Advanced Cemented Carbides for Powder Metal Tooling Applications

Dr. Leonid I. Frayman
Chief Metallurgist

Presented at MPIF “PM Compacting & Tooling” Seminar (October 27-28, 2009. Cleveland, OH.)
...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$_2$C (Molybdenum Carbide), TaC (Tantalum Carbide), Cr$_3$C$_2$ (Chromium Carbide), VC (Vanadium Carbide), TiC (Titanium Carbide), etc. or their mixes.
## Carbides: Selected Mechanical Properties.

<table>
<thead>
<tr>
<th>Carbide Formula</th>
<th>Vickers (HV) Hardness @ Various Temperatures, °C (°F)</th>
<th>Rockwell Hardness @ Room Temperature, HRa</th>
<th>Ultimate Compressive Strength, MPa (ksi)</th>
<th>Transverse Rupture Strength, MPa (ksi)</th>
<th>Modulus of Elasticity, GPa (10^6 ksi)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>20 °C (78 °F)</td>
<td>730 °C (1350 °F)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TiC*</td>
<td>2930</td>
<td>640</td>
<td>93</td>
<td>1330-3900 (193-522)</td>
<td>280-400 (40.6-58.0)</td>
</tr>
<tr>
<td>HfC*</td>
<td>2860</td>
<td>-</td>
<td>84</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>VC*</td>
<td>2800</td>
<td>250</td>
<td>83</td>
<td>620 (89.9)</td>
<td>70 (10.1)</td>
</tr>
<tr>
<td>NbC</td>
<td>2400</td>
<td>350</td>
<td>83</td>
<td>1400 (203)</td>
<td>-</td>
</tr>
<tr>
<td>TaC*</td>
<td>1570</td>
<td>800</td>
<td>82</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Cr&lt;sub&gt;3&lt;/sub&gt;C&lt;sub&gt;2&lt;/sub&gt;*</td>
<td>-</td>
<td>-</td>
<td>81</td>
<td>100 (14.5)</td>
<td>170-380 ((24.7-55.1)</td>
</tr>
<tr>
<td>Mo&lt;sub&gt;2&lt;/sub&gt;C*</td>
<td>-</td>
<td>-</td>
<td>74</td>
<td>2700 (392)</td>
<td>50 (7.3)</td>
</tr>
<tr>
<td>WC*</td>
<td>2400</td>
<td>280</td>
<td>81</td>
<td>2700-3600 (392-522)</td>
<td>530-560 (76.9-81.2)</td>
</tr>
</tbody>
</table>

*NOTE: TiC-Titanium Carbide; HfC-Hafnium Carbide; VC-Vanadium Carbide; NbC-Niobium Carbide; TaC-Tantalum Carbide; Cr<sub>3</sub>C<sub>2</sub>- Chromium Carbide; Mo<sub>2</sub>C - 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 °F.

...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 – 1600°C
  - Atmosphere – H₂, N₂, A, CH₄, CO or Mixture
  - Binder – Co, Ni, Fe
- **1929**
  - Comp. 10 -20%
  - CH₄ Carburized W Powder (Closer to 6.13%C)
  - Sinter - < 1400°C 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

<table>
<thead>
<tr>
<th>Composition, wt.%</th>
<th>Hardness, HRa</th>
<th>Abrasion Resistance, 1/vol.loss cm³</th>
<th>Transverse Rupture Strength, 1,000 lb/in²</th>
<th>Ultimate Compression Strength, 1,000 lb/in²</th>
<th>Ultimate Tensile Strength, 1,000 lb/in²</th>
<th>Modulus of Elasticity, 10⁶ lb/in²</th>
<th>Thermal Expansion, @75 °C-400 °C Cal/ (s°C·cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>WC-6%Co</td>
<td>92.8</td>
<td>35-60</td>
<td>335</td>
<td>860</td>
<td>160</td>
<td>92</td>
<td>2.9</td>
</tr>
<tr>
<td>WC-9%Co</td>
<td>89.5</td>
<td>10-13</td>
<td>425</td>
<td>660</td>
<td>-</td>
<td>87</td>
<td>2.7</td>
</tr>
<tr>
<td>WC-13%Co</td>
<td>88.2</td>
<td>4-8</td>
<td>500</td>
<td>600</td>
<td>-</td>
<td>81</td>
<td>3.0</td>
</tr>
</tbody>
</table>

### Other Materials (for comparison & consideration)

<table>
<thead>
<tr>
<th>Material</th>
<th>Hardness, HRa</th>
<th>Abrasion Resistance, 1/vol.loss cm³</th>
<th>Transverse Rupture Strength, 1,000 lb/in²</th>
<th>Ultimate Compression Strength, 1,000 lb/in²</th>
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<th>Thermal Expansion, @75 °C-400 °C Cal/ (s°C·cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tool Steel (T8)</td>
<td>85 (66 HRc)</td>
<td>2</td>
<td>575</td>
<td>600</td>
<td>-</td>
<td>34</td>
<td>6.5</td>
</tr>
<tr>
<td>Carbon Steel (AISI 1095)</td>
<td>79 (66 HRc)</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>300</td>
<td>30</td>
<td>-</td>
</tr>
<tr>
<td>Cast Iron</td>
<td>-</td>
<td>2</td>
<td>105</td>
<td>-</td>
<td>-</td>
<td>15-30</td>
<td>9.2</td>
</tr>
</tbody>
</table>
# Room & Hot Hardness of WC-Co Cemented Carbide vs. High Speed Tool Steel

<table>
<thead>
<tr>
<th>Material</th>
<th>Properties</th>
<th>Hardness (HRC) @ Various Working Temperatures</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>@ 20 °C (78 °F)</td>
</tr>
<tr>
<td>Cemented Carbide [WC +6%Co]</td>
<td></td>
<td>77 -79</td>
</tr>
<tr>
<td>High Speed Steel --AISI T4 Grade [0.8%C+18%W+4%Cr+1%V+5%Co]</td>
<td></td>
<td>63 - 65</td>
</tr>
</tbody>
</table>
Manufacturing Process of Cemented Carbides:

Virgin

Powder Making → Ready Powder → Pressing → Shaping → Sintering → Shaped Parts

Sintered Parts

Rework

Final Treatment: (Grinding, Coating, etc.)

Finished Parts
Processing Advancements
Full range of manufacturing capabilities:

- Attrition
- Vacuum Drying
- Spray Drying
- Mechanical Pressing
- Powder shaping / “Green” & “Hard” Machining
- Cold Isostatic Pressing
- Pressure Sintering (Sinter-HIP)
Preparation of Powder Compositions at General Carbide Manufacturing Facilities.

Milling

Vacuum Drying

Spray Drying
Mixing / Milling in the Attritor

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 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.
Spray Drying for Carbide Grade Formulations

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.
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?

www.generalcarbide.com
“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 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.
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.
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$_3$C$_2$ (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
- Coordinate Measuring Machine
- Coercimeter equipment

www.generalcarbide.com
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

- Ultrafine: 0.5 μm
- Submicron: 0.8 μm
- Medium: 1-2 μm
- Coarse: >= 3 μm

Shock Resistance/Toughness vs. Wear Resistance
Constant binder content - varying grain size

- 4 μm
- 2 μm
- 0.8 μm
- 0.5 μm

1500x
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.
## Grade GC-010CR

**Composition:** (Grain size 0.8 micron)

<table>
<thead>
<tr>
<th>Component</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tungsten Carbide</td>
<td>89.0%</td>
</tr>
<tr>
<td>Cobalt</td>
<td>10.0%</td>
</tr>
<tr>
<td>Other</td>
<td>1.0%</td>
</tr>
</tbody>
</table>

**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

Wear Resistance

Shock Resistance/Toughness

- < 4%
- 4% - 10%
- 10% - 16%
- > 16%
Constant grain size/varying binder content

1500x

6%

10%

16%

24%
### Grade Specifications

**Tungsten Carbide Grades with Cobalt Binder**

<table>
<thead>
<tr>
<th>Weight Percent</th>
<th>WC</th>
<th>Co</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.6 micron</td>
<td>80</td>
<td>12</td>
<td>9.2 - 9.3</td>
</tr>
<tr>
<td>0.8 micron</td>
<td>91</td>
<td>10</td>
<td>9.08 - 9.1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Hardness (HRA)</th>
<th>Density (g/cm³)</th>
<th>Average Eresion Resistance Strength (psi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>8.4 - 9.0</td>
<td>14.8 - 14.9</td>
<td>500,000</td>
</tr>
</tbody>
</table>

**Common Resistant Specialty Grades**

<table>
<thead>
<tr>
<th>Weight Percent</th>
<th>WC</th>
<th>Co</th>
<th>Other</th>
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<tr>
<td>8.4 - 9.0</td>
<td>14.8 - 14.9</td>
<td>500,000</td>
</tr>
</tbody>
</table>

**W/Cr Co Grades with Transistor Carbide**

<table>
<thead>
<tr>
<th>Weight Percent</th>
<th>WC</th>
<th>Co</th>
<th>Tc</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.6 micron</td>
<td>80</td>
<td>12</td>
<td>9.2 - 9.3</td>
<td></td>
</tr>
<tr>
<td>0.8 micron</td>
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<th>Hardness (HRA)</th>
<th>Density (g/cm³)</th>
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<tbody>
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<td>8.4 - 9.0</td>
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<td>500,000</td>
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</table>

**WC/NI Grades**

<table>
<thead>
<tr>
<th>Weight Percent</th>
<th>WC</th>
<th>Ni</th>
<th>Co</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.6 micron</td>
<td>80</td>
<td>12</td>
<td>9.2 - 9.3</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Hardness (HRA)</th>
<th>Density (g/cm³)</th>
<th>Average Eresion Resistance Strength (psi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>8.4 - 9.0</td>
<td>14.8 - 14.9</td>
<td>500,000</td>
</tr>
</tbody>
</table>

**WC/NI Co Grades**

<table>
<thead>
<tr>
<th>Weight Percent</th>
<th>WC</th>
<th>Ni</th>
<th>Co</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.6 micron</td>
<td>80</td>
<td>12</td>
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<td>500,000</td>
</tr>
</tbody>
</table>

*Available in 580 EDH Grade

**SinterHIP Process Guaranteed**

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See [www.generalcarbide.com](http://www.generalcarbide.com) for .pdf format download
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.

1. Cycle start
2. Charging (filling) die with powder
3. Compaction begins
4. Compaction completed
5. Ejection of part
6. Recharging die
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.

Unique and Proprietary crystal structure
Tungsten Carbide grain has a perfect stoichiometric balance of 6.13% carbon throughout

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

GC-411CT*

*Test conducted in wire tank for 100 hours.
### Powder Metal Tooling Grades

<table>
<thead>
<tr>
<th>Industry Code</th>
<th>Standard</th>
<th>Premium</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>C2/C9</td>
<td>GC-106</td>
<td>GC-0004</td>
<td>High Wear Dies</td>
</tr>
<tr>
<td></td>
<td></td>
<td>GC-010*</td>
<td>Small WEDM Dies &amp; Pins Excellent for pressing ceramics &amp; large non-EDM liners</td>
</tr>
<tr>
<td>C10</td>
<td>GC-209</td>
<td>GC-813CT*</td>
<td>High wear / Fine Teeth / WEDM Dies &amp; Cores / Intricate Forms / Excellent for Stainless PM</td>
</tr>
<tr>
<td>C11</td>
<td>GC-211*</td>
<td>GC-313T*</td>
<td>Med. Size WEDM Dies High Toughness Form, Gear Dies &amp; Cores GC-411CT for Stainless PM Excellent Wear</td>
</tr>
<tr>
<td></td>
<td></td>
<td>GC-411CT*</td>
<td></td>
</tr>
</tbody>
</table>

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

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## POWDER METAL TOOLING GRADES

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

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CT- Grades are Corrosion resistant

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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
- Average Transverse Rupture Strength, psi (ASTM B406): 470,000
- Typical Porosity (ASTM B276): A02-B00-C00

**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.

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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

**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.
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

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

See www.generalcarbide.com/articles for .pdf download of all chapters
...ANY QUESTIONS?
OR COMMENTS...
PLEASE...