GENERALCARBIDE®

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Advanced Cemented Carbides for Powder Metal Tooling Applications

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Chief Metallurgist

41th Anniversary
1968-2009

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CARBIDES?...

...What do we know about them?

Agenda:

What is a cemented carbide?

Why do we use cemented carbide in PM?

What advancements have been made for PM tooling applications in:

- carbide processing and manufacturing?
- carbide grade development?
- carbide failure analysis and troubleshooting?

What is Cemented Carbide?

Definition:

Cemented Carbide is a **composite material** of a **soft binder metal** usually either **Cobalt (Co)** or **Nickel (Ni)** or **Iron (Fe)** or a mixture thereof and **hard carbides** like **WC** (Tungsten Carbide), **Mo_2C** (Molybdenum Carbide), **TaC** (Tantalum Carbide), **Cr_3C_2** (Chromium Carbide), **VC** (Vanadium Carbide), **TiC** (Titanium Carbide), etc. or their mixes.

Carbides: Selected Mechanical Properties.

Carbide Formula	Vickers (HV) Hardness @ Various Temperatures, °C (°F)		Rockwell Hardness @ Room Temperature, HRa	Ultimate Compressive Strength, MPa (ksi)	Transverse Rupture Strength, MPa (ksi)	Modulus of Elasticity, GPa (10^6 ksi)
	20 °C (78 °F)	730 °C (1350 °F)				
TiC*	2930	640	93	1330-3900 (193-522)	280-400 (40.6-58.0)	370 (52.9)
HfC*	2860	-	84	-	-	-
VC*	2800	250	83	620 (89.9)	70 (10.1)	360 (51.4)
NbC	2400	350	83	1400 (203)	-	270 (38.5)
TaC*	1570	800	82	-	-	470 (68,2)
Cr_3C_2*	-	-	81	100 (14.5)	170-380 ((24.7-55.1)	280 (40.0)
Mo_2C*	-	-	74	2700 (392)	50 (7.3)	375 (53.6)
WC*	2400	280	81	2700-3600 (392-522)	530-560 (76.9-81.2)	665 (95)

*NOTE: TiC-Titanium Carbide; HfC-Hafnium Carbide; VC-Vanadium Carbide; NbC-Niobium Carbide; TaC-Tantalum Carbide; Cr_3C_2 - Chromium Carbide; Mo_2C - Molybdenum Carbide; WC-Tungsten Carbide.

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**;

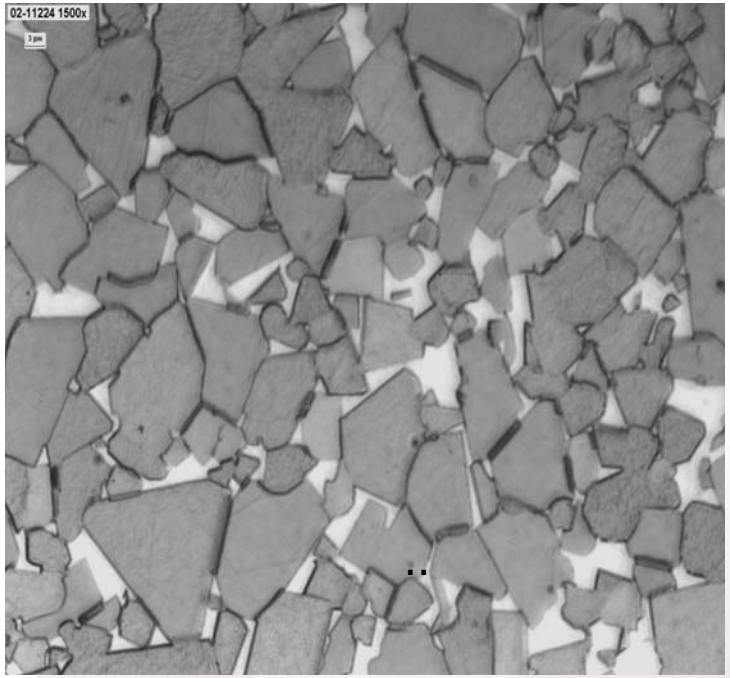
-***Compressive Strength:*** Compressive Strength is over **600,000 psi**;

-***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…

Karl Schroter Patents

- **1925**
  - **Comp. – WC + 3 -10 Co, WC (4 –10 %C)**
  - **Sinter - 1500 – 1600ºC**
  - **Atmosphere – H_2, N_2, A, CH_4, CO or Mixture**
  - **Binder – Co, Ni, Fe**
- **1929**
  - **Comp. 10 -20%**
  - **CH_4 Carburized W Powder (Closer to 6.13%C)**
  - **Sinter - < 1400ºC with 10 – 20 % Binder**
- **1930 – with Hans Wolff – Krupp**
  - **Manufacture of Complex Shapes**
  - **Press – presinter – machine – sinter**
  - **With or without binders**
- **Patent Acquisitions:**
  - **Krupp (Germany) 1925 - Widia**
  - **GE (United States) 1925 - Carboloy**
  - **Thomson-Houston (UK) 1925 - Ardoloy**



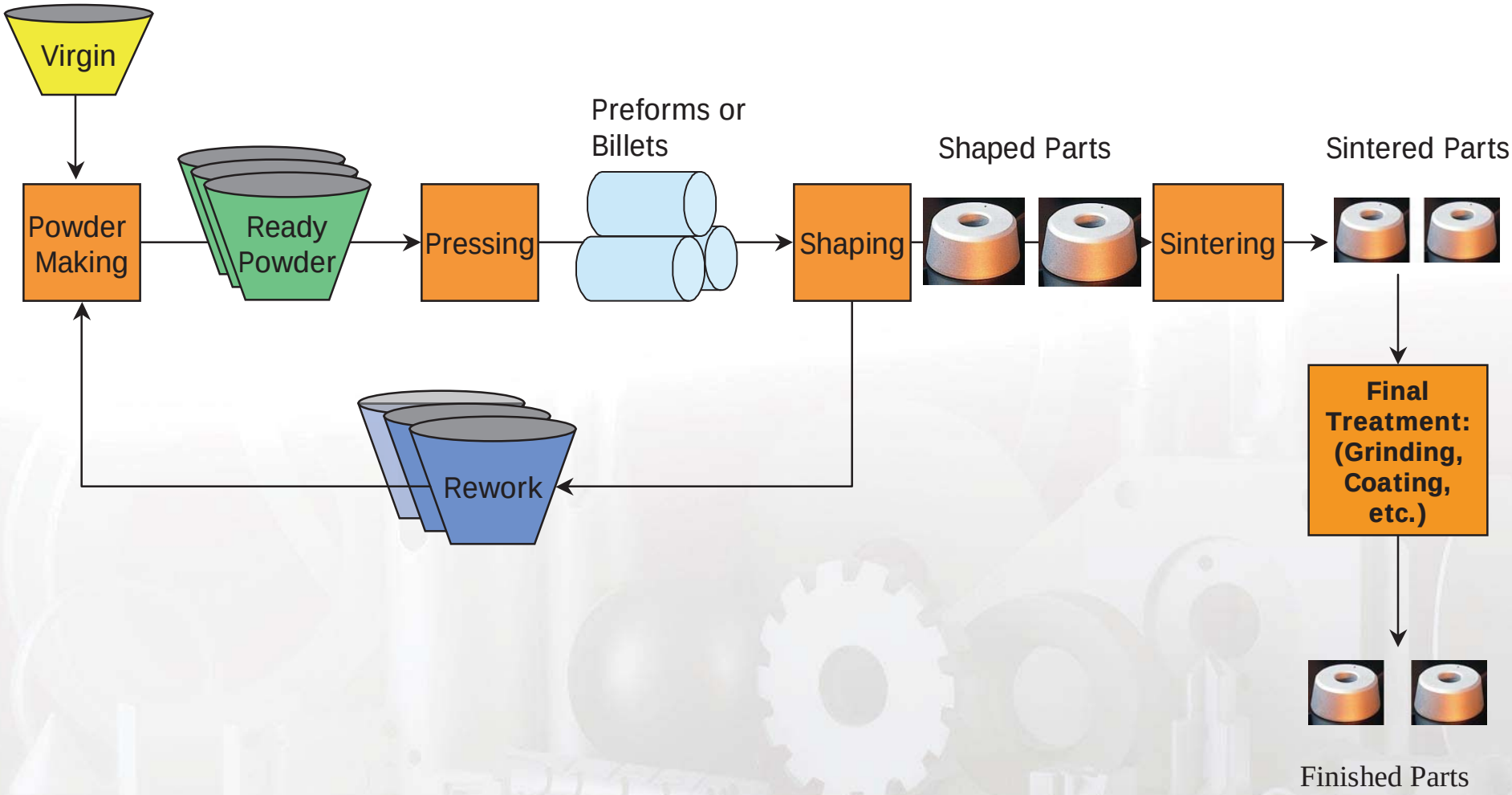
PROPERTIES OF SOME SELECTED **WC-Co** CEMENTED CARBIDE GRADES

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

Room & Hot Hardness of WC-Co Cemented Carbide vs. High Speed Tool Steel

Material \ Properties	Hardness (HRC) @ Various Working Temperatures		
	@ 20 °C (78 °F)	@ 760 °C (1400 °F)	@ 1093 °C (2000 °F)
Cemented Carbide [WC +6%Co]	77 -79	27 - 29	21 - 23
High Speed Steel --AISI T4 Grade [0.8%C+18%W+4%Cr+1%V+5%Co]	63 - 65	17 - 19	N/A

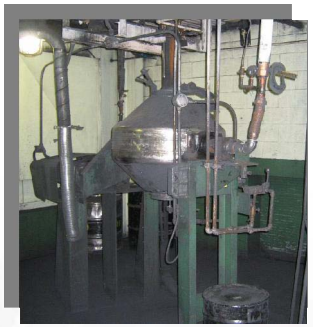
Manufacturing Process of Cemented Carbides:



Processing Advancements

Full range of manufacturing capabilities:

Attrition



Vacuum Drying

Spray Drying

Mechanical Pressing

Powder shaping / “Green” & “Hard” Machining

Pressure Sintering (Sinter-HIP)

Cold Isostatic Pressing

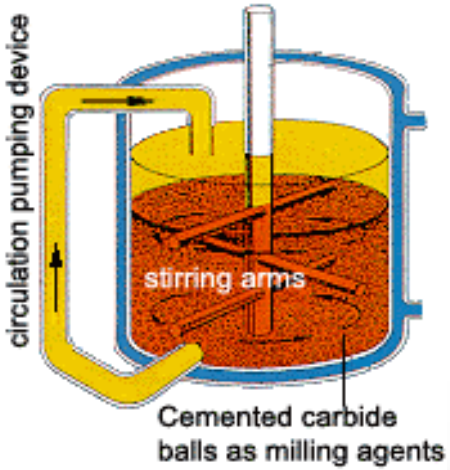
Preparation of Powder Compositions at General Carbide Manufacturing Facilities.

Milling

Vacuum Drying

Spray Drying

Mixing / Milling in the Attritor



Attritor Mill

Milling

In the process of **attrition milling**, a milling media (e.g. cemented carbide balls) is introduced into the milling attritor together with special milling liquid. During this process agglomerates of the basic materials are destroyed and a ***homogeneous mix is achieved.***

Vacuum Drying of Cemented Carbide Powder Blends.

Vacuum Drying

Vacuum drying is ideal for **WC-Co** materials because it removes moisture while preventing oxidation or explosions that could occur when the milling liquid (solvent) combines with air.

Processing Advancement:

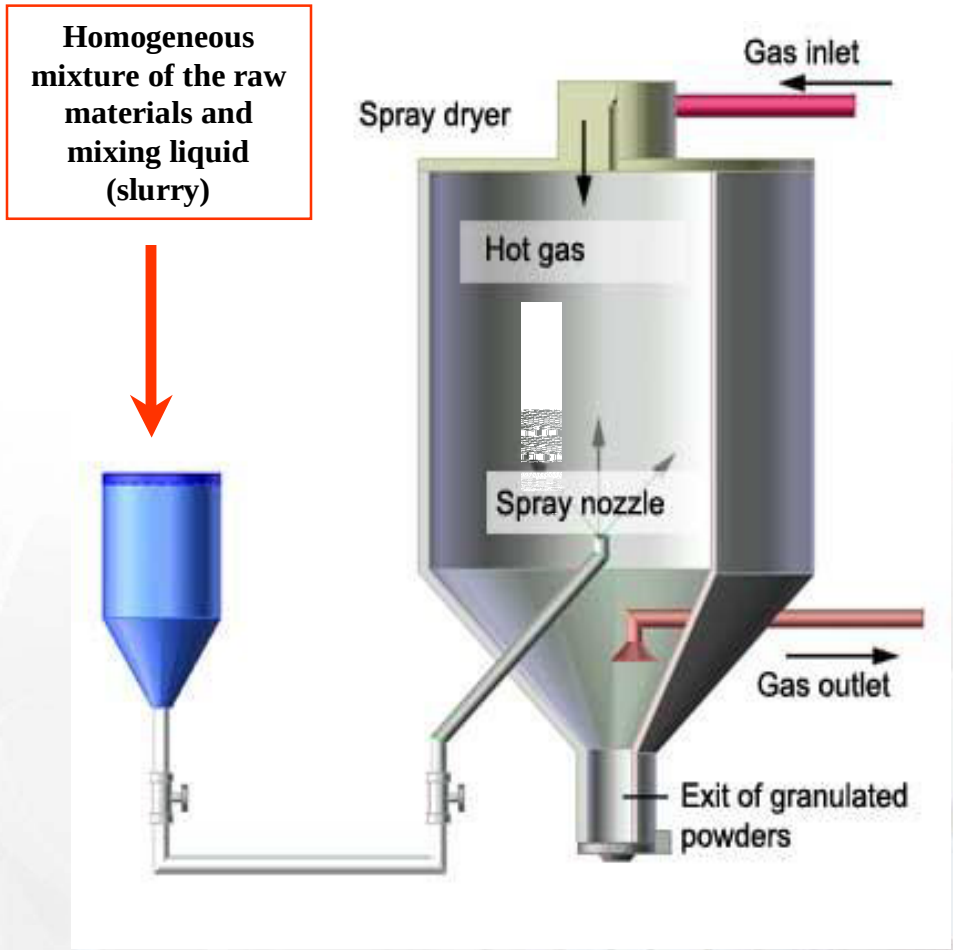
Spray Drying for Carbide Grade Formulations

Spray Dryer at General Carbide

Spray Dry processing of Cemented Carbides provides uniform particle size and weight, uniform lubricant wax distribution and uniform carbon balance within bulk material.

Spray Drying ensures excellent particle flow in the die cavity. At General Carbide, spray drying is routinely used to dry and granulate the attritor-milled cemented carbide suspension.

Principle of the Spray Drying Process



Granulation via Spray Drying

By means of granulation, fine particles of the different basic materials are agglomerated to larger grains.

To achieve this, paraffin is added at a previous milling operation into the "slurry" which is vaporized in small drops via this process.

The drops rise in the spray dryer and hit upon an inverted stream of hot gas. The liquid parts of the mixing and milling agent evaporate and the solid particles agglomerate under the stabilizing effect of the paraffin to produce spheroidized grains.

High Quality Cemented Carbide Powder Compositions

Spray-Dried Cemented Carbide Powders

Vacuum-Dried Cemented Carbide Powders

Bulk powder blends after milling and drying processing

Common Pressing Techniques for Cemented Carbide Products

Cold Compaction by Hydraulic Press

in "Rigid Die" Tool Set

Cold Isostatic Pressing (CIP)

in "Flexible Tool Set

Advancements in Thermal Consolidation of Cemented Carbides

Methods of Thermal Consolidation Used in Manufacturing of Cemented Carbides:

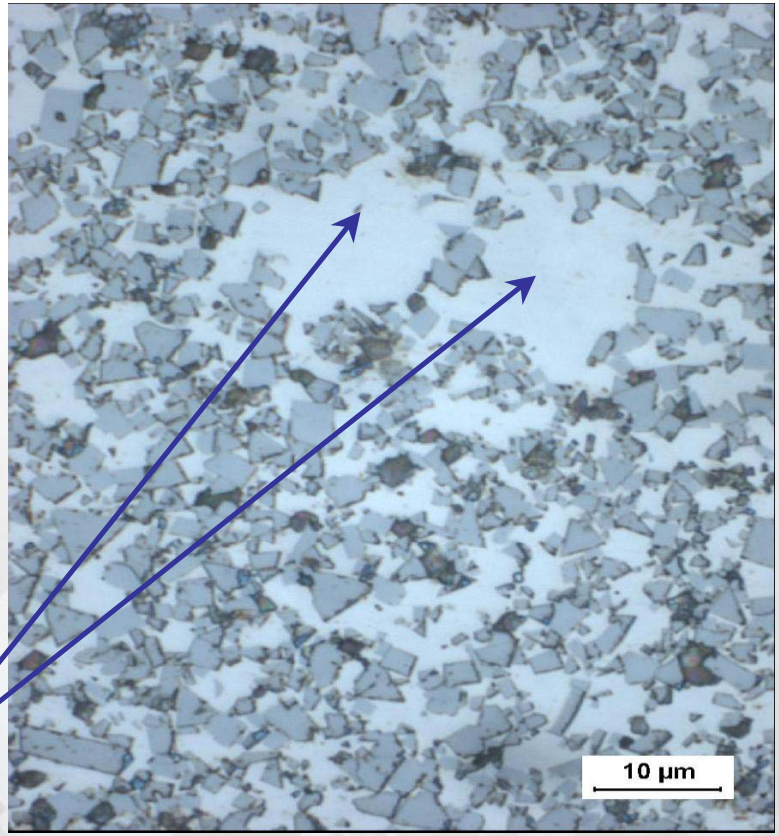
- Vacuum Sintering
- Atmospheric Sintering (less frequently used);
- Hot Isostatic (Isotropic) Pressing [HIP];
- Sinter-HIP Processing;
- Hot Pressing (Anisotropic) under Vacuum.

Sinter-HIP vs. post-HIP: Pros & Cons…

What do we know?

"Cobalt-Lake" defects that can be found in the process of routine Vacuum Sintering:

During routine sintering of WC-Co cemented carbides, Cobalt (Co) or Co-based liquid eutectic substances frequently generate a defect of the structure known as a "Cobalt Pool" or "Cobalt Lake". It is a condition where Co is squeezed into a macro-void that might occur within the material at the liquid stage of the sintering operation.



"Cobalt Lake" defects

"Cobalt Lake" Defects and Techniques to Eliminate Them:

- **Once a "Co-Lake" defect occurs, it is very difficult to get any amount of WC particles into the affected areas.**
- **HIP (post sintering) and Sinter-HIP techniques have been developed and applied to achieve better homogeneity of the cemented carbide structure, thereby improving mechanical properties.**
- **Both processes are performed in special pressure-tight vessels through the simultaneous application of heat and pressure for a pre-determined time.**

HIP Technique

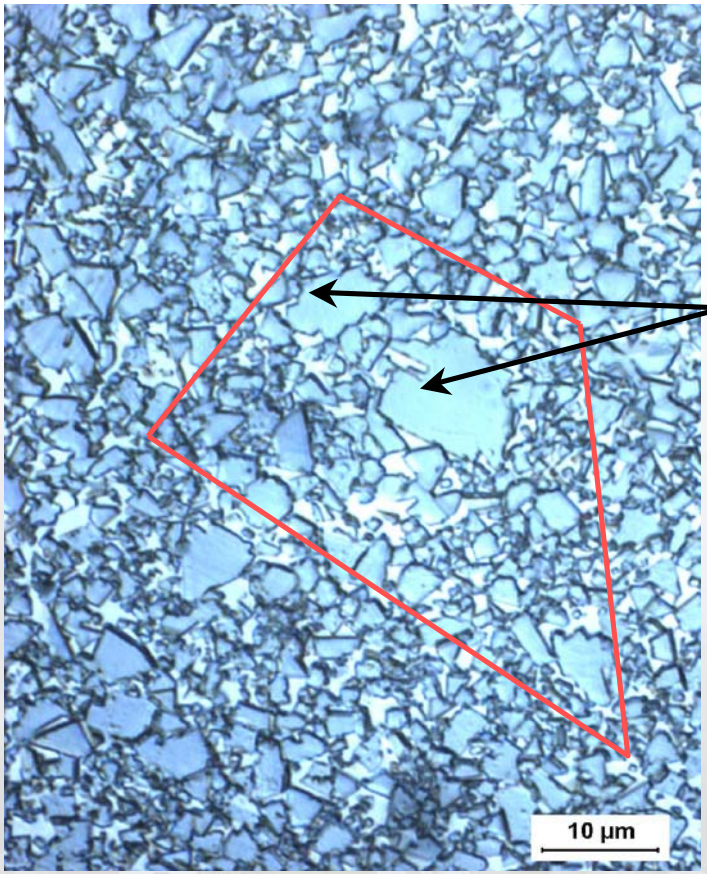
Hot Isostatic Pressing, is a technology of isotropic compression and compaction of the material by use of high-temperature and high-pressure gas as a pressure and heat transmitting medium.

Disadvantages of Post-HIP Processing.

- **Performed on parts which were already sintered that diminishes productivity.**
- **Performed at very high pressure in a separate pressure-tight vessel, thereby, requiring an extra manufacturing operation and reducing efficiency.**
- **Can result in grain growth of the microstructure.**

Potential for Defects from“Post-HIP” Processing

Due to the fact, that a post-HIP process is performed *at the solid-phase diffusion temperature*, there is a risk of *intensive grain growth of **WC-** particles* within the sintered body that could affect the mechanical properties of the final product.



Large Grains Within Cluster Zone

Sinter-HIP Advantage:

Sinter-HIP processing combines both Sinting 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.**

Multiple Sinter-HIP Processing at General Carbide:

Five Sinter-HIP furnaces are used daily on 100% of our products.

Research & Development Capabilities for Advanced PM Tool Grades

Capabilities in Material Analysis

- WC-Co traditional bi-phase cemented carbide material products;
- Cemented Carbides with Nickel-based binding phase;
- Cemented carbides containing TaC (Tantalum Carbide), Cr_3C_2 (Chromium Carbide), VC (Vanadium Carbide), NbC (Niobium Carbide)
- Tungsten Carbide Composites (GenTuff Products)
- PVD / CVD Multi-Layer Coatings applied onto Cemented Carbide products;
- Engineered ceramic compositions and special materials.

Diversified QC &Test Equipment

Rockwell Hardness Tester

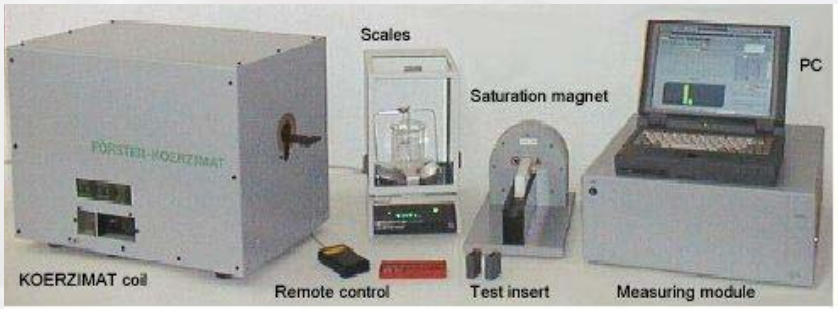
Transverse Rupture Strength Test Machine

Density Tester

Nikon Microscope

Magnetic Saturation Machine

Coercimeter equipment



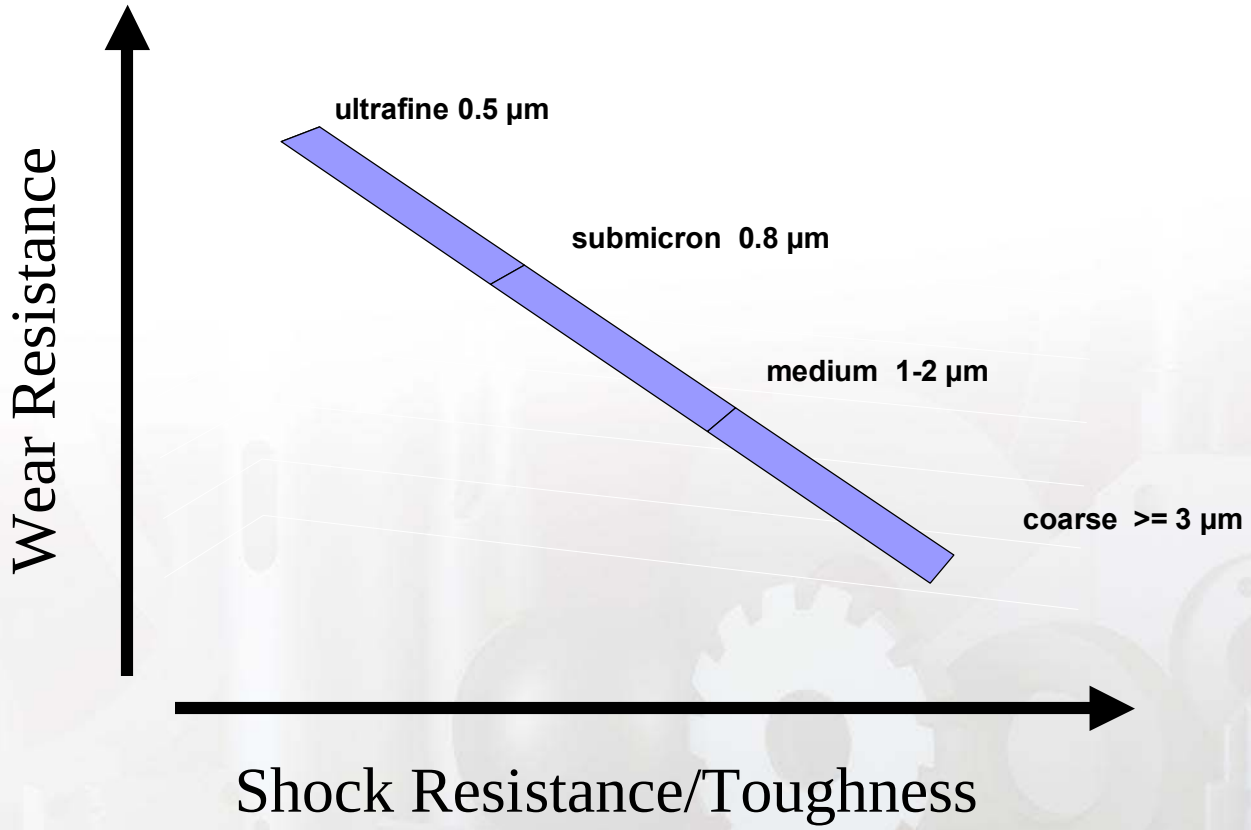
Coordinate Measuring Machine

General Carbide New Materials & QC Lab

Materials/Grade Selection & Material Consideration for PM Tool Applications

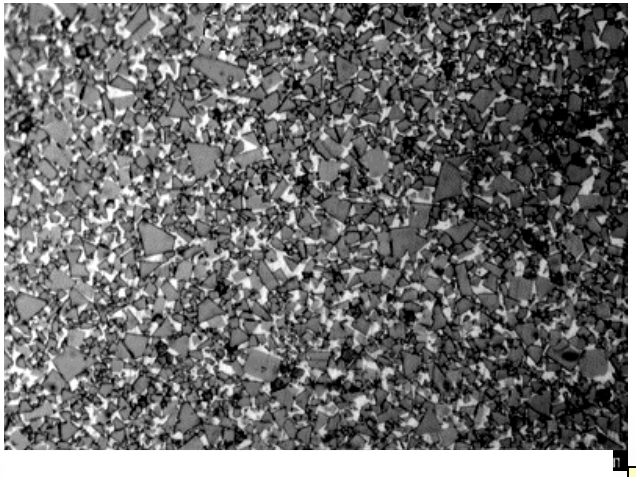
…effect of grain size versus binder content…

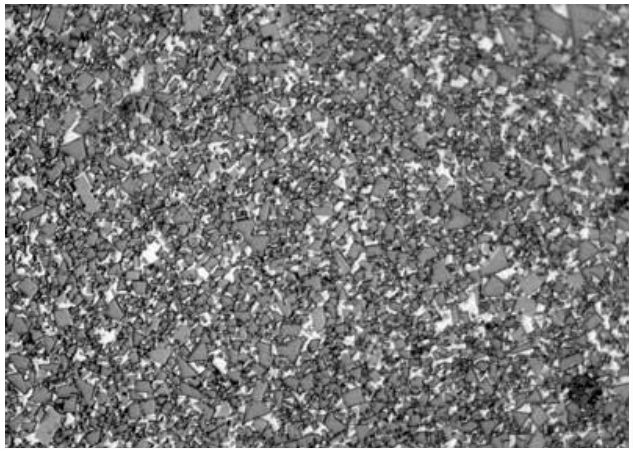
Effect of Grain Size



Constant binder content - varying grain size

4 µm

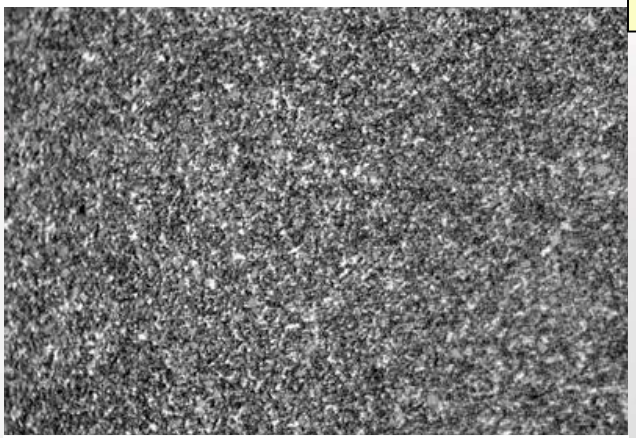


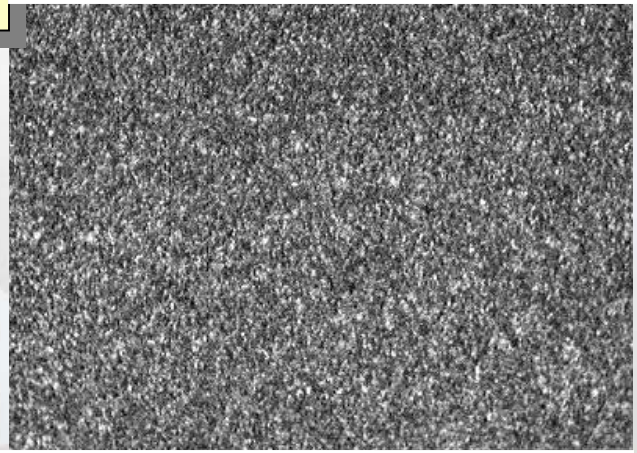


2 µm

1500x

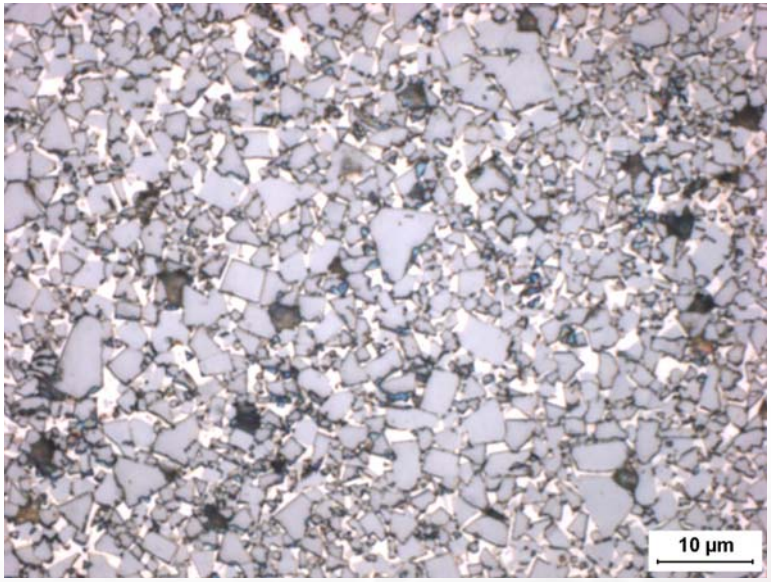
0.8 µm





0.5 µm

Grain Size vs. Cobalt Content:



GC-411CT

Hardness: 88.0 - 89.0

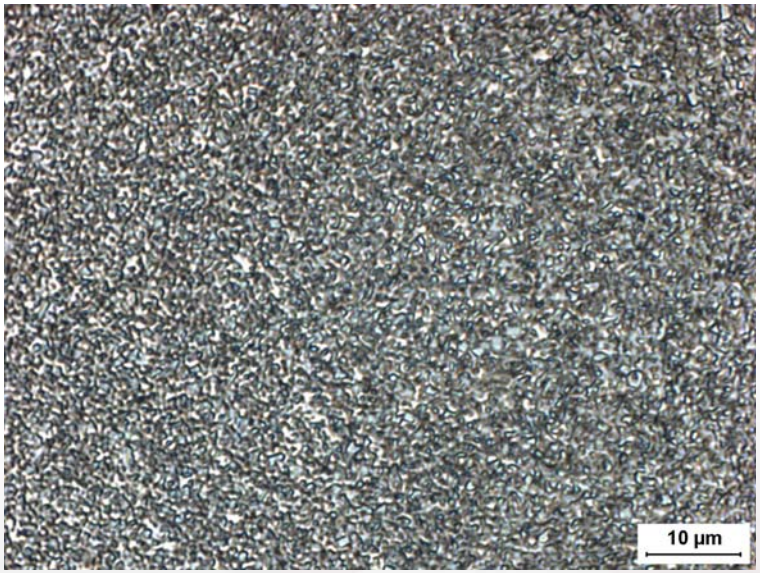
TRS: 490,000 psi

Average grain size: 4.5 micron

Galling Resistance: Moderate

Corrosion Resistance: High

Wear resistance: Good



GC-010

Hardness: 91.4 - 92.2

TRS: 550,000 psi

Average grain size: 0.8 micron

Galling Resistance: Low

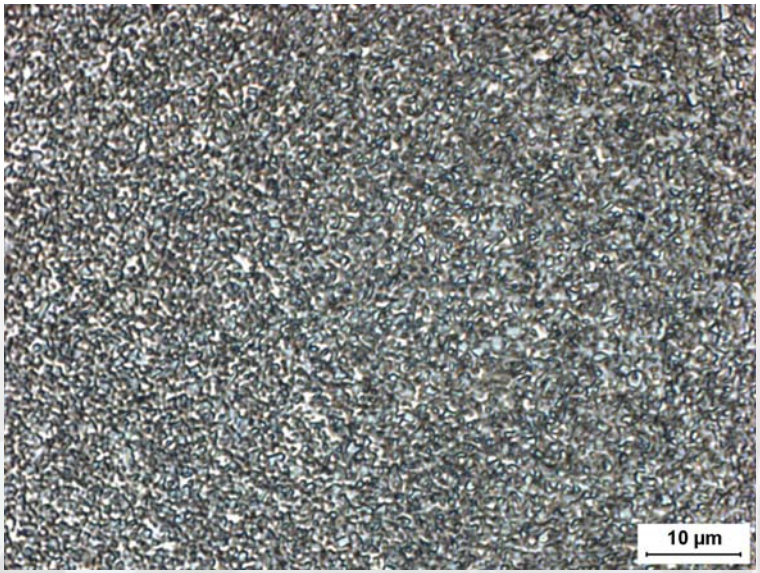
Corrosion Resistance: Low

Wear resistance: High

Fine grain formulations:

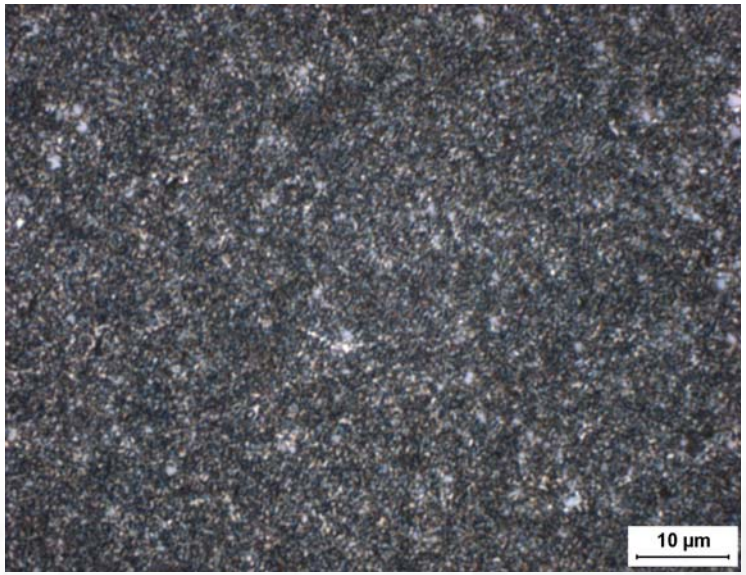
What does it do for Cemented Carbide ?

A finer grain material can achieve higher hardness with a given cobalt binder but has a lower transverse rupture strength value



GC-010

Grade GC-010CR



Composition: (Grain size 0.8 micron)

Tungsten Carbide:	89.0%
Cobalt:	10.0%
Other:	1.0%

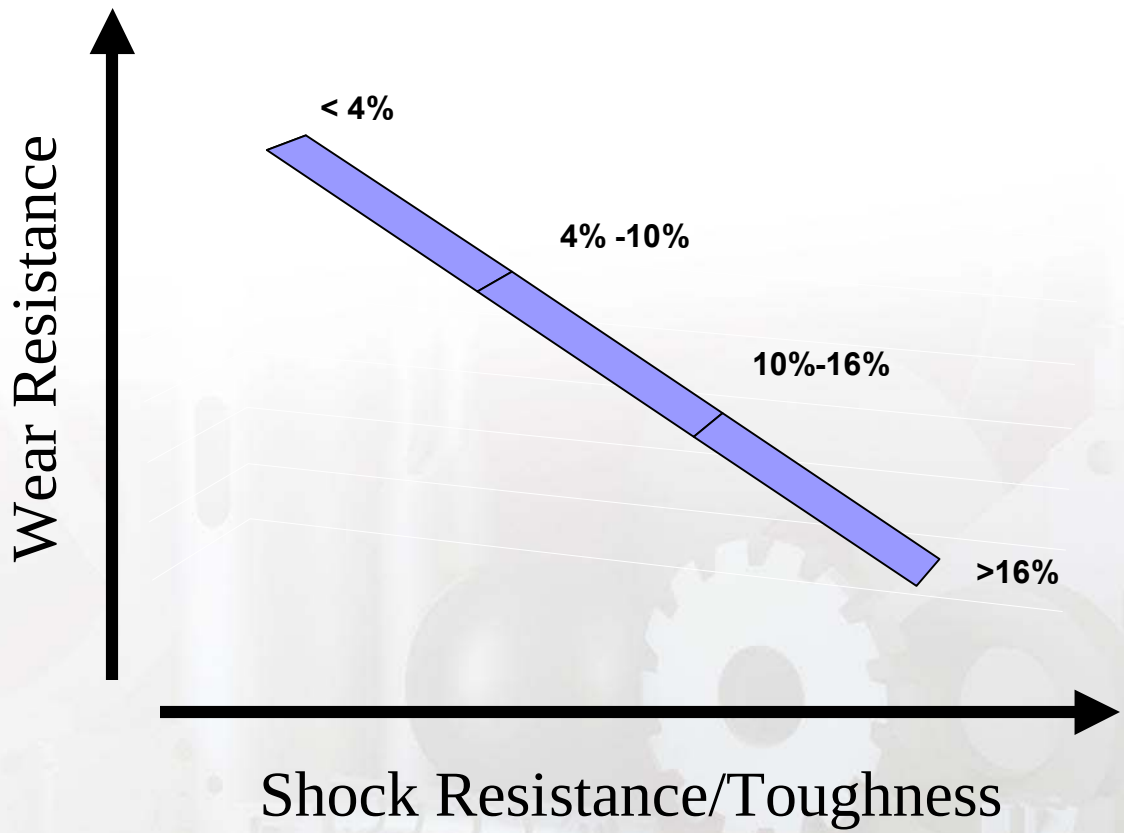
Physical properties:

Hardness, HRA (ASTM B294)	92.3 - 93.3
Density, g/cc (ASTM B311)	14.25-14.35
Average Transverse Rupture Strength, psi (ASTM B406)	590,000
Typical Porosity (ASTM B276)	A02-B00-C00

Grade Attributes: The submicron particle size, coupled with the low binder content, provides a very hard, wear resistant grade. The presence of a corrosion resistance additive provides moderate resistance to corrosion..

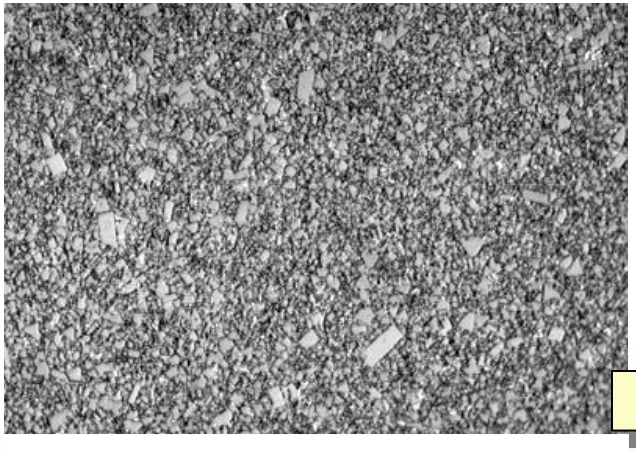
Typical Application: EDM blanks, valve components, concrete forming dies, rotary tooling, powder metal dies and core pins, and all 10% sub-micron applications where corrosion resistance is required.

Effect of Binder Content

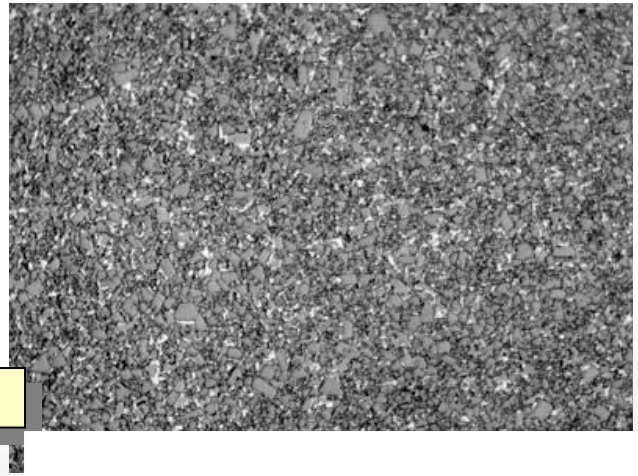


Constant grain size/varying binder content

6%

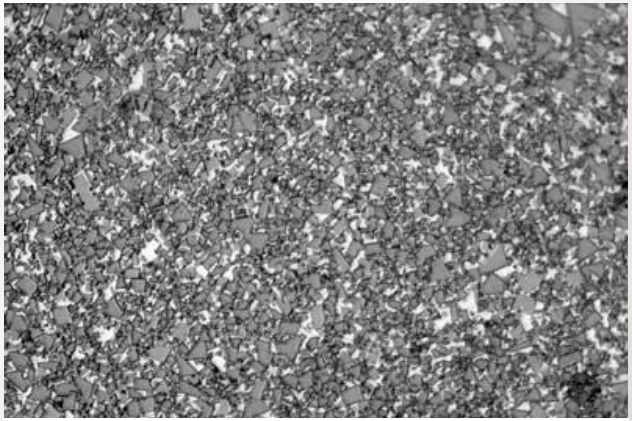


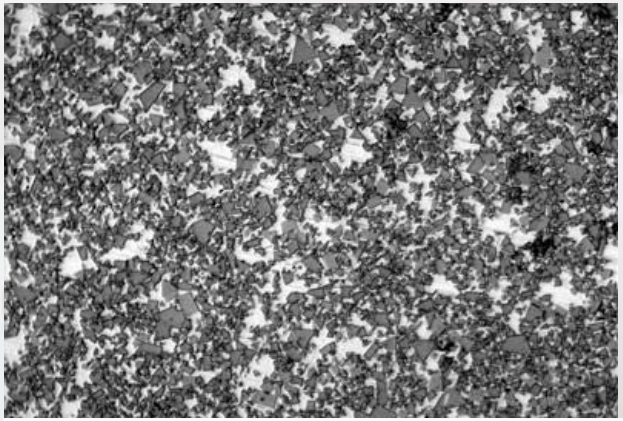
1500x



10%

16%





24%

GENERALCARBIDE. INVESTED IN YOUR SUCCESS

GENERAL CARBIDE PRODUCTS ARE MADE IN THE USA

Grade Specifications

GENERALCARBIDE.

	Chemical Composition Weight Percent WC	Co	Other	Hardness HRA	Density g/cm³	Average Transverse Rupture Strength (psi)
Tungsten Carbide Grades with Cobalt Binder						
0.6 micron						
GC-012F*	88	12		92.2 - 93.2	14.08 - 14.20	520,000
GC-015F*	85	15		90.8 - 91.8	13.79 - 13.92	605,000
0.8 micron ("submicron")						
GC-005	94.5	5.5		93.4 - 94.2	14.88 - 14.97	500,000
GC-010*	90	10		91.4 - 92.2	14.39 - 14.51	550,000
GC-010CR*	89	10	1	92.3 - 93.3	14.25 - 14.35	590,000
GC-015*	85	15		89.3 - 90.3	13.89 - 14.03	600,000
GC-015CR*	84	15	1	90.4 - 91.4	13.74 - 13.86	650,000
1.0 micron						
GC-103	96.3	3.7		92.7 - 93.5	15.12 - 15.21	480,000
GC-106	94	6		91.9 - 92.7	14.86 - 14.97	510,000
GC-109	91	9		91.0 - 91.8	14.54 - 14.66	520,000
2.0 micron						
GC-206	94	6		91.2 - 92.2	14.86 - 14.97	500,000
GC-209	91	9		90.2 - 91.2	14.53 - 14.65	505,000
GC-211*	89	11		89.4 - 90.4	14.33 - 14.45	530,000
3.0 micron						
GC-310*	90	10		89.3 - 90.3	14.46 - 14.58	515,000
GC-313*	87	13		88.1 - 89.1	14.15 - 14.27	530,000
GC-315*	85	15		87.5 - 88.5	13.95 - 14.09	540,000
GC-320*	80	20		85.6 - 86.6	13.46 - 13.64	525,000
GC-325*	75	25		83.5 - 84.7	13.03 - 13.23	520,000
GC-330*	70	30		81.6 - 82.9	12.61 - 12.82	500,000
6.0 micron						
GC-618*	82	18		85.2 - 86.2	13.67 - 13.81	465,000
GC-712*	88	12		87.7 - 88.7	14.25 - 14.37	510,000
GC-950*	85	15		86.4 - 87.4	13.95 - 14.09	480,000
11.0 micron						
GC-915*	85	15		85.6 - 86.6	13.95 - 14.09	470,000
1.0 and 6.0 micron (mixed structure)						
GC-606M	94	6		90.4 - 91.4	14.89 - 15.00	480,000
GC-608M	92	8		89.8 - 90.8	14.66 - 14.78	490,000
GC-610M	90	10		88.8 - 89.8	14.46 - 14.58	500,000
GC-612M	88	12		88.2 - 89.2	14.25 - 14.37	505,000

*Available in Wire EDM Grade

Note: Micron sizes refer to the nominal grain size for all grades

SinterHIP Process Guaranteed

1151 Garden Street, PO Box C
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F **800.547.2659** +1 724.836.6274

email: sales@generalcarbide.com
www.generalcarbide.com

GENERAL CARBIDE PRODUCTS ARE MADE IN THE USA

Grade Specifications

GENERALCARBIDE.

	Chemical Composition Weight Percent WC	Co	TaC	Other	Hardness HRA	Nominal Grain Size microns	Density g/cm³	Average Transverse Rupture Strength (psi)
Corrosion Resistant Specialty Grades								
GC-010CR*	89	10		1	92.3 - 93.3	0.8	14.25 - 14.35	590,000
GC-015CR*	84	15		1	90.4 - 91.4	0.8	13.74 - 13.86	650,000
GC-813CT*	86.5	10.5	2	1	90.5 - 91.5	3.0	14.24 - 14.36	500,000
GC-411CT*	86	11	2	1	88.5 - 89.5	4.0	14.19 - 14.31	490,000
WC/Co Grades with Tantalum Carbide	WC	Co	TaC	Other				
GC-0004*	89	7	4		91.7 - 92.7	1.0	14.72 - 14.83	450,000
GC-813CT*	86.5	10.5	2	1	90.5 - 91.5	3.0	14.24 - 14.36	500,000
GC-313T*	85	13	2		88.5 - 89.5	3.0	14.14 - 14.26	510,000
GC-0014*	73	13	14		88.3 - 89.3	3.0	14.02 - 14.14	485,000
GC-315T*	83	15	2		87.5 - 88.5	3.0	13.93 - 14.07	525,000
GC-320T*	77	20	3		85.8 - 86.8	3.0	13.44 - 13.62	500,000
GC-325T*	72	25	3		83.7 - 84.9	3.0	13.01 - 13.21	490,000
GC-411CT*	86	11	2	1	88.5 - 89.5	4.0	14.19 - 14.31	490,000
GC-613T*	84	13	3		87.4 - 88.4	6.0	14.13 - 14.25	465,000
GC-618T*	79	18	3		85.3 - 86.3	6.0	13.65 - 13.79	480,000
WC/Ni Grades	WC	Ni	Mo_2C					
GC-N061	92.5	6	1.5		91.2 - 92.0	1.0	14.72 - 14.83	480,000
GC-N101	88.5	10	1.5		89.2 - 90.0	1.0	14.30 - 14.42	495,000
GC-N121	86.5	12	1.5		88.1 - 89.1	1.0	14.11 - 14.23	500,000
WC/Ni/Co Grades	WC	Ni	Co	Cr_3C_2				
GC-N129	86	10	2	2	88.6 - 89.7	3.0	13.92 - 14.04	490,000
GC-N176	80	14.5	3	2.5	85.2 - 86.3	6.0	13.33 - 13.48	470,000
GC-N256	73	20	5	2	78.2 - 80.2	6.0	12.75 - 12.95	440,000

*Available in Wire EDM Grade

Note: Micron sizes refer to the nominal grain size for all grades

SinterHIP Process Guaranteed

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www.generalcarbide.com

01/07/06 Rev.A

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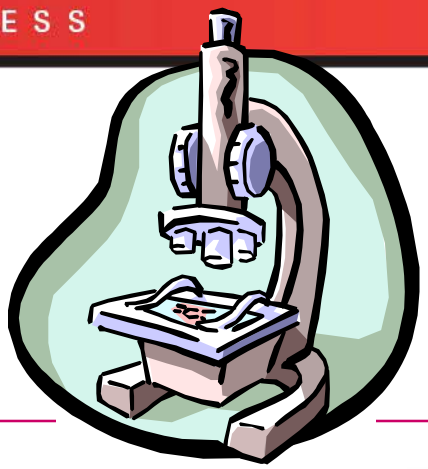
In Summary, General Carbide Offers Distinct Grade Development Capability Specifically for PM Industry, including:

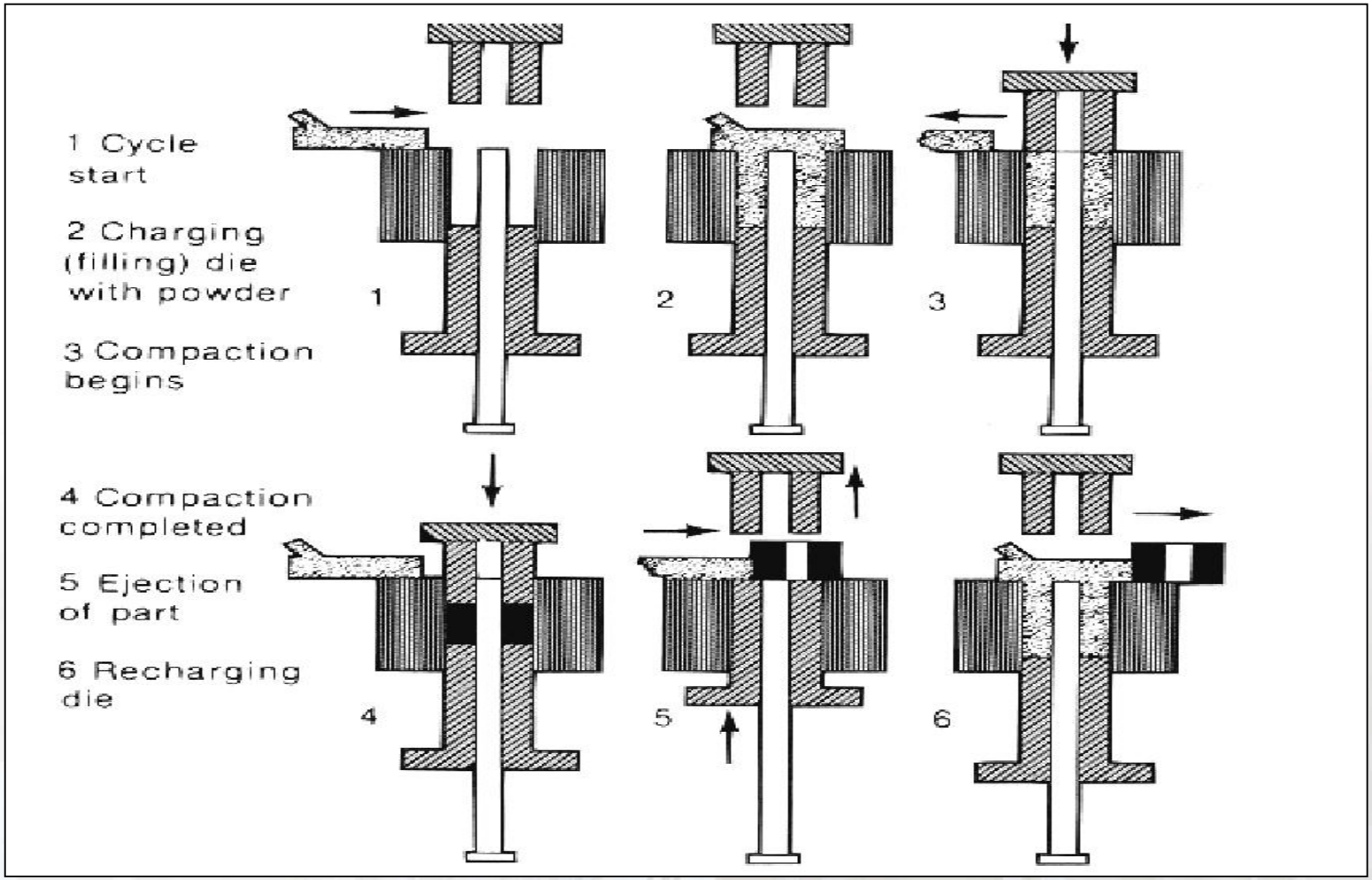


- **WC** range: 0.6 to 11 micron
- 12 grades with **TaC**
- 6 grades with **Ni** - binder
- 6 corrosion resistant grades with **Co** - binder
- **Cobalt** range: 3.5% to 30%

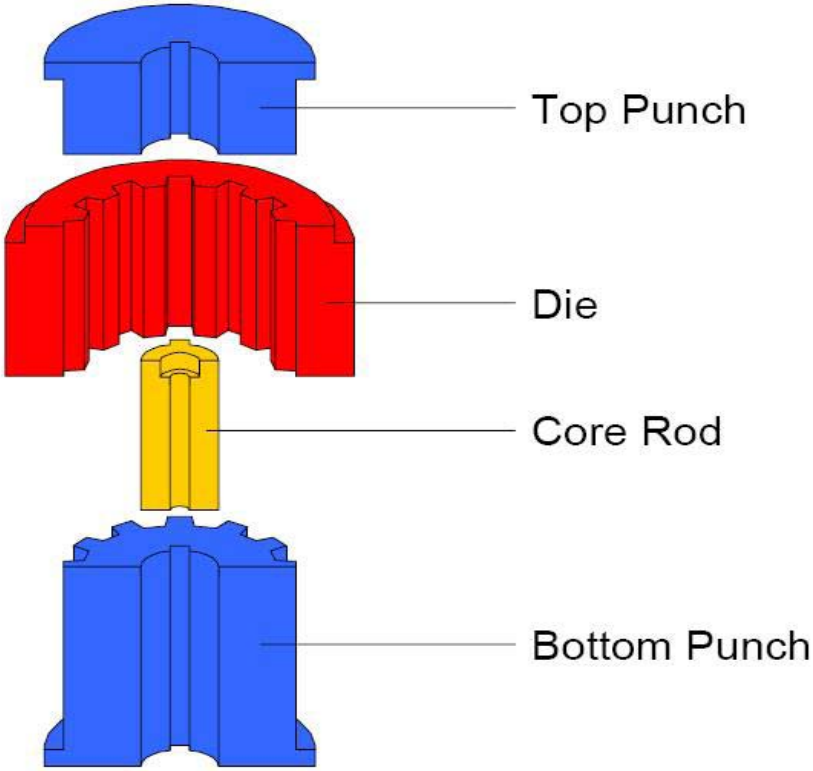
Wide variety of grades for many applications …

General Carbide grades recommended and commonly used in the Powder Metal Industry

Schematic of Compacting Process by Traditional PM Press.



Main Tooling Elements for Rigid Die Compaction /Sizing of Powdered Material Components.



Considerations for PM Compacting Tools Materials Selection.

- **Tool members within PM die set during compaction or sizing are subjected to relatively high compaction pressure being frequently as high as 690-900 MPa (approximately 50 -- 65 tsi)**
- **The whole PM tooling must be robust enough to last from several hundred press strokes to more than a million cycles without any damage or wear while keeping proper dimensions and tolerances.**
- **The initial cost of PM tooling depends upon the level of complexity of the powder component to be produced as well as on the robustness and durability of the tool members themselves.**

Summary:

Strong, tough and wear-resistant tool materials as well as the proper processing of those materials into tooling applications play a crucial role in both successful tool performance and cost-efficiency.

Requirements of Each Separate Tool Element within Compacting / Sizing Tool Die Assembly

•The whole **Die Set** must be able to withstand sizable radial pressure during compaction or sizing operations and hold the tolerances in the horizontal cross-section of the component to be formed.

• **The Die** itself (**Die Insert**) experiences the most abrasion and friction as well as other wear patterns during either compaction or sizing, especially along its internal circumferential surface because of ejection motion of the "green" compact as it is leaving the **Die**.

Therefore, Cemented Carbide Die Inserts are frequently used due to their high wear resistance.

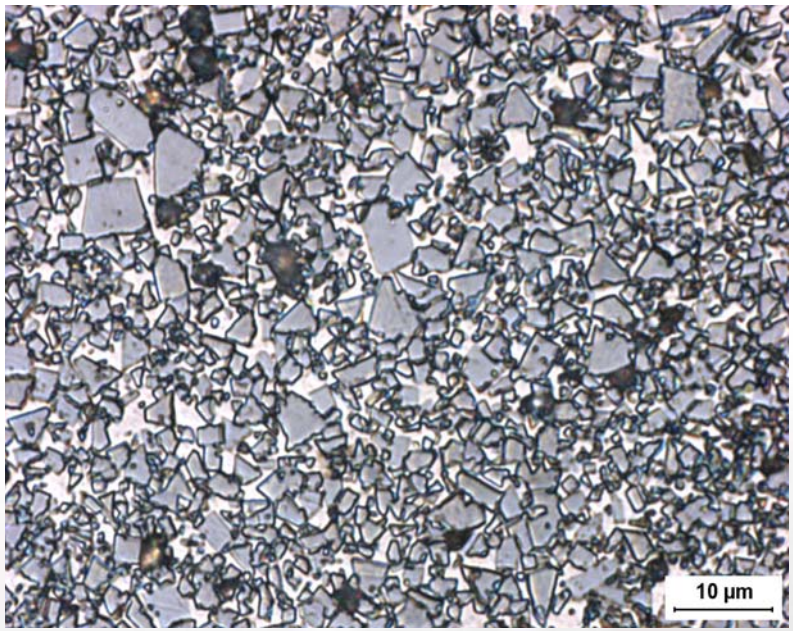
• Both **Bottom Punch** and **Upper Punch** should be able to resist expansion under repeated compaction/ sizing cycles. Therefore, punches need high compressive yield strength as well as sustainable toughness and high fatigue strength frequently linked to high wear resistance.

Note: ***Cemented Carbide Punch Inserts often ensure both high wear resistance and favorable fatigue stress distribution.***

• **Core Rods** and **Pins** should possess high hardness and wear resistance, and for this reason, they are mainly fabricated from Cemented Carbides. Also, **Core Rods** and **Pins** are subjected to cyclic dynamic loads during compaction /sizing, especially challenging when they have thin cross-section and/or get complex shape by design.

Advancements in Grade Development for PM Applications

Premium WC Crystal Structure Utilization.



GC-411CT
GC-415CT
GC-425CT
GC-613CT
GC-618T
GC-813CT
GC-712C

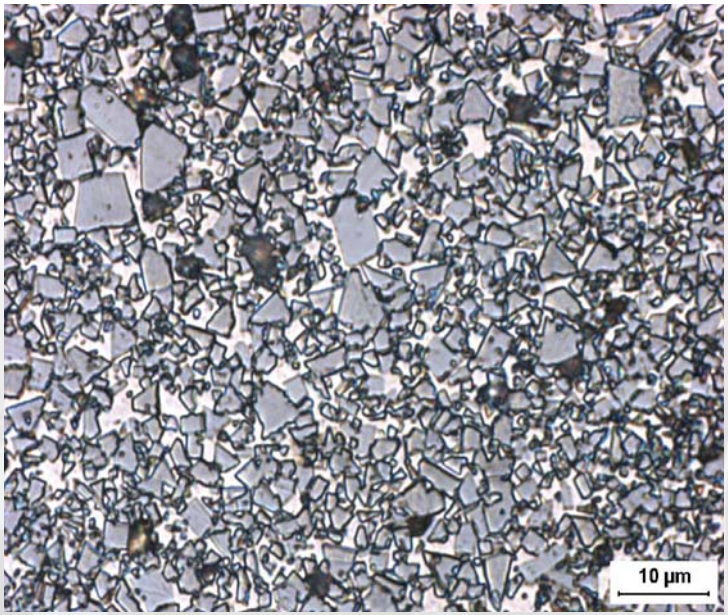
Unique and Proprietary crystal structure

Tungsten Carbide grain has a perfect stoichiometric balance of 6.13 % carbon throughout

Tantalum Carbide (TaC) Additions:

What does it do for Cemented Carbide ?

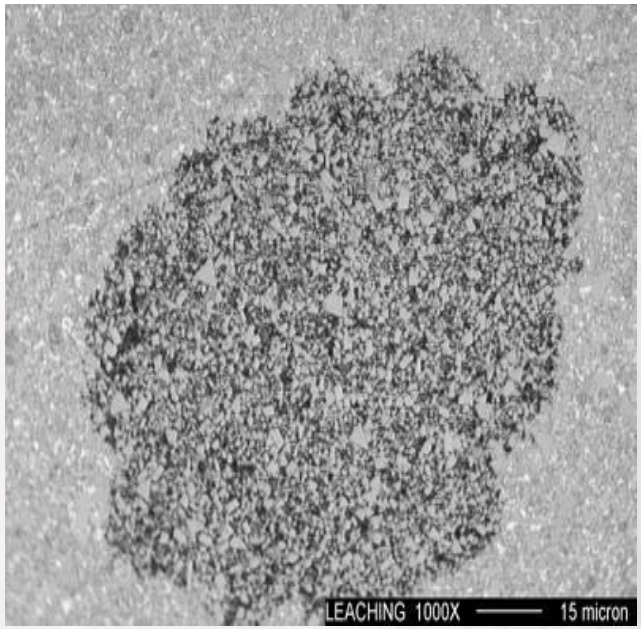
- **Anti-galling agent**
- **Reduces friction between the work material and die wall**
- **Acts as an internal built-in lubricant**

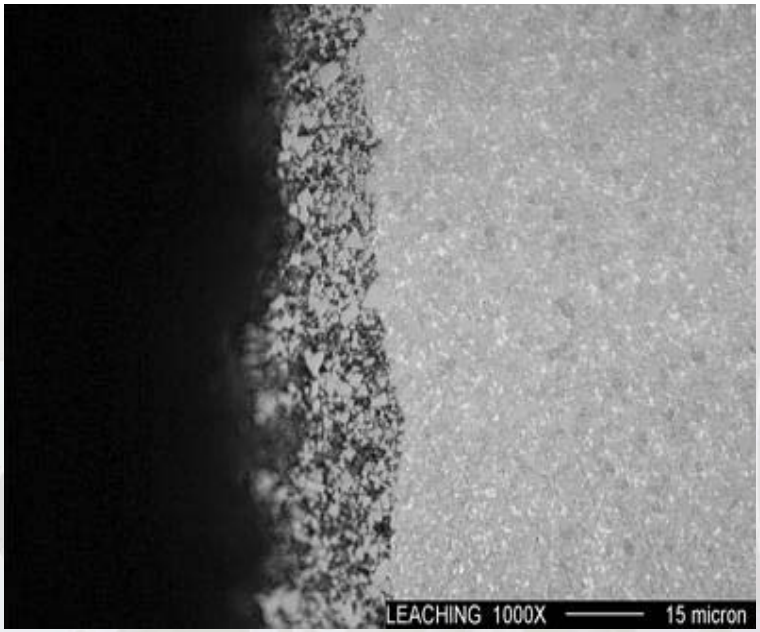


GC-613CT

Typical corrosion/leaching condition

The selective dissolution of the binder from the cemented carbide microstructure.

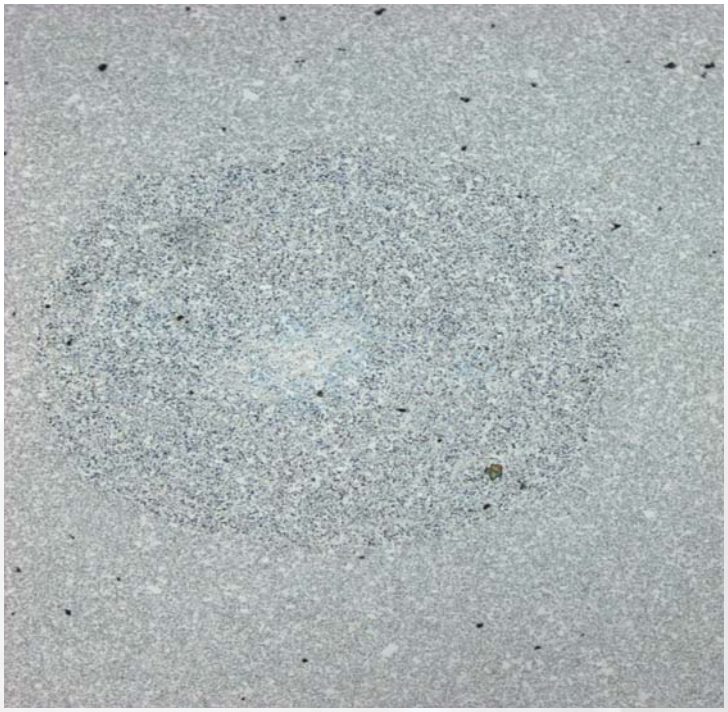




Corrosion Resistance of GC-411CT vs. GC-313 Grade.

GC-313*

(regular WC-Co) grade



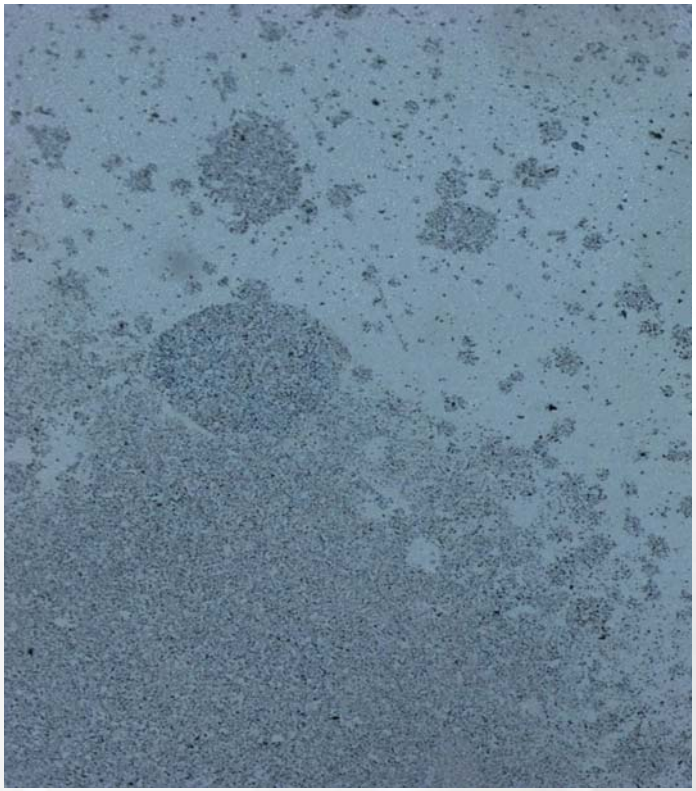
GC-411CT*

(specially alloyed corrosion -resistant grade)

*Test conducted in tap water over 48 hours.

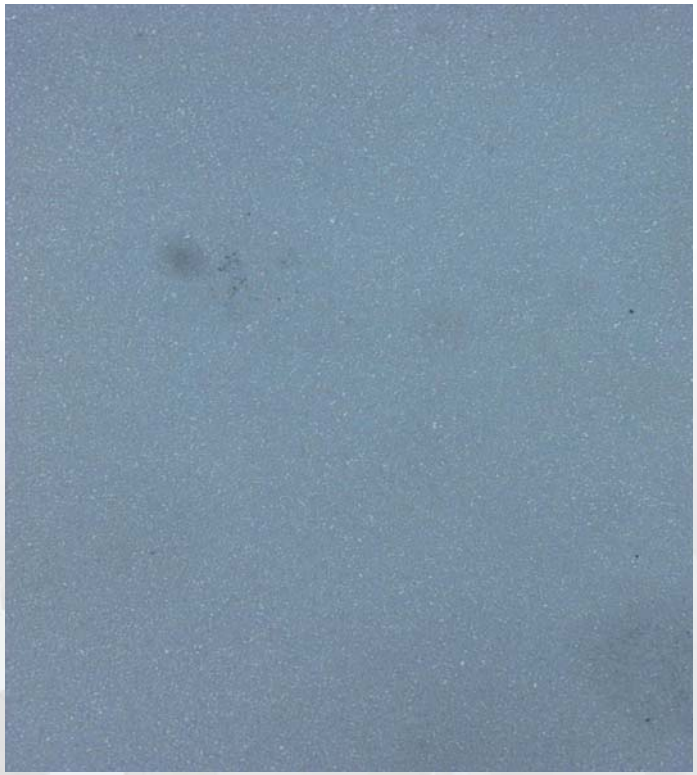
Sustained Electrolytic Attack in Aqueous Solution

GC-313*



*Test conducted in wire tank for 100 hours.

GC-411CT*



*Test conducted in wire tank for 100 hours.

POWDER METAL TOOLING GRADES

INDUSTRY CODE	STANDARD	PREMIUM	COMMENTS
C2/C9	GC-106	GC-0004 GC-010*	High Wear Dies Small WEDM Dies & Pins-Excellent for pressing ceramics & large non-EDM liners
C10	GC-209	GC-813CT*	High wear / Fine Teeth/ WEDM Dies & Cores/ Intricate Forms / Excellent for Stainless PM
C11	GC-211*	GC-313T* GC-411CT*	Med. Size WEDM Dies High Toughness Form, Gear Dies & Cores GC-411CT for Stainless PM Excellent Wear

*** - WEDM Grade**
T - Addition of TaC for Lubricity
CT- Grades are Corrosion resistant

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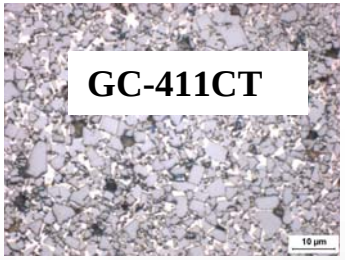
POWDER METAL TOOLING GRADES

INDUSTRY CODE	STANDARD GRADE	PREMIUM GRADE	COMMENTS
C12	GC-313* GC-712C*	GC-411CT*	Med/ Lg WEDM Dies High Toughness Form, Gear Dies & Cores Excellent Wear
C13	GC-315*	GC-613CT* GC-415CT	Med/XL WEDM Dies Extreme Toughness Good Wear Complex Internal Shapes
C14	GC-320*	GC-618T*	High Impact Sizing Dies Complex Internal Shapes Excellent Shock & Impact Strength



*** - WEDM Grade**
T - Addition of TaC for Lubricity
CT- Grades are Corrosion resistant

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GENERALCARBIDE.

GRADE SPECIFICATIONS

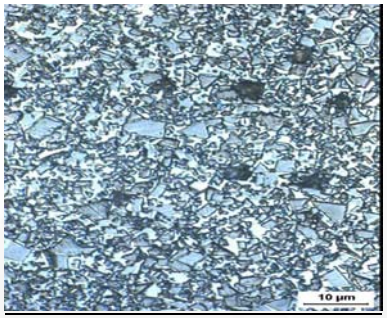
Grade: **GC-415CT**

Composition:

Tungsten Carbide (4.5 micron):		81.0%
Cobalt:		16.0%
Tantalum Carbide:	2.0%	
Other:		1.0%

Physical Properties:

Hardness, HRA (ASTM B294)	87.4 - 88.4
Density, g/cc (ASTM B311)	13.72 - 13.82
Average Transverse Rupture Strength, psi (ASTM B406)	450,000
Typical Porosity (ASTM B276)	A02-B00-C00



Performance Characteristics

Wear Resistance.....Moderate

Impact Resistance.....High

Galling Resistance.....High

Corrosion Resistance.... Mod /High

Grade Attributes: The relatively coarse carbide particle grains size being coupled with medium binder content provides a wear resistant grade with good resistance to impact. The tantalum carbide ensures efficient withstanding to galling.
The corrosion-resistant additive exhibits relatively high resistance to binder leaching at the EDM shape processing as well as its structure prevents from the negative influence of residual lubricants that may remain on the working surfaces of the tools being stored in the tooling premises for future usage.

Typical Applications:
Wire EDM blocks, punches and dies, powder metal dies, slitters.

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GENERALCARBIDE.

GRADE SPECIFICATIONS

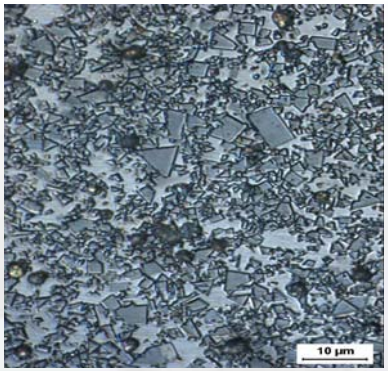
Grade: **GC-425CT**

Composition:

Tungsten Carbide (3-, 4-, and 6-micron WC grains):	70.5%
Cobalt:	25.0%
Tantalum Carbide:	4.0%
Other	0.5%

Physical Properties:

Hardness, HRA (ASTM B294)	83.5 - 84.5
Density, g/cc (ASTM B311)	12.88 - 13.12
Average Transverse Rupture Strength, psi (ASTM B406)	470,000
Typical Porosity (ASTM B276)	A02-B00-C00



Performance Characteristics

Wear Resistance.....Modest

Impact Resistance.....High

Galling Resistance.....High

Corrosion Resistance.....Modest

Grade Attributes: The mixture of intermediate carbide particle grain sizes coupled with the higher binder content provides a grade that can withstand heavy impact and, at the same time, exhibits moderate wear resistance and corrosion resistance. This grade also exhibits relatively good machinability. The tantalum carbide additive ensures high anti-galling properties

Typical Applications: Sizing dies and core pins for powder metal tooling, die inserts for heavy loaded cold heading applications, general metalforming dies, mandrels, and bushings

General Carbide provides the following, specifically for Wire EDM Material processing:

- **Proprietary WC Crystal**
- **Special WEDM Material Recipe**
- **Magna-Flux within Part's Body at "Green" State**
- **Special Sinter-HIP Furnace Cycle**
- **Thermal Stress Relieving**
- **Vibratory Stress Relieving**
- **Ultrasonic check for internal cracks**
- **Semi-Finish Grinding Option (in-house)**
- ***Delivery - 8 working days or less***

Failure Analysis & Troubleshooting for PM tools

Typical Defects and Failures of Cemented Carbide Products / Applications

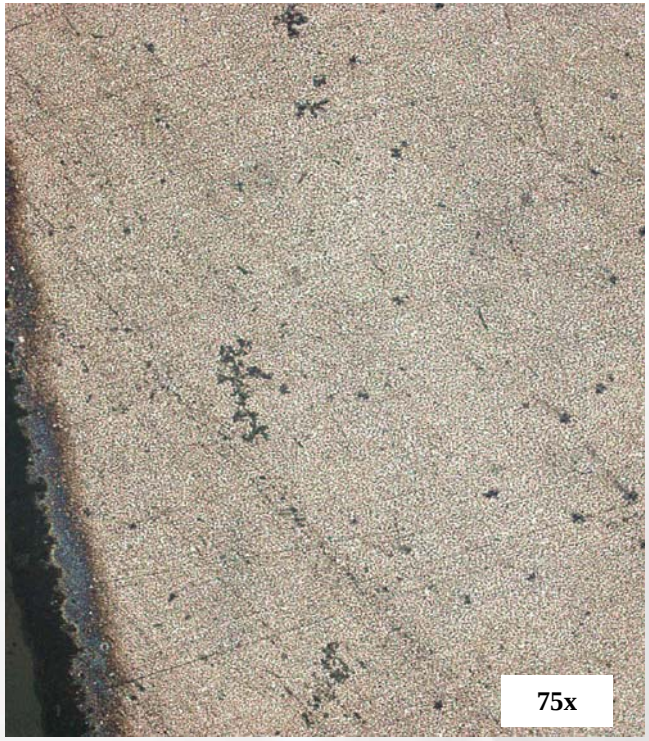
By its origin, most frequently encountered defects/ failures of cemented carbide products can be divided into 4 main groups:

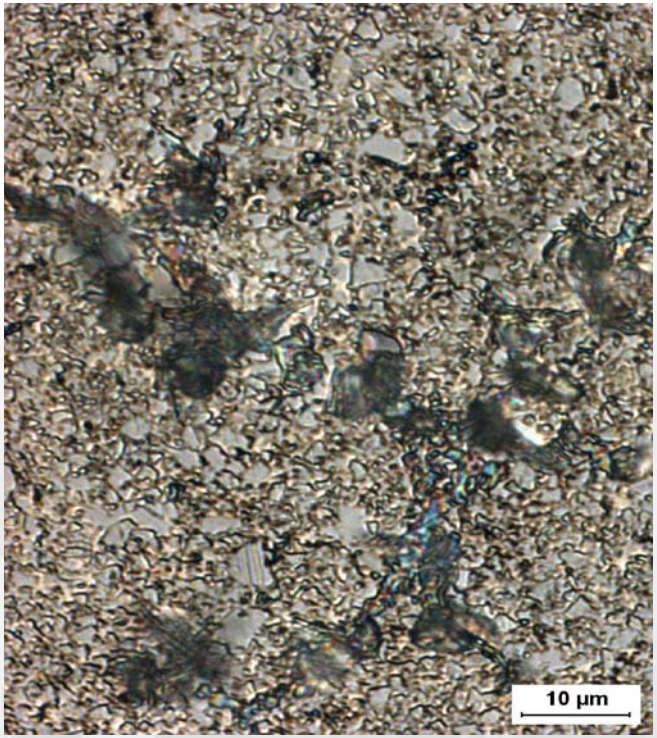
- **Processing defects (Eta-Phase occurrence, large grain cluster formations, powder shaping cracks);**
- **Fabrication defects (braze cracks, thermal cracks);**
- **Environmental failures from corrosion, erosion, etc.;**
- **Mechanical failures caused by brittle fracturing, wear, fatigue, etc.**

Observed Processing Defects that can occur in Cemented Carbide

POROSITY @ 500x | CARBON @ 500x | BURNOUT @ 100x | POOLING @ 1500X

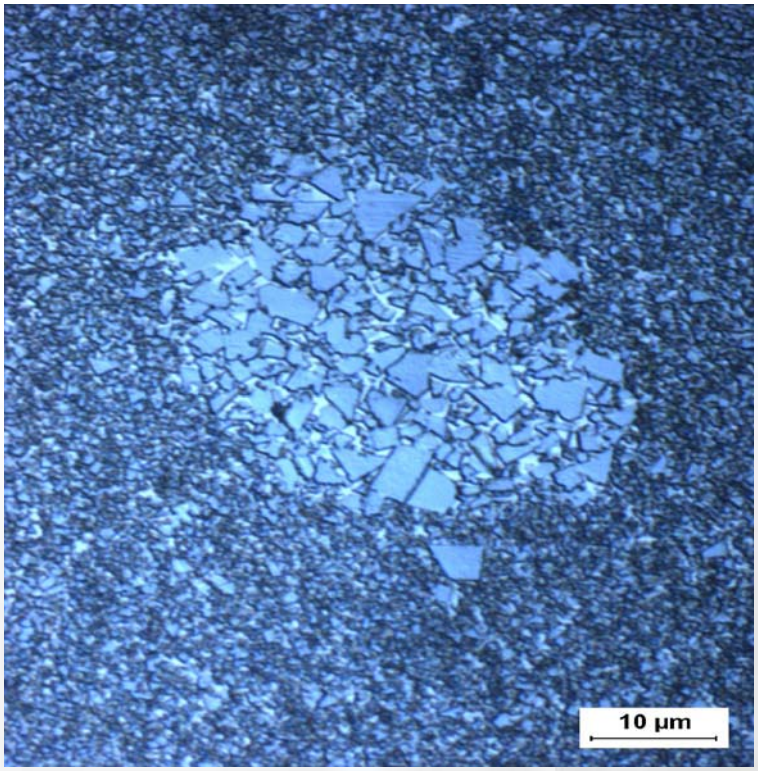
Possible Defect seen in Carbide Processing



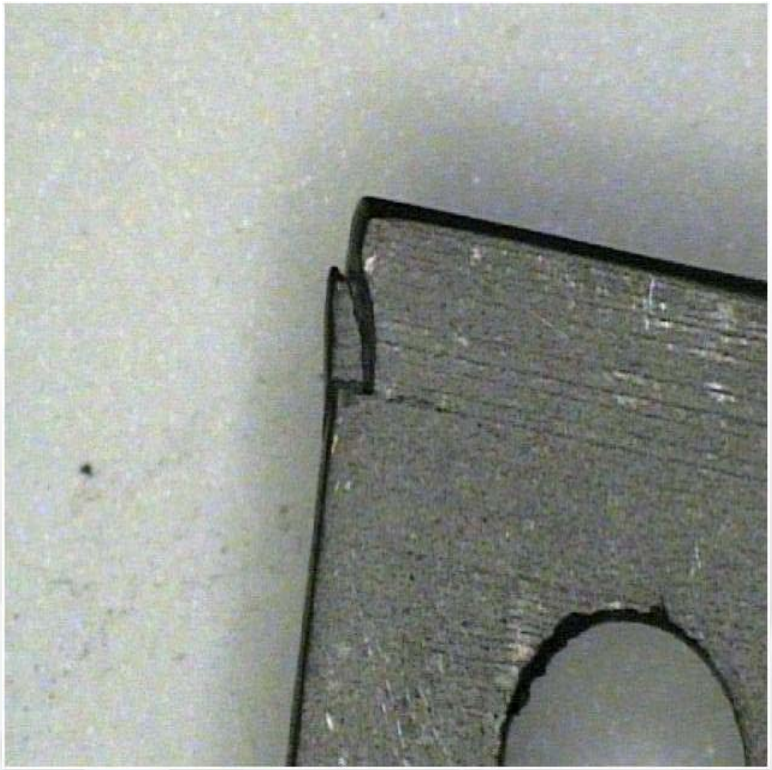


Eta-Phase in Cemented Carbide Materials

Possible Processing Defects seen in Carbide Products



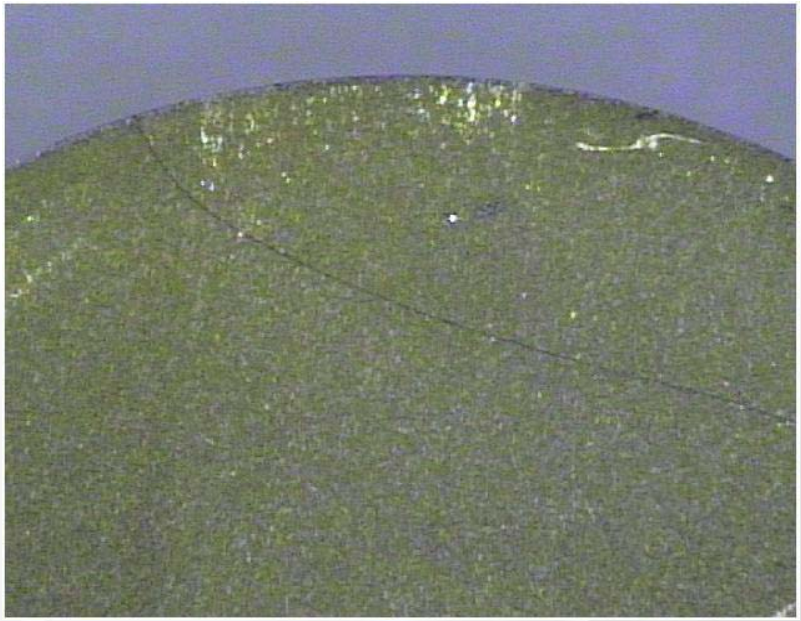
Large Carbide grains cluster formation



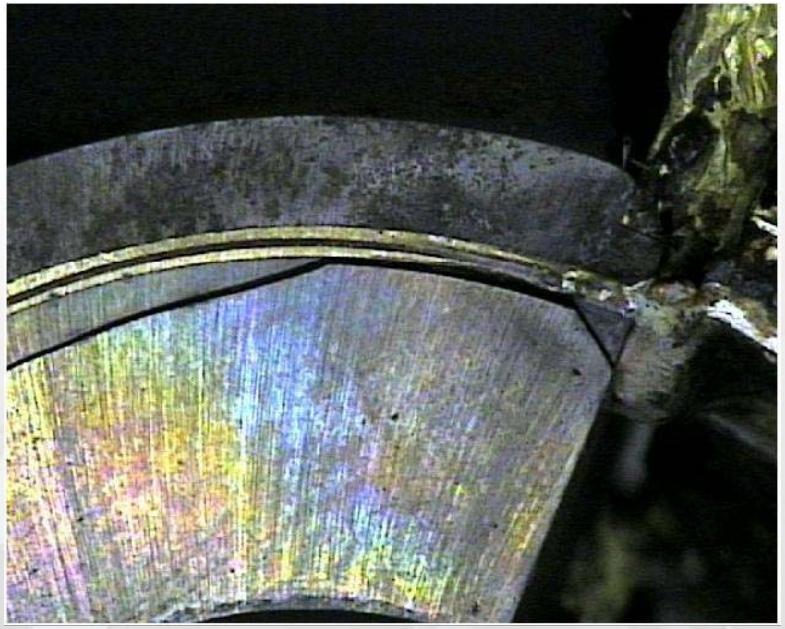
Chipping crack resulting from green carbide shaping operation

Fabrication Defects

EDM Crack



Brazing Crack



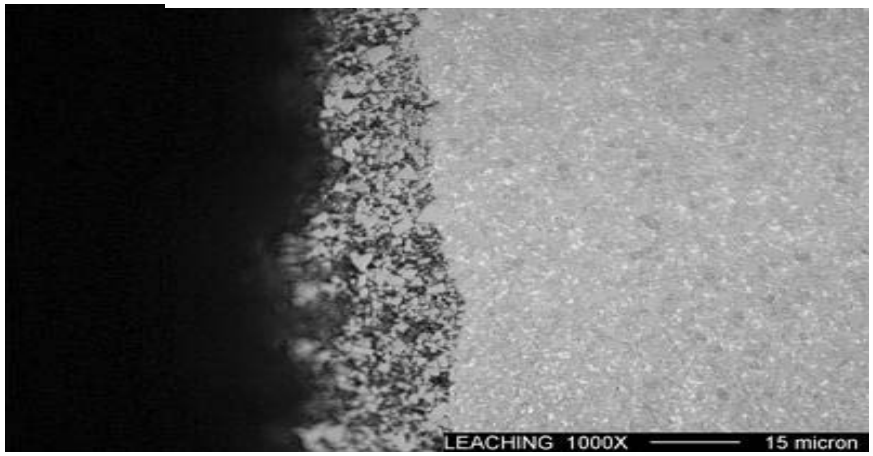
Environmental Corrosion & Pitting Defects

Observable pitting

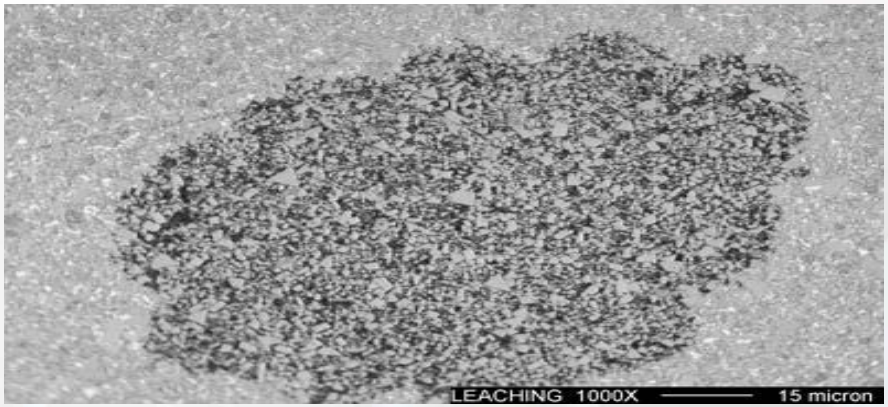
Corrosive attack on binder material

Environmental Failures

a)

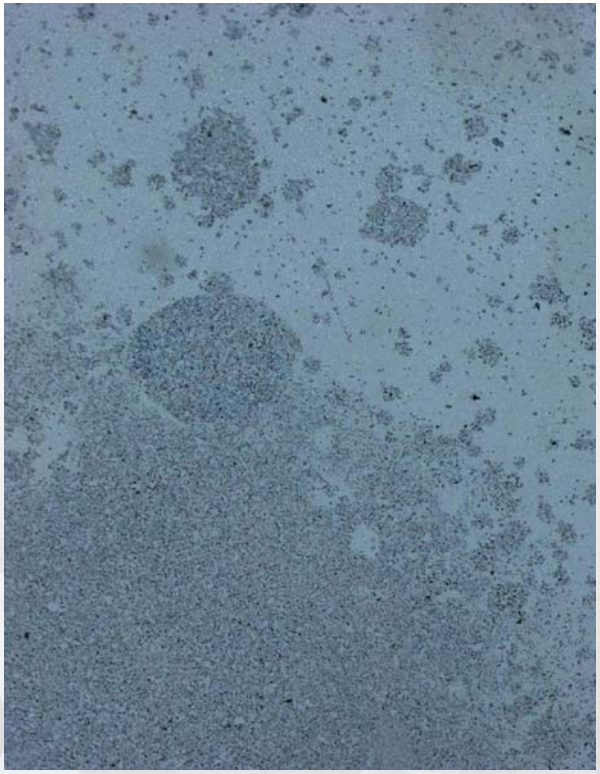


b)



The selective dissolution ("leaching") of the binder from the cemented carbide microstructure

Electrolytic Attack*



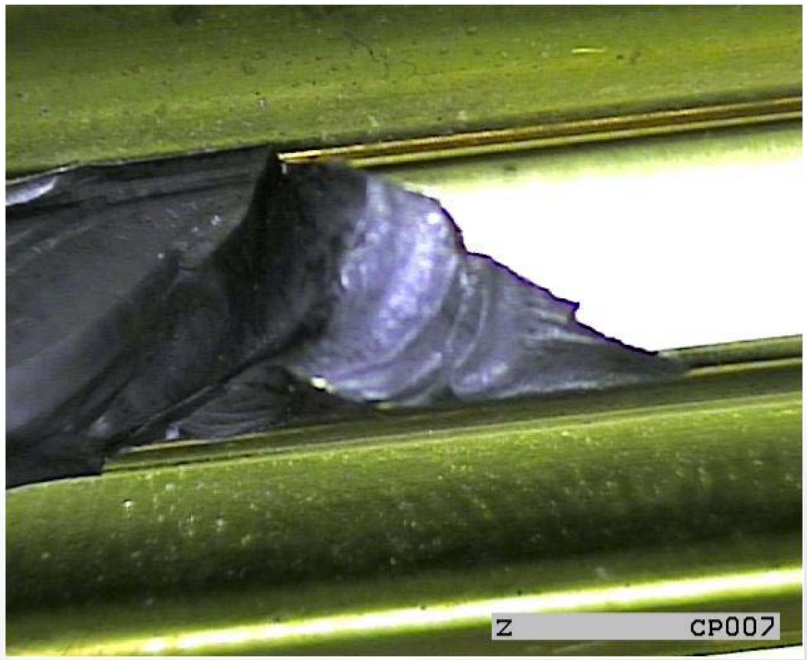
*Test conducted in wire EDM tank for 100 hours.

Wear Failure Patterns

Abrasive Wear

Galling /Scuffing Wear

Carbide Failure Patterns



Brittle Fracture Defect

Cyclic Fatigue Failure

Designer's Guide to Tungsten Carbide

Chapter I.... **Background of Cemented Carbide**

Chapter II.... **Unique properties of Cemented Carbide**

Chapter III.... **Design Considerations**

Chapter IV.... **Attaching and Assembling Techniques**

Chapter V.... **Finishing Techniques for Cemented Carbide**

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…ANY QUESTIONS?

OR COMMENTS…

PLEASE…

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