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

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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 **Die Set** 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.

- The **Die** (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:

- **Abrasive Wear**
- **Adhesive Wear**
- **Impact Wear**
- **Corrosive Wear**

Therefore, tools should effectively resist wear, corrosion, galling and impact...
Effect of Grain Size

Shock Resistance/Toughness

Wear Resistance

- ultrafine 0.5 µm
- submicron 0.8 µm
- medium 1-2 µm
- coarse >= 3 µm
Constant binder content with varying grain size

4 µm

2 µm

0.8 µm

0.5 µm

1500x
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.
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%

1500x

10%

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

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** ($W_G$)
  \[ W_G = \frac{P}{T}, \text{where} \]
  
  $P =$ load in Newtons
  
  $T =$ total crack length in mm ($\Sigma c$)

- **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

<table>
<thead>
<tr>
<th>GRADE</th>
<th>Rockwell Hardness (Scale A, HRA)</th>
<th>HV (kgf/mm²)</th>
<th>Palmqvist Fracture Toughness, $W_K$ (MN * (m^(-3/2)))</th>
<th>Average CTE $10^{-6}$ °C @ [RT-800°C]</th>
</tr>
</thead>
<tbody>
<tr>
<td>GC-813CT</td>
<td>90.5 - 91.5</td>
<td>1420 - 1505</td>
<td>13</td>
<td>5.87</td>
</tr>
<tr>
<td>GC-313</td>
<td>88.1 - 89.1</td>
<td>1180 - 1280</td>
<td>18</td>
<td>6.26</td>
</tr>
<tr>
<td>GC-613CT</td>
<td>87.4 - 88.4</td>
<td>1110 - 1210</td>
<td>23</td>
<td>6.15</td>
</tr>
<tr>
<td>GC-411CT</td>
<td>88.5 - 89.5</td>
<td>1220 - 1320</td>
<td>17</td>
<td>6.29</td>
</tr>
<tr>
<td>GC-415CT</td>
<td>87.4 - 88.4</td>
<td>1110 - 1210</td>
<td>21</td>
<td></td>
</tr>
</tbody>
</table>

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

*Test conducted in tap water over 48 hours.
WEDM Rough Cut Comparison:

GC-411CT
WEDM cut edge area:
Rough cut with minimal micro-cracks and reduced re-cast layer.

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-8133CT increased productivity 350%
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 ....
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

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

Go to www.generalcarbide.com/articles for .pdf download of all chapters
Any questions, please?....
Thank you!

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PROPERTIES OF SOME SELECTED WC-Co CEMENTED CARBIDE GRADES vs. OTHER TOOL MATERIALS.

<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)

| Tool Steel (T8)   | 85 (66 HRc)  | 2 | 575 | 600 | - | 34 | 6.5 |
| Carbon Steel (AISI 1095) | HRC 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 °F**.

...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 ...