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University of Kentucky
College of Agriculture,
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IDENTIFYING WOOD—*A Primer for Everyone*

PART

9

Wood Structure and Mechanical Performance Are Related

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There is a strong correlation between wood density and mechanical properties, and this is true for both softwood and hardwood species. Density and strength properties can vary even within species due to different growth conditions. For an example, look at the southern pine railroad ties in the photograph below (Figure 9-1); the tie on the left with the wider rings probably had been exposed to more sunlight and rain after the surrounding trees had been thinned, and it grew faster than the tie on the right. By looking at the dark latewood bands you can tell that the tie on the left has a significantly lower percentage of higher density latewood than the tie on the right. The right-hand tie would be significantly denser and stronger.

You can see a similar growth response in some ring porous hardwoods. Oak is a good example, because these species make a uniform width of earlywood pores regardless of the growing season. The amount of latewood formed is determined by the time remaining in the growing season; fast-grown trees, or trees grown in locations with longer growing seasons, tend to be denser because there is a higher proportion of fibers in each growth ring. (This is opposite what was seen with the southern pine ties in Figure 9-1. The thin-walled earlywood pores with their large opening contribute very little to wood strength properties.) See Figure 9-2.

Rays don't contribute as much to strength properties as the fibers and the vessels, but they can affect wood use in other ways. When wood dries, for example, it dries through moisture loss of the individual cells. Because the fibers and the rays are oriented at right angles relative to each other, stress concentrators form during drying where these cells intersect. Over time these stresses dissipate, but if drying is rapid, separa-

Figure 9-1. Two southern pine railroad ties. The tie on the left has wider growth rings and a lower percentage of higher density latewood compared to the slower-grown tie on the right.

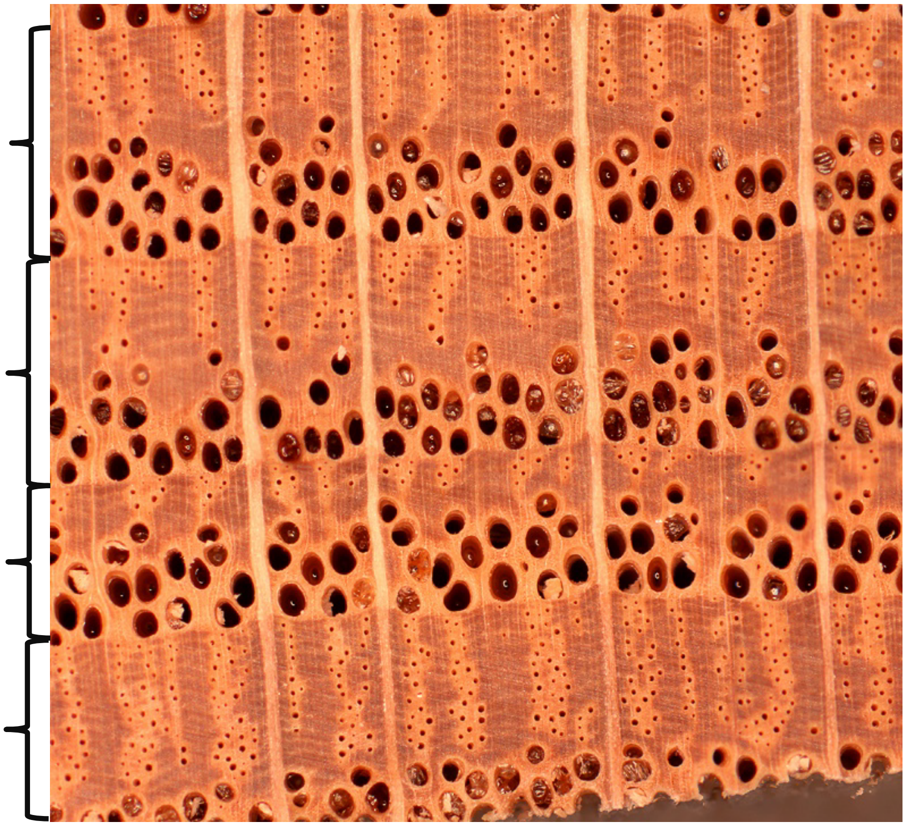

Figure 9-2. I've marked four growth rings in this micrograph of red oak; the ring second from the bottom is narrower than the others, but notice how similar the row of earlywood pores is to those in the wider growth rings.

tions between the cells can form, creating *checks* on board ends and surfaces. Drying checks are more noticeable in species with wide rays (ex., oak and beech) because the checks tend to be wider and deeper.

Ray orientation will also affect the drying rate. Think of the ends of ray cells as small pipes, essentially conduits for rapid moisture loss. Flatsawn boards (which have lots of ray ends on the wide board surfaces) will consequently dry faster than quartersawn boards (which have a smaller number of ray cell ends on the narrow board surfaces).

Choosing Species for Particular Uses

Many factors can affect whether a species is suitable for an intended use. The types and amounts of natural extractives might detrimentally affect gluability or color considerations, for instance. Factors such as weight (density) may or may not be important. Often it is the strength properties that are of paramount interest. Wood strength can be affected by the density as well as by the geometry of a piece of wood; for example, short and thick columns are less likely to buckle than tall slender columns. The amount of stress sustained and the ability to resist failure ("strength") will also differ according to whether the wood is used in tension, lateral compression or bending. Failure might be defined as excessive deformation even if the piece of wood does not fail by breaking. (As an example of failure by excessive deformation, consider your thoughts if your attic roof trusses started to bow downwards and the attached plaster started to fall down!) *Toughness* (the ability to resist impact breakage) is another strength property that is important in some applications (baseball bats, bridges, railroad ties). Toughness can be greatly affected by wood cellular structure.

Because pores are mostly air, individual pores can't have the same strength as thicker-walled fibers. This significantly affects toughness when groups of large earlywood pores are clustered together (as in ring porous species). The rings of dense fibers and the airy earlywood pores have very different strength properties. The fibers can easily resist an impact, but the earlywood pores may shatter if the growth rings are parallel to the impact direction. Ash is an example of a species with little impact strength. It's generally strong and light so it's often used for rake handles, but it's a poor choice for axe handles; hickory is used instead because of its superior impact resistance.

Baseball Bats

In spite of its low impact strength, professional baseball players have used white ash (*Fraxinus americana*) for years. It's lighter than the hickory and red oak bats that were used in years past by some famous ballplayers—leading to faster swings and farther hits. If ash is so vulnerable to breakage under impact, though, how has it been used so successfully for so many years?

Backyard baby-boomer baseball players probably know the answer to this question because we rarely if ever owned an aluminum bat. You need to hit the ball with the *edge* of the growth rings (*i.e.*, on the radial surface). If a batter swings the bat against the tangential face the bat will be more likely to break apart than if the radial face is used to hit the ball. See Figures 9-3 and 9-4.

Figure 9-3. This illustration simulates what happens when a ballplayer hits a baseball on a radial surface with the edge of the growth rings pointed toward the ball. The baseball bat is made from a ring porous species, white ash (*Fraxinus americana*).

Figure 9-4. This illustration simulates what happens when a ballplayer hits a baseball on the tangential surface with the growth rings pointed straight up and down. This is the same piece of white ash (*Fraxinus americana*) used in the previous image.

Figure 9-5. White ash baseball bat. The label is placed on the tangential face, so if the batter holds the bat with the label side up then the ball will strike a radial face (see Figure 9-1). The number 180 in the Louisville Slugger label on this bat means that this is a good quality amateur bat; the best bats (pro grade wood) are marked 125.

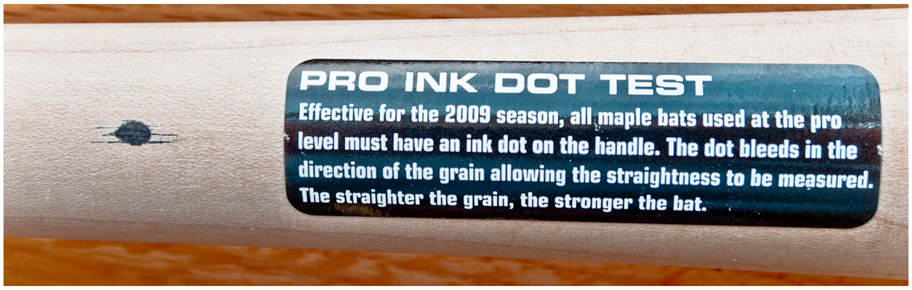

Figure 9-6. A maple bat (made by Rawlings in 2012) with a drop of ink on the side of the handle to show whether the grain is straight or not; this bat checks out fine.

If you hit a baseball as shown in Figure 9-3 (on the radial surface, with the edges of the growth rings) most of the impact stress would be sustained by the thicker-walled fibers, not the vessels. This bat would perform well. If you were to hit a baseball with the bat oriented as shown in Figure 9-4 (i.e., on the tangential face with the growth rings perpendicular to the ground), though, you might break the earlywood and the bat could fail. The outer part of the bat could come apart; this is known as flaking or "shelling off."

The best way to decrease the amount of flaking and increase the life of a bat is to learn to hold the bat correctly. Batters are supposed to swing a wooden bat with the label side up! (The label is always placed on the tangential face, which is ***not*** the side of the bat that you're supposed to hit with). If a batter holds the bat with the label side up then the ball will always strike the more resilient radial face. If a batter doesn't pay attention and hits with the label perpendicular to the ground (*i.e.*, on a tangential face) then the chance of bat breakage increases. See Figure 9-5.

In addition to the bat orientation, the professional ballplayers themselves have probably contributed to the increasing likelihood of a cracked bat over the years. I can think of two significant changes: 1) ballplayers are more likely to wear batting gloves than they used to, and the bat handles have been made thinner to keep the overall feel of the bat comfortable for the batters; 2) some ballplayers prefer to use lighter bats to increase the speed of their swings. Since bat weight is a function of wood density, the way to get a lower density bat is to select bats with narrower growth rings (for ring-porous bats, anyway). This also makes these bats less able to resist the impact of a pitcher's fastball!

Bat breakage seems to be more of a problem nowadays than it used to be; as a boy, I remember many more bats breaking in the handle than in the barrel; we had little choice regarding anything except the bat length, and we didn't have a preference for thinner barrels because we didn't have batting gloves. We wrapped the barrels with friction tape instead. I admit, though, that we often misused the bats by pounding them on the ground as we faced the pitcher!

Ash versus Maple Bats

Flaking is one of the biggest reasons for the decline in popularity of ash as a bat material, and it led to experiments with alternative wooden bat species such as the diffuse porous sugar maple (*Acer saccharum*). Diffuse porous species don't have the large pore size difference that ring porous species have, so they don't flake like white ash. Sugar maple bats were relatively unknown until Barry Bonds had a record season in 2001 using a maple bat. After that they became very popular, and maple bats have been outselling ash bats for several years.

Maple bats have been somewhat controversial in the professional ball leagues because some of them broke into pieces fairly spectacularly during practice and games. Better manufacturing and inspection standards have reduced the amount of breakage. The problem seems to have been twofold: 1) some bats were being manufactured out of maple with too low a density to have adequate strength; 2) some bats were being manufactured with a perceptible slope of grain in the wood, reducing the impact strength. Even a slight slope of grain is enough to significantly decrease the impact strength of wood. The density and slope of grain of maple bats are now measured to eliminate these problems; density is monitored when the bats are made, and the slope of grain is checked by observing how closely the bleeding from a drop of ink follows the axis of the bat. Ink tends to follow the pores, and this makes a visual slope of grain indicator pretty effective. See Figure 9-6.

Have Aluminum Bats Contributed to Wooden Bat Breakage?

Breakage of wooden bats seems to have increased as ballplayers have grown up using aluminum bats. Aluminum bats became more widely available in the 1970s, and even though they were pricey their durability led to their being widely used in schools and amateur baseball leagues. Bat orientation has never been an issue with aluminum bats because the material is uniform, and batters sometimes rotate the bat while settling in for the pitch. This habit can carry over to professional ball play, so since the 1990s most major league ball clubs have conducted "wooden bat camps" for new players.

Vocabulary

If you don't remember any of the following words, please review this section. Vocabulary is very important!

1. Ring porous
2. Semi-ring porous
3. Semi-diffuse porous
4. Diffuse porous
5. *Fraxinus americana* (white ash)
6. *Quercus alba* (white oak)
7. *Acer saccharum* (sugar maple)
8. *Acer saccharinum* (silver maple)
9. *Acer rubrum* (red maple)
10. *Tilia americana* (American basswood)
11. *Carya spp.*(shorthand for one of the hickory species)
12. *Aluminum ballpingus* (Aluminum baseball bat)

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