Surface Integrity of Cutting Edge of Cemented Carbide Tool

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The text of the talk is available at http://www.opi.zcu.cz/
Cemented carbides are harder than hardened steel or SiC. Cemented carbides are impossible to cut with a hacksaw but they can be used to sharpen a knife.

Yet, they can be destroyed by: non-uniform heating, distilled water, temperatures above 700 °C, ion bombardment, harsh grinding...
Microstructure of cemented carbide

Hard phase => tungsten carbide
Ductile phase (binder) => Co, Ni, Fe
Microstructure of cemented carbide

WC
Co

500 nm

200 nm
“Treppeneffekt” may be caused by the presence of vanadium carbide

This group includes the cemented carbide with the trade designation TSM33. In general, cemented carbides exhibit considerably lower fracture toughness values (8 – 16 MPa·m$^{1/2}$) than steels (structural steel: 30 - 140). The TSM33 material with the mean WC grain size of 0.5-0.8 µm would be expected to show the $K_{IC}$ level of 8.4-9.4 MN·m$^{-3/2}$. Instead, its toughness is close to 16.7 MN·m$^{-3/2}$.
Cemented carbides are composites: each constituent has different properties and responds differently to external effects.
<table>
<thead>
<tr>
<th><strong>Cobalt - properties</strong></th>
<th><strong>Tungsten carbide WC - properties</strong></th>
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</thead>
<tbody>
<tr>
<td><strong>Mechanical Properties</strong></td>
<td><strong>Value</strong></td>
</tr>
<tr>
<td>Bulk modulus (GPa)</td>
<td>181</td>
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<tr>
<td>Material condition</td>
<td>Soft</td>
</tr>
<tr>
<td>Hardness - Vickers</td>
<td>170</td>
</tr>
<tr>
<td>Tensile modulus (GPa)</td>
<td>211</td>
</tr>
<tr>
<td>Tensile strength (MPa)</td>
<td>760</td>
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<td>Yield strength (MPa)</td>
<td>345-485</td>
</tr>
<tr>
<td><strong>Physical Properties</strong></td>
<td></td>
</tr>
<tr>
<td>Boiling point (°C)</td>
<td>2870</td>
</tr>
<tr>
<td>Density (g/cm³)</td>
<td>8.9</td>
</tr>
<tr>
<td>Melting point (°C)</td>
<td>1495</td>
</tr>
<tr>
<td><strong>Thermal Properties</strong></td>
<td></td>
</tr>
<tr>
<td>Coefficient of thermal expansion (x10⁻⁶ C⁻¹)</td>
<td>12.5</td>
</tr>
</tbody>
</table>

Effect of carbide particle size on residual stresses

Increasing the binder content contributes to stress relaxation
In addition to the cobalt content, the free length of the cobalt phase (intergranular distance) is an important aspect.

Microstructure of WC cemented carbide with 10 % Co prior to grinding: carbide particle sizes: 10 µm and 20 µm.
Integrity of cutting edge of tool: effects of grinding and thin film deposition

Schematic drawing of the cutting edge of a tool and an actual condition of the cutting edge of a cemented carbide tool after grinding

Theoretical cutting edge shape

Microgeometry after:
1. grinding
2. edge adjustment
3. deposition

Microscope image of the cutting edge after deposition

Film
substrate

After drag-finishing

After deposition

Spot Magn 5.0 350x SE 243 AA6082- nastr.OSG.61620 - NOVY

10 µm

nastroj pro 12050 Omlety_5

50 µm
Drag-finishing

Residual stresses in the surface of cemented carbide following various treatments

Effects of residual stresses on cutting edge condition

Adhesive (left) and cohesive (right) damage in coated cemented carbides
Residual stresses without the effects of prior manufacturing operations

PVD LAYER

CVD LAYER

The residual stress in the CVD coating on cemented carbide is tensile.

Damage of thin film-substrate system is caused by excessive compressive stress in the subsurface layer of the cemented carbide.

Higher temperatures during CVD process facilitate the relaxation of residual stresses caused by the prior grinding of cemented carbide.

By contrast, compressive stresses develop in PVD films. At the same time, the compressive stress in the cemented carbide, if present, does not relax. This leads to cohesive failure in the cemented carbide.
Another concept is pursued in the research directed by Prof. Berend Denkena (Institut für Fertigungstechnik und Werkzeugmaschinen at Leibniz Universität Hannover).

Prof. Berend Denkena points out the beneficial effects of compressive residual stresses in the thin film and in the substrate on the life of the tool. He therefore recommends that compressive stress is introduced into the surface of cemented carbide at levels which the material can safely sustain. Thanks to high compressive stress, the difference between the compressive stresses in the film and in the cemented carbide will drop to a minimum, which will reduce the risk of cohesive failure.

Experiments carried out by authors of this presentation partly support Prof. Denkena’s ideas. The compressive stress in the surface of cemented carbide does slow down the spreading of cracks.

Dependence of the crack propagation extent (sum of lengths of cracks radiating from the corners of Vickers indentation) on the residual stress in the cemented carbide surface

http://www.pzh-hannover.de/aktuelles-aus-dem-pzh.html?&L=1&tx_ttnews%5BbackPid%5D=505&tx_ttnews%5Btt_news%5D=611&cHash=b57d4f9aa240389ca8c834f7844c4b87
Conclusion

Authors’ own results indicate that there is an increase in fracture toughness in relation to compressive residual stress. Despite that, this relationship does not necessarily apply to the full extent of Prof. B. Denkena’s arguments, as the compressive stress values were in the range of 100-1900 MPa. One may expect that when these values approach the compressive strength of the cemented carbide, different conditions will set in and cohesive failure will occur.

For the understanding of cemented carbides, these two contradictions are so essential that the facts must be ascertained before further research steps are planned.
Thank you for your attention

Thank you for your questions