Investigating Tool Wear and Surface Quality in Hard Turning

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Research Objective

❖ Determine the effect of varying cutting conditions
  – cutting forces
  – tool wear
  – “white layer”
  – surface finish
## Test Matrix

<table>
<thead>
<tr>
<th>Test #</th>
<th>Speed (m/min)</th>
<th>Feed (mm/rev)</th>
<th>DOC (mm)</th>
<th>Hardness HRC</th>
<th>Tool Material</th>
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</thead>
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<td>0.152</td>
<td>0.203</td>
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</table>
Cutting Tool

- Kennametal and Sumitomo CBN inserts
  - 80° diamond shape
  - 20° edge chamfer, 0.004” wide
  - Mini-tip CBN brazed to the carbide tool

- CBN grades
  - High CBN content designed for roughing
  - Lower CBN content designed for finishing conditions
Turning Bar

- Kennametal DCLNR-164D
  - 5° lead angle
  - Negative 5° side rake and back rake
Tool Wear Results

- Tool wear occurs on nose radius of the tool.
- At a 0.203mm (0.008”) depth of cut, the cut also occurs primarily on the 20° chamfer.
Crater Wear

- Edge preparation has been shown to be a factor in hard turning
- Crater affects this cutting edge geometry
- This is particularly true for hard turning, where depths of cut are so small
Crater Wear
Progression of Crater Wear
Progression of Crater Wear
Progression of Crater Wear
Progression of Crater Wear
Progression of Crater Wear
Tool Failure
Changes in Cutting Edge Geometry

New Tool

Pass10
Changes in Cutting Edge Geometry

Pass20

Pass30
Changes in Cutting Edge Geometry

Pass40

Pass50
Flank Wear
Progression of Flank Wear
Progression of Flank Wear
Progression of Flank Wear
Progression of Flank Wear
Progression of Flank Wear
Tool Failure
Rate of Flank Wear

Flank Wear Rates

\[ y = 72.517x^{0.410} \]

\[ y = 34.911x^{0.412} \]

\[ y = 18.586x^{0.592} \]

\[ y = 18.346x^{0.461} \]
Surface Finish, Low Feed
Microstructure Analysis

Turned Surface
- No apparent damage

EDM Surface
- Significant white layer
Conclusions

❖ Tool Wear

– The Zygo New View 200 provided a very powerful method for monitoring both crater and flank wear
– Because edge preparation is known to affect cutting results, a qualitative understanding of changes due to crater wear must be important
– Changes in cutting geometry due to crater wear were shown
– Maximum flank land for all conditions was found to be approximately 150 to 200 microns at failure
– A power-law relationship was found between flank wear and volume of removed material
– The cutting conditions change the coefficient of this equation, which could provide a powerful method for determining tool life
Conclusions

❖ Surface Roughness
  – Measured values match theoretical for larger feed rate
  – Smaller feed rates do not match well, but has been explained in past research as a result of increased plowing action
  – Tool wear improved roughness for most conditions due to flattening of the nose radius

❖ Surface integrity
  – Thermal damage (white layer) was found on all EDM surfaces and surfaces machined with low CBN content tools
  – No significant damage was found on any surface turned with high CBN content tools
  – High content CBN tools have increased thermal conductivity--resulting in less heat into the workpiece