Sawtooth Selection: Comparison of Stellite™ and Carbide

SAWTech 2005
New Zealand and Australia

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Objective

“Compare the grinding and wear characteristics of common and recently developed grades of Stellites and Carbides”
Forintek Canada Corp.

Funding

- Test commissioned by Deloro Stellite, Bellville, Ontario
- Permission granted to share confidential results
Outline

• Background
• Testing method
• Sawtooth and grinding quality
• Sawing set-up and wear measurement
• Grinding & wear results
• Conclusions
• New project and preliminary results
Why are Grinding & Wear Important?

- When cutting, grinding and wear affect:
  - Sawing deviation and target size
  - Horsepower
  - Surface quality
- In the filing room, grinding and wear affect:
  - Tool life, regrinding and re-tipping
  - Time required to regrind

- Forintek has previously shown that side grinding accuracy is very important to sawing deviation and target size. Consequently, the ability of a tool material to be ground accurately is very important. It will be shown later that some materials allow a more accurate sharpening.
- Forintek and others have also shown that hp increases and surface quality degrades as a saw tip wears. Consequently, a saw tooth that experiences less wear will require less horsepower and produce a more consistent surface finish quality.
- In the grinding room, tool life is also very important because a tool material that experiences little wear will last longer between regrinds and requires less regrinding and re-tipping.
• Cobalt based alloy used in the wood working industry
• Tips are formed by powder metallurgy and sintering, or cast ingot wrought processing
• Tested alloys:
  ➢ Chromium and tungsten
  ➢ Chromium, tungsten and tungsten carbide

Stellite™

• Stellite is a trademarked name owned by Deloro in Bellville, Ontario.
• Stellite materials are non-ferrous cobalt-chromium alloys. There are other manufacturers of cobalt-chromium alloys used in the sawmilling industry such as CAMCO.
• Tips are formed at high heat and pressure
• Three compositions of Stellites were tested including the standard cobalt-chromium & tungsten formulation and a new cobalt-chromium-tungsten & tungsten carbide formulation.
Tungsten carbide crystals in a cobalt or nickel matrix used in wood working industry
Crystal sizes typically range from 0.5 to 3 μm

Tungsten carbide is a composite material where hard tungsten carbide crystal are embedded in a softer cobalt matrix. The tungsten carbide gives the material hardness and cobalt give the material toughness.

To understand the difference between hardness and toughness consider a steel kitchen knife and a ceramic cup. The steel knife is very tough. If it is dropped, it will not shatter. On the other hand the ceramic cut is very hard, it is very difficult to scratch it but is it is dropped, it will shatter.

Cobalt is the weak link in the tungsten carbide tool material. It is soft and as a result, easily worn away by cutting and the subsequent abrasion. Cobalt is also very susceptible to chemical attack. This is the main reason why it can not be used with corrosive wood species such as cedar.

The tungsten carbide crystal size has a significant effect on the properties of the carbide. The micro grain carbides with crystal diameter less than 1 micron typically generate a better surface finish. Unfortunately, quality control problems where the crystals tend to clump together has reduced the reliability of these tips.
• The high chromium content gives Stellite very high corrosion resistance. The high cobalt content gives Stellite high toughness but low hardness. The high toughness allows a great flexibility in rake angles.

• The tungsten carbide crystals give carbide a high hardness and abrasion resistance. Unfortunately, Carbide tends to be more brittle than Stellite and as a result requires a small rake angle to ensure that the tip does not fracture.
The Factors considered in the grinding analysis:

- The wheels type and speed required
- The achievable sharpness of the tool edge
- The time required to sharpen tools include grinding rate and number of passes
- Ease of grinding including pressure and the need for different grit wheels
- Occurrence of potential problems such as burrs and edge chipping
Three measurements of edge sharpness / tool wear were used:

• Tool tip diameter: this the diameter of the tip of the tool. It provides a measure of the tool sharpness as that experienced by the workpiece

• Tool width: is width of the tool tip that has experience substantial wear. This provides a measure that is representative of what a sawfiler might feel as they pass their thumb across the sawtip

• Edge recession: this is the amount that the tool has worn back from the ideal sharpness point. This is the most precise and reliable measure of wear that is commonly used in industry
Testing Method

- Single circular sawblade test
- 20 km cutting distance
- Southern yellow pine (Un-graded, rough sawn)
- Specific gravity 0.47-0.54
- Green (most boards >40% MC)
- Length 97 inches +/- 1 in.
- Width 10 inches
- Wear measurements:
  - 0 km
  - 5 km
  - 10 km
  - 20 km

Southern yellow pine (SYP) was used in this cutting test at the request of the client and was shipped from Mississippi for the test.

Six wood species commonly make up SYP. The lighter species have a similar specific gravity to hemlock and Douglas fir.

The SYP was prone to pitch pockets that gummed up the saws and increased friction. It is also very heavy.
Sawblade Specifications

- New untensioned sawblade supplied by *Calsaw Canada*
- 31 teeth
- 19 inch diameter
- 0.090 inch plate thickness
- 0.70 in² gullet area
- #3 involute spline
- Hook angle 30°
- Back clearance angle 8°

A special thanks to Calsaw for supplying the sawblade used in this test.
A 31 tooth sawblade had every second horn removed so that 16 teeth could be tested.
### Inspection Results - VTI

<table>
<thead>
<tr>
<th>Sawblade</th>
<th>Average</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kerf (in)</td>
<td>0.132</td>
<td>0.002</td>
</tr>
<tr>
<td>Left side clearance (in)</td>
<td>0.022</td>
<td>0.001</td>
</tr>
<tr>
<td>Right side clearance (in)</td>
<td>0.021</td>
<td>0.001</td>
</tr>
<tr>
<td>Left radial angle (degrees)</td>
<td>1.9</td>
<td>0.3</td>
</tr>
<tr>
<td>Right radial angle (degrees)</td>
<td>2.0</td>
<td>0.2</td>
</tr>
</tbody>
</table>

*Sawblade within acceptable tolerances*

• An inspection of the sawblade on the VTI after sharpening showed that tip parameters were within acceptable quality standards.
Eight different tip materials were tested. Six of these were Stellites and two Carbides.

S1, S4 and S5 are Stellite that have tungsten carbide crystals added. S5 has the least tungsten carbide followed by S1 and S4 has the most. The hardest indicates that the Rockwell C (HRC) increases with the amount of tungsten carbide added.

S2 and S3 are standard powder metallurgy Stellites where a current was passed through the powder during sintering. This was expected to increase the cohesion of the Stellite components.

S6 is standard grade 12 powder metallurgy

Two carbides were tested for comparison: C1 is a standard OM2 (less cobalt and harder than OM1) supplied by IKS. It is one recommends by several sawmills in Mississippi. C2 is a newer nickel bindered carbide Nicut-400 supplied Pacific Hard Metals.
Sawtooth Wear Measurement

- Lead Impression
- Projection Microscope
- Tracing
- Measurement
Feeds and Speeds

• RPM – 2700
  (Calculated critical speed – 2804 RPM)
• Rim speed – 13,474 fpm
• Feed speed – 96 fpm
• Depth of cut – 5.25 inches
• Bite – 0.028 inches
• GFI – 0.21

The saw feeds and speeds were set to match those typically used in industry where possible. The RPM, rim speed and bite are all comparable. The feed speed ended up low due to small number of saw tips. The Gullet feed index also ended up small but since the objective was not volume production this was not a concern.
Grinding Results

- All tips (pre-tinned) were easy to mount
- All Stellite grades behaved similar to GR-12
  - Burrs were commonly found and affected tooth wear
- Carbide grades did not have burrs
- Carbide tips suffer slightly from excessive fine grinding

As expected, the Stellites showed burrs after sharpening and the carbides did not. What was surprising was that the tip conditions after sharpening had a significant effect on how the teeth wore.

The effect of fine grinding and burr removal will be examined in the next few slides.
In order to examine the effect of burrs and fine grinding, the sawblade was sharpened twice. In the first sharpening, the sawtip was prepare as typically done in industry with multiple heavy grinding passes. In the second sharpening, the sawtips were first sharpened heavy grinding passes but then finished with a number of fine passes.

This graph show the initial recession or condition of the saw tips. A smaller value is typically better than a higher value. The blue graphs show the typical heavy passes grinding which resulted in burrs. The green graphs show the results of the fine grinding which prevented burrs.

The results show that the Stellite typically showed improved initial sharpness with the fine grinding. The Carbides on the other hand seemed to degrade with the fine grinding.

The reason for these results is likely due to the material characteristics and the methods employed for fine grinding. Stellite tends to be a more tolerant or forgiving material in terms of grinding than carbide. The reason is due the increased toughness of Stellite. In addition, the crystal structure of carbide means that when the tip is very sharp, a single crystals will form the tip. In this test, the sawblades were first sharpened at Calsaw and then re-sharpened at Forintek. The problem with setting-up the saw on different machines is that the alignment of the grinding wheel can vary slightly. This slight variation is likely enough the break he single crystal at the edge of the sawtip and result in a higher fine sharpened recession.
Effect of burr removal and fine grinding was also examined after 5 km of cutting with very interesting results.

As the graph shows, most of the sawtips that were fine ground performed worse than those course ground. This was particularly evident in the Ni-cut and Stellite grades with added tungsten carbide. What this seems to indicate is that the tip is very fragile in materials that have a low toughness which is very reasonable. These materials seem to prefer a larger initial tip radius or even a hone.

The material that was the exception was S6, standard grade 12 PM. This material again was very tolerant of grinding variability and is likely the reason for its popularity.

The bottom line is that sawtips needs to be accurately ground for cutting precision but not excessively fine ground such that the tip is weakened.
This graph shows the recession wear of the sawtips over the 20 km cutting distance.

The graph shows that most of the tips performed well up to 10 km of cutting. S1, S4 and C1 did not perform as well displaying significant edge chipping. The effect of this does not show up on the graphs because the chipped regions were avoided in the measurements.

At the end of the 20 km cutting test, S6 showed the lowest recession followed by S5 and C2. Although, S1 and C1 appear to have performed well, their extensive chipping would preclude them from being used on SYP. S2, S3 and S4 displayed very high wear which would make them also unsuitable for SYP.
Best Wear Results

Recession from initial (0 km)

Saw tooth recession (mm)

Cutting distance (km)

- Removing the poorer performing materials, this graph shows the better tip performance. The C2, S5 and S6.
The measurements of tip diameter or sharpness show similar result to the recession. C2, S5 and S6 all showed higher sharpness at the end of the cutting test. S1 and C1 again had extensive chipping that would preclude them from being used on SYP. S2, S3 and S4 were dull and significantly worn.
• Once again, the poorer performing materials have been removed for clarity.
• The images of the saw teeth taken on the Forintek VTI show the extensive chipping experienced by C1 and S1 and the high edge wear on S4. These saw teeth are clearly unsuited to cutting SYP.
• This slide shows the saw teeth with the least amount of wear. S5 showed the most uniform wear. S6 and C2 showed more extensive wear on one corner.
Conclusions

• Little difference in grinding of cobalt and nickel based tungsten carbides
• Little difference in grinding of traditional and alloyed Stellites
• Burrs significantly effect the initial wear of Stellite tips
• Carbides and Stellites wear at different rates and with different results

• The saw teeth used in this test can generally be prepared as with common Stellites and Carbides
• It is important to control the burring on Stellite tooth materials. It is important to minimize the size of burrs but also to not over sharpen the edges.
• Stellites tend to wear more initially and then more slowly. It tends to be a more forgiving material that allows long cutting times from 8 hours to 16 hours between saw changes.
• Carbide tend to wear slowly initial and deteriorate rapidly. For this reason, Carbide typically perform better than Stellite over short cutting times such as 4 to 8 hours although some mills to run their carbides longer.
## Conclusions - Preliminary

<table>
<thead>
<tr>
<th>Tip</th>
<th>Type</th>
<th>Grade</th>
<th>Ranking</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1</td>
<td>Stellite</td>
<td>Edge Star 62</td>
<td>Not Suitable</td>
</tr>
<tr>
<td>S2</td>
<td>Stellite</td>
<td>Edge Star 7</td>
<td>Not Suitable</td>
</tr>
<tr>
<td>S3</td>
<td>Stellite</td>
<td>Edge Star 1</td>
<td>Not Suitable</td>
</tr>
<tr>
<td>S4</td>
<td>Stellite</td>
<td>Edge Star 63</td>
<td>Not Suitable</td>
</tr>
<tr>
<td>S5</td>
<td>Stellite</td>
<td>Edge Star 69</td>
<td>1</td>
</tr>
<tr>
<td>S6</td>
<td>Stellite</td>
<td>GR-12PM</td>
<td>2</td>
</tr>
<tr>
<td>C1</td>
<td>Carbide</td>
<td>OM2</td>
<td>Not Suitable</td>
</tr>
<tr>
<td>C2</td>
<td>Ni-cut</td>
<td>400</td>
<td>3</td>
</tr>
</tbody>
</table>

- In terms of ranking of the results, S5, S6 and C2 performed very closely. The consistency of the edge on S5 would indicate that it performed the best since this would tend to minimize re-sharpening efforts. C2 would probably be ranked third since it started to show signs of corner chipping.
New Project:
Evaluation of Sawtooth Materials for Optimum Sawing Performance

Wood Machining Research Seminar
Cranbrook, BC
by Darrell Wong
Wood Machining and Optimization Group

This project started in April 2004 and is planned to be completed in March 2006.
Objective

“Identify the most appropriate tool materials for each sawing application that maximizes durability, sawing performance and production throughput”
Deliverables

• Develop method to evaluate sawtip materials for sawmilling applications
• Identify optimum sawing parameters for commercially available sawtips
• Identify the appropriate sawtip materials & optimum saw parameters for common Canadian wood species
Wear Mechanisms

- Abrasive - friction between the cutting tool and work piece removes particles from the cutting tool
- Chemical - cutting tool is chemically attacked by chemicals in the work piece
- Fracture - chipping of the tool edge as a result of high impact loads
Interior Species Chemical Wear

Volume loss per unit surface area

- Lodge pole pine
- Sub alpine fir
- White spruce
- Tap water

Preliminary results

Stellite 12, Carbide-OM2, Carbide-NICUT
Note that the axis here is 5 times that shown in the previous slide. The corrosive wear shown by the WRC on OM2 is very high.
Sub Alpine Fir – Combined Wear

- Preliminary results
- Stellite 12
- OM2

Cutting distance (meters)

Saw tip Diameter (mm)
<table>
<thead>
<tr>
<th>Activities</th>
<th>Completion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Develop list of durability test methods</td>
<td>June</td>
</tr>
<tr>
<td>Develop method to test material durability</td>
<td>September</td>
</tr>
<tr>
<td>Develop method to determine optimum operating parameters</td>
<td>November</td>
</tr>
<tr>
<td>Test methods on commercial tool materials and Canadian wood species</td>
<td>March</td>
</tr>
</tbody>
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