Tool Life and White Layer Formation in Interrupted Hard Turning With Binderless cBN Tool

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OBJECTIVE

- Characterize interruptions
- Study effect of each type of interruption on tool
- Study performance of binderless cBN on interrupted cutting
Research Tasks

Charaterize interruptions

Design workpiece with defined interruption geometry

Perform experiments with Binderless cBN and conventional cBN

Study flank wear, crater wear, surface finish and white layer formation

Explain observations
Characterizing Interruptions

- Just frequency is not enough – why?
- Consider two cases:

CASE A

CASE B

Both would have same frequency of interruptions – but clearly they are different
Characterizing Interruptions

- Need New Parameters
  - Interruption Ratio (IR)
    \[ IR = \frac{\text{Uncut Distance}}{\text{Cut Distance}} \]
    
  - Interruptions per Unit Length (IL)
    \[ IL = \frac{\text{Number of Interruptions}}{\text{Length of Cut}} \]

- Low IR vs High IR
  - Low IL vs High IL
EXPERIMENTAL WORK

Tool Materials
- HSS
- Carbide
- Ceramic
- Diamond
- cBN

Making Pure cBN
- High purity hBN
- Pressure, Temperature
  - No catalysts
- cBN

Direct conversion sintering

Pure cBN
- Has higher thermal conductivity
- Fine-grained version has higher toughness even at higher temperatures
- Better thermal stability

Pure cBN tested in literature with success:
- Continuous turning of hard steels
- Milling of cast iron, soft steel

Low cBN
- 50-55% Non-metallic binder

High cBN
- 85-99% Metallic binder

Pure cBN
- 100% No binder
EXPERIMENTAL WORK

Cutting Tools
- Kennametal grade KD120 (high content cBN, metallic binder)
- Recently developed high purity, binderless cBN
- Same tool geometries

High cBN Cutting Tool

Binderless cBN Cutting Tool
EXPERIMENTAL WORK

- **Workpieces**
  - AISI 52100 alloy steel (through hardened)
  - 58 HRC

<table>
<thead>
<tr>
<th>Component</th>
<th>Wt. %</th>
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<tbody>
<tr>
<td>C</td>
<td>0.98 - 1.1</td>
</tr>
<tr>
<td>Cr</td>
<td>1.45</td>
</tr>
<tr>
<td>Fe</td>
<td>97</td>
</tr>
<tr>
<td>Mn</td>
<td>0.35</td>
</tr>
<tr>
<td>P</td>
<td>Max 0.025</td>
</tr>
<tr>
<td>S</td>
<td>Max 0.025</td>
</tr>
<tr>
<td>Si</td>
<td>0.23</td>
</tr>
</tbody>
</table>

A. IR=0.100
   IL=0.217

B. IR=0.300
   IL=0.217

C. IR=0.100
   IL=0.652

D. IR=0.300
   IL=0.652
EXPERIMENTAL WORK

■ Cutting Conditions

<p>| | |</p>
<table>
<thead>
<tr>
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<tbody>
<tr>
<td>Cutting Speed</td>
<td>120 m/min</td>
</tr>
<tr>
<td>Feed Rate</td>
<td>0.10 mm/rev</td>
</tr>
<tr>
<td>Depth of Cut</td>
<td>0.05 mm</td>
</tr>
<tr>
<td>Coolant</td>
<td>Dry</td>
</tr>
</tbody>
</table>

■ Measured Outputs

- Flank wear
- Crater wear
- Surface finish
- White layer thickness
EXPERIMENTAL RESULTS

Flank Wear in Binderless cBN

Fewer interruptions per unit length produced greater flank wear
EXPERIMENTAL RESULTS

Flank Wear in High cBN

The graph shows the relationship between the number of passes and flank wear (VBmax) for different IR and IL values. The graph indicates that fewer interruptions per unit length produced greater flank wear. For example, IR=0.3, IL=0.217 resulted in higher flank wear compared to IR=0.1, IL=0.217. Similarly, IR=0.3, IL=0.652 led to more flank wear than IR=0.1, IL=0.652.
EXPERIMENTAL RESULTS

Flank Wear for IR=0.3 of High cBN & Binderless cBN

High cBN showed less flank wear than binderless cBN
EXPERIMENTAL RESULTS

Surface Roughness in Binderless cBN

Fewer interruptions per unit length produced greater surface roughness
EXPERIMENTAL RESULTS

Surface Roughness in High cBN

Fewer interruptions per unit length produced greater surface roughness
**EXPERIMENTAL RESULTS**

### White Layer Thickness

- **IR=0.3**, **IL=0.652**
- **IR=0.1**, **IL=0.217**

**Binderless cBN**

**High cBN**

High cBN caused thicker white layer than binderless cBN
EXPERIMENTAL RESULTS

- **Binderless cBN**
  - IR: Little effect on measured outputs
  - IL: Large effect on measured outputs
    - Lower IL led to larger flank wear, surface roughness

- **High cBN**
  - IR: Some effect at high IL
  - IL: Large effect
    - Lower IL led to higher flank wear, surface roughness and white layer thickness
EXPERIMENTAL RESULTS

- Flank Wear
  - High cBN outperformed binderless cBN in all but one test

- Crater Wear
  - Little with either tool

- Surface Roughness
  - Increases with cutting time, flank wear
  - Binderless cBN had a greater roughness at low IL

- White Layer
  - Thicker with high cBN tool
DISCUSSION

- **Grooves**
  - Three-body abrasive wear from cBN particles

- **Flank Wear**
  - Binderless cBN has comparable transverse rupture strength to high cBN
  - High wear could be due to lack of binder leading to cBN particles being plucked out

- **White Layer**
  - Thermal mechanisms: binderless cBN has greater thermal conductivity

<table>
<thead>
<tr>
<th></th>
<th>Binderless cBN (fine)</th>
<th>High-cBN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hardness (GPa)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>R. T.</td>
<td>50-55</td>
<td>35-40</td>
</tr>
<tr>
<td>1200°C</td>
<td>10</td>
<td>12</td>
</tr>
<tr>
<td>T. R. S. (GPa)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>R. T.</td>
<td>1.35</td>
<td>1.40</td>
</tr>
<tr>
<td>1000 °C</td>
<td>1.60</td>
<td>0.55</td>
</tr>
<tr>
<td>Thermal Stability</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(K in air)</td>
<td>1620</td>
<td>1270</td>
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<tr>
<td>Thermal Conductivity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(W/m.K)</td>
<td>360-400</td>
<td>100-130</td>
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DISCUSSION

- **Cutting Speed Effect**
  - IR=0.3, IL=0.652 at 180 m/min

Binderless cBN showed less wear at higher speeds than high cBN
CONCLUSION

- New interrupted cutting parameters (IR & IL)
- IL affects both high cBN and binderless cBN
- Binderless cBN only performed better with low IR and high IL
- Flank wear characterized by grooves caused by three-body wear
CONCLUSION

- Binderless cBN produced thinner white layer
- Binderless cBN performs well at higher speeds
ACKNOWLEDGEMENTS

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ANY QUESTIONS?