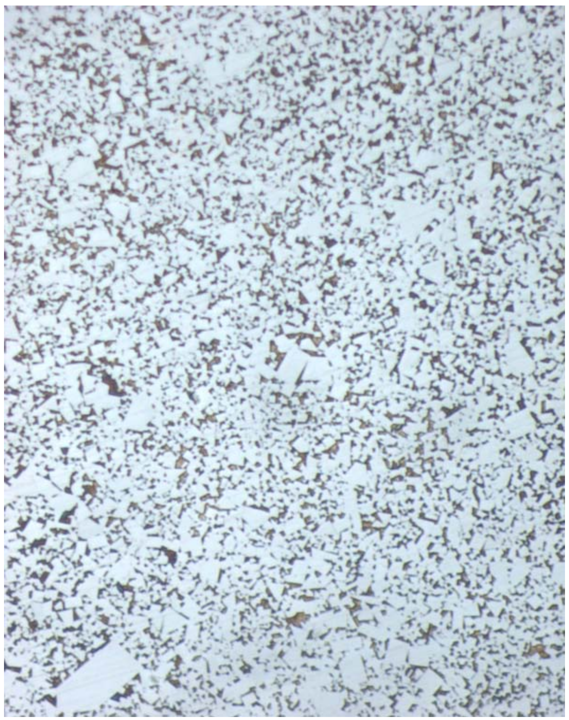
The selective dissolution of the **Co**-binder from regular **WC-Co** cemented carbide microstructure.





Stamping Lubricants

GC-313*

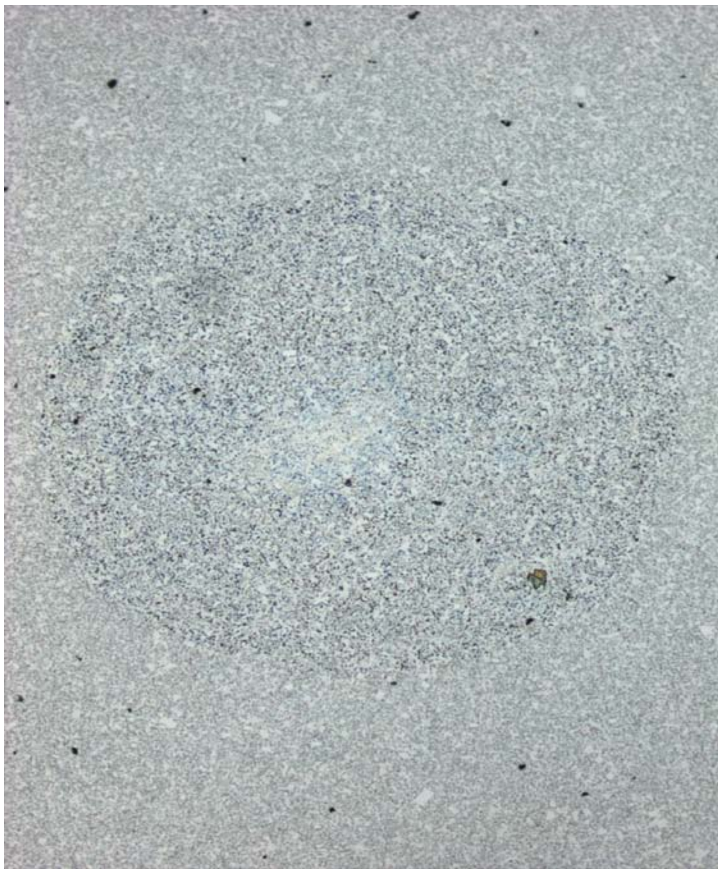


GC-411CT*

* Immersed in stamping fluid for two weeks

Corrosion resistance of GC-411CT

GC-313*

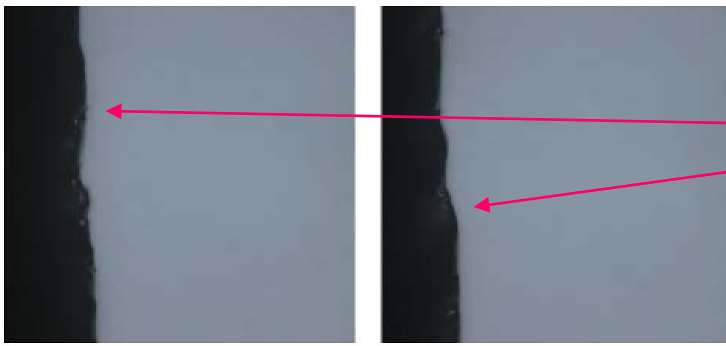


GC-411CT*

*Test conducted in tap water over 48 hours.

WEDM Rough Cut Comparison:

GC-411CT / WEDM / ROUGHCUT / 500x

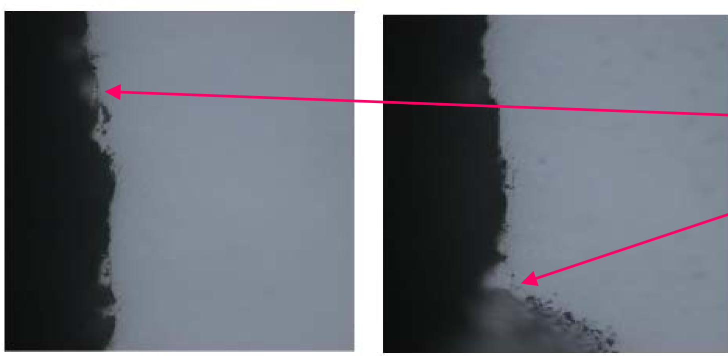


GC-411CT

WEDM cut edge area:

Rough cut with minimal micro-cracks and reduced re-cast layer.

GC-313 / WEDM / ROUGHCUT / 500x



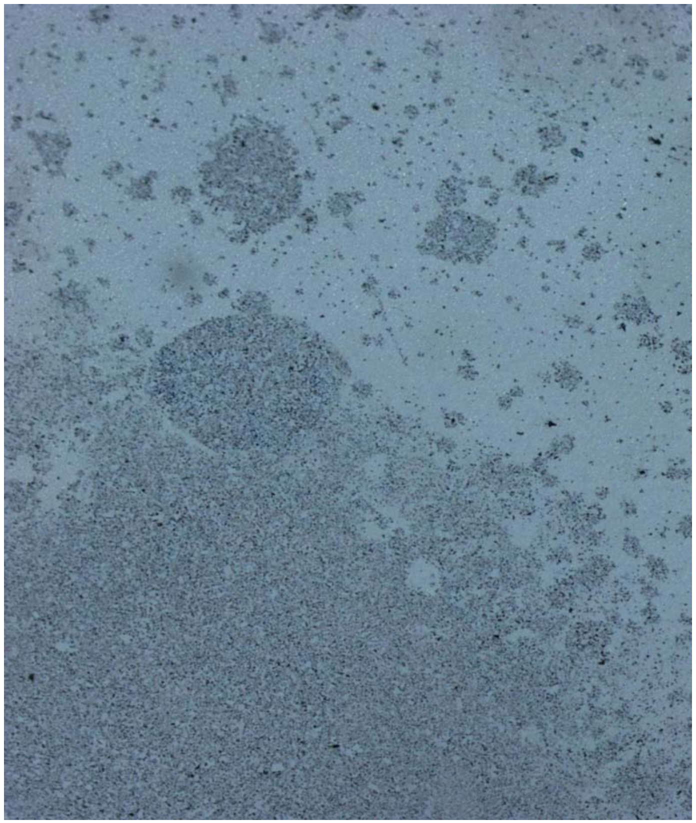
GC-313

WEDM cut edge area:

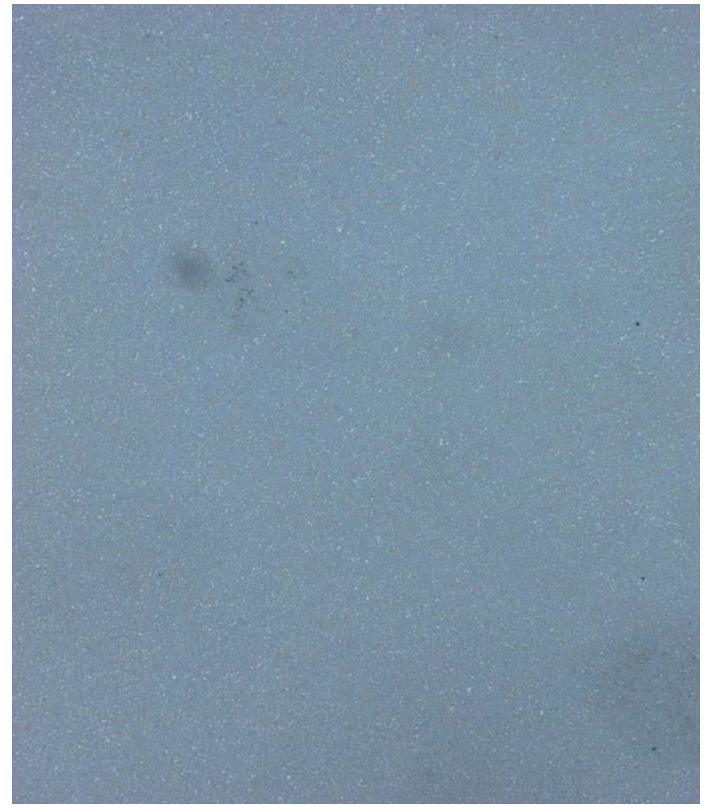
Standard carbide grade exhibits rough cut with the presence of micro-crack type defects and deeper re-cast layer.

Electrolytic Attack

GC-313*



GC-411CT*



*Test conducted in WEDM tank for 100 hours.

To achieve improved adhesive wear resistance ....

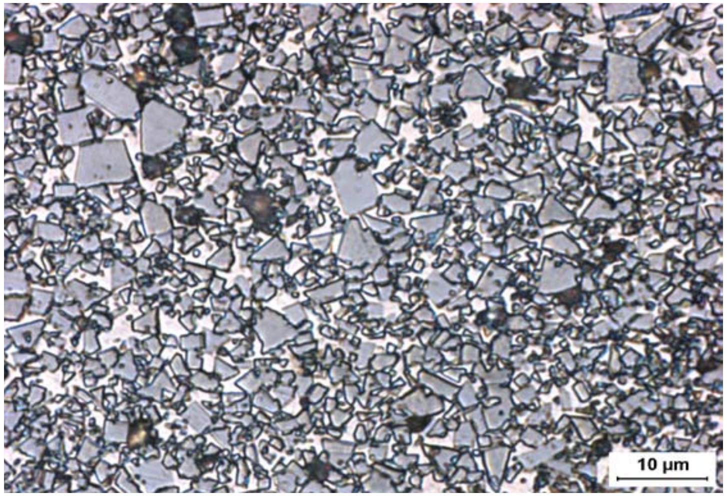
Examples:

Pierce punch, cut off die, die sections and punches..............

Tantalum Carbide (TaC) Additions:

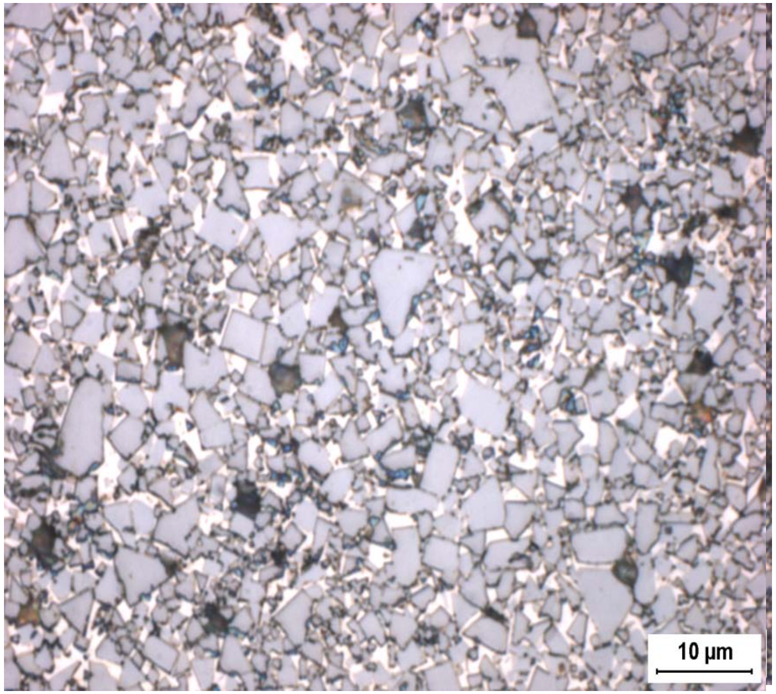
What does it do for Cemented Carbide ?

- Anti-galling agent
- Reduces friction between the work material and die wall
- Acts as an internal built-in lubricant



GC-613CT

Grade GC-411CT



Composition:

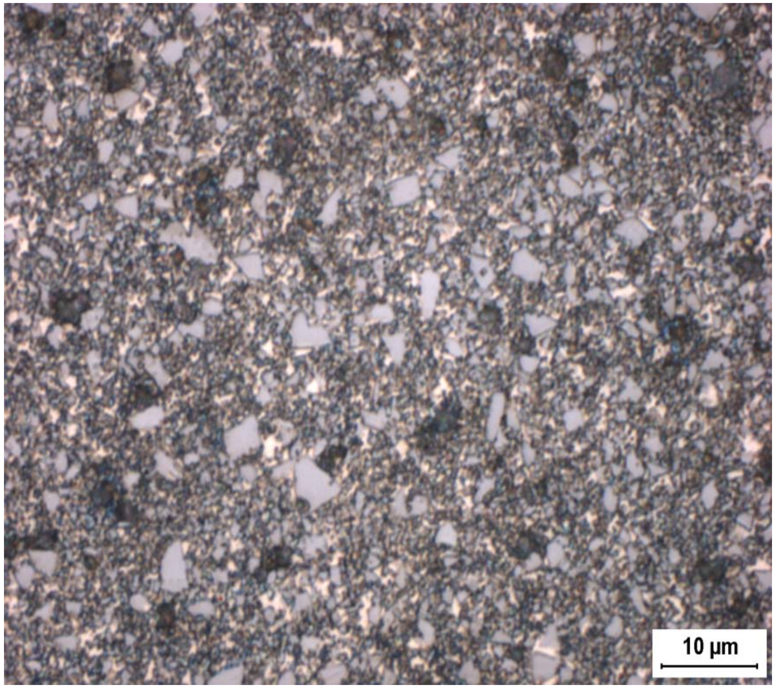
Tungsten Carbide:	86.0%
Cobalt:	11.0%
Tantalum Carbide	2.0%
Other:	1.0%

Physical properties:

Hardness, HRA (ASTM B294)	88.5-89.5
Density, g/cc (ASTM B311)	14.19 -14.31
Aver. Trans. Rupture Strength, psi (ASTM B406)	490,000
Typical Porosity (ASTM B276)	A02-B00-C00

Grade Attributes: A relatively coarse carbide particle grains size being coupled with medium binder content provides a wear resistant grade with moderate withstanding to impact. The tantalum carbide ensures sufficient resistance to galling. ***Good sliding wear characteristics for PM compaction tool applications.***
The corrosion-resistant additive exhibits high resistance to binder leaching at the EDM processing as well as prevents from the negative influence of residual lubricants that may remain on the working surfaces of tools being stored in tooling premises for future usage.
Typical Applications: Powder metal dies, wire EDM blocks, motor lamination stamping punches and dies, pierce punches and dies.

Grade GC-813CT



Composition:

Tungsten Carbide: (mixed: 1.0 and 4.5 microns)	86.5%
Cobalt:	10.5%
Tantalum Carbide	2.0%
Other:	1.0%

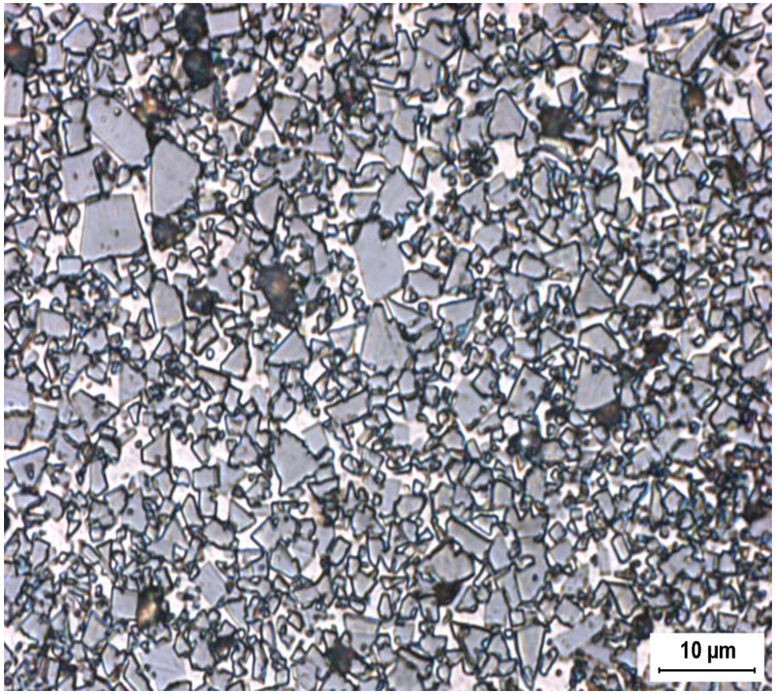
Physical properties:

Hardness, HRA (ASTM B294)	90.5-91.5
Density, g/cc (ASTM B311)	14.24 -14.36
Aver. Trans. Rupture Strength, psi (ASTM B406)	460,000
Typical Porosity (ASTM B276)	A02-B00-C00

Grade Attributes: The unique mixed particle sizes of the tungsten carbide, coupled with the intermediate binder content, provides an excellent wear resistant grade with resistance to impact. The tantalum carbide addition provides resistance to galling as often experienced in cold rolled steel and stainless steel stamping, as well as thermal edge deformation resistance. Enhanced ejection force for metallic powders cold compaction dies. The corrosion resistant additive provides resistance to corrosion in the EDM process, from lubrication, and from atmospheric corrosion on stored dies.

Typical Applications: Stamping punches and dies sections, WEDM blocks, powder metal tooling, including dies and punches.

Grade GC-613CT



Composition:

Tungsten Carbide: (6.0 micron)	83.0%
Cobalt:	13.0%
Tantalum Carbide	3.0%
Other:	1.0%

Physical properties:

Hardness, HRA (ASTM B294)	87.4-88.4
Density, g/cc (ASTM B311)	14.13 -14.25
Aver. Trans. Rupture Strength, psi (ASTM B406)	465,000
Typical Porosity (ASTM B276)	A02-B00-C00

Grade Attributes: The coarse structure coupled with medium binder content provides a grade with good wear resistance and the capability to withstand moderate impact loads. The tantalum carbide adds lubricity and exceptional resistance to galling in all wear areas. For PM applications, ***ejection forces during powder compaction are sizably less versus conventional carbide grades.*** The presence of corrosion-resistant additive provides moderate resistance to corrosion.

Typical Applications: Powder Metal Dies (Wire EDM) , sizing and PM punches, WEDM blocks, Stamping Dies.

What does higher mechanical strength and impact resistance, improved galling resistance and anti-corrosion properties mean to the stamper?……………………

Customer Results

- .009” cold rolled steel using GC-813CT, 350% increase.
- .025” cold rolled steel using GC-411CT, 9:1 increase in tool life.
- .014” silicon steel using GC-411CT,   over 2:1 increase in tool life.
- .025 cold rolled steel using GC-411CT, over 2:1 increase in tool life.
- slitting silicon steel using GC-415CT, 9:1 increase in tool life.
- .020” phosphorous bronze using GC-411CT,   5:1 increase in tool life.
- .012” stainless using GC-411CT, 4:1 increase in tool life.
- .039” cold rolled steel using GC-411CT, 5:1 increase in tool life.
- more tests in progress……

GC-813CT increased productivity 350%

MetalForming FEBRUARY 2010

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The Official Publication of PMA

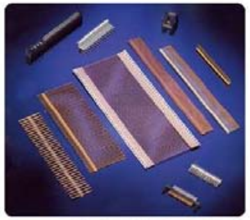
Tooling Update

Tooling Change Generates 350-Percent Productivity Increase

Intricate Metal Forming Co. (IMF), Roanoke, VA, performs high-speed progressive stamping of electronic contacts of square, round and rectangular wire, including stamping of 0.009-in. Type 1006 cold-rolled steel to manufacture bandoliers with U-shaped channels that seat the pins for trimming and shaping.

Recently, the firm experienced excessive tooling wear when stamping the bandolier or carrier strip to support the electrical contact. Presses were running at speeds of 1200 strokes/min., yielding 17 coils—at 100,000 parts per coil—before the tooling needed to be sharpened. Production manager Larry Rehak turned to carbide supplier General Carbide, Greensburg, PA, to help engineer a solution, which came during the third quarter of 2009 when IMF switched to General Carbide's GC-813CT bi-modal tooling made with additions of chromium carbide and tantalum carbide.

General Carbide produces tungsten carbide preforms and blanks used for wear, cutting and metalforming operations. GC-813CT (rated to a hardness of 90.5 to 91.5 HRa), reports Rehak, has reduced corrosion and galling, and has enabled IMF to run as many as 65 coils per tool sharpening and experience a 350-percent productivity increase. With its previous tooling, IMF changed tooling once each day; now, tools remain in the press for four days. GC tooling now runs in three IMF presses.



Telephone: 724.836.3000
www.generalcarbide.com

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GRADE SPECIFICATIONS

Grade: GC-813CT

Composition:

Tungsten Carbide:	86.5%
Cobalt:	10.5%
Tantalum Carbide:	2.0%
Other:	1.0%

Physical Properties:

Hardness, HRA (ASTM B294)	90.5 - 91.5
Density, g/cc (ASTM B311)	14.24 - 14.36
Average Transverse Rupture Strength, psi (ASTM B406)	460,000
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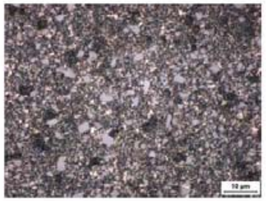

Performance Characteristics

Wear ....Mod–High
Impact ....Moderate
Galling ....Mod–High
Corrosion.......High

Grade Attributes: The carbide particle's multi-grain size matrix coupled with the medium binder content provides an excellent wear resistant grade with resistance to impact. The tantalum carbide addition efficiently withstands galling that often occurs in cold rolled steel and stainless steel stamping and it provides thermal edge deformation resistance.

Other alloying agents ensure resistance to corrosion in the EDM process and prevent atmospheric corrosion from residual lubrication on die surfaces at tooling stores.

Typical Applications: All lamination tooling, large EDM blocks, stamping punches, dies and powder metal tooling.

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FAX: 800.547.2659 • +1 724.836.6274
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IMF
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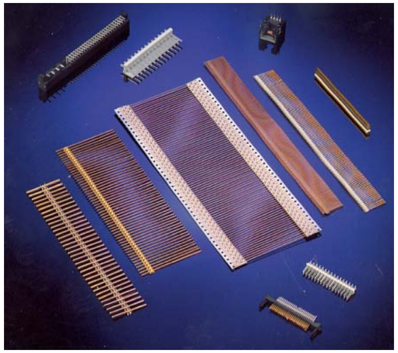
Roanoke, Virginia 24012
Phone: (540) 345-9233
Fax: (540) 345-9293
www.imfco.com

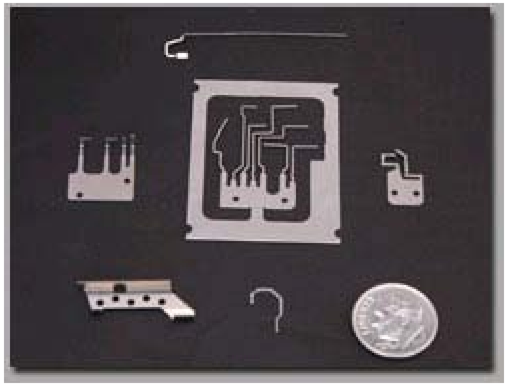
Key Points to Remember….



Unique tungsten carbide powder, tantalum carbide (TaC) and corrosion resistant additives in recently-developed CT carbide grades at General Carbide:

- Showed positive improvements in mechanical properties (fracture toughness).
- Demonstrated superior performance in a corrosive environment compared to standard tungsten carbide-cobalt (WC-Co) grades such as GC-313.

More Key Points to Remember….



- Wire EDM - enhanced compatibility.
- Sub-micron grades are susceptible to grain pullout during punch retraction, leading to premature wear.
- Stamping dies using General Carbide grade GC-813CT increased productivity 350% on 1006 cold rolled steel ….

In Summary :

Recently-developed cemented carbide grades demonstrate enhanced functional characteristics:

- ➢ **Superior corrosion resistance**
- ➢ **Superior toughness**
- ➢ **Anti-galling characteristics**

Ability to withstand higher mechanical forces:

- ➢ **Retains size within required tolerances**
- ➢ **Galling resistance improves surface finish**
- ➢ **Minimizes breakage and extends wear life**
- ➢ **Provides an advantage in reduced manufacturing costs**

Designer's Guide to Tungsten Carbide

Go to www.generalcarbide.com/articles for .pdf download of all chapters

Any questions, please?….

Thank you!

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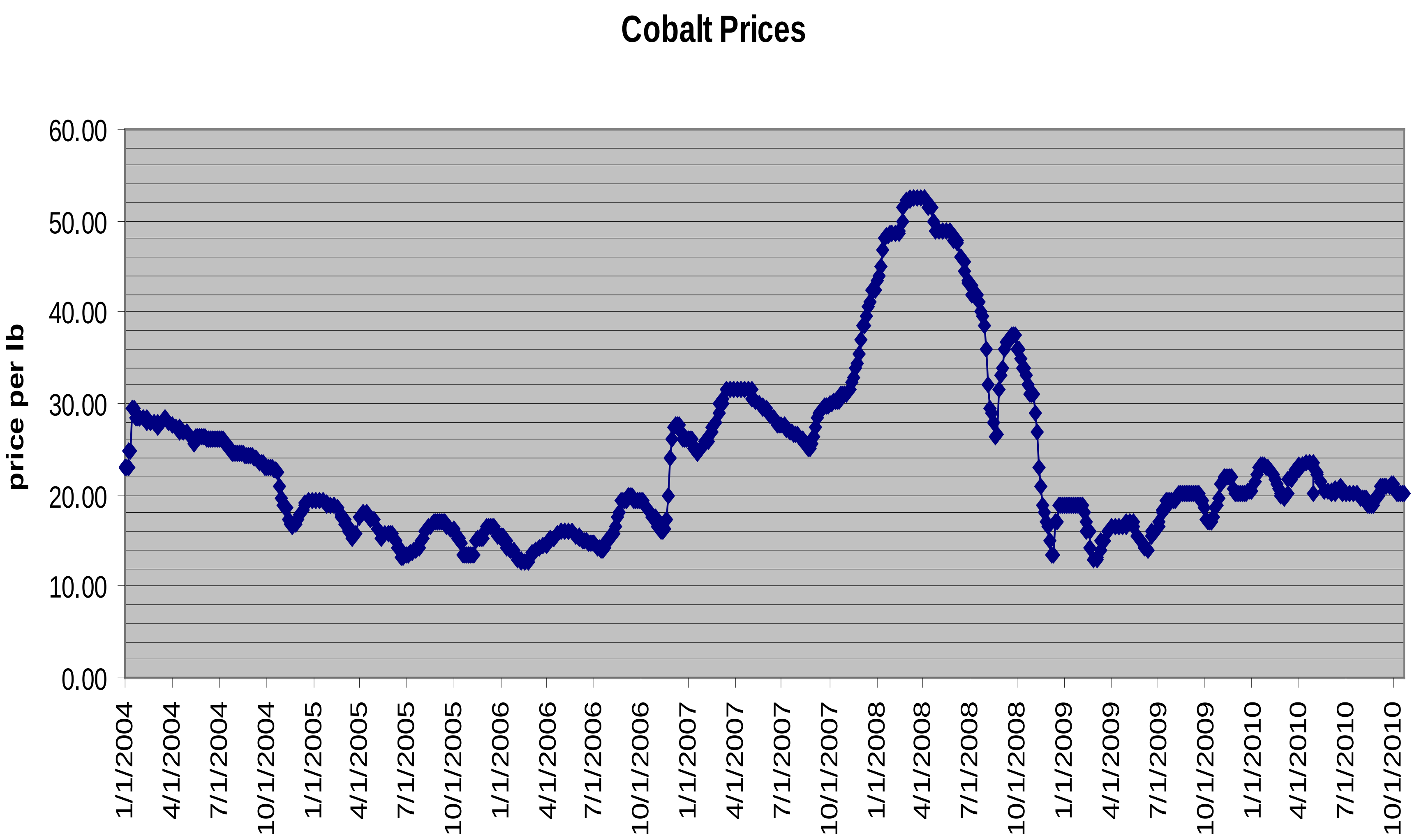

Cobalt Prices
price per lb
60.00
50.00
40.00
30.00
20.00
10.00
0.00
1/1/2004
4/1/2004
7/1/2004
10/1/2004
1/1/2005
4/1/2005
7/1/2005
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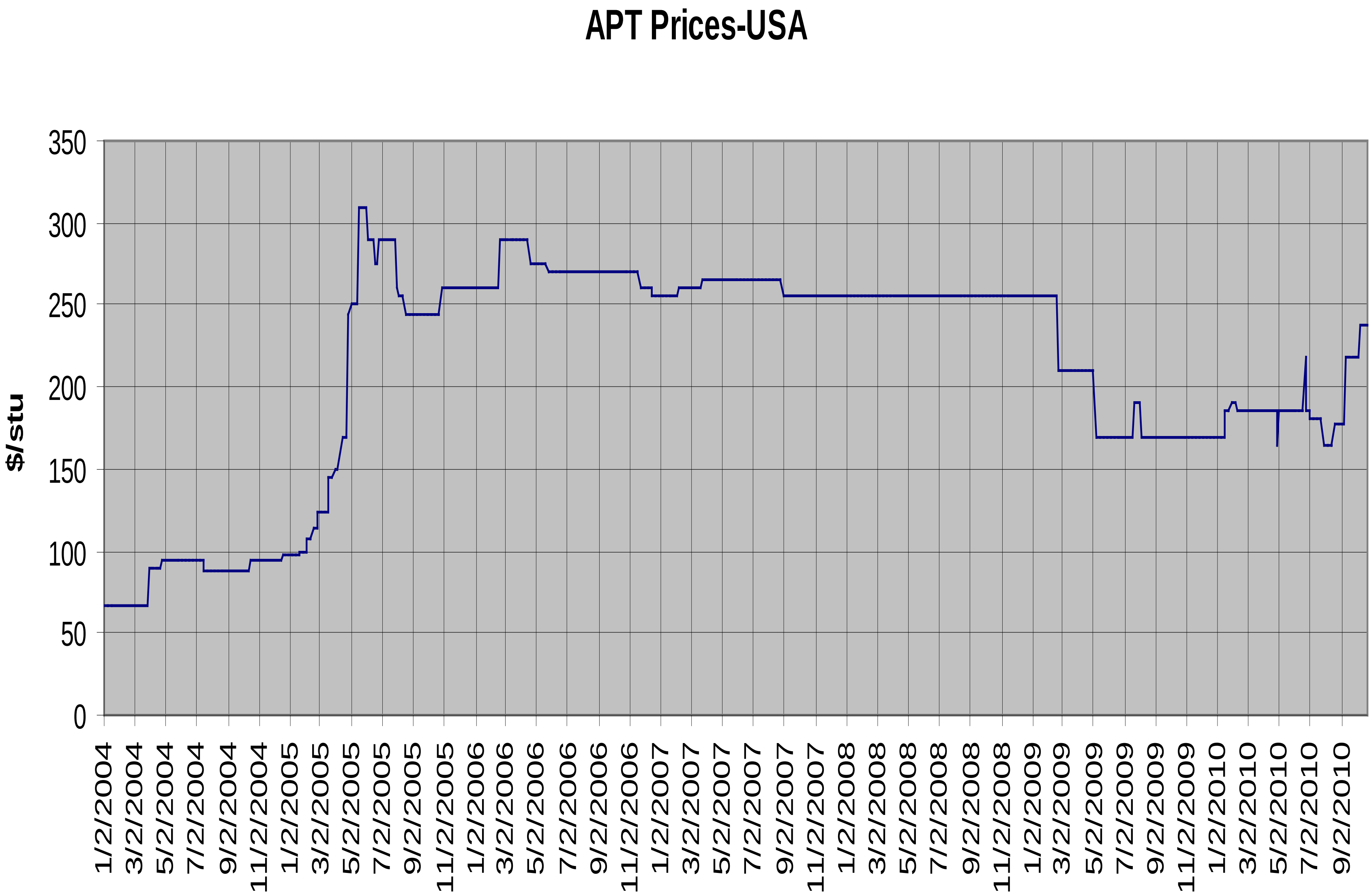
APT Prices-USA
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PROPERTIES OF SOME SELECTED WC-Co CEMENTED CARBIDE GRADES vs. OTHER TOOL MATERIALS.

Composition, wt. %	Hardness, HRa	Abrasion Resistance, 1/vol.loss cm^3	Transverse Rupture Strength, 1,000 lb/in^2	Ultimate Compression Strength, 1,000 lb/in^2	Ultimate Tensile Strength, 1,000 lb/in^2	Modulus of Elasticity, 10^6 lb/in^2	Thermal Expansion, @75 °C-400 °C Cal/ (s·°C ·cm)
WC-6%Co	92.8	35-60	335	860	160	92	2.9
WC-9%Co	89.5	10-13	425	660	-	87	2.7
WC-13%Co	88.2	4-8	500	600	-	81	3.0
Other Materials (for comparison & consideration)							
Tool Steel (T8)	85 (66 HRc)	2	575	600	-	34	6.5
Carbon Steel (AISI 1095)	79 (66 HRc)	1	-	-	300	30	-
Cast Iron	-	2	105	-	-	15-30	9.2

Why Do We Need and Use Cemented Carbide?

… because of its unique combination of superior physical and mechanical properties including:

-***Abrasion Resistance:*** Cemented carbide can outlast wear-resistant steel grades by a factor up to **100 to 1**;

-***Deflection Resistance:*** Cemented Carbide has a Modulus of Elasticity **three times** that of steel which translates into one third of deflection when compared to the steel bars of the same geometry and loading;

-***Tensile Strength:*** Tensile Strength is varied from **160,000 psi to 300,000 psi**;

-***Compressive Strength:*** Compressive Strength is over **600,000 psi**;

-***High Temperature Wear Resistance:*** Good wear resistance **up to 1,000 ºF**.

…thus, Cemented Carbide is often the best material choice for particularly tough applications providing the most cost-effective solution to a challenging problem…

Methods of Thermal Consolidation Used in Manufacturing of Cemented Carbides:

- **Vacuum Sintering**
- **Atmospheric Sintering (less frequently used);**
- **Hot Isostatic (Isotropic) Pressing [HIP];**
- **Sinter-HIP Processing;**
- **Hot Pressing (Anisotropic) under Vacuum.**

Sinter-HIP Advantage:

Sinter-HIP processing combines both Sintering and HIP into **ONE** single processing operation at the last consolidation stage while the whole operation is performed in one furnace.

Sinter-HIP vs. Post-HIP:

Cost-Efficient and Productive Alternative…

- **Sinter-HIP requires 10-15 times less pressure than post-HIP processing.**
- **Sinter-HIP - the overall time of applied pressure is 4-6 times less compared to post-HIP processing.**
- **Sinter-HIP reduces Argon-gas consumption by 90% vs. post-HIP process.**

New Materials Lab:

Manufacturing process for cemented carbide products:

From APT (Ammonium Para-Tungstate) …to Finished Part /Tool …