RockBats
Technical Note
RB-TN-B
(proprietary)

September, 2006

Effect of Slope-of-Grain on Strength of Solid-Wood Baseball Bats.

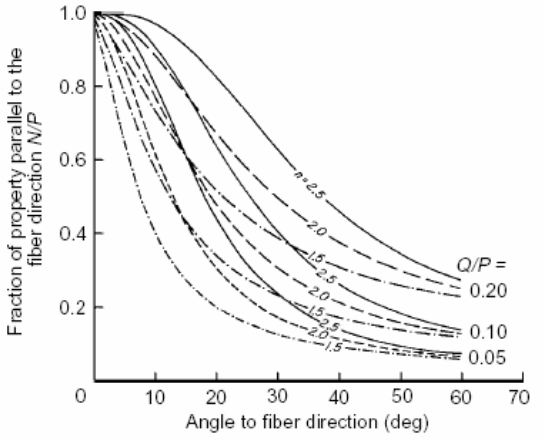
The effect of slope-of-grain on mechanical properties of wood is characterized by what is called a Hankinson-type formula. As the angle between fiber direction and longitudinal axis increases, the strength properties of wood decrease. In the Wood Handbook (1), this effect is represented by the formula:

$$N = \frac{PQ}{P\sin^n\theta + Q\cos^n\theta}$$

Where N is the strength at an angle θ to the fiber direction. P is the strength perpendicular to the fiber, Q is the strength parallel to the fiber; and n is an empirically determined constant.

Different properties follow different curves on the graph to the right.

Property	*n*	*Q/P*
Tensile strength	1.5–2	0.04–0.07
Compression strength	2–2.5	0.03–0.40
Bending strength	1.5–2	0.04–0.10
Modulus of elasticity	2	0.04–0.12
Toughness	1.5–2	0.06–0.10



In the above table, the property most related to baseball bat performance is toughness. Furthermore, the Wood Handbook specifically states that impact bending properties fall close to the curve having Q/P = 0.05 and n=1.5. In the graph above, the curve that best represents Q/P=0.05 and n=1.5 is the absolute bottom curve having the steepest slope.

Using the above graph, if strength losses in impact bending were limited to 10%, that translates to a maximum fiber angle of approximately 2 to 3 degrees.

When physically measuring slope-of-grain, the most common method is to report the length of slope required for the grain to deviate 1 inch. For 2 degrees of fiber angle, this translates to a 1:28 slope of grain. In other words, the center grain at the knob end of a baseball bat can only deviate ½-inch from center for 14 inches of handle length. For 3 degrees of fiber angle, this translates to a 1:19 slope of grain, which is a ½-inch deviation from center for 9.5 inches of handle length.

It is important to understand that there are two planes involved when measuring slope of grain: the **radial plane**, and the **tangential plane**. Slope of grain in the radial plane is the easiest to measure, because this involves viewing the annual ring lines on the radial face. Slope of grain in the tangential plane is more difficult to measure, because this requires an estimate of grain angle on the tangential face. This can usually be done visually on woods with large rays, such as Oak or Ash. However, on a wood like Sugar Maple, which has extremely small rays, this assessment has to be done with a more refined method (see Tech Note 2B).

It is also important to understand that the true slope of grain (SOG) is the combined effect of **radial** slope of grain (SOGR) and **tangential** slope of grain (SOGT). The true SOG is represented by the formula:

$$SOG = \sqrt{(SOGR)^2 + (SOGT)^2}$$

Thus, true SOG in baseball bat billets should be limited to approximately 1:20 slope of grain to maintain a strength level of 90% of clear, straight-grained wood.