Saw Tooth Design and Tipping Materials

Bruce Lehmann, P.Eng, Ph.D.
Sr. Engineer, Thin Kerf Technologies Inc.
British Columbia, Canada

Introduction

The purposes of a saw tooth are to:

1. Remove a chip from the wood being cut, and
2. Carry the chips out of the cut.

Saw teeth are subjected to high forces, abrasion, heat, and corrosive chemicals in the wood. In addition, they encounter rocks, sand, nails and other foreign matter imbedded in the wood. All these factors are involved in selecting a tooth shape and a tipping material.

Fundamentals of Tooth Design

Tooth Geometry

The geometry of a tooth is the result of a compromise that is affected mostly by the hardness of the wood. From the point of view of the cutting forces, it is desirable to reduce them as much as possible by increasing the hook angle. However, this results in a tooth with a small sharpness angle that may be weakened enough for the tooth to bend or even break. For this reason, teeth for cutting hardwoods, or softwoods with hard knots, have smaller hook angles.

Also, the sharpness angle is increased if the tipping material is brittle. Carbide tips for cutting particle board may have a hook angle of -10°.

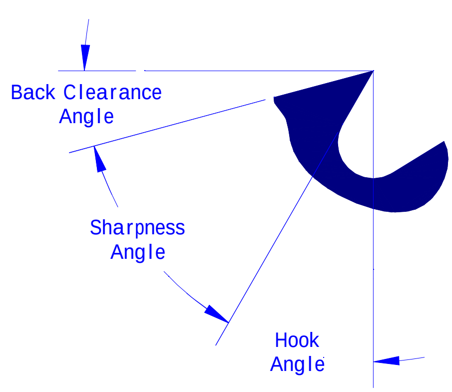

Figure 1. Tooth Angles

The back clearance angle should be as small as possible to increase tooth strength and stiffness. The back clearance angle must be a few degrees for the saw to feed (consider a tooth with zero back clearance: it will just burn the wood), and another few degrees to clear the spring-back of the wood fibres.

Tooth Angle	Effect of Angle	Typical Values	
		Hardwood	**Softwood**
Hook	Increasing the hook angle decreases the cutting forces and power consumption.	20°	30°
Sharpness	Increasing the sharpness angle reduces the strength and stiffness of the tooth.	62°	48°
Back Clearance	A minimum amount is required to stop rubbing on the back of the tooth. Also, needed for the saw to feed.	8°	12°

Gullet Area

The gullet of a tooth has one purpose: to hold and carry the sawdust created at the tooth tip until the tooth leaves the bottom of the cut. If the sawdust spills from the gullet, it will pack between the sawn surfaces and the saw plate, resulting in heating and binding of the saw.

Sawdust spillage can occur for three reasons:

1. The sawdust is very fine (small bite per tooth) so it easily spills out through the side clearance.
2. The volume of sawdust exceeds the volume of the gullet, which happens when feeding too fast. The packed sawdust is under pressure to spill. Also, the friction between the sawdust plug and the sides of the wood will increase the power requirement. Once the gullet is fully packed, feeding faster will result in much larger sawing deviations.
3. The bottom of the gullet has worn round, instead of having a sharp, square corner. The worn edges are not as effective for keeping the sawdust in the gullet. The gullets should be ground occasionally to sharpen the corners.

The maximum feed speed for a given depth of cut can be calculated as follows:

$$f_{\max} = \frac{GFI \cdot cA}{PD}$$

where c = blade speed

A = Gullet area

P = Tooth pitch

D = Depth of cut

GFI = Gullet Feed Index (percentage of gullet filled)

= 0.7 for bandsaws

= 0.3 for circular saws

The easiest method for measuring the gullet area is to count squares on grid paper. See Figure 2.

Example: Bandsaw cutting 12 inch material.

D = 12 inch
c = 9800 ft/min
P = 1.75 inch
A = 0.65 sq. inch
GFI = 0.7

$$f_{\max} = \frac{(0.7)(0.65)(9800)}{(12)(1.75)}$$
$$= 212 \text{ ft / min.}$$

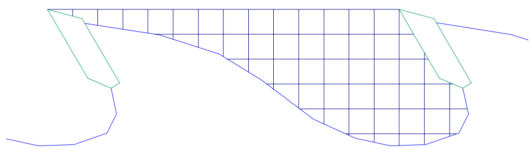

Figure 2. Counting Squares to Measure Gullet Area.

Gullet Cracking

The shape of the gullet has a significant effect on gullet cracking, especially for bandsaws. The gullet is like a notch cut into the edge of the blade. The sharper and deeper the notch, the higher will be the concentration of stresses at the bottom of the gullet. Typically, the stresses at the bottom of the gullet are larger then in the surrounding plate by a factor of 2.0 - 2.5.

The gullet stress can be reduced by:
1. Increasing the radius of the bottom of the gullet
2. Decreasing the gullet depth

Other concerns are the scratches from the grinding wheel, grinding burrs, and overheating the plate during grinding. All of these promote the starting of cracks.

Tipping Materials

The use of a material other than saw steel for the tips is desirable because the plate and the tips are subjected to very different conditions. Saw steel is very hard and can hold a good edge, but it is not a tool steel, as such.

The choice of tipping material depends upon:
1. The species and moisture content of the wood.
2. The presence of hard material such as knots, glue, sand, nails, etc.

3. Cost of tips, sharpening and re-tipping.

Wear Mechanisms

The environment of a saw tooth is severe. The tips impact the wood at a speed of about 10,000 ft/min (50 m/s) and temperatures at the surface of a tip have been measured to reach 700 C. The wear mechanism for each tip material is different.

There are two mechanisms of wear:

1. Abrasive wear resulting from the chip flowing across the face and back of the tooth. Glues used in composite wood products are very abrasive, and some species, like teak, contain silica.
2. Corrosive or chemical wear resulting from the reaction of water and other chemicals in the wood with the tipping material. Some species, such as western red cedar, have an acid that is very corrosive. The higher the moisture content, the greater will be the component of chemical wear.

These two wear mechanisms occur together in varying proportions, but research is showing that chemical wear is involved more than was expected.

Material Structure

The structure of the tip material affects its wear resistance. Figure 3 shows the typical wear profiles of steel and carbide tips. A dull steel tooth has a smooth, round wear pattern, however, for carbide, the surface is uneven. Carbide is composed of very hard tungsten carbide particles held together with cobalt. Since the cobalt is much softer and more prone to chemical attack than the tungsten carbide, the wear mechanism is for the carbide particles to break off after the cobalt has receded.

When cutting wet western red cedar, the acids quickly remove the cobalt so carbide tips wear very quickly for this species. Stellite is a better material for cutting wet cedar because it is an alloy of cobalt and chromium, with no chemically free cobalt. Although Stellite is softer than carbide, it lasts twice as long when cutting wet cedar. However, carbide is superior when cutting dry cedar because the amount of chemical erosion is less.

Although high strength is a desirable property for a tipping material because it makes the tooth more resistant to abrasive wear, it also results in a tooth that is more brittle. This means that the tip will chip or break more easily from either careless handling of the saws or from hitting knots or sand in the wood. For this reason, headrig saws, which make the first cuts into a log, still use steel teeth, because they are more robust and easier to repair. On the other hand, it is unlikely that diamond tips will be used for log break down because they would chip off long before they were dull.

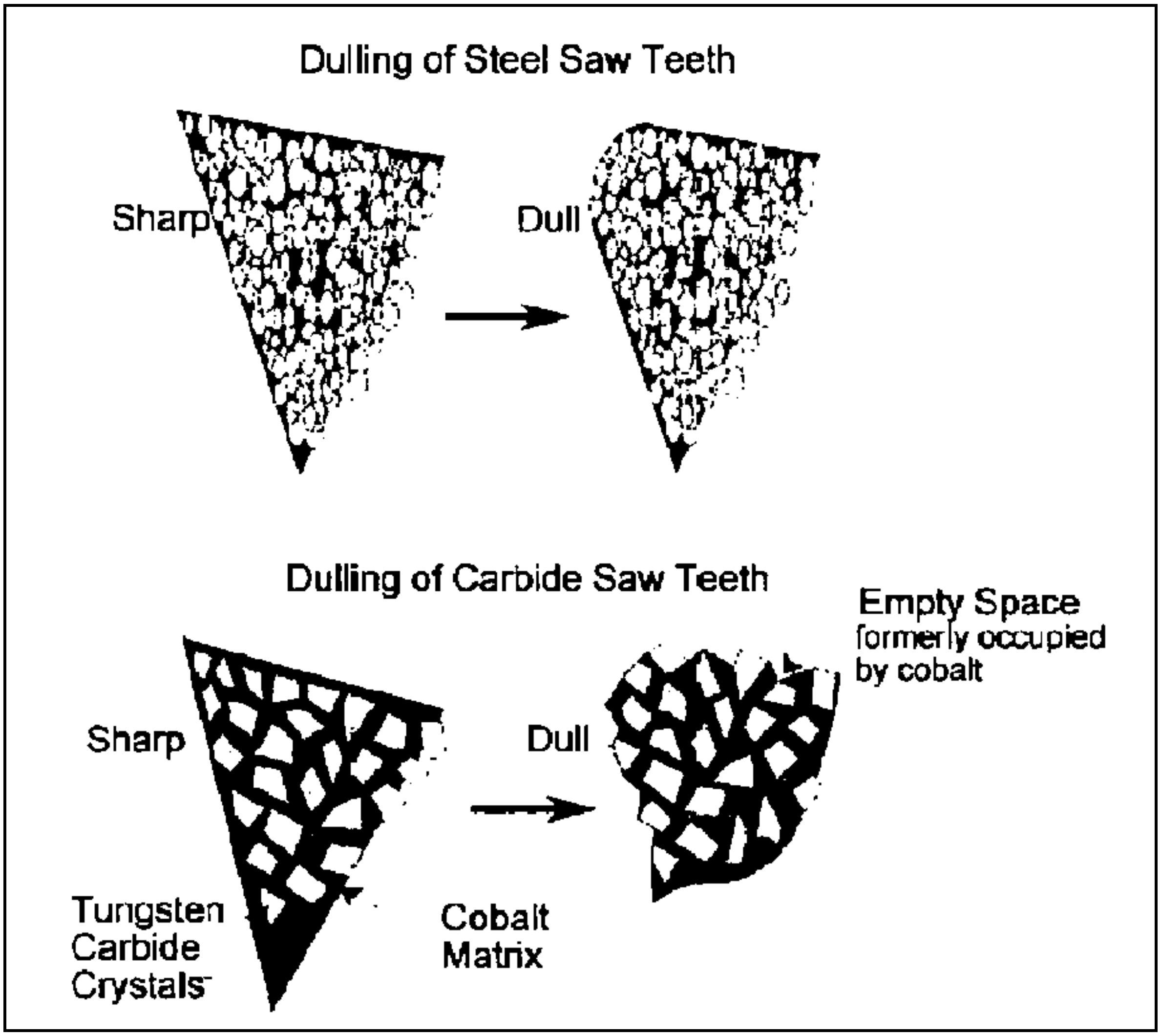

Figure 3. Wear Profiles of Steel and Carbide Teeth.

Relative Properties of Tipping Materials

Table I shows the properties of the materials used for saw tips. The wear factors are relative to swaged saw steel. Wear resistance generally increases with the hardness of the material, but one should remember that materials such as ceramics and diamond are also very resistant to chemicals.

Saw steel, induction hardening, Stellite and carbide are in common use. Ceramics and cermets are being introduced because they can now be brazed to the saw plate. The cost of ceramic tips will be less than that of carbide, and they will last longer. However, they are more brittle than carbide. Cermets and diamonds will only be used where a long life justifies the cost.

Table I. Relative Properties of Tipping Materials

Material	Wear Resistance[1]	Description & Properties	Benefits & Uses
Saw Steel	1	A very high strength steel, alloyed with other elements to increase high temperature strength and fatigue resistance.	For inexpensive saws, or for teeth that are often damaged
Plasma or Induction Hardening	2 - 3.5	Hardening a thin layer of steel tip by rapid heating and cooling.	Simple method to improve wear resistance of saw steel tips.
Stellite[2]	5 - 12	Alloy of cobalt and chromium. Softer than carbide, but retains hardness at high temperatures (700 C) seen on tooth surface.	Hard and strong. Can use larger hook angles. Improved resistance to chemical wear when water present (ex. wet wood).
Carbide	6 - 20	Hard tungsten carbide in soft cobalt binder. Brittle and easily chipped. Increasing amount of cobalt reduces brittleness and wear resistance.	High wear resistance, but cobalt binder can be chemically corroded by acids (example: wet red cedar)
Ceramics[3] Cermets	>20	Aluminum oxide, zirconia Titanium carbide or titanium nitride	Better wear resistance than carbides, but more brittle.
Diamond	> 1000	Brittle layer of synthetic diamond on carbide backing. Self-sharpening property. Very expensive. Layer of synthetic diamond applied to top or face of tooth to produce self-sharpening action.	High wear resistance for cutting composite wood materials. Too easily damaged for sawing lumber

Other materials such as hard metal plating, and high speed steel have been used, but are either impractical, or less expensive materials provide equal or better wear resistance.

[1] Based on data collected by Dr. Eberhart Kirbach.
[2] Stellite is a trademark of Deloro Stellite
[3] Source: Carbide Processors Inc., 3847 S. Union Ave., Tacoma, WA, USA 98409