



NEWS AND VIEWS OF THIS KILN DRYING BUSINESS *(Reports)*

The Problem: What is the cause of case-hardening in lumber and how can it be relieved?

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Case-hardening causes wood to become distorted when resawn, ripped, or machined. Cupping of the two pieces of a resawn board is a typical example of the effect of case-hardening. Tests can be made to detect its presence and the wood can be treated to relieve the stresses that case-hardening causes. This discussion will be centered around causes and remedies.

It is unfortunate that the word "case-hardening" was ever used to describe a condition that exists in dry wood. We know that case-hardened steel means, but when we try to apply the same idea to wood we get a terribly confused picture. However, case-hardened wood does not machine easily. Saws pinch in resawing and ripping, and this difficulty may be why such wood was called case-hardened—just hard to work. The distortions which are noticed in machining case-hardened wood are caused by an unbalancing of stresses in the dried board; thus, case-hardened lumber is stressed lumber. If we can explain how these stresses occur and why they remain in the board after it has been dried, then the required remedial treatments are indicated.

The exposed surfaces of freshly sawn boards immediately start to dry. Soon these surface layers are below the fiber-saturation point and shrinkage of the cell walls of the fibers making up the outer surface start to shrink. The cumulative effect of this reduction in dimension of a great number of fibers making up the surface layer of the board is a tension stress perpendicular to the grain. This tension stress is developed because the shrinkage of these surface fibers is being restrained by the layer of green nonshrinking fibers beneath the surface.

As drying of the surface layer continues, these tension forces increase because of the further reduction in moisture content below the fiber-saturation point and the continued re-

straint exerted by the interior portions of the board. Something has to give; either the tension forces of the surface layers squeeze the green fibers beneath, or the surface layers stretch. The latter usually happens—the surface layers of the fibers actually are deformed; the cell cavities are enlarged. This stretch or deformation is permanent and is called "tension set." The wood technician puts it this way:

"Wood fibers that are restrained from shrinking in diameter will stretch, enlarging the cell cavities, if the stress exceeds the proportional limit in tension perpendicular to the grain. Fibers that have been stressed beyond the proportional limit will not fully return to their normal (smaller) sizes when the stress is removed. Such fibers are said to be set in tension or to have a tension set."

As the interior portions of the board dry and shrink, the stress in the surface layer eventually changes from tension to compression. The tension-set outer layer is now dry and strong, and it resists the compression forces without taking a squeeze equivalent to the stretch that developed in the very early stages of drying. The outer layer of fibers, because of the stretch or tension set, persists in being bigger than it ought to be, and as a result the dried board is in a stressed condition—compression in the outer layers and tension in the internal portions. This is all due to the fact that in the early stages of drying the outer layers were stretched in tension or took a tension set. This condition is called "case-hardening." We think that it would be better to say that the surfaces of the stock are "set in tension" rather than to say that they are case-hardened.

The stresses in the dried board are in balance. But when this balance is broken as by resawing, the stresses tend to rebalance themselves, thus causing the pieces to distort. The outer layer of the board, which is in compression because of the tension set that is present, actually gets wider as a result of the resawing, and cupping results.

Obviously, the remedy is to squeeze or compress the outer layers of the

fibers of the board by an amount equal to the stretch that took place in the early stages of drying. If this can be done, stresses in the dried board will no longer be present and machining will not result in distortions of one kind or another. Fortunately, this squeeze can be accomplished. The idea is to subject the dried board to a relative humidity that is sufficiently high, so that the surface layers of fibers will absorb enough moisture to increase the compression forces, causing the needed squeeze or compression to take place. If at the same time the board can be subjected to a higher temperature, the increased plasticity of the wood hastens the compression, or "relief" of tension set takes place. Relief of case-hardening then is accomplished by a conditioning treatment resulting in a moisture regain gradient. The conditioning treatment must not be overdone. If the compression is greater than the original tension set, reverse case-hardening develops, and this situation is very difficult to cope with.

From a practical kiln operating standpoint, the problem confronting the kiln operator is to determine what the conditioning treatment should be and how long it should last. Here is one of the phases of kiln operation that may be considered a craft. Some operators are very successful in being able to turn out stress-free stock; others have difficulty in determining what the conditioning treatment should be and how long it should last. Technically speaking, no one has devised a practical system of determining what the conditioning treatment should be; thus, rule of thumb procedures are used as a guide and, by trial and error methods, a dry-kiln operator gains the experiences which enable him to do a successful job with the kiln equipment that he has.

One of the more recent approaches to this problem of determining the conditioning treatment for stress relief involves calculating the moisture content of the mid-thickness of the boards being dried and using this value, with corrections, as the EMC of the conditioning treatment. This approach is presented here as the basis for a guide for determining the conditioning treatment as a part of

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the process of kiln drying wood. Experience will determine what further corrections need to be made.

The moisture content of the mid-thickness of a board being kiln dried can be calculated, using the following equation:

$$Y = \frac{3}{2} (A - EMC) + EMC$$

Where Y is the moisture content of the mid-thickness of the board, A is the average moisture content and EMC is the equilibrium moisture content condition existing in the kiln. For example, if the average moisture content A is 6 percent and the EMC is 4 percent, the mid-thickness moisture content is:

$$Y = \frac{3}{2} (6 - 4) = \frac{3}{2} (2) + 4 = 7 \text{ percent}$$

This would be the EMC of the conditioning treatment, but better conditioning results are obtained if these values are increased. If the wood being dried is softwood, the EMC of the conditioning treatment calculated in this way should be increased by dividing the mid-thickness value by 0.93, if a hardwood, by 0.85. In the example, the EMC of the conditioning treatment would be

$$\frac{7}{0.93} = 7.5 \text{ for softwoods and}$$

$$\frac{7}{0.85} = 8.2 \text{ for hardwoods}$$

The time required for conditioning to relieve the tension set depends upon the degree of "tension set" present and the temperatures used. High temperatures hasten the action. The usual time necessary is approximately 5 hours per inch of thickness for softwoods and 18 to 24 hours per inch for hardwoods.